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FATIGUE LIFE SIMULATION OF THE SPECIMENS MADE OF MECHANICAL COMPONENT

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Abstract: *This paper describes the validation of a Monte-Carlo simulation and finite element analysis of a practical application (mechanical component) using the fatigue testing techniques. Fatigue testing techniques investigate how the component structure reacts to stress over a long period of time and during different levels of its operations. The importance of implementing the Monte Carlo techniques in fatigue life analysis is motivated by the growing evolution of statistical methods for defining fracture and fatigue of mechanical components. The practical application was simulated with a Monte Carlo method and the statistical analysis was realized using the Weibull 9 software. Fatigue life prediction was simulated using finite element analysis with Ansys 15 software.*

Keywords: *mechanical component, fatigue testing, simulation, Monte Carlo method, FEA*

1. INTRODUCTION

Fatigue failure is defined as the progressive degradation of the strength of a material or structural component during use such that failure can occur at much lower stress levels than the ultimate stress level. Fatigue is a dynamic aspect which initiates small (micro) cracks in the material or component and causes them to grow into large (macro) cracks; these, if not detected, can result in catastrophic failure. Fatigue damage can be produced in a variety of ways. Cyclic fatigue is caused by repeated fluctuating loads [4].

Fatigue design life implies the average life to be expected under average aerospace apparatus utilization and loads environment. To this design life, application of a fatigue life scatter factor accounts for the typical variations from the average utilization, loading environments, and basic fatigue strength allowable. This leads to a safe-life period during which the probability of a structural crack occurring is very low. With fail-safe, inspectable design, the actual structural life is much greater. The overall fatigue life of the aerospace apparatus is the time at which the repair of the structure is no longer economically feasible [3].

As a means of transportation, the helicopter has witnessed a significant progress in the past 10 years. We must take into account that by its construction alone, the helicopter is subjected continuously to periodical loads; therefore it must withstand a considerable high number of fatigue cycles. The most susceptible elements at these stresses during the construction of the helicopter are the main and the tail or anti-torque rotor assembly, in which the blades and their mechanical fastening elements play a key role.

The blades and the rotor's component elements, but also the supple platinum, enter in the category of the vital parts of the helicopter, parts that by their failure or their loss, cause inevitably the destruction of the entire flying apparatus. A vital part is a piece that fulfils the following 3 conditions:

- Is a part that can't be doubled and whose breaking entails or could entail a serious accident;
- From the standpoint of exploitation (as part of the helicopter), the piece is subjected to significant alternate stresses (fatigue stress);
- The current technique of designing helicopters can't ensure very significant security coefficients.

2. EXPERIMENTAL STUDY

2.1 Description of material specimens. The French helicopter constructors introduced the system for reducing the vibrations like supple platinum. Supple platinum (Fig. 1) is made of a titanium alloy and is placed between the inferior part of the main transmission box and the mechanical board at the helicopter. Supple platinum is a vital part and has the role to reduce the vertical vibrations produced by the main rotor's blade.

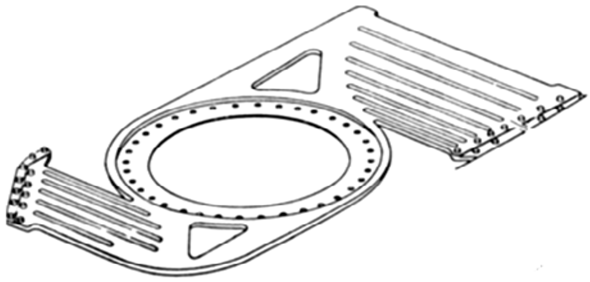

Figure 1. Mechanical component - supple platinum

Due to its configuration, mechanical component (supple platinum) cannot be subjected to stress tests. That's why the tests are being made on specimens, with standardized dimensions, made of the same material as supple platinum (a titanium alloy known in the aviation as TA 10).

2.2 Testing specimen. The tests of the specimens made of supple platinum consist of the repeated stress using a bending force, on a test bench that includes a fixation device for the specimen; the device for the tensioning of the specimen; the energy installation; the command installation; the electronic installation.

The experimental research has been performed on specimens made out of supple platinum, specifically from removed portions that result from the technological processing. Figure 2 shows the constructive model of the specimen used in fatigue tests and, also, the placement of strain gages [5].

Figure 2. Specimen for fatigue life testing

3. SIMULATION FATIGUE TESTS

3.1 Fatigue life predictions using finite element analysis. The finite element analysis is a numerical method for solving problems of engineering and mathematical physics and it is useful for problems with complicated geometries, loadings, and material properties where analytical solutions cannot be obtained [2].

Engineers design today's mechanical components using structural mechanics solutions that compute the response to applied forces and displacements. Fatigue simulation expands on structural analysis to account for extended real-life loadings. Fatigue life simulation is based on a single static structural FEA result and an expected loading history while the part is in use. Engineers have used the ANSYS Fatigue module for simple geometries and loadings for many years. For the majority of realistic geometries and real-life loading, ANSYS nCode DesignLife is the ideal choice. Images show static structural results (above) and fatigue life results (right) [1].

Figure 3 shows the constructive model of the specimen used in fatigue life tests, design in SolidWorks 2014 software.

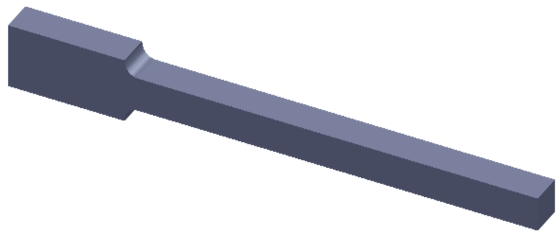

Figure 3. Specimen for fatigue life testing

The model with finite elements was realized in the Ansys 15 software. Approximately 771 hexahedron elements and 1488 nodes have been used for mesh discretization the specimen. The load was simulated by applying on the free end of a force of 500 N. In figure 4 is described Total Deformation of specimens and in figure 5 is presented Equivalent Elastic Strain.

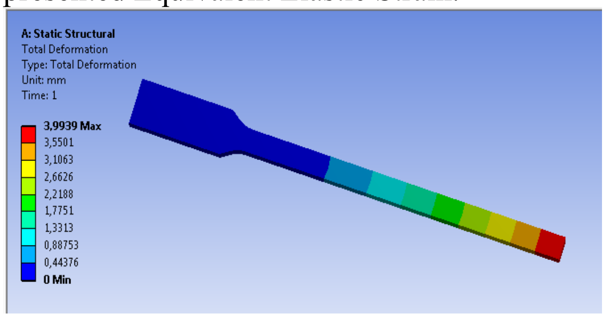

Figure 4. Total deformation

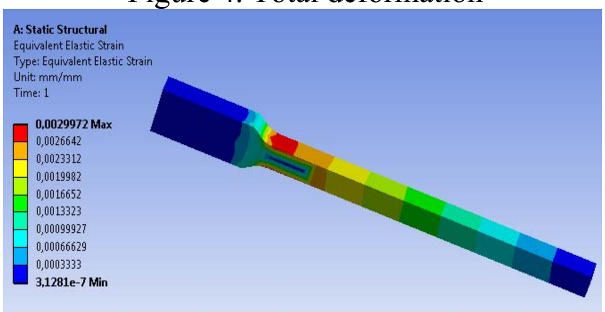

Figure 5. Equivalent Elastic Strain

Figure 6 illustrated the distributions of Equivalent (Von Mises) Stress.

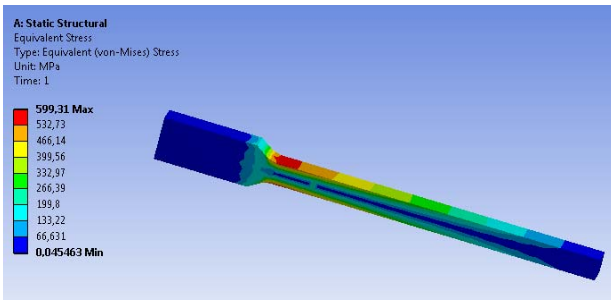

Figure 6. Distributions of Equivalent Stress

The main purpose of the analysis with finite elements of the specimens is to validate the fatigue life (figure 7) that occurs in normal testing on specimen.

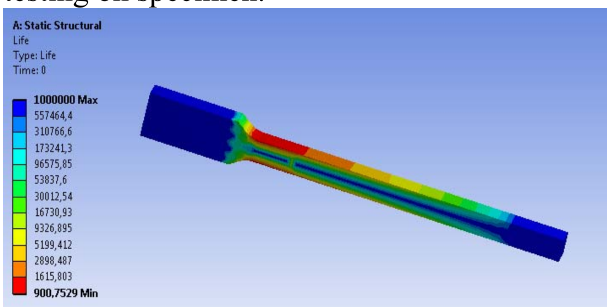

Figure 7. Fatigue life estimation

The distributions of Fatigue Damage is a contour plot of the fatigue damage at a given design life. Fatigue damage is defined as the design life divided by the available life (figure 8).

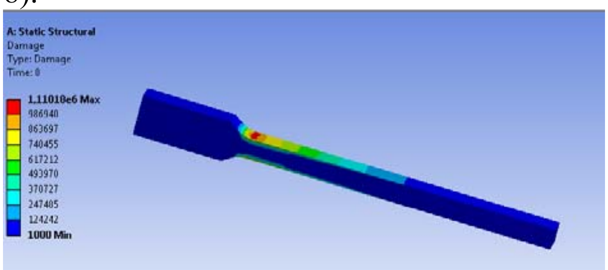

Figure 8. The distributions of Fatigue Damage

3.2 Fatigue life predictions using Monte Carlo method. Using the Monte Carlo method, we simulated N stages of a mechanical component with the help of a statistical distribution (Weibull) which are suited to the analyzed case study (figure 9).

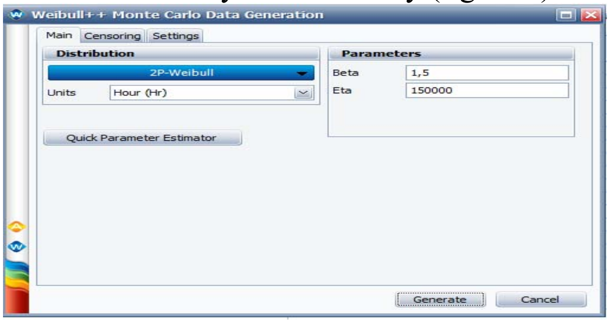

Figure 9. Monte Carlo simulation

Using the previously determined parameters (β=1,5; η=150000) we simulated with the help of Weibull 9 software the values for the number of cycles to failure in fatigue testing condition (figure 10).

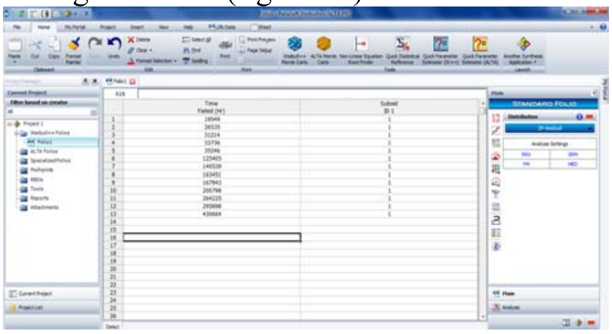

Figure 10. Data using the Monte Carlo method

Mean time to failure describes the expected time to failure for a mechanical component. The Mean Life (MTTF) can be calculated in the Quick Calculation Pad (figure 11).

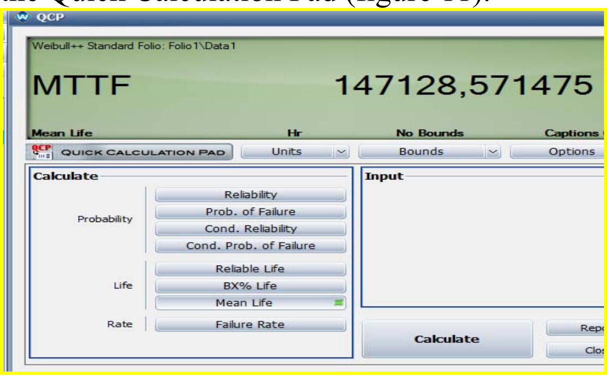

Figure 11. The distributions of Fatigue Damage

4. CONCLUSIONS & ACKNOWLEDGMENT

For the case study under analysis, figure 12 shows the number of cycles to failure from finite elements analysis, the simulation with the Monte Carlo method and the data from the fatigue testing. We can observe that, by using the simulation methods (FEA and Monte Carlo) of fatigue life, can be obtain a good results even in early stage Product Design and Development.

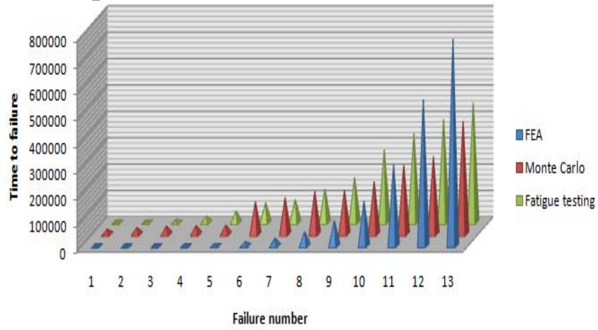

Figure 12. Comparative study of simulation methods

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