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NUMERICAL MODELLING IN SAFETY ENGINEERING

Abstract. Numerical modeling is one of the most promising and most developed scientific research tools [2]. The important advantage of this method is the ability to obtain results in a much more efficient way than using conventional experimental tools. In addition, the application of experimental methods is not feasible in solving numerous technical issues due to the inability to make direct measurements of the analyzed physical quantities. In the above mentioned applications, numerical modeling is an ideal research tool, which strongly contributes to the development of the contemporary science.

This paper presents the stress analysis of the landing gear, which is a key element to ensure high operational reliability coefficient of the aircraft. The performed analysis is an example of the application of computational methods in solving technical issues in the area closely related to safety engineering.

Keywords: numerical modeling, safety engineering, analysis, CAE.

Computer Aided Engineering

Computer Aided Engineering (CAE) is the application of computer software to aid in engineering tasks and to simulate performance in order to improve product designs or assist in solving engineering problems for a wide range of industries. This includes simulation, validation and optimization of products, processes and manufacturing tools. CAE consists of Computer Aided Design (CAD), Computer Aided Analysis (CAA) and Computer Aided Manufacturing (CAM) – Fig. 1 [4, 5].

Fig. 1. Components of Computer Aided Engineering

CAE in safety engineering

Safety engineering is a field that focuses on preventing accidents and reducing opportunities for human error. It can be applied to many disciplines such as aerospace, manufacturing, medicine, automotive industry [3] and broad range of product design. Safety engineering principles can be applied to new products or within the existing ones to improve safety [5].

CAE (including numerical modeling) tools applied during the product development process can provide valuable data concerning design details that need to be improved in order to assure safe exploitation of the final product by identifying hazards or dangers for the intended users [7].

As an example of CAE application in safety engineering, the product development process of small aircraft landing gear is presented (Fig. 2). The landing gear is a key element to ensure high operational reliability coefficient of the aircraft [1, 6]. The performed analysis is an example of the application of computational methods in solving technical issues in the area closely related to safety engineering [4].
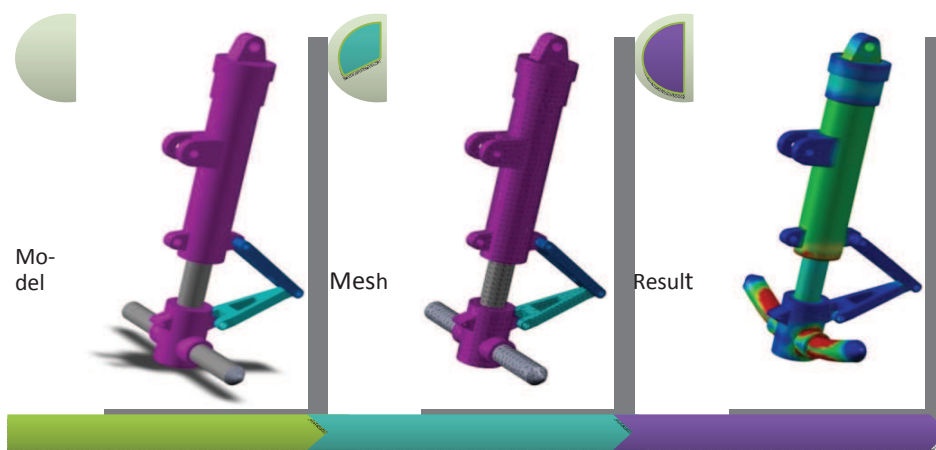

Fig. 2. The product development process of small aircraft landing gear

The CAD model

The first step in the above mentioned process is preparing the numerical model using the CAD tools. The final assembly consists of separate parts that need to be sketched and inserted into one assembly using mates (Fig. 3).
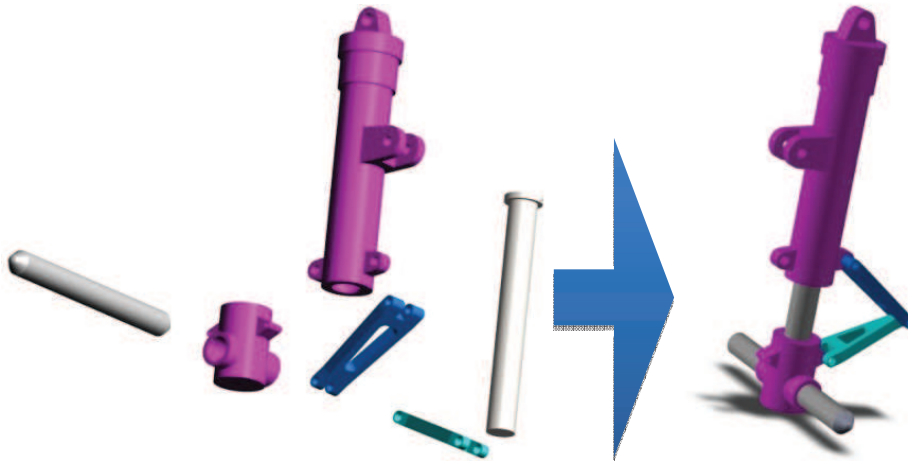

Fig. 3. Joining the separate parts into one assembly

Meshing the computational domain

The next step is the numerical mesh generation. This process can be automated in case of relatively simple geometry. The automatic mesh generation process can be performed using the tetrahedral mesh (Fig. 4), which is characterized by greater numerical diffusiveness than hexahedral mesh and polyhedral mesh. Moreover automatic mesh generation does not allow the user to fully control the mesh resolution in the areas of special interest like sharp corners, edges, etc.

User interaction is required in case of meshing more complicated geometries in order to assure high quality of the resulting mesh. The hexahedral mesh (the least diffusive mesh type) generation cannot be performed automatically as it requires the interaction of skilled and experienced engineer.
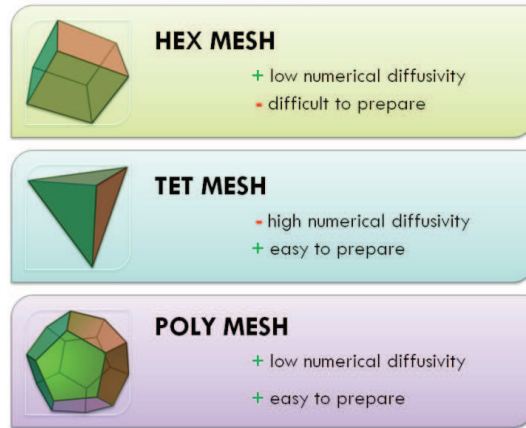
Fig. 4. Mesh types and its characteristics

It can be stated that the discretization of the computational domain is the most demanding step in the numerical analysis process and it strongly influences the obtained results.

The boundary conditions

The final task in solving technical issues in the area related to safety engineering using numerical methods is the calculation performed by the specialized computer code. It is an automatic process but it needs input data in the form of above mentioned discretized computational domain and boundary conditions as shown in Fig. 5. All components of the landing gear are made off carbon steel.
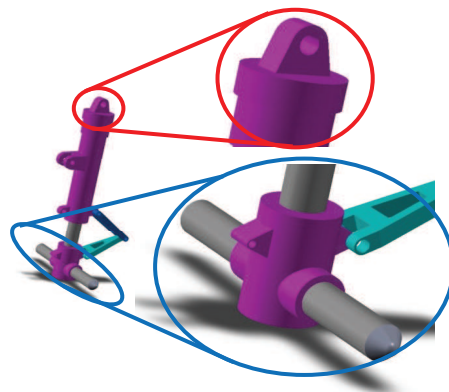

Fig. 5. Boundary conditions: red line – fixture, blue line – bearing load equal 26 700 N

Numerical modeling results

The results of stress analysis of small aircraft landing gear are depicted in Fig. 6a. The maximal stress value is approx. 220 MPa, which assures the factor of safety equal 2,82.

The maximal displacement in the analyzed assembly equals 0,9 mm as shown in Fig. 6b.

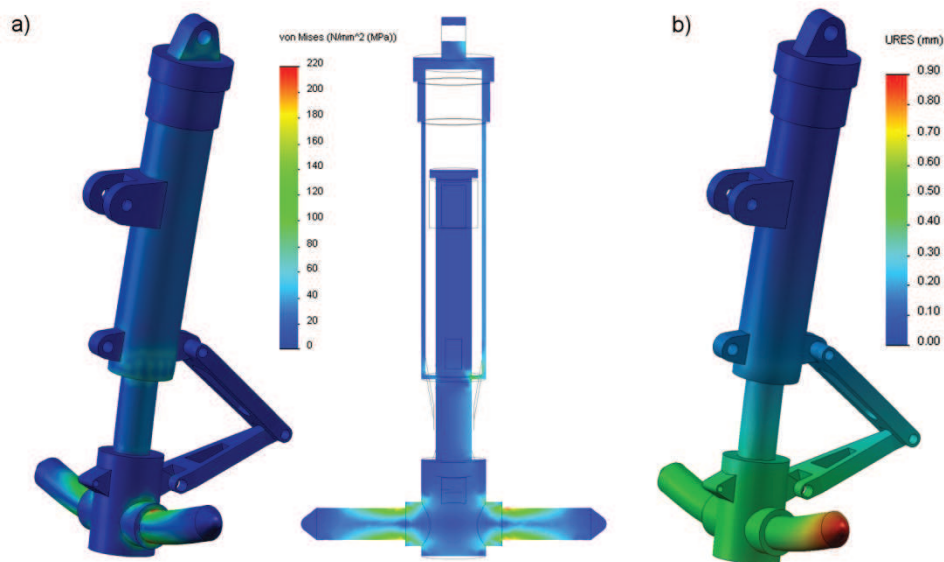The above values guarantee the safe exploitation of the landing gear.

Fig. 6. The results of stress (a) and displacement (b) analysis

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ZASTOSOWANIE MODELOWANIA NUMERYCZNEGO W INŻYNIERII BEZPIECZEŃSTWA

Streszczenie

Modelowanie numeryczne jest obecnie jedną z najbardziej obiecujących i rozwijanych naukowych metod badawczych, której najistotniejszą zaletą jest możliwość uzyskania danych wynikowych w sposób daleko bardziej efektywny niż z zastosowaniem klasycznych metod eksperymentalnych. Ponadto liczne są zagadnienia, do rozwiązania których aplikacja metod doświadczalnych nie jest wykonalna z uwagi na brak możliwości dokonania bezpośrednich pomiarów analizowanych wielkości fizycznych. Między innymi w takich zastosowaniach doskonale sprawdza się modelowanie numeryczne jako narzędzie badawcze służące rozwojowi współczesnej nauki.

W pracy przedstawiono problematykę zastosowania numerycznych metod obliczeniowych w rozwiązywaniu zagadnień technicznych z obszaru ściśle związanego z inżynierią bezpieczeństwa na przykładzie analizy wytrzymałościowej podwozia samolotu, czyli kluczowego elementu zapewniającego wysoki współczynnik niezawodności eksploatacji statku powietrznego.

Słowa kluczowe: modelowanie numeryczne, inżynieria bezpieczeństwa, analizy, CAE.