Extended abstract

DOI: 10.46793/41DAS2025.005P

INFLUENCE OF STRINGER GEOMETRY ON THE STRUCTURAL INTEGRITY OF CRACKED STIFFENED PLATES

Stefan-Dan PASTRAMA[1]

[1] 0000-0003-1099-702X, National University of Science and Technology POLITEHNICA, 313, Splaiul Independentei, Sector 6, 060042, Bucharest, Romania, E-mail: stefan.pastrama@upb.ro

1. Introduction

Aluminum stiffened panels are extensively used in aeronautical, automotive, marine industry, and in many other fields. They are light sheets reinforced by stringers in order to increase their strength and stiffness and are designed to cope with a variety of loading conditions. Usual stiffener cross-sections used in industry are rectangular, T-shaped, L-shaped, I-shaped, U-shaped, etc. They can be continuously attached to the plate or discretely attached by welding, bolting, riveting, bonding, etc.

Stiffeners improve the strength and stability of the structure and are also used to decrease or even stop the growth of cracks that can appear during the manufacturing process or in service. In order to avoid catastrophic failures, the knowledge of the crack size, stress field, material properties and the parameters used to assess the integrity of structures containing cracks should be known or calculated. Such parameters are the stress intensity factor (SIF), the J-integral or the crack tip opening displacement (CTOD). They can be obtained using analytical, numerical, or experimental methods.

In this paper, a part of a research involving the influence of different type of stringers on the structural integrity of thin aluminum plates is presented. Continuously attached stiffeners with rectangular, L and T-shaped cross-section are considered. Further, the results obtained using the finite element method (FEM) for a cracked plate with a rectangular stiffener are presented in two variants: with the stiffener broken and unbroken. The proposed numerical model is also validated by comparing the obtained results with those calculated using the compounding method, [1].

2. The studied structure and the finite element model

A thin aluminum plate continuously stiffened with a stringer having a rectangular cross section was first studied using FEM, for a constant remote stress σ = 100MPa. A crack symmetric with respect to the stiffener and having a length $2a$ was considered in two cases: broken stiffener and unbroken stiffener. The geometry of the cracked plate and stringers are shown in Fig. 1.

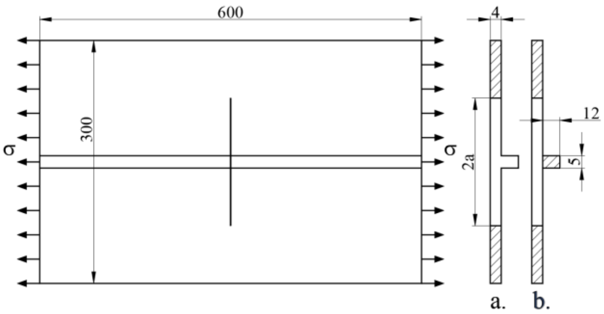

Fig. 1. The studied structure: a. Broken rectangular stiffener; b. Unbroken rectangular stiffener.

Different crack lengths were considered for the numerical analyses: $2a$ = 30, 60, 90, 120, 150, 180, and 210 mm, corresponding to the ratios $2a/W$=0.1, 0.2, …, 0.7, where W = 300mm is the plate width.

The three-dimensional numerical analyses were undertaken using the software Ansys [2]. The elastic constants of the material of the plate and stiffener were taken as: Young's modulus E = 70GPa and Poisson ratio ν = 0.33. Each model was meshed with tetrahedral elements, suitable for fracture mechanics analyses in Ansys, to obtain SIF. Depending on the crack length, the meshes contained between 82294 … 127493 nodes and 50217 … 74336 elements. A detail of the FE model for a/W = 0.2 (broken stiffener) with the map of von Mises stresses near the crack tips is shown in Fig. 2.

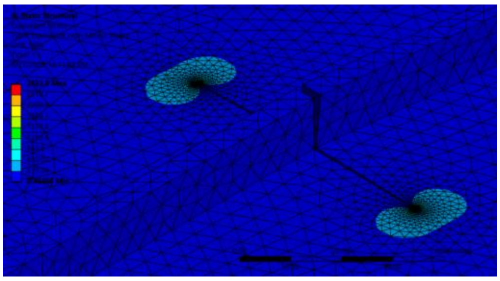

Fig. 2. Mesh in the crack tips area for 2a/W=0.2, broken stiffener

3. Results

For all studied cases, the main goal of the analyses was to obtain the stress intensity factor K_I as the fundamental parameter in linear elastic fracture mechanics, used to assess the structural integrity of a cracked structure. Results for SIF are presented in the dimensionless form $F = \frac{K_I}{\sigma\sqrt{\pi a}}$, as a function of the parameter $\lambda = \frac{2E_1 at}{AE_2}$, where E_1 and E_2 are the Young's moduli of the plate and stiffener, $A = 60$ mm^2 is the cross section area of the stiffener, and $t = 4$ mm is the thickness of the plate.

The models were validated by comparing the results with those obtained with the compounding method [1]. It is known that, even for a thin plate, SIF varies along the thickness of the plate and this variation can be emphasized if a three-dimensional analysis is performed [3]. The compounding results are obtained using equations available in the literature, and they are two-dimensional. The variation of SIF along the thickness and the value found using the compounding method for the case a/W=0.2 (λ = 4) in the case of broken and unbroken stiffener is presented in Fig. 3 as a function of the non-dimensional parameter d/t where d is the depth, measured from the stiffener side.

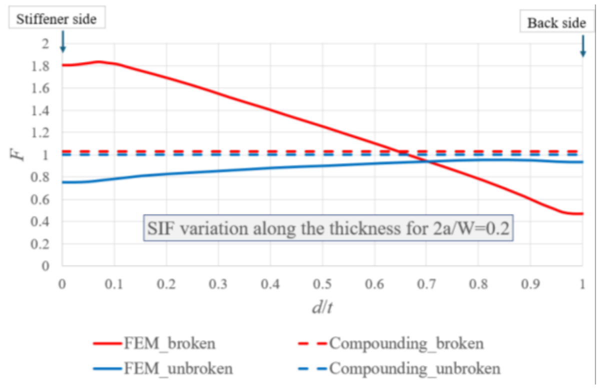

Fig. 3. SIF variation for $2a/W$=0.2.

One can notice that, in the case of a broken stiffener, the highest value of SIF occurs near the surface of the plate on the stiffener side and decreases along the thickness. The value that matches the one obtained using the compounding method occurs at a depth around 2.6 mm.

In the case of the unbroken stiffener, the variation of SIF along the thickness is opposite: the highest value occurs near the surface back to the stiffener. The compounding value underestimates the closest non-dimensional numerical SIF with about 5.2%, validating thus the numerical model. The same pattern is noticed for all studied crack lengths. A similar behavior was predicted in [2] for a cracked plate with two stiffeners.

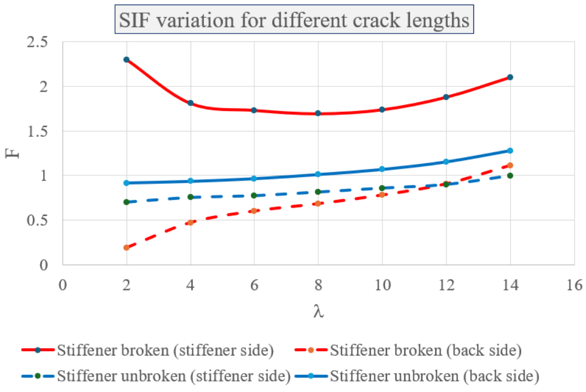

Fig. 4. Non-dimensional SIF variation for different crack lengths

Similar analyses are performed for stiffeners with L and T-shaped cross section, keeping the same area of the cross-section as for the rectangular stringer, in order to verify if the shape of the stiffener influences the values of SIF.

4. Conclusions

Extensive finite element analyses were conducted to study the structural integrity of aluminum thin stiffened plates with cracks crossing the stiffener and having different lengths. Also, different type of cross-section were considered for the stringers in order to find the influence of the stringer on the crack propagation and if the shape of the stringer influences the SIF values at the crack tips.

It can be concluded that, in the case when the stiffener is broken, the variation of SIF along the thickness is important and the results match the two-dimensional ones obtained with the compounding method close to the mid-plane of the plate, but closer to the surface opposite to the stiffener. In the case of unbroken stiffener, much smaller values of SIF are obtained. It can be emphasized also that the shape of the stiffener, keeping its cross-section area constant, is not significant.

References

[1] Cartwright, D.J. and Rooke, D.P. Approximate Stress Intensity Factors Compounded from Known Solutions, *Engng. Fracture Mech.*, 1974, 6, 563-571.

[2] Ansys® Student, Release 2025 R1, https://www.ansys.com/academic/students/ansys-student, ANSYS, Inc, 2025.

[3] Moreira, P.M.G.P., Pastrama, S.D., de Castro, P.M.S.T. Three-dimensional stress intensity factor calibration for a stiffened cracked plate, *Engng. Fracture Mech.*, 2009, 76(14), 2298-2308.