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Finite Element Analysis of Camshaft Using Inventor Software

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Abstract: ***In this work the 3D model of the camshaft was done using Autodesk Inventor version 2021 with the literature data and finite element analysis is performed by applying restrictions and loads conditions, first by the absence of the torque and then by applying the torque. Three materials were analyzed in both situations: Cast Iron, Stainless Steel AISI 202 and Steel Alloy. Following the comparative study for the three materials, it can be specified the importance of the material for the construction of the camshaft.***
Keywords: Camshaft, Static analysis, Autodesk Inventor

I. INTRODUCTION

Camshafts are used to control engine exhaust and intake timers. Not only do they control the timing of valve opening and closing, but they also withstand the pressure of the exhaust valve pressure. It can be said that the camshaft is the engine brain, if the brain had a problem in work, then there will be a negative effect on the engine body work. The main problem is the vibration of the camshaft and its deformation.

The camshaft frequency and load deformation are performed using the finite element method which provides approximate values of the problem but also provides maximum safe values for design and functioning.

J. Zu et al. [1] designed and optimized a new camshaft model, by analyzing the unique cam mechanism, analyzed the contact tensions, radius of curvature and pressure angle, considering the output torque as the main objective of the design. He then compared the results and optimized them using the method of genetic algorithms [2] for both the conventional engine and the cam-driven engine.

The general polynomial curves were used to represent the profiles of both the intake and exhaust cams (stroke), which increased the average torque by 18%. A modified curve equation called "B-splines" [2] was used to increase the performance of the analysis and is improved by 24%. In addition, the output torque generated by the best profiles increased by 28% compared to that generated by the initial profiles.

Dhavale et al. [3] discussed stress analysis and camshaft failure analysis also represented the importance of the camshaft in an engine. They derived some relationships by analyzing the specific material for the manufacture of the camshaft, also analyzed the results using the FEM method. Dhavale used iron alloy with specific weight ratios of various elements such as carbon, silicon, manganese, molybdenum, nickel, aluminum copper, titanium, magnesium, sulfur, phosphorus, 3.42%, 2.33%, 0.296%, 0.010%, 0.038%, 0.010%, 0.518%, 0.028%, 0.026%, 0.009%.

The camshaft stress analysis was performed to determine the stress concentration level in the breaking region by the finite element method. The damage occurs as a sudden break very close to the place where there was a concentration of stresses. The main reason for the break was determined to be a casting defect. It was found that the fault is related to the production of the camshaft material.

Mali et al. [4] used the finite element method to perform the analysis and generated the results. The obtained frequency of the existing roller was in the range of 828.32 Hz at 3272.8 Hz, and frequency for the modified rollers was in the range of 953.60 Hz at 3162.7 Hz. The maximum values of the deformation for the existing roller was 23.41 mm and for the modified roller was 21.675 mm, resulting in an improved mechanical efficiency of the internal combustion engine of 65% to 70%.

Duque et al. [5] analyzed the contact pressure generated between the camshaft and the roller pin and compared the contact pressure generated between the camshaft and the roller pin of a cast iron camshaft and an assembled camshaft. They also suggested that the assembled camshaft is a good solution to reduce engine weight and performance. They used FEM to design the desired camshaft model and analysis. They first performed some simulations on the ordinary camshaft to define an acceptable value of the contact pressure after which they introduced the assembled camshaft. After investigation, the theory suggested that the camshaft should be made of steel that should be induction treated to at least 1 mm and up to 60-64 HRC, and the roller should also be made of steel carburized with induction treatment up to at least 0.08 mm.

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Volume 9 Issue XII Dec 2021- Available at www.ijraset.com

Marmik Kumar et al. [6] designed, remodeled and analyzed the camshaft using FEM, to make the camshaft robust and versatile for all possible loading conditions. They also analyzed the dynamic behavior of the camshaft under load conditions to calculate the exact value of the load for optimal operation of the camshaft. From the FEM analysis they found that the maximum voltage was 240.6 N / mm2, the safety factor falls within the safety limits.

Wanjari et al. [7] analyzed the different results of the camshaft at different speeds and loading conditions. They analyzed the reasons for the failure and the factors that influence the performance of a camshaft, analyzed the modification of the camshaft material, so that the heat flow and shear stresses are balanced in some satisfactory regions. The shear stress values in gray cast iron were minimal and the total deformation value was low for forged steel.

The maximum value of the shear load and the total deformation was obtained for maximum values of the loads 3500N and 5000N. The maximum value of the stresses is obtained in the initial stage of starting the vehicle when it was functioning at 1650 - 1950 rpm. The conclusion was that the gray cast iron is the best material for making the camshaft for the vehicle to pass this engine speed range as soon as possible.

S. G. Thorat et al. [8] calculated the loading conditions of the camshaft based on the engine specifications, using Ansys and also used the formulas for the total camshaft deformation for a load of 1134 N and obtained 0.00059 mm a total deformation for camshaft. He compared the results obtained by calculations with those obtained with the Ansys software.

Jasdanwalla et al. [9] calculated, using Ansys software, the cam deformation for different materials under loading conditions. They calculated the deformation in the cam, the total pressure and load, simultaneously calculated the total deformation of the exhaust cam, the combustion cam and the intake cam.

Some of the researchers analyzed the crack of the camshaft, calculated the maximum load that a camshaft can support, using different materials, such as cast iron and stainless steels, but did not get the desired results, there was always some deficiency of camshaft resistance. Then they performed a tribological analysis on the camshaft. They changed the behavior and nature of the contact between the follower and the camshaft and replaced the flat follower with the round follower, which led to improved results in terms of reducing wear and friction between the follower and the cam.

II. CAMSHAFT DESIGN

Solid modeling of the camshaft was done using Autodesk Inventor version 2021 with the literature data.

The solid models of the camshaft are shown in Fig. 1.

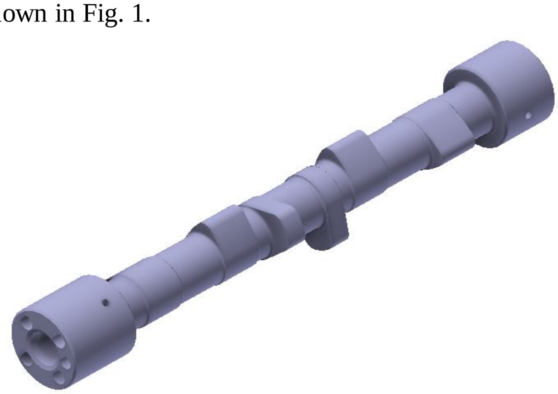

Fig. 1 A geometrical model of the camshaft

III.STATIC ANALYSIS IN THE ABSENCE OF TORQUE

To determine the state of stresses and strains, the finite element analysis of the camshaft was performed with the Autodesk Inventor software.

A. Choosing Material

Knowing that the material from which the camshafts are made must ensure complex conditions of rigidity and surface hardness and that the shafts are made of alloy steels with medium carbon content, from the program library were chosen the materials with the properties in Table 1.

TABLE I
Material Properties

Parameters	Cast Iron	Stainless Steel AISI 202	Steel Alloy
Young's Modulus [MPa]	120500	204773	205000
Poisson's Ratio	0.30	0.29	0.30
Shear Modulus [MPa]	58100	79978.8	80000
Mass Density [Ns^2/mm^4]	7.15E-09	7.855E-09	7.73 E-09
Tensile Strength [MPa]	884	667.409	400
Yield Strength [MPa]	758	412.304	250

B. The Restrictions Condition

After adopting the material, we applied the limit conditions, in accordance with the information in the literature [6] – [8], namely: 1. pin constraint, Fig. 2 and fixing the shaft end, Fig. 3.

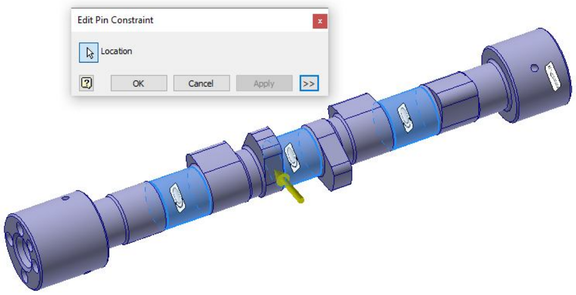

Fig. 2 Pin Constraint

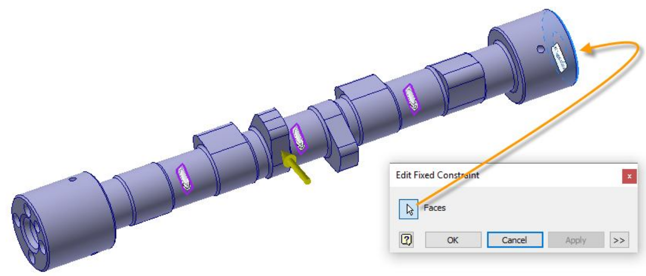

Fig. 3 Fixed Constraint

C. Load Conditions

The next step was to apply loads to the camshaft.
Applying a force with the value of 10346.467 N on one of the cams of the shaft Fig. 4.

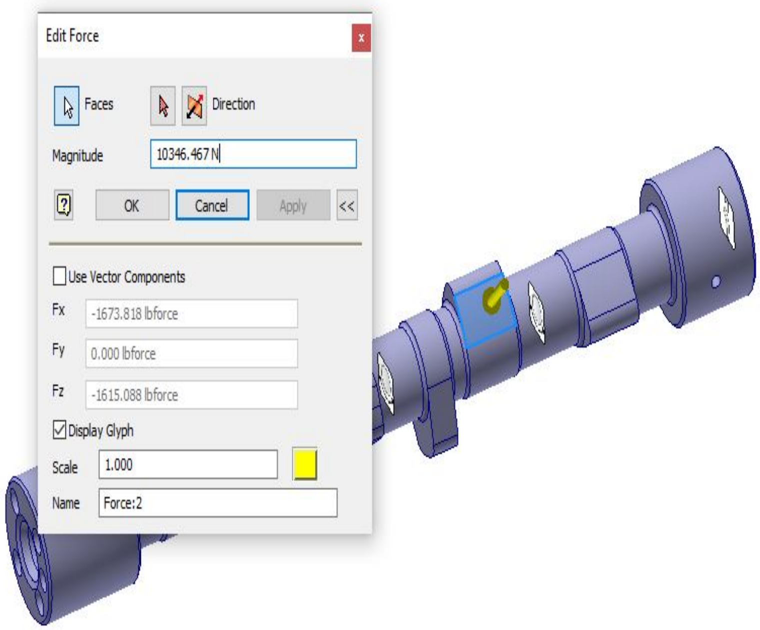

Fig. 4 Force applied to the rim

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ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue XII Dec 2021- Available at www.ijraset.com

D. Generate Meshing

To generate the discretization, the automatic generation mode with tetrahedral elements was used, the solid model being discretized in 13676 elements and 21590 nodes, the discretization of the shaft being presented in Fig. 5.

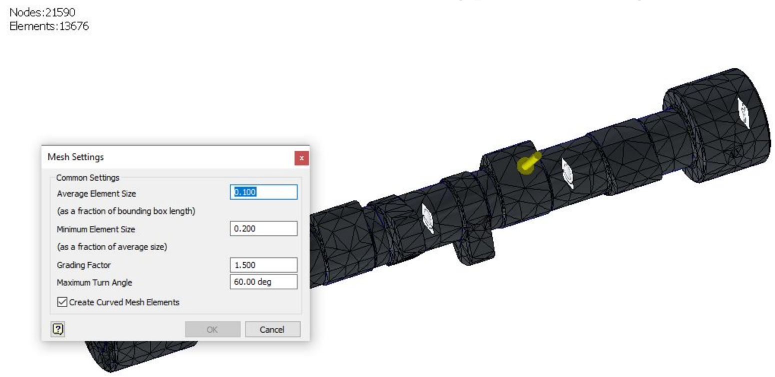

Fig. 5 Force applied to the rim

E. Static Analysis Results

1) *Cast Iron Results:* After completing these steps, the analysis was performed and a complex report was generated with all the results obtained for each material. The following figures show the results obtained from the FEM analysis for the Cast Iron camshaft. The maximum value of Von Mises stress is 105.7 Mpa, a value that falls within the allowable limits. The maximum deformation was 0.048 mm, and the minimum value of the safety factor was 7.17.

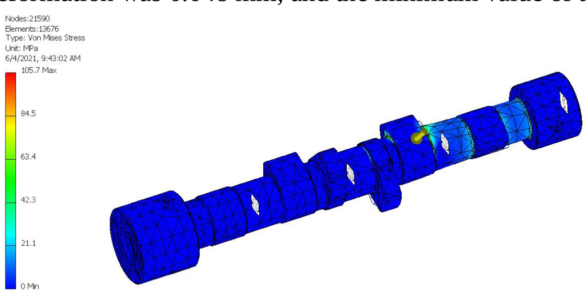

Fig. 6 Von Mises stress – *Cast Iron* camshaft

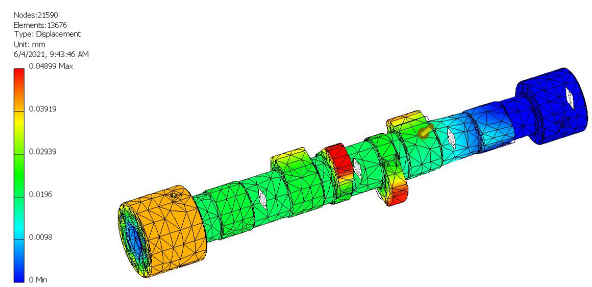

Fig. 7 Total deformation - *Cast Iron* camshaft

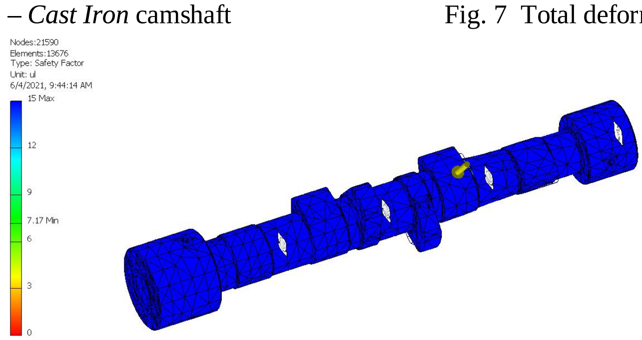

Fig. 8 Safety factor - *Cast Iron* camshaft

2) *Stainless Steel AISI 202 Results:* Fig. 9 - 11 shows the results of the analysis for the Stainless Steel AISI 202 camshaft. It is observed that the maximum value of Von Mises stress is 106.2 MPa. The maximum deformation was 0.028 mm, and the minimum value of the safety factor was 3.88.

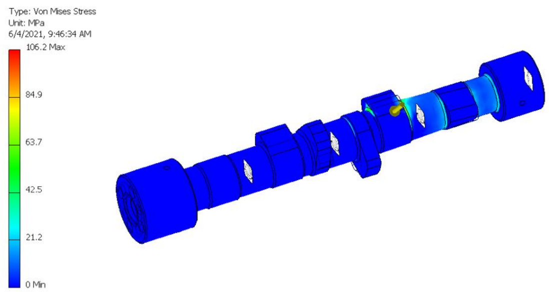

Fig. 9 Von Mises stress – *Stainless Steel* camshaft

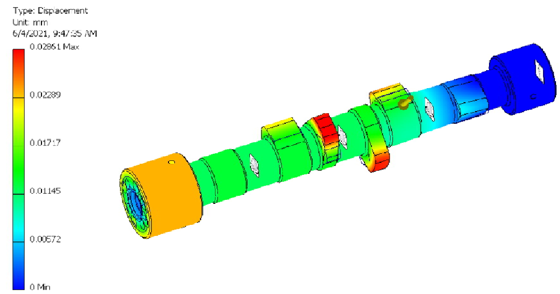

Fig. 10 Total deformation - *Stainless Steel* camshaft

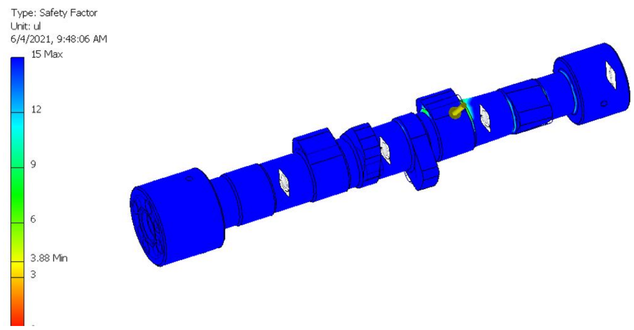

Fig. 21 Safety factor - *Stainless Steel* camshaft

3) *Steel Alloy Results:* The following figures show the results obtained from the FEM analysis for the Steel Alloy camshaft. It is observed that the maximum value of Von Mises stress is 106.7 MPa. The maximum deformation was 0.028 mm, and the minimum value of the safety factor was 2.37.

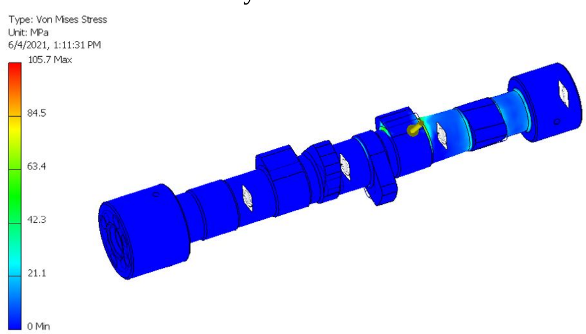

Fig. 12 Von Mises stress – *Steel Alloy* camshaft

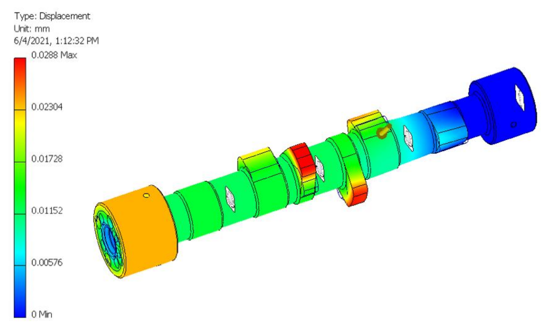

Fig. 33 Total deformation - *Steel Alloy* camshaft

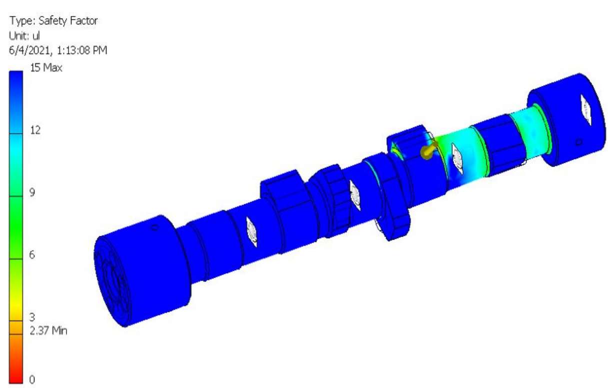

Fig. 44 Safety factor - *Steel Alloy* camshaft

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Volume 9 Issue XII Dec 2021- Available at www.ijraset.com

IV. STATIC ANALYSIS IN THE CONDITION OF IMPOSING THE TORQUE

Fig. 15 shows the results for the Von Mises stress when the torque is imposed. The maximum value of stresses is 104.1 MPa and is recorded at the end of the section straight to the cam on which force was applied, a value that falls within the allowable limits. The maximum deformation was 0.045 mm, and the minimum value of the safety factor was 7.29.

A. Cast Iron Results

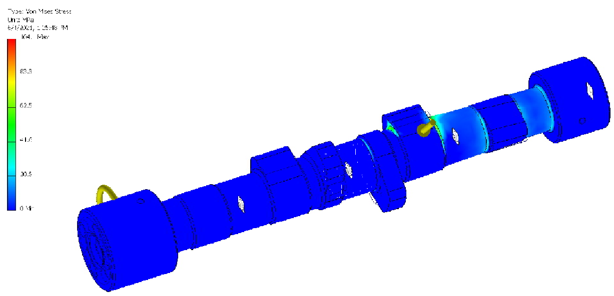

Fig. 15 Von Mises stress – *Cast Iron* camshaft

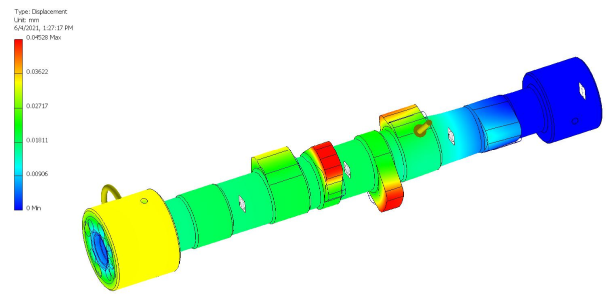

Fig. 56 Total deformation - *Cast Iron* camshaft

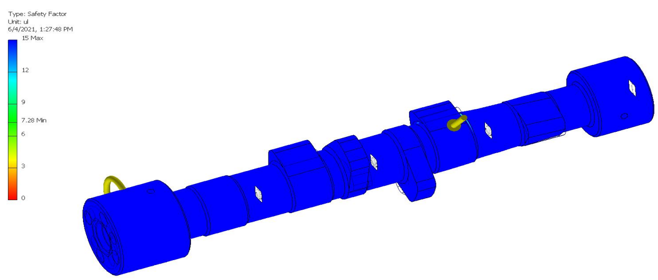

Fig. 67 Safety factor - *Cast Iron* camshaft

B. Stainless Steel AISI 202 Results

Fig. 18 - 20 shows the results of the analysis when applying the torque for the Stainless Steel AISI 202 camshaft. It is observed that the maximum value of Von Mises stress is 104.6 MPa and is recorded at the end of the section straight to the cam on which force was applied, a value that falls within the allowable limits. The maximum deformation was 0.026 mm, and the minimum value of the safety factor was 3.94.

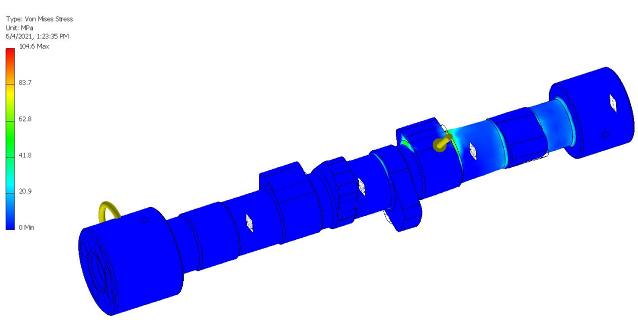

Fig. 18 Von Mises stress – *Stainless Steel* camshaft

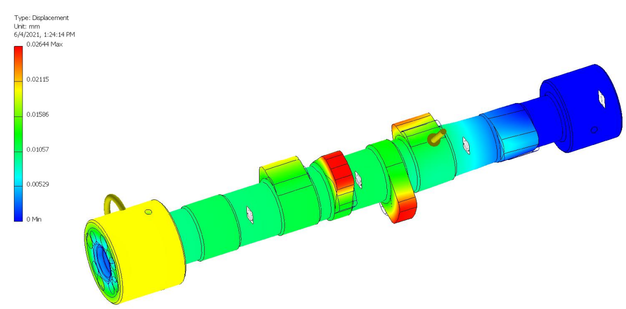

Fig. 79 Total deformation - *Stainless Steel* camshaft

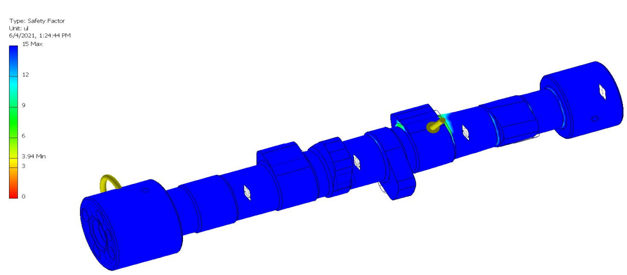

Fig. 20 Safety factor - *Stainless Steel* camshaft

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Volume 9 Issue XII Dec 2021- Available at www.ijraset.com

C. Steel Alloy Results

The following figures show the results of the FEM analysis in case of torsion application for the steel alloy camshaft. The maximum value of the Von Mises stress was 104.1 MPa, close to the values obtained when using the other materials. Instead, larger differences were recorded for the safety factor that recorded the value of 2.4, Fig. 23.

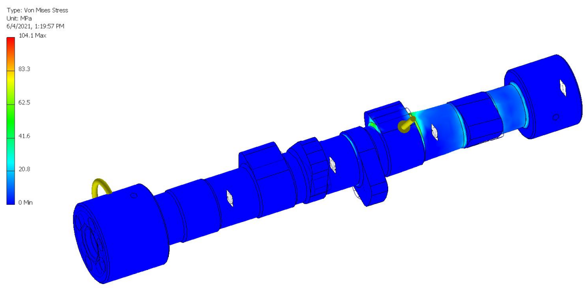

Fig. 21 Von Mises stress – *Steel Alloy* camshaft

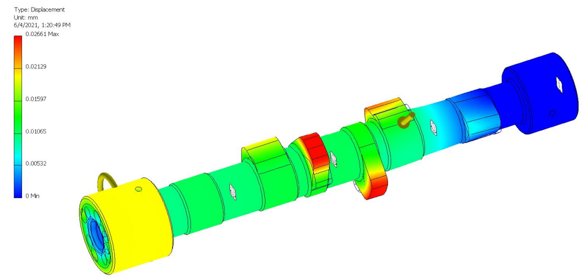

Fig. 22 Total deformation - *Steel Alloy* camshaft

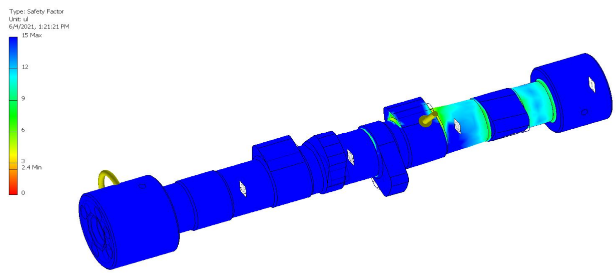

Fig. 23 Safety factor - *Steel Alloy* camshaft

V. CONCLUSION

This work presents a study on how to check camshaft by using finite element analysis. In order to determine the state of tension, deformations and safety factor, the solid model of the camshaft was made using the Autodesk Inventor 2021 software.

The paper presents a comparative study by assigning three materials used in the construction of the camshaft: Cast Iron, Stainless Steel AISI 202 and Steel Alloy, in order to choose the optimal variant to meet the requirements of strength and reliability of road vehicles. Two types of static analysis were performed, one in the absence of the torque and the other in the case of applying a torque to the camshaft. From the resulting data it can be seen that in the absence of the torque, approximate values were recorded for the Von Mises stresses, for the three materials. Larger differences were reported in the case of the safety factor and the value of the total deformations. In the situation of applying the torque, it is observed that the Von Mises stress tend to become uniform, larger differences remaining between the values of the safety factor.

It can be concluded that all three materials analyzed meet the imposed requirements, but Steel Alloy is the material with the best correlation between the analyzed parameters.

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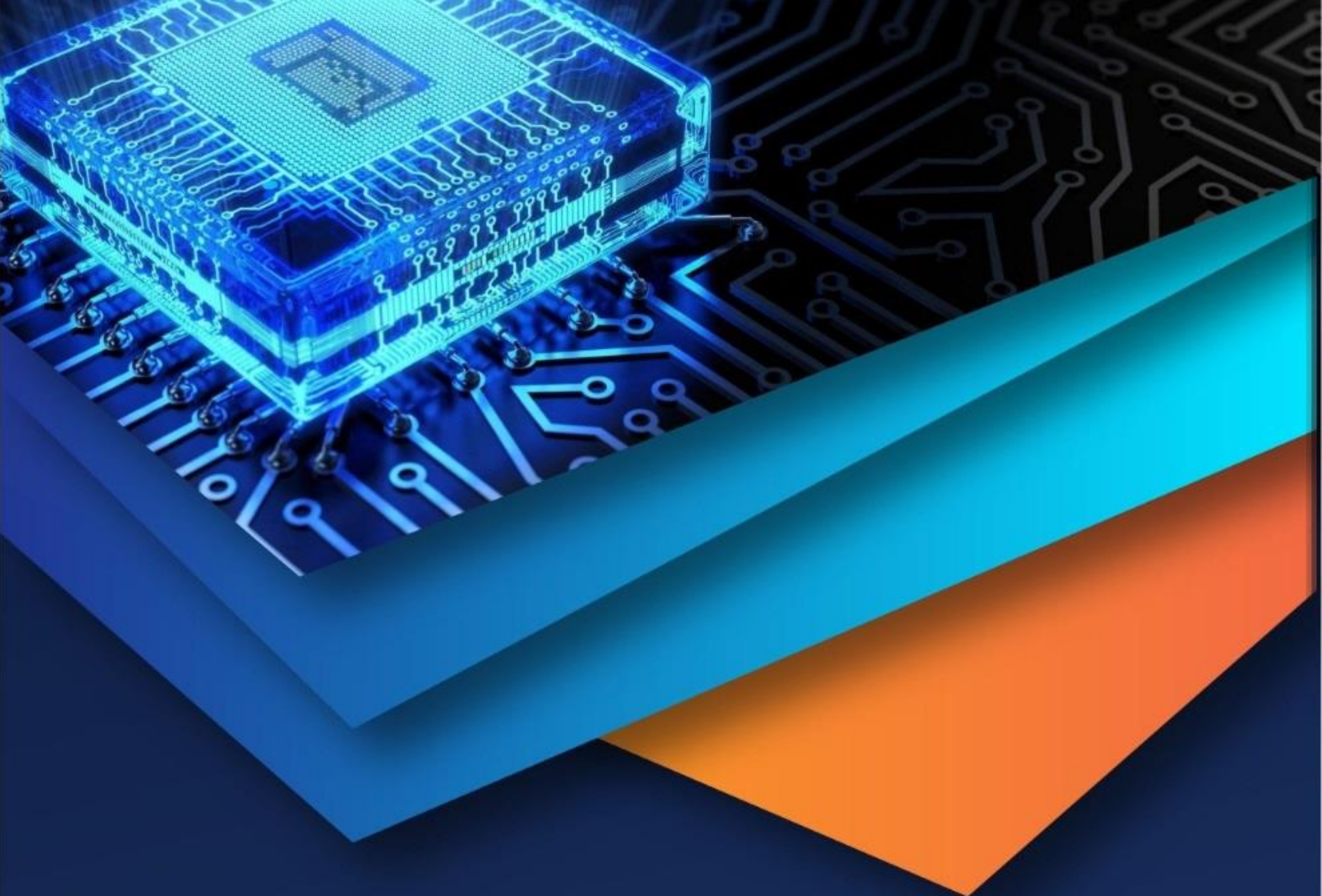

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