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Research Article

STRESS-DEFORMATION ANALYSIS OF THE F16 AIRCRAFT AUXILIARY LANDING GEAR

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ABSTRACT

Stress is known as an internal force value acting on a unit area of a part. Stress-deformation analyzes play an important role in finding structural safety and integrity. According to literature, aircraft faults during landing are more frequent than faults during take-off and flight. In this study, the geometry of the auxiliary landing gear of the F16 aircraft is drawn in the SolidWorks package program, which is one of the computer-aided design programs. Later, the finite element analysis is performed on the ANSYS program of the drawing design. Stress and deformation values are determined for each part of the landing gear of F16 aircraft. Two results are obtained by interpreting the stress-deformation analyzes. In the first result, the maximum stress reduces when the shaft diameter in the landing gear is increased. In the second result, the maximum stress and maximum deformation increase when the moment is applied. With these analyzes, endurance tests are carried out by obtaining the stress-deformation values of each part for different shaft sizes of the aircraft landing gear.
Keywords: F16 aircraft, auxiliary landing gear, finite element analysis, stress analysis, deformation analysis.

1. INTRODUCTION

As it is known, the landing gears are aircraft elements that carry the weight of the aircraft, protect the airframe from external shock when landing and take-off, reduce the most of shock when the aircraft is moving or when taxiing on the ground. Landing gears are evaluated under various names according to the size of the aircraft, its purpose, the amount of load it carries and in addition to other functions. On a regular aircraft there are main landing gear and auxiliary landing gear [1, 2]. Auxiliary landing gears are usually located in the tail or the nose of the aircraft. These landing gears taking the main load on itself, making landing more secure by helping to reduce the load on the main landing gear and ensure the aircraft to steer the aircraft during ground motion [1, 3]. It is very important to have information about the production of aircraft and the life span of the materials produced. Therefore, many analyzes are made before aircraft are produced [4, 5].

In order to do these analyzes, The ANSYS software program, which has adopted the finite element method as its principle is uses [3, 6-8]. In work of Tümer [9], vibration analysis in the NACA 4424 and NACA 4415 profiled aircraft wing have performed in the ANSYS program.

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Tümer has compare d these two different wing models. Heirendt et al. have presented a steady state model for examining the thermal behavior of an aircraft landing gear slider bearing [10]. They have compared the results of lubrication and non-lubrication of this slider bearing.

In work of Sevgi [11], the best results have been obtained for the boundary conditions given to the sleigh-type landing gear designed for a light commercial helicopter and for the specified loading conditions. Geometry and its main dimensions have been modeled by ANSYS computer program before analysis for this landing gear.

In work of Rajesh and Abhay [12], the executive jet aircraft have studied thoroughly and a nose landing gear similar to those of executive jets is modeled using CATIA. The same geometry is imported to ANSYS ICEM and flow on the body is analyzed for different angle of attack. Pressure variation, temperature, density and velocity distribution around the body is noted and then coefficient for lift and drag are plotted against angle of attack for obtained results. Infante et al. have performed the analysis and numerical simulation of the landing gear component using the finite element method in order to determine the stresses that the component is subject to, understanding the defect causes of the landing gear [13].

In this study, the stress-deformation analysis of the auxiliary landing gear of the F16 aircraft was carried out in the ANSYS program. Two models were used in those analyzes. The first of these models has given the aircraft a certain amount of force from the rim. The second one is the application of the given moment in addition to the forces given in the first model. In addition, as a result of raising the shaft radius of the landing gear used in first model, stress and deformation values of the landing gear were examined.

2. MODELING AND NUMERICAL RESULTS

In the numerical study, the design of the landing gear which we used in the stress-deformation analyzes was realized first. When the design was being carried out, the auxiliary landing gear of the F16 aircraft was taken as reference. The piston, cylinder, shaft, rims and wheels of the reference landing gear were drawn in the SolidWorks program. Technical pictures of these drawings are given respectively in Figures 1-5.

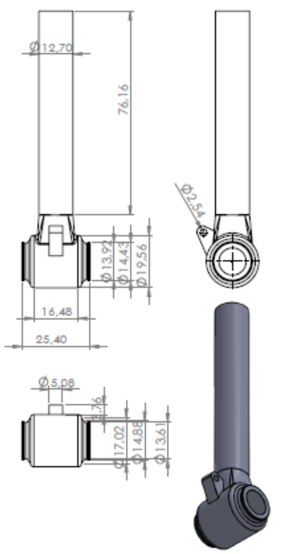

Figure 1. The piston of the landing gear

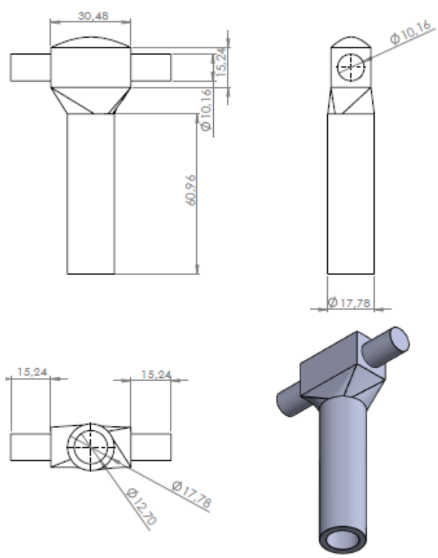

Figure 2. Cylinder of landing gear

In Figure 1 is shown two different diameters of the shaft are passed through the piston, and two rims are connected to each other. From the top the cylinder shown in Figure 2 is fixed in the aircraft.

For this work, the shaft shown in Figure 3 is designed in two different sizes (radius *36 mm* and *52 mm*). This shafts was passed through the piston and connections of rims were made. The rim shown in Figure 4 is one of the most important parts of the landing gear which is attached to the wheels and which connects with the shaft. The rims of the landing gear are made of alloy steel.

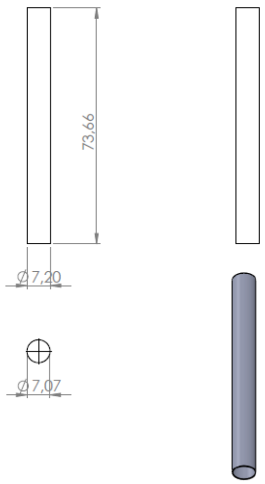

Figure 3. The shaft of the landing gear

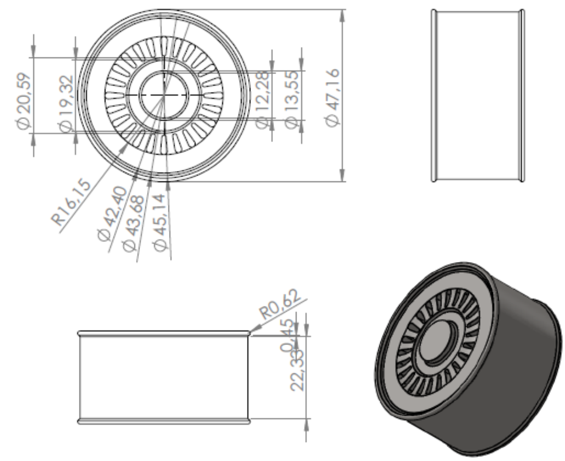

Figure 4. The rim of the landing gear

For this work, the shaft shown in Figure 3 is designed in two different sizes (radius *36 mm* and *52 mm*). This shafts was passed through the piston and connections of rims were made. The rim shown in Figure 4 is one of the most important parts of the landing gear which is attached to the wheels and which connects with the shaft. The rims of the landing gear are made of alloy steel.

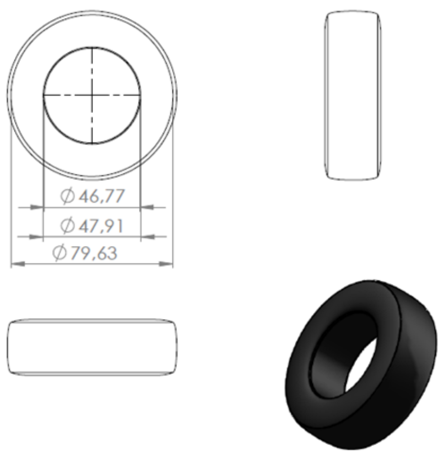

Figure 5. The wheel of the landing gear

The technical robustness of rims and wheels is important during take-off and landing of aircraft. Breaking rims or bursting wheels are cause serious damage to the aircraft, such as when the aircraft will be unbalanced on landing and take-off. Therefore, appropriate rims and wheels must be selected.

Each piece of the landing gear was assembled at the assembly part of the SolidWorks program to form the landing gear shown in Figure 6.

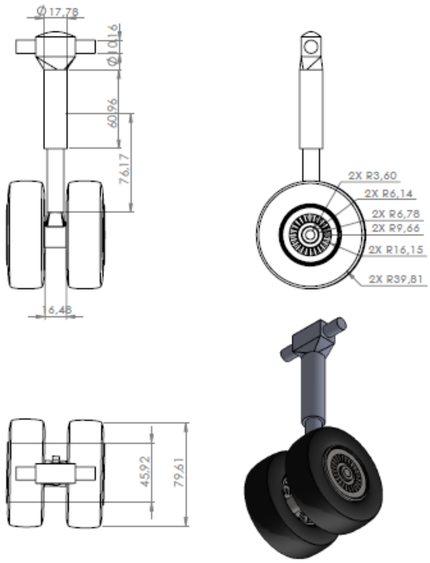

Figure 6. Technical picture of the auxiliary landing gear

In the second stage of the numerical study, stress-deformation analysis was realized out in the Ansys program of the landing gear which was constructed with reference to the nose landing gear of the F16 aircraft. When the stress-deformation analysis is performed, the structure module is used in the Ansys program. In SolidWorks, two different landing gear models, which were created by changing the shaft diameter of the landing gear we designed, were transferred to the structure module respectively. The figure transferred to Ansys is shown in Figure 6.

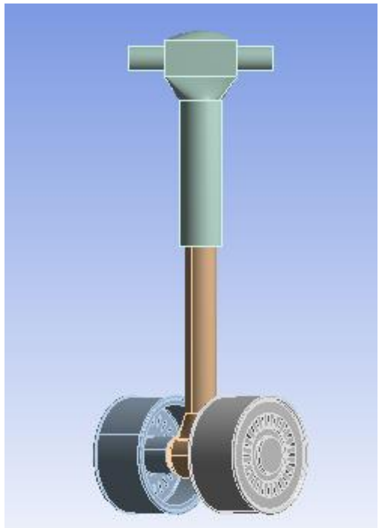

Figure 7. Display of landing gear at Ansys

When the analyzes were done, the volume of each part of the landing gear is different from each other, so it was chosen as *2 mm* when constructing mesh structure of the landing gear. This 2 mm represents the maximum length that one edge of each piece should take. In addition, since the number of elements on the contact surfaces of the five parts is useful in terms of resolution accuracy, the size of the mesh structure for the contacting surfaces of the five parts is chosen to be 1 mm. Figure 8 show that the mesh structure of the landing gear as a result of this measurement.

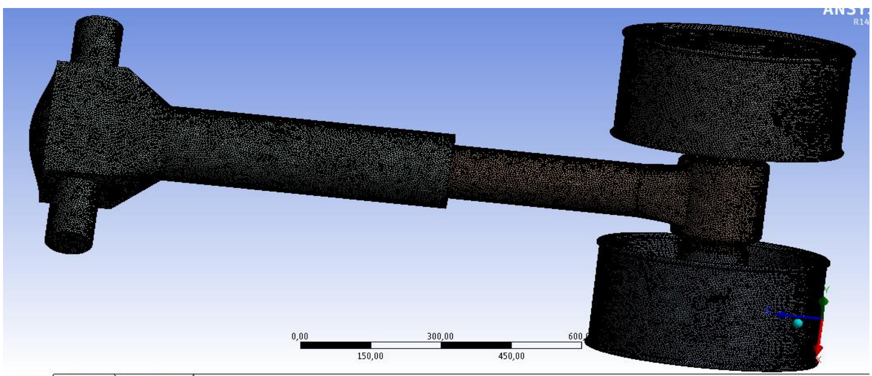

Figure 8. Mesh structure of the landing gear

In addition, two cases has been considered in the stress-deformation analyzes that we made. The first of these cases, the cylinder is supported with fixed support from the top as a boundary condition to different shaft size landing gear models as shown in Figure 9. On the other hand, force (*385,6 N*) was applied to the rims of the aircraft as much as one third of the weight of a aircraft (*385,6 KN*). In the second model shown in Figure 10, as a boundary condition, a rotation torque of *100 N.m* was applied in addition to the boundary conditions of the first model.

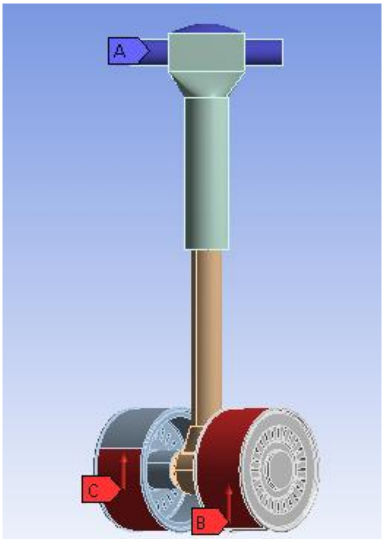

Figure 9. Boundary conditions of the first model

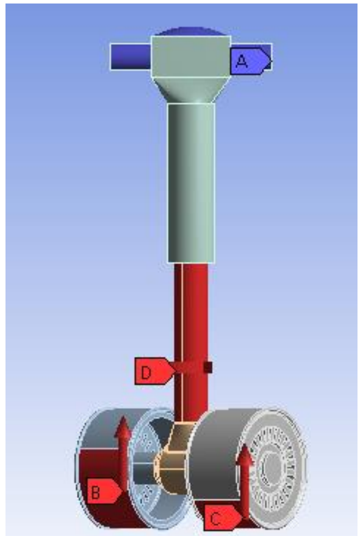

Figure 10. Boundary conditions of the second model

As a final step, we need to define what kind of results we want in the "Solution" section before analyzing in order to determine the results necessary for stress-deformation analysis. In this study, Von-Mises (Equivalent) stresses, maximum shear stresses and Total Deformations were defined and analyzed. One of the parts of the landing gear, the radius of the shaft was increased from *36 mm* to *52 mm* and a new geometry was created. The Ansys Workbench values were examined by comparing these two geometries that we created. In the case of the *36 mm* landing gear shown in Figure 11, the deformation mostly occurred at the rim parts and the average values were found to be $2{,}4644.10^{-6}\ m$. Figure 12 shows that the rims are the most deformed parts of the *56 mm* landing gear and their average values are $4{,}617.10^{-6}\ m$.

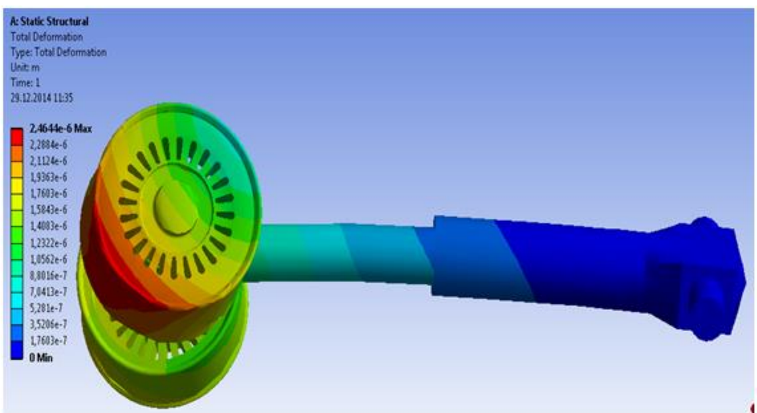

Figure 11. First model and total deformation in the *36 mm* landing gear

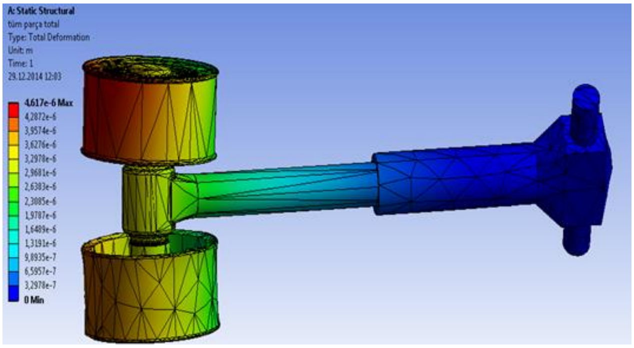

Figure 12. First model and total deformation in the *52 mm* landing gear

In Figure 13, the maximum basic stresses in the *36 mm* landing gear have formed at the piston part and the average value is *2.516,105 Pa*. In Figure 14, the maximum basic stresses of the landing gear with a shaft radius of *52 mm* takes place at the piston and its value is *2.0989,105 Pa.*

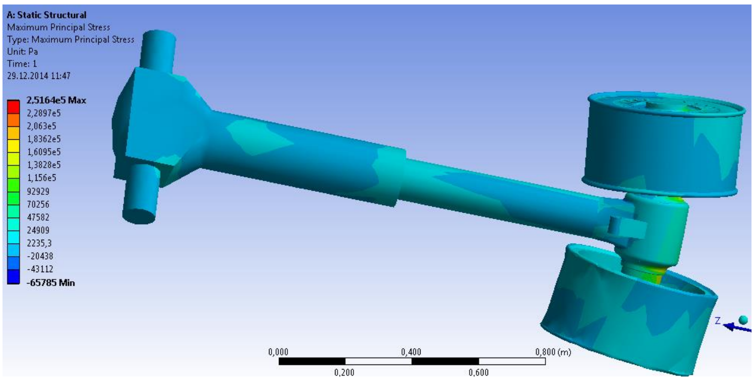

Figure 13. First model and maximum stresses in *36 mm* landing gear

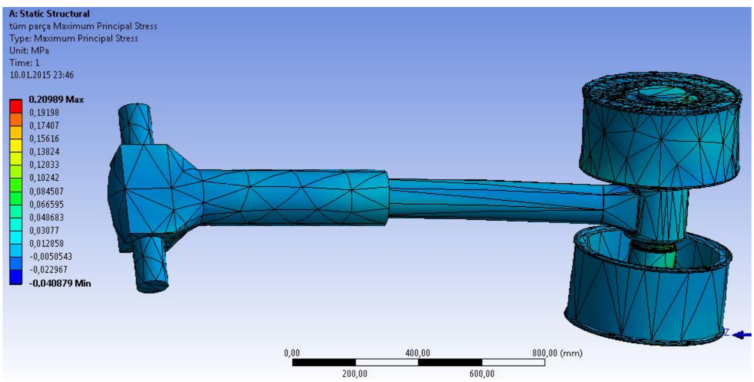

Figure 14. First model and maximum stresses in *52 mm* landing gear

The total amount of deformation to be formed in the second model landing gear with a shaft radius of *52 mm* is shown in Figure 15.

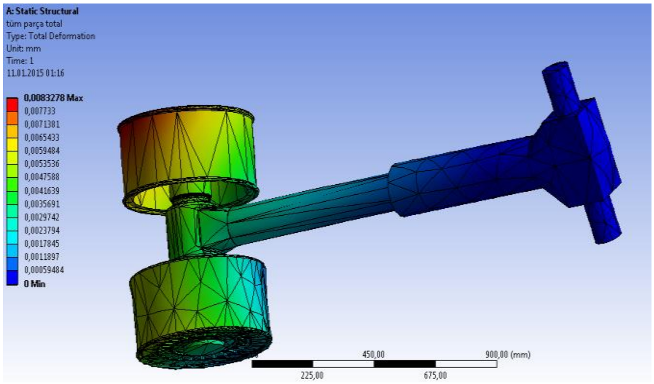

Figure 15. Second model and total deformation of *52 mm* landing gear

Maximum value of average deformation of second model and 52 mm landing gear model shown in Figure 15. is 0,0083278 mm. The maximum total deformation value of the first model and *52 mm* of the landing gear shown in Figure 12. is *0,004617 mm*. When we applied a torque of $100\ N.m$ to the landing gear, the total deformation amount increased about *1.8* times. The maximum stresses to be formed in the second model landing gear with a shaft radius *of 52 mm* are shown in Figure 16.

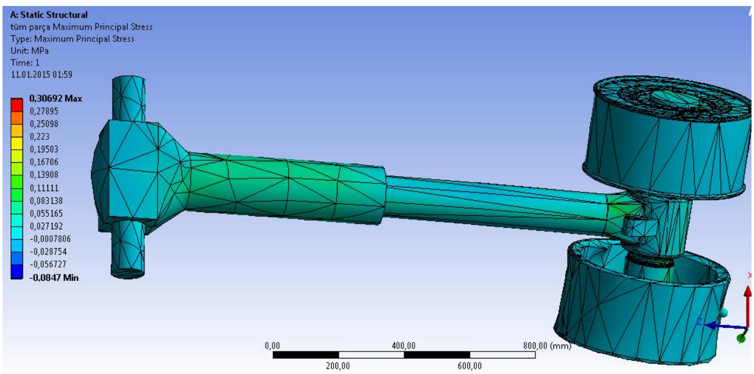

Figure 16. Second model and maximum stresses of *52 mm* landing gear

It is seen that the maximum amount of stress in the second model and the *52 mm* landing gear shown in Figure 16 is *0,30692 MPa.*

In Figure 14, the value when we apply moment to the landing gear is *0.20989 MPa*. As a result, when we apply a moment, the maximum amount of stress increases. It is also seen that the value of the stress generated in the cylinder part of the landing gear increases.

When the study is examined, it is seen that the most deformation values are found in the rim and the shafts of the landing gear. The total deformation of the *36 mm* rim part is given in Figure 17 and its value is 0.00*2464 mm.* Figure 18 shows the total amount of deformation in the *52 mm* rim and the value is 0.00*4617 mm.* When 100 *N.m* torque is applied to the landing gear, it is seen that the total deformation amount in the rim part is 0.0083278 *mm* in Figure 19.

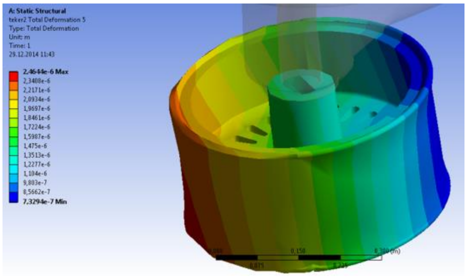

Figure 17. The total deformation of the rim part when the shaft radius of the landing gear is *36 mm* and first model.

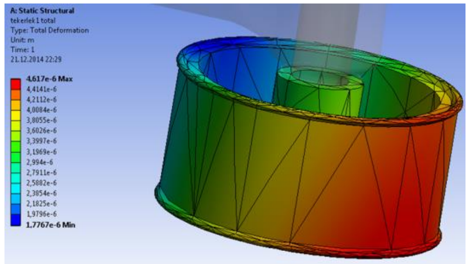

Figure 18. The total deformation of the rim part when the shaft radius of the landing gear is *52 mm* and first model.

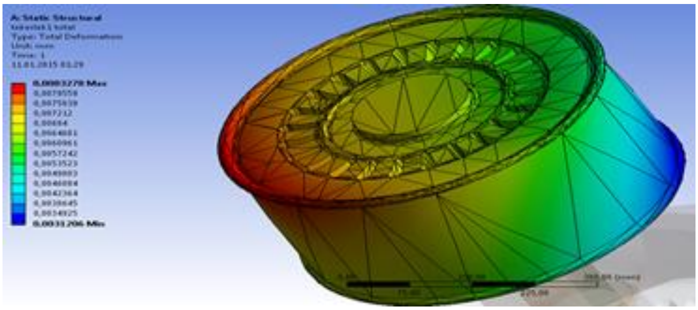

Figure 19. The total deformation of the rim part when the shaft radius of the landing gear is *52 mm* and second model.

The total deformation of the shaft part is shown in Figure 20. And the value is 0.001*677 mm*. In Figure 21 is showed the total deformation of the shaft in the geometry that we made the radius of the shaft to *52 mm*. And the value is 0.00*35518 mm*. It is seen that the maximum total deformation amount in the second model shaft part is 0.00*6924mm* in Figure 22.

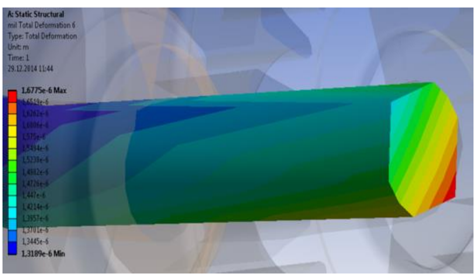

Figure 20. The total deformation of the shaft part when the shaft radius of the landing gear is *36 mm* and second model.

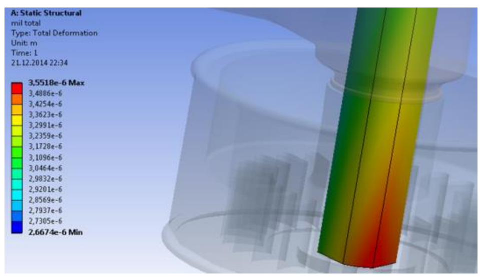

Figure 21. The total deformation of the shaft part when the shaft radius of the landing gear is *52 mm* and first model.

Numerical comparison of deformation amounts of *36* and *52 mm* for model first of the landing gear is given in Figure 23.

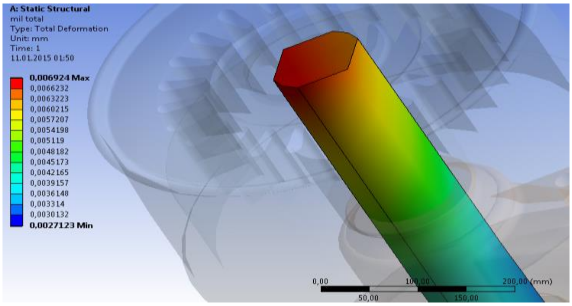

Figure 22. The total deformation of the shaft part when the shaft radius of the landing gear is *52 mm* and second model.

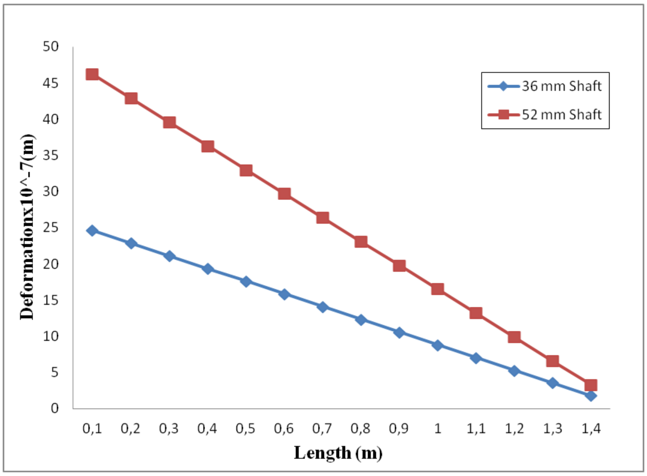

Figure 23. 1st Model-Length-Deformation amount

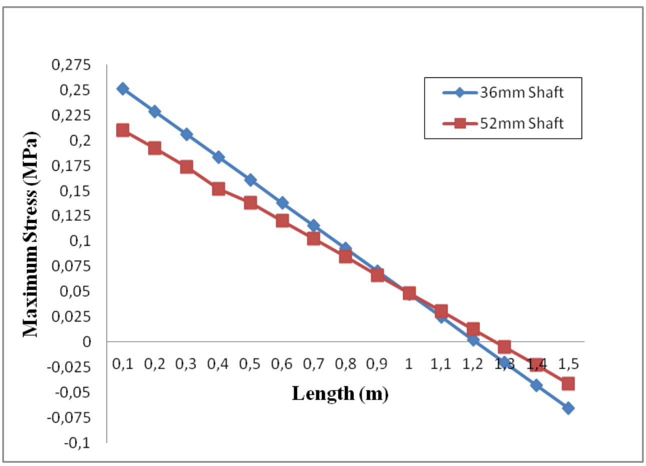

Figure 24. 1st Model-Length-Maximum stress

As shown in Figure 23, due to the force given from the rim part, it has undergone more deformation near the rim part (x-axis is 0,1). Also the deformation is approaching more than to zero towards the fixed support part.

The total amount of deformation that occurs in the system where the shaft diameter is large is larger than the total deformation in the system where the shaft diameter is small. In this case it is necessary to reduce the shaft diameter in order to reduce the total amount of deformation.

As seen in Figure 24, the maximum stresses in the landing gear are inversely proportional to the shaft diameter. In Figure 25, when the shaft radius is *52 mm* in the landing gear and a *100 N.m* torque is applied to the piston part, the maximum value of the total amount of deformation is *0.0083278 mm*. When the moment is not applied, the maximum total deformation value is *0.004617 mm* only when force is applied. As a result, the moment increases the amount of maximum deformation when applied to the system. In Figure 26, when we apply a moment, the maximum amount of stress increases.

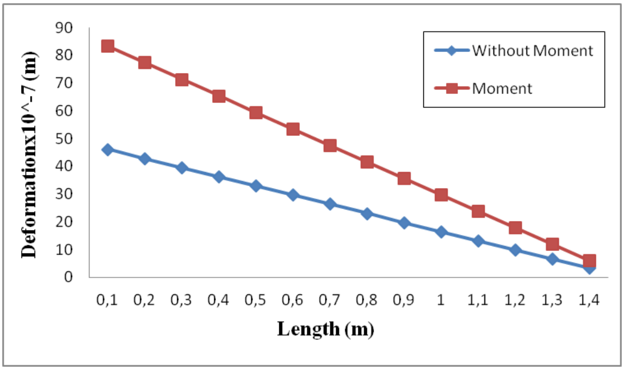

Figure 25. Total deformation without Moment-Moment

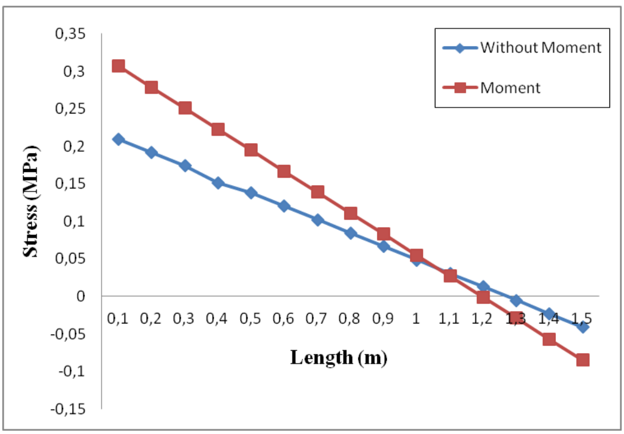

Figure 26. Total stress without Moment-Moment

3. CONCLUSIONS

In this study, the drawing of the nose landing gear, one of the auxiliary landing gears of the F16 aircraft is performed in SolidWorks and the stress-deformation analyses are carried out in the Ansys program.

The auxiliary landing gear consists of 5 parts: cylinder, piston, shaft, rim and wheel. In SolidWorks, two drawings are constructed: a *36 mm* radius landing gear linking the rims and a *52 mm* radius landing gear. Ansys Workbench 14.5 transfer of these landing gear models we have drawn in SolidWorks has been realized and 2 models have been created. In the Ansys program for Model 1, the analysis is performed by giving the same boundary conditions for the two drawings. As a boundary condition, the forces to be applied to the rim parts in the size of *385,6 N* and the solutions to be formed as a result of selecting the fixed support of the cylinder have been compared. In the second model, a torque of *100 N.m* is applied to the piston of the landing gear that a shaft radius of *52 mm*.

Two main results are obtained from the analysis of stress and deformation. One of those results is that, there is increase in maximum deformation and decrease in maximum stress when the shaft radius in the landing gear is increased. Second of those results, depending upon the moment amount there are the increase in maximum stress and maximum deformation when a moment is applied to cylinder of the landing gear.

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