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STATIC AND TRANSIENT ANALYSIS OF RACK AND PINION

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Abstract: This project Rack and pinion gears are used to convert rotation into linear motion.The flat, toothed part is the rack and the gear is the pinion. A piston coaxial to the rack provides hydraulic assistance force, and an open centered rotary valve controls the assist level. A rack and pinion gears system is composed of two gears. The normal round gear is the pinion gear and the straight or flat gear is the rack. The rack has teeth cut into it and they mesh with the teeth of the pinion gear. A ring and pinion gear is the differential's critical point of power transfer. A ring and pinion gear set is one of the simplest performance modifications that can be performed on a vehicle. In this project I have analysed the Rack and pinion system by doing Static structural analysis, modal analysis, Transient static structural analysis and fatigue analysis. In all these analyses I have used the same mesh size (same number of nodes and same number of elements) for the purpose of comparison of the result.
Keywords: “*Ansys Workbench, Rack , Pinion, Basalt Fiber, Kevlar Fiber, E-Glass Fiber*”

I.NTRODUCTION

1. Introduction to Rack and Pinion

The advantages of high transmission efficiency, strong carrying capacity and the stability of the transmission ratio, the gear and rack transmission system is commonly used in force and motion transmission in the mechanical system. The reliability and stability of the gear and rack directly influences the regular operation of the mechanical equipment.

Fig.1.1 Rack and Pinion gear assembly.

The traditional measures are usually used to calculate the contact stress and bending stress which can only help obtain the value of a single point of time on one Contact surface[1].

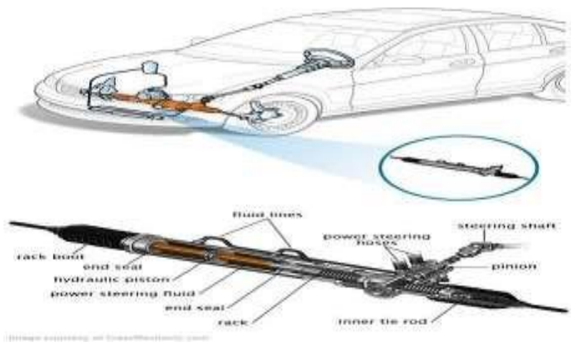

Fig.1.2 Rack and Pinion gear Assembly in car.

Thus the figure 1.2 shows the rack and pinion, Moreover, it has the following problems: complicated calculation process, time- consuming, in exactitude of the calculated result. The structure static analysis is a systematic verification process in steady load.

However, when the load changes with time, the dynamics and statics characteristics which the system represented are different. The three dimensional model of the gear and rack transmission system was built by the 3D design software UG, and the model analysis was conducted on the gear and rack transmission system by the software of ANSYS Workbench in order to identify the natural frequencies of the gear and rack transmission system. On this basis, transient dynamic analysis of the gear and rack system is carried out to get equivalent stress distribution at different times in the gear and rack meshing contact process and the strength of contact and bending strength of the gear and rack is examined [2].

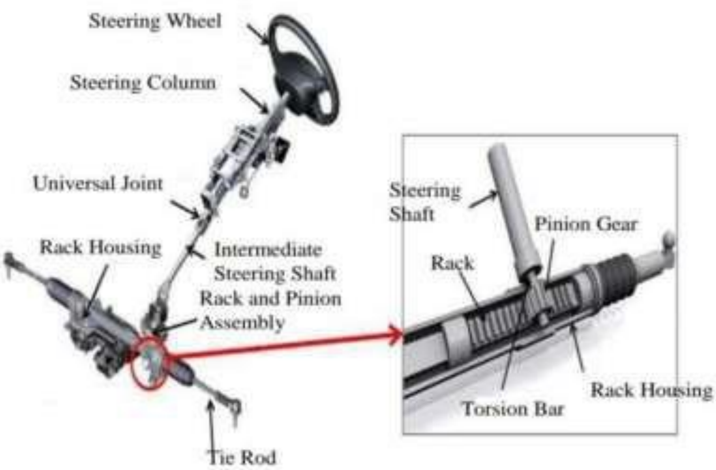

Fig.1.3 Rack and Pinion gear in steering system.

The figure 1.3 shows the picture of the Car bonnet (Hood) The hood or bonnet is the hinged cover over the engine of motor vehicles that allows access to the engine compartment, or trunk on rear-engine and some mid- engine vehicles) for maintenance and repair [4]. Hoods are typically made out of the same material as the rest of the body work. This may include steel, aluminum, fiberglass or carbon fiber. In our project, we are going to replace the mentioned material, which is used to manufacture the hood with the Composite Fibers.

2.MODELLING OF RACK AND PINION:

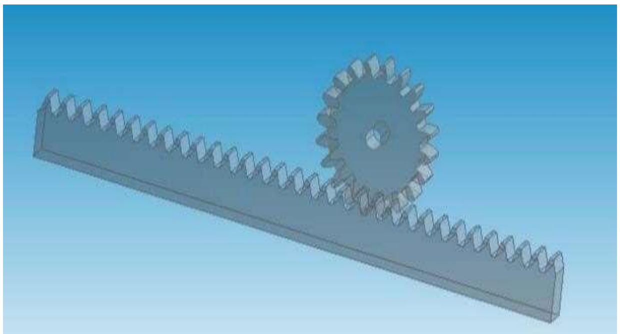

Fig.2.1 Modelling of Rack and Pinion gear Assembled .

3.MATERIAL SELECTION OF RACK AND PINION:

1. AL 7475

Density: 2.81g/cc
Young's Modulus: 70.3GPa
Poisson's Ratio: 0.33
Thermal Conductivity: 163 W/m-K
Specific Heat Capacity: 0.88 J/g-°C

2. Nickel Aluminium Bronze Alloy

Density: 7.53g/cc
Young's
Modulus:110GPa
Poisson's Ratio: 0.32
Thermal Conductivity: 41.9 W/mK
Specific Heat Capacity:419.0 J/kg.

3 .Graphite Cast Iron

Density: 7.91g/cc
Young's Modulus:
99GPa
Poisson's Ratio: 0.21
Thermal Conductivity: 46 W/mK
Specific Heat: 490 J/kg.

4 . Sand Cast Magnesium Alloy

Density: 1.81g/cc Young's Modulus:
45GPa Poisson's Ratio: 0.35
Thermal Conductivity: 62W/m.K
Composition: Aluminium 10.7%
Magnesium 90%

4. MESHING OF RACK AND PINION.

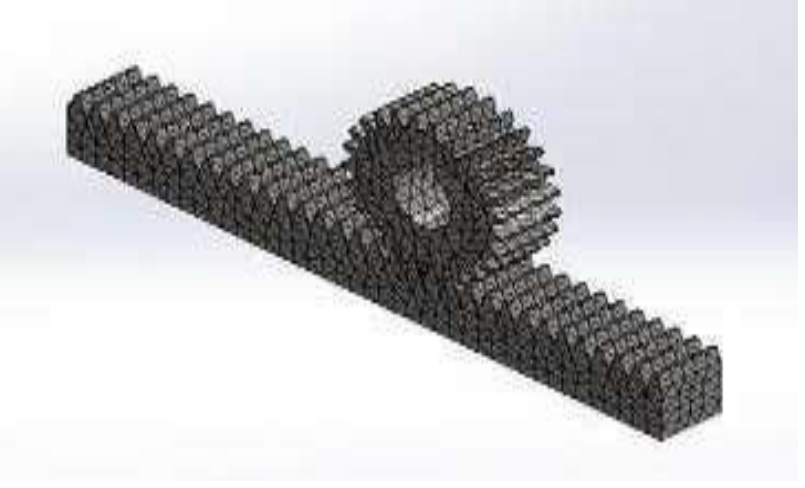

Fig.4.1 Meshing of Rack and Pinion**.**

Thus, the figure 4.1 show the meshing of the rack and pinion tetra-hex.

5.STATIC STRUCTURAL ANALYSIS:

A static structural analysis determines the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time. A static structural load can be performed using the ANSYS, Samcef, or ABAQUS solver.

The types of loading that can be applied in a static analysis include:

1.Externally applied forces and pressures

2.Steady-state inertial forces (such as gravity or rotational velocity)

3.Imposed (nonzero) displacements

4.Temperatures (for thermal strain)

Preparing the Analysis

1.Analysis System

2.From the Toolbox, drag a Static StructuralStatic Structural (Samcef),

3.Define Engineering Data.

Material properties can be linear or nonlinear, isotropic or orthotropic, and constant or temperature- dependent. You must define stiffness in some form (for example, Young's modulus, hyperelastic coefficients, and so on). For inertial loads (such as **Standard Earth Gravity**), you must define the data required for mass calculations, such as density.

Attach Geometry

A “rigid” part is essentially a point mass connected to the rest of the structure via joints. Hence in a static structural analysis the only applicable loads on a rigid part are acceleration and rotational velocity loads. You can also apply loads to a rigid part via joint loads. The output from a rigid part is the overall motion of the part plus any force transferred via that part to the rest of the structure. Rigid behavior cannot be used with the Samcef or ABAQUS solver.If your model includes nonlinearities such as large deflection or hyperelasticity, the solution time can be significant due to the iterative solution procedure. Hence you may want to simplify your model if possible. For example you may be able to represent your 3D structure as a 2-D plane stress, plane strain, or axisymmetric model or you may be able to reduce your model size through the use of symmetry or anti symmetry surfaces. Similarly if you can omit nonlinear behavior in one or more parts of your assembly without affecting results in critical regions it will be advantageous to do so.

Large Deflection is typically needed for slender structures [5]. Small deflection and small strain analyses assume that displacements are small enough that the resulting stiffness changes are insignificant. Setting Large Deflection to On will take into account stiffness changes resulting from changes in element shape and orientation due to large deflection, large rotation, and large strain. Therefore the results will be more accurate. However this effect requires an iterative solution. In addition it may also need the load to be applied in small increments. Therefore, the solution may take longer to solve.

Input parameter:

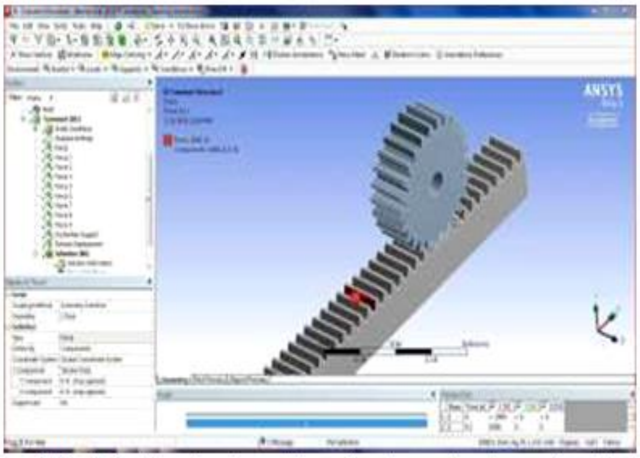

Fig.5.1 (Analysis setting for transient analysis)

Frictionless Support:

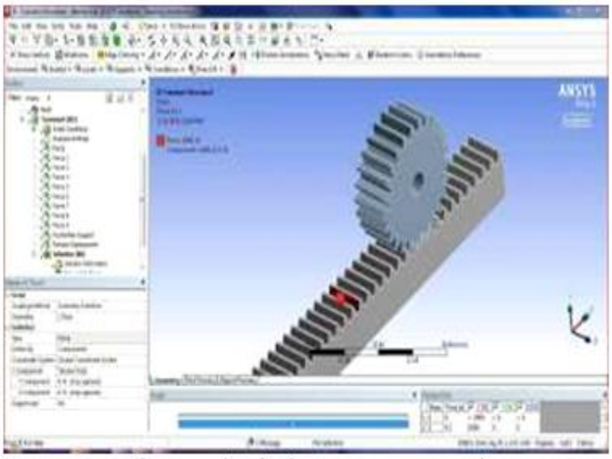

Fig.5.2 (Frictionless support)

Remote Displacement:

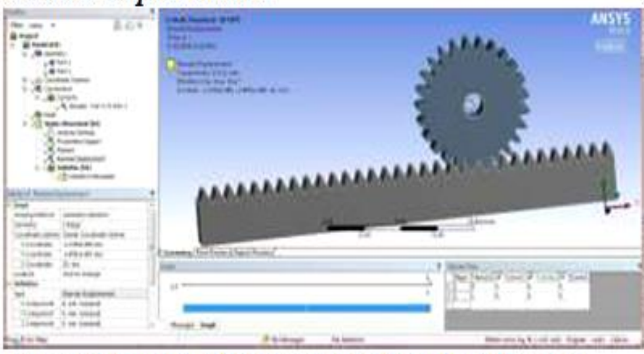

Fig. 5.3 *Remote Displacement of Rack and pinion*

Static Structural - Al 7475 *(Total Deformation*

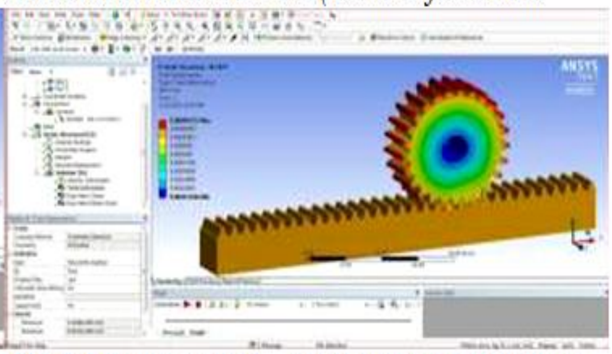

Fig. 5.4 *Static structural - AL7475 (Total Deformation)*

Equivalent Von- Mises Stress:

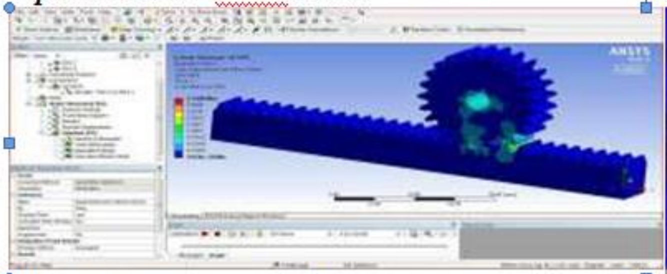

Fig. 5.5. *Equivalent von- Mises stress.*

Equivalent Von Mises Stress:

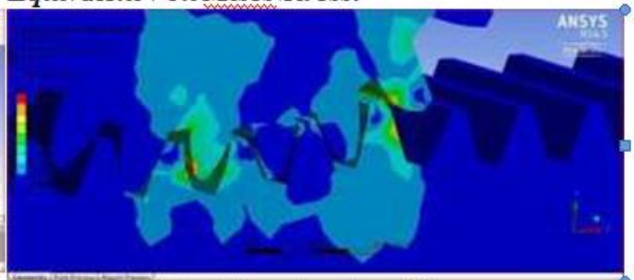

Fig. 5.6. *Equivalent Von mises stress Max. (def-2.2432, Min. Def-8. 1388e-10)*

Equivalent Elastic Strain:

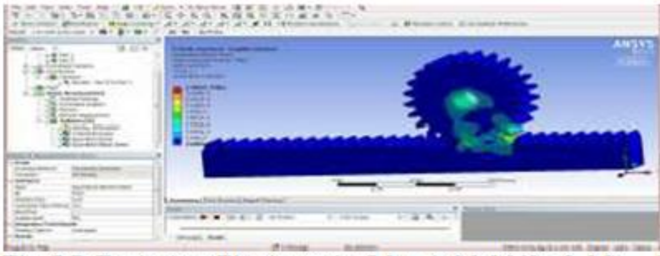

Fig. 5.7. Equivalent Elastic strain (Max.def-2.2662e-5, Min. Def-2. 6059e-14)

Static Structural - Sand Cast Magnesium Alloy-Total Deformation

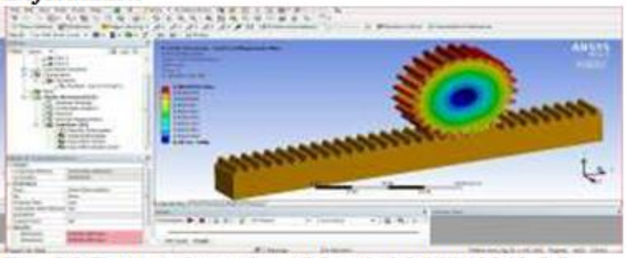

Fig. 5.8. Total deformation. (Max.def-0.00049942, Min. Def-8. 2072e-5)

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Equivalent Von Mises Stress:

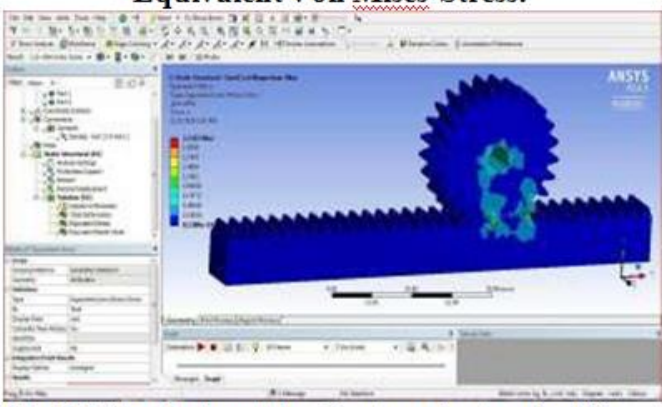

Fig.5.9 (Analysis setting for transient analysis)

Equivalent Elastic Strain:

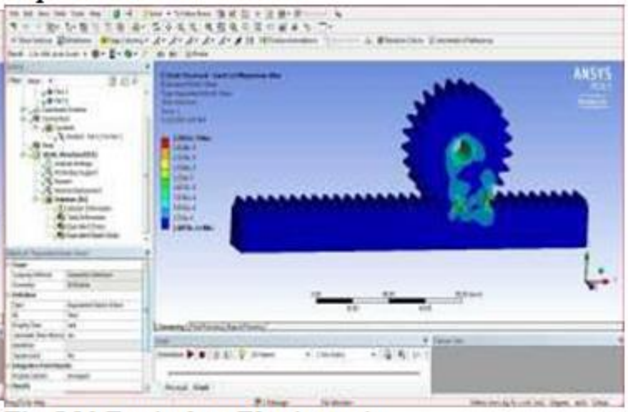

Fig. 5.10 Equivalent Elastic strain

6. TRANSIENT STRUCTURAL ANALYSIS

Gear and rack system is commonly used as a component in mechanical device, so its strength check has practical implications. Typically the contact stress, bending stress of gear and rack are computed by traditional methods. However, the conventional formula to calculate the contact stress in the gear is only on one certain point of time and on one contact surface. The pitch circle circumferential force acting on the top gear can be used to calculate the bending stress. The contact stress calculated by transient dynamics analysis in this paper is a range of values which describes the contact stress values at different times and in different contact position of the gear and rack. At different point of time, the influence of the bending of gear and rack is different due to the size of the meshing force and the acting position. This transient dynamics description method can describe the gear and rack meshing process more realistically.

Transient Dynamic Finite Element Model:

As discussed above, through modal analysis of gear and rack intrinsic characteristics of the system are obtained [6]. On the basis of the above, the transient response analysis is performed in this part by adding the transient dynamic module (Transient Structural).

Load Settings:

First, set the gear speed. Here the steady speed of gear is set to 0.65r/s. The default units in ANSYS workbench is rad/s and the speed of gear can be transformed into 4.08rad/s, as shown in Fig. (4). Second set the rack load. In this paper the gear drives the rack to transmit power, so it needs to apply horizontal load along the moving direction of the rack. Set the load to 400N. A cylindrical support needs to be added to the gear and displacement on the bottom surface of the rack is added in Transient. According to the actual condition of the rack, add forced displacement to the rack in the X, Y, Z directions. Finally add the options of the results in Solution and the transient analysis setting is completed.

7. Transient Dynamic Analysis Results and Discussion

The transient dynamics analysis is done on the gear and rack meshing process. The equivalent stress contour of the gear and rack in the meshing process is shown in Fig. The behavior of the Rack and pinion system which when subjected to transient loads is sown in the figure below.he

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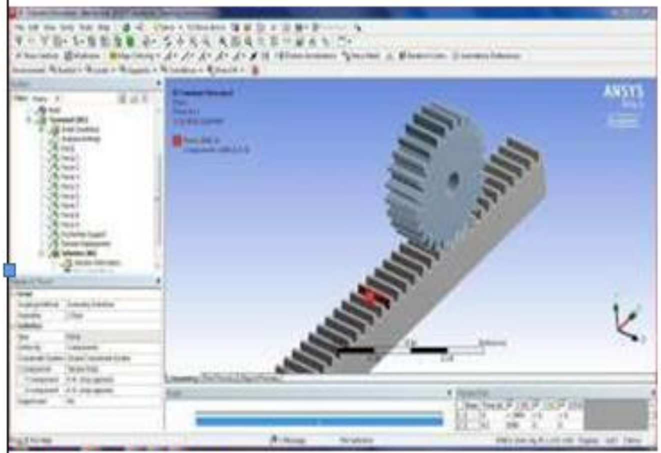
fixing constrain of the rack and pinion.



Input parameter:

Fig.6.1 (Analysis setting for transient analysis)

Frictionless Support:

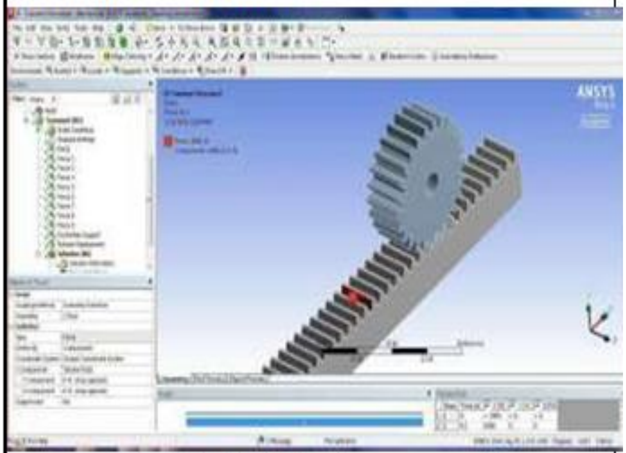


Fig.6.2 (Frictionless support)

Force(1000N):

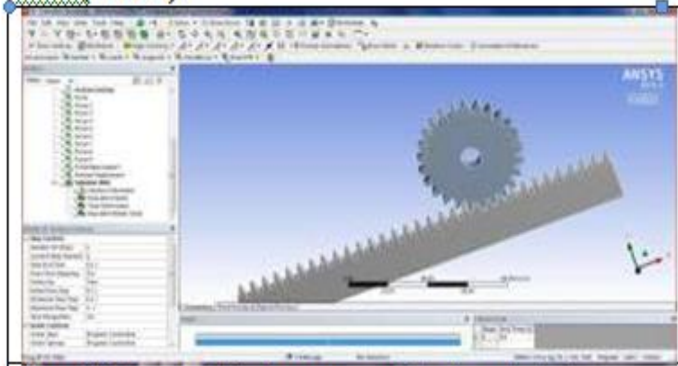


Fig. 6.3 Remote Displacement of Rack and pinion

Static Structural - Al 7475 (Total Deformation

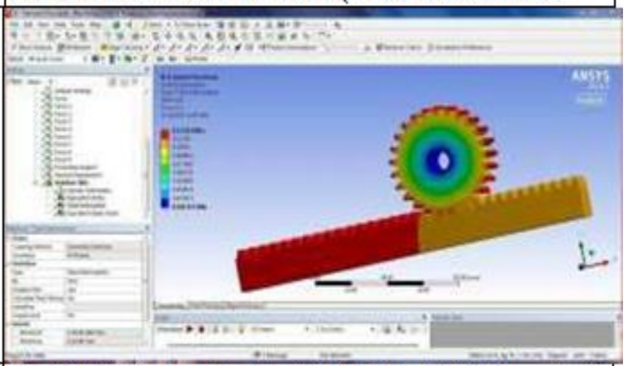


Fig. 6.4 Static structural - AL7475 (Total Deformation)

Equivalent Von- Mises Stress:

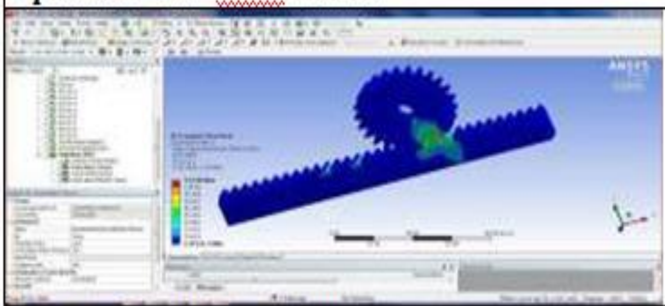


Fig. 6.5. Equivalent von- Mises stress.

Equivalent Von Mises Stress:

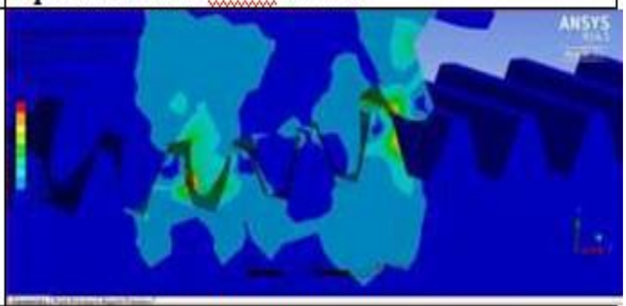


Fig. 6.6. Equivalent Von mises stress Max.

8. RESULTS.

1. STATIC STRUCTURAL ANALYSIS:

Results	AL 7475	Nickel Aluminium Bronze Alloy	Graphite Cast Iron	Sand Cast Magnesium Alloy
Von misses stress (Mpa)	2.3449	2.33344	2.2432	2.2015
Total Deformation (mm)	0.00044162	0.00011646	0.00049942	0.00045166
Von misses strain	3.351e-5	2.1228e-5	2.2662e-5	2.6059e-5

Thus, the table show the static structural Analysis of rack and pinion

2. TRANSIENT STRUCTURAL ANALYSIS:

Results	AL 7475	Nickel Aluminium Bronze Alloy	Graphite Cast Iron	Sand Cast Magnesium Alloy
Von misses stress (Mpa)	124.38	123.74	133.23	122.51
Total Deformation (mm)	0.12264	0.078388	0.089754	0.18907
Von misses strain	0.001848	0.0011826	0.0014098	0.0028386

Thus, the table show the transient structural Analysis of rack and pinion

CONCLUSION

Based on physical and thermal properties **Nickel Aluminium Bronze Alloy** has got more strength than other and it is clear from the results that the load carrying capacity of former is larger than the later. Hence Nickel Aluminium Bronze Alloy is preferred for the manufacture of rack and pinion.

In static structural analysis the total deformation and von - mises stresses are less in Nickel Aluminium Bronze Alloy than the other 3 preferred materials. Hence Nickel Aluminium Bronze Alloy has better strength than others. Under transient conditions the total deformation of Nickel Aluminium Bronze Alloy is less than that of other preferable materials. Hence former is preferred under Transient conditions. Hence keeping all the analysis in view the **Nickel Aluminium Bronze Alloy** is preferred over all.

REFERENCES

[1] X.Q. Zhang, D.G. He, and R. Zheng, “Contact stress analysis of gear and rack,” Journal of Mechanical Transmission, vol. 7, pp. 30-32, 2011.
[2] Y.X. Li, Z. Wang, and M.X. Wang, “Discussion of large modulusgear- rack bending fatigue strength,” Journal of Mechanical Transmission, vol. 10, pp. 1- 3, 2012.
[3] Q.J. Xiao, H.G. Jia, and X.F. Han, “Study on dynamic contact of gear and rack by considering elastic and plastic properties of material,” Coal Mine Machinery,vol. 1, pp. 86-89, 2013.
[4] J.J. Wang, and R.F. Li, “The theoretical system of the gear vibration theory,”China Mechanical Engineering, vol. 9, pp. 55- 58, 1998.
[5] L. Zhou, S.F. Zheng, and X.M. Lian, “Modeling and research on torsional vibration of transmission

[6] System under speeding-up condition," Journal of Vibration Engineering, vol. 12, pp. 601-605, 2010. [7].X. X.Y. Xu, C.C. Zhu, and X.R. Zhang, "Experimental modal analysis of heavy duty marine gearbox," Journal of Vibration and Shock, vol. 7, pp. 266-270, 2011.
[7] F. Sun, "Modal analysis and research of gear with fewer teeth based on ANSYS," Machinery Design & Manufacture, vol. 5, pp. 119-121, 2011.