EPS
Escola Politècnica
UdG Superior

Projecte/Treball Fi de Carrera

Estudi: Enginyeria Tècn. Ind. Química Ind. Pla 2002

Títol: Caracterització del comportament viscoelàstic de dos polímers termoplàstics, PP i PS

Document: Annex

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Àrea: Ciència dels materials i enginyeria metal·lúrgica (CMEM)

Convocatòria (mes/any): 09/08

Índex de l’annex

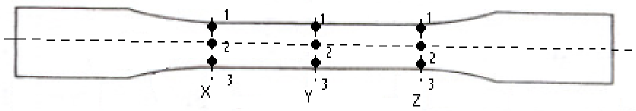
A. FULLS DE CONTROL I RESULTATS

En aquest apartat de l'annex és on es troben tots els fulls de control i de resultats de les provetes assajades en el projecte.

Cal recordar que hi ha un full de control amb cada proveta, on hi ha les mides d'aquesta, la data en què s'han mesurat, el nom de la proveta i algunes característiques de l'assaig com ara tipus d'assaig, nom del fitxer de dades, màquina utilitzada, temperatura i humitat, etc. També hi ha un requadre per anotar possibles incidències que s'hagin donat durant l'assaig.

El full de resultats només és per les provetes destinades a tracció. Els resultats que hi figuren són els de les propietats mecàniques principals i que tenen un càlcul senzill: mòdul de Young, límit de ruptura, màxima deformació i resistència. Els altres resultats obtinguts en aquest projecte gràcies als assajos experimentals estan desenvolupats a la memòria.

FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 07/08/07
Proveta: PP/TR/0,05-01	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,12	X	3,293	3,199	3,285
Y	13,11	Y	3,278	3,187	3,270
Z	13,10	Z	3,253	3,154	3,255
Mitjana	13,110	Mitjana	3,242	Dif. Max	

ASSAIG: Tracció 0,05 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 17/01/08
Tª del laboratori (ºC): 21,4	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 39	**Temperatura assaig (ºC):** 21,4
Programa d'assaig: tracció_ext	**Fitxer de dades:** PP_TR_0,05_01

Incidències:
L'assaig s'ha aturat abans d'arribar a la ruptura de la proveta.

FULL DE RESULTATS

DIMENSIONS

Proveta	PP/TR/0,05-01	**Llarg extensòmetre (mm)**	50
Gruix mitjà (mm)	3,242	**Amplada mitjana (mm)**	13,11

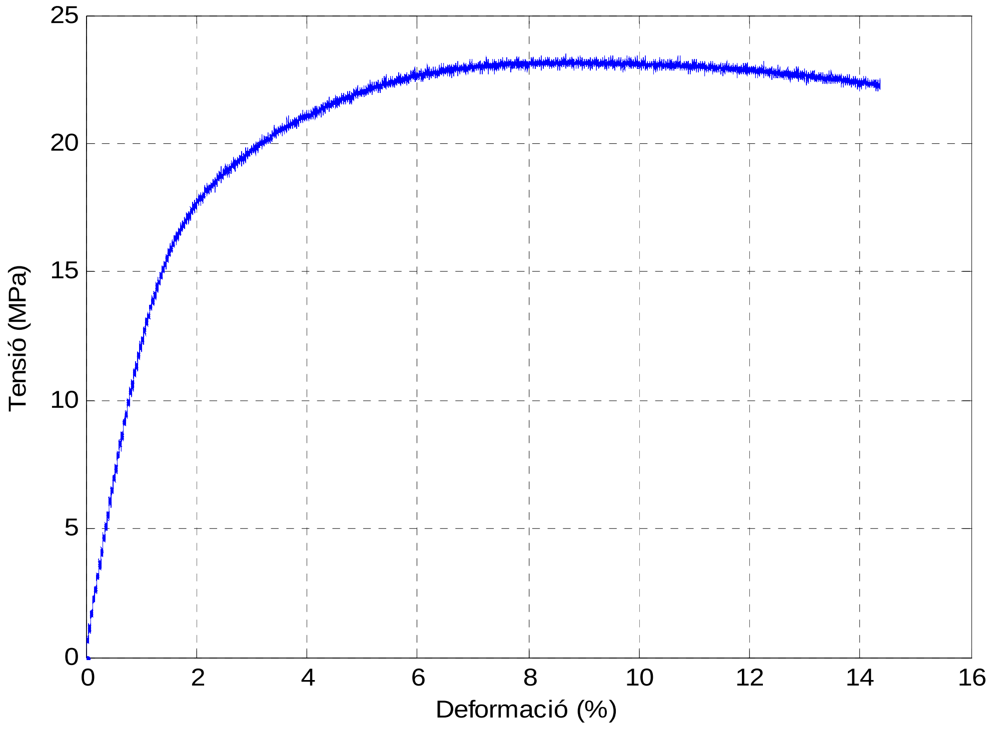
ASSAIG: Tracció 0,05 mm/min

Personal responsable: Isabel Bagudanch	**Data:** 17/01/08
Tª del laboratori (ºC): 21,4	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 39	**Temperatura assaig (ºC):** 21,4
Programa d'assaig: tracció_ext	**Fitxer de dades:** PP_TR_0,05_01

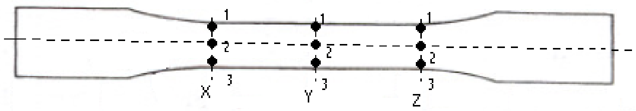
RESULTATS

Mòdul de Young (GPa)	1,397	**Màxima deformació (%)**	--
Límit de ruptura (MPa)	--	**Resistència (MPa)**	23,491

GRÀFICA



FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 07/08/07
Proveta: PP/TR/0,05-02	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,14	X	3,290	3,165	3,298
Y	13,14	Y	3,273	3,151	3,279
Z	13,12	Z	3,253	3,214	3,257
Mitjana	13,133	Mitjana	3,242	Dif. Max	

ASSAIG: Tracció 0,05 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 17/07/08
Tª del laboratori (ºC): 20,0	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 38	**Temperatura assaig (ºC):** 20,0
Programa d'assaig: tracció_ext	**Fitxer de dades:** PP_TR_0,05_02

Incidències:
L'assaig s'ha aturat abans d'arribar a la ruptura de la proveta.

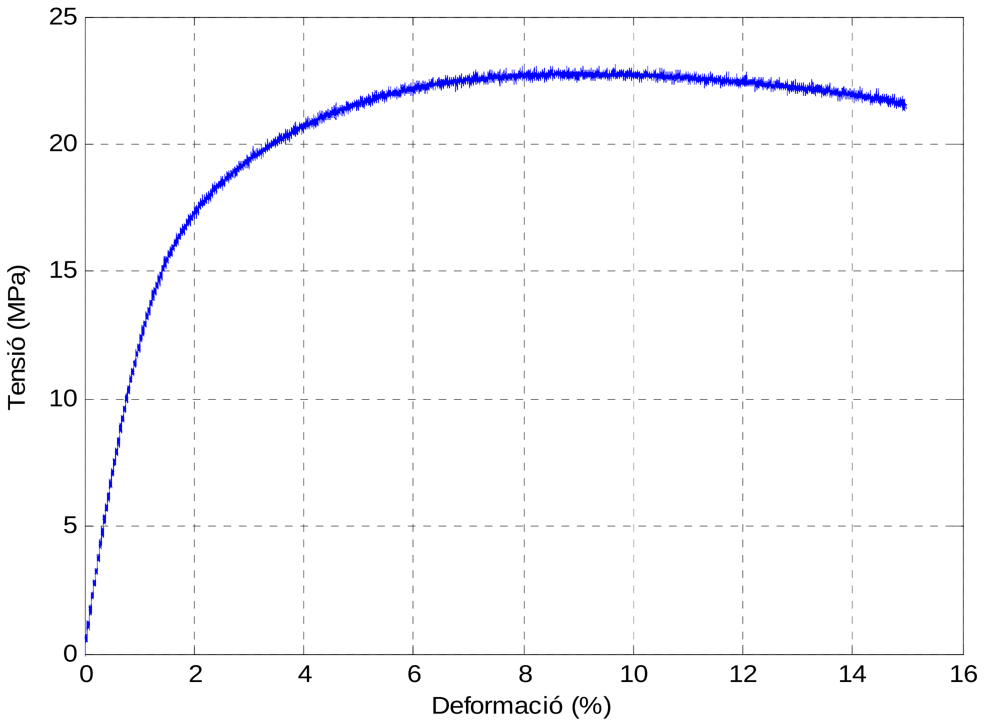
FULL DE RESULTATS

DIMENSIONS			
Proveta	PP/TR/0,05-02	**Llarg extensòmetre (mm)**	50
Gruix mitjà (mm)	3,242	**Amplada mitjana (mm)**	13,133

ASSAIG: Tracció 0,05 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 17/07/08
Tª del laboratori (ºC): 20,0	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 38	**Temperatura assaig (ºC):** 20,0
Programa d'assaig: tracció_ext	**Fitxer de dades:** PP_TR_0,05_02

RESULTATS			
Mòdul de Young (GPa)	1,450	**Màxima deformació (%)**	--
Límit de ruptura (MPa)	--	**Resistència (MPa)**	23,120

GRÀFICA



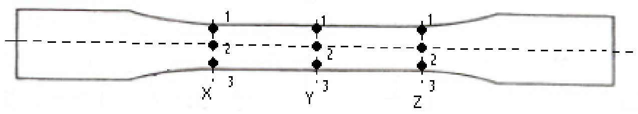
FULL DE CONTROL ASSAIG

DIMENSIONS

Personal responsable: Isabel Bagudanch	**Data:** 07/08/07

Proveta:

PP/TR/0,5-01



Ample (mm)		Gruix (mm)			
			1	2	3
X	13,30	X	3,354	3,262	3,355
Y	13,25	Y	3,334	3,217	3,334
Z	13,30	Z	3,315	3,229	3,316
Mitjana	13,283	Mitjana	3,302	Dif. Max	

ASSAIG: Tracció 0,5 mm/min

Personal responsable: Isabel Bagudanch	**Data:** 14/01/08
Tª del laboratori (ºC): 20,0	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 45	**Temperatura assaig (ºC):** 20,0
Programa d'assaig: tracció_ext	**Fitxer de dades:** PP_TR_0,5_01

Incidències:
L'assaig s'ha aturat abans d'arribar a la ruptura de la proveta.

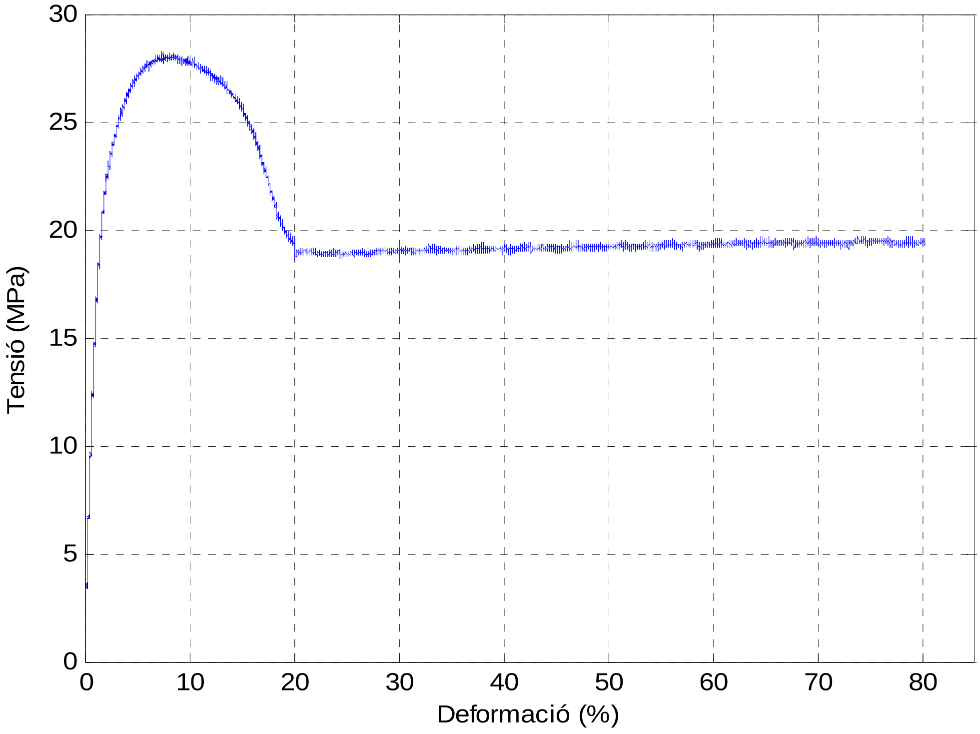
FULL DE RESULTATS

DIMENSIONS			
Proveta	PP/TR/0,5-01	**Llarg extensòmetre (mm)**	50
Gruix mitjà (mm)	3,302	**Amplada mitjana (mm)**	13,283

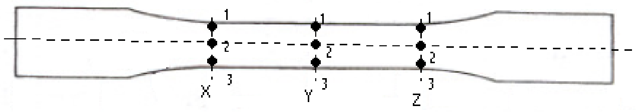
ASSAIG: Tracció 0,5 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 14/01/08
Tª del laboratori (ºC): 20,0	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 45	**Temperatura assaig (ºC):** 20,0
Programa d'assaig: tracció_ext	**Fitxer de dades:** PP_TR_0,5_01

RESULTATS			
Mòdul de Young (GPa)	1,710	**Màxima deformació (%)**	--
Límit de ruptura (MPa)	--	**Resistència (MPa)**	28,250

GRÀFICA



FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 07/08/07
Proveta: PP/TR/0,5-02	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,19	X	3,316	3,254	3,318
Y	13,14	Y	3,303	3,238	3,297
Z	13,17	Z	3,285	3,217	3,280
Mitjana	13,167	Mitjana	3,279	Dif. Max	

ASSAIG: Tracció 0,5 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 15/01/08
Tª del laboratori (ºC): 21,0	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 44	**Temperatura assaig (ºC):** 21,0
Programa d'assaig: tracció_ext	**Fitxer de dades:** PP_TR_0,5_02

Incidències:
L'assaig s'ha aturat abans d'arribar a la ruptura de la proveta.

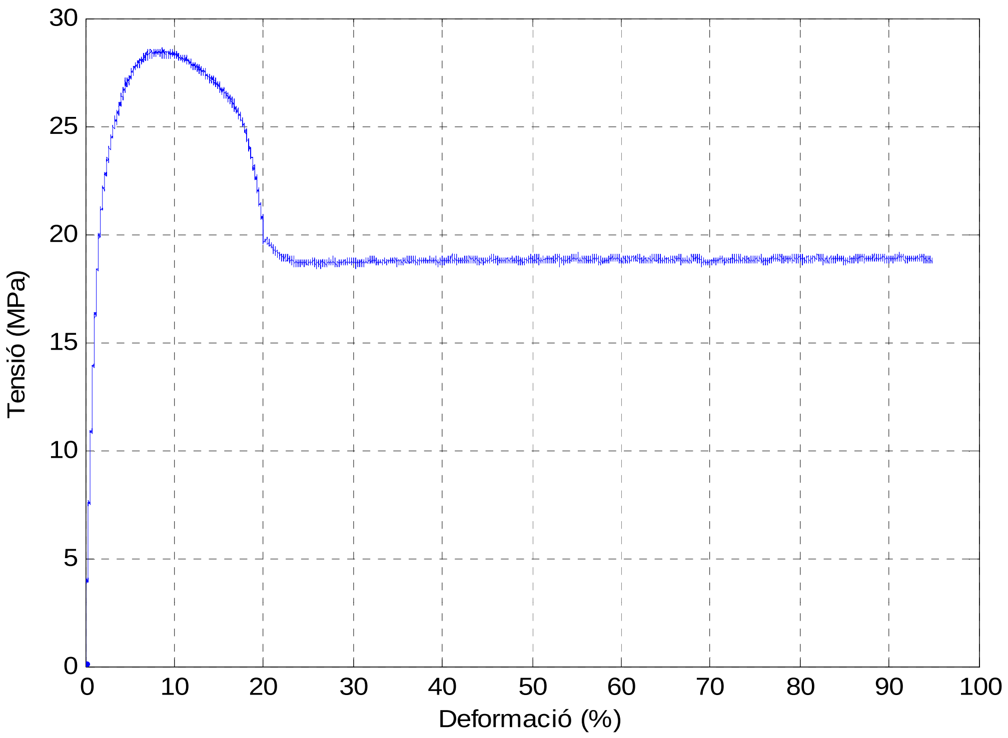
FULL DE RESULTATS

DIMENSIONS			
Proveta	PP/TR/0,5-02	**Llarg extensòmetre (mm)**	50
Gruix mitjà (mm)	3,279	**Amplada mitjana (mm)**	13,167

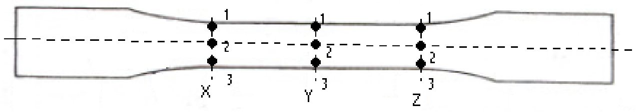
ASSAIG: Tracció 0,5 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 15/01/08
Tª del laboratori (ºC): 21,0	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 44	**Temperatura assaig (ºC):** 21,0
Programa d'assaig: tracció_ext	**Fitxer de dades:** PP_TR_0,5_02

RESULTATS			
Mòdul de Young (GPa)	1,502	**Màxima deformació (%)**	--
Límit de ruptura (MPa)	--	**Resistència (MPa)**	28,627

GRÀFICA



FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 07/08/07
Proveta: PP/TR/0,5-03	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,13	X	3,293	3,210	3,297
Y	13,14	Y	3,271	3,146	3,282
Z	13,11	Z	3,249	3,148	3,257
Mitjana	13,127	Mitjana	3,239	Dif. Max	

ASSAIG: Tracció 0,5 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 15/01/08
Tª del laboratori (ºC): 20,8	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 43	**Temperatura assaig (ºC):** 20,8
Programa d'assaig: tracció_ext	**Fitxer de dades:** PP_TR_0,5_03

Incidències:
L'assaig s'ha aturat abans d'arribar a la ruptura de la proveta.

FULL DE RESULTATS

DIMENSIONS

Proveta	PP/TR/0,5-03	**Llarg extensòmetre (mm)**	50
Gruix mitjà (mm)	3,239	**Amplada mitjana (mm)**	13,127

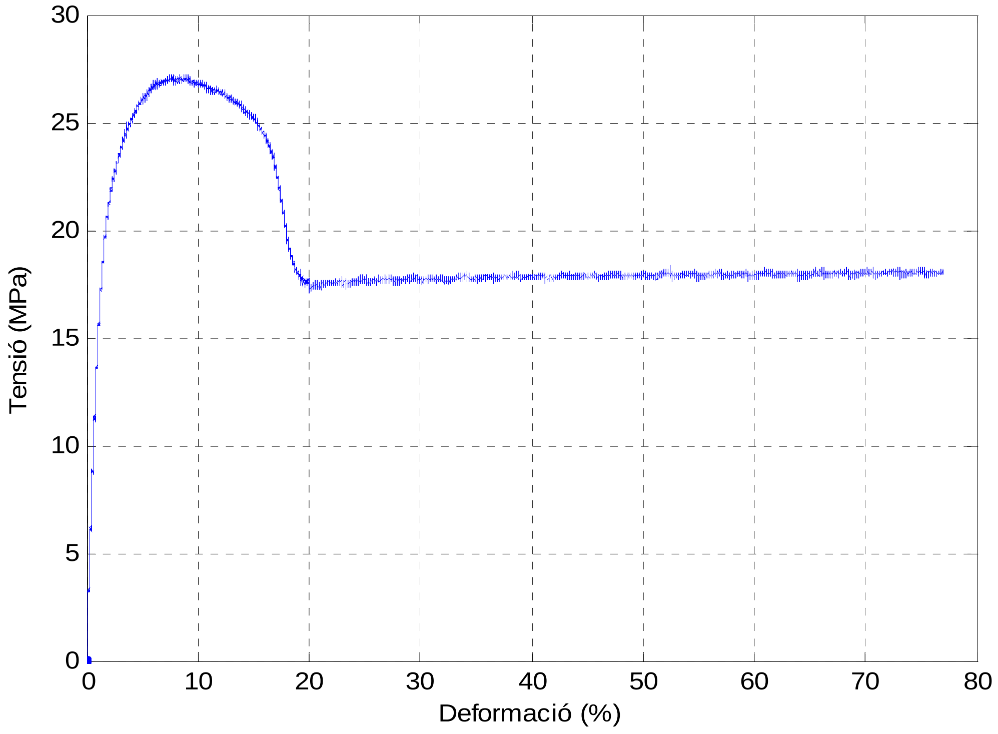
ASSAIG: Tracció 0,5 mm/min

Personal responsable: Isabel Bagudanch	**Data:** 15/01/08
Tª del laboratori (ºC): 20,8	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 43	**Temperatura assaig (ºC):** 20,8
Programa d'assaig: tracció_ext	**Fitxer de dades:** PP_TR_0,5_03

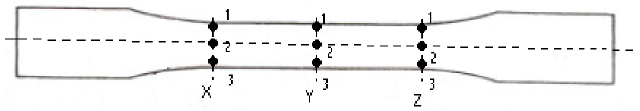
RESULTATS

Mòdul de Young (GPa)	1,599	**Màxima deformació (%)**	--
Límit de ruptura (MPa)	--	**Resistència (MPa)**	27,268

GRÀFICA



FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 07/08/07
Proveta: PP/TR/5-01	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,14	X	3,318	3,256	3,316
Y	13,14	Y	3,303	3,247	3,298
Z	13,14	Z	3,324	3,254	3,319
Mitjana	13,140	Mitjana	3,293	Dif. Max	

ASSAIG: Tracció 5 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 10/01/08
Tª del laboratori (ºC): 21,1	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 49	**Temperatura assaig (ºC):** 21,1
Programa d'assaig: tracció_ext	**Fitxer de dades:** PP_TR_5_01

Incidències:
L'assaig s'ha aturat a l'arribar al màxim desplaçament que permetia la màquina Shimadzu, tot i així no s'ha arribat a la ruptura de la proveta.

FULL DE RESULTATS

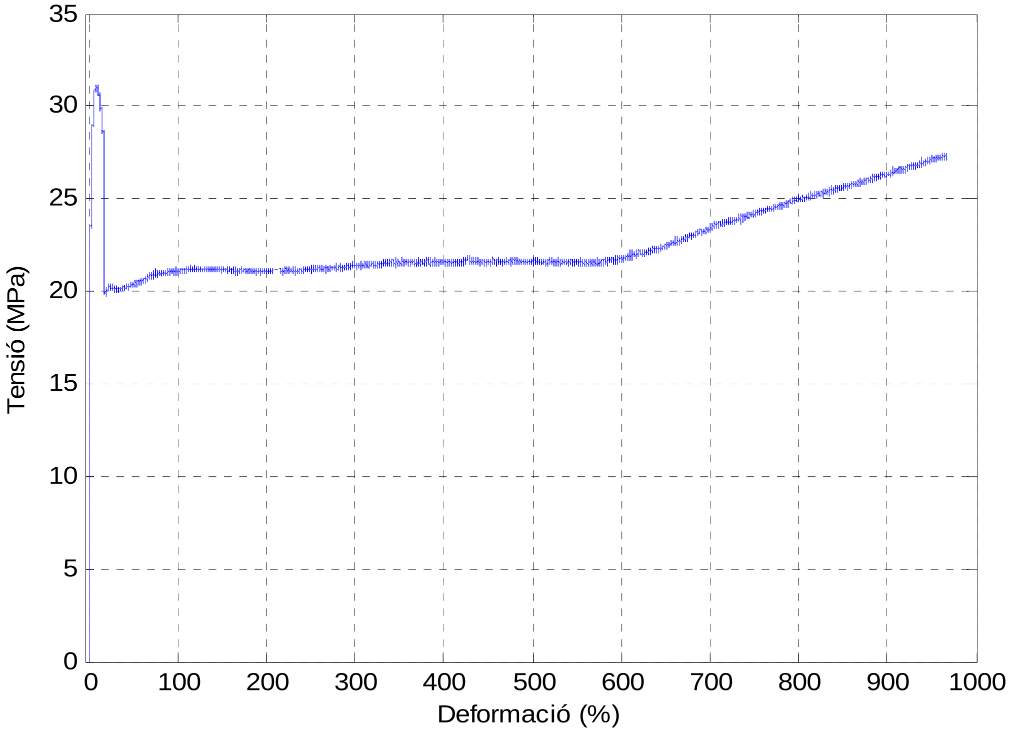
DIMENSIONS			
Proveta	PP/TR/5-01	**Llarg extensòmetre (mm)**	50
Gruix mitjà (mm)	3,293	**Amplada mitjana (mm)**	13,14

ASSAIG: Tracció 5 mm/min

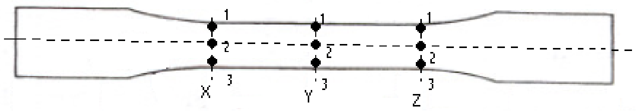
Personal responsable: Isabel Bagudanch	**Data:** 10/01/08
Tª del laboratori (ºC): 21,1	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 49	**Temperatura assaig (ºC):** 21,1
Programa d'assaig: tracció_ext	**Fitxer de dades:** PP_TR_5_01

RESULTATS			
Mòdul de Young (GPa)	1,853	**Màxima deformació (%)**	--
Límit de ruptura (MPa)	--	**Resistència (MPa)**	31,199

GRÀFICA



FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 07/08/07
Proveta: PP/TR/5-02	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,20	X	3,283	3,194	3,278
Y	13,19	Y	3,303	3,179	3,303
Z	13,17	Z	3,324	3,191	3,320
Mitjana	13,187	Mitjana	3,264	Dif. Max	

ASSAIG: Tracció 5 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 14/01/08
Tª del laboratori (ºC): 19,4	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 44	**Temperatura assaig (ºC):** 19,4
Programa d'assaig: tracció_ext	**Fitxer de dades:** PP_TR_5_02

Incidències:
L'assaig s'ha aturat a l'arribar al màxim desplaçament que permetia la màquina Shimadzu, tot i així no s'ha arribat a la ruptura de la proveta.

FULL DE RESULTATS

DIMENSIONS

Proveta	PP/TR/5-02	**Llarg extensòmetre (mm)**	50
Gruix mitjà (mm)	3,264	**Amplada mitjana (mm)**	13,187

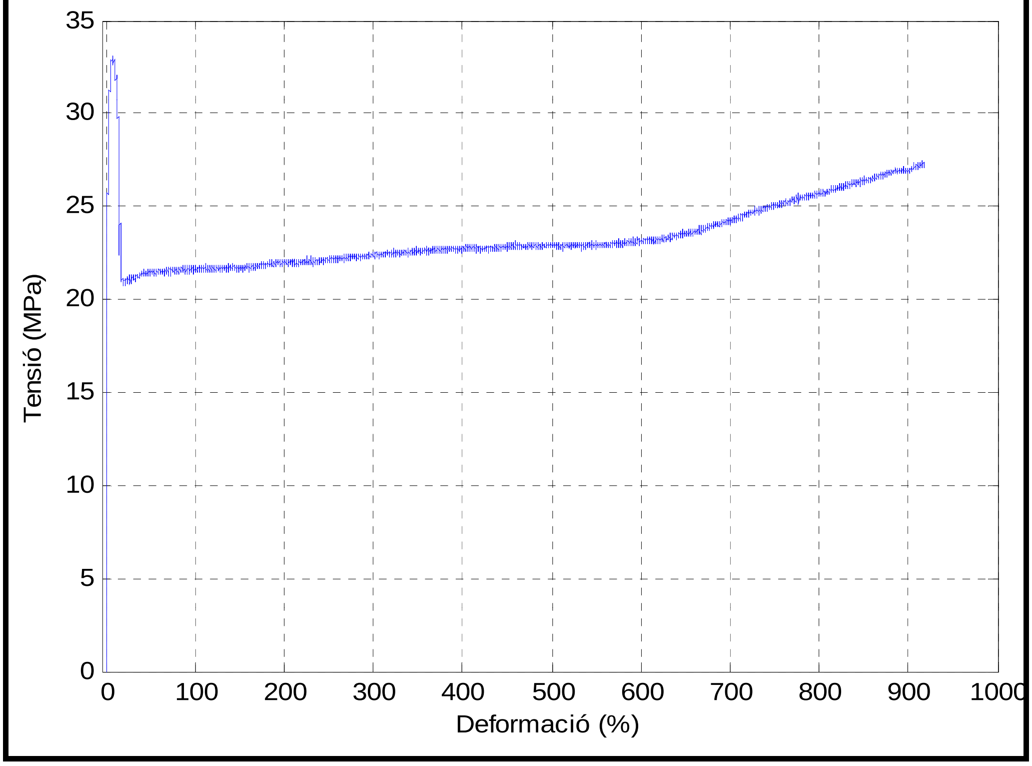
ASSAIG: Tracció 5 mm/min

Personal responsable: Isabel Bagudanch	**Data:** 14/01/08
Tª del laboratori (ºC): 19,4	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 44	**Temperatura assaig (ºC):** 19,4
Programa d'assaig: tracció_ext	**Fitxer de dades:** PP_TR_5_02

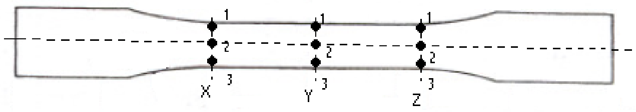
RESULTATS

Mòdul de Young (GPa)	1,978	**Màxima deformació (%)**	--
Límit de ruptura (MPa)	--	**Resistència (MPa)**	33,143

GRÀFICA



FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 07/08/07
Proveta: PP/TR/5-03	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,16	X	3,310	3,226	3,314
Y	13,17	Y	3,336	3,240	3,331
Z	13,16	Z	3,352	3,254	3,389
Mitjana	13,163	Mitjana	3,306	Dif. Max	

ASSAIG: Tracció 5 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 14/01/08
Tª del laboratori (ºC): 19,7	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 45	**Temperatura assaig (ºC):** 19,7
Programa d'assaig: tracció_ext	**Fitxer de dades:** PP_TR_5_03

Incidències:
L'assaig s'ha aturat abans d'arribar a la ruptura de la proveta.

FULL DE RESULTATS

DIMENSIONS

Proveta	PP/TR/5-03	**Llarg extensòmetre (mm)**	50
Gruix mitjà (mm)	3,306	**Amplada mitjana (mm)**	13,163

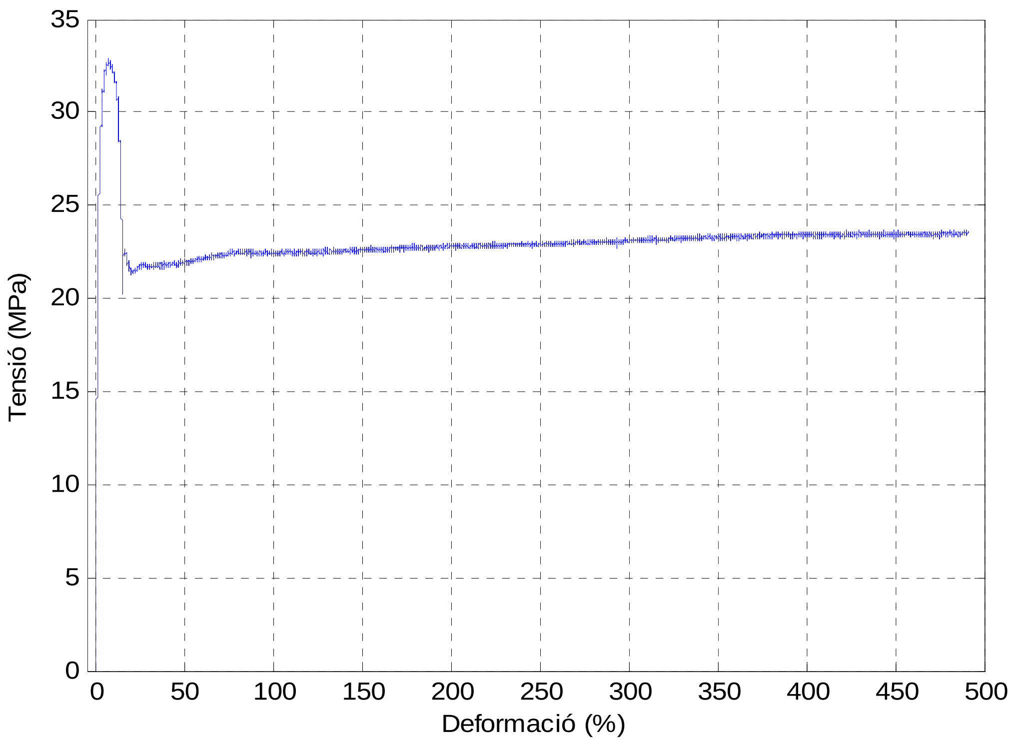
ASSAIG: Tracció 5 mm/min

Personal responsable: Isabel Bagudanch	**Data:** 14/01/08
Tª del laboratori (ºC): 19,7	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 45	**Temperatura assaig (ºC):** 19,7
Programa d'assaig: tracció_ext	**Fitxer de dades:** PP_TR_5_03

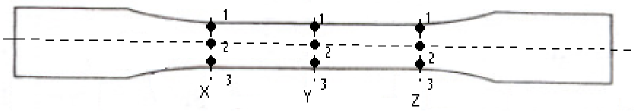
RESULTATS

Mòdul de Young (GPa)	1,918	**Màxima deformació (%)**	--
Límit de ruptura (MPa)	--	**Resistència (MPa)**	32,890

GRÀFICA



FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 07/08/07
Proveta: PP/TR/50-01	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,11	X	3,290	3,176	3,286
Y	13,12	Y	3,278	3,148	3,267
Z	13,11	Z	3,254	3,120	3,247
Mitjana	13,113	Mitjana	3,230	Dif. Max	

ASSAIG: Tracció 50 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 09/08/07
Tª del laboratori (ºC): 25,7	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 48	**Temperatura assaig (ºC):** 26,0
Programa d'assaig: tracció_ext	**Fitxer de dades:** PP_TR_50_01

Incidències:

FULL DE RESULTATS

DIMENSIONS

Proveta	PP/TR/50-01	**Llarg extensòmetre (mm)**	50
Gruix mitjà (mm)	3,230	**Amplada mitjana (mm)**	13,113

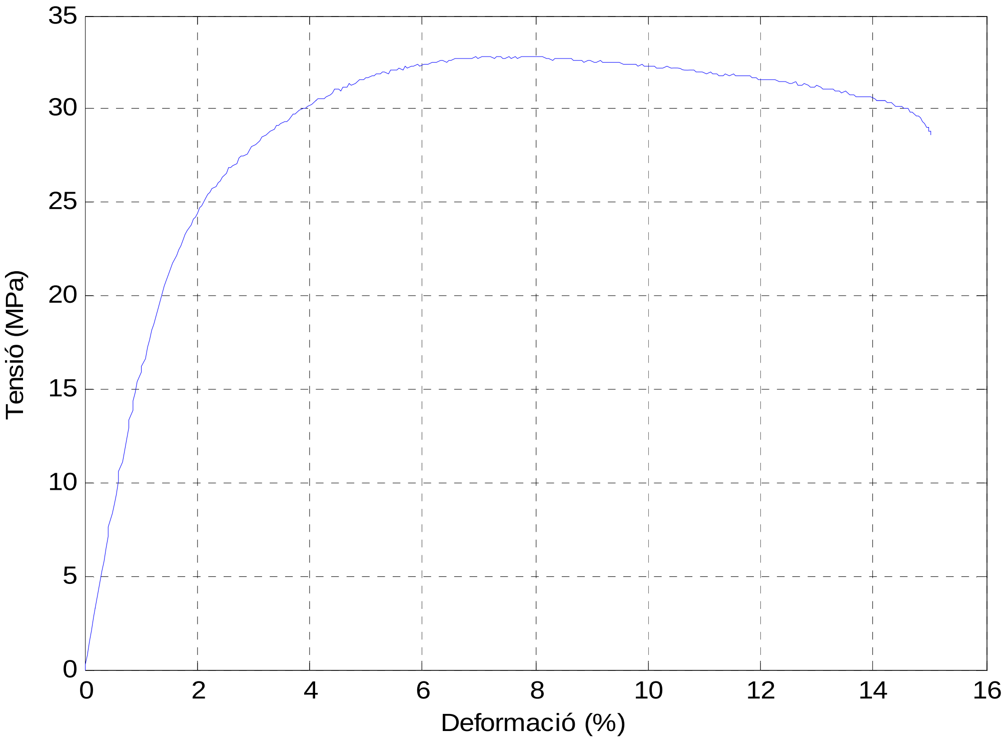
ASSAIG: Tracció 50 mm/min

Personal responsable: Isabel Bagudanch	**Data:** 09/08/07
Tª del laboratori (ºC): 25,7	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 48	**Temperatura assaig (ºC):** 26,0
Programa d'assaig: tracció_ext	**Fitxer de dades:** PP_TR_50_01

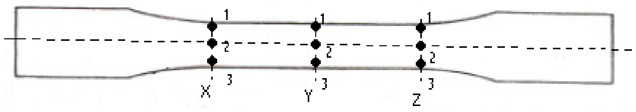
RESULTATS

Mòdul de Young (GPa)	1,783	**Màxima deformació (%)**	15,027
Límit de ruptura (MPa)	28,553	**Resistència (MPa)**	32,834

GRÀFICA



FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 07/08/07
Proveta: PP/TR/50-02	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,12	X	3,282	3,187	3,287
Y	13,12	Y	3,267	3,149	3,276
Z	13,11	Z	3,247	3,128	3,254
Mitjana	13,117	Mitjana	3,231	Dif. Max	

ASSAIG: Tracció 50 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 09/08/07
Tª del laboratori (ºC): 26,0	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 47	**Temperatura assaig (ºC):** 26,0
Programa d'assaig: tracció_ext	**Fitxer de dades:** PP_TR_50_02

Incidències:

FULL DE RESULTATS

DIMENSIONS

Proveta	PP/TR/50-02	**Llarg extensòmetre (mm)**	50
Gruix mitjà (mm)	3,231	**Amplada mitjana (mm)**	13,117

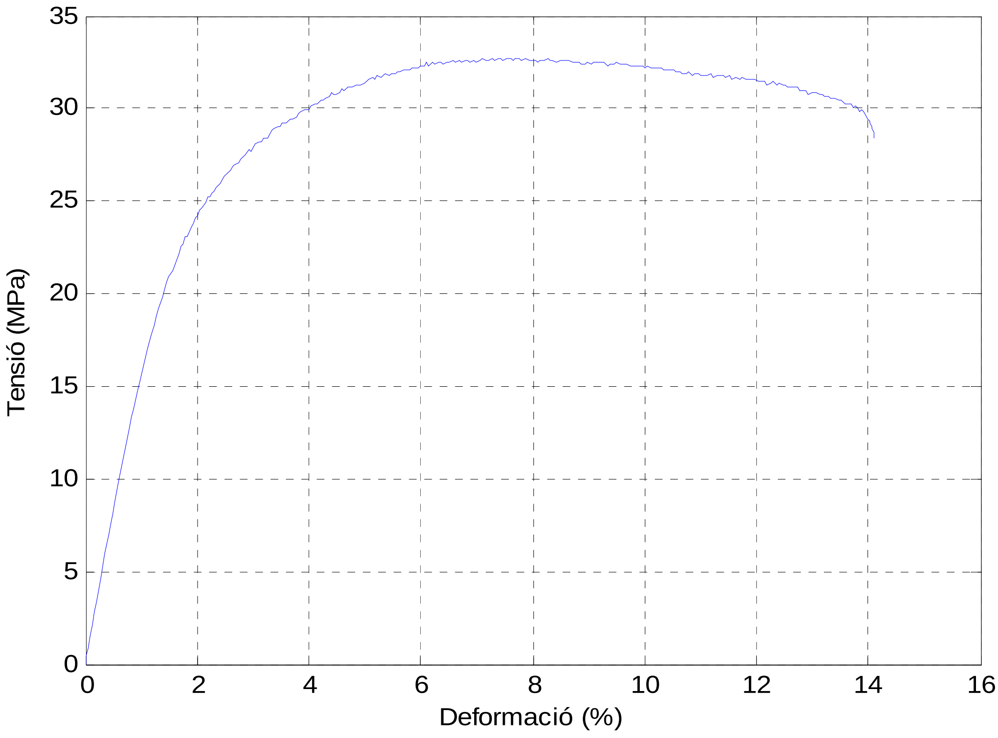
ASSAIG: Tracció 50 mm/min

Personal responsable: Isabel Bagudanch	**Data:** 09/08/07
Tª del laboratori (ºC): 26,0	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 47	**Temperatura assaig (ºC):** 26,0
Programa d'assaig: tracció_ext	**Fitxer de dades:** PP_TR_50_02

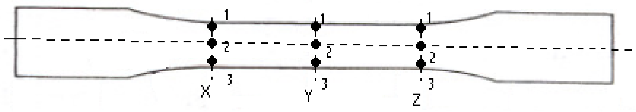
RESULTATS

Mòdul de Young (GPa)	1,693	**Màxima deformació (%)**	14,105
Límit de ruptura (MPa)	28,425	**Resistència (MPa)**	32,739

GRÀFICA



FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 07/08/07
Proveta: PP/TR/50-03	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,11	X	3,252	3,120	3,246
Y	13,12	Y	3,277	3,147	3,269
Z	13,12	Z	3,293	3,174	3,290
Mitjana	13,117	Mitjana	3,230	Dif. Max	

ASSAIG: Tracció 50 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 09/08/07
Tª del laboratori (ºC): 26,1	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 46	**Temperatura assaig (ºC):** 26,1
Programa d'assaig: tracció_ext	**Fitxer de dades:** PP_TR_50_03

Incidències:

FULL DE RESULTATS

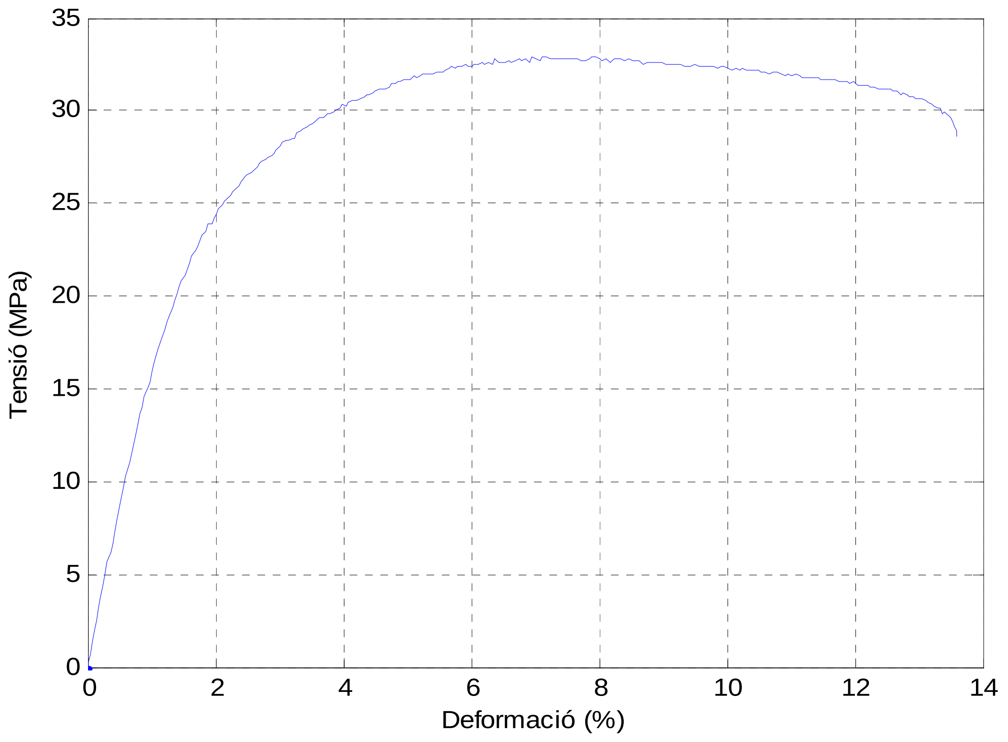
DIMENSIONS			
Proveta	PP/TR/50-03	**Llarg extensòmetre (mm)**	50
Gruix mitjà (mm)	3,230	**Amplada mitjana (mm)**	13,117

ASSAIG: Tracció 50 mm/min

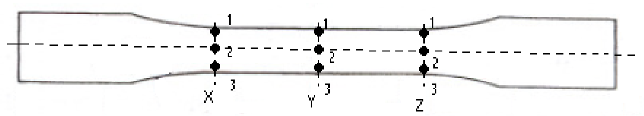
Personal responsable: Isabel Bagudanch	**Data:** 09/08/07
Tª del laboratori (ºC): 26,1	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 46	**Temperatura assaig (ºC):** 26,1
Programa d'assaig: tracció_ext	**Fitxer de dades:** PP_TR_50_03

RESULTATS			
Mòdul de Young (GPa)	1,766	**Màxima deormació (%)**	13,603
Límit de ruptura (MPa)	28,618	**Resistència (MPa)**	32,859

GRÀFICA



FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 07/08/07
Proveta: PP/TR/500-01	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,12	X	3,282	3,200	3,287
Y	13,11	Y	3,267	3,172	3,278
Z	13,10	Z	3,248	3,129	3,257
Mitjana	13,110	Mitjana	3,236	Dif. Max	

ASSAIG: Tracció 500 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 10/01/08
Tª del laboratori (ºC): 22,4	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 47	**Temperatura assaig (ºC):** 22,4
Programa d'assaig: tracció_ext	**Fitxer de dades:** PP_TR_500_01

Incidències:

FULL DE RESULTATS

DIMENSIONS

Proveta	PP/TR/500-01	**Llarg extensòmetre (mm)**	50
Gruix mitjà (mm)	3,236	**Amplada mitjana (mm)**	13,11

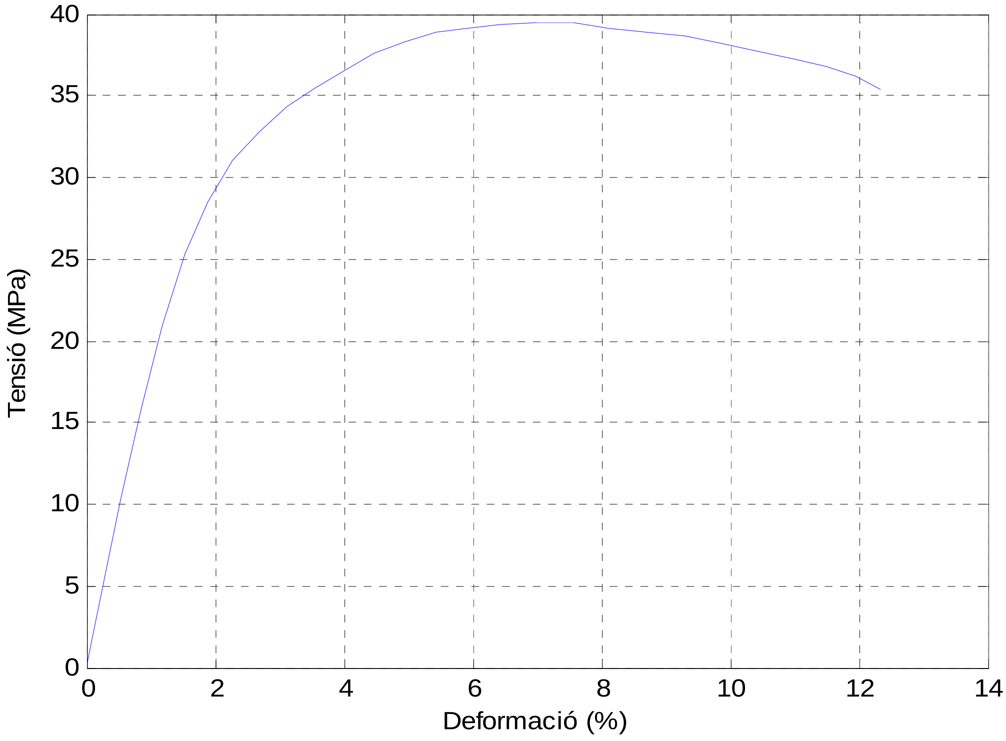
ASSAIG: Tracció 500 mm/min

Personal responsable: Isabel Bagudanch	**Data:** 10/01/08
Tª del laboratori (ºC): 22,4	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 47	**Temperatura assaig (ºC):** 22,4
Programa d'assaig: tracció_ext	**Fitxer de dades:** PP_TR_500_01

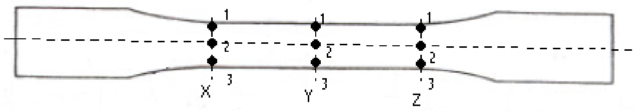
RESULTATS

Mòdul de Young (GPa)	1,687	**Màxima deformació (%)**	12,328
Límit de ruptura (MPa)	35,357	**Resistència (MPa)**	39,519

GRÀFICA



FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 07/08/07
Proveta: PP/TR/500-02	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,12	X	3,290	3,186	3,286
Y	13,11	Y	3,273	3,144	3,267
Z	13,10	Z	3,255	3,126	3,246
Mitjana	13,110	Mitjana	3,230	Dif. Max	

ASSAIG: Tracció 500 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 10/01/08
Tª del laboratori (ºC): 22,3	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 47	**Temperatura assaig (ºC):** 22,3
Programa d'assaig: tracció_ext	**Fitxer de dades:** PP_TR_500_02

Incidències:

FULL DE RESULTATS

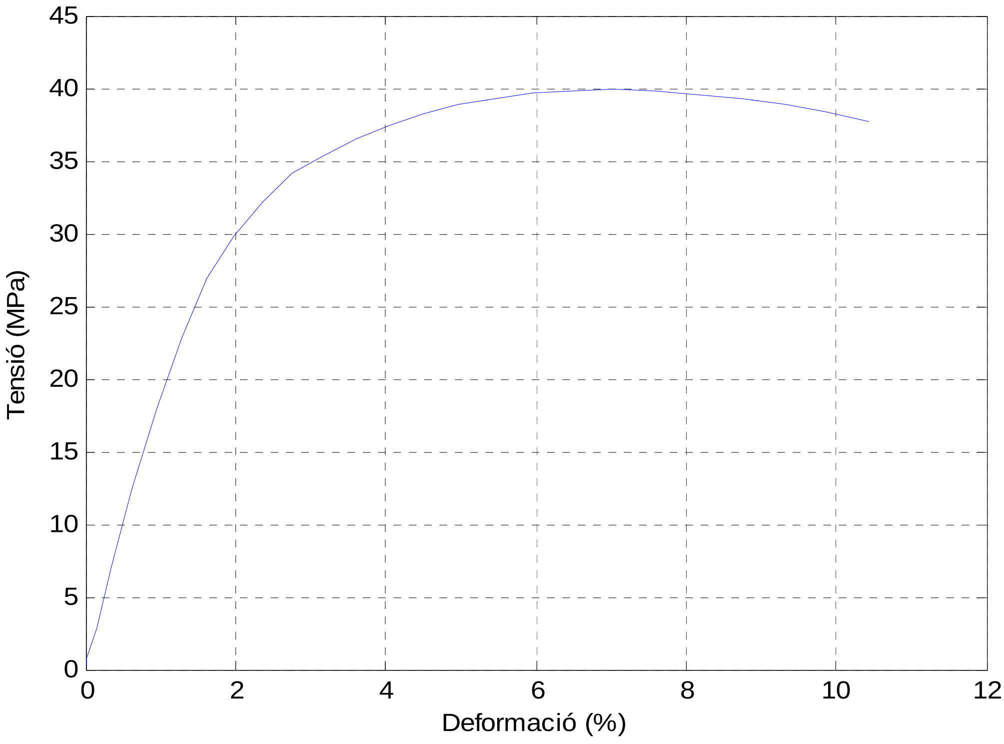
DIMENSIONS			
Proveta	PP/TR/500-02	**Llarg extensòmetre (mm)**	50
Gruix mitjà (mm)	3,23	**Amplada mitjana (mm)**	13,11

ASSAIG: Tracció 500 mm/min

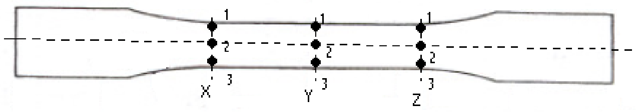
Personal responsable: Isabel Bagudanch	**Data:** 10/01/08
Tª del laboratori (ºC): 22,3	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 47	**Temperatura assaig (ºC):** 22,3
Programa d'assaig: tracció_ext	**Fitxer de dades:** PP_TR_500_02

RESULTATS			
Mòdul de Young (GPa)	1,701	**Màxima deformació (%)**	10,428
Límit de ruptura (MPa)	37,748	**Resistència (MPa)**	39,888

GRÀFICA



FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 07/08/07
Proveta: PP/TR/500-03	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,12	X	3,292	3,176	3,286
Y	13,12	Y	3,279	3,157	3,270
Z	13,12	Z	3,254	3,129	3,247
Mitjana	13,120	Mitjana	3,232	Dif. Max	

ASSAIG: Tracció 500 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 10/01/08
Tª del laboratori (ºC): 22,0	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 49	**Temperatura assaig (ºC):** 22,0
Programa d'assaig: tracció_ext	**Fitxer de dades:** PP_TR_500_03

Incidències:

FULL DE RESULTATS

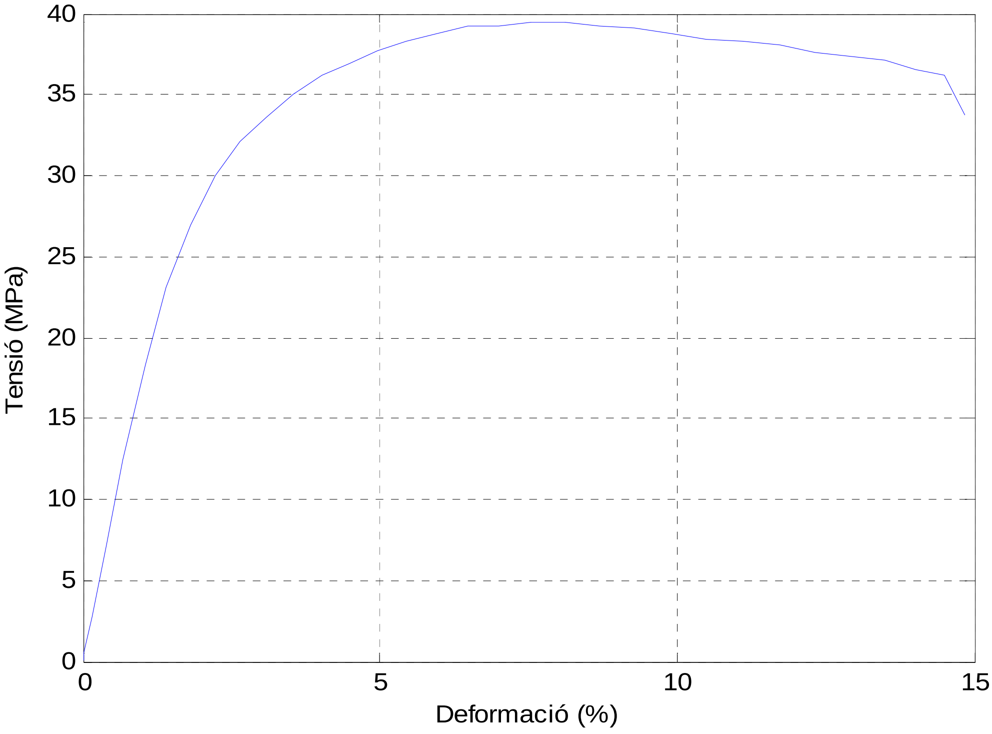
DIMENSIONS			
Proveta	PP/TR/500-03	**Llarg extensòmetre (mm)**	50
Gruix mitjà (mm)	3,232	**Amplada mitjana (mm)**	13,12

ASSAIG: Tracció 500 mm/min

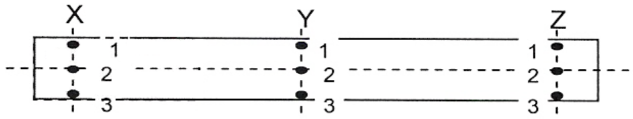
Personal responsable: Isabel Bagudanch	**Data:** 10/01/08
Tª del laboratori (ºC): 22,0	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 49	**Temperatura assaig (ºC):** 22,0
Programa d'assaig: tracció_ext	**Fitxer de dades:** PP_TR_500_03

RESULTATS			
Mòdul de Young (GPa)	1,671	**Màxima deformació (%)**	14,498
Límit de ruptura (MPa)	36,148	**Resistència (MPa)**	39,501

GRÀFICA



FULL DE CONTROL ASSAIG

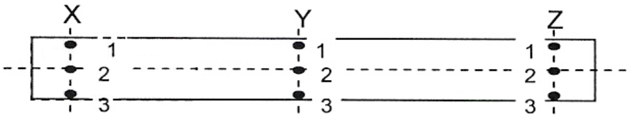
DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 20/02/08
Proveta: PP/RT/50-01	

Ample (mm)		Gruix (mm)			
			1	2	3
X	12,93	X	3,288	3,314	3,319
Y	12,98	Y	3,234	3,302	3,267
Z	13,01	Z	3,289	3,318	3,367
Mitjana	12,973	Mitjana	3,300	Dif. Max	

ASSAIG: Relaxació de tensions (0,2%)	
Personal responsable: Isabel Bagudanch	**Data:** 29/02/08
Tª del laboratori (ºC): 20,0	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 45	**Temperatura assaig (ºC):** 20,0
Programa d'assaig: relaxacio_tensions	**Fitxer de dades:** PP_RT_50_01

Incidències:

FULL DE CONTROL ASSAIG

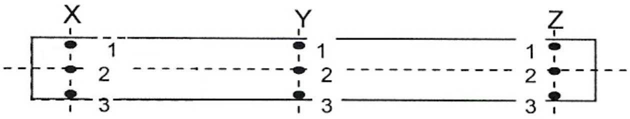
DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 20/02/08
Proveta: PP/RT/50-02	

Ample (mm)		Gruix (mm)			
			1	2	3
X	12,92	X	3,308	3,302	3,286
Y	12,98	Y	3,263	3,292	3,223
Z	12,93	Z	3,311	3,310	3,287
Mitjana	12,943	Mitjana	3,287	Dif. Max	

ASSAIG: Relaxació de tensions (0,3%)	
Personal responsable: Isabel Bagudanch	**Data:** 29/02/08
Tª del laboratori (ºC): 20,2	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 44	**Temperatura assaig (ºC):** 20,2
Programa d'assaig: relaxacio_tensions	**Fitxer de dades:** PP_RT_50_02

Incidències:

FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 20/02/08
Proveta: PP/RT/50-03	

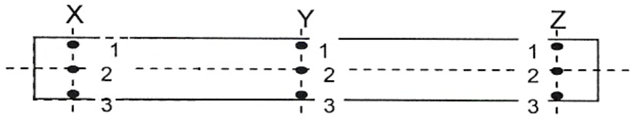
Ample (mm)		Gruix (mm)			
			1	2	3
X	12,93	X	3,289	3,313	3,323
Y	13,01	Y	3,251	3,301	3,258
Z	12,95	Z	3,289	3,319	3,309
Mitjana	12,963	Mitjana	3,295	Dif. Max	

ASSAIG: Relaxació de tensions (0,4%)	
Personal responsable: Isabel Bagudanch	**Data:** 29/02/08
Tª del laboratori (ºC): 20,1	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 44	**Temperatura assaig (ºC):** 20,1
Programa d'assaig: relaxacio_tensions	**Fitxer de dades:** PP_RT_50_03

Incidències:

FULL DE CONTROL ASSAIG

DIMENSIONS

Personal responsable: Isabel Bagudanch	**Data:** 20/02/08
Proveta: PP/RT/50-04	

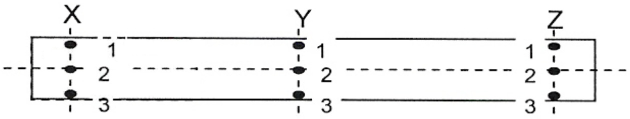
Ample (mm)		Gruix (mm)			
			1	2	3
X	12,92	X	3,286	3,318	3,324
Y	12,99	Y	3,231	3,305	3,262
Z	12,93	Z	3,287	3,321	3,303
Mitjana	12,947	Mitjana	3,293	Dif. Max	

ASSAIG: Relaxació de tensions (0,5%)

Personal responsable: Isabel Bagudanch	**Data:** 29/02/08
Tª del laboratori (ºC): 20,1	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 43	**Temperatura assaig (ºC):** 20,1
Programa d'assaig: relaxacio_tensions	**Fitxer de dades:** PP_RT_50_04

Incidències:

FULL DE CONTROL ASSAIG

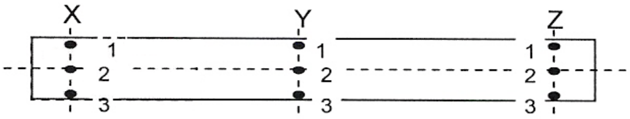
DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 20/02/08
Proveta: PP/RT/50-05	

Ample (mm)		Gruix (mm)			
			1	2	3
X	12,93	X	3,284	3,305	3,332
Y	13,00	Y	3,231	3,294	3,255
Z	12,92	Z	3,286	3,312	3,306
Mitjana	12,950	Mitjana	3,289	Dif. Max	

ASSAIG: Relaxació de tensions (0,6%)	
Personal responsable: Isabel Bagudanch	**Data:** 29/02/08
Tª del laboratori (ºC): 20,0	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 44	**Temperatura assaig (ºC):** 20,0
Programa d'assaig: relaxacio_tensions	**Fitxer de dades:** PP_RT_50_05

Incidències:

FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 20/02/08
Proveta: PP/RT/50-06	

Ample (mm)		Gruix (mm)			
			1	2	3
X	12,93	X	3,287	3,320	3,303
Y	12,92	Y	3,232	3,309	3,270
Z	12,93	Z	3,284	3,310	3,318
Mitjana	12,927	Mitjana	3,293	Dif. Max	

ASSAIG: Relaxació de tensions (0,7%)	
Personal responsable: Isabel Bagudanch	**Data:** 29/02/08
Tª del laboratori (ºC): 20,0	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 44	**Temperatura assaig (ºC):** 20,0
Programa d'assaig: relaxacio_tensions	**Fitxer de dades:** PP_RT_50_06

Incidències:

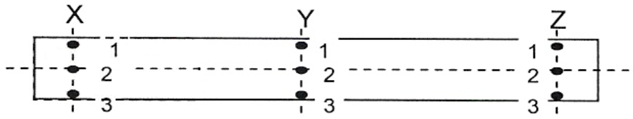
FULL DE CONTROL ASSAIG

DIMENSIONS

Personal responsable: Isabel Bagudanch	**Data:** 20/02/08

Proveta:

PP/RT/50-07



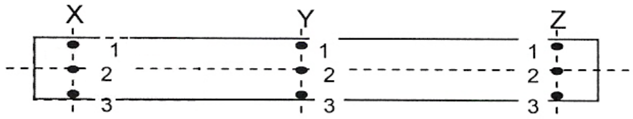
Ample (mm)		Gruix (mm)			
			1	2	3
X	12,92	X	3,284	3,324	3,307
Y	12,93	Y	3,237	3,284	3,259
Z	12,93	Z	3,287	3,306	3,317
Mitjana	12,927	Mitjana	3,289	Dif. Max	

ASSAIG: Relaxació de tensions (0,85%)

Personal responsable: Isabel Bagudanch	**Data:** 29/02/08
Tª del laboratori (ºC): 20,1	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 44	**Temperatura assaig (ºC):** 20,1
Programa d'assaig: relaxacio_tensions	**Fitxer de dades:** PP_RT_50_07

Incidències:

FULL DE CONTROL ASSAIG

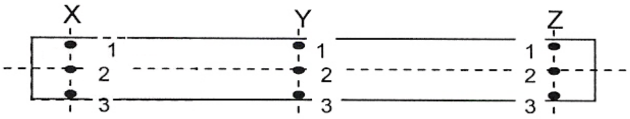
DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 20/02/08
Proveta: PP/RT/50-08	

Ample (mm)		Gruix (mm)			
			1	2	3
X	12,94	X	3,310	3,317	3,287
Y	12,99	Y	3,257	3,301	3,234
Z	12,95	Z	3,308	3,313	3,288
Mitjana	12,960	Mitjana	3,291	Dif. Max	

ASSAIG: Relaxació de tensions (1,1%)	
Personal responsable: Isabel Bagudanch	**Data:** 29/02/08
Tª del laboratori (ºC): 20,1	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 43	**Temperatura assaig (ºC):** 20,1
Programa d'assaig: relaxacio_tensions	**Fitxer de dades:** PP_RT_50_08

Incidències:

FULL DE CONTROL ASSAIG

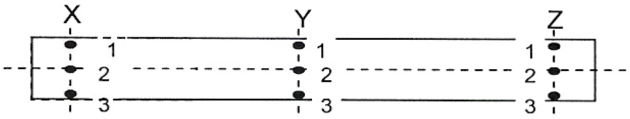
DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 20/02/08
Proveta: PP/RT/50-09	

Ample (mm)		Gruix (mm)			
			1	2	3
X	12,92	X	3,285	3,301	3,310
Y	12,99	Y	3,231	3,293	3,268
Z	12,93	Z	3,284	3,317	3,305
Mitjana	12,947	Mitjana	3,288	Dif. Max	

ASSAIG: Relaxació de tensions (1,28%)	
Personal responsable: Isabel Bagudanch	**Data:** 29/02/08
Tª del laboratori (ºC): 20,2	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 43	**Temperatura assaig (ºC):** 20,2
Programa d'assaig: relaxacio_tensions	**Fitxer de dades:** PP_RT_50_09

Incidències:

FULL DE CONTROL ASSAIG

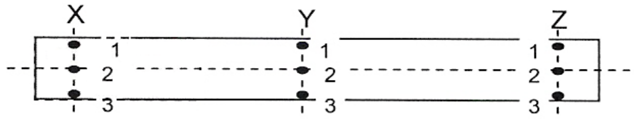
DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 20/02/08
Proveta: PP/RT/50-10	

Ample (mm)		Gruix (mm)			
			1	2	3
X	12,93	X	3,309	3,322	3,287
Y	12,96	Y	3,260	3,293	3,233
Z	12,93	Z	3,306	3,311	3,288
Mitjana	12,940	Mitjana	3,290	Dif. Max	

ASSAIG: Relaxació de tensions (1,46%)	
Personal responsable: Isabel Bagudanch	**Data:** 29/02/08
Tª del laboratori (ºC): 19,8	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 43	**Temperatura assaig (ºC):** 19,8
Programa d'assaig: relaxacio_tensions	**Fitxer de dades:** PP_RT_50_10

Incidències:

FULL DE CONTROL ASSAIG

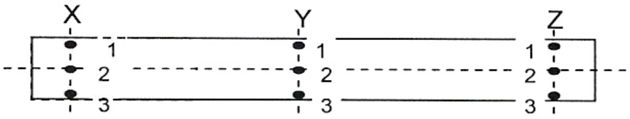
DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 19/06/08
Proveta: PP/TF/1-01	

Ample (mm)		Gruix (mm)			
			1	2	3
X	12,91	X	3,283	3,224	3,234
Y	12,97	Y	3,302	3,241	3,324
Z	12,92	Z	3,348	3,303	3,343
Mitjana	12,933	Mitjana	3,289	Dif. Max	

ASSAIG: Termofluència (100N)	
Personal responsable: Isabel Bagudanch	**Data:** 26/06/08
Tª del laboratori (ºC): 24,5	**Màquina utilitzada:** MTS Insight
Hr del laboratori (%): 55	**Temperatura assaig (ºC):** 25,0
Programa d'assaig: termofluencia	**Fitxer de dades:** PP_TF_1_01

Incidències:

FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 19/06/08
Proveta: PP/TF/1-02	

Ample (mm)		Gruix (mm)			
			1	2	3
X	12,91	X	3,249	3,189	3,216
Y	12,96	Y	3,237	3,187	3,240
Z	12,89	Z	3,300	3,256	3,276
Mitjana	12,920	Mitjana	3,239	Dif. Max	

ASSAIG: Termofluència (200N)	
Personal responsable: Isabel Bagudanch	**Data:** 26/06/08
Tª del laboratori (ºC): 24,7	**Màquina utilitzada:** MTS Insight
Hr del laboratori (%): 52	**Temperatura assaig (ºC):** 25,1
Programa d'assaig: termofluencia	**Fitxer de dades:** PP_TF_1_02

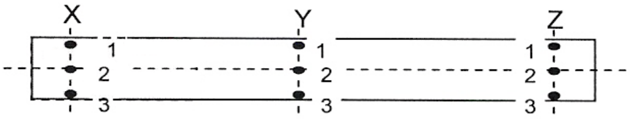
Incidències:

FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 19/06/08

Proveta:

PP/TF/1-03



Ample (mm)		Gruix (mm)			
			1	2	3
X	12,88	X	3,203	3,173	3,188
Y	12,92	Y	3,216	3,176	3,251
Z	12,91	Z	3,251	3,229	3,261
Mitjana	12,903	Mitjana	3,216	Dif. Max	

ASSAIG: Termofluència (300N)	
Personal responsable: Isabel Bagudanch	**Data:** 26/06/08
Tª del laboratori (ºC): 25,0	**Màquina utilitzada:** MTS Insight
Hr del laboratori (%): 54	**Temperatura assaig (ºC):** 25,3
Programa d'assaig: termofluencia	**Fitxer de dades:** PP_TF_1_03

Incidències:

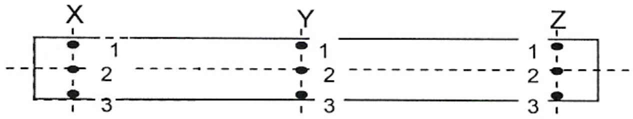
FULL DE CONTROL ASSAIG

DIMENSIONS

Personal responsable: Isabel Bagudanch	**Data:** 19/06/08

Proveta:

PP/TF/1-04



Ample (mm)		Gruix (mm)			
			1	2	3
X	12,89	X	3,230	3,166	3,215
Y	12,91	Y	3,250	3,203	3,211
Z	12,91	Z	3,236	3,215	3,238
Mitjana	12,903	Mitjana	3,218	Dif. Max	

ASSAIG: Termofluència (400N)

Personal responsable: Isabel Bagudanch	**Data:** 26/06/08
Tª del laboratori (ºC): 25,1	**Màquina utilitzada:** MTS Insight
Hr del laboratori (%): 55	**Temperatura assaig (ºC):** 25,2
Programa d'assaig: termofluencia	**Fitxer de dades:** PP_TF_1_04

Incidències:

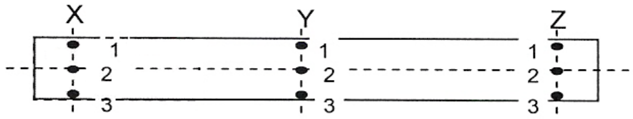
FULL DE CONTROL ASSAIG

DIMENSIONS

Personal responsable: Isabel Bagudanch	**Data:** 19/06/08

Proveta:

PP/TF/1-05



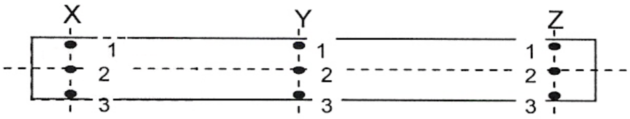
Ample (mm)		Gruix (mm)			
			1	2	3
X	12,87	X	3,139	3,046	3,106
Y	12,87	Y	3,152	3,037	3,135
Z	12,88	Z	3,188	3,076	3,171
Mitjana	12,873	Mitjana	3,117	Dif. Max	

ASSAIG: Termofluència (500N)

Personal responsable: Isabel Bagudanch	**Data:** 26/06/08
Tª del laboratori (ºC): 25,3	**Màquina utilitzada:** MTS Insight
Hr del laboratori (%): 56	**Temperatura assaig (ºC):** 25,4
Programa d'assaig: termofluencia	**Fitxer de dades:** PP_TF_1_05

Incidències:

FULL DE CONTROL ASSAIG

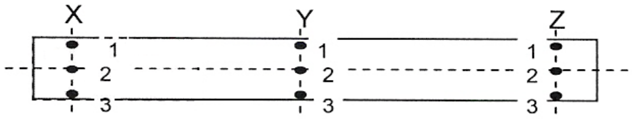
DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 19/06/08
Proveta: PP/TF/1-06	

Ample (mm)		Gruix (mm)			
			1	2	3
X	12,87	X	3,220	3,179	3,198
Y	12,91	Y	3,228	3,170	3,214
Z	12,9	Z	3,229	3,201	3,210
Mitjana	12,893	Mitjana	3,205	Dif. Max	

ASSAIG: Termofluència (600N)	
Personal responsable: Isabel Bagudanch	**Data:** 26/06/08
Tª del laboratori (ºC): 25,2	**Màquina utilitzada:** MTS Insight
Hr del laboratori (%): 53	**Temperatura assaig (ºC):** 25,2
Programa d'assaig: termofluencia	**Fitxer de dades:** PP_TF_1_06

Incidències:

FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 19/06/08
Proveta: PP/TF/1-07	

Ample (mm)		Gruix (mm)			
			1	2	3
X	12,87	X	3,218	3,179	3,195
Y	12,92	Y	3,228	3,170	3,199
Z	12,89	Z	3,222	3,194	3,213
Mitjana	12,893	Mitjana	3,202	Dif. Max	

ASSAIG: Termofluència (700N)	
Personal responsable: Isabel Bagudanch	**Data:** 26/06/08
Tª del laboratori (ºC): 25,0	**Màquina utilitzada:** MTS Insight
Hr del laboratori (%): 56	**Temperatura assaig (ºC):** 25,0
Programa d'assaig: termofluencia	**Fitxer de dades:** PP_TF_1_07

Incidències:

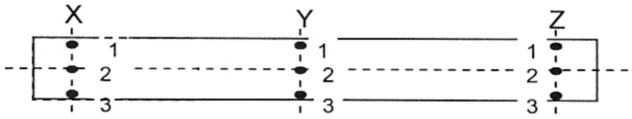
FULL DE CONTROL ASSAIG

DIMENSIONS

Personal responsable: Isabel Bagudanch	**Data:** 19/06/08

Proveta:

PP/TF/1-08



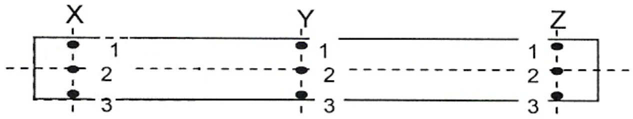
Ample (mm)		Gruix (mm)			
			1	2	3
X	12,88	X	3,230	3,203	3,215
Y	12,89	Y	3,216	3,158	3,218
Z	12,88	Z	3,236	3,165	3,190
Mitjana	12,883	Mitjana	3,203	Dif. Max	

ASSAIG: Termofluència (800N)

Personal responsable: Isabel Bagudanch	**Data:** 26/06/08
Tª del laboratori (ºC): 24,8	**Màquina utilitzada:** MTS Insight
Hr del laboratori (%): 55	**Temperatura assaig (ºC):** 24,9
Programa d'assaig: termofluencia	**Fitxer de dades:** PP_TF_1_08

Incidències:

FULL DE CONTROL ASSAIG

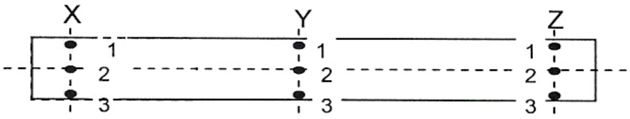
DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 19/06/08
Proveta: PP/TF/1-09	

Ample (mm)		Gruix (mm)			
			1	2	3
X	12,93	X	3,265	3,249	3,271
Y	12,95	Y	3,249	3,191	3,247
Z	12,92	Z	3,265	3,215	3,221
Mitjana	12,933	Mitjana	3,241	Dif. Max	

ASSAIG: Termofluència (900N)	
Personal responsable: Isabel Bagudanch	**Data:** 26/06/08
Tª del laboratori (ºC): 25,0	**Màquina utilitzada:** MTS Insight
Hr del laboratori (%): 52	**Temperatura assaig (ºC):** 25,0
Programa d'assaig: termofluencia	**Fitxer de dades:** PP_TF_1_09

Incidències:

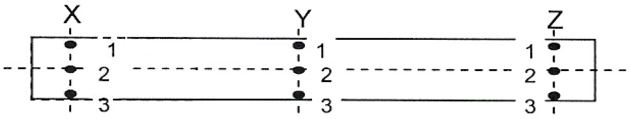
FULL DE CONTROL ASSAIG

DIMENSIONS					
Personal responsable: Isabel Bagudanch				**Data:** 19/06/08	
Proveta: PP/TF/1-10					
Ample (mm)		Gruix (mm)			
			1	2	3
X	12,87	X	3,219	3,155	3,192
Y	12,93	Y	3,234	3,187	3,203
Z	12,90	Z	3,268	3,212	3,247
Mitjana	12,900	Mitjana	3,213	Dif. Max	

ASSAIG: Termofluència (1000N)	
Personal responsable: Isabel Bagudanch	**Data:** 27/06/08
Tª del laboratori (ºC): 24,9	**Màquina utilitzada:** MTS Insight
Hr del laboratori (%): 56	**Temperatura assaig (ºC):** 25,1
Programa d'assaig: termofluencia	**Fitxer de dades:** PP_TF_1_10

Incidències:

FULL DE CONTROL ASSAIG

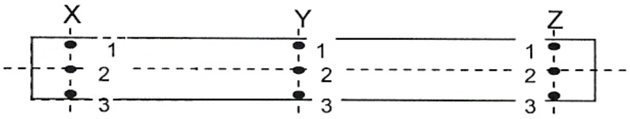
DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 20/02/08
Proveta: PP/BL/RT	

Ample (mm)		Gruix (mm)			
			1	2	3
X	12,93	X	3,288	3,307	3,332
Y	13,01	Y	3,228	3,289	3,254
Z	12,94	Z	3,287	3,318	3,306
Mitjana	12,960	Mitjana	3,290	Dif. Max	

ASSAIG: Principi de superposició de Boltzmann (per relaxació de tensions)	
Personal responsable: Isabel Bagudanch	**Data:** 27/03/08
Tª del laboratori (ºC): 20,0	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 46	**Temperatura assaig (ºC):** 19,9
Programa d'assaig: boltzmann	**Fitxer de dades:** PP_BL_RT

Incidències:

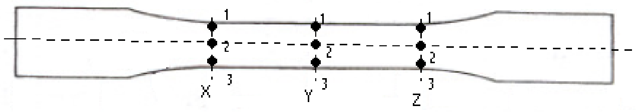
FULL DE CONTROL ASSAIG

DIMENSIONS					
Personal responsable: Isabel Bagudanch			**Data:** 19/06/08		
Proveta: PP/BL/TF					
Ample (mm)		Gruix (mm)			
			1	2	3
X	12,89	X	3,253	3,181	3,219
Y	12,89	Y	3,226	3,178	3,232
Z	12,88	Z	3,249	3,201	3,237
Mitjana	12,887	Mitjana	3,220	Dif. Max	

ASSAIG: Principi de superposició de Boltzmann (per termofluència)	
Personal responsable: Isabel Bagudanch	**Data:** 18/07/08
Tª del laboratori (ºC): 25,5	**Màquina utilitzada:** MTS Insight
Hr del laboratori (%): 50	**Temperatura assaig (ºC):** 25,5
Programa d'assaig: boltzmann	**Fitxer de dades:** PP_BL_TF

Incidències:

FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 07/08/07
Proveta: PS/TR/0,05-01	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,22	X	3,237	3,125	3,247
Y	13,23	Y	3,257	3,148	3,266
Z	13,23	Z	3,272	3,169	3,281
Mitjana	13,227	Mitjana	3,222	Dif. Max	

ASSAIG: Tracció 0,05 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 14/01/08
Tª del laboratori (ºC): 20,2	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 42	**Temperatura assaig (ºC):** 20,2
Programa d'assaig: tracció_ext	**Fitxer de dades:** PS_TR_0,05_01

Incidències:

FULL DE RESULTATS

DIMENSIONS

Proveta	PS/TR/0,05-01	**Llarg extensòmetre (mm)**	50
Gruix mitjà (mm)	3,222	**Amplada mitjana (mm)**	13,227

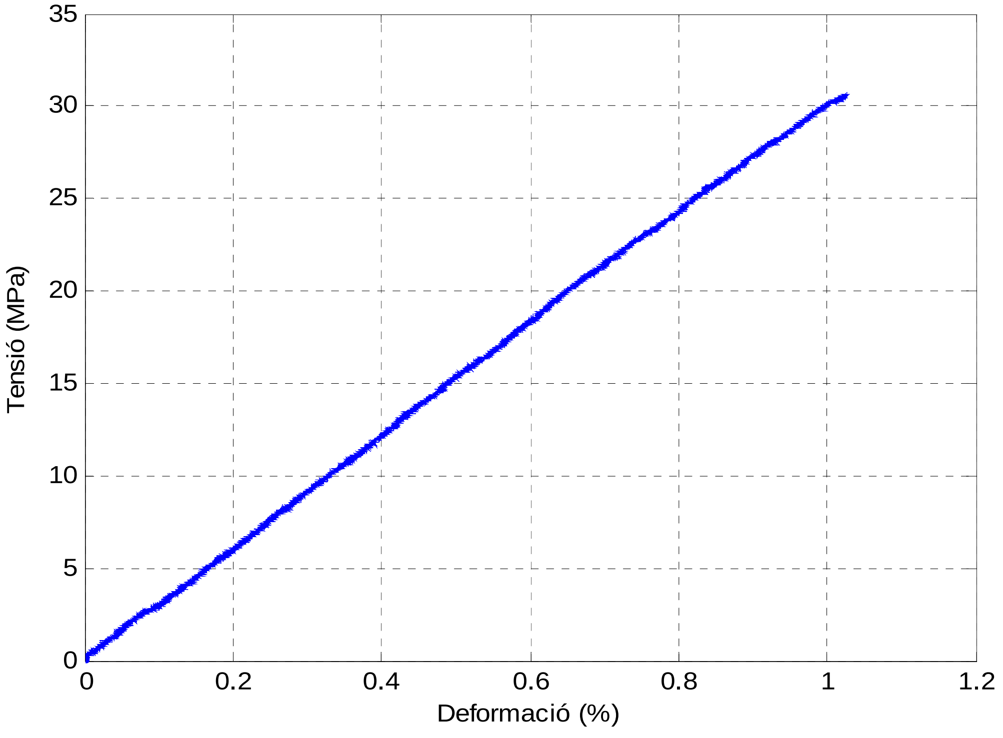
ASSAIG: Tracció 0,05 mm/min

Personal responsable: Isabel Bagudanch	**Data:** 14/01/08
Tª del laboratori (ºC): 20,2	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 42	**Temperatura assaig (ºC):** 20,2
Programa d'assaig: tracció_ext	**Fitxer de dades:** PS_TR_0,05_01

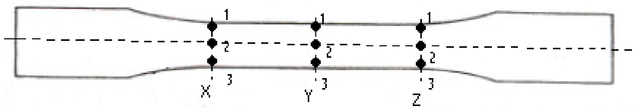
RESULTATS

Mòdul de Young (GPa)	2,860	**Màxima deformació (%)**	1,030
Límit de ruptura (MPa)	30,724	**Resistència (MPa)**	30,724

GRÀFICA



FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 07/08/07
Proveta: PS/TR/0,05-02	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,23	X	3,247	3,131	3,241
Y	13,22	Y	3,269	3,154	3,259
Z	13,23	Z	3,281	3,170	3,276
Mitjana	13,227	Mitjana	3,225	Dif. Max	

ASSAIG: Tracció 0,05 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 14/01/08
Tª del laboratori (ºC): 19,5	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 45	**Temperatura assaig (ºC):** 19,5
Programa d'assaig: tracció_ext	**Fitxer de dades:** PS_TR_0,05_02

Incidències:

FULL DE RESULTATS

DIMENSIONS

Proveta	PS/TR/0,05-02	**Llarg extensòmetre (mm)**	50
Gruix mitjà (mm)	3,225	**Amplada mitjana (mm)**	13,227

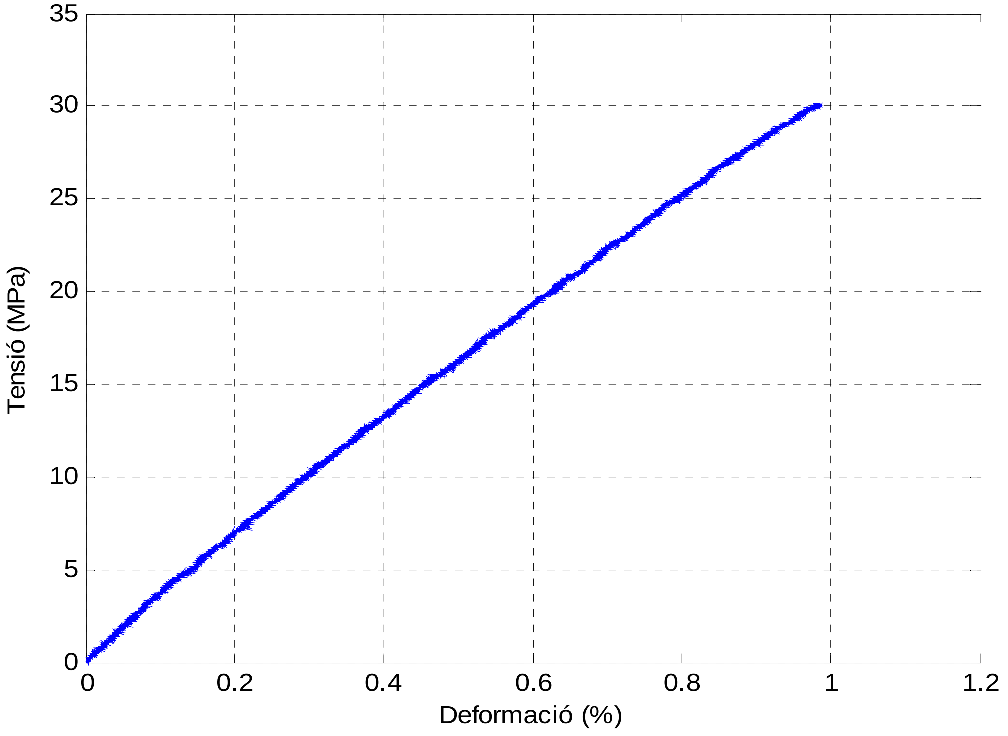
ASSAIG: Tracció 0,05 mm/min

Personal responsable: Isabel Bagudanch	**Data:** 14/01/08
Tª del laboratori (ºC): 19,5	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 45	**Temperatura assaig (ºC):** 19,5
Programa d'assaig: tracció_ext	**Fitxer de dades:** PS_TR_0,05_02

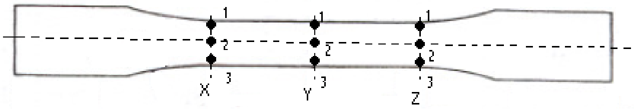
RESULTATS

Mòdul de Young (GPa)	3,352	**Màxima deformació (%)**	0,988
Límit de ruptura (MPa)	30,183	**Resistència (MPa)**	30,183

GRÀFICA



FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 07/08/07
Proveta: PS/TR/0,5-01	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,21	X	3,237	3,134	3,247
Y	13,23	Y	3,255	3,168	3,268
Z	13,23	Z	3,269	3,172	3,277
Mitjana	13,223	Mitjana	3,225	Dif. Max	

ASSAIG: Tracció 0,5 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 14/01/08
Tª del laboratori (ºC): 20,5	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 44	**Temperatura assaig (ºC):** 20,5
Programa d'assaig: tracció_ext	**Fitxer de dades:** PS_TR_0,5_01

Incidències:

FULL DE RESULTATS

DIMENSIONS

Proveta	PS/TR/0,5-01	**Llarg extensòmetre (mm)**	50
Gruix mitjà (mm)	3,225	**Amplada mitjana (mm)**	13,223

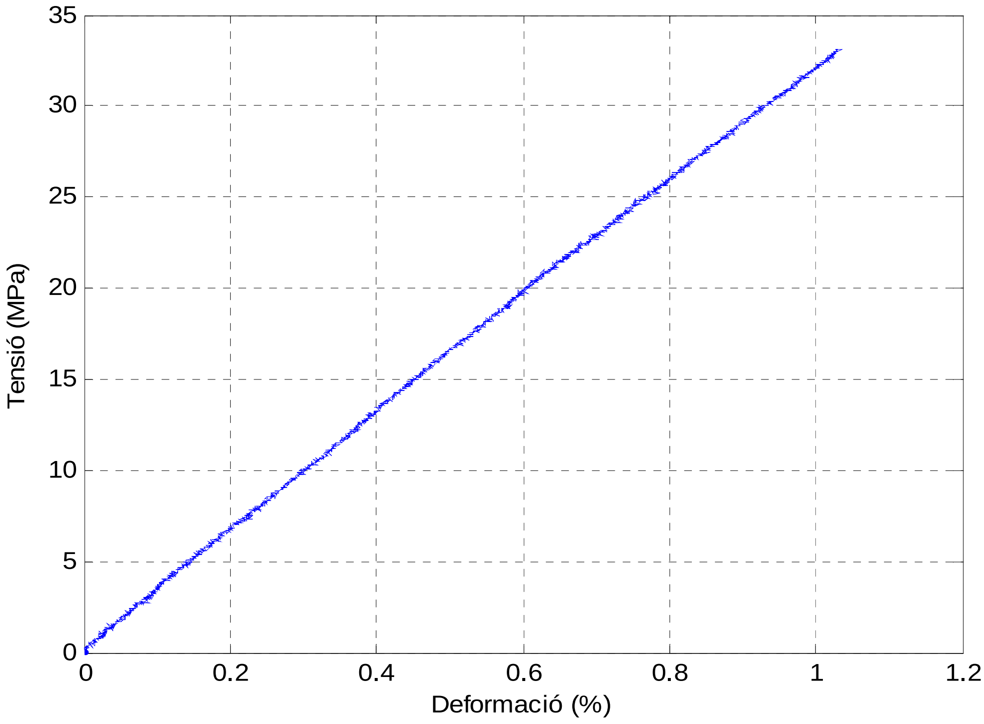
ASSAIG: Tracció 0,5 mm/min

Personal responsable: Isabel Bagudanch	**Data:** 14/01/08
Tª del laboratori (ºC): 20,5	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 44	**Temperatura assaig (ºC):** 20,5
Programa d'assaig: tracció_ext	**Fitxer de dades:** PS_TR_0,5_01

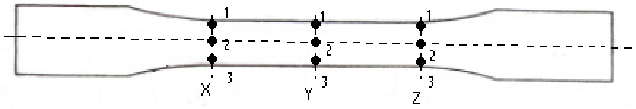
RESULTATS

Mòdul de Young (GPa)	3,169	**Màxima deformació (%)**	1,034
Límit de ruptura (MPa)	33,123	**Resistència (MPa)**	33,123

GRÀFICA



FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 07/08/07
Proveta: PS/TR/0,5-02	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,24	X	3,243	3,138	3,245
Y	13,24	Y	3,262	3,149	3,269
Z	13,23	Z	3,269	3,211	3,282
Mitjana	13,237	Mitjana	3,230	Dif. Max	

ASSAIG: Tracció 0,5 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 14/01/08
Tª del laboratori (ºC): 20,5	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 44	**Temperatura assaig (ºC):** 20,5
Programa d'assaig: tracció_ext	**Fitxer de dades:** PS_TR_0,5_02

Incidències:

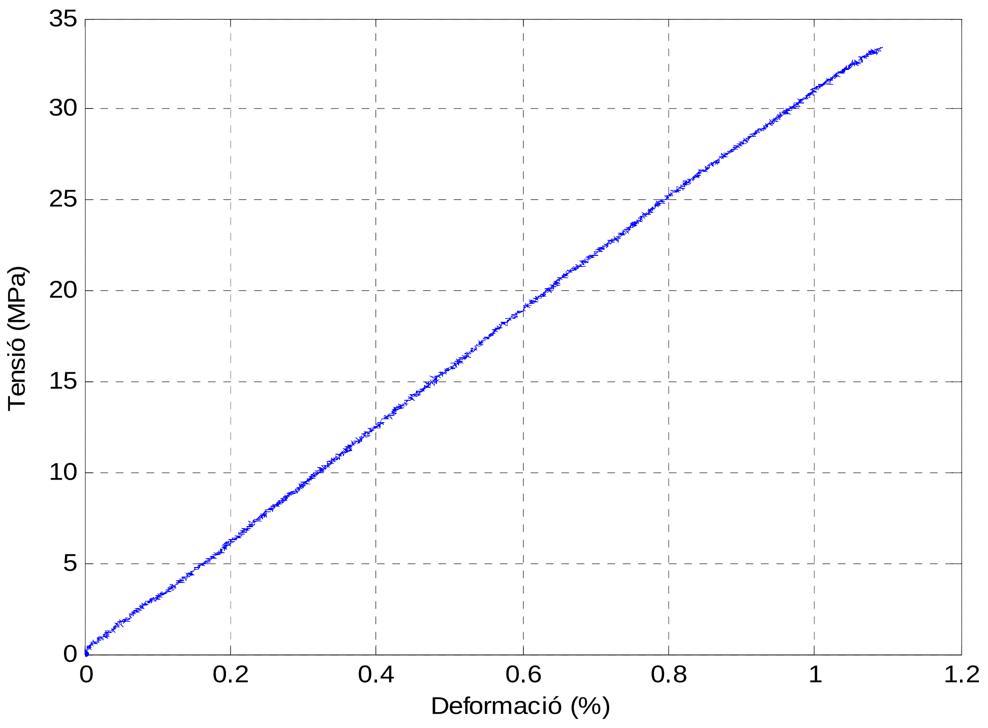
FULL DE RESULTATS

DIMENSIONS			
Proveta	PS/TR/0,5-02	**Llarg extensòmetre (mm)**	50
Gruix mitjà (mm)	3,230	**Amplada mitjana (mm)**	13,237

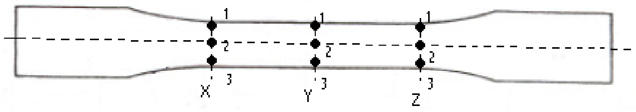
ASSAIG: Tracció 0,5 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 14/01/08
Tª del laboratori (ºC): 20,5	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 44	**Temperatura assaig (ºC):** 20,5
Programa d'assaig: tracció_ext	**Fitxer de dades:** PS_TR_0,5_02

RESULTATS			
Mòdul de Young (GPa)	2,978	**Màxima deformació (%)**	1,092
Límit de ruptura (MPa)	33,402	**Resistència (MPa)**	33,402

GRÀFICA



FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 07/08/07
Proveta: PS/TR/0,5-03	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,23	X	3,239	3,126	3,251
Y	13,25	Y	3,259	3,150	3,269
Z	13,23	Z	3,276	3,167	3,280
Mitjana	13,237	Mitjana	3,224	Dif. Max	

ASSAIG: Tracció 0,5 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 14/01/08
Tª del laboratori (ºC): 20,6	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 44	**Temperatura assaig (ºC):** 20,6
Programa d'assaig: tracció_ext	**Fitxer de dades:** PS_TR_0,5_03

Incidències:

FULL DE RESULTATS

DIMENSIONS

Proveta	PS/TR/0,5-03	**Llarg extensòmetre (mm)**	50
Gruix mitjà (mm)	3,224	**Amplada mitjana (mm)**	13,237

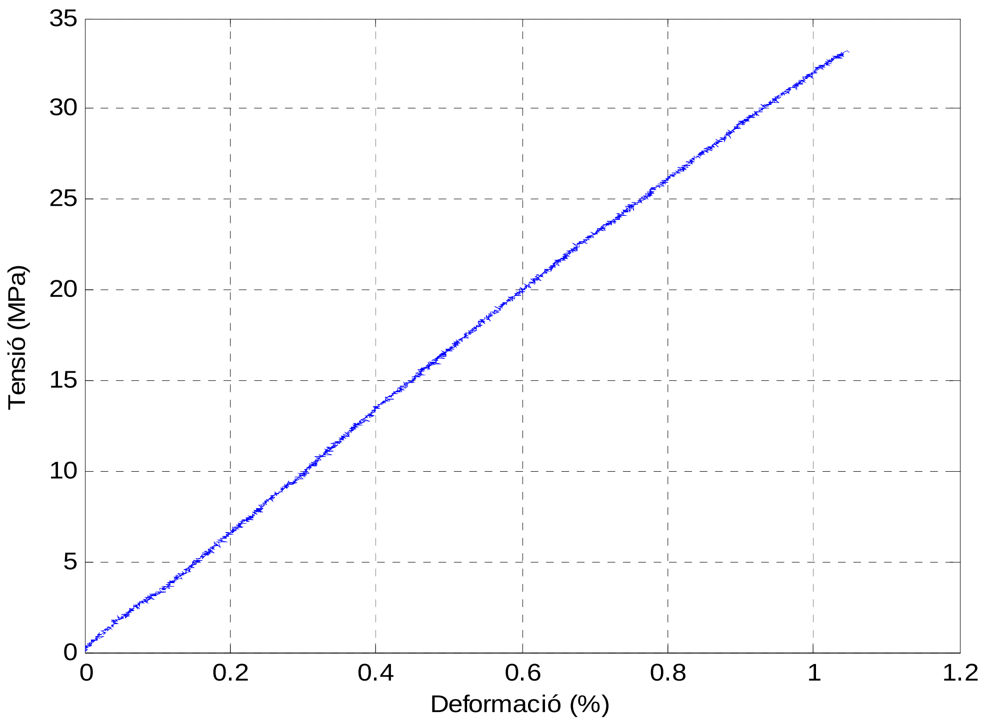
ASSAIG: Tracció 0,5 mm/min

Personal responsable: Isabel Bagudanch	**Data:** 14/01/08
Tª del laboratori (ºC): 20,6	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 44	**Temperatura assaig (ºC):** 20,6
Programa d'assaig: tracció_ext	**Fitxer de dades:** PS_TR_0,5_03

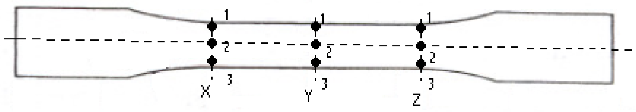
RESULTATS

Mòdul de Young (GPa)	3,199	**Màxima deformació (%)**	1,05
Límit de ruptura (MPa)	33,208	**Resistència (MPa)**	33,208

GRÀFICA



FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 07/08/07
Proveta: PS/TR/5-01	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,22	X	3,241	3,121	3,247
Y	13,23	Y	3,257	3,150	3,268
Z	13,23	Z	3,277	3,163	3,281
Mitjana	13,227	Mitjana	3,223	Dif. Max	

ASSAIG: Tracció 5 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 14/01/08
Tª del laboratori (ºC): 19,0	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 43	**Temperatura assaig (ºC):** 19,0
Programa d'assaig: tracció_ext	**Fitxer de dades:** PS_TR_5_01

Incidències:

FULL DE RESULTATS

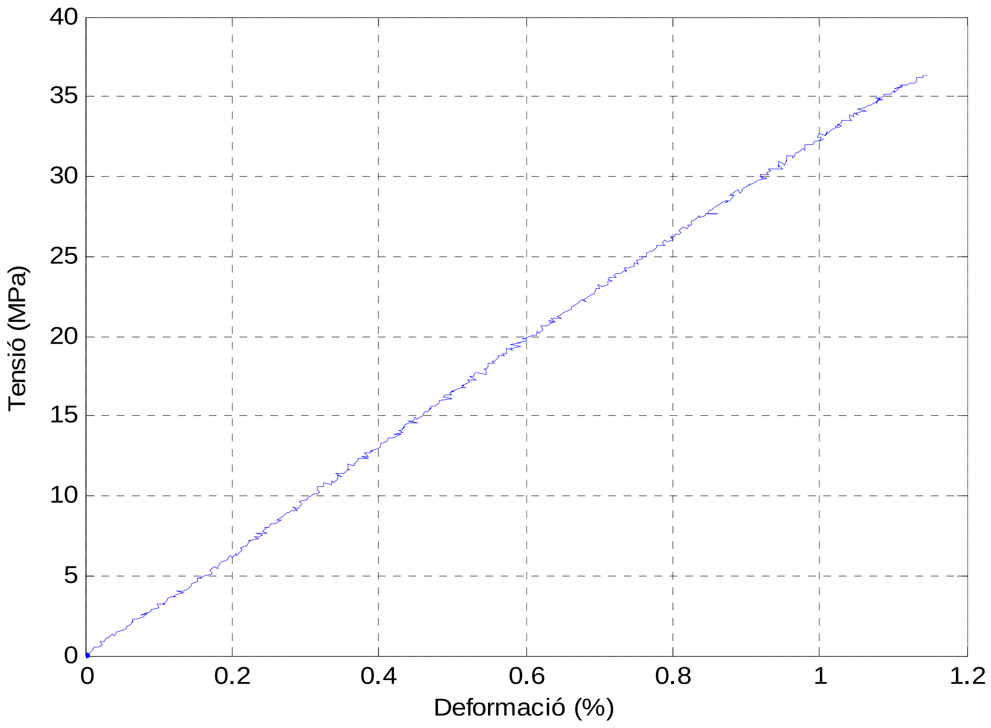
DIMENSIONS			
Proveta	PS/TR/5-01	**Llarg extensòmetre (mm)**	50
Gruix mitjà (mm)	3,223	**Amplada mitjana (mm)**	13,227

ASSAIG: Tracció 5 mm/min

Personal responsable: Isabel Bagudanch	**Data:** 14/01/08
Tª del laboratori (ºC): 19,0	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 43	**Temperatura assaig (ºC):** 19,0
Programa d'assaig: tracció_ext	**Fitxer de dades:** PS_TR_5_01

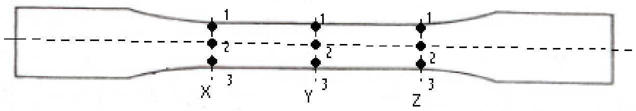
RESULTATS			
Mòdul de Young (GPa)	3,244	**Màxima deformació (%)**	1,147
Límit de ruptura (MPa)	36,322	**Resistència (MPa)**	36,322

GRÀFICA



FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 07/08/07
Proveta: PS/TR/5-02	



Ample (mm)		Gruix (mm)			
			1	2	3
X	13,24	X	3,284	3,206	3,280
Y	13,25	Y	3,274	3,171	3,264
Z	13,22	Z	3,251	3,129	3,243
Mitjana	13,237	Mitjana	3,234	Dif. Max	

ASSAIG: Tracció 5 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 14/01/08
Tª del laboratori (ºC): 18,9	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 44	**Temperatura assaig (ºC):** 18,9
Programa d'assaig: tracció_ext	**Fitxer de dades:** PS_TR_5_02

Incidències:

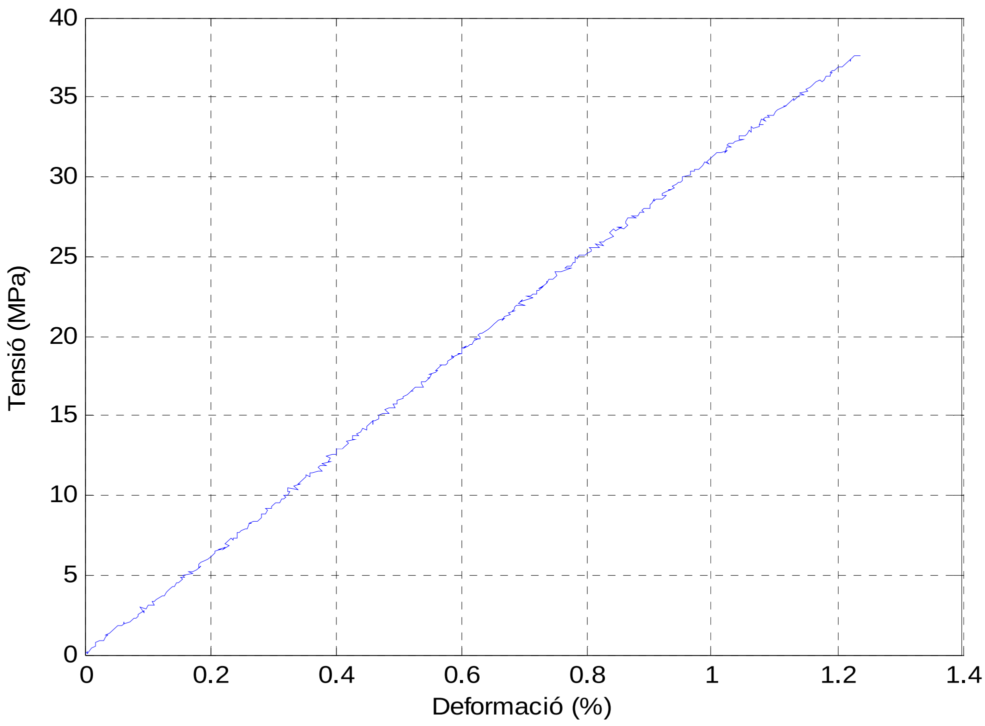
FULL DE RESULTATS

DIMENSIONS			
Proveta	PS/TR/5-02	**Llarg extensòmetre (mm)**	50
Gruix mitjà (mm)	3,234	**Amplada mitjana (mm)**	13,237

ASSAIG: Tracció 5 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 14/01/08
Tª del laboratori (ºC): 18,9	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 44	**Temperatura assaig (ºC):** 18,9
Programa d'assaig: tracció_ext	**Fitxer de dades:** PS_TR_5_02

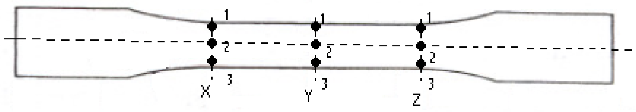
RESULTATS			
Mòdul de Young (GPa)	3,093	**Màxima deformació (%)**	1,238
Límit de ruptura (MPa)	37,631	**Resistència (MPa)**	37,631

GRÀFICA



FULL DE CONTROL ASSAIG

DIMENSIONS

Personal responsable: Isabel Bagudanch	**Data:** 07/08/07
Proveta: PS/TR/5-03	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,22	X	3,243	3,134	3,250
Y	13,24	Y	3,266	3,166	3,274
Z	13,23	Z	3,284	3,179	3,285
Mitjana	13,230	Mitjana	3,231	Dif. Max	

ASSAIG: Tracció 5 mm/min

Personal responsable: Isabel Bagudanch	**Data:** 14/01/08
Tª del laboratori (ºC): 19,2	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 44	**Temperatura assaig (ºC):** 19,2
Programa d'assaig: tracció_ext	**Fitxer de dades:** PS_TR_5_03

Incidències:

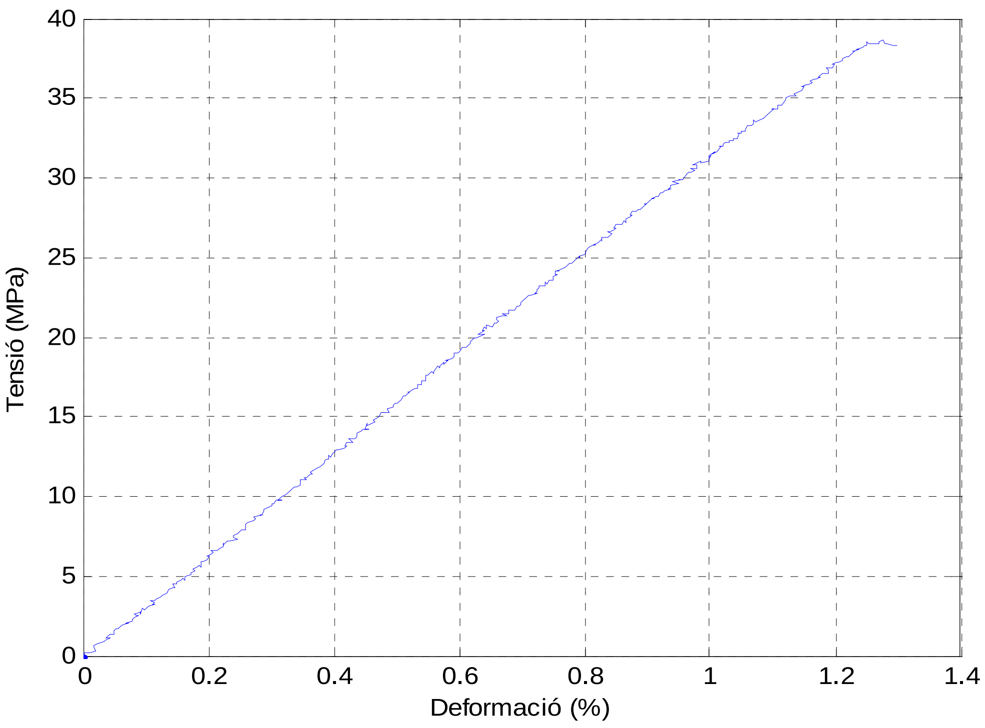
FULL DE RESULTATS

DIMENSIONS			
Proveta	PS/TR/5-03	**Llarg extensòmetre (mm)**	50
Gruix mitjà (mm)	3,231	**Amplada mitjana (mm)**	13,230

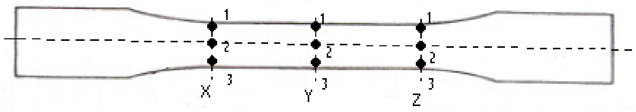
ASSAIG: Tracció 5 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 14/01/08
Tª del laboratori (ºC): 19,2	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 44	**Temperatura assaig (ºC):** 19,2
Programa d'assaig: tracció_ext	**Fitxer de dades:** PS_TR_5_03

RESULTATS			
Mòdul de Young (GPa)	3,106	**Màxima deformació (%)**	1,298
Límit de ruptura (MPa)	38,6	**Resistència (MPa)**	38,6

GRÀFICA



FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 07/08/07
Proveta: PS/TR/50-01	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,22	X	3,237	3,128	3,247
Y	13,24	Y	3,254	3,166	3,264
Z	13,24	Z	3,272	3,167	3,280
Mitjana	13,233	Mitjana	3,224	Dif. Max	

ASSAIG: Tracció 50 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 09/08/07
Tª del laboratori (ºC): 26,2	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 46	**Temperatura assaig (ºC):** 26,2
Programa d'assaig: tracció_ext	**Fitxer de dades:** PS_TR_50_01

Incidències:

FULL DE RESULTATS

DIMENSIONS

Proveta	PS/TR/50-01	**Llarg extensòmetre (mm)**	50
Gruix mitjà (mm)	3,224	**Amplada mitjana (mm)**	13,233

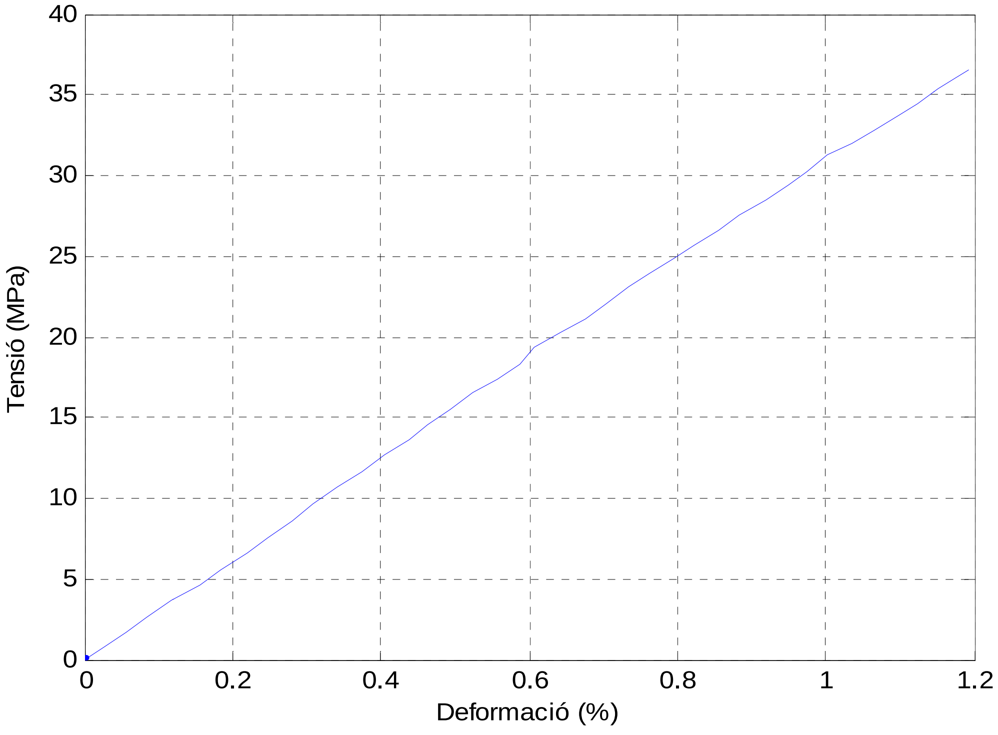
ASSAIG: Tracció 50 mm/min

Personal responsable: Isabel Bagudanch	**Data:** 09/08/07
Tª del laboratori (ºC): 26,2	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 46	**Temperatura assaig (ºC):** 26,2
Programa d'assaig: tracció_ext	**Fitxer de dades:** PS_TR_50_01

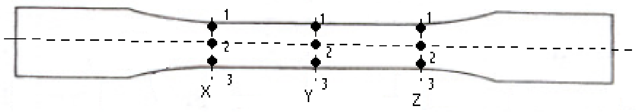
RESULTATS

Mòdul de Young (GPa)	3,112	**Màxima elongació (%)**	1,194
Límit de ruptura (MPa)	36,588	**Resistència (MPa)**	36,588

GRÀFICA



FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 07/08/07
Proveta: PS/TR/50-02	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,23	X	3,243	3,132	3,250
Y	13,24	Y	3,261	3,172	3,273
Z	13,25	Z	3,277	3,178	3,285
Mitjana	13,240	Mitjana	3,230	Dif. Max	

ASSAIG: Tracció 50 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 09/08/07
Tª del laboratori (ºC): 26,3	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 46	**Temperatura assaig (ºC):** 26,3
Programa d'assaig: tracció_ext	**Fitxer de dades:** PS_TR_50_02

Incidències:

FULL DE RESULTATS

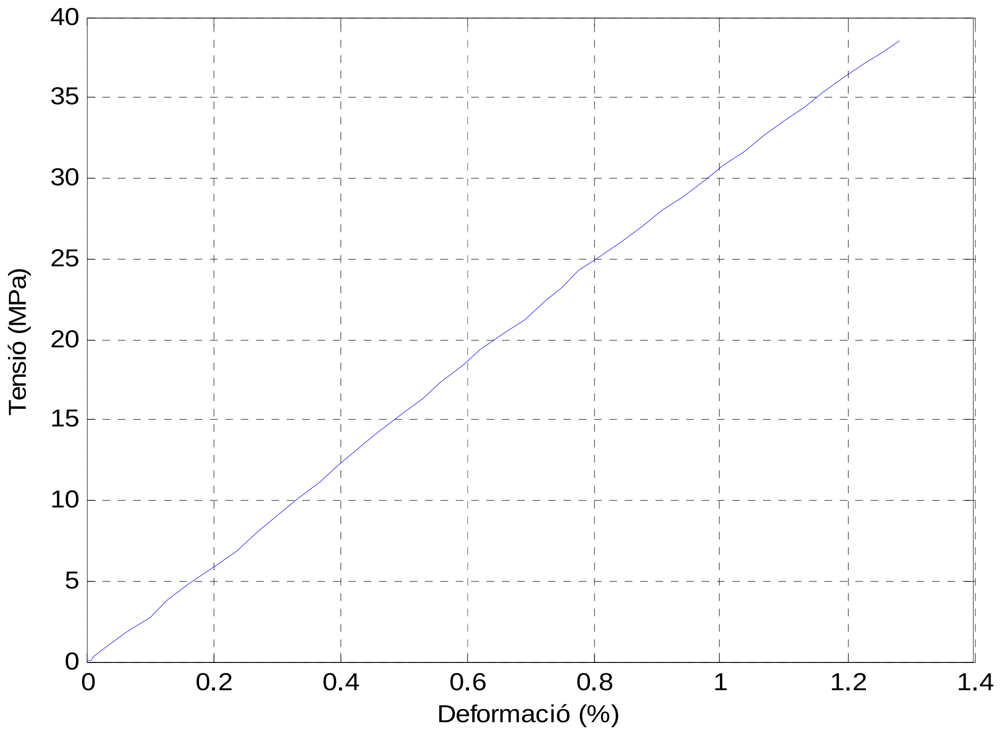
DIMENSIONS			
Proveta	PS/TR/50-02	**Llarg extensòmetre (mm)**	50
Gruix mitjà (mm)	3,230	**Amplada mitjana (mm)**	13,240

ASSAIG: Tracció 50 mm/min

Personal responsable: Isabel Bagudanch	**Data:** 09/08/07
Tª del laboratori (ºC): 26,3	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 46	**Temperatura assaig (ºC):** 26,3
Programa d'assaig: tracció_ext	**Fitxer de dades:** PS_TR_50_02

RESULTATS			
Mòdul de Young (GPa)	2,928	**Màxima elongació (%)**	1,281
Límit de ruptura (MPa)	38,51	**Resistència (MPa)**	38,51

GRÀFICA



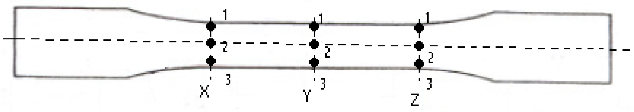
FULL DE CONTROL ASSAIG

DIMENSIONS

Personal responsable: Isabel Bagudanch	**Data:** 07/08/07

Proveta:

PS/TR/50-03



Ample (mm)		Gruix (mm)			
			1	2	3
X	13,23	X	3,242	3,129	3,252
Y	13,24	Y	3,262	3,150	3,270
Z	13,24	Z	3,283	3,186	3,280
Mitjana	13,237	Mitjana	3,228	Dif. Max	

ASSAIG: Tracció 50 mm/min

Personal responsable: Isabel Bagudanch	**Data:** 09/08/07
Tª del laboratori (ºC): 26,3	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 45	**Temperatura assaig (ºC):** 26,3
Programa d'assaig: tracció_ext	**Fitxer de dades:** PS_TR_50_03

Incidències:

FULL DE RESULTATS

DIMENSIONS			
Proveta	PS/TR/50-03	**Llarg extensòmetre (mm)**	50
Gruix mitjà (mm)	3,228	**Amplada mitjana (mm)**	13,237

ASSAIG: Tracció 50 mm/min

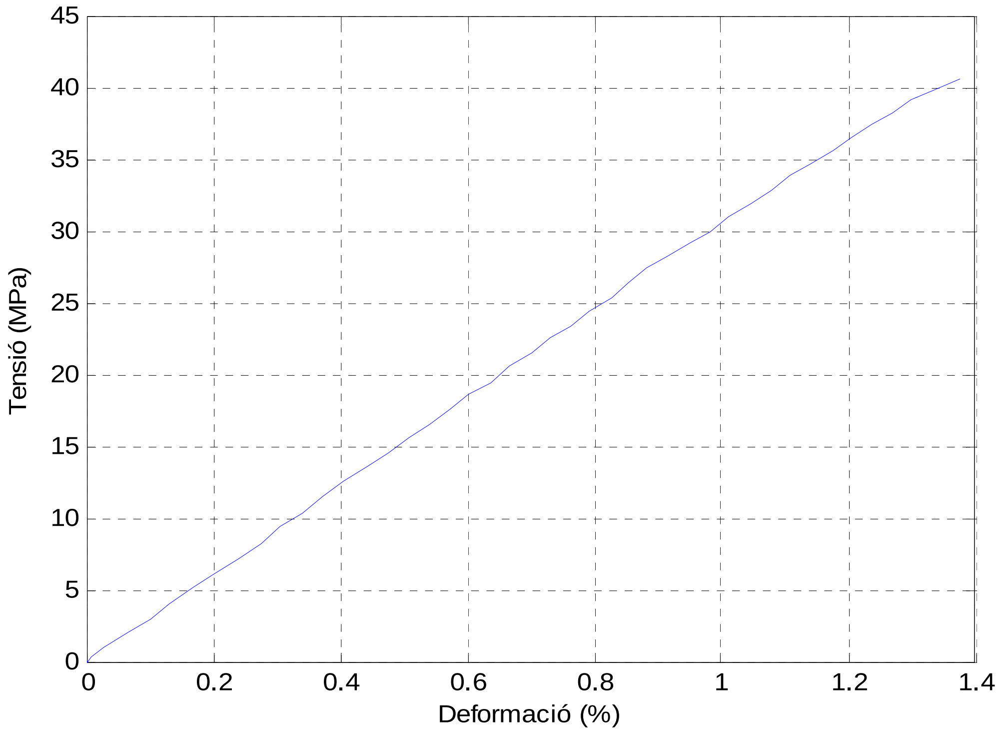
Personal responsable: Isabel Bagudanch

Data: 09/08/07

Tª del laboratori (ºC): 26,3	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 45	**Temperatura assaig (ºC):** 26,3
Programa d'assaig: tracció_ext	**Fitxer de dades:** PS_TR_50_03

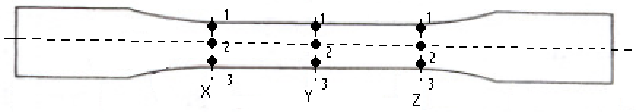
RESULTATS			
Mòdul de Young (GPa)	2,967	**Màxima elongació (%)**	1,375
Límit de ruptura (MPa)	40,554	**Resistència (MPa)**	40,554

GRÀFICA



FULL DE CONTROL ASSAIG

DIMENSIONS

Personal responsable: Isabel Bagudanch	**Data:** 07/08/07
Proveta: PS/TR/500-01	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,24	X	3,280	3,171	3,284
Y	13,23	Y	3,269	3,145	3,259
Z	13,23	Z	3,247	3,121	3,239
Mitjana	13,233	Mitjana	3,224	Dif. Max	

ASSAIG: Tracció 500 mm/min

Personal responsable: Isabel Bagudanch	**Data:** 10/01/08
Tª del laboratori (ºC): 21,5	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 49	**Temperatura assaig (ºC):** 21,5
Programa d'assaig: tracció_ext	**Fitxer de dades:** PS_TR_500_01

Incidències:

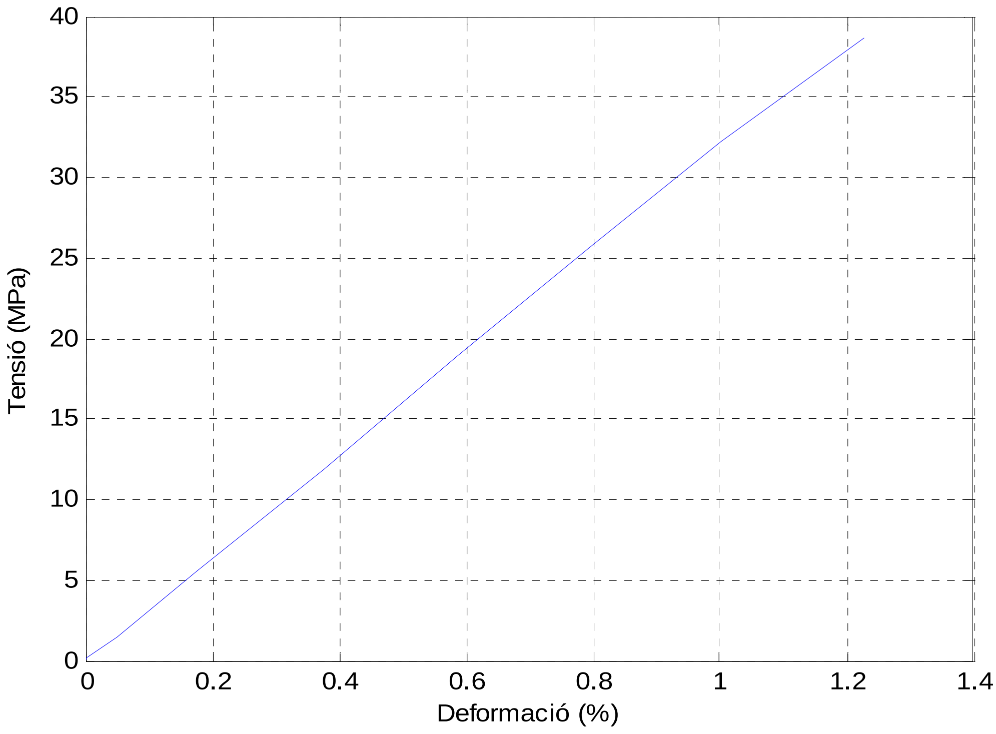
FULL DE RESULTATS

DIMENSIONS			
Proveta	PS/TR/500-01	**Llarg extensòmetre (mm)**	50
Gruix mitjà (mm)	3,224	**Amplada mitjana (mm)**	13,233

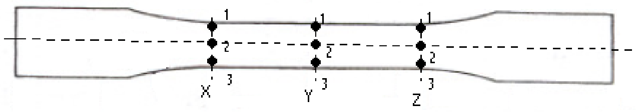
ASSAIG: Tracció 500 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 10/01/08
Tª del laboratori (ºC): 21,5	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 49	**Temperatura assaig (ºC):** 21,5
Programa d'assaig: tracció_ext	**Fitxer de dades:** PS_TR_500_01

RESULTATS			
Mòdul de Young (GPa)	3,186	**Màxima deformació (%)**	1,228
Límit de ruptura (MPa)	38,712	**Resistència (MPa)**	38,712

GRÀFICA



FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 07/08/07
Proveta: PS/TR/500-02	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,22	X	3,249	3,126	3,241
Y	13,24	Y	3,269	3,169	3,260
Z	13,24	Z	3,281	3,180	3,276
Mitjana	13,233	Mitjana	3,228	Dif. Max	

ASSAIG: Tracció 500 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 10/01/08
Tª del laboratori (ºC): 21,5	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 49	**Temperatura assaig (ºC):** 21,5
Programa d'assaig: tracció_ext	**Fitxer de dades:** PS_TR_500_02

Incidències:

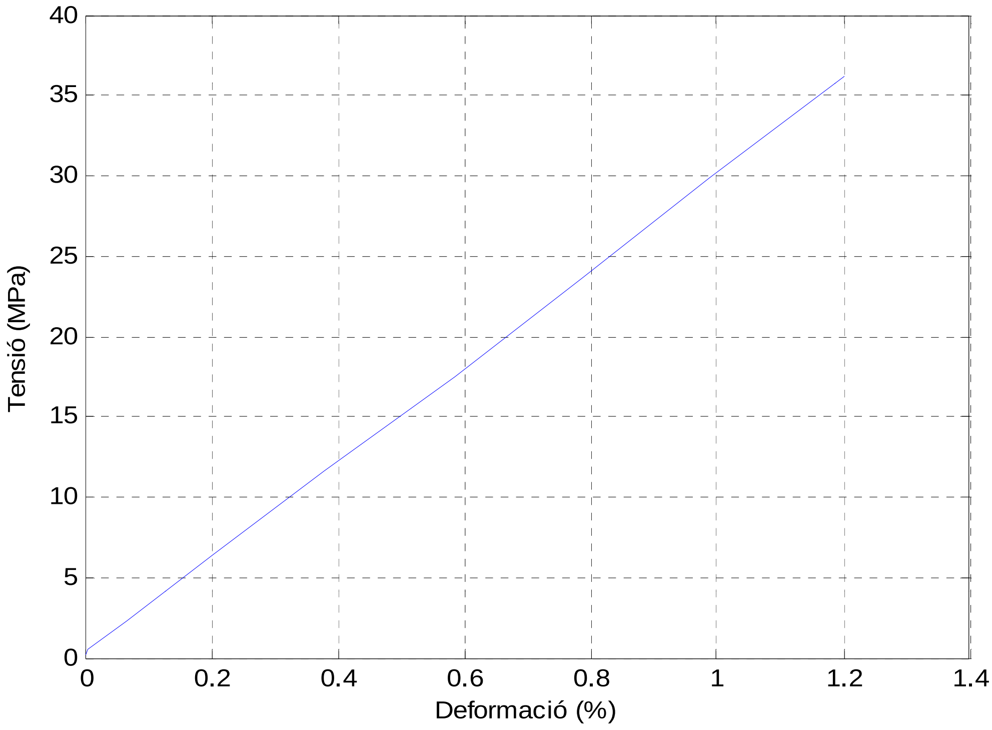
FULL DE RESULTATS

DIMENSIONS			
Proveta	PS/TR/500-02	**Llarg extensòmetre (mm)**	50
Gruix mitjà (mm)	3,228	**Amplada mitjana (mm)**	13,233

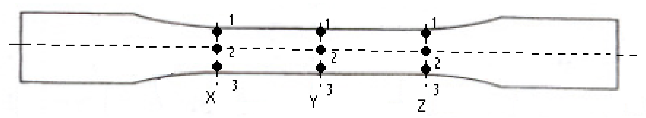
ASSAIG: Tracció 500 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 10/01/08
Tª del laboratori (ºC): 21,5	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 49	**Temperatura assaig (ºC):** 21,5
Programa d'assaig: tracció_ext	**Fitxer de dades:** PS_TR_500_02

RESULTATS			
Mòdul de Young (GPa)	2,991	**Màxima deformació (%)**	1,202
Límit de ruptura (MPa)	36,250	**Resistència (MPa)**	36,250

GRÀFICA



FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 07/08/07
Proveta: PS/TR/500-03	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,22	X	3,250	3,127	3,239
Y	13,23	Y	3,269	3,149	3,259
Z	13,23	Z	3,282	3,166	3,276
Mitjana	13,227	Mitjana	3,224	Dif. Max	

ASSAIG: Tracció 500 mm/min	
Personal responsable: Isabel Bagudanch	**Data:** 10/01/08
Tª del laboratori (ºC): 21,4	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 49	**Temperatura assaig (ºC):** 21,4
Programa d'assaig: tracció_ext	**Fitxer de dades:** PS_TR_500_03

Incidències:

FULL DE RESULTATS

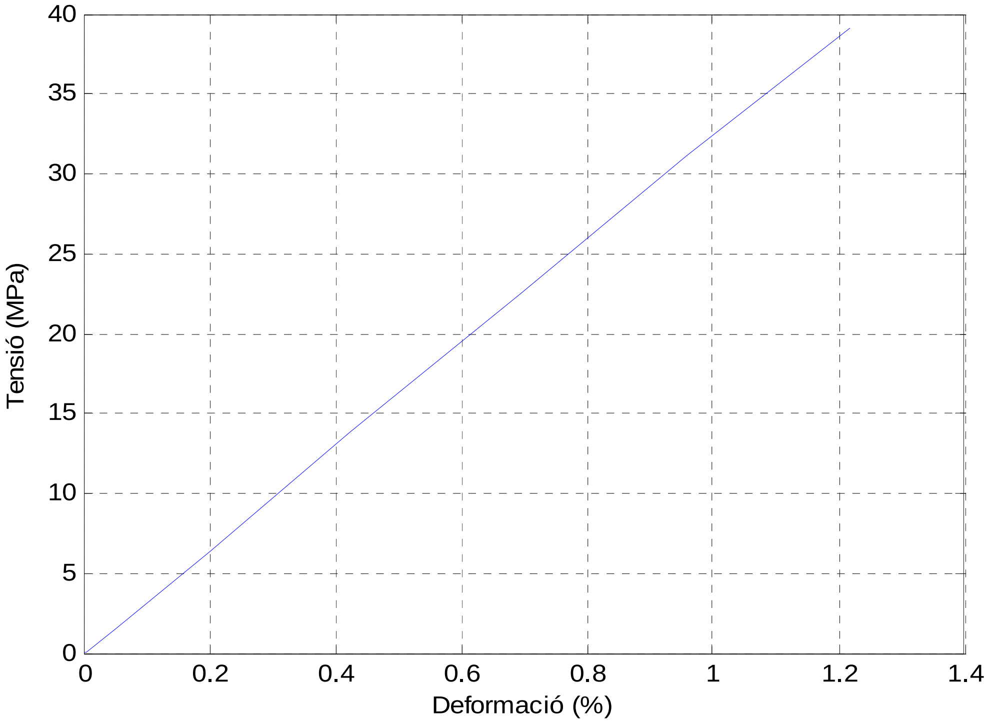
DIMENSIONS			
Proveta	PS/TR/500-03	**Llarg extensòmetre (mm)**	50
Gruix mitjà (mm)	3,224	**Amplada mitjana (mm)**	13,227

ASSAIG: Tracció 500 mm/min

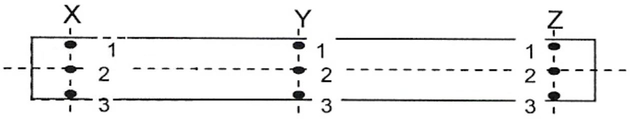
Personal responsable: Isabel Bagudanch	**Data:** 10/01/08
Tª del laboratori (ºC): 21,4	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 49	**Temperatura assaig (ºC):** 21,4
Programa d'assaig: tracció_ext	**Fitxer de dades:** PS_TR_500_03

RESULTATS			
Mòdul de Young (GPa)	3,231	**Màxima deformació (%)**	1,217
Límit de ruptura (MPa)	39,096	**Resistència (MPa)**	39,096

GRÀFICA



FULL DE CONTROL ASSAIG

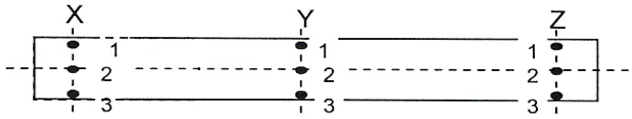
DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 20/02/08
Proveta: PS/RT/50-01	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,02	X	3,255	3,271	3,271
Y	13,10	Y	3,150	3,219	3,184
Z	13,02	Z	3,261	3,275	3,289
Mitjana	13,047	Mitjana	3,242	Dif. Max	

ASSAIG: Relaxació de tensions (0,2%)	
Personal responsable: Isabel Bagudanch	**Data:** 07/03/08
Tª del laboratori (ºC): 20,0	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 45	**Temperatura assaig (ºC):** 20,0
Programa d'assaig: relaxacio_tensions	**Fitxer de dades:** PS_RT_50_01

Incidències:

FULL DE CONTROL ASSAIG

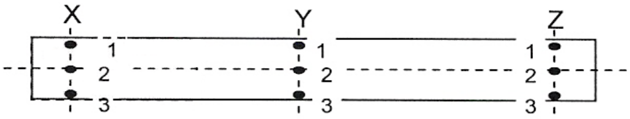
DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 20/02/08
Proveta: PS/RT/50-02	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,02	X	3,257	3,278	3,286
Y	13,07	Y	3,145	3,194	3,177
Z	13,03	Z	3,253	3,273	3,272
Mitjana	13,040	Mitjana	3,237	Dif. Max	

ASSAIG: Relaxació de tensions (0,3%)	
Personal responsable: Isabel Bagudanch	**Data:** 07/03/08
Tª del laboratori (ºC): 20,2	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 44	**Temperatura assaig (ºC):** 20,2
Programa d'assaig: relaxacio_tensions	**Fitxer de dades:** PS_RT_50_02

Incidències:

FULL DE CONTROL ASSAIG

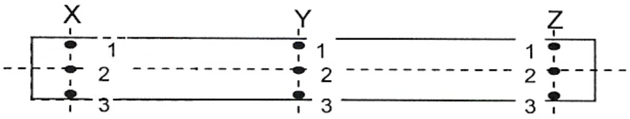
DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 20/02/08
Proveta: PS/RT/50-03	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,03	X	3,255	3,270	3,269
Y	13,09	Y	3,143	3,209	3,173
Z	13,02	Z	3,255	3,273	3,295
Mitjana	13,047	Mitjana	3,238	Dif. Max	

ASSAIG: Relaxació de tensions (0,4%)	
Personal responsable: Isabel Bagudanch	**Data:** 07/03/08
Tª del laboratori (ºC): 20,1	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 44	**Temperatura assaig (ºC):** 20,1
Programa d'assaig: relaxacio_tensions	**Fitxer de dades:** PS_RT_50_03

Incidències:

FULL DE CONTROL ASSAIG

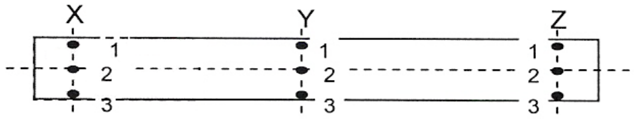
DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 20/02/08
Proveta: PS/RT/50-04	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,02	X	3,253	3,274	3,290
Y	13,06	Y	3,144	3,201	3,181
Z	13,02	Z	3,253	3,267	3,267
Mitjana	13,033	Mitjana	3,237	Dif. Max	

ASSAIG: Relaxació de tensions (0,5%)	
Personal responsable: Isabel Bagudanch	**Data:** 07/03/08
Tª del laboratori (ºC): 20,1	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 43	**Temperatura assaig (ºC):** 20,1
Programa d'assaig: relaxacio_tensions	**Fitxer de dades:** PS_RT_50_04

Incidències:

FULL DE CONTROL ASSAIG

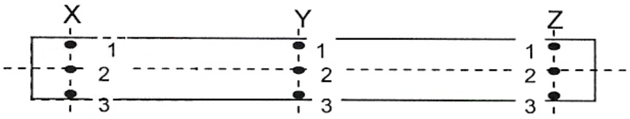
DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 20/02/08
Proveta: PS/RT/50-05	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,02	X	3,250	3,268	3,269
Y	13,07	Y	3,146	3,210	3,174
Z	13,02	Z	3,256	3,271	3,298
Mitjana	13,037	Mitjana	3,238	Dif. Max	

ASSAIG: Relaxació de tensions (0,6%)	
Personal responsable: Isabel Bagudanch	**Data:** 07/03/08
Tª del laboratori (ºC): 20,0	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 44	**Temperatura assaig (ºC):** 20,0
Programa d'assaig: relaxacio_tensions	**Fitxer de dades:** PS_RT_50_05

Incidències:

FULL DE CONTROL ASSAIG

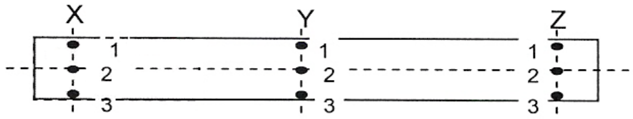
DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 20/02/08
Proveta: PS/RT/50-06	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,02	X	3,253	3,258	3,271
Y	13,07	Y	3,158	3,212	3,181
Z	13,02	Z	3,257	3,269	3,283
Mitjana	13,037	Mitjana	3,238	Dif. Max	

ASSAIG: Relaxació de tensions (0,7%)	
Personal responsable: Isabel Bagudanch	**Data:** 07/03/08
Tª del laboratori (ºC): 20,0	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 44	**Temperatura assaig (ºC):** 20,0
Programa d'assaig: relaxacio_tensions	**Fitxer de dades:** PS_RT_50_06

Incidències:

FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 19/06/08
Proveta: PS/TF/1-01	

Ample (mm)		Gruix (mm)			
			1	2	3
X	13,00	X	3,242	3,127	3,221
Y	13,01	Y	3,220	3,138	3,211
Z	13,00	Z	3,235	3,158	3,202
Mitjana	13,003	Mitjana	3,195	Dif. Max	

ASSAIG: Termofluència (100 N)	
Personal responsable: Isabel Bagudanch	**Data:** 27/06/08
Tª del laboratori (ºC): 25,5	**Màquina utilitzada:** MTS Insight
Hr del laboratori (%): 49	**Temperatura assaig (ºC):** 25,5
Programa d'assaig: termofluencia	**Fitxer de dades:** PS_TF_1_01

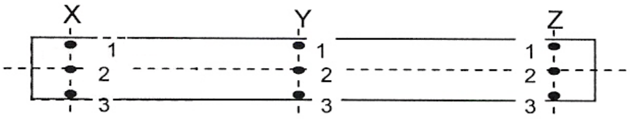
Incidències:

FULL DE CONTROL ASSAIG

DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 19/06/08

Proveta:

PS/TF/1-02



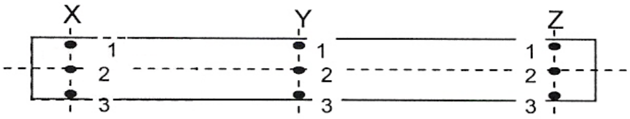
Ample (mm)		Gruix (mm)			
			1	2	3
X	13,00	X	3,222	3,139	3,215
Y	13,00	Y	3,220	3,137	3,218
Z	12,99	Z	3,247	3,156	3,223
Mitjana	12,997	Mitjana	3,197	Dif. Max	

ASSAIG: Termofluència (200 N)	
Personal responsable: Isabel Bagudanch	**Data:** 27/06/08
Tª del laboratori (ºC): 25,3	**Màquina utilitzada:** MTS Insight
Hr del laboratori (%): 49	**Temperatura assaig (ºC):** 25,2
Programa d'assaig: termofluencia	**Fitxer de dades:** PS_TF_1_02

Incidències:

FULL DE CONTROL ASSAIG

DIMENSIONS

Personal responsable: Isabel Bagudanch	**Data:** 19/06/08
Proveta: PS/TF/1-03	

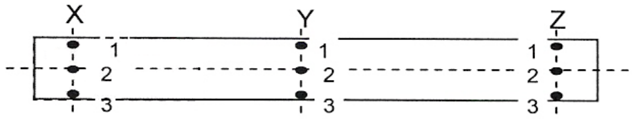
Ample (mm)		Gruix (mm)			
			1	2	3
X	12,99	X	3,216	3,127	3,179
Y	13,00	Y	3,218	3,108	3,186
Z	12,98	Z	3,184	3,107	3,177
Mitjana	12,990	Mitjana	3,167	Dif. Max	

ASSAIG: Termofluència (300 N)

Personal responsable: Isabel Bagudanch	**Data:** 27/06/08
Tª del laboratori (ºC): 25,6	**Màquina utilitzada:** MTS Insight
Hr del laboratori (%): 48	**Temperatura assaig (ºC):** 25,6
Programa d'assaig: termofluencia	**Fitxer de dades:** PS_TF_1_03

Incidències:

FULL DE CONTROL ASSAIG

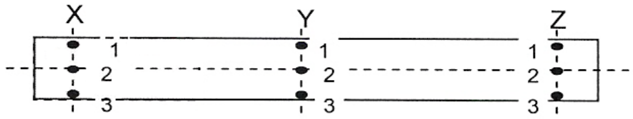
DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 19/06/08
Proveta: PS/TF/1-04	

Ample (mm)		Gruix (mm)			
			1	2	3
X	12,98	X	3,208	3,136	3,207
Y	13,04	Y	3,215	3,109	3,200
Z	12,98	Z	3,214	3,106	3,179
Mitjana	13,000	Mitjana	3,175	Dif. Max	

ASSAIG: Termofluència (400 N)	
Personal responsable: Isabel Bagudanch	**Data:** 27/06/08
Tª del laboratori (ºC): 25,3	**Màquina utilitzada:** MTS Insight
Hr del laboratori (%): 50	**Temperatura assaig (ºC):** 25,5
Programa d'assaig: termofluencia	**Fitxer de dades:** PS_TF_1_04

Incidències:

FULL DE CONTROL ASSAIG

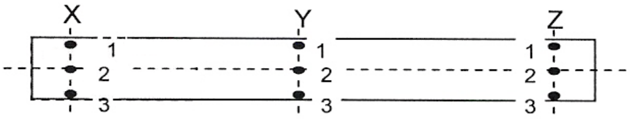
DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 19/06/08
Proveta: PS/TF/1-05	

Ample (mm)		Gruix (mm)			
			1	2	3
X	12,98	X	3,204	3,125	3,197
Y	13,00	Y	3,215	3,11	3,195
Z	12,99	Z	3,219	3,141	3,202
Mitjana	12,990	Mitjana	3,179	Dif. Max	

ASSAIG: Termofluència (500 N)	
Personal responsable: Isabel Bagudanch	**Data:** 27/06/08
Tª del laboratori (ºC): 25,5	**Màquina utilitzada:** MTS Insight
Hr del laboratori (%): 48	**Temperatura assaig (ºC):** 25,5
Programa d'assaig: termofluencia	**Fitxer de dades:** PS_TF_1_05

Incidències:

FULL DE CONTROL ASSAIG

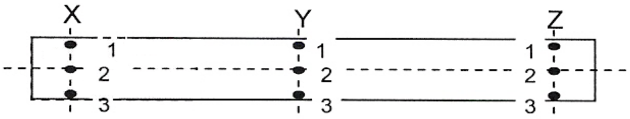
DIMENSIONS	
Personal responsable: Isabel Bagudanch	**Data:** 19/06/08
Proveta: PS/TF/1-06	

Ample (mm)		Gruix (mm)			
			1	2	3
X	12,98	X	3,228	3,129	3,207
Y	13,05	Y	3,216	3,125	3,210
Z	13,00	Z	3,224	3,101	3,186
Mitjana	13,010	Mitjana	3,181	Dif. Max	

ASSAIG: Termofluència (600 N)	
Personal responsable: Isabel Bagudanch	**Data:** 27/06/08
Tª del laboratori (ºC): 25,7	**Màquina utilitzada:** MTS Insight
Hr del laboratori (%): 49	**Temperatura assaig (ºC):** 25,7
Programa d'assaig: termofluencia	**Fitxer de dades:** PS_TF_1_06

Incidències:

FULL DE CONTROL ASSAIG

DIMENSIONS					
Personal responsable: Isabel Bagudanch				**Data:** 19/06/08	
Proveta: PS/TF/1-07					
Ample (mm)		Gruix (mm)			
			1	2	3
X	12,99	X	3,231	3,143	3,206
Y	13,04	Y	3,206	3,124	3,217
Z	12,98	Z	3,196	3,110	3,200
Mitjana	13,003	Mitjana	3,181	Dif. Max	

ASSAIG: Termofluència (700 N)	
Personal responsable: Isabel Bagudanch	**Data:** 27/06/08
Tª del laboratori (ºC): 25,5	**Màquina utilitzada:** MTS Insight
Hr del laboratori (%): 47	**Temperatura assaig (ºC):** 25,5
Programa d'assaig: termofluencia	**Fitxer de dades:** PS_TF_1_07

Incidències:

FULL DE CONTROL ASSAIG

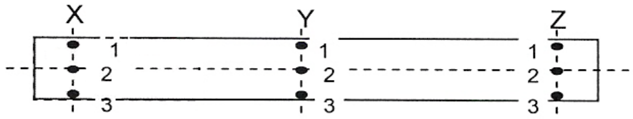
DIMENSIONS

Personal responsable: Isabel Bagudanch

Data: 19/06/08

Proveta:

PS/TF/1-08



Ample (mm)		Gruix (mm)			
			1	2	3
X	12,98	X	3,211	3,119	3,196
Y	13,00	Y	3,229	3,132	3,207
Z	12,98	Z	3,231	3,150	3,195
Mitjana	12,987	Mitjana	3,186	Dif. Max	

ASSAIG: Termofluència (800 N)

Personal responsable: Isabel Bagudanch

Data: 27/06/08

Tª del laboratori (ºC): 25,3	**Màquina utilitzada:** MTS Insight
Hr del laboratori (%): 49	**Temperatura assaig (ºC):** 25,4
Programa d'assaig: termofluencia	**Fitxer de dades:** PS_TF_1_08

Incidències:

FULL DE CONTROL ASSAIG

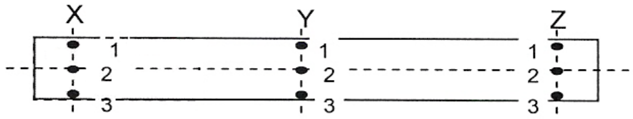
DIMENSIONS

Personal responsable: Isabel Bagudanch

Data: 20/02/08

Proveta:

PS/BL/RT



Ample (mm)		Gruix (mm)			
			1	2	3
X	13,02	X	3,264	3,284	3,306
Y	13,08	Y	3,171	3,221	3,180
Z	13,03	Z	3,262	3,279	3,273
Mitjana	13,043	Mitjana	3,249	Dif. Max	

ASSAIG: Principi de superposició de Boltzmann (per relaxació de tensions)

Personal responsable: Isabel Bagudanch

Data: 27/03/08

Tª del laboratori (ºC): 20,1	**Màquina utilitzada:** Shimadzu
Hr del laboratori (%): 43	**Temperatura assaig (ºC):** 20,1
Programa d'assaig: boltzmann	**Fitxer de dades:** PS_BL_RT

Incidències:

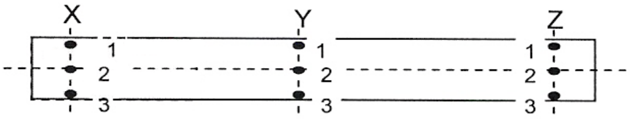
FULL DE CONTROL ASSAIG

DIMENSIONS

Personal responsable: Isabel Bagudanch	**Data:** 19/06/08

Proveta:

PS/BL/TF



Ample (mm)		Gruix (mm)			
			1	2	3
X	12,98	X	3,187	3,133	3,178
Y	13,00	Y	3,2	3,119	3,21
Z	13,00	Z	3,21	3,136	3,217
Mitjana	12,993	Mitjana	3,177	Dif. Max	

ASSAIG: Principi de superposició de Boltzmann (per termofluència)

Personal responsable: Isabel Bagudanch	**Data:** 18/07/08
Tª del laboratori (ºC): 25,5	**Màquina utilitzada:** MTS Insight
Hr del laboratori (%): 49	**Temperatura assaig (ºC):** 25,5
Programa d'assaig: termofluencia	**Fitxer de dades:** PS_BL_TF

Incidències:

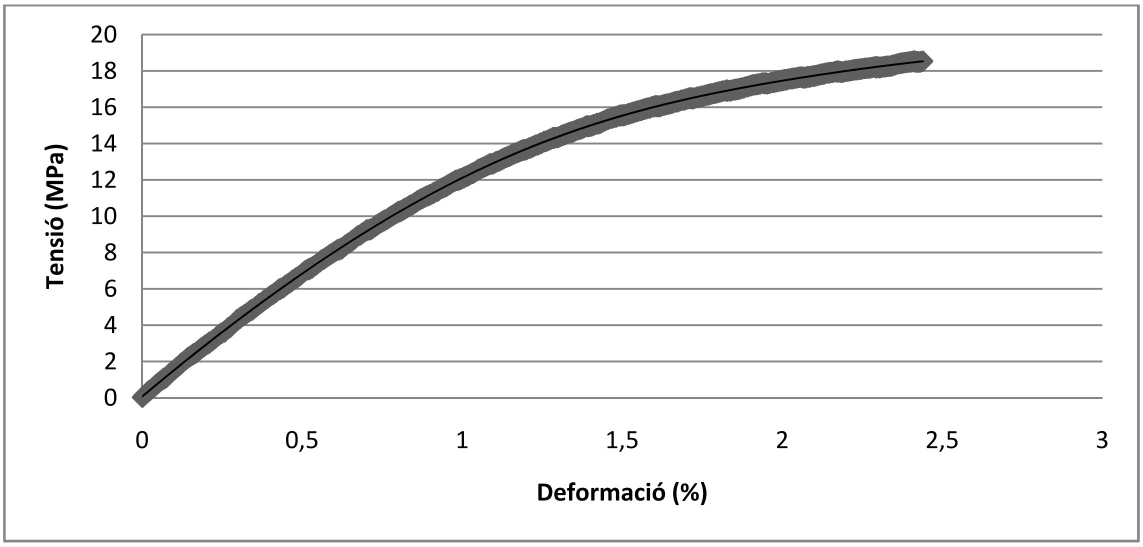
B. AJUST DE LES CORBES ESFORÇ-DEFORMACIÓ

L'ajust d'aquestes corbes s'utilitza per al càlcul del mòdul tangent i el que s'ha fet és ajustar-ho a una polinòmica de sisè ordre per al PP i a una recta per al PS ja que s'obté un bon ajust i una expressió senzilla i que permet simplificar molt el càlcul de la derivada.

El que s'ha fet per calcular el mòdul tangent és derivar l'expressió polinòmica i substituir pels valors de deformació (en valor unitari, no percentual) de manera que les unitats del mòdul tangent són en MPa que si es divideix per 1000 es tenen en GPa. Aleshores es fa la representació gràfica del mòdul tangent en funció de la deformació per a cada velocitat d'assaig (veure apartat 6.2.3.2).

B.1 Polipropilè

- Velocitat 0,05 mm/min

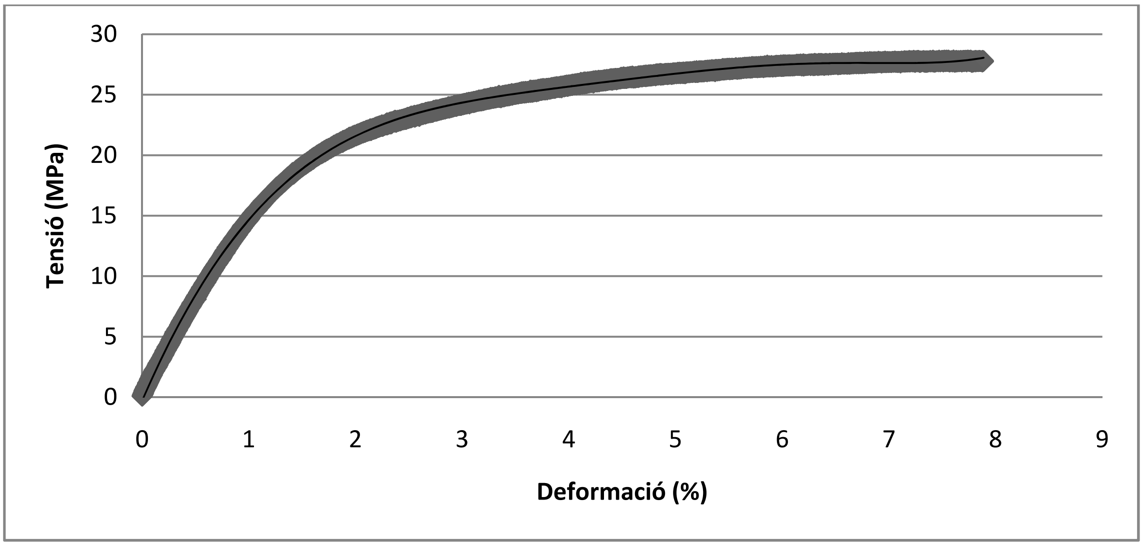


$$\sigma = -0{,}1483 \cdot \varepsilon^6 + 1{,}036 \cdot \varepsilon^5 - 2{,}306 \cdot \varepsilon^4 + 1{,}644 \cdot \varepsilon^3 - 3{,}077 \cdot \varepsilon^2 + 14{,}90 \cdot \varepsilon + 6{,}120 \cdot 10^{-2}$$

$$r^2 = 1{,}000$$

$$E_t = \frac{d\sigma}{d\varepsilon} = -0{,}8898 \cdot \varepsilon^5 + 5{,}180 \cdot \varepsilon^4 - 9{,}224 \cdot \varepsilon^3 + 4{,}932 \cdot \varepsilon^2 - 6{,}154 \cdot \varepsilon + 14{,}90$$

- Velocitat 0,5 mm/min

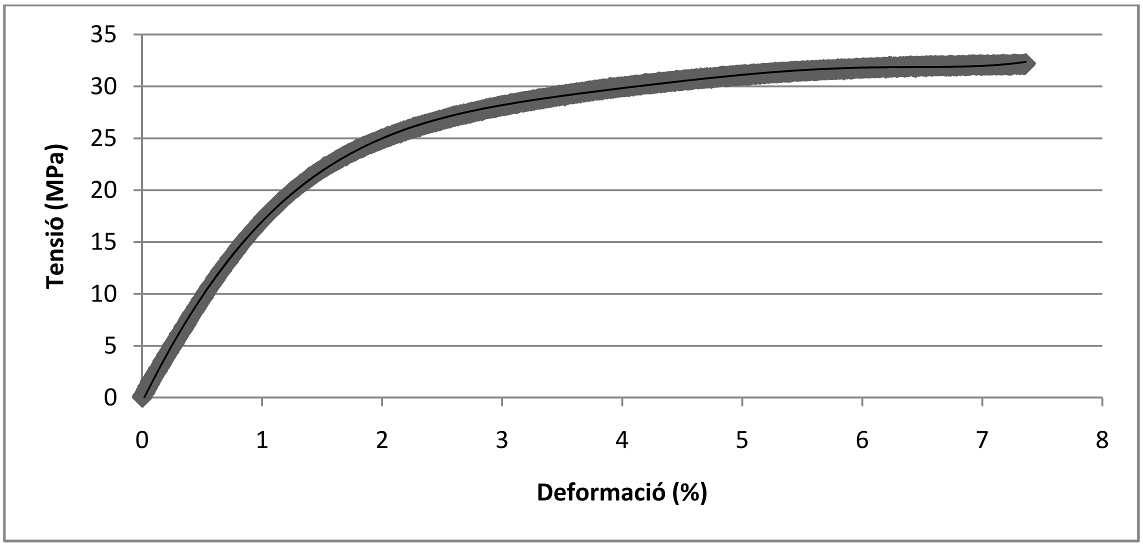


$$\sigma = 9{,}673 \cdot 10^{-4} \cdot \varepsilon^{6} - 1{,}785 \cdot 10^{-2} \cdot \varepsilon^{5} + 6{,}821 \cdot 10^{-2} \cdot \varepsilon^{4} + 0{,}593 \cdot \varepsilon^{3} - 36{,}031 \cdot \varepsilon^{2} + 20{,}34 \cdot \varepsilon - 0{,}3042$$

$$\mathrm{r}^{2} = 0{,}9996$$

$$\mathrm{E_t} = \frac{d\sigma}{d\varepsilon} = 5{,}8038 \cdot 10^{-3} \cdot \varepsilon^{5} - 0{,}08925 \cdot \varepsilon^{4} + 0{,}27284 \cdot \varepsilon^{3} + 1{,}779 \cdot \varepsilon^{2} - 72{,}062 \cdot \varepsilon + 20{,}34$$

- Velocitat 5 mm/min

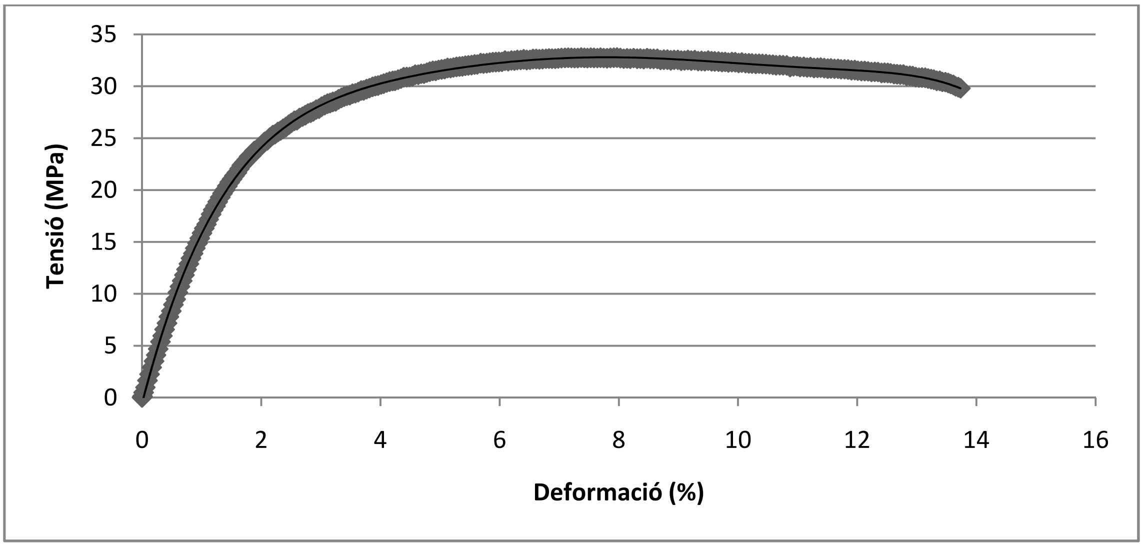


$$\sigma = 1{,}653 \cdot 10^{-3} \cdot \varepsilon^{6} - 3{,}008 \cdot 10^{-2} \cdot \varepsilon^{5} + 0{,}1361 \cdot \varepsilon^{4} + 0{,}553 \cdot \varepsilon^{3} - 6{,}909 \cdot \varepsilon^{2} + 23{,}64 \cdot \varepsilon - 0{,}403$$

$$r^2 = 0{,}9998$$

$$E_t = \frac{d\sigma}{d\varepsilon} = 9{,}918 \cdot 10^{-3} \cdot \varepsilon^5 - 0{,}1504 \cdot \varepsilon^4 + 0{,}5444 \cdot \varepsilon^3 + 1{,}659 \cdot \varepsilon^2 - 13{,}818 \cdot \varepsilon + 23{,}64$$

- Velocitat 50 mm/min

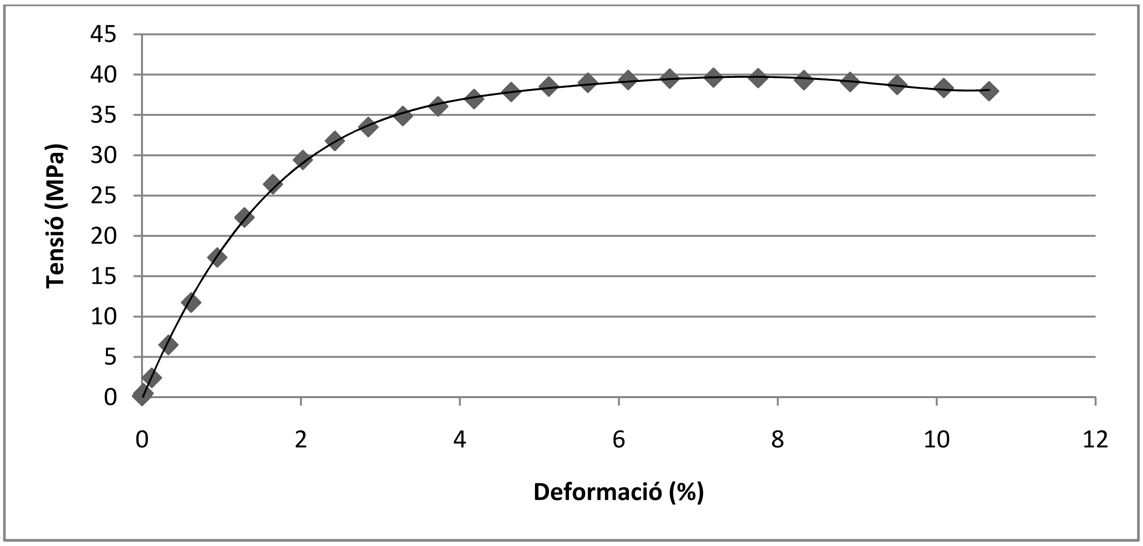


$$\sigma = -1{,}354 \cdot 10^{-4} \cdot \varepsilon^6 + 6{,}464 \cdot 10^{-3} \cdot \varepsilon^5 - 0{,}1242 \cdot \varepsilon^4 + 1{,}239 \cdot \varepsilon^3 - 6{,}975 \cdot \varepsilon^2 + 22{,}21 \cdot \varepsilon - 0{,}5472$$

$$r^2 = 0{,}9996$$

$$E_t = \frac{d\sigma}{d\varepsilon} = -8{,}124 \cdot 10^{-4} \cdot \varepsilon^5 + 0{,}03232 \cdot \varepsilon^4 - 0{,}4968 \cdot \varepsilon^3 + 3{,}717 \cdot \varepsilon^2 - 13{,}95 \cdot \varepsilon + 22{,}21$$

- Velocitat 500 mm/min



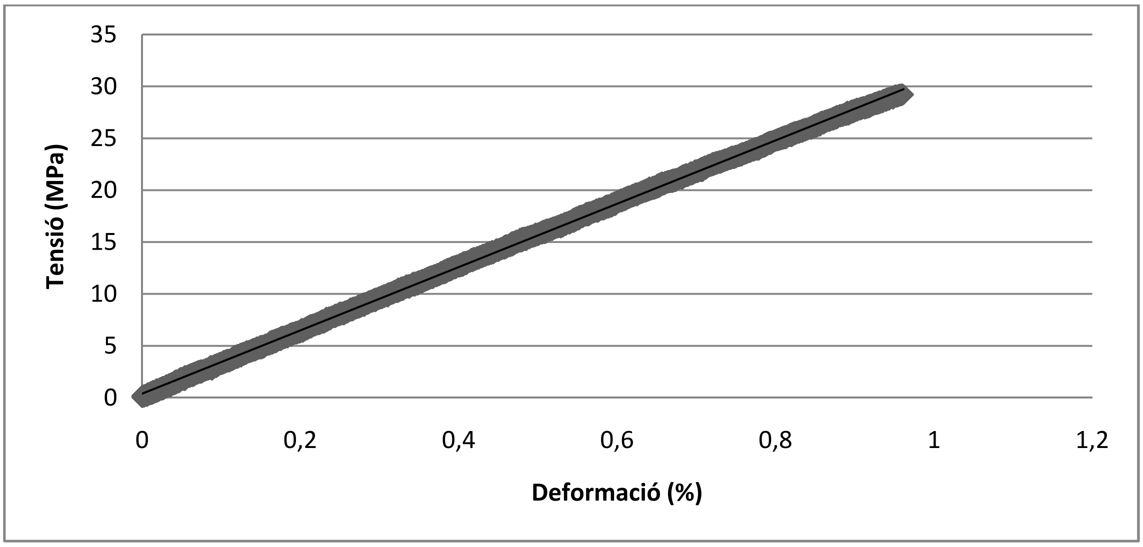
$$\sigma = 1{,}946 \cdot 10^{-4} \cdot \varepsilon^6 - 4{,}330 \cdot 10^{-3} \cdot \varepsilon^5 + 7{,}933 \cdot 10^{-3} \cdot \varepsilon^4 + 0{,}5134 \cdot \varepsilon^3 - 5{,}511 \cdot \varepsilon^2 + 23{,}51 \cdot \varepsilon - 0{,}2358$$

$$r^2 = 0{,}9996$$

$$E_t = \frac{d\sigma}{d\varepsilon} = 1{,}1676 \cdot 10^{-3} \cdot \varepsilon^5 - 0{,}02165 \cdot \varepsilon^4 + 0{,}031732 \cdot \varepsilon^3 + 1{,}5402 \cdot \varepsilon^2 - 11{,}022 \cdot \varepsilon + 23{,}51$$

B.2 Poliestirè

- Velocitat 0,05 mm/min

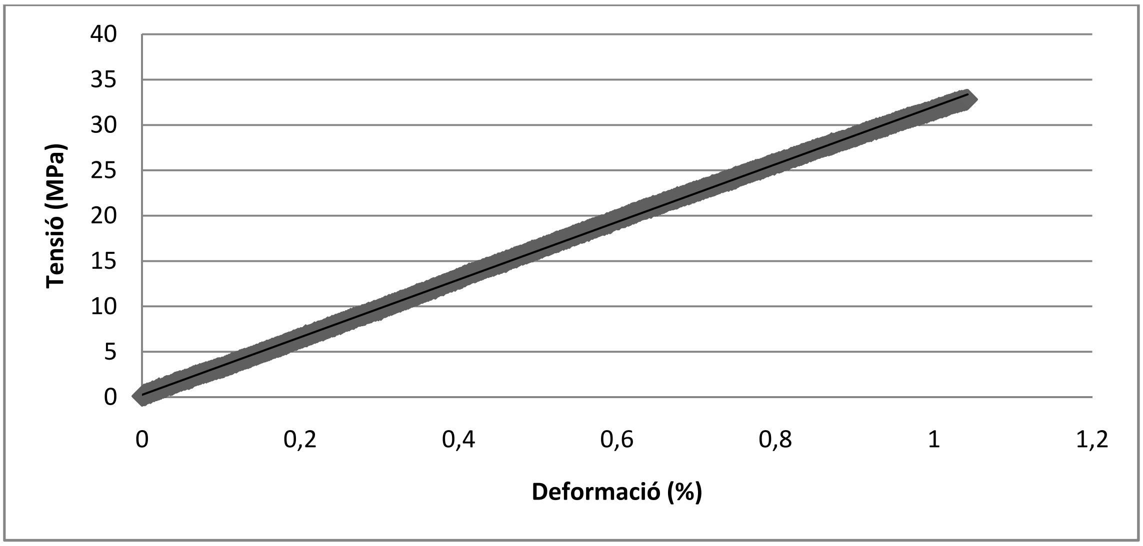


$$\sigma = 30{,}51 \cdot \varepsilon + 0{,}289$$

$$r^2 = 0{,}999$$

$$E_t = \frac{d\sigma}{d\varepsilon} = 3051$$

- Velocitat 0,5 mm/min

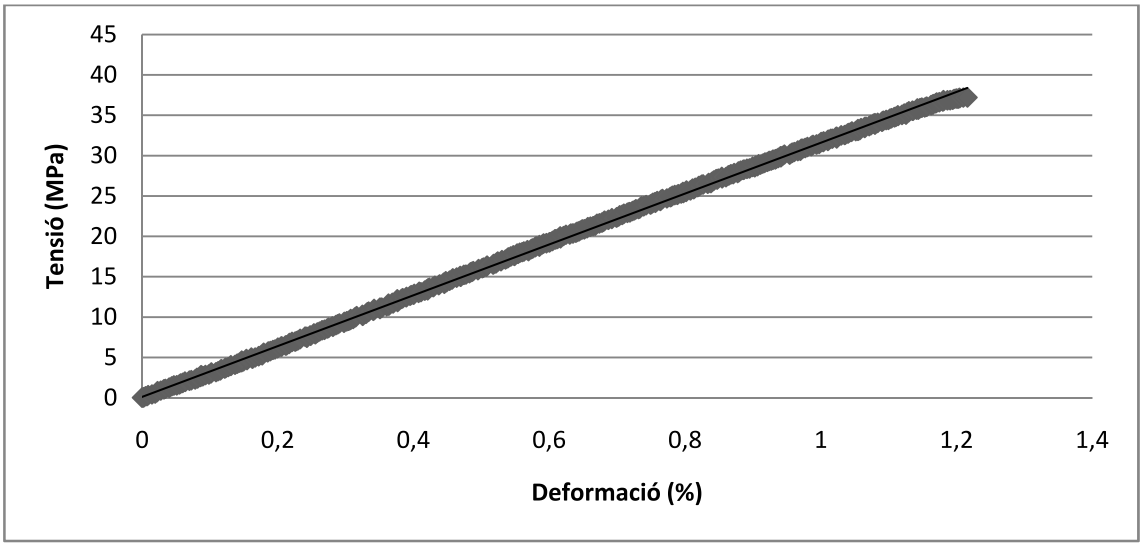


$$\sigma = 31{,}75 \cdot \varepsilon + 0{,}269$$

$$r^2 = 0{,}999$$

$$E_t = \frac{d\sigma}{d\varepsilon} = 3175$$

- Velocitat 5 mm/min

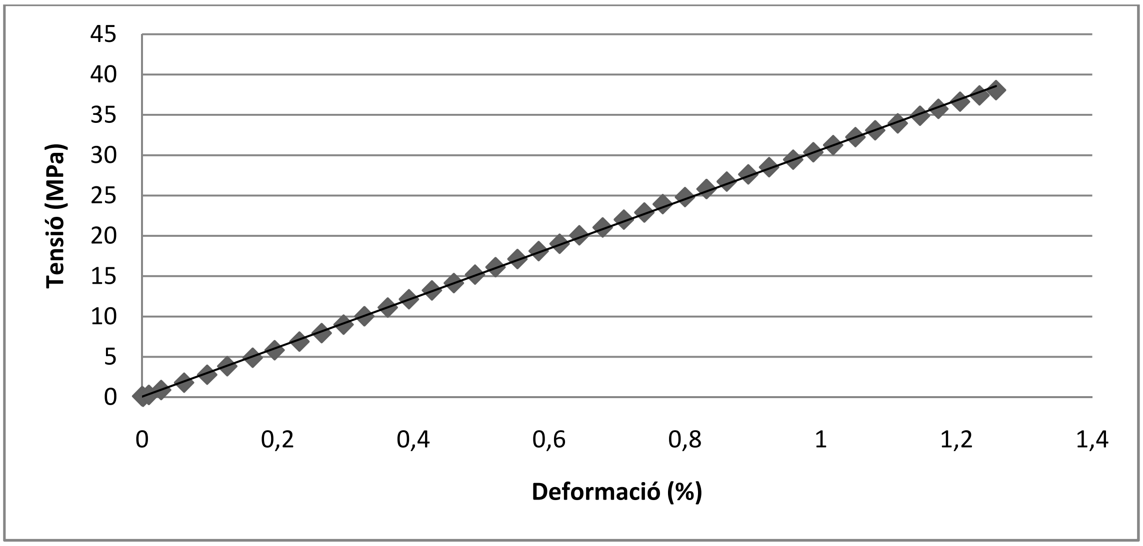


$$\sigma = 31{,}48 \cdot \varepsilon + 0{,}118$$

$$r^2 = 0{,}999$$

$$E_t = \frac{d\sigma}{d\varepsilon} = 3148$$

- Velocitat 50 mm/min

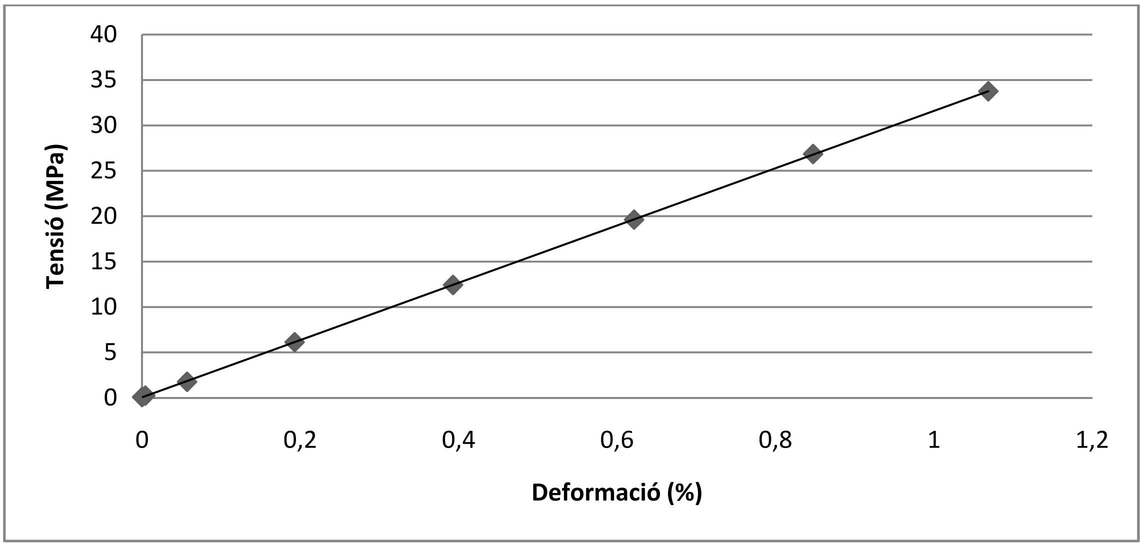


$$\sigma = 30{,}60 \cdot \varepsilon + 0{,}062$$

$$r^2 = 0{,}999$$

$$E_t = \frac{d\sigma}{d\varepsilon} = 3060$$

- Velocitat 500 mm/min



$$\sigma = 3153 \cdot \varepsilon + 0{,}054$$

$$r^2 = 1$$

$$E_t = \frac{d\sigma}{d\varepsilon} = 3153$$

C. FITXA DELS MATERIALS UTILITZATS PER A LA INJECCIÓ DE LES PROVETES

En aquestes fitxes hi ha algunes de les principals propietats físiques, mecàniques, òptiques... dels polímers utilitzats, PP i PS, segons els seus respectius fabricants.

ISPLEN® PP 090 G2M

El **Isplen® PP 090 G2M** es un polipropileno homopolímero de fluidez muy alta dirigido a aplicaciones de moldeo por inyección. Se caracteriza por presentar unas excelente procesabilidad que permite un llenado fácil de los moldes y ciclos cortos para piezas de gran tamaño.

El **Isplen® PP 090 G2M** es fácil de procesar en máquinas estándar de inyección en un amplio rango de temperaturas (210 – 250 °C) dependiendo del espesor de las paredes, la geometría de la pieza y otros parámetros de diseño. Los artículos fabricados con este grado tiene buenas propiedades mecánicas, alta resistencia química y facilidad de decoración.

APLICACIONES

El **Isplen® PP 090 G2M** es ampliamente utilizado para inyectar artículos como pequeños contenedores domésticos, envases rígidos, mobiliario de jardín y doméstico, jeringuillas de un solo uso y cubre-agujas.

PROPIEDADES	METODO	UNIDAD	VALOR
Físicas			
Indice de fluidez (230 °C; 2,16 kg)	ISO 1133	g/10 min	35
Densidad	ISO 1183	g/cm^3	0,905
Mecánicas			
Módulo de Flexión	ISO 178	MPa	1650
Impacto Izod, con muesca (23 °C)	ISO 180	kJ/m^2	2,5
Alargamiento en el punto de rotura	ISO 527	%	50
Térmicas			
Temperatura H.D.T.	ISO 75/B	°C	80
Otras			
Dureza Shore	ISO 868	Escala D	72

Nota: Los valores mostrados son medios y no deben ser tomados como especificaciones del producto. Están obtenidos a partir de probetas inyectadas y acondicionadas siguiendo procedimientos recogidos en normas ISO.

El **Isplen® PP 090 G2M** cumple con las normas de la FDA y las Directivas Europeas relativas al contacto de alimentos. Para información más detallada pueden dirigirse a nuestras Delegaciones Comerciales.

ALMACENAMIENTO

El **Isplen® PP 090 G2M** debe almacenarse en ambiente seco, zona pavimentada, bien drenada y no encharcable, temperatura inferior a 60 °C y protegido de la radiación UV. El almacenamiento en condiciones no adecuadas puede iniciar procesos de degradación que influyen negativamente en la procesabilidad y en las propiedades del producto transformado.

Abril 2007

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Fax +34 91 348 89 91
América del Sur: Tel. +54 11 4329 20 49
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28931 MOSTOLES (Madrid)

104

Product Information

October 2003

BASF Plastics
key to your success

Polystyrol 143 E

Product description

Polystyrol 143 E is a medium strength, easy flowing general purpose grade, suitable for blending with impact modified Polystyrene, Styrolux and for coextruded gloss layers.

Processing

Polystyrol 143 E can be injection molded at temperatures between 180 and 280 °C. Recommended mold temperatures are between 10 and 60 °C. Extrusion melt temperature should not exceed 240 °C

Applications

In blends with high impact polystyrene or Styrolux: thermoformed articles like cups for cold beverages and lids. As easy flowing coextruded gloss layer on food packaging containers and vending cups.
Injection molded articles like razors, tooth brushes, packing articles.

Form supplied and storage

Polystyrol 143 E should be kept in its original containers in cool, dry place. Avoid direct exposure to sunlight. Polystyrol 143 E can be stored in silos.

Food legislation

If used unmodified and under appropriate processing conditions, parts from Polystyrol 143 E comply with the usual requirements for food packaging. For detailed written confirmations please contact our regional sales offices.

Product safety

During processing of Polystyrol 143 E small quantities of styrene monomer may be released into the atmosphere. At styrene vapour concentrations below 20 ppm no negative effects on health are expected. In our experience, the concentration of styrene does not exceed 1 ppm in well ventilated workplaces - that is where five to eight air changes per hour are made.

Note

The statements in this document are based on our present technical knowledge and experience. They do not relieve processors of the responsibility of carrying out their own tests, and purchasers of our products are expected to carry out receiving inspections. Neither do they imply any binding assurence of suitability for a particular purpose. Any proprietary rights should be respected and existing legislation observed.

BASF Aktiengesellschaft
Regional Business Unit Styrenic Polymers Europe
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BASF

Polystyrol 143 E

BASF Plastics
key to your success

Typical Properties for uncoloured products	Test method		Unit	Value	
	ISO	ASTM		ISO	ASTM
Mechanical properties					
Tensile stress at yield / at break*	527	D 638	MPa	46*	
Strain at yield	527	D 638	%		
Strain at break	527	D 638	%	2*	
Young´s modulus	527	D 638	MPa	3300	
Flexural strength	178	D 790-1	MPa	72	
Flexural modulus	178	D 790-1	MPa		
Shear modulus	6721-2		MPa	1350	
Charpy impact strength 23°C / - 30°C	179/1eU		kJ/m^2	< 25	
Charpy notched impact strength 23°C / - 30°C	179/1eA		kJ/m^2	3	
Izod notched impact strength 23°C	180/1A	D 256-A	kJ/m^2		
Izod notched impact strength -30°C	180/1A	D 256-A	kJ/m^2		
Ball indentation hardness H 132/30, H 358/30*	2039-1		MPa	150*	
Rockwell hardness, - Scale	2039-2		-		
Thermal properties					
Vicat softening temperature VST/B/50	306		°C	84	
Vicat softening temperature VST/A/120	306		°C	90	
Temp.of deflection under load 1.8 MPa/HDT A	75		°C	72	
DTUL 0.45 MPa/ HDT B	75		°C	82	
Processing					
Melt volume rate MVR 200/5	1133		ml/10 min	9,5	
Melt temperature range	-		°C	180-280	
Dielectric properties					
Dielectric constant at 100 Hz - 1MHz	IEC 250			2,5	
Volume resistivity	IEC 93		Ω cm	> 10^{16}	
Surface resistivity	IEC 93		Ω	> 10^{14}	
Dielectric strength	IEC 243/1		kV/mm	135	
Optical properties					
Specular gloss (smooth surface; DIN 67530)			%		
UV colour fastness (D E) acc.to IBM 7.17	-	-	-		
Flammability					
UL 94 (1,6 mm)			class	94HB	
UL 94 (3,2 mm)			class	94HB	
IEC 65 (2,4 mm)	IEC 65		+ / -		
IEC 695-2-1 (1,0 mm)	IEC 695-2-1		°C		
Miscellaneous properties					
Density	1183		g/cm^3	1,05	
Water adsorption (Method A)	62		%	< 0,1	
Moisture adsorpt. (23°C/50% r.h.)	-	-	%	< 0,1	

NB : no break

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D. NORMATIVA UTILTIZADA EN ELS ASSAJOS

Per a realitzar els assajos a tracció s'ha seguit el que marca la normativa. S'han consultat diverses normatives (ASTM, ISO...), en aquest apartat de l'annex s'inclouen totes les normatives consultades.

Val a dir que s'han fet assajos a tracció a velocitats diferents a les que marca la normativa, això és perquè interessava veure quina evolució presentaven les propietats dels materials amb la variació de la velocitat.

Designation: D 5938 – 96

AMERICAN SOCIETY FOR TESTING AND MATERIALS
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If not listed in the current combined index, will appear in the next edition.

Standard Guide
Describing the General Principles for Determination of Tensile Properties of Plastics[1]

This standard is issued under the fixed designation D 5938; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide specifies the general principles for determining the tensile properties of plastics under defined conditions.

1.2 Several different types of test specimen are defined to suit different types of material that are detailed in other standards.

1.3 This guide is used to investigate the tensile behaviour of the test specimens and for determining the tensile strength, tensile modulus and other aspects of the tensile stress/strain relationship under the conditions defined.

1.4 This guide is selectively suitable for use with the following range of materials:

1.4.1 Rigid and semirigid thermoplastics moulding and extrusion materials, including filled and reinforced compounds in addition to unfilled types, rigid and semirigid thermoplastics sheets and films,

1.4.2 Rigid and semirigid thermosetting moulding materials, including filled and reinforced compounds, rigid and semirigid thermosetting sheets, including laminates,

1.4.3 Fibre-reinforced thermoset and thermoplastics composites incorporating unidirectional or nonunidirectional reinforcements such as mat, woven fabrics, woven rovings, chopped strands, combination and hybrid reinforcements, rovings and milled fibres, sheets made from pre-impregnated materials (prepregs), and

1.4.4 Thermotropic liquid crystal polymers.

1.5 This guide is not suitable normally for use with rigid cellular materials or sandwich structures containing cellular material.

1.6 This guide is applied using specimens that may be either moulded to the chosen dimensions or machined, cut, or punched from finished and semifinished products such as mouldings, laminates, films, and extruded or cast sheet. In some cases, a multipurpose test specimen (see ISO 3167:1993 (Specification D 5936)), may be used.

1.7 This guide specifies preferred dimensions for the test specimens. Tests that are carried out on specimens of different dimensions, or on specimens that are prepared under different conditions, may produce results that are not comparable. Other factors, such as the speed of testing and the conditioning of the specimens, also can influence the results. Consequently, when comparative data are required, these factors must be carefully controlled and recorded.

1.8 This guide is identical to ISO 527-1. This standard is comparable to Test Method D 638 but neither standard should be substituted for the other. The two standards may differ with respect to test specimen dimensions, test specimen conditioning, test equipment, testing conditions, etc. The two methods may not give the same results.

1.9 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standard:*

D 638 Test Method for Tensile Properties of Plastics[2]

D 5936 Specification for Multipurpose Test Specimens Used for Testing Plastics[3]

2.2 *ISO Standards:*[4]

ISO 291:1977 Plastics—Standard Atmospheres for Conditioning and Testing

ISO 527-1 Determination of Tensile Properties—Part 1: General Principles

ISO 2602:1980 Statistical Interpretation of Test Results—Estimation of the Mean—Confidence Interval

ISO 5893:1985 Rubber and Plastics Test Equipment—Tensile, Flexural and Compression Types (Constant Rate of Traverse)—Description

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *gage length, L_o, n*—initial distance between the gage marks on the central part of the test specimen. See figures of the test specimens in the relevant part of ISO 527. It is expressed in millimetres (mm).

3.2 *modulus of elasticity in tension, Young's modulus, E_t*—ratio of the stress difference σ_2 minus σ_1 to the corresponding strain difference values $\epsilon_2 = 0.0025$ minus $\epsilon_1 = 0.0005$ (see Fig. 1, curve d and 10.3, Eq 8). It is expressed in megapascals, (MPa). This definition does not apply to films and rubber.

3.2.1 *Discussion*—With computer-aided equipment, the determination of the modulus E_t using two distinct stress/strain points can be replaced by a linear regression procedure

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[1] This guide is under the jurisdiction of ASTM Committee D-20 on Plastics and is the direct responsibility of Subcommittee D20.61 on U.S. Technical Advisory Group for ISO/TC 61 on Plastics.

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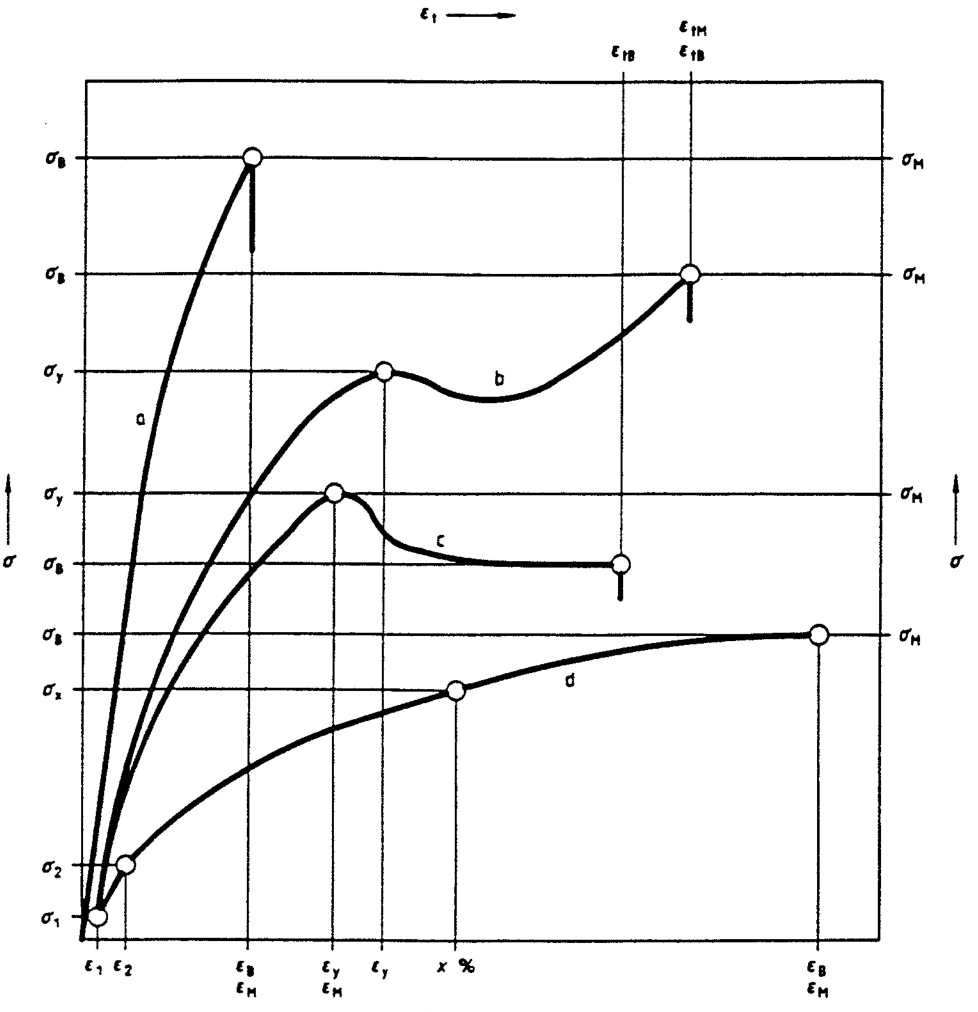
[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 08.03.

[4] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.



Curve a	Brittle materials
Curves b and c	Tough materials with yield point
Curve d	Tough materials without yield point

The points for the calculation of Young's modulus E_t according to 10.3 are indicated by (σ_1, ε_1) and (σ_2, ε_2), shown only for Curve d (ε_1 = 0.0005, ε_2 = 0.0025).

FIG. 1 Typical Stress/Strain Curves

applied on the part of the curve between these mentioned points.

3.3 *nominal tensile strain,* ϵ_t, *n*—increase in length per unit original length of the distance between grips (grip separation). It is expressed as a dimensionless ratio or in percentage (%) (see 10.2, Eqs 6 and 7).

3.3.1 It is used for strains beyond yield point (see 3.7.3). For strains up to yield point, see 3.6. It represents the total relative elongation that takes place along the free length of the test specimen.

3.3.1.1 *nominal tensile strain at break,* ϵ_{tB}, *n*—nominal tensile strain at the tensile stress at break (see 3.7.2), if the specimen breaks after yielding (see Fig. 1, curves b and c). It is expressed as a dimensionless ratio, or in percentage (%). For breaking without yielding, see 3.6.3.

3.3.2 *nominal tensile strain at tensile strength,* ϵ_{tM}, *n*—nominal tensile strain at tensile strength (see 3.7.1), if this occurs after yielding (see Fig. 1, curve b). It is expressed as a dimensionless ratio or in percentage (%). For strength values without or at yielding, see 3.6.2.

3.4 *speed of testing,* ν—rate of separation of the grips of the testing machine during the test. It is expressed in millimetres per minute (mm/min).

3.5 *Poisson's ratio,* μ, *n*—negative ratio of the tensile strain ϵ_n, in one of the two axes normal to the direction of pull, to the corresponding strain ϵ in the direction of pull, within the initial linear portion of the longitudinal versus normal strain curve. It is expressed as a dimensionless ratio.

3.5.1 Poisson's ratio is indicated as μ_b (width direction) or μ_h (thickness direction) according to the relevant axis. Poisson's ratio is used preferentially for long-fibre-reinforced materials.

3.6 *tensile strain,* ϵ, *n*—increase in length per unit original length of the gage. It is expressed as a dimensionless ratio or in percentage (%) (see 10.2, Eqs 4 and 5). It is used for strains up to yield point (see 3.6.3). For strains beyond yield point, see 3.3).

3.6.1 *tensile strain at break,* ϵ_B, *n*—tensile strain at the tensile stress at break (see 3.6.2), if it breaks without yielding (see Fig. 1, curves a and d). It is expressed as a dimensionless ratio or in percentage (%). For breaking after yielding, see 3.3.1.

3.6.2 *tensile strain at tensile strength,* ϵ_M, *n*—tensile strain at the point corresponding to tensile strength (see 3.6.1), if this occurs without or at yielding (see Fig. 1, curves a and d). It is expressed as a dimensionless ratio or in percentage (%). For strength values higher than the yield stress, see 3.3.2.

3.6.3 *tensile strain at yield,* ϵ_Y, *n*—tensile strain at the yield stress (see 3.7.3 and Fig. 1, curves b and c). It is expressed as a dimensionless ratio or in percentage (%).

3.6.4 *tensile stress at* χ *% strain,* σ_x, *n*—stress at which the strain reaches the specified value expressed in percentage. It is expressed in megapascals (MPa). See 3.5.

3.6.4.1 It may be measured, for example, if the stress/strain curve does not exhibit a yield point (see Fig. 1, curve d). In this case, take χ from the relevant product standard or as agreed upon by the interested parties. However, χ must be lower than the strain corresponding to the tensile strength, in any case.

3.7 *tensile stress,* σ *(engineering), n*—tensile force per unit area of the original cross-section within the gage length carried by the test specimen at any given moment. It is expressed in megapascals (MPa) (see 10.1, Eq 3).

3.7.1 *tensile strength,* σ_M, *n*—maximum tensile stress sustained by the test specimen during a tensile test (see Fig. 1). It is expressed in megapascals (MPa).

3.7.2 *tensile stress at break,* σ_B, *n*—the tensile stress at which the test specimen ruptures (see Fig. 1). It is expressed in megapascals (MPa).

3.7.3 *tensile stress at yield, yield stress,* σ_Y, *n*—first stress at which an increase in strain occurs without an increase in stress. It is expressed in megapascals (MPa). It may be less than the maximum attainable stress (see Fig. 1, curves b and c).

4. Principle

4.1 The test specimen is extended along its major longitudinal axis at constant speed until the specimen fractures or until the stress (load) or the strain (elongation) reaches some predetermined value. During this procedure, the load sustained by the specimen and the elongation are measured.

5. Apparatus

5.1 *Testing Machine:*

5.1.1 *General*—Ensure that the machine complies with ISO 5893 and meets the specifications given as follows:

5.1.2 *Speeds of Testing*—Ensure that the tensile-testing machine is capable of maintaining the speeds of testing (see 3.4) as specified in Table 1.

5.1.3 *Grips*—Attach the grips for holding the test specimen to the machine so that the major axis of the test specimen coincides with the direction of pull through the centerline of the grip assembly. Attachment can be achieved, for example, by using centering pins in the grips. Hold the test specimen so that slip relative to the grips is prevented as far as possible. Slip prevention preferably is effected with the type of grip that maintains or increases pressure on the test specimen, as the force applied to the test specimen increases. Ensure that the clamping system does not cause premature fracture at the grips.

TABLE 1 Recommended Testing Speeds

Speed	Tolerance
mm/min	%
1	±20[A]
2	±20[A]
5	±20
10	±20
20	±10
50	±10
100	±10
200	±10
500	±10

[A] These tolerances are smaller than those indicated in ISO 5893.

5.1.4 *Load Indicator*—Incorporate the load indicator with a mechanism capable of showing the total tensile load carried by the test specimen when held by the grips. Ensure that the mechanism is free from inertia lag at the specified rate of testing and indicates the load with an accuracy of at least 1 % of the actual value. Attention is drawn to ISO 5893.

5.1.5 *Extensometer*—Use an extensometer that complies with ISO 5893. Use one that is capable of determining the relative change in the gage length on the test specimen at any time during the test. It is desirable, but not essential, that this instrument should automatically record this change. Ensure that the instrument is essentially free from inertia lag at the specified speed of testing and capable of measuring the change of gage length with an accuracy of 1 % of the relevant value or better. This corresponds to ±1 μm for the measurement of the modulus, based on a gage length of 50 mm. When an extensometer is attached to the test specimen, take care to ensure that any distortion of or damage to the test specimen is minimal. It is essential that there is no slippage between the extensometer and the test specimen.

5.1.5.1 The specimens also may be instrumented with longitudinal strain gages, the accuracy of which shall be 1 % of the relevant value or better. This corresponds to a strain accuracy of 20×10^{-6} (20 microstrain) for the measurement of the modulus. Choose the gages, surface preparation, and bonding agents, to exhibit adequate performance on the subject material.

5.2 *Devices for Measuring Width and Thickness of the Test Specimens:*

5.2.1 *Rigid Materials*—Use a micrometer, or its equivalent, capable of reading to 0.02 mm or less, and provided with means for measuring the thickness and width of the test specimens. Ensure that the dimensions and shape of the anvils are suitable for the specimens being measured and do not exert a force on the specimen such as to detectably alter the dimension being measured.

5.2.2 *Flexible Materials*—Use a dial-gage, capable of reading to 0.02 mm or less, and provided with a flat circular foot which applies a pressure of 20 kPa ± 3 kPa, for measuring the thickness.

6. Test Specimens

6.1 *Shape and Dimensions*—See that part of ISO 527 relevant to the material being tested.

6.2 *Preparation of Specimens*—See that part of ISO 527 relevant to the material being tested.

6.3 *Gage Marks:*

6.3.1 If optical extensometers are used, especially for thin sheet and film, gage marks on the specimen are necessary to define the gage length. Ensure that the gage marks are approximately equidistant from the midpoint, and that the distance between the marks are measured to an accuracy of 1 % or better.

6.3.2 Ensure that the gage marks are not scratched, punched, or impressed upon the test specimen in any way that may damage the material being tested. Ensure that the marking medium has no detrimental effect on the material being tested, and that, in the case of parallel lines, they are as narrow as possible.

6.4 *Checking the Test Specimens*—Ensure that the specimens are free of twist and have mutually perpendicular pairs of parallel surfaces. The surfaces and edges must be free from scratches, pits, sink marks and flash. Check the specimens for conformity with these requirements by visual observation against straightedges, squares, and flat plates, and with micrometer calipers. Reject or machine to proper size and shape before testing any specimens showing observed or measured departure from one or more of these requirements.

6.5 *Anisotropy*—See that part ISO 527 relevant to the material being tested.

7. Number of Test Specimens

7.1 Use a minimum of five test specimens for each of the required directions of testing and for the properties considered (modulus of elasticity, tensile strength, etc.). The number of measurements may be more than five if greater precision of the mean value is required. It is possible to evaluate precision by means of the confidence interval (95 % probability, see ISO 2602).

7.2 Discard dumb-bell specimens that break within the shoulders or the yielding of which spreads to the width of the shoulders and test additional specimens.

7.3 Do not include data from parallel-sided specimens where jaw slippage occurs, or where failure occurs within 10 mm of either jaw, or where an obvious fault has resulted in premature failure, in the analysis. Repeat tests on new test specimens.

7.3.1 Do not exclude data, however variable, from the analysis for any other reason, as the variability in such data is a function of the variable nature of the material being tested.

NOTE 1—When the majority of failures falls outside the criteria for an acceptable failure, the data may be analyzed statistically, but it should be recognized that the final result is likely to be conservative. In such instances, it is preferable for the tests to be repeated with the dumb-bell specimens to reduce the possibility of unacceptable results.

8. Conditioning

8.1 Condition the test specimen as specified in the appropriate standard for the material concerned. In the absence of this information, select the most appropriate condition from ISO 291, unless otherwise agreed upon by the interested parties.

9. Procedure

9.1 *Test Atmosphere*—Conduct the test in the same atmosphere used for conditioning the test specimen, unless otherwise agreed upon by the interested parties, for example, for testing at elevated or low temperatures.

9.2 *Dimensions of Test Specimen:*

9.2.1 Measure the width b to the nearest 0.1 mm and the thickness h to the nearest 0.02 mm at the center of each specimen and within 5 mm of each end of the gage length.

9.2.2 Record the minimum and maximum values for width and thickness of each specimen, and ensure that they are within the tolerances indicated in the standard applicable for the given material.

9.2.3 Calculate the arithmetic means for the width and thickness of each specimen, which shall be used for calculation purposes.

NOTE 2—In the case of injection-moulded specimens, it is not necessary to measure the dimensions of each specimen. It is sufficient to measure one specimen from each lot to make sure that the dimensions correspond to the specimen type selected (see the relevant part of ISO 527). With multiple-cavity moulds, ensure that the dimensions of the specimens are the same for each cavity.

NOTE 3—For test specimens stamped from sheet or film material, it is permissible to assume that the mean width of the central parallel portion of the die is equivalent to the corresponding width of the specimen. Base the adoption of such a procedure on comparative measurements taken at periodic intervals.

9.3 *Clamping*—Place the test specimen in the grips, ensuring to align the longitudinal axis of the test specimen with the axis of the testing machine. To obtain correct alignment when centering pins are used in the grips, it is necessary to tension the specimen only slightly before tightening the grips (see 9.4). Tighten the grips evenly and firmly to avoid slippage of the test specimen.

9.4 *Prestresses:*

9.4.1 Ensure that the specimen is not stressed substantially prior to test. Such stresses can be generated during centering of a film specimen, or can be caused by the clamping pressure, especially with less rigid materials. Ensure that the residual stress σ_0 at the start of a test does not exceed the following value for modulus measurement:

$$|\sigma_0| \leq 5 \times 10^{-4} E_t \tag{1}$$

which corresponds to a prestrain of $\epsilon_0 \leq 0.05$ %, and for measuring relevant stresses σ, for example, $\sigma = \sigma_Y$, σ_M or σ_B:

$$\sigma_0 \leq 10^{-2} \sigma \tag{2}$$

9.5 *Setting of Extensometers:*

9.5.1 After balancing the prestresses, set and adjust a calibrated extensometer to the gage length of the test specimen, or provide longitudinal strain gages, in accordance with 5.1.5. Measure the initial distance (gage length) if necessary. For the measurement of Poisson's ratio, provide two elongation- or strain-measuring devices to act in the longitudinal and normal axes simultaneously.

9.5.2 For optical measurements of elongation, place gage marks on the specimen in accordance with 6.3.

9.5.3 The elongation of the free length of the test specimen, measured from the movement of the grips, is used for the values of the nominal tensile strain ϵ_t (see 3.3).

9.6 *Testing Speed:*

9.6.1 Set the speed of testing in accordance with the appropriate standard for the material concerned. In the absence of this information, the speed of testing should be agreed between the interested parties in accordance with Table 1.

9.6.2 It may be necessary or desirable to adopt different speeds for the determination of the elastic modulus, of the stress/strain properties up to the yield point, and for the measurement of tensile strength and maximum elongation. For each testing speed, use separate specimens.

9.6.3 For the measurement of the modulus of elasticity, a strain rate as near as possible to 1 % of the gage length per minute is provided by the selected speed of testing. The resulting testing speed for different types of specimens is given in that part of ISO 527 relevant to the material being tested.

9.7 *Recording of Data:*

9.7.1 Record the force and the corresponding values of the increase of the gage length and of the distance between grips during the test. It is preferable to use an automatic recording system that yields complete stress/strain curves for this operation (see Section 10, Eqs 3, 4, and 5).

9.7.2 Determine all relevant stresses and strains defined in Section 3 from the stress/strain curve (see Fig. 1), or using other suitable means.

9.7.3 For failures outside the criteria for an acceptable failure, see 7.2 and 7.3.

10. Calculation and Expression of Results

10.1 *Stress Calculations*—Calculate all stress values defined in 3.7 on the basis of the initial cross-sectional area of the test specimen:

$$\sigma = \frac{F}{A} \tag{3}$$

where:

σ = the tensile stress value in question, expressed in megapascals,
F = the measured force concerned, in newtons, and
A = the initial cross-sectional area of the specimen, expressed in square millimeters.

10.2 *Strain Calculations:*

10.2.1 Calculate all strain values defined in 3.6 on the basis of the gage length:

$$\epsilon = \frac{\Delta L_0}{L_0} \tag{4}$$

$$\epsilon\,(\%) = 100 \times \frac{\Delta L_0}{L_0} \tag{5}$$

where:

ϵ = the strain value in question, expressed as a dimensionless ratio, or in percentage,
L_0 = the gage length of the test specimen, expressed in millimeters, and
ΔL_0 = the increase in the specimen length between the gage marks, expressed in millimeters.

10.2.2 Calculate the values of the nominal tensile strain, defined in 3.3 on the basis of the initial distance between the grips:

$$\epsilon_t = \frac{\Delta L}{L} \tag{6}$$

$$\epsilon_t\,(\%) = 100 \times \frac{\Delta L}{L} \tag{7}$$

where:

ϵ_t = nominal tensile strain, expressed as a dimensionless ratio or percentage, %,
L = initial distance between grips, expressed in millimeters, and
ΔL = increase of the distance between grips, expressed in millimeters.

10.3 *Modulus Calculation*—Calculate the modulus of elasticity (Young's modulus), defined in 3.2 on the basis of two specified strain values:

$$E_t = \frac{\sigma_2 - \sigma_1}{\epsilon_2 - \epsilon_1} \tag{8}$$

where:

E_t = Young's modulus of elasticity, expressed in megapascals,
σ_1 = the stress, in megapascals, measured at the strain value $\epsilon_1 = 0.0005$, and
σ_2 = the stress, in megapascals, measured at the strain value $\epsilon_2 = 0.0025$.

For computer-aided equipment, see 3.2.

10.4 *Poisson's Ratio*—If required, calculate Poisson's ratio defined in 3.5 on the basis of two corresponding strain values perpendicular to each other:

$$\mu_n = -\frac{\epsilon_n}{\epsilon} \tag{9}$$

where:

μ_n = Poisson's ratio, expressed as a dimensionless ratio with $n = b$ (width) or h (thickness) indicating the normal direction chosen,
ϵ = the strain in the longitudinal direction, and
ϵ_n = the strain in the normal direction, with $n = b$ (width) or h (thickness).

10.5 *Statistical Parameters*—Calculate the arithmetic means of the test results and, if required, the standard deviations and the 95 % confidence intervals of the mean values according to the procedure given in ISO 2602.

10.6 *Significant Figures*—Calculate the stresses and the modulus to three significant figures. Calculate the strains and Poisson's ratio to two significant figures.

11. Precision

11.1 See that part of ISO 527 relevant to the material being tested.

12. Test Report

12.1 Report the following information:

12.1.1 Reference to the relevant part of ISO 527,

12.1.2 All the data necessary for identification of the material tested, including type, source, manufacturer's code number and history, where these are known,

12.1.3 Description of the nature and form of the material in terms of whether it is a product, semifinished product, test panel or specimen. It should include the principal dimensions, shape, method of manufacture, succession of layers and any pretreatment,

12.1.4 Type of test specimen, the width and thickness of the parallel section, including mean, minimum and maximum values,

12.1.5 Method of preparing the test specimens, and any details of the manufacturing method used,

12.1.6 If the material is in product or semifinished product form, the orientation of the specimen in relation to the product or semifinished product from which it is cut,

12.1.7 Number of test specimens tested,

12.1.8 Standard atmosphere for conditioning and testing, plus any special conditioning treatment, if required by the relevant standard for the material or product concerned,

12.1.9 Accuracy grading of the test machine (see ISO 5893),

12.1.10 Type of elongation or strain indicator,

12.1.11 Type of clamping device and clamping pressure, if known,

12.1.12 Testing speeds,

12.1.13 Individual test results,

12.1.14 Mean value(s) of the measured property(ies), quoted as the indicative value(s) for the material tested,

12.1.15 Standard deviation, or coefficient of variation, or confidence limits of the mean, or all, if required,

12.1.16 Statement as to whether any test specimens have been rejected and replaced, and if so, the reasons, and

12.1.17 Date of measurement.

13. Keywords

13.1 plastics; tensile properties

APPENDIX

(Nonmandatory Information)

X1. YOUNG'S MODULUS AND RELATED VALUES

X1.1 Due to their viscoelastic behavior, many properties of polymer materials depend not only on temperature but also on time. With regard to the tensile test, this causes nonlinear stress/strain curves (bending towards the strain axis) even within the range of linear viscoelasticity. This effect is pronounced in the case of tough polymers. Consequently, the values of the tangent modulus of tough materials taken from the initial part of the stress/strain curves often depend strongly on the scales used. Thus the conventional method (tangent at the initial point of the stress/strain curve) does not give reliable moduli for these materials.

X1.2 The method for the measurement of Young's modulus prescribed in this part of ISO 527 is based, therefore, on two specified strain values, for example, 0.25 % and 0.05 %. The lower strain value has been set at not zero in order to avoid errors in the measured modulus caused by possible onset effects at the beginning of the stress/strain curve.

X1.3 In the case of brittle polymers, both the new and the conventional methods give the same values for the modulus. The new method, however, allows accurate and reproducible measurement of the moduli of tough plastics. The definition of the initial tangent modulus, therefore, has been deleted in the present part of ISO 527.

X1.4 The aspects mentioned above for the modulus similarly relate to the offset yield point, which in ISO/R 527 was defined by the deviation of the stress/strain curve from its initial linearity. The offset yield point, therefore, is replaced by a point of specified strain (stress at χ % strain, σ_x, see 3.6.4). Since the definition of such a substitute yield point is significant for tough materials only, choose the specified strain near the yield strain commonly found.

Designation: D 638 – 02a

Standard Test Method for Tensile Properties of Plastics[1]

This standard is issued under the fixed designation D 638; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope *

1.1 This test method covers the determination of the tensile properties of unreinforced and reinforced plastics in the form of standard dumbbell-shaped test specimens when tested under defined conditions of pretreatment, temperature, humidity, and testing machine speed.

1.2 This test method can be used for testing materials of any thickness up to 14 mm (0.55 in.). However, for testing specimens in the form of thin sheeting, including film less than 1.0 mm (0.04 in.) in thickness, Test Methods D 882 is the preferred test method. Materials with a thickness greater than 14 mm (0.55 in.) must be reduced by machining.

1.3 This test method includes the option of determining Poisson's ratio at room temperature.

NOTE 1—This test method and ISO 527-1 are technically equivalent.

NOTE 2—This test method is not intended to cover precise physical procedures. It is recognized that the constant rate of crosshead movement type of test leaves much to be desired from a theoretical standpoint, that wide differences may exist between rate of crosshead movement and rate of strain between gage marks on the specimen, and that the testing speeds specified disguise important effects characteristic of materials in the plastic state. Further, it is realized that variations in the thicknesses of test specimens, which are permitted by these procedures, produce variations in the surface-volume ratios of such specimens, and that these variations may influence the test results. Hence, where directly comparable results are desired, all samples should be of equal thickness. Special additional tests should be used where more precise physical data are needed.

NOTE 3—This test method may be used for testing phenolic molded resin or laminated materials. However, where these materials are used as electrical insulation, such materials should be tested in accordance with Test Methods D 229 and Test Method D 651.

NOTE 4—For tensile properties of resin-matrix composites reinforced with oriented continuous or discontinuous high modulus $>$20-GPa ($>3.0 \times 10^6$-psi) fibers, tests shall be made in accordance with Test Method D 3039/D 3039M.

1.4 Test data obtained by this test method are relevant and appropriate for use in engineering design.

1.5 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 229 Test Methods for Rigid Sheet and Plate Materials Used for Electrical Insulation[2]

D 412 Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension[3]

D 618 Practice for Conditioning Plastics for Testing[4]

D 651 Test Method for Tensile Strength of Molded Electrical Insulating Materials[5]

D 882 Test Methods for Tensile Properties of Thin Plastic Sheeting[4]

D 883 Terminology Relating to Plastics[4]

D 1822 Test Method for Tensile-Impact Energy to Break Plastics and Electrical Insulating Materials[4]

D 3039/D 3039M Test Method for Tensile Properties of Polymer Matrix Composite Materials[6]

D 4000 Classification System for Specifying Plastic Materials[7]

D 4066 Classification System for Nylon Injection and Extrusion Materials[7]

D 5947 Test Methods for Physical Dimensions of Solid Plastic Specimens[8]

E 4 Practices for Force Verification of Testing Machines[9]

E 83 Practice for Verification and Classification of Extensometer[9]

E 132 Test Method for Poisson's Ratio at Room Temperature[9]

E 691 Practice for Conducting an Interlaboratory Study to

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[1] This test method is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.10 on Mechanical Properties.

Current edition approved November 10, 2002. Published January 2003. Originally approved in 1941. Last previous edition approved in 2002 as D 638 – 02.

[2] *Annual Book of ASTM Standards*, Vol 10.01.

[3] *Annual Book of ASTM Standards*, Vol 09.01.

[4] *Annual Book of ASTM Standards*, Vol 08.01.

[5] Discontinued; see *1994 Annual Book of ASTM Standards*, Vol 10.01.

[6] *Annual Book of ASTM Standards*, Vol 15.03.

[7] *Annual Book of ASTM Standards*, Vol 08.02.

[8] *Annual Book of ASTM Standards*, Vol 08.03.

[9] *Annual Book of ASTM Standards*, Vol 03.01.

***A Summary of Changes section appears at the end of this standard.**

Determine the Precision of a Test Method[10]

2.2 *ISO Standard:*

ISO 527-1 Determination of Tensile Properties[11]

3. Terminology

3.1 *Definitions*—Definitions of terms applying to this test method appear in Terminology D 883 and Annex A2.

4. Significance and Use

4.1 This test method is designed to produce tensile property data for the control and specification of plastic materials. These data are also useful for qualitative characterization and for research and development. For many materials, there may be a specification that requires the use of this test method, but with some procedural modifications that take precedence when adhering to the specification. Therefore, it is advisable to refer to that material specification before using this test method. Table 1 in Classification D 4000 lists the ASTM materials standards that currently exist.

4.2 Tensile properties may vary with specimen preparation and with speed and environment of testing. Consequently, where precise comparative results are desired, these factors must be carefully controlled.

4.2.1 It is realized that a material cannot be tested without also testing the method of preparation of that material. Hence, when comparative tests of materials per se are desired, the greatest care must be exercised to ensure that all samples are prepared in exactly the same way, unless the test is to include the effects of sample preparation. Similarly, for referee purposes or comparisons within any given series of specimens, care must be taken to secure the maximum degree of uniformity in details of preparation, treatment, and handling.

4.3 Tensile properties may provide useful data for plastics engineering design purposes. However, because of the high degree of sensitivity exhibited by many plastics to rate of straining and environmental conditions, data obtained by this test method cannot be considered valid for applications involving load-time scales or environments widely different from those of this test method. In cases of such dissimilarity, no reliable estimation of the limit of usefulness can be made for most plastics. This sensitivity to rate of straining and environment necessitates testing over a broad load-time scale (including impact and creep) and range of environmental conditions if tensile properties are to suffice for engineering design purposes.

NOTE 5—Since the existence of a true elastic limit in plastics (as in many other organic materials and in many metals) is debatable, the propriety of applying the term "elastic modulus" in its quoted, generally accepted definition to describe the "stiffness" or "rigidity" of a plastic has been seriously questioned. The exact stress-strain characteristics of plastic materials are highly dependent on such factors as rate of application of stress, temperature, previous history of specimen, etc. However, stress-strain curves for plastics, determined as described in this test method, almost always show a linear region at low stresses, and a straight line drawn tangent to this portion of the curve permits calculation of an elastic modulus of the usually defined type. Such a constant is useful if its arbitrary nature and dependence on time, temperature, and similar factors are realized.

4.4 *Poisson's Ratio*—When uniaxial tensile force is applied to a solid, the solid stretches in the direction of the applied force (axially), but it also contracts in both dimensions lateral to the applied force. If the solid is homogeneous and isotropic, and the material remains elastic under the action of the applied force, the lateral strain bears a constant relationship to the axial strain. This constant, called Poisson's ratio, is defined as the negative ratio of the transverse (negative) to axial strain under uniaxial stress.

4.4.1 Poisson's ratio is used for the design of structures in which all dimensional changes resulting from the application of force need to be taken into account and in the application of the generalized theory of elasticity to structural analysis.

NOTE 6—The accuracy of the determination of Poisson's ratio is usually limited by the accuracy of the transverse strain measurements because the percentage errors in these measurements are usually greater than in the axial strain measurements. Since a ratio rather than an absolute quantity is measured, it is only necessary to know accurately the relative value of the calibration factors of the extensometers. Also, in general, the value of the applied loads need not be known accurately.

5. Apparatus

5.1 *Testing Machine*—A testing machine of the constant-rate-of-crosshead-movement type and comprising essentially the following:

5.1.1 *Fixed Member*—A fixed or essentially stationary member carrying one grip.

5.1.2 *Movable Member*—A movable member carrying a second grip.

5.1.3 *Grips*—Grips for holding the test specimen between the fixed member and the movable member of the testing machine can be either the fixed or self-aligning type.

5.1.3.1 Fixed grips are rigidly attached to the fixed and movable members of the testing machine. When this type of grip is used extreme care should be taken to ensure that the test specimen is inserted and clamped so that the long axis of the test specimen coincides with the direction of pull through the center line of the grip assembly.

5.1.3.2 Self-aligning grips are attached to the fixed and movable members of the testing machine in such a manner that they will move freely into alignment as soon as any load is applied so that the long axis of the test specimen will coincide with the direction of the applied pull through the center line of the grip assembly. The specimens should be aligned as perfectly as possible with the direction of pull so that no rotary motion that may induce slippage will occur in the grips; there is a limit to the amount of misalignment self-aligning grips will accommodate.

5.1.3.3 The test specimen shall be held in such a way that slippage relative to the grips is prevented insofar as possible. Grip surfaces that are deeply scored or serrated with a pattern similar to those of a coarse single-cut file, serrations about 2.4 mm (0.09 in.) apart and about 1.6 mm (0.06 in.) deep, have been found satisfactory for most thermoplastics. Finer serrations have been found to be more satisfactory for harder plastics, such as the thermosetting materials. The serrations

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[10] *Annual Book of ASTM Standards*, Vol 14.02.

[11] Available from American National Standards Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036.

should be kept clean and sharp. Breaking in the grips may occur at times, even when deep serrations or abraded specimen surfaces are used; other techniques must be used in these cases. Other techniques that have been found useful, particularly with smooth-faced grips, are abrading that portion of the surface of the specimen that will be in the grips, and interposing thin pieces of abrasive cloth, abrasive paper, or plastic, or rubber-coated fabric, commonly called hospital sheeting, between the specimen and the grip surface. No. 80 double-sided abrasive paper has been found effective in many cases. An open-mesh fabric, in which the threads are coated with abrasive, has also been effective. Reducing the cross-sectional area of the specimen may also be effective. The use of special types of grips is sometimes necessary to eliminate slippage and breakage in the grips.

5.1.4 *Drive Mechanism*—A drive mechanism for imparting to the movable member a uniform, controlled velocity with respect to the stationary member, with this velocity to be regulated as specified in Section 8.

5.1.5 *Load Indicator*—A suitable load-indicating mechanism capable of showing the total tensile load carried by the test specimen when held by the grips. This mechanism shall be essentially free of inertia lag at the specified rate of testing and shall indicate the load with an accuracy of ±1 % of the indicated value, or better. The accuracy of the testing machine shall be verified in accordance with Practices E 4.

NOTE 7—Experience has shown that many testing machines now in use are incapable of maintaining accuracy for as long as the periods between inspection recommended in Practices E 4. Hence, it is recommended that each machine be studied individually and verified as often as may be found necessary. It frequently will be necessary to perform this function daily.

5.1.6 The fixed member, movable member, drive mechanism, and grips shall be constructed of such materials and in such proportions that the total elastic longitudinal strain of the system constituted by these parts does not exceed 1 % of the total longitudinal strain between the two gage marks on the test specimen at any time during the test and at any load up to the rated capacity of the machine.

5.1.7 *Crosshead Extension Indicator*—A suitable extension indicating mechanism capable of showing the amount of change in the separation of the grips, that is, crosshead movement. This mechanism shall be essentially free of inertial lag at the specified rate of testing and shall indicate the crosshead movement with an accuracy of ±10 % of the indicated value.

5.2 *Extension Indicator* (extensometer)—A suitable instrument shall be used for determining the distance between two designated points within the gage length of the test specimen as the specimen is stretched. For referee purposes, the extensometer must be set at the full gage length of the specimen, as shown in Fig. 1. It is desirable, but not essential, that this instrument automatically record this distance, or any change in it, as a function of the load on the test specimen or of the elapsed time from the start of the test, or both. If only the latter is obtained, load-time data must also be taken. This instrument shall be essentially free of inertia at the specified speed of testing. Extensometers shall be classified and their calibration periodically verified in accordance with Practice E 83.

5.2.1 *Modulus-of-Elasticity Measurements*—For modulus-of-elasticity measurements, an extensometer with a maximum strain error of 0.0002 mm/mm (in./in.) that automatically and continuously records shall be used. An extensometer classified by Practice E 83 as fulfilling the requirements of a B-2 classification within the range of use for modulus measurements meets this requirement.

5.2.2 *Low-Extension Measurements*—For elongation-at-yield and low-extension measurements (nominally 20 % or less), the same above extensometer, attenuated to 20 % extension, may be used. In any case, the extensometer system must meet at least Class C (Practice E 83) requirements, which include a fixed strain error of 0.001 strain or ±1.0 % of the indicated strain, whichever is greater.

5.2.3 *High-Extension Measurements*—For making measurements at elongations greater than 20 %, measuring techniques with error no greater than ±10 % of the measured value are acceptable.

5.2.4 *Poisson's Ratio*—Bi-axial extensometer or axial and transverse extensometers capable of recording axial strain and transverse strain simultaneously. The extensometers shall be capable of measuring the change in strains with an accuracy of 1 % of the relevant value or better.

NOTE 8—Strain gages can be used as an alternative method to measure axial and transverse strain; however, proper techniques for mounting strain gages are crucial to obtaining accurate data. Consult strain gage suppliers for instruction and training in these special techniques.

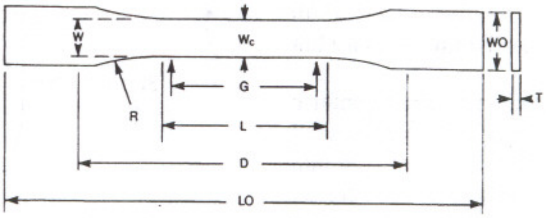
5.3 *Micrometers*—Suitable micrometers for measuring the width and thickness of the test specimen to an incremental discrimination of at least 0.025 mm (0.001 in.) should be used. All width and thickness measurements of rigid and semirigid plastics may be measured with a hand micrometer with ratchet. A suitable instrument for measuring the thickness of nonrigid test specimens shall have: *(1)* a contact measuring pressure of 25 ± 2.5 kPa (3.6 ± 0.36 psi), *(2)* a movable circular contact foot 6.35 ± 0.025 mm (0.250 ± 0.001 in.) in diameter, and *(3)* a lower fixed anvil large enough to extend beyond the contact foot in all directions and being parallel to the contact foot within 0.005 mm (0.0002 in.) over the entire foot area. Flatness of the foot and anvil shall conform to Test Method D 5947.

5.3.1 An optional instrument equipped with a circular contact foot 15.88 ± 0.08 mm (0.625 ± 0.003 in.) in diameter is recommended for thickness measuring of process samples or larger specimens at least 15.88 mm in minimum width.

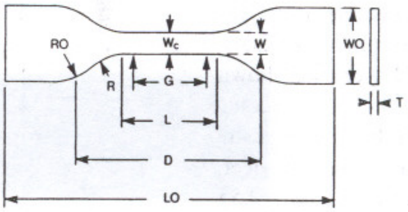
6. Test Specimens

6.1 *Sheet, Plate, and Molded Plastics*:

6.1.1 *Rigid and Semirigid Plastics*—The test specimen shall conform to the dimensions shown in Fig. 1. The Type I specimen is the preferred specimen and shall be used where sufficient material having a thickness of 7 mm (0.28 in.) or less is available. The Type II specimen may be used when a material does not break in the narrow section with the preferred Type I specimen. The Type V specimen shall be used where only limited material having a thickness of 4 mm (0.16 in.) or less is available for evaluation, or where a large number of



TYPES I, II, III & V



TYPE IV

Specimen Dimensions for Thickness, *T*, mm (in.)[A]

Dimensions (see drawings)	7 (0.28) or under		Over 7 to 14 (0.28 to 0.55), incl	4 (0.16) or under		Tolerances
	Type I	Type II	Type III	Type IV[B]	Type V[C,D]	
W—Width of narrow section[E,F]	13 (0.50)	6 (0.25)	19 (0.75)	6 (0.25)	3.18 (0.125)	±0.5 (±0.02)[B,C]
L—Length of narrow section	57 (2.25)	57 (2.25)	57 (2.25)	33 (1.30)	9.53 (0.375)	±0.5 (±0.02)[C]
WO—Width overall, min[G]	19 (0.75)	19 (0.75)	29 (1.13)	19 (0.75)	...	+ 6.4 (+ 0.25)
WO—Width overall, min[G]	...	...	...	...	9.53 (0.375)	+ 3.18 (+ 0.125)
LO—Length overall, min[H]	165 (6.5)	183 (7.2)	246 (9.7)	115 (4.5)	63.5 (2.5)	no max (no max)
G—Gage length[I]	50 (2.00)	50 (2.00)	50 (2.00)	...	7.62 (0.300)	±0.25 (±0.010)[C]
G—Gage length[I]	...	...	...	25 (1.00)	...	±0.13 (±0.005)
D—Distance between grips	115 (4.5)	135 (5.3)	115 (4.5)	65 (2.5)[J]	25.4 (1.0)	±5 (±0.2)
R—Radius of fillet	76 (3.00)	76 (3.00)	76 (3.00)	14 (0.56)	12.7 (0.5)	±1 (±0.04)[C]
RO—Outer radius (Type IV)	...	...	...	25 (1.00)	...	±1 (±0.04)

[A] Thickness, *T*, shall be 3.2± 0.4 mm (0.13 ± 0.02 in.) for all types of molded specimens, and for other Types I and II specimens where possible. If specimens are machined from sheets or plates, thickness, *T*, may be the thickness of the sheet or plate provided this does not exceed the range stated for the intended specimen type. For sheets of nominal thickness greater than 14 mm (0.55 in.) the specimens shall be machined to 14 ± 0.4 mm (0.55 ± 0.02 in.) in thickness, for use with the Type III specimen. For sheets of nominal thickness between 14 and 51 mm (0.55 and 2 in.) approximately equal amounts shall be machined from each surface. For thicker sheets both surfaces of the specimen shall be machined, and the location of the specimen with reference to the original thickness of the sheet shall be noted. Tolerances on thickness less than 14 mm (0.55 in.) shall be those standard for the grade of material tested.

[B] For the Type IV specimen, the internal width of the narrow section of the die shall be 6.00 ± 0.05 mm (0.250± 0.002 in.). The dimensions are essentially those of Die C in Test Methods D 412.

[C] The Type V specimen shall be machined or die cut to the dimensions shown, or molded in a mold whose cavity has these dimensions. The dimensions shall be:
W = 3.18 ± 0.03 mm (0.125 ± 0.001 in.),
L = 9.53 ± 0.08 mm (0.375 ± 0.003 in.),
G = 7.62 ± 0.02 mm (0.300 ± 0.001 in.), and
R = 12.7 ± 0.08 mm (0.500 ± 0.003 in.).
The other tolerances are those in the table.

[D] Supporting data on the introduction of the L specimen of Test Method D 1822 as the Type V specimen are available from ASTM Headquarters. Request RR:D20-1038.

[E] The width at the center W_c shall be +0.00 mm, −0.10 mm (+0.000 in., −0.004 in.) compared with width *W* at other parts of the reduced section. Any reduction in *W* at the center shall be gradual, equally on each side so that no abrupt changes in dimension result.

[F] For molded specimens, a draft of not over 0.13 mm (0.005 in.) may be allowed for either Type I or II specimens 3.2 mm (0.13 in.) in thickness, and this should be taken into account when calculating width of the specimen. Thus a typical section of a molded Type I specimen, having the maximum allowable draft, could be as follows:

[G] Overall widths greater than the minimum indicated may be desirable for some materials in order to avoid breaking in the grips.

[H] Overall lengths greater than the minimum indicated may be desirable either to avoid breaking in the grips or to satisfy special test requirements.

[I] Test marks or initial extensometer span.

[J] When self-tightening grips are used, for highly extensible polymers, the distance between grips will depend upon the types of grips used and may not be critical if maintained uniform once chosen.

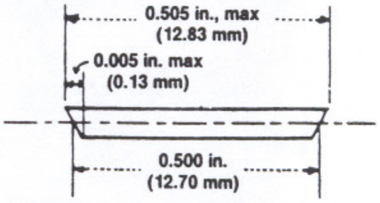


FIG. 1 Tension Test Specimens for Sheet, Plate, and Molded Plastics

specimens are to be exposed in a limited space (thermal and environmental stability tests, etc.). The Type IV specimen should be used when direct comparisons are required between materials in different rigidity cases (that is, nonrigid and semirigid). The Type III specimen must be used for all materials with a thickness of greater than 7 mm (0.28 in.) but not more than 14 mm (0.55 in.).

6.1.2 *Nonrigid Plastics*—The test specimen shall conform to the dimensions shown in Fig. 1. The Type IV specimen shall be used for testing nonrigid plastics with a thickness of 4 mm (0.16 in.) or less. The Type III specimen must be used for all materials with a thickness greater than 7 mm (0.28 in.) but not more than 14 mm (0.55 in.).

6.1.3 *Reinforced Composites*—The test specimen for reinforced composites, including highly orthotropic laminates, shall conform to the dimensions of the Type I specimen shown in Fig. 1.

6.1.4 *Preparation*—Test specimens shall be prepared by machining operations, or die cutting, from materials in sheet, plate, slab, or similar form. Materials thicker than 14 mm (0.55 in.) must be machined to 14 mm (0.55 in.) for use as Type III specimens. Specimens can also be prepared by molding the material to be tested.

NOTE 9—Test results have shown that for some materials such as glass cloth, SMC, and BMC laminates, other specimen types should be considered to ensure breakage within the gage length of the specimen, as mandated by 7.3.

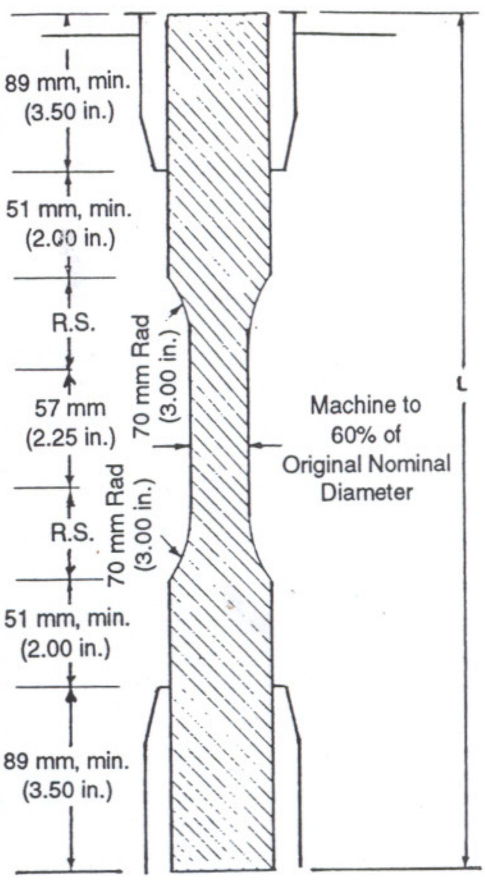
NOTE 10—When preparing specimens from certain composite laminates such as woven roving, or glass cloth, care must be exercised in cutting the specimens parallel to the reinforcement. The reinforcement will be significantly weakened by cutting on a bias, resulting in lower laminate properties, unless testing of specimens in a direction other than parallel with the reinforcement constitutes a variable being studied.

NOTE 11—Specimens prepared by injection molding may have different tensile properties than specimens prepared by machining or die-cutting because of the orientation induced. This effect may be more pronounced in specimens with narrow sections.

6.2 *Rigid Tubes*—The test specimen for rigid tubes shall be as shown in Fig. 2. The length, *L*, shall be as shown in the table in Fig. 2. A groove shall be machined around the outside of the specimen at the center of its length so that the wall section after machining shall be 60 % of the original nominal wall thickness. This groove shall consist of a straight section 57.2 mm (2.25 in.) in length with a radius of 76 mm (3 in.) at each end joining it to the outside diameter. Steel or brass plugs having diameters such that they will fit snugly inside the tube and having a length equal to the full jaw length plus 25 mm (1 in.) shall be placed in the ends of the specimens to prevent crushing. They can be located conveniently in the tube by separating and supporting them on a threaded metal rod. Details of plugs and test assembly are shown in Fig. 2.

6.3 *Rigid Rods*—The test specimen for rigid rods shall be as shown in Fig. 3. The length, *L*, shall be as shown in the table in Fig. 3. A groove shall be machined around the specimen at the center of its length so that the diameter of the machined portion shall be 60 % of the original nominal diameter. This groove shall consist of a straight section 57.2 mm (2.25 in.) in length with a radius of 76 mm (3 in.) at each end joining it to the outside diameter.

6.4 All surfaces of the specimen shall be free of visible flaws, scratches, or imperfections. Marks left by coarse machining operations shall be carefully removed with a fine file or abrasive, and the filed surfaces shall then be smoothed with abrasive paper (No. 00 or finer). The finishing sanding strokes shall be made in a direction parallel to the long axis of the test specimen. All flash shall be removed from a molded specimen, taking great care not to disturb the molded surfaces. In machining a specimen, undercuts that would exceed the dimensional tolerances shown in Fig. 1 shall be scrupulously avoided. Care shall also be taken to avoid other common machining errors.

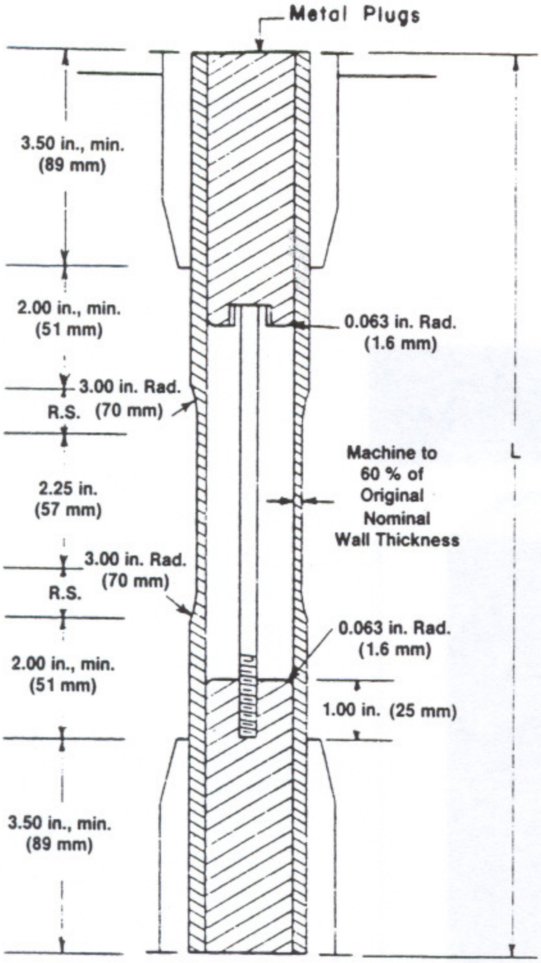


DIMENSIONS OF ROD SPECIMENS

Nominal Diameter	Length of Radial Sections, 2R.S.	Total Calculated Minimum Length of Specimen	Standard Length, *L*, of Specimen to Be Used for 89-mm (3½-in.) Jaws[A]
	mm (in.)		
3.2 (⅛)	19.6 (0.773)	356 (14.02)	381 (15)
4.7 (1⁄16)	24.0 (0.946)	361 (14.20)	381 (15)
6.4 (¼)	27.7 (1.091)	364 (14.34)	381 (15)
9.5 (⅜)	33.9 (1.333)	370 (14.58)	381 (15)
12.7 (½)	39.0 (1.536)	376 (14.79)	400 (15.75)
15.9 (⅝)	43.5 (1.714)	380 (14.96)	400 (15.75)
19.0 (¾)	47.6 (1.873)	384 (15.12)	400 (15.75)
22.2 (⅞)	51.5 (2.019)	388 (15.27)	400 (15.75)
25.4 (1)	54.7 (2.154)	391 (15.40)	419 (16.5)
31.8 (1¼)	60.9 (2.398)	398 (15.65)	419 (16.5)
38.1 (1½)	66.4 (2.615)	403 (15.87)	419 (16.5)
42.5 (1¾)	71.4 (2.812)	408 (16.06)	419 (16.5)
50.8 (2)	76.0 (2.993)	412 (16.24)	432 (17)

[A] For other jaws greater than 89 mm (3.5 in.), the standard length shall be increased by twice the length of the jaws minus 178 mm (7 in.). The standard length permits a slippage of approximately 6.4 to 12.7 mm (0.25 to 0.50 in.) in each jaw while maintaining the maximum length of the jaw grip.

FIG. 3 Diagram Showing Location of Rod Tension Test Specimen in Testing Machine



DIMENSIONS OF TUBE SPECIMENS

Nominal Wall Thickness	Length of Radial Sections, 2R.S.	Total Calculated Minimum Length of Specimen	Standard Length, *L*, of Specimen to Be Used for 89-mm (3.5-in.) Jaws[A]
	mm (in.)		
0.79 (1⁄32)	13.9 (0.547)	350 (13.80)	381 (15)
1.2 (3⁄64)	17.0 (0.670)	354 (13.92)	381 (15)
1.6 (1⁄16)	19.6 (0.773)	356 (14.02)	381 (15)
2.4 (3⁄32)	24.0 (0.946)	361 (14.20)	381 (15)
3.2 (1⁄8)	27.7 (1.091)	364 (14.34)	381 (15)
4.8 (3⁄16)	33.9 (1.333)	370 (14.58)	381 (15)
6.4 (1⁄4)	39.0 (1.536)	376 (14.79)	400 (15.75)
7.9 (5⁄16)	43.5 (1.714)	380 (14.96)	400 (15.75)
9.5 (3⁄8)	47.6 (1.873)	384 (15.12)	400 (15.75)
11.1 (7⁄16)	51.3 (2.019)	388 (15.27)	400 (15.75)
12.7 (1⁄2)	54.7 (2.154)	391 (15.40)	419 (16.5)

[A] For other jaws greater than 89 mm (3.5 in.), the standard length shall be increased by twice the length of the jaws minus 178 mm (7 in.). The standard length permits a slippage of approximately 6.4 to 12.7 mm (0.25 to 0.50 in.) in each jaw while maintaining the maximum length of the jaw grip.

FIG. 2 Diagram Showing Location of Tube Tension Test Specimens in Testing Machine

6.5 If it is necessary to place gage marks on the specimen, this shall be done with a wax crayon or India ink that will not affect the material being tested. Gage marks shall not be scratched, punched, or impressed on the specimen.

6.6 When testing materials that are suspected of anisotropy, duplicate sets of test specimens shall be prepared, having their long axes respectively parallel with, and normal to, the suspected direction of anisotropy.

7. Number of Test Specimens

7.1 Test at least five specimens for each sample in the case of isotropic materials.

7.2 Test ten specimens, five normal to, and five parallel with, the principle axis of anisotropy, for each sample in the case of anisotropic materials.

7.3 Discard specimens that break at some flaw, or that break outside of the narrow cross-sectional test section (Fig. 1, dimension "L"), and make retests, unless such flaws constitute a variable to be studied.

NOTE 12—Before testing, all transparent specimens should be inspected in a polariscope. Those which show atypical or concentrated strain patterns should be rejected, unless the effects of these residual strains constitute a variable to be studied.

8. Speed of Testing

8.1 Speed of testing shall be the relative rate of motion of the grips or test fixtures during the test. The rate of motion of the driven grip or fixture when the testing machine is running idle may be used, if it can be shown that the resulting speed of testing is within the limits of variation allowed.

8.2 Choose the speed of testing from Table 1. Determine this chosen speed of testing by the specification for the material being tested, or by agreement between those concerned. When the speed is not specified, use the lowest speed shown in Table 1 for the specimen geometry being used, which gives rupture within ½ to 5-min testing time.

8.3 Modulus determinations may be made at the speed selected for the other tensile properties when the recorder response and resolution are adequate.

TABLE 1 Designations for Speed of Testing[A]

Classification[B]	Specimen Type	Speed of Testing. mm/min (in./min)	Nominal Strain[C] Rate at Start of Test, mm/mm· min (in./in.·min)
Rigid and Semirigid	I, II, III rods and tubes	5 (0.2) ± 25 %	0.1
		50 (2) ± 10 %	1
		500 (20) ± 10 %	10
	IV	5 (0.2) ± 25 %	0.15
		50 (2) ± 10 %	1.5
		500 (20) ± 10 %	15
	V	1 (0.05) ± 25 %	0.1
		10 (0.5) ± 25 %	1
		100 (5)± 25 %	10
Nonrigid	III	50 (2) ± 10 %	1
		500 (20) ± 10 %	10
	IV	50 (2) ± 10 %	1.5
		500 (20) ± 10 %	15

[A] Select the lowest speed that produces rupture in ½ to 5 min for the specimen geometry being used (see 8.2).

[B] See Terminology D 883 for definitions.

[C] The initial rate of straining cannot be calculated exactly for dumbbell-shaped specimens because of extension, both in the reduced section outside the gage length and in the fillets. This initial strain rate can be measured from the initial slope of the tensile strain-versus-time diagram.

8.4 Poisson's ratio determinations shall be made at the same speed selected for modulus determinations.

9. Conditioning

9.1 *Conditioning*—Condition the test specimens at 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D 618, unless otherwise specified by contract or the relevant ASTM material specification. Reference pre-test conditioning, to settle disagreements, shall apply tolerances of ±1°C (1.8°F) and ±2 % relative humidity.

9.2 *Test Conditions*—Conduct the tests at 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5 % relative humidity, unless otherwise specified by contract or the relevant ASTM material specification. Reference testing conditions, to settle disagreements, shall apply tolerances of ±1°C (1.8°F) and ±2 % relative humidity.

10. Procedure

10.1 Measure the width and thickness of rigid flat specimens (Fig. 1) with a suitable micrometer to the nearest 0.025 mm (0.001 in.) at several points along their narrow sections. Measure the thickness of nonrigid specimens (produced by a Type IV die) in the same manner with the required dial micrometer. Take the width of this specimen as the distance between the cutting edges of the die in the narrow section. Measure the diameter of rod specimens, and the inside and outside diameters of tube specimens, to the nearest 0.025 mm (0.001 in.) at a minimum of two points 90° apart; make these measurements along the groove for specimens so constructed. Use plugs in testing tube specimens, as shown in Fig. 2.

TABLE 2 Modulus, 10^6·psi, for Eight Laboratories, Five Materials

	Mean	S_r	S_R	I_r	I_R
Polypropylene	0.210	0.0089	0.071	0.025	0.201
Cellulose acetate butyrate	0.246	0.0179	0.035	0.051	0.144
Acrylic	0.481	0.0179	0.063	0.051	0.144
Glass-reinforced nylon	1.17	0.0537	0.217	0.152	0.614
Glass-reinforced polyester	1.39	0.0894	0.266	0.253	0.753

10.2 Place the specimen in the grips of the testing machine, taking care to align the long axis of the specimen and the grips with an imaginary line joining the points of attachment of the grips to the machine. The distance between the ends of the gripping surfaces, when using flat specimens, shall be as indicated in Fig. 1. On tube and rod specimens, the location for the grips shall be as shown in Fig. 2 and Fig. 3. Tighten the grips evenly and firmly to the degree necessary to prevent slippage of the specimen during the test, but not to the point where the specimen would be crushed.

10.3 Attach the extension indicator. When modulus is being determined, a Class B-2 or better extensometer is required (see 5.2.1).

NOTE 13—Modulus of materials is determined from the slope of the linear portion of the stress-strain curve. For most plastics, this linear portion is very small, occurs very rapidly, and must be recorded automatically. The change in jaw separation is never to be used for calculating modulus or elongation.

10.3.1 *Poisson's Ratio Determination:*

10.3.1.1 When Poisson's ratio is determined, the speed of testing and the load range at which it is determined shall be the same as those used for modulus of elasticity.

10.3.1.2 Attach the transverse strain measuring device. The transverse strain measuring device must continuously measure the strain simultaneously with the axial strain measuring device.

TABLE 3 Tensile Stress at Yield, 10^3 psi, for Eight Laboratories, Three Materials

	Mean	S_r	S_R	I_r	I_R
Polypropylene	3.63	0.022	0.161	0.062	0.456
Cellulose acetate butyrate	5.01	0.058	0.227	0.164	0.642
Acrylic	10.4	0.067	0.317	0.190	0.897

TABLE 4 Elongation at Yield, %, for Eight Laboratories, Three Materials

	Mean	S_r	S_R	I_r	I_R
Cellulose acetate butyrate	3.65	0.27	0.62	0.76	1.75
Acrylic	4.89	0.21	0.55	0.59	1.56
Polypropylene	8.79	0.45	5.86	1.27	16.5

10.3.1.3 Make simultaneous measurements of load and strain and record the data. The precision of the value of Poisson's ratio will depend on the number of data points of axial and transverse strain taken.

10.4 Set the speed of testing at the proper rate as required in Section 8, and start the machine.

10.5 Record the load-extension curve of the specimen.

10.6 Record the load and extension at the yield point (if one exists) and the load and extension at the moment of rupture.

NOTE 14—If it is desired to measure both modulus and failure properties (yield or break, or both), it may be necessary, in the case of highly extensible materials, to run two independent tests. The high magnification extensometer normally used to determine properties up to the yield point may not be suitable for tests involving high extensibility. If allowed to remain attached to the specimen, the extensometer could be permanently damaged. A broad-range incremental extensometer or hand-rule technique may be needed when such materials are taken to rupture.

11. Calculation

11.1 Toe compensation shall be made in accordance with Annex A1, unless it can be shown that the toe region of the curve is not due to the take-up of slack, seating of the specimen, or other artifact, but rather is an authentic material response.

11.2 *Tensile Strength*—Calculate the tensile strength by dividing the maximum load in newtons (or pounds-force) by the original minimum cross-sectional area of the specimen in square metres (or square inches). Express the result in pascals (or pounds-force per square inch) and report it to three significant figures as tensile strength at yield or tensile strength at break, whichever term is applicable. When a nominal yield or break load less than the maximum is present and applicable, it may be desirable also to calculate, in a similar manner, the corresponding tensile stress at yield or tensile stress at break and report it to three significant figures (see Note A2.8).

11.3 Elongation values are valid and are reported in cases where uniformity of deformation within the specimen gage length is present. Elongation values are quantitatively relevant and appropriate for engineering design. When non-uniform deformation (such as necking) occurs within the specimen gage length nominal strain values are reported. Nominal strain values are of qualitative utility only.

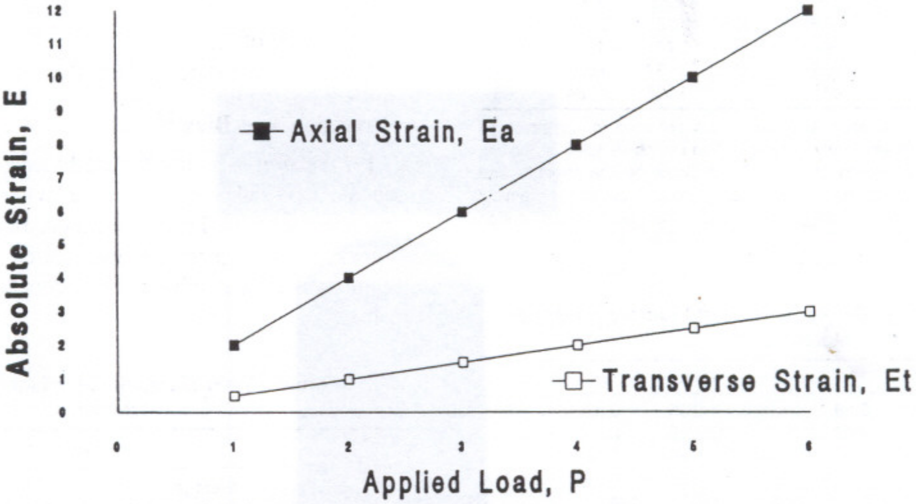


FIG. 4 Plot of Strains Versus Load for Determination of Poisson's Ratio

11.3.1 *Percent Elongation*—Percent elongation is the change in gage length relative to the original specimen gage length, expressed as a percent. Percent elongation is calculated using the apparatus described in 5.2.

11.3.1.1 *Percent Elongation at Yield*—Calculate the percent elongation at yield by reading the extension (change in gage length) at the yield point. Divide that extension by the original gage length and multiply by 100.

11.3.1.2 *Percent Elongation at Break*—Calculate the percent elongation at break by reading the extension (change in gage length) at the point of specimen rupture. Divide that extension by the original gage length and multiply by 100.

11.3.2 *Nominal Strain*—Nominal strain is the change in grip separation relative to the original grip separation expressed as a percent. Nominal strain is calculated using the apparatus described in 5.1.7.

11.3.2.1 *Nominal strain at break*—Calculate the nominal strain at break by reading the extension (change in grip separation) at the point of rupture. Divide that extension by the original grip separation and multiply by 100.

11.4 *Modulus of Elasticity*—Calculate the modulus of elasticity by extending the initial linear portion of the load-extension curve and dividing the difference in stress corresponding to any segment of section on this straight line by the corresponding difference in strain. All elastic modulus values shall be computed using the average initial cross-sectional area of the test specimens in the calculations. The result shall be expressed in pascals (pounds-force per square inch) and reported to three significant figures.

11.5 *Secant Modulus*—At a designated strain, this shall be calculated by dividing the corresponding stress (nominal) by the designated strain. Elastic modulus values are preferable and shall be calculated whenever possible. However, for materials where no proportionality is evident, the secant value shall be calculated. Draw the tangent as directed in A1.3 and Fig. A1.2, and mark off the designated strain from the yield point where the tangent line goes through zero stress. The stress to be used in the calculation is then determined by dividing the load-extension curve by the original average cross-sectional area of the specimen.

11.6 *Poisson's Ratio*—The axial strain, ϵ_a, indicated by the axial extensometer, and the transverse strain, ϵ, indicated by the transverse extensometers, are plotted against the applied load, P, as shown in Fig. 4. A straight line is drawn through each set of points, and the slopes, $d\epsilon_a / dP$ and $d\epsilon_t / dP$, of these lines are determined. Poisson's ratio, μ, is then calculated as follows:

$$\mu = -(d\epsilon_t / dP)/(d\epsilon_a / dP) \tag{1}$$

where:

$d\epsilon_t$ = change in transverse strain,
$d\epsilon_a$ = change in axial strain, and
dP = change in applied load;

or

$$\mu = -(d\epsilon_t) / (d\epsilon_a) \tag{2}$$

11.6.1 The errors that may be introduced by drawing a straight line through the points can be reduced by applying the method of least squares.

11.7 For each series of tests, calculate the arithmetic mean of all values obtained and report it as the "average value" for the particular property in question.

11.8 Calculate the standard deviation (estimated) as follows and report it to two significant figures:

$$s = \sqrt{(\Sigma X^2 - n\bar{X}^2) / (n-1)} \tag{3}$$

where:

s = estimated standard deviation,
X = value of single observation,

n = number of observations, and
$\bar{X}$ = arithmetic mean of the set of observations.

11.9 See Annex A1 for information on toe compensation.

TABLE 5 Tensile Strength at Break, 10^3 psi, for Eight Laboratories, Five Materials[A]

	Mean	S_r	S_R	I_r	I_R
Polypropylene	2.97	1.54	1.65	4.37	4.66
Cellulose acetate butyrate	4.82	0.058	0.180	0.164	0.509
Acrylic	9.09	0.452	0.751	1.27	2.13
Glass-reinforced polyester	20.8	0.233	0.437	0.659	1.24
Glass-reinforced nylon	23.6	0.277	0.698	0.784	1.98

[A] Tensile strength and elongation at break values obtained for unreinforced propylene plastics generally are highly variable due to inconsistencies in necking or "drawing" of the center section of the test bar. Since tensile strength and elongation at yield are more reproducible and relate in most cases to the practical usefulness of a molded part, they are generally recommended for specification purposes.

TABLE 6 Elongation at Break, %, for Eight Laboratories, Five Materials[A]

	Mean	S_r	S_R	I_r	I_R
Glass-reinforced polyester	3.68	0.20	2.33	0.570	6.59
Glass-reinforced nylon	3.87	0.10	2.13	0.283	6.03
Acrylic	13.2	2.05	3.65	5.80	10.3
Cellulose acetate butyrate	14.1	1.87	6.62	5.29	18.7
Polypropylene	293.0	50.9	119.0	144.0	337.0

[A] Tensile strength and elongation at break values obtained for unreinforced propylene plastics generally are highly variable due to inconsistencies in necking or "drawing" of the center section of the test bar. Since tensile strength and elongation at yield are more reproducible and relate in most cases to the practical usefulness of a molded part, they are generally recommended for specification purposes.

TABLE 7 Tensile Yield Strength, for Ten Laboratories, Eight Materials

Material	Test Speed, in./min	Values Expressed in psi Units				
		Average	S_r	S_R	r	R
LDPE	20	1544	52.4	64.0	146.6	179.3
LDPE	20	1894	53.1	61.2	148.7	171.3
LLDPE	20	1879	74.2	99.9	207.8	279.7
LLDPE	20	1791	49.2	75.8	137.9	212.3
LLDPE	20	2900	55.5	87.9	155.4	246.1
LLDPE	20	1730	63.9	96.0	178.9	268.7
HDPE	2	4101	196.1	371.9	549.1	1041.3
HDPE	2	3523	175.9	478.0	492.4	1338.5

12. Report

12.1 Report the following information:

12.1.1 Complete identification of the material tested, including type, source, manufacturer's code numbers, form, principal dimensions, previous history, etc.,

12.1.2 Method of preparing test specimens,

12.1.3 Type of test specimen and dimensions,

12.1.4 Conditioning procedure used,

12.1.5 Atmospheric conditions in test room,

12.1.6 Number of specimens tested,

12.1.7 Speed of testing,

12.1.8 Classification of extensometers used. A description of measuring technique and calculations employed instead of a minimum Class-C extensometer system,

12.1.9 Tensile strength at yield or break, average value, and standard deviation,

12.1.10 Tensile stress at yield or break, if applicable, average value, and standard deviation,

12.1.11 Percent elongation at yield, or break, or nominal strain at break, or all three, as applicable, average value, and standard deviation,

12.1.12 Modulus of elasticity, average value, and standard deviation,

12.1.13 Date of test, and

12.1.14 Revision date of Test Method D 638.

13. Precision and Bias [12]

13.1 *Precision*—Tables 2-6 are based on a round-robin test conducted in 1984, involving five materials tested by eight laboratories using the Type I specimen, all of nominal 0.125-in. thickness. Each test result was based on five individual determinations. Each laboratory obtained two test results for each material.

TABLE 8 Tensile Yield Elongation, for Eight Laboratories, Eight Materials

Material	Test Speed, in./min	Values Expressed in Percent Units				
		Average	S_r	S_R	r	R
LDPE	20	17.0	1.26	3.16	3.52	8.84
LDPE	20	14.6	1.02	2.38	2.86	6.67
LLDPE	20	15.7	1.37	2.85	3.85	7.97
LLDPE	20	16.6	1.59	3.30	4.46	9.24
LLDPE	20	11.7	1.27	2.88	3.56	8.08
LLDPE	20	15.2	1.27	2.59	3.55	7.25
HDPE	2	9.27	1.40	2.84	3.91	7.94
HDPE	2	9.63	1.23	2.75	3.45	7.71

TABLE 9 Tensile Break Strength, for Nine Laboratories, Six Materials

Material	Test Speed, in./min	Values Expressed in psi Units				
		Average	S_r	S_R	r	R
LDPE	20	1592	52.3	74.9	146.4	209.7
LDPE	20	1750	66.6	102.9	186.4	288.1
LLDPE	20	4379	127.1	219.0	355.8	613.3
LLDPE	20	2840	78.6	143.5	220.2	401.8
LLDPE	20	1679	34.3	47.0	95.96	131.6
LLDPE	20	2660	119.1	166.3	333.6	465.6

13.1.1 Tables 7-10 are based on a round-robin test conducted by the polyolefin subcommittee in 1988, involving eight polyethylene materials tested in ten laboratories. For each material, all samples were molded at one source, but the individual specimens were prepared at the laboratories that tested them. Each test result was the average of five individual determinations. Each laboratory obtained three test results for each material. Data from some laboratories could not be used for various reasons, and this is noted in each table.

13.1.2 In Tables 2-10, for the materials indicated, and for test results that derived from testing five specimens:

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[12] Supporting data are available from ASTM Headquarters. Request RR:D20-1125 for the 1984 round robin and RR:D20-1170 for the 1988 round robin.

TABLE 10 Tensile Break Elongation, for Nine Laboratories, Six Materials

Material	Test Speed, in./min	Values Expressed in Percent Units				
		Average	S_r	S_R	r	R
LDPE	20	567	31.5	59.5	88.2	166.6
LDPE	20	569	61.5	89.2	172.3	249.7
LLDPE	20	890	25.7	113.8	71.9	318.7
LLDPE	20	64.4	6.68	11.7	18.7	32.6
LLDPE	20	803	25.7	104.4	71.9	292.5
LLDPE	20	782	41.6	96.7	116.6	270.8

13.1.2.1 S_r is the within-laboratory standard deviation of the average; $I_r = 2.83\ S_r$. (See 13.1.2.3 for application of I_r.)

13.1.2.2 S_R is the between-laboratory standard deviation of the average; $I_R = 2.83\ S_R$. (See 13.1.2.4 for application of I_R.)

13.1.2.3 *Repeatability*—In comparing two test results for the same material, obtained by the same operator using the same equipment on the same day, those test results should be judged not equivalent if they differ by more than the I_r value for that material and condition.

13.1.2.4 *Reproducibility*—In comparing two test results for the same material, obtained by different operators using different equipment on different days, those test results should be judged not equivalent if they differ by more than the I_R value for that material and condition. (This applies between different laboratories or between different equipment within the same laboratory.)

13.1.2.5 Any judgment in accordance with 13.1.2.3 and 13.1.2.4 will have an approximate 95 % (0.95) probability of being correct.

13.1.2.6 Other formulations may give somewhat different results.

13.1.2.7 For further information on the methodology used in this section, see Practice E 691.

13.1.2.8 The precision of this test method is very dependent upon the uniformity of specimen preparation, standard practices for which are covered in other documents.

13.2 *Bias*—There are no recognized standards on which to base an estimate of bias for this test method.

14. Keywords

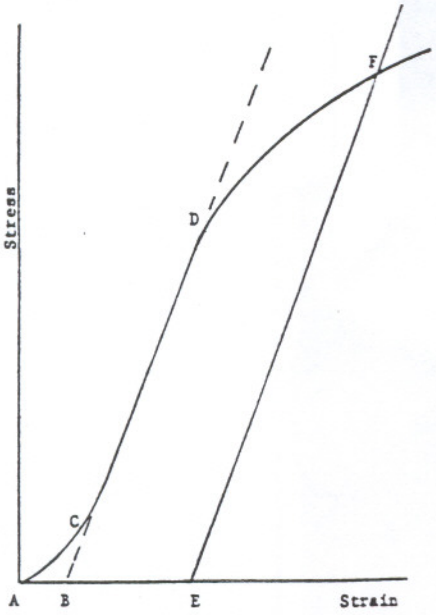
14.1 modulus of elasticity; percent elongation; plastics; tensile properties; tensile strength

ANNEXES

(Mandatory Information)

A1. TOE COMPENSATION

A1.1 In a typical stress-strain curve (Fig. A1.1) there is a toe region, *AC*, that does not represent a property of the material. It is an artifact caused by a takeup of slack and alignment or seating of the specimen. In order to obtain correct values of such parameters as modulus, strain, and offset yield point, this artifact must be compensated for to give the corrected zero point on the strain or extension axis.

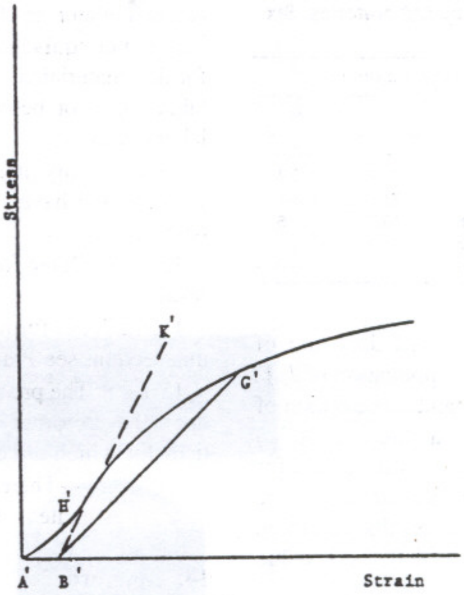


NOTE 1—Some chart recorders plot the mirror image of this graph.

FIG. A1.1 Material with Hookean Region

A1.2 In the case of a material exhibiting a region of Hookean (linear) behavior (Fig. A1.1), a continuation of the linear (*CD*) region of the curve is constructed through the zero-stress axis. This intersection (*B*) is the corrected zero-strain point from which all extensions or strains must be measured, including the yield offset (*BE*), if applicable. The elastic modulus can be determined by dividing the stress at any point along the line *CD* (or its extension) by the strain at the same point (measured from Point *B*, defined as zero-strain).

A1.3 In the case of a material that does not exhibit any linear region (Fig. A1.2), the same kind of toe correction of the zero-strain point can be made by constructing a tangent to the maximum slope at the inflection point (*H′*). This is extended to intersect the strain axis at Point *B′*, the corrected zero-strain point. Using Point *B′* as zero strain, the stress at any point (*G′*) on the curve can be divided by the strain at that point to obtain a secant modulus (slope of Line *B′ G′*). For those materials with no linear region, any attempt to use the tangent through the inflection point as a basis for determination of an offset yield point may result in unacceptable error.



NOTE 1—Some chart recorders plot the mirror image of this graph.

FIG. A1.2 Material with No Hookean Region

A2. DEFINITIONS OF TERMS AND SYMBOLS RELATING TO TENSION TESTING OF PLASTICS

A2.1 *elastic limit*—the greatest stress which a material is capable of sustaining without any permanent strain remaining upon complete release of the stress. It is expressed in force per unit area, usually pounds-force per square inch (megapascals).

NOTE A2.1—Measured values of proportional limit and elastic limit vary greatly with the sensitivity and accuracy of the testing equipment, eccentricity of loading, the scale to which the stress-strain diagram is plotted, and other factors. Consequently, these values are usually replaced by yield strength.

A2.2 *elongation*—the increase in length produced in the gage length of the test specimen by a tensile load. It is expressed in units of length, usually inches (millimetres). (Also known as *extension.*)

NOTE A2.2—Elongation and strain values are valid only in cases where uniformity of specimen behavior within the gage length is present. In the case of materials exhibiting necking phenomena, such values are only of qualitative utility after attainment of yield point. This is due to inability to ensure that necking will encompass the entire length between the gage marks prior to specimen failure.

A2.3 *gage length*—the original length of that portion of the specimen over which strain or change in length is determined.

A2.4 *modulus of elasticity*—the ratio of stress (nominal) to corresponding strain below the proportional limit of a material. It is expressed in force per unit area, usually megapascals (pounds-force per square inch). (Also known as *elastic modulus* or *Young's modulus*).

NOTE A2.3—The stress-strain relations of many plastics do not conform to Hooke's law throughout the elastic range but deviate therefrom even at stresses well below the elastic limit. For such materials the slope of the tangent to the stress-strain curve at a low stress is usually taken as the modulus of elasticity. Since the existence of a true proportional limit in plastics is debatable, the propriety of applying the term "modulus of elasticity" to describe the stiffness or rigidity of a plastic has been seriously questioned. The exact stress-strain characteristics of plastic materials are very dependent on such factors as rate of stressing, temperature, previous specimen history, etc. However, such a value is useful if its arbitrary nature and dependence on time, temperature, and other factors are realized.

A2.5 *necking*—the localized reduction in cross section which may occur in a material under tensile stress.

A2.6 *offset yield strength*—the stress at which the strain exceeds by a specified amount (the offset) an extension of the initial proportional portion of the stress-strain curve. It is expressed in force per unit area, usually megapascals (pounds-force per square inch).

NOTE A2.4—This measurement is useful for materials whose stress-strain curve in the yield range is of gradual curvature. The offset yield strength can be derived from a stress-strain curve as follows (Fig. A2.1):

On the strain axis lay off *OM* equal to the specified offset.

Draw *OA* tangent to the initial straight-line portion of the stress-strain curve.

Through *M* draw a line *MN* parallel to *OA* and locate the intersection of *MN* with the stress-strain curve.

The stress at the point of intersection *r* is the "offset yield strength." The specified value of the offset must be stated as a percent of the original gage length in conjunction with the strength value. *Example:* 0.1 % offset yield strength = ... MPa (psi), or yield strength at 0.1 % offset ... MPa (psi).

A2.7 *percent elongation*—the elongation of a test specimen expressed as a percent of the gage length.

A2.8 *percent elongation at break and yield:*

A2.8.1 *percent elongation at break*—the percent elongation at the moment of rupture of the test specimen.

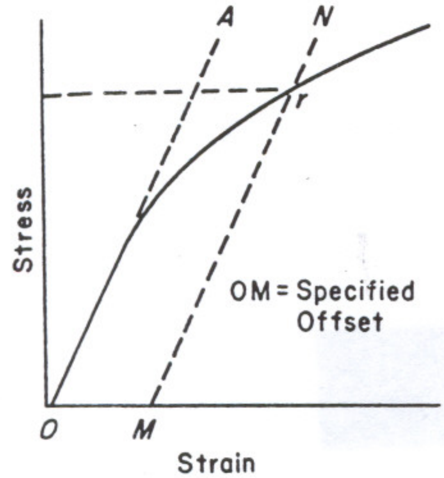


FIG. A2.1 Offset Yield Strength

A2.8.2 *percent elongation at yield*—the percent elongation at the moment the yield point (A2.21) is attained in the test specimen.

A2.9 *percent reduction of area (nominal)*—the difference between the original cross-sectional area measured at the point of rupture after breaking and after all retraction has ceased, expressed as a percent of the original area.

A2.10 *percent reduction of area (true)*—the difference between the original cross-sectional area of the test specimen and the minimum cross-sectional area within the gage boundaries prevailing at the moment of rupture, expressed as a percentage of the original area.

A2.11 *proportional limit*—the greatest stress which a material is capable of sustaining without any deviation from proportionality of stress to strain (Hooke's law). It is expressed in force per unit area, usually megapascals (pounds-force per square inch).

A2.12 *rate of loading*—the change in tensile load carried by the specimen per unit time. It is expressed in force per unit time, usually newtons (pounds-force) per minute. The initial rate of loading can be calculated from the initial slope of the load versus time diagram.

A2.13 *rate of straining*—the change in tensile strain per unit time. It is expressed either as strain per unit time, usually metres per metre (inches per inch) per minute, or percent elongation per unit time, usually percent elongation per minute. The initial rate of straining can be calculated from the initial slope of the tensile strain versus time diagram.

Note A2.5—The initial rate of straining is synonymous with the rate of crosshead movement divided by the initial distance between crossheads only in a machine with constant rate of crosshead movement and when the specimen has a uniform original cross section, does not "neck down," and does not slip in the jaws.

A2.14 *rate of stressing (nominal)*—the change in tensile stress (nominal) per unit time. It is expressed in force per unit area per unit time, usually megapascals (pounds-force per square inch) per minute. The initial rate of stressing can be calculated from the initial slope of the tensile stress (nominal) versus time diagram.

Note A2.6—The initial rate of stressing as determined in this manner has only limited physical significance. It does, however, roughly describe the average rate at which the initial stress (nominal) carried by the test specimen is applied. It is affected by the elasticity and flow characteristics of the materials being tested. At the yield point, the rate of stressing (true) may continue to have a positive value if the cross-sectional area is decreasing.

A2.15 *secant modulus*—the ratio of stress (nominal) to corresponding strain at any specified point on the stress-strain curve. It is expressed in force per unit area, usually megapascals (pounds-force per square inch), and reported together with the specified stress or strain.

Note A2.7—This measurement is usually employed in place of modulus of elasticity in the case of materials whose stress-strain diagram does not demonstrate proportionality of stress to strain.

A2.16 *strain*—the ratio of the elongation to the gage length of the test specimen, that is, the change in length per unit of original length. It is expressed as a dimensionless ratio.

A2.16.1 *nominal strain at break*—the strain at the moment of rupture relative to the original grip separation.

A2.17 *tensile strength (nominal)*—the maximum tensile stress (nominal) sustained by the specimen during a tension test. When the maximum stress occurs at the yield point (A2.21), it shall be designated tensile strength at yield. When the maximum stress occurs at break, it shall be designated tensile strength at break.

A2.18 *tensile stress (nominal)*—the tensile load per unit area of minimum original cross section, within the gage boundaries, carried by the test specimen at any given moment. It is expressed in force per unit area, usually megapascals (pounds-force per square inch).

Note A2.8—The expression of tensile properties in terms of the minimum original cross section is almost universally used in practice. In the case of materials exhibiting high extensibility or necking, or both (A2.15), nominal stress calculations may not be meaningful beyond the yield point (A2.21) due to the extensive reduction in cross-sectional area that ensues. Under some circumstances it may be desirable to express the tensile properties per unit of minimum prevailing cross section. These properties are called true tensile properties (that is, true tensile stress, etc.).

A2.19 *tensile stress-strain curve*—a diagram in which values of tensile stress are plotted as ordinates against corresponding values of tensile strain as abscissas.

A2.20 *true strain* (see Fig. A2.2) is defined by the following equation for ϵ_T:

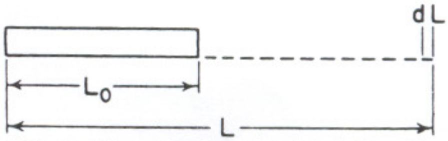


FIG. A2.2 Illustration of True Strain Equation

$$\epsilon_T = \int_{L_o}^{L} \mathrm{d}L/L = \ln L/L_o \qquad \text{(A2.1)}$$

where:

$\mathrm{d}L$ = increment of elongation when the distance between the gage marks is L,
L_o = original distance between gage marks, and
L = distance between gage marks at any time.

A2.21 *yield point*—the first point on the stress-strain curve at which an increase in strain occurs without an increase in stress (Fig. A2.2).

NOTE A2.9—Only materials whose stress-strain curves exhibit a point of zero slope may be considered as having a yield point.

NOTE A2.10—Some materials exhibit a distinct "break" or discontinuity in the stress-strain curve in the elastic region. This break is not a yield point by definition. However, this point may prove useful for material characterization in some cases.

A2.22 *yield strength*—the stress at which a material exhibits a specified limiting deviation from the proportionality of stress to strain. Unless otherwise specified, this stress will be the stress at the yield point and when expressed in relation to the tensile strength shall be designated either tensile strength at yield or tensile stress at yield as required in A2.17 (Fig. A2.3). (See *offset yield strength.*)

A2.23 *Symbols*—The following symbols may be used for the above terms:

Symbol	Term
W	Load
ΔW	Increment of load
L	Distance between gage marks at any time
L_o	Original distance between gage marks
L_u	Distance between gage marks at moment of rupture
ΔL	Increment of distance between gage marks = elongation
A	Minimum cross-sectional area at any time
A_o	Original cross-sectional area
ΔA	Increment of cross-sectional area
A_u	Cross-sectional area at point of rupture measured after breaking specimen
A_T	Cross-sectional area at point of rupture, measured at the moment of rupture
t	Time
Δt	Increment of time
σ	Tensile stress
$\Delta\sigma$	Increment of stress
σ_T	True tensile stress
σ_U	Tensile strength at break (nominal)
σ_{UT}	Tensile strength at break (true)
ϵ	Strain
$\Delta\epsilon$	Increment of strain
ϵ_U	Total strain, at break
ϵ_T	True strain
$\%El$	Percentage elongation
Y.P.	Yield point
E	Modulus of elasticity

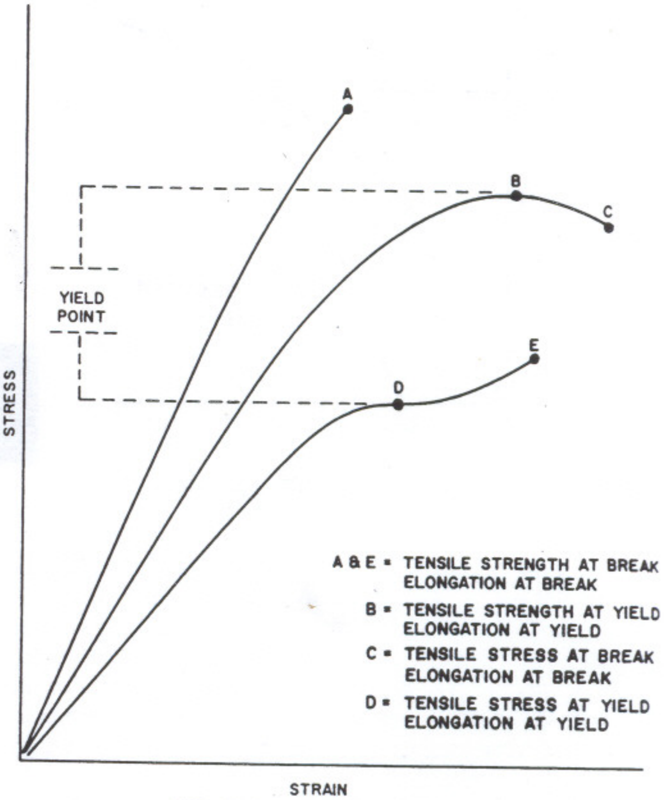


FIG. A2.3 Tensile Designations

A2.24 Relations between these various terms may be defined as follows:

$\sigma = W/A_o$
$\sigma_T = W/A$
$\sigma_U = W/A_o$(where W is breaking load)
$\sigma_{UT} = W/A_T$(where W is breaking load)
$\epsilon = \Delta L/L_o = (L - L_o)/L_o$
$\epsilon_U = (L_u - L_o)/L_o$
$\epsilon_T = \int_{L_o}^{L} dL/L = \ln L/L_o$
$\%El = [(L - L_o)/L_o] \times 100 = \epsilon \times 100$

Percent reduction of area (nominal) = $[(A_o - A_u)/A_o] \times 100$
Percent reduction of area (true) = $[(A_o - A_T)/A_o] \times 100$
Rate of loading = $\Delta W/\Delta t$
Rate of stressing (nominal) = $\Delta\sigma/\Delta = (\Delta W)/A_o)/\Delta t$
Rate of straining = $\Delta\epsilon/\Delta t = (\Delta L/L_o)\Delta t$

For the case where the volume of the test specimen does not change during the test, the following three relations hold:

$$\sigma_T = \sigma(1 + \epsilon) = \sigma L/L_o \qquad \text{(A2.2)}$$

$$\sigma_{UT} = \sigma_U(1 + \epsilon_U) = \sigma_U L_u/L_o$$

$$A = A_o/(1 + \epsilon)$$

SUMMARY OF CHANGES

This section identifies the location of selected changes to this test method. For the convenience of the user, Committee D20 has highlighted those changes that may impact the use of this test method. This section may also include descriptions of the changes or reasons for the changes, or both.

D 638–02a:
(*1*) Added 5.1.7.
(*2*) Added new text from 11.3 to 11.3.2.1.
(*3*) Revised 12.1.11.
(*4*) Added A2.16.1.
D 638–02:
(*1*) Revised 9.1 and 9.2.
D 638–01:
(*1*) Modified 7.3 regarding conditions for specimen discard.
D 638–00:
(*1*) Added 11.1 and renumbered subsequent sections.
D 638–99:
(*1*) Added and clarified extensometer classification requirements.
D 638–98:
(*1*) Revised 10.3 and added 12.1.8 to clarify extensometer usage.
(2) Added 12.1.14.
(*3*) Replaced reference to Test Methods D 374 with Test Method D 5947 in 2.1 and 5.3.

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ICS 83.080

Octubre 1996

TÍTULO

Plásticos

Determinación de las propiedades en tracción

Parte 1: Principios Generales

(ISO 527-1:1993 y Corrigendum 1:1994)

Plastics. Determination of tensile properties. Part 1: General principles. (ISO 527-1:1993 including Corr 1:1994).

Plastiques. Détermination des propriétés en traction. Partie 1: Principes généraux. (ISO 527-1:1993 inclut Corr 1:1994).

CORRESPONDENCIA

Esta norma UNE es la versión oficial, en español, de la Norma Europea EN ISO 527-1 de fecha febrero de 1996, que a su vez adopta íntegramente la Norma Internacional ISO 527-1:1993 y su Corrigendum 1:1994.

OBSERVACIONES

Esta norma anula y sustituye a la Norma UNE 53-023/1 de fecha octubre de 1994.

ANTECEDENTES

Esta Norma Española ha sido elaborada por el comité técnico AEN/CTN 53 *Plásticos y Caucho* cuya Secretaría desempeña ANAIP-COFACO.

Editada e impresa por AENOR
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LAS OBSERVACIONES A ESTE DOCUMENTO HAN DE DIRIGIRSE A:

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17 Páginas

Grupo 13

NORMA EUROPEA
EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN ISO 527-1

Febrero 1996

ICS 83.080

Descriptores: Véase documento ISO.

Versión en español

Plásticos
Determinación de las propiedades en tracción
Parte 1: Principios Generales
(ISO 527-1:1993 incluye Corr 1:1994)

Plastics. Determination of tensile properties. Part 1: General principles. (ISO 527-1:1993 including Corr 1:1994).

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Kunststoffe. Bestimmung der Zugeigenschaften. Teil 1: Allgemeine Grundsätze. (ISO 527-1:1993 einschließlich Corr 1:1994).

Esta Norma Europea ha sido aprobada por CEN el 1994-12-14. Los miembros de CEN están sometidos al Reglamento Interior de CEN/CENELEC que define las condiciones dentro de las cuales debe adoptarse, sin modificación, la Norma Europea como norma nacional.

Las correspondientes listas actualizadas y las referencias bibliográficas relativas a estas normas nacionales, pueden obtenerse en la Secretaría Central de CEN, o a través de sus miembros.

Esta Norma Europea existe en tres versiones oficiales (alemán, francés e inglés). Una versión en otra lengua realizada bajo la responsabilidad de un miembro de CEN en su idioma nacional, y notificada a la Secretaría Central, tiene el mismo rango que aquéllas.

Los miembros de CEN son los organismos nacionales de normalización de los países siguientes: Alemania, Austria, Bélgica, Dinamarca, España, Finlandia, Francia, Grecia, Irlanda, Islandia, Italia, Luxemburgo, Noruega, Países Bajos, Portugal, Reino Unido, Suecia y Suiza.

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European Committee for Standardization
Comité Européen de Normalisation
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SECRETARÍA CENTRAL: Rue de Stassart, 36 B-1050 Bruxelles

ANTECEDENTES

El texto de la Norma Internacional del Comité Técnico ISO/TC 61, *Plásticos* de la Organización Internacional de Normalización (ISO), ha sido adoptado como Norma Europea por el Comité Técnico CEN/TC 249, *Plásticos*, cuya Secretaría desempeña IBN.

Esta Norma Europea deberá tener el rango de norma nacional, bien por publicación de un texto idéntico, bien por ratificación, lo más tarde en agosto de 1996, y las normas nacionales técnicamente divergentes con esta, deberán ser anuladas igualmente lo más tarde en agosto de 1996.

De acuerdo con el Reglamento Interior de CEN/CENELEC, están obligados a adoptar esta Norma Europea los siguientes países: Alemania, Austria, Bélgica, Dinamarca, España, Finlandia, Francia, Grecia, Irlanda, Islandia, Italia, Luxemburgo, Noruega, Países Bajos, Portugal, Reino Unido, Suecia y Suiza.

DECLARACIÓN

El texto de la Norma Internacional ISO 527-1:1993 ha sido aprobado por CEN como Norma Europea sin ninguna modificación.

1 OBJETO Y CAMPO DE APLICACIÓN

1.1 Esta parte de la Norma ISO 527 establece principios generales para la determinación de las propiedades en tracción de los plásticos y materiales compuestos de plástico en condiciones definidas.

Se definen diversos tipos de probetas, en función de los diferentes tipos de materiales que se enumeran en las partes siguientes de la Norma ISO 527.

1.2 Los métodos se utilizan para estudiar el comportamiento en tracción de las probetas y para la determinación de la resistencia a la tracción, del módulo en tracción y de otros aspectos de las relaciones esfuerzo/deformación en tracción en condiciones definidas.

1.3 Los métodos se han de seleccionar convenientemente para su uso, teniendo en cuenta el siguiente rango de materiales:

- Materiales termoplásticos rígidos y semirígidos para moldeo y extrusión, incluidas las composiciones cargadas y reforzadas, además de los tipos no cargados; hojas y películas de termoplásticos rígidos y semirígidos;
- Materiales termoendurecibles rígidos y semirígidos para moldeo, incluidas las composiciones cargadas y reforzadas; hojas termoendurecibles rígidas y semirígidas, incluidos los estratificados;
- Materiales compuestos termoplásticos y termoendurecibles reforzados con fibras, que llevan refuerzos unidireccionales y multidireccionales, tales como fieltros, tejidos, tejidos bobinados, hilos de base cortados, combinación de refuerzos e híbridos, bobinados y fibras molidas; hojas fabricadas a partir de materiales preimpregnados ("prepregs");
- Polímeros de cristales líquidos termótropos.

Los métodos que se describen en esta norma no son, normalmente, recomendables para ser usados con materiales celulares rígidos o con estructuras tipo sandwich que contengan materiales celulares.

1.4 Los métodos están adaptados a la utilización de probetas que se moldean con las dimensiones elegidas, o que se mecanizan, se cortan o troquelan a partir de productos elaborados o semielaborados, tales como piezas moldeadas, estratificados, películas y hojas extruidas o coladas. En ciertos casos, se puede utilizar una probeta para usos múltiples (véase Norma ISO 3167:1993, *Plásticos. Probetas para usos múltiples*).

1.5 Los métodos especifican las dimensiones recomendadas para las probetas. Ensayos realizados con probetas de dimensiones diferentes o con probetas preparadas en condiciones diferentes, pueden dar resultados que no sean comparables. Igualmente, en los resultados pueden influir otros factores, tales como la velocidad de ensayo y el acondicionamiento de las probetas. En consecuencia, cuando se necesitan resultados comparativos, estos factores se deben controlar y registrar cuidadosamente.

2 NORMAS PARA CONSULTA

La(s) norma(s) que a continuación se relaciona(n) contiene(n) disposiciones válidas para esta Norma Internacional. En el momento de la publicación la(s) edición(es) indicada(s) estaba(n) en vigor. Toda norma está sujeta a revisión por lo que las partes que basen sus acuerdos en esta Norma Internacional deben estudiar la posibilidad de aplicar la edición más reciente de la(s) norma(s) indicada(s) a continuación. Los miembros de CEI e ISO poseen el registro de Normas Internacionales en vigor en cada momento.

ISO 291:1977 – *Plásticos. Atmósferas normales para acondicionamiento y ensayos.*

ISO 2602:1980 – *Interpretación estadística de los resultados de ensayo. Estimación de la media. Intervalo de confianza.*

ISO 5893:1985 – *Aparatos de ensayo de caucho y plásticos. Tipos para tracción, flexión y compresión (velocidad de desplazamiento constante). Descripción.*

3 PRINCIPIO DEL MÉTODO

La probeta se alarga a lo largo de su eje principal, a velocidad constante, hasta rotura o hasta que el esfuerzo (carga) o la deformación (alargamiento) hayan alcanzado un valor determinado previamente. En el ensayo se miden la carga soportada por la probeta y el alargamiento de ésta.

4 DEFINICIONES

Para las necesidades de la Norma ISO 527, se aplican las definiciones siguientes.

4.1 longitud de referencia, L_o: Distancia inicial entre las marcas en la parte central de la probeta; véanse figuras de las probetas en la parte correspondiente de la Norma ISO 527.

Dicha distancia se expresa en milímetros (mm).

4.2 velocidad de ensayo, v: Velocidad de separación de las mordazas de la máquina de ensayo, durante el ensayo.

Se expresa en milímetros por minuto (mm/min).

4.3 esfuerzo en tracción, σ: Fuerza de tracción por unidad de superficie de la sección transversal inicial de la longitud de referencia, soportada por la probeta en cada instante del ensayo.

Se expresa en megapascales (MPa) [véase 10.1, ecuación (3)].

4.3.1 esfuerzo en el punto de fluencia; esfuerzo de fluencia, σ_y: Primer esfuerzo para el cual tiene lugar un aumento de la deformación sin aumentar el esfuerzo.

Se expresa en megapascales (MPa).

Puede ser inferior al valor máximo del esfuerzo alcanzado (véase figura 1, curvas b y c).

4.3.2 resistencia a la tracción en el punto de rotura, σ_B: Esfuerzo en tracción soportado en el momento de la rotura de la probeta (véase figura 1).

Se expresa en megapascales (MPa).

4.3.3 resistencia a la tracción, σ_M: Esfuerzo máximo en tracción soportado por la probeta durante el ensayo de tracción (véase figura 1).

Se expresa en megapascales (MPa).

4.3.4 esfuerzo de tracción a ***x*** **% de deformación** (véase 4.4), σ_x: Esfuerzo para el que la deformación alcanza el valor especificado x expresado en porcentaje.

Se expresa en megapascales (MPa).

Se puede medir, por ejemplo, si la curva esfuerzo/deformación no presenta punto de fluencia (véase figura 1, curva d). En este caso, el valor de x debe ser el indicado por la norma de producto correspondiente o el acordado por las partes interesadas. Sin embargo, el valor de x debe ser, en todos los casos, inferior a la deformación correspondiente a la resistencia a la tracción.

4.4 deformación, ε: Incremento de la longitud por unidad de longitud inicial de la longitud de referencia.

Se expresa como una relación sin dimensiones, o en porcentaje (%) [véase 10.2, ecuaciones (4) y (5)].

Se utiliza para deformaciones hasta el punto de fluencia (véase 4.3.1); para deformaciones más allá del punto de fluencia, véase 4.5.

4.4.1 deformación por tracción en el punto de fluencia, ε_y: Deformación por tracción que corresponde al esfuerzo de fluencia (véanse 4.3.1 y figura 1, curvas b y c).

Se expresa como una relación sin dimensiones, o como porcentaje (%).

4.4.2 deformación en el punto de rotura por tracción, ε_B: Deformación por tracción que corresponde al valor del esfuerzo de tracción en el punto de rotura (véase 4.3.2), cuando hay rotura sin alcanzar el punto de fluencia (véase figura 1, curvas a y d).

Se expresa como una relación sin dimensiones o como porcentaje (%).

Para la rotura después del punto de fluencia, véase 4.5.1.

4.4.3 deformación en la resistencia a la tracción, ε_M: Deformación por tracción que corresponde al valor de la resistencia a la tracción (véase 4.3.3) si esto se produce sin alcanzar el punto de fluencia o en el punto de fluencia (véase figura 1, curvas a y d).

Se expresa como una relación sin dimensiones, o como porcentaje (%).

Para valores de esfuerzo superiores al esfuerzo en el punto de fluencia, véase 4.5.2.

4.5 deformación nominal en tracción, ε_t: Incremento de la longitud inicial, por unidad de longitud, de la distancia entre las mordazas (separación de las mordazas).

Se expresa como una relación sin dimensiones o como porcentaje (%) [véase 10.2, ecuaciones (6) y (7)].

Se utiliza para deformaciones más allá del punto de fluencia (véase 4.3.1). Para deformaciones hasta el punto de fluencia, véase 4.4. Representa el alargamiento relativo total que se produce en la longitud libre de la probeta.

4.5.1 deformación nominal en el punto de rotura por tracción, ε_{tB}: Deformación nominal por tracción que corresponde al esfuerzo de tracción en el punto de rotura (véase 4.3.2), cuando la rotura de la probeta se produce después del punto de fluencia (véase figura 1, curvas b y c).

Se expresa como una relación sin dimensiones, o como porcentaje (%).

Para la rotura sin alcanzar el punto de fluencia, véase 4.2.2.

4.5.2 deformación nominal en la resistencia a la tracción, ε_{tM}: Deformación nominal por tracción que corresponde a la resistencia a la tracción (véase 4.3.3), si esto se produce después del punto de fluencia (véase figura 1, curva b).

Se expresa como una relación sin dimensiones, o como porcentaje (%).

Para valores de resistencia sin alcanzar, o en, el punto de fluencia, véase 4.4.3.

4.6 módulo de elasticidad en tracción; E_t: Relación entre la diferencia de esfuerzos, σ_2 menos σ_1, y la diferencia de los valores de deformación correspondientes, ε_2 = 0,002 5 menos ε_1 = 0,000 5 [véanse figura 1, curva d, y 10.3, ecuación (8)].

Se expresa en megapascales (MPa).

Esta definición no se aplica ni a películas ni a cauchos.

NOTA 1 – Con un equipo asistido por ordenador, la determinación del módulo E_r utilizando dos puntos de esfuerzo/deformación distintos, se puede sustituir por un método de regresión lineal aplicada a la parte de la curva situada entre estos puntos mencionados.

4.7 coeficiente de Poisson, μ: Relación negativa de la deformación ε_n según uno de los dos ejes perpendiculares a la dirección del esfuerzo, en la parte lineal de la curva de deformación longitudinal.

Se expresa como una relación sin dimensiones.

El coeficiente de Poisson se indica con la designación μ_b (dirección de la anchura) o μ_h(dirección del espesor) de acuerdo con el eje correspondiente. El coeficiente de Poisson se utiliza, preferentemente, para materiales reforzados con fibras largas.

5 APARATOS

5.1 Máquina de ensayo

5.1.1 Generalidades. La máquina debe estar conforme con la Norma ISO 5893 y responder a las especificaciones de 5.1.2 a 5.1.5, como sigue.

5.1.2 Velocidad de ensayo. La máquina de ensayo de tracción debe ser capaz de mantener las velocidades de ensayo (véase 4.2) como se especifica en la tabla 1.

Tabla 1
Valores recomendados para las velocidades de ensayo

Velocidad mm/min	Tolerancia %
1	± 20[1]
2	± 20[1]
5	± 20
10	± 20
20	± 10
50	± 10
100	± 10
200	± 10
500	± 10

1) Estas tolerancias son más bajas que las indicadas en la ISO 5893.

5.1.3 Mordazas. Las mordazas que sujetan las probetas deben fijarse en la máquina de manera que el eje principal de la probeta coincida con la dirección de la línea central de tracción del conjunto del sistema de sujeción. Esto se puede lograr, por ejemplo, utilizando pernos de centrado en las mordazas. La probeta debe mantenerse de manera que se evite, tanto como sea posible, su deslizamiento con respecto a las mordazas. Esto se debe lograr, preferentemente, con el tipo de mordazas en que la presión sobre la probeta aumenta cuando aumenta la fuerza aplicada a la probeta. El sistema de sujeción no debe ocasionar la rotura prematura de la probeta en las mordazas.

5.1.4 Indicador de fuerza. El indicador de fuerza debe poseer un mecanismo capaz de indicar la fuerza de tracción total soportada por la probeta cuando está sujeta por las mordazas. Particularmente, este mecanismo debe estar exento de cualquier efecto debido a la inercia a la velocidad de ensayo especificada, y debe indicar la fuerza con una exactitud de, por lo menos, el 1% del valor medido. Se debe tener en cuenta la Norma ISO 5893.

5.1.5 Extensómetro. El extensómetro debe estar conforme con la Norma ISO 5893. Debe ser capaz de determinar la variación relativa de la longitud de referencia de la probeta en cada instante del ensayo. Es deseable, pero no esencial, que este instrumento pueda registrar automáticamente esta variación. Particularmente, el instrumento debe estar exento de retardo debido a la inercia a la velocidad de ensayo especificada y debe ser capaz de medir la variación de la longitud de referencia, con una exactitud del 1%, o superior, del valor medido. Esto corresponde a ± 1 µm para la medición del módulo, sobre la base de una longitud de referencia de 50 mm.

Cuando se fija el extensómetro a la probeta, se debe evitar al máximo cualquier alteración o daño causados a la probeta. Es esencial que no se produzca ningún deslizamiento entre el extensómetro y la probeta.

Las probetas pueden también estar instrumentadas con galgas extensiométricas de deformación longitudinal cuya exactitud debe ser, por lo menos, el 1% para el valor medido. Esto corresponde a una exactitud para la deformación de 20×10^{6} (20 microdeformaciones) para la medición del módulo. Las galgas extensiométricas, la superficie de preparación y los adhesivos se deberían elegir de manera que se logre un comportamiento adecuado del material sometido al ensayo.

5.2 Dispositivos para la medición de la anchura y del espesor de las probetas

5.2.1 Materiales rígidos. Se debe utilizar un micrómetro, o su equivalente, que permita una lectura de 0,02 mm o menor, y provisto de medios capaces de medir el espesor y la anchura de las probetas. Los palpadores deben tener dimensiones y formas adaptadas a las probetas que se han de medir, y no deben ejercer sobre la probeta una fuerza que pueda variar las dimensiones que se han de medir.

5.2.2 Materiales flexibles. Se debe utilizar un comparador de esfera que permita una lectura de 0,02 mm o menor, y que esté provisto de un palpador plano circular que aplique una presión de 20 kPa ± 3 kPa para la medición del espesor.

6 PROBETAS

6.1 Forma y dimensiones

Véase la parte correspondiente de la Norma ISO 527.

6.2 Preparación de las probetas

Véase la parte correspondiente de la Norma ISO 527.

6.3 Señales

Cuando se utilizan extensómetros ópticos, especialmente para hojas delgadas y películas, es necesario fijar las marcas sobre la probeta, con objeto de definir la longitud de referencia. Estas marcas deben estar aproximadamente equidistantes del centro, y la distancia entre ellas se debe medir con una exactitud de, por lo menos, el 1%.

Las marcas se deben señalar, estampar o imprimir sobre la probeta de manera que no se dañe al material sometido al ensayo. Se debe comprobar que el medio empleado para marcar no provoca detrimento alguno en el material a ensayar, y en el caso de líneas paralelas, éstas deben ser tan estrechas como sea posible.

6.4 Control de las probetas

Las probetas deben estar exentas de torsión y deben tener superficies paralelas recíprocamente perpendiculares. Las superficies y los bordes deben estar exentos de rayas, oquedades, rechupados y rebabas. Las probetas se deben controlar en cuanto al cumplimiento de estos requisitos, mediante observación visual de la rectitud de los bordes, de la perpendicularidad y de la lisura y por la medida con calibres micrométricos. Las probetas que presenten cualquier falta, observable o medible, de uno o varios de estos requisitos, se deben eliminar o mecanizar a las dimensiones y a la forma correctas antes del ensayo.

6.5 Anisotropía

Véase la parte correspondiente de la Norma ISO 527.

7 NÚMERO DE PROBETAS

7.1 Debe someterse al ensayo un número mínimo de cinco probetas, para cada una de las direcciones requeridas, así como para las propiedades consideradas (módulo de elasticidad, resistencia a la tracción, etc.). El número de mediciones puede ser superior a cinco si se requiere una precisión mayor sobre el valor medio. Es posible evaluar esto por medio del intervalo de confianza (probabilidad a 95%, véase Norma ISO 2602).

7.2 Las probetas en forma de haltera que no se rompan en la zona de caras paralelas se deben eliminar y se deben ensayar probetas suplementarias.

7.3 En el análisis, no se deben incluir los resultados de los ensayos de las probetas de caras paralelas y para las cuales se produce deslizamiento en las mordazas o rotura a 10 mm en su interior, ni tampoco los resultados de ensayos de probetas que presenten un defecto apreciable y fallen prematuramente. Se deberán realizar ensayos repetidos con nuevas probetas.

Por cualquier otra razón, los resultados, incluso dispersos, no se deben excluir del análisis, ya que esta dispersión puede ser función de la naturaleza del material sometido al ensayo.

NOTA 2 – Cuando la mayoría de los fallos se producen fuera de los criterios de fallos aceptables, los resultados de los ensayos se pueden analizar estadísticamente, si bien conviene admitir que hay que ser cauteloso con el resultado final. En este caso, es preferible repetir los ensayos con las probetas en forma de haltera, con objeto de reducir las posibilidades de resultados inaceptables.

8 ACONDICIONAMIENTO

La probeta se debe acondicionar según se especifica en la norma del material correspondiente. Cuando no se dispone de esta información, se debe elegir la condición más apropiada de la Norma ISO 291, salvo indicación contraria acordada entre las partes interesadas.

9 PROCEDIMIENTO OPERATORIO

9.1 Atmósfera de ensayo

Se efectúa el ensayo en la misma atmósfera que la utilizada para el acondicionamiento, salvo indicación contraria acordada por las partes interesadas, por ejemplo, para ensayos a alta o baja temperatura.

9.2 Dimensiones de las probetas

Se miden la anchura *b*, con una aproximación de 0,1 mm, y el espesor *h*, con una aproximación de 0,02 mm, en el centro de cada probeta y a 5 mm por debajo de cada extremidad de la longitud de referencia.

Se registran los valores mínimos y máximos para la anchura y el espesor de cada probeta, y se asegura que caen dentro de las tolerancias indicadas por la norma del material correspondiente.

Se calculan las medias aritméticas para la anchura y el espesor de cada probeta, que se deben utilizar en los cálculos.

NOTAS

3 En el caso de probetas moldeadas por inyección, no es necesario medir las dimensiones de cada probeta. Basta con medir una probeta de un lote para asegurarse de que las dimensiones corresponden al tipo de probeta elegido (véase la parte correspondiente de la Norma ISO 527). En el caso de moldes de cavidades múltiples, conviene asegurarse de que las dimensiones de las probetas son las mismas para cada cavidad.

4 En el caso de probetas troqueladas a partir de materiales en forma de hoja o de película, se permite admitir que la anchura media de la parte central paralela del material es equivalente a la anchura de la probeta. La adopción de tal procedimiento debería basarse en medidas comparativas, efectuadas periódicamente.

9.3 Fijación

Se coloca la probeta en las mordazas, teniendo cuidado de alinear el eje longitudinal de la probeta con el eje de la máquina de ensayo. Para obtener una alineación correcta, si se utilizan pernos de centrado en las mordazas, sólo es necesario atirantar ligeramente la probeta antes de apretar las mordazas (véase 9.4). Se aprietan las mordazas uniforme y firmemente, para evitar el menor deslizamiento de la probeta.

9.4 Preesfuerzos

La probeta no se debe someter a grandes esfuerzos antes del ensayo. Tales esfuerzos previos se generan durante el centrado de una probeta en forma de película, o son provocados por la presión de apriete de las mordazas, particularmente con los materiales poco rígidos.

El esfuerzo residual, σ_0, que permanece al comienzo del rango no debe ser superior, en la medida del módulo, a los valores siguientes:

$$| \sigma_0 | \leq 5 \times 10^{-4} E_t \qquad \ldots (1)$$

que corresponde a una predeformación de $\varepsilon_0 \leq 0{,}05\%$, y para la medición de los esfuerzos σ correspondientes, por ejemplo, $\sigma = \sigma_y, \sigma_M$ o σ_B:

$$\sigma_0 \leq 10^{-2} \sigma \qquad \ldots (2)$$

9.5 Regulación de los extensómetros

Después de la compensación de los preesfuerzos, se monta y regula un extensómetro calibrado, sobre la longitud de referencia de la probeta, o se utilizan galgas extensiométricas de esfuerzos longitudinales, de acuerdo con 5.1.5. Se mide la distancia inicial (longitud de referencia) si es necesario. Para la medición del coeficiente de Poisson, se deben aplicar dos dispositivos de medida simultáneos para las direcciones longitudinal y perpendicular.

Para mediciones ópticas del alargamiento, se sitúan marcas sobre la probeta, de acuerdo con 6.3.

La medición del alargamiento de la longitud libre de la probeta, a partir del movimiento de las mordazas, se utiliza para la determinación del valor de la deformación nominal en tracción ε_t (véase 4.5).

9.6 Velocidad de ensayo

Se regula la velocidad de ensayo conforme a la norma del material correspondiente. Cuando no se dispone de esta información, la velocidad se debería acordar entre las partes interesadas, de acuerdo con 5.1.2, tabla 1.

Puede ser necesario o deseable adoptar diferentes velocidades para la determinación del módulo de elasticidad, de las propiedades esfuerzo/deformación hasta el punto de fluencia y para la medición de la resistencia a la tracción y del alargamiento máximo. Para cada velocidad de ensayo, se deben utilizar probetas diferentes.

Para la medición del módulo de elasticidad, la velocidad de ensayo elegida debe dar lugar a una velocidad de deformación lo más próxima posible al 1% de la longitud de referencia por minuto. Las velocidades de ensayo que resultan para los diferentes tipos de probetas se dan en las partes correspondientes de la Norma ISO 527.

9.7 Registro de los resultados

Se registran la fuerza y los valores correspondientes del incremento de la longitud de referencia y de la distancia entre las mordazas durante el ensayo. Es preferible utilizar un sistema de registro automático que dé lugar a curvas de esfuerzo/deformación completas para esta operación [véase capítulo 10, ecuaciones (3), (4) y (5)].

Se determinan todos los esfuerzos y deformaciones necesarios y definidos en el capítulo 4, a partir de la curva de esfuerzo/deformación (véase figura 1) o con ayuda de otros medios convenientes.

Para los fallos no conformes con el criterio de fallo aceptable, véanse 7.2 y 7.3.

10 CÁLCULO Y EXPRESIÓN DE LOS RESULTADOS

10.1 Cálculo de esfuerzos

Se calculan todos los valores de esfuerzos definidos en 4.3, sobre la base del área de la sección transversal inicial de la probeta:

$$\sigma = \frac{F}{A} \qquad \ldots (3)$$

donde

σ es el valor del esfuerzo en tracción correspondiente, expresado en megapascales;

F es la fuerza medida correspondiente, en newton;

A es el área de la sección transversal inicial de la probeta, en milímetros cuadrados.

10.2 Cálculo de las deformaciones

Se calculan todos los valores de deformaciones definidas en 4.4, sobre la base de la longitud de referencia de la probeta:

$$\varepsilon = \frac{\Delta L_0}{L_0} \quad \text{... (4)}$$

$$\varepsilon\ (\%) = 100 \times \frac{\Delta L_0}{L_0} \quad \text{... (5)}$$

donde

ε es el valor de deformación correspondiente, expresado como una relación sin dimensiones, o en porcentaje;

L_0 es la longitud de referencia de la probeta, en milímetros;

ΔL_0 es el incremento de la longitud de la probeta entre las marcas de referencia, en milímetros.

Los valores de la deformación nominal en tracción, definidos en 4.5, se deben calcular sobre la base de la distancia inicial entre mordazas:

$$\varepsilon_t = \frac{\Delta L}{L} \quad \text{... (6)}$$

$$\varepsilon_t\ (\%) = 100 \times \frac{\Delta L}{L} \quad \text{... (7)}$$

donde

ε_t es la deformación nominal en tracción, expresada como una relación sin dimensiones, o en porcentaje;

L es la distancia inicial entre mordazas, en milímetros;

ΔL es el incremento de la distancia entre mordazas, en milímetros.

10.3 Cálculo del módulo

Se calcula el módulo de elasticidad en tracción definido en 4.6, sobre la base de dos valores de deformación especificados:

$$E_t = \frac{\sigma_2 - \sigma_1}{\varepsilon_2 - \varepsilon_1} \quad \text{...(8)}$$

donde

E_t es el módulo de elasticidad en tracción, expresado en megapascales;

σ_1 es el esfuerzo, en megapascales, medido al valor de deformación $\varepsilon_1 = 0{,}000\,5$;

σ_2 es el esfuerzo, en megapascales, medido al valor de deformación $\varepsilon_2 = 0{,}002\,5$.

Para el equipo informático de apoyo, véase 4.6, nota 1.

10.4 Coeficiente de Poisson

Se calcula, si se requiere, el coeficiente de Poisson definido en 4.7, sobre la base de dos valores de deformación correspondientes y perpendiculares entre sí:

$$\mu_n = - \frac{\varepsilon_n}{\varepsilon} \qquad \ldots(9)$$

donde

μ_n es el coeficiente de Poisson, expresado como una relación sin dimensiones, con $n = b$ (anchura) o h (espesor) indicando la dirección normal elegida;

ε es la deformación en la dirección longitudinal;

ε_n es la deformación en la dirección normal, con $n = b$ (anchura) o h (espesor).

10.5 Parámetros estadísticos

Se calculan las medias aritméticas de los resultados de ensayo y, si se requiere, las desviaciones típicas y los intervalos de confianza al 95% de los valores medios, según el procedimiento operatorio dado en la Norma ISO 2602.

10.6 Cifras significativas

Se calculan los esfuerzos y los módulos con tres cifras significativas. Se calculan las deformaciones y el coeficiente de Poisson con dos cifras significativas.

11 PRECISIÓN

Véase la parte correspondiente de la Norma ISO 527.

12 INFORME DEL ENSAYO

El informe del ensayo debe contener la información siguiente:

a) referencia a la parte correspondiente de la Norma ISO 527;

b) todas las informaciones necesarias para la identificación del material sometido al ensayo, incluidos el tipo, su origen, su referencia comercial, sus antecedentes, siempre que sean conocidos;

c) descripción de la naturaleza y de la forma del material, si se trata de un producto, de un producto semielaborado, de una plancha o de una probeta. Deberían incluirse las dimensiones principales, la forma, el método de fabricación, la distribución de capas y los tratamientos preliminares;

d) tipo de probeta, la anchura y el espesor de la sección paralela; la media, los valores mínimos y máximos;

e) método de preparación de la probeta y los detalles del método de fabricación utilizado;

f) si el material está en forma de producto o de producto semielaborado, la orientación de la probeta, respecto al producto o al producto semielaborado del que se ha tomado;

g) número de probetas ensayadas;

h) atmósfera normal para el acondicionamiento y el ensayo, o cualquier tratamiento especial de acondicionamiento particular, si se requiere en la norma del material o del producto correspondiente;

i) grado de exactitud de la máquina de ensayo (véase Norma ISO 5893);

j) tipo de indicador de alargamiento o de deformación;

k) tipo de dispositivo de sujeción y la presión de la sujeción, siempre que sean conocidos;

l) velocidad del ensayo;

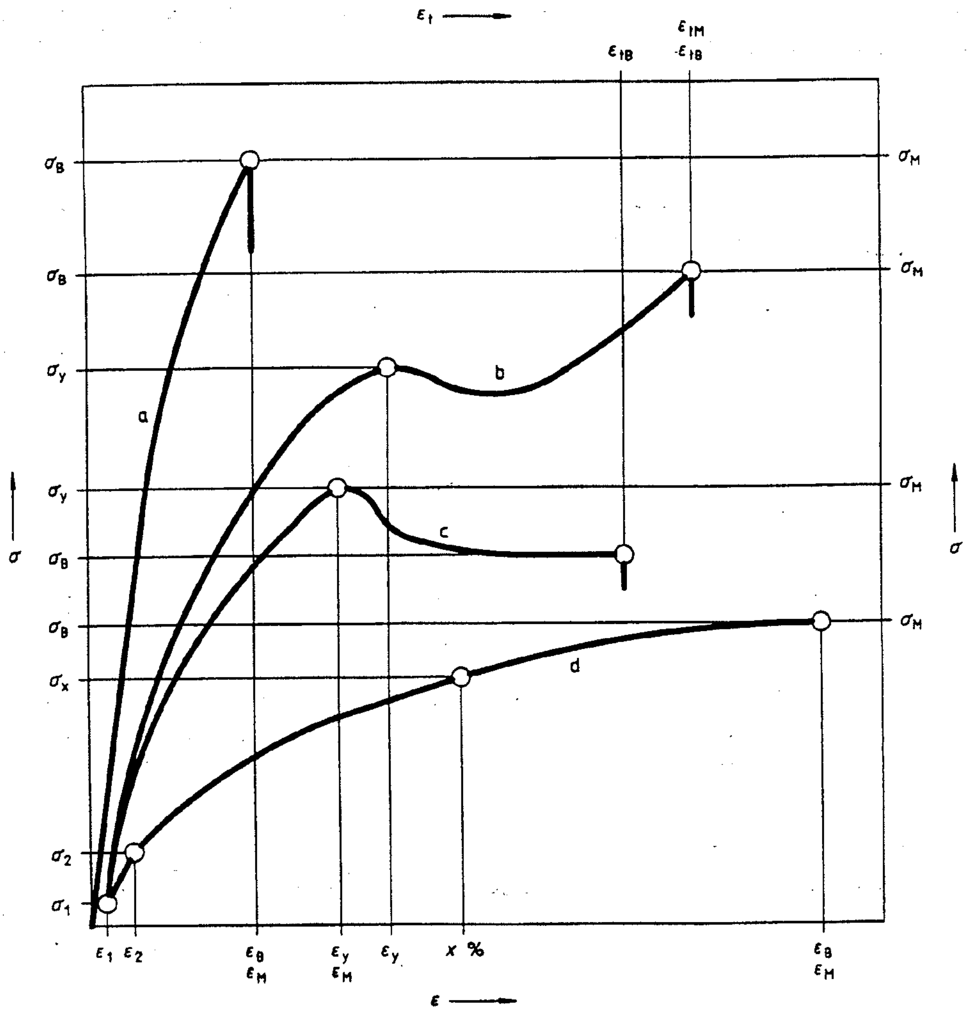
m) resultados de ensayo individuales;

n) valor(es) medio(s) de la(s) propiedad(es) medida(s), citado(s) como valor(es) indicativo(s) para el material sometido al ensayo;

o) desviación típica y/o coeficiente de variación y/o límites de confianza de la media, si esto es requerido;

p) si se han eliminado probetas y se han sustituido, y si es así, las razones de ello;

q) la fecha de la medición.



Curva a	Materiales frágiles;
Curvas b y c	Materiales dúctiles con punto de fluencia;
Curva d	Materiales dúctiles sin punto de fluencia;

Los puntos para el cálculo de los módulos en tracción E_t según 10.3 están indicados por (σ_1, ε_1) y (σ_2, ε_2), indicados solamente sobre la curva d (ε_1= 0,000 5; ε_2= 0,002 5).

Fig. 1 – Curvas típicas de esfuerzo/deformación

ANEXO A (Informativo)

MÓDULO DE ELASTICIDAD EN TRACCIÓN Y VALORES ASOCIADOS

Como consecuencia del comportamiento viscoelástico de los polímeros, muchas de sus propiedades no sólo dependen de la temperatura sino también del tiempo. En el ensayo de tracción, esto se traduce en curvas de esfuerzo/deformación no lineales (curvadas hacia el eje de la deformación), incluso en el caso de la viscoelasticidad lineal. Este efecto es pronunciado en el caso de los polímeros resilientes. Así, el método convencional (tangente en el punto inicial de la curva esfuerzo/deformación) no da el valor fiable del módulo para estos materiales.

El método para la medición del módulo de elasticidad en tracción descrito en esta parte de la Norma ISO 527 se basa en dos valores de deformación especificados, es decir, el 0,25% y el 0,05%. (El valor más pequeño de la deformación no se ha llevado a cero, para evitar los posibles errores al principio de la curva esfuerzo/deformación).

Para los polímeros frágiles, el nuevo método y el método convencional dan los mismos valores para el módulo. El método nuevo, sin embargo, permite medidas exactas y reproducibles del módulo de los plásticos resilientes. No obstante, la definición del módulo tangente inicial se ha suprimido en esta parte de la Norma ISO 527.

Las consideraciones expuestas más arriba para el módulo son válidas igualmente para el punto de fluencia convencional que, en la ISO/R 527, estaba definida por la desviación de la curva esfuerzo/deformación a partir de la parte lineal. El punto de fluencia convencional se sustituye, por tanto, por un punto que corresponde a una deformación especificada (esfuerzo a x% de deformación, σ_x, véase 4.3.4). Puesto que la definición de este nuevo punto de fluencia no es significativa más que para materiales resilientes, la deformación especificada se debe elegir próxima al punto de fluencia habitual.

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