DESIGN OPTIMIZATION OF THE STEP/SCARF REPAIR OF AN AERONAUTICAL PANEL TARGETING THE MAXIMUM COMPRESSIVE STRENGTH AND THE MINIMIZATION OF MATERIAL REMOVAL

S. Psarras[1], M. P. Giannoutsou[1] and V. Kostopoulos[1]

[1] Applied Mechanics Laboratory, Department of Mechanical Engineering and Aeronautics, University of Patras, Patras University Campus, GR-26504 Rio-Patras, Greece

Email: spsarras@upatras.gr , web page: http://www.aml.mech.upatras.gr/en/home/

Keywords : Repair patch, optimization, elliptical geometry, parametric study, algorithm

ABSTRACT

The design and evaluation of different elliptical composite repair patches, for the purpose of forming an optimum patch design, is a complex and time-consuming process [1-4]. Geometry and effectiveness of a repair patch depend on various parameters, such as length of step, dimensions of major and minor semi-axes of each ply's ellipse, as well as on each ply's ellipse's eccentricity. The optimum values of the previously mentioned parameters are strongly related to layup and loading conditions. Consequently, examination of many different patch geometries is crucial, in order to find an optimum patch which will meet the needs and demands of strength and geometric restrictions of a mechanical problem.

In terms of this complexity of stepped composite patches, and due to the need for reducing the required time for the repair by optimizing the repair's shape, an effort was made to develop a uniform and more automated parametric process of elliptical patch geometry design via finite element models and evaluation and comparison of the obtained results with experiments [5].

For this reason, an optimization algorithm in Python was developed in Abaqus PDE environment. It is worth mentioning that the whole algorithm is fully parametrically constructed so as to run smoothly regardless of the given parts' dimensions, materials, layups, number of plies or load direction. Suitable conditions and loops are implemented in the code in order to achieve that. Creation of the parts in Abaqus, definition of datum axes and planes, partitions of the parts, meshing, as well as definition of surfaces which participate in interactions and constraints are fully parametrically defined over the parts' dimensions. Similarly, positions of the parts in the assembly, are calculated according to the given dimensions and relative positions of the parts. Definition of material properties and composite layups are also determined using the material property variables. Also, the algorithm can create a model of repaired plate with elliptical patch whose ellipses are either relatively rotated or with parallel major axes. Moreover, the model is suitably modified in case load direction is different from 0°. The elliptical stepped hole in the plate, the patch and the orientation of each ply in plate's layup are rotated according to the load direction.

Finally, a post-processing code extracts and analyzes the results of the analyses. For each model, the ratio of strength per unit of undamaged removed material volume (r) is calculated, the max force is extracted, and strength-displacement curve is plotted. The r and strength results are saved printed and then compared. Also, deviation [%] of r ratios and max forces from the corresponding values of the optimum circular repair are calculated. Concerning the detection of the optimum patch, patches that offer a very low value of r or strength at least at one load type are rejected. Among the residual geometries, that with the maximum average r ratio (considering all load types) is picked as optimum. Overall, more than 40 different patch geometries were designed but five of those were selected as near-optimum. These five patches are shown in Figure 1.

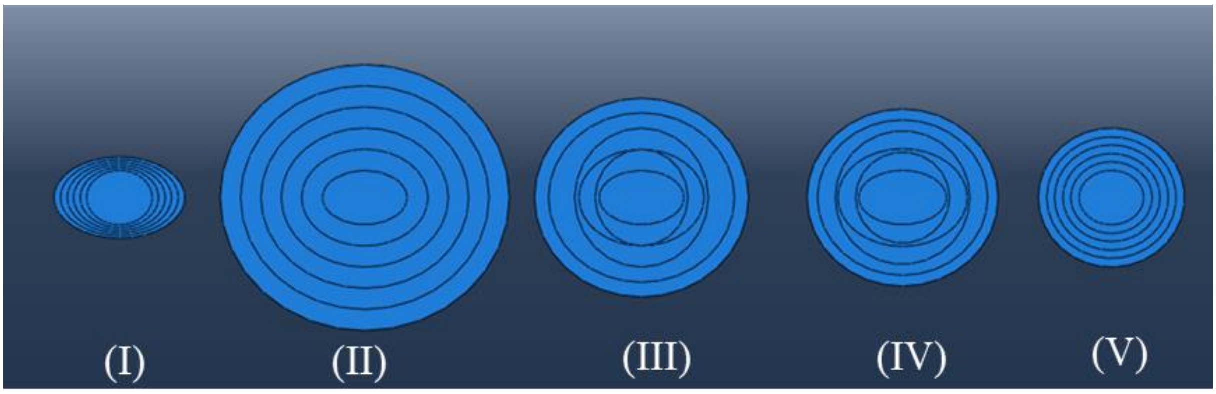

Figure 1 : Five near-optimum elliptical patches. The different geometries are numbered from (I) to (V)

The results reveal that elliptical form of repair patches can offer up to 10.5 % increase of strength and at the same time a 391.9% increase in r ratio (repair V loaded at 0°) compared to the strength that the optimum circular patch provides. Also, an interesting conclusion is the fact that the length of step plays an important role in the repair's efficiency because as repair (I) that does not have adequate step length in y direction exhibited much lower strength than the circular patch (7.4% and 56.4% lower when loaded at 45° and 90° correspondingly).

REFERENCES

[1] C. H. Wang and A. J. Gunnion, "Optimum shapes for minimising bond stress in scarf repairs," *Australian Journal of Mechanical Engineering,* vol. 6, no. 2, pp. 153-158, 2008/01/01 2008.

[2] C. Wang and A. Gunnion, "Optimum shapes of scarf repairs," *Composites Part A-applied Science and Manufacturing - COMPOS PART A-APPL SCI MANUF,* vol. 40, pp. 1407-1418, 09/01 2009.

[3] M. Ramji, R. Srilakshmi, and M. Prakash, "Towards optimization of patch shape on the performance of bonded composite repair using FEM," *Composites Part B: Engineering,* vol. 45, pp. 710–720, 02/01 2013.

[4] C. Wang and C. Duong, "Design and optimization of scarf repairs," 2016, pp. 211-239.

[5] S. Psarras, T. Loutas, G. Galanopoulos, G. Karamadoukis, G. Sotiriadis, and V. Kostopoulos, "Evaluating experimentally and numerically different scarf-repair methodologies of composite structures," *International Journal of Adhesion and Adhesives,* p. 102495, 2019/11/05/ 2019.