MODELING OF A HIGH PRESSURE TURBINE DISC FOR THE AL-31F JET ENGINE

Miroslav SPODNIAK
Technical university of Kosice, Faculty of aeronautics, Rampová 7, 041 21 Košice
miroslavspodniak1@gmail.com
Marián HOCKO*
Technical university of Kosice, Faculty of aeronautics, Rampová 7, 041 21 Košice
**Corresponding author.* E-mail: marian.hocko@tuke.sk

Summary: This article deals with a description of the creation of a mathematical model for high pressure turbine disc for Saturn-Ljuka AL-31F turbofan jet engine. The Creating a mathematical model is based on modeling in CAD software. Mathematical model was carried out on the bases of dimensional, shape and material disc characteristics, which are available for the particular high pressure engine turbine. The method described below enables relatively fast model creating for the other usage, which enables the counting of critical stress or low cycle fatigue etc. The value of mathematical model depends on the accuracy of required input data for the particular investigated object.

Keywords: high pressure turbine, jet engine, CAD software, mesh, mathematical model

1. INTRODUCTION

The jet engine has to provide enough trust and an infallible operating during the whole flight also its each phase and each regime of flight. This fact is conditioned by a trouble-free operation, ensuring the operation of the jet engine parts its fatigue life including high pressure turbine disc of jet engine.

A high pressure turbine disc of jet engine pertains to the most stressed parts, which are occurred in the jet engine. Apart from the centrifugal forces caused by the jet engine rotor spinning, there are some other forces, like extreme high temperature, which have impact on life of high pressure turbine. The fatigue life and reliable its function is greatly affected by cycle fatigue. A cycle fatigue is caused by the period change of stress and deformations during the engine operation cycle. The high pressure turbine disc is part that is exposed the great stress. Cycle fatigue is caused mainly because of tension, which is induced by the temperature gradients, centrifugal forces of disc spinning parts and rotor blades. Cyclic temperature relief has a significant impact during transitional regimes of a jet engine. These varieties of the temperature cause thermal fatigue of material, the beginning of a disc cracks and their gradual increasing. [1]

In order to by possible prevent not only high pressure turbine disc damage but other parts of jet engines as well, there are engine tests executed. The jet engine tests in real conditions are as it is well known very expensive, heavy on time, economic and ecologic, that is why there is a need to create a software simulation and analyses. In order to by practicable to perform some analyses, is necessary to make suitable mathematical model. [1, 2]

2. CHARACTERISTIC OF INVESTIGATE HIGH PRESSURE TURBINE DISC

A pressure turbine of a bypass turbofan jet engine like AL-31F, that is used in Su-27 aircraft, is axial, two shafts. The pressure turbine consists of a one stage high pressure turbine and a one stage low pressure turbine. Both of them have rotor blades and stator vanes mounted, which are cooled by air. On lower regimes it is for the purpose to increase the engine thrust used partly for disconnection of cooling both of pressure turbines.

A high pressure turbine consists of a disc, rotor blades, gudgeon and a high pressure turbine shaft. A high pressure turbine disc is made by ironwork with consequent chip machining. The disc inner rim rabbets are made in order to ensure attaching rotor blades. There are 90 rotor blades with rabbets to locate elastic blade locks given to ensure axial movement and slant holes for cooling the air input. On the right side of the disc, there is located a labyrinth seal rim and a rim, which is used to remove disc. In the disc flange section there are roll holes drilled to fit screws that are connecting the shaft, the disc and the high pressure turbine rotor pivot. [3, 4, 13]

3. 3D MODELLING OF HIGH PRESSURE TURBINE DISC

In case of high pressure turbine disc investigation, is inevitable to create mathematical model, which was carried out for purposes of this paper in 3D cad software. 3D modelling is the process of developing a mathematical representation of any three dimensional object by using 3D software. Modelling described in this paper was carried out by the program SolidWorks. [5]

Figure 1 3D high pressure turbine disc of AL-31F jet engine

Creating of mathematical model was performed like mass modelling so called Constructive Solid Geometry (CSG). This conception is based on parts modelling using geometrical objects on the computer transformation and using Boolean operators.

CSG representation uses the set operations like addition, subtraction and intersection and particular object creates by set tree operations, which are applied to the primitives. The model like this is subsequently possible to display in the tree structure. This method of modelling can divide into accurate presentation and approximate presentation.

As was described in previous chapters creating of the mathematical model of high pressure turbine for purposes this work was carried out in SolidWorks program. The information from the available resources and technical documentation were used to create an identical 3D high pressure turbine model of the AL-31F jet engine. The first step in creating mathematical model was making 2D sketch, which was afterwards using the tool Revolve extruded to the 3D body. Next step after creating the high pressure turbine disc was necessary to make holes for the attaching screws, as it is shown on the Picture 1. Other parts are suspenders for attaching rotor blades. 3D mathematical model of high pressure turbine disc Saturn/Ljulka AL-31F created by solid modelling is shown on the Picture 1. [5, 6, 7, 11]

4. CREATING SYMMETRICAL SEGMENT OF HIGH PRESSURE TURBINE AND ITS MESHING

In order to simplify the calculation process and afterwards ensure investigate time saving, was symmetrical segment formed. In this symmetrical segment is simpler to apply outside and inside forces, which have influence on disc. It is easier to count fatigue life of the high pressure turbine. Symmetrical segment of the high pressure turbine in SolidWorks environment is shown on the Picture 2.

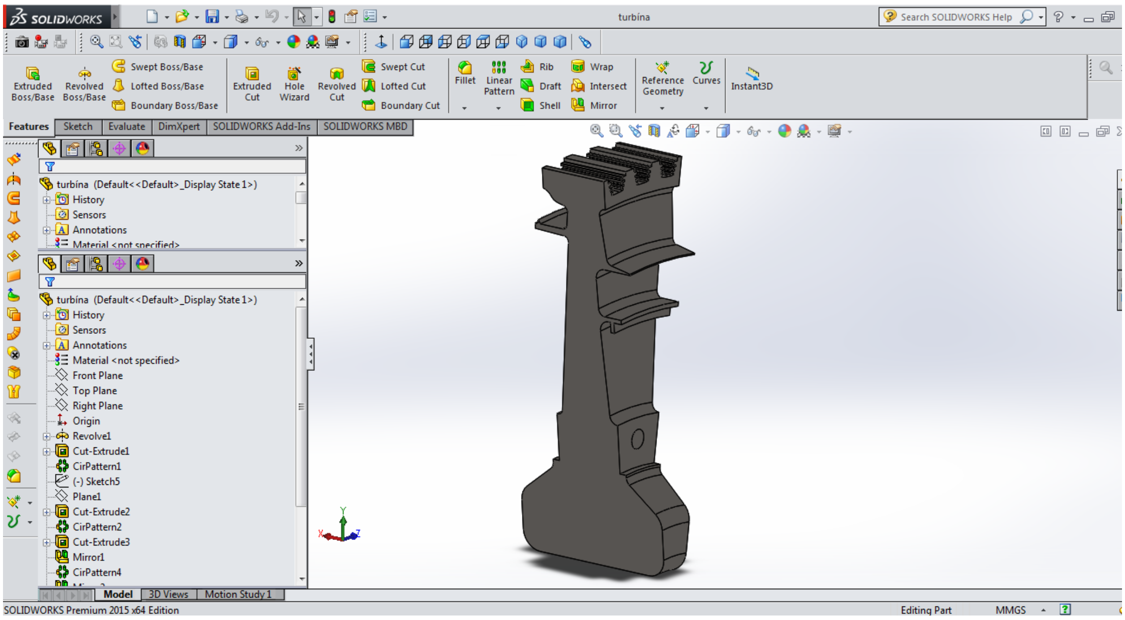

Figure 2 Symmetrical segment of high pressure turbine disc AL-31F

After modelling high pressure turbine disc and creating required symmetrical segment, for the computation purposes meshing is necessary. So that would be possible to make some calculations and life estimations the mesh is foundation. The meshing model is shown on the Picture 3. The mesh was created in SolidWorks using Jacobian Points. This method ensures the highest quality of mesh. The generated elements are parabolic and can map curved geometry much more accurately than linear elements, which have the same size. The parabolic elements also called second-order components, or components of higher order are in comparison with linear elements or first order components more difficult. A linear tetrahedral element is defined by four corner nodes connected by six straight edges. A parabolic tetrahedral element is defined by four corner nodes, six mind side nodes, and six edges. It is generally known, that for the same mesh density, parabolic nodes represent much more exact results than the linear elements, which is caused due to, that they can map curved geometry exactly and because of that are mathematical approximation much more precisely produced. However the parabolic components are for numerical calculation more difficult than linear components. For structural problems, each node in a solid element has three degrees of freedom that represent the translations in three orthogonal directions. SolidWorks uses Cartesian coordinate system in formulating the problem. Picture num. 4 represented schematic drawings of linear and parabolic solid elements. Jacobiho method enables 4, 16 or 29 nodes for meshing. [7, 8, 9, 11]

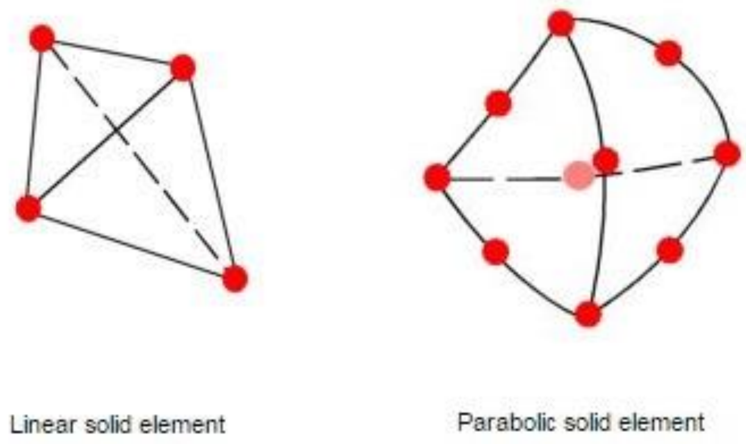

Figure 3 Meshing elements

5. CREATING MESH, PROPERTIES AND PARAMETERS

3D software enables the opportunity to choose meshing parameters for the mathematical model, which has impact on the final result of mathematical model. One of the most fundamental parameters of the meshing is Mesh Density. Default setting of Mesh Density is somewhere in the middle, for this model was the highest fineness selected. This Mesh Density setting decreases dimensions of individual elements and increases the total number elements of the mesh.

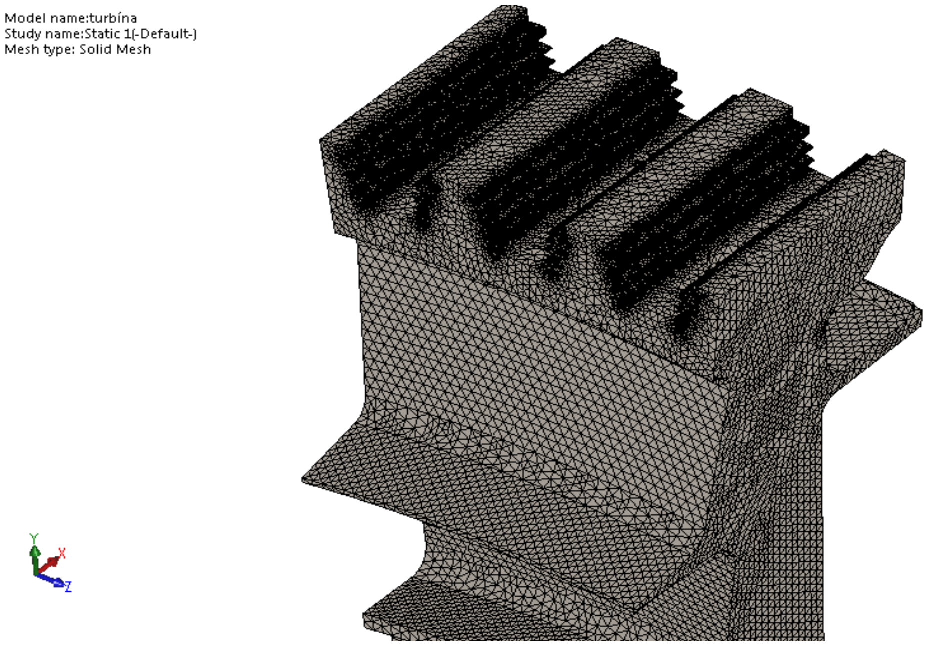

Figure 4 Finite element model

As was discussed in previous chapter software SolidWorks dispose of two kinds mesh, where the first is Standard Mesh and the second is Curvature Based Mesh. In this article the second one type was used. There are some other parameters like maximal size element, which is maximal size of meshing element in the curvature of the model; the opposite is minimal size element. In our case the maximal element dimension is 1,5 mm and minimal is 0,3 mm. The final meshing model is represented by the Pictures 4 and 5. [7, 11]

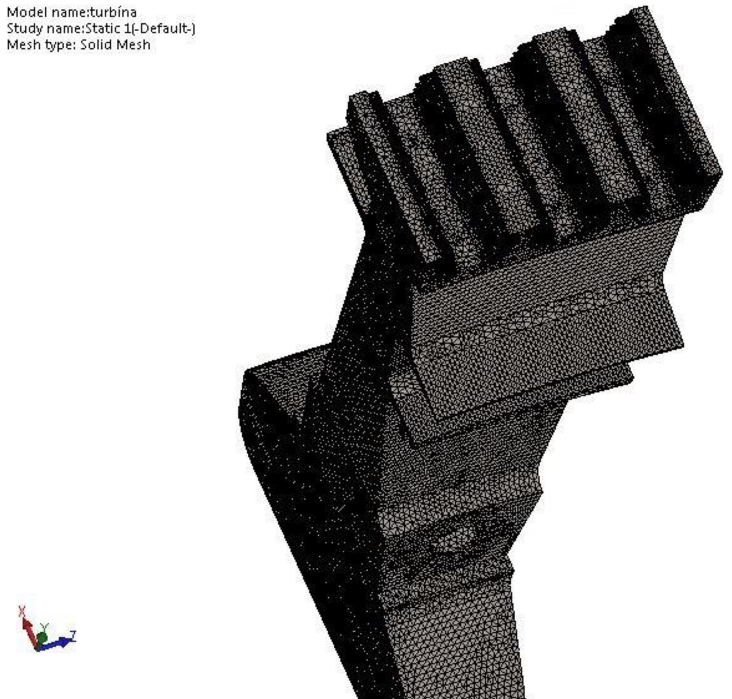

Figure 5 Finite element model

6. BOUNDARY CONDITIONS

As was mentioned due to simplification of numerical counting was needful to create symmetrical segment. However the segment is necessary to bound using the suitable fixtures. The fixture allows to prescribe zero or non-zero displacements on vertices, edges, or faces for use with static frequency, buckling, dynamic and nonlinear studies. For this case was suitable the fixture Roller/Sliding. Use the Roller/Sliding restraint to specify that a planar face can move freely into its plane but cannot move in the direction normal to its plane. The face can shrink or expand under loading. This fixture we can see on the Picture 6. [7, 11]

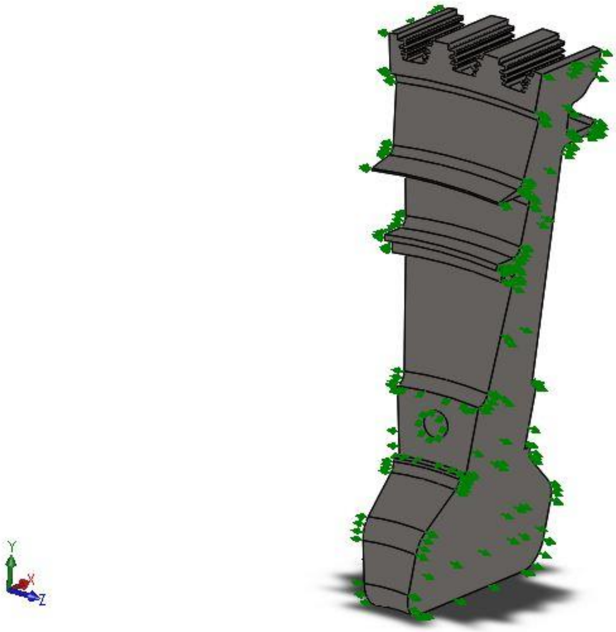

Figure 6 Boundary conditions of 3D model

CONCLUSION

The mesh of mathematical model has a substantial influence on the other computations accuracy. The mesh affects stress analyses, cycle fatigue analyses of the particular jet engine part. As was described in this article there are few factors, which are decisive in term of model meshing. Contemporary software and hardware equipment enables some diversely ways in term of creating mathematical models. The creation of the mathematical model in CAD software provides some benefits compared to the physical testing, amount of savings, like time saving, financial, environment and economic saving.

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