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STRENGTH ANALYSIS OF HELICOPTER MAIN ROTOR BLADE MADE FROM COMPOSITE MATERIALS

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Abstract: In this investigation some aspects of design, production and experimental verification of composite structural elements are considered. Attention is focused on strength analysis of composite structures with application to helicopter main rotor blades HT-40. Special attention in this consideration is focused on strength analyses of composite structures with application on helicopter main rotor blades. For that purpose strength analysis of helicopter main rotor blade segment made from composite materials is considered using finite element method (FEM) and experimental verifications. In this study honeycomb sandwich structure is considered. Just honeycomb sandwich structural element is modeled using shell finite elements. For structural analysis of this type construction Msc/NASTRAN software code is used. For precise determination of aerodynamic loads of main rotor blades in this consideration the complete helicopter is modeled using CFD numerical simulation including main rotor, tail rotor and fuselage. To validate computation procedure in this consideration the honeycomb structural element is experimental tested. The results of numerical simulations are compared with own experiments.

Keywords: helicopter main rotor blade, sandwich construction, strength analyses, Finite Element Method (FEM), experimental verification

INTRODUCTION

Due to its good mechanical properties with respects to strength and stiffness of composite materials have found application in the aerospace industry. Here is considering the use of composite materials in helicopter main rotor blades HT-40 or precise segments of these blades. In the basic version of the blade segments of the honeycomb structure have been wherein the dural skins. After the end of their useful lives, these segments are redesigned and made of composite materials. Reserved the sandwich construction but skins made of composite materials and proper honeycomb filling. Strength calculations and experimental verification were realized in a Military Technical Institute (MTI) and production of composite blades in Moma Stanojlović - Batajnica. Defining loads the main rotor blades of helicopters was carried out using CFD numerical simulation [1,2]. Structural analysis of the blade segments is mainly realizen by means of FEM [3-8] including strength analysis of segments with one side and the analysis of the strength of an adhesive bond with the main segments of the spar of the blade with other side. In addition to the strength of the analysis calculation is carried out and experimental verification of complete segments of the composite strength of the blade and their connection to the main spar. In this consideration are shown the essential aspects of the results of structural analysis and experimental verification of the strength of the blade segment.

STRUCTURAL ANALYSIS OF SEGMENT OF MAIN ROTOR BLADE

In the process of designing complex constructions of composite materials such as the considered segment of the blade of the main helicopter rotor, a precise analysis of the stress states and reserve strength factors is essential. By using FEM applications have determined the stresses as well as the critical zones from the aspect of strength and potentially critical sites that can occur during exploitation [3,4]. Figure 1 shows the global structural drawings of the entire blade, while only the composite segment is considered.

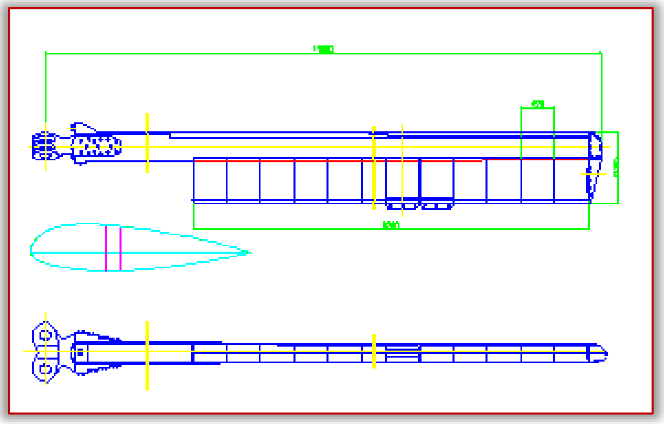

Figure 1. Helicopter main rotor blade

In this consideration the structural analysis of critical part of the segment of composite blade, shown in Figure 4, is considered. This part is subjected axial force Fx = 50.8 N originating from aerodynamic drag forces on the blade segment. Structural analysis of the complex specimen carried out by using Finite Element Method (FEM). Here FEM [5-7] is used for strength analysis of skins made from composite materials and all other components including glued compound for binding to a metal segment of the composite spar on one side and a comparison with the experimental results on the other hand.

Resuts of structural analysis by FEM using software code MSC/NASTRAN [8] are shown in Figures 2, 3. We note that the maximal loaded parts are joints of honeycomb with composite skin on upper side assembly, as well as the places of bonding the composite spar for dural or dural tail part. The primary objective of this analysis was the modeling of composite structures with honeycomb filling and then comparisons with experimental results. The maximum value of the stresses in junction zones honeycomb with composite skins, which are also critical points with respects to the initial failure and the fracture.

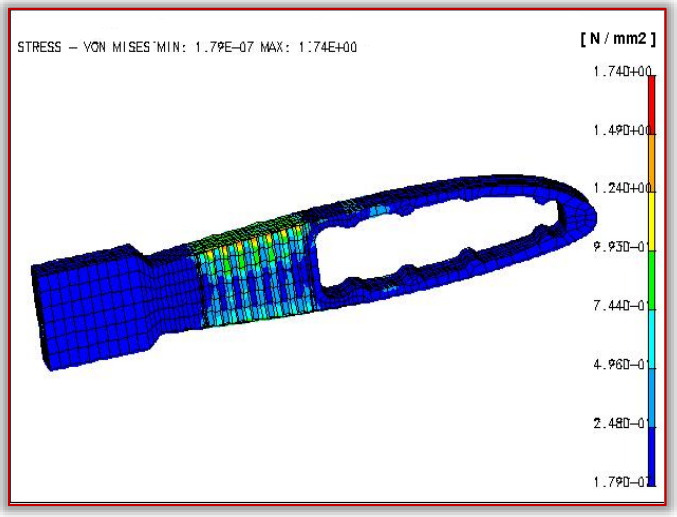

Figure 2. Specimen of helicopter rotor blade – Von Misses stress distribution

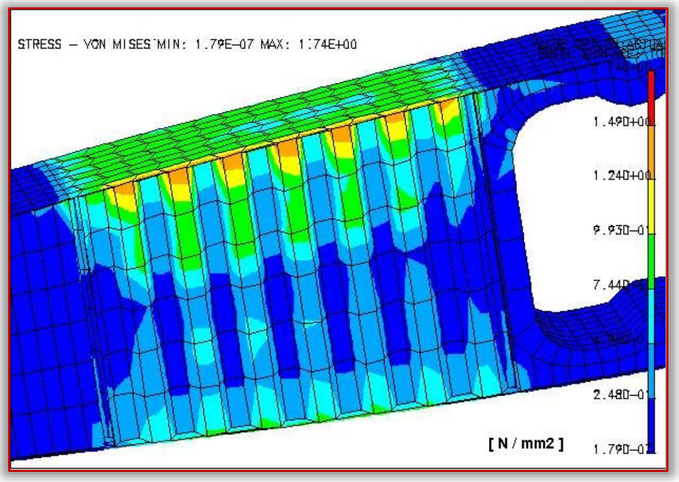

Figure 3. Von Misses stress distribution in honeycomb part of segment of blade

In the previous figures are presented graphically the results of the stress state in all parts of the complex composite specimen the main rotor blades of helicopters.

EXPERIMENTAL STRENGTH ANALYSIS OF THE SEGMENT OF MAIN ROTOR BLADE

In order to determine the static strength tests were carried out complete static strength. Static tests are realized in the segment blades for loads that occur on the last segment - at the end of the range of blades. Figure 4 shows the composite segment of the main rotor blade together with the work spar with that within perform static tensile tests.

During the tests were measured strain / stresses by means of strain gauges and displacements. Figure 8 shows a complete consruction of the blade segments and the method of introducing the load. It introduces all three components of the load acting on himself composite blade segment.

The tests were performed:

(1) to limit load (j = 1.0),

(2) to computation ultimate load (j = 1.5) and the effective failure.

Test results blade segment are shown loading case for j = 1 is defined as follows:

≡ N = 2539 N - force component normal to the chord,

≡ T = 279 N - component force in the direction of chord and

≡ F_C = 2202 N - centrifugal force (normal to the plane of airfoil, towards the end of the rotor).

Point of attack of the aerodynamic force is half of the expansion segment and in the first third of the chord segment, while striking point of centrifugal force in the tendon segment.

Figure 6 shows the arrangement of strain gauges on bottom side of segment of composite material. Measured strains / stresses in the rosette for a cycle to limit loads, indicated with 3,4, and 5 in Figure 6, as shown in Figure 7.

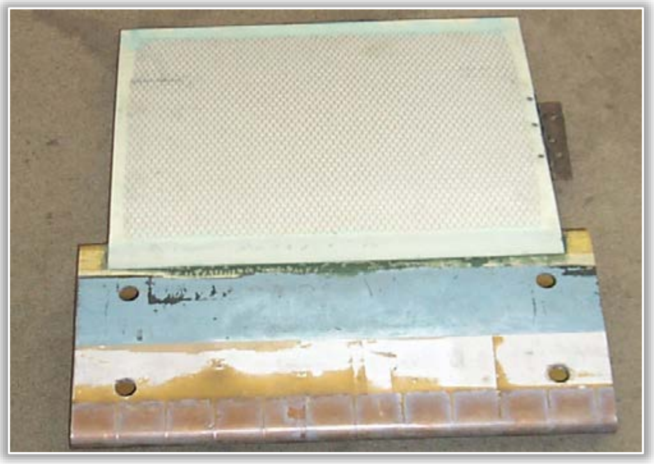

Figure 4. The composite segment with part spar

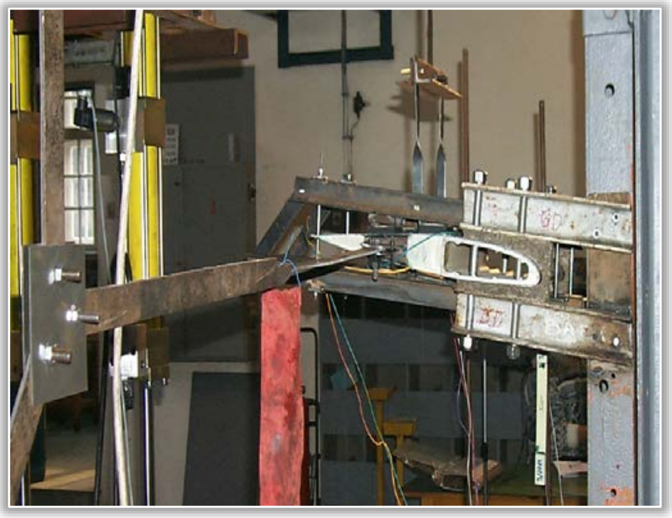

Figure 5. The manner of incorporation and the introduction of load testing for static strength of the composite blade segment

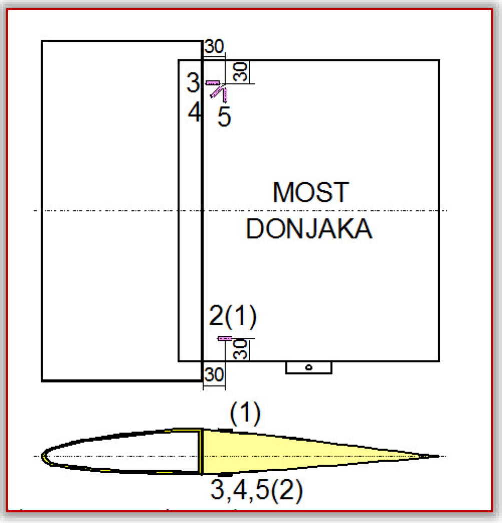

Figure 6. Schedule of strain gauges for measuring the stresses

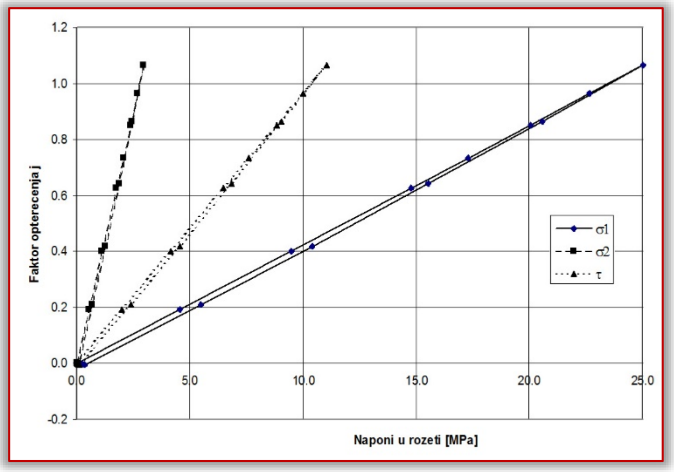

Figure 7. Experimental determined stresses in strain gages up to coefficient of load j=1.08

Measured strains/stresses in the strain gages/rosette for a cycle to limit loads, indicated with 3, 4, and 5 in Figure 6, are shown in Figure 7.

CONCLUSIONS

The paper presents a computation analysis of the determination of the stress states in the composite segment of the blade of the main rotor of the helicopter HT-40 with one and its experimental strength test on the other side. Structural analysis of stress conditions using FEM encompassed the precise modeling of the complete segment of the blade, including the honeycomb filling and the self-bonding connections between the composite segment and the metal part spar.

In order to verify the real strength of the composite segment was carried out experimental analysis of the strength of the composite blade segment. Tests were carried out with the measurements of stresses and displacements up to the effective fracture. For this tests was selected the most loaded blade segment located at the end of the blade span. Effective fracture of the segment during the test is determined by the high workload which is in turn verified the validity of the composite segment in terms of strength. In parallel tests were performed static strength metal segments with honeycomb and composite segment with honeycomb filling.

The investigation up to the effective failure metal and composite helicopter main rotor blade segment was found that the composite segment with a coefficient of mountainous workload ($j_1 = 4{,}48$) has significantly higher static strength relative to the metal segment ($j_1 = 2{,}97$).

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