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Design and Optimisation of Thermoplastic Composite Aircraft Passenger Door

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Abstract. The papers deals with optimization of selected parts of an aircraft passenger door manufactured from high performance thermoplastic material. Work associated with the design and optimization of a novel shape, dimensioning of structural parts and developing of optimized manufacturing process for those parts is presented. The paper is focuses on horizontal beams, vertical frames and a lock system structural part. The results tend to achieve more cost and strength effective design of selected parts of the door structure. The novel design of the beam and frame significantly reduces manufacturing process time in comparison to current thermoset technology.

Introduction

Composite materials are increasingly finding use in new structures. With ever increasing demands on structures, especially in the area of its testing needed to approve a structure and obtain certification, both design and composite material applications cannot do without numerical simulations. Experimental testing of each design, or only partial changes in the design of the composite structure, is currently unrealistic, both in terms of time and money. Numerical simulations thus play an irreplaceable role in the application of composite materials. In the design of pressurised aircraft fuselage, the main role in weight reduction. The passenger door was selected for application of thermoplastic composites from point of view of its complex design integrated. The main focus is concentrated on the design of composite profiles and load transfer between door and fuselage.

Global FE model

The preliminary design of pressurised transport aircraft passenger door from composites materials was used for analysis of boundary condition and load distribution (Figure 1 left). The finite element (FE) model of passenger door was analysed in NX/Nastran FE code from point of view of displacements and reaction forces in the attachments points for defined pressurise loading [1].

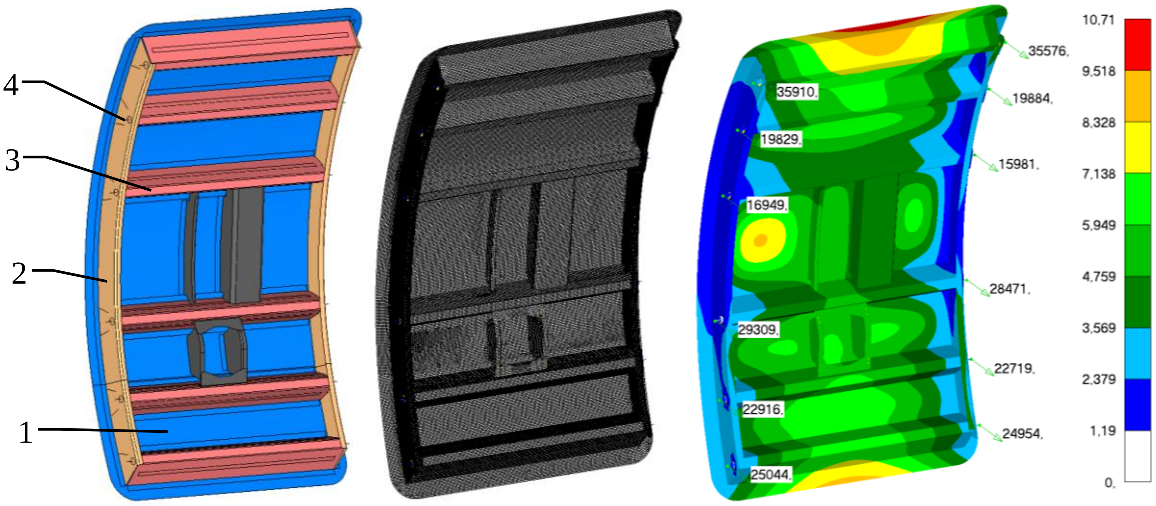

Fig. 1: CAD, FE model and analyses of preliminary design of pressurised transport aircraft passenger door from composites materials (1-skin, 2-vertical frame, 3-horizontal beam, 4-attachment points)

Local FE model

The cut-out section from global FE model was used for detail design and optimisation of connection between main parts of attachment point (skin, vertical frame, horizontal beam) [1].

The different shape o horizontal beam and metal bracket were design and numerically verified on the cut-out section of door (see Fig. 2).

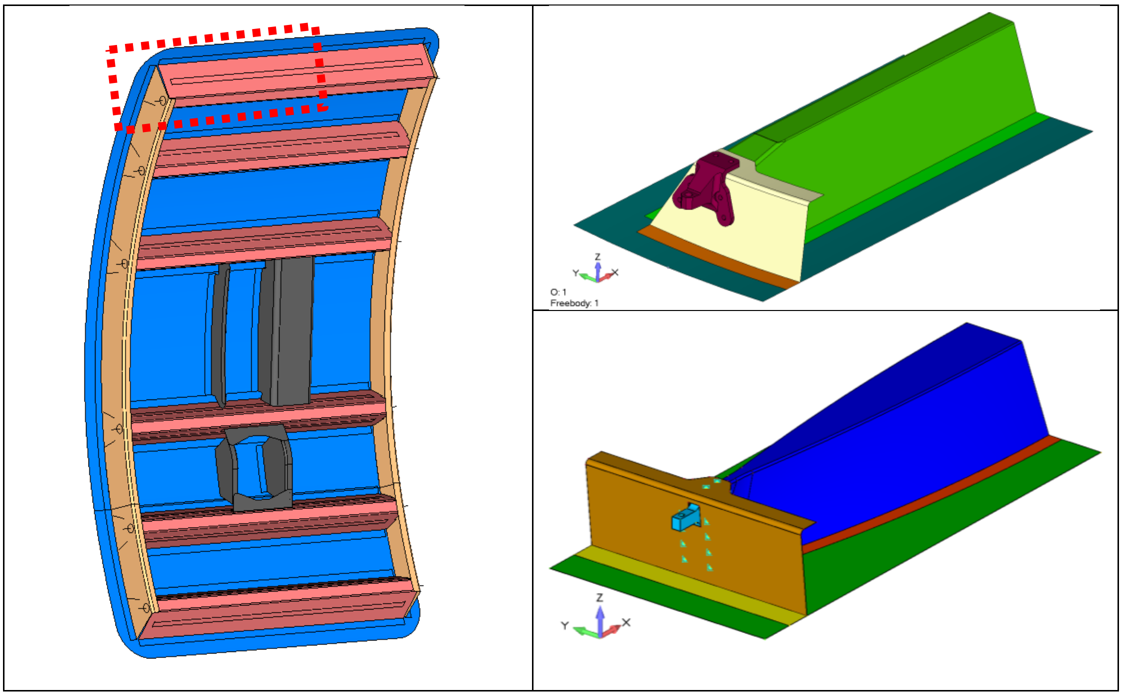

Fig. 2: Cut-out section of passenger door (left) and design proposals (left).

The optimal design was selected on the basis of these criteria:

- Displacement of skin part (requirements from point of view of aerodinamics)
- Allowable strain in composite parts
- Stess and bolt load distibution on metal fitting
- manufacturability

Optimisation

The topology optimisation was used for weight optimisation of metal fittings [2]. Optimization according to the maximum maxiumum Von Misses stress parameter Eq. (1) [5] was performed using the optimization algorithm of the TOSCA [4] code with the MSC/Nastran solver.

$$sig\_topo\_mises = \max \left| \frac{(\sigma_{vMises})^2}{\left(f(\rho_i)\sigma_y\right)^2} \cdot \sigma_y \right| \tag{1}$$

where σ_{vMises} is the von Mises stress in the center of the element, σ_y is the reference stress, $f(\rho_i)\sigma_y$ is the stress interpolation factor on elements that have a reduced density during topological optimization.

The total number of iterations of the optimization algorithm was 55. The boundary condfition for load and attachment was used from cut-out section analsyis. Figure 3 shows steps for topology weight optimisation.

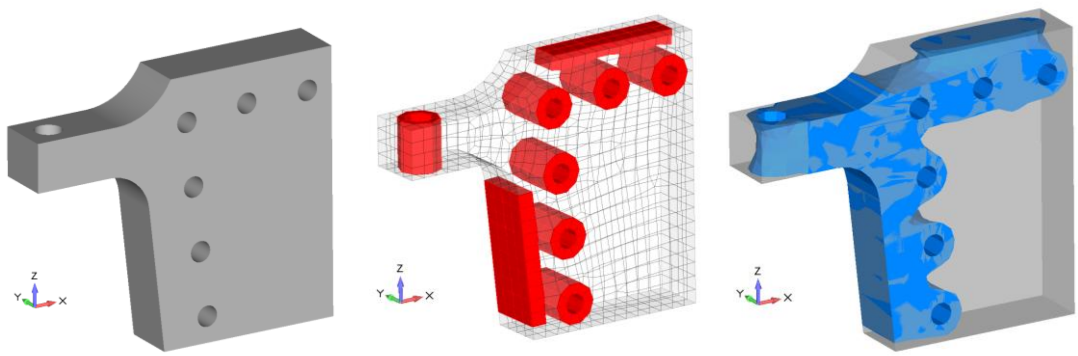

Fig. 3: Initial volume (left), restriction area (centre) and optimised design (right) of metal fitting.

The weight of metal fitting was reduced about 2.3 times for initial volume. In comparison with the previous design, the weight reduction is about 50 g. The total weight reduction for 12 fittings on the one aircraft door is about 0.6 kg.

Verification

The design of optimised metal bracket and attachment in composite horizontal beam was verified by experiments on simplified specimens (see Fig. 4) [3]. The test specimen design match boundary condition requirements of FE model of cut-out section and global FE model of the door. The aim of the test was verified optimised design of metal fitting, fasteners and lay-up of horizontal beam representing by composite plates.

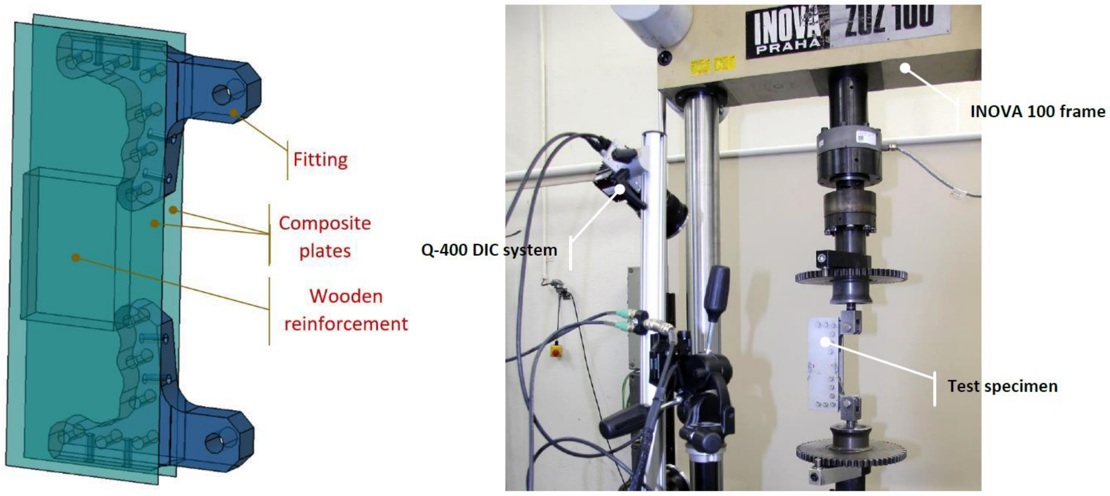

Fig. 4: Design of test specimen and arrangement of the test

Figure 5 shows proposed test specimen representative for the door fitting and comparison between experimental and simulation data for static load of 30 kN. The contactless strain measurement system Dantec Q-400 was used for the field of strain on the composite plate during loading.

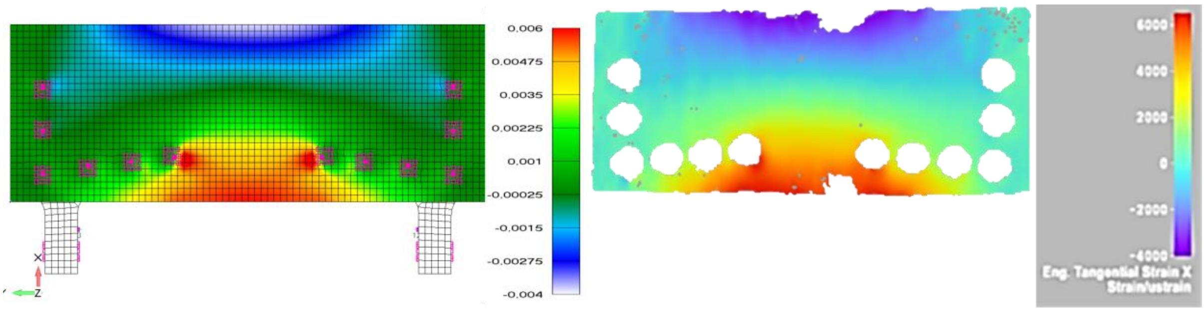

Fig. 5: Comparison of strain field between simulation (mm/mm) and experimental (μm/m) data on composite plates.

Comparison between test and simulation shows good agreement in the maximum and minimum value of strain and load distribution in the field between bolts for optimised fitting attachment.

Conclusions

The novel structural elements were designed. Numerical results were verified by experiments. Good agreement between numerical and experimental data was achieved. The results are to be used for design, manufacturing and experimental verification of a demonstrator.

Acknowledgment

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