MODELING AND FINITE ELEMENT ANALYSIS OF SPUR GEAR

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Abstract: *The contact stress in the mating gears is the key parameter in gear design. This paper presents the stress analysis of mating teeth of spur gear to find maximum contact stress in the gear teeth. The results obtained from Finite Element Analysis (FEA) are compared with theoretical Hertzian equation values. For the analysis, steel, grey cast iron, aluminium alloy and ASTM A572 HSLA steel are used as the materials of spur gear. The spur gears are sketched, modeled and assembled in CATIA V5. As Finite Element Method (FEM) is the easy and accurate technique for stress analysis, FEA is done in finite element software ANSYS Workbench 18.1. Also deformation for steel, grey cast iron, aluminium alloy and ASTM A572 HSLA steel is obtained as efficiency of the gear depends on its deformation. The results show that the difference between maximum contact stresses obtained from Hertz equation and Finite Element Analysis is very less and it is acceptable. The deformation patterns of steel, grey cast iron, aluminium alloy and ASTM A572 HSLA steel gears depict that the difference in their deformation is negligible.*

***Index Terms* –Spur gear, Maximum contact stress, ANSYS, Failure, Torque.**

I. INTRODUCTION

Spur gears or straight-cut gears are the simplest type of gear. They consist of a cylinder or disk with teeth projecting radially. Though the teeth are not straight-sided (but usually of special form to achieve a constant drive ratio, mainly involute but less commonly cycloidal), the edge of each tooth is straight and aligned parallel to the axis of rotation. These gears mesh together correctly only if fitted to parallel shafts. No axial thrust is created by the tooth loads. Spur gears are excellent at moderate speeds but tend to be noisy at high speeds.

A.ORIGINS:

Gears are considered as one of the oldest piece of equipment known to mankind, so old in fact that their origin can be traced back to The Chinese South-Pointing Chariot in the 27th century B.C – a vehicle built on two wheels which bore a movable indicator that always pointed South no matter how the chariot turned. The chariot, allegedly designed by mechanical engineer Ma Jun, possessed rotating wheels that were mechanically geared to keep the indicator pointing in a southern direction without the use of magnets.

The earliest description of gears was written in the 4th century B.C. by Aristotle. He wrote that the “direction of rotation is reversed when one gear wheel drives another gear wheel” (Hellenic World encyclopaedia). In the 3rd century B.C., various Greek Inventors used gears in water wheels and clocks, and sketches of various types of gears of around this time were found in Leonardo da Vinci’s notebooks later on.

For a long period after these discoveries, there were no major development concerning wheels until the 17th century, when the first attempts to provide constant velocity ratios (conjugate profiles) was recorded and there was mention of the utilization of the involute curve.

The 19th century saw the first use of form cutters and rotating cutters and in 1835 English inventor Whitworth patented the first gear hobbing process. Various other patents followed until 1897 when Herman Pfauter of Germany invented the first hobbing machine capable of cutting both spur and helical gears. Through the 20th century various types of machines developed. But, the next major step came in 1975 when the Pfauter Company in Germany introduced the first NC hobbing machine and in 1982 the Full 6 axis machine was introduced.

B. MATERIALS USED FOR SPUR GEAR:

1. Structural steel
2. Grey Cast Iron
3. Aluminium Alloy
4. ASTM A572 HSLA steel

II. SOFTWARE

The software will start (by default) with all toolbars docked to the edges of the main window. The toolbars contain buttons, which when clicked, open the various information windows or operate features in the software. The toolbars and windows can be freely moved around inside the main program window, to create your own screen layout.

A. INRODUCTION TO CATIA

CATIA started as an in-house development in 1977 by French aircraft manufacturer Avion Marcel Dassault, at that time customer of the CADAM software to develop Dassault's Mirage fighter jet. It was later adopted by the aerospace, automotive, shipbuilding, and other industries. Initially named CATI (*conception assistée tridimensionnelle interactive* – French for *interactive aided three-dimensional design*), it was renamed CATIA in 1981 when Dassault created a subsidiary to develop and sell the software and signed a non-exclusive distribution agreement with IBM. In 1984, the Boeing Company chose CATIA V2 as its main 3D CAD tool, becoming its largest customer. In 1988, CATIA V3 was ported from mainframe computers to UNIX. In 1990, General Dynamics Electric Boat Corp chose CATIA as its main 3D CAD tool to design the U.S. Navy's Virginia class submarine. Also, Lockheed was selling its CADAM system worldwide through the channel of IBM since 1978. In 1992, CADAM was purchased from IBM, and the next year CATIA CADAM V4 was published. In 1996, it was ported from one to four UNIX operating systems, including IBM AIX, Silicon Graphics IRIX, Sun Microsystems SunOS, and Hewlett-Packard HP-UX. In 1998, V5 was released and was an entirely rewritten version of CATIA with support for UNIX, Windows NT and Windows XP (since 2001). In the years prior to 2000, problems caused by incompatibility between versions of CATIA (Version 4 and Version 5) led to $6.1B in additional costs due to years of project delays in production of the Airbus A380. In 2008, Dassault Systèmes released CATIA V6. While the server can run on Microsoft Windows, Linux or AIX, client support for any operating system other than Microsoft Windows was dropped. In November 2010, Dassault Systèmes launched CATIA V6R2011x, the latest release of its PLM2.0 platform, while continuing to support and improve its CATIA V5 software. In June 2011, Dassault Systèmes launched V6 R2012. In 2012, Dassault Systèmes launched V6 2013x. In 2014, Dassault Systèmes launched 3DEXPERIENCE Platform R2014x and CATIA on the Cloud, a cloud version of its software.

B. INTRODUCTION TO ANSYS WORKBENCH

ANSYS mechanical is a finite element analysis tool for structural analysis including linear, nonlinear and dynamic studies. This computer simulation product provides finite elements to model behavior and supports material models and equation solvers for a wide range of mechanical design problems. ANSYS mechanical also includes thermal HYPER LINK and coupled analysis capabilities acoustics, piezoelectric, thermal –structural and thermos electric analysis.

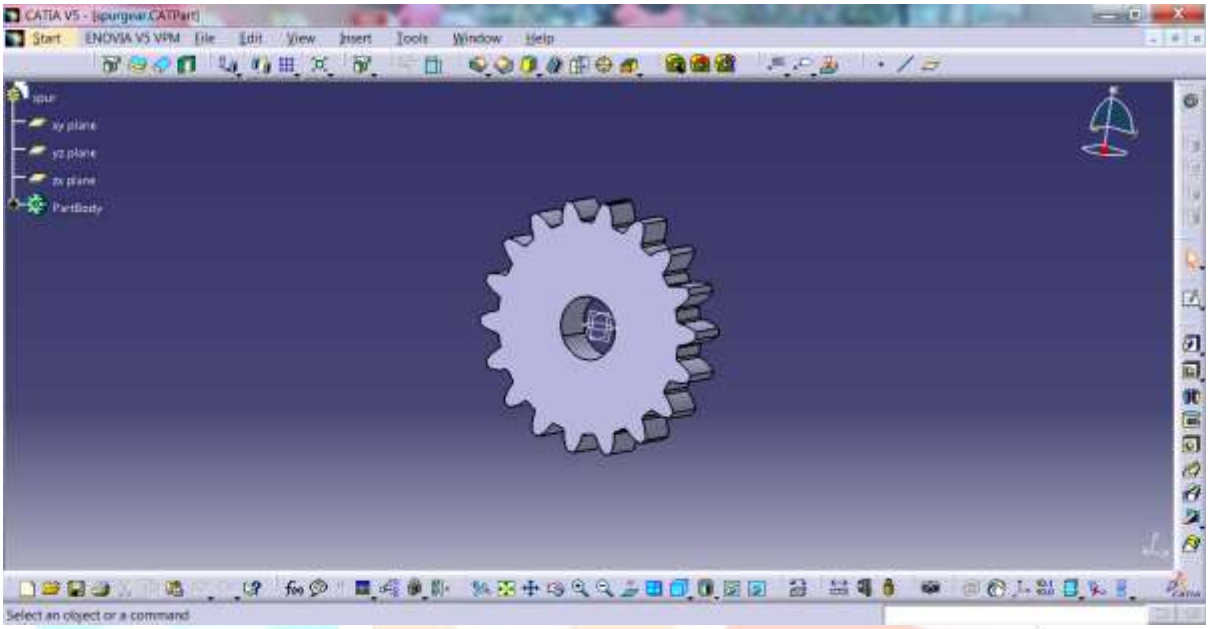
III.DESIGN

DESIGN CALCULATION:

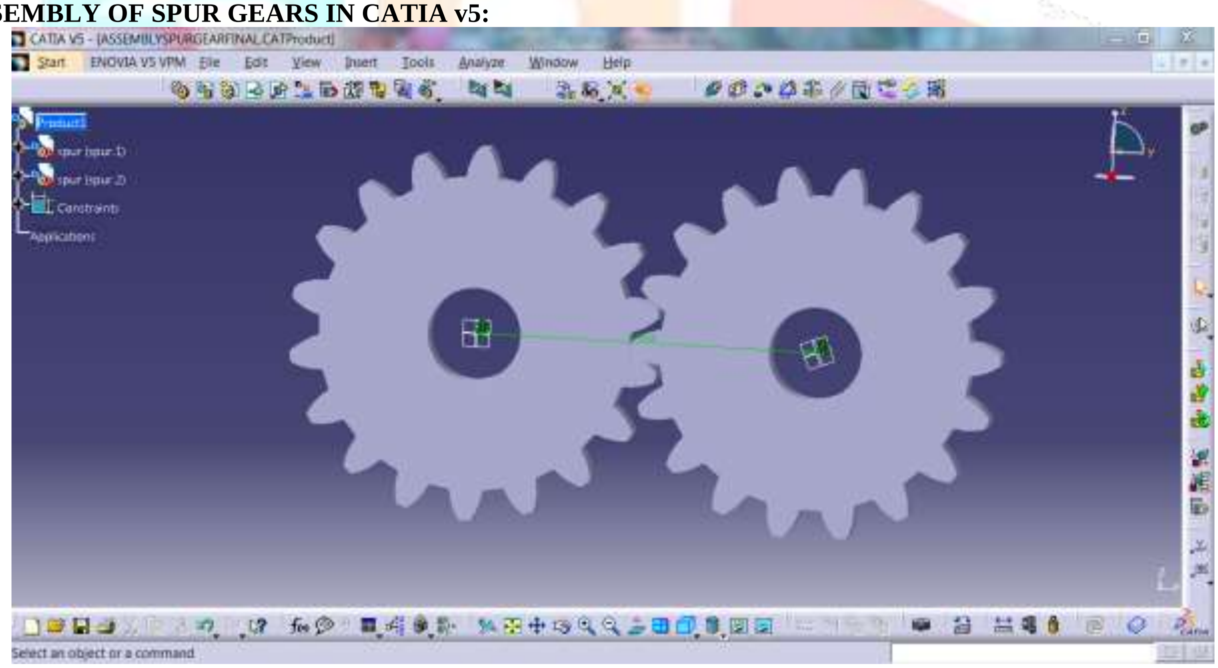
Model = TATA SUPER ACE
Engine = TATA475 TCIC BSIII)
Torque(T) = 135.24 N.m
Speed(N) = 2500 rpm
Power(P) = = 35405.74 W = 35.40 kW
Torque (T) = F×(d/2)
Where, F-load,
d- Pitch circle diameter (z×m=180mm)
F = T/ (d/2)
F = 135240 / 90
Load (F) = 1502.66 N
Using Lewis equation,
Tangential load, F =b×y×pc×σb
pc =π×m = 31.41 mm
y= Lewis form factor=0.134mm
b = face width = 54mm
The maximum allowable stress= 8.7413N/mm2.
Ultimate tensile strength for structural steel=460 MPa
Ultimate tensile strength for composite=35 MPa
Allowable stress for structural steel = ultimate tensile strength/3
= 460/3 = 153.33 N/mm2> 8.7413N/mm2
Allowable stress for composite = ultimate tensile strength/3= 35/3 = 11.66 N/mm2>8.7413N/mm2
So, the design is safe.
Calculations of Gear Tooth Properties:
Module = D/Z = 180/18 = 10mm
Pitch circle diameter (P.C.D) = Z×m = 18×10 = 180mm
Base circle diameter (Db) = D cos α = 180×cos20 = 169.145mm

Outside circle diameter = (Z+2) ×m= (18+2) ×10 = 200mm
Clearance = circular pitch/20 = 31.4/20 = 1.57mm

SPUR GEAR DESIGN IN CATIA v5:



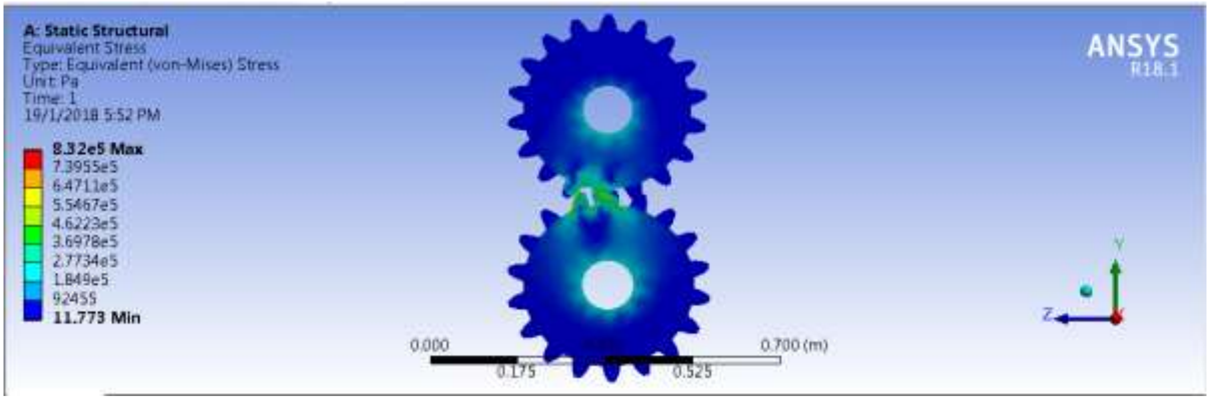
ASSEMBLY OF SPUR GEARS IN CATIA v5:



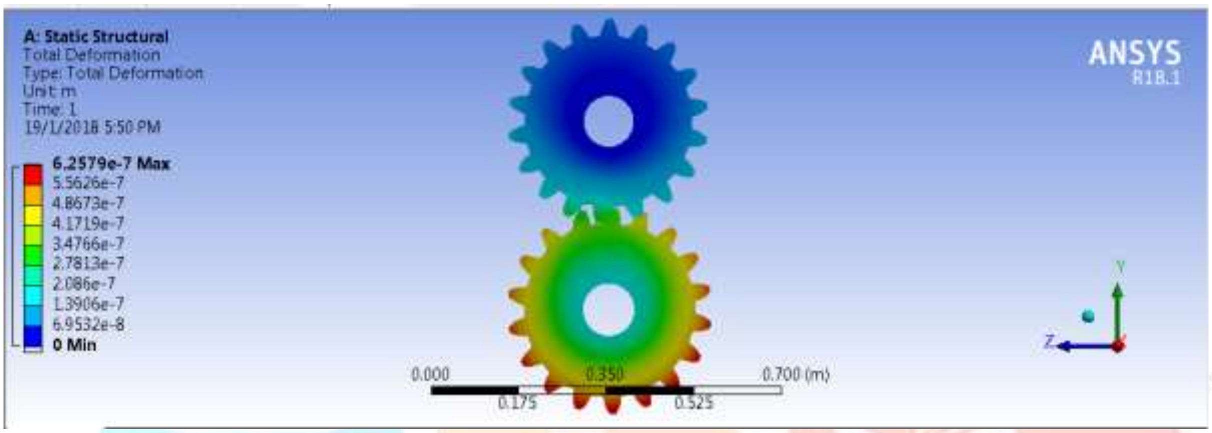
IV. RESULT AND DISCUSSION

ANALYSIS RESULT OF STRUCTURAL STEEL SPUR GEAR SET:

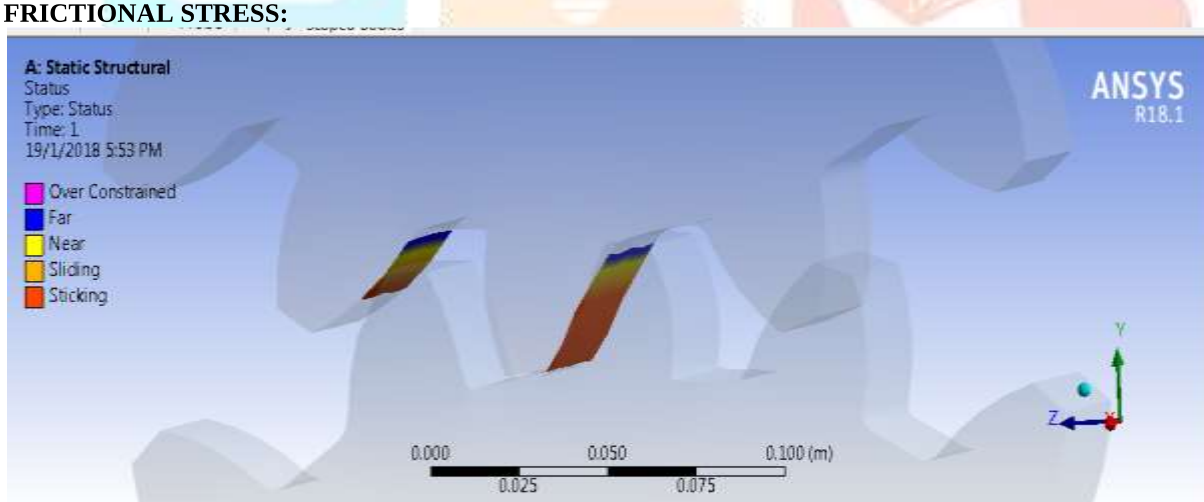
EQUIVALENT STRESS:



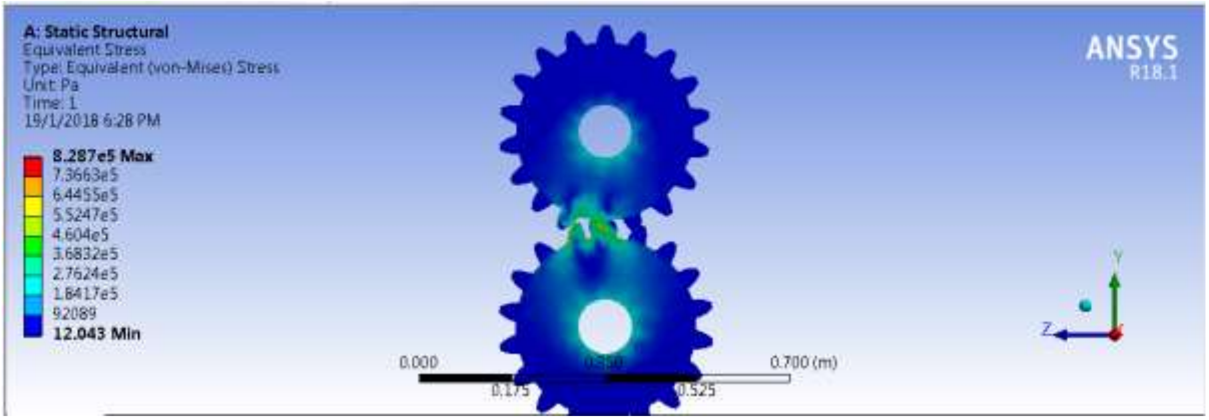
TOTAL DEFORMATION:



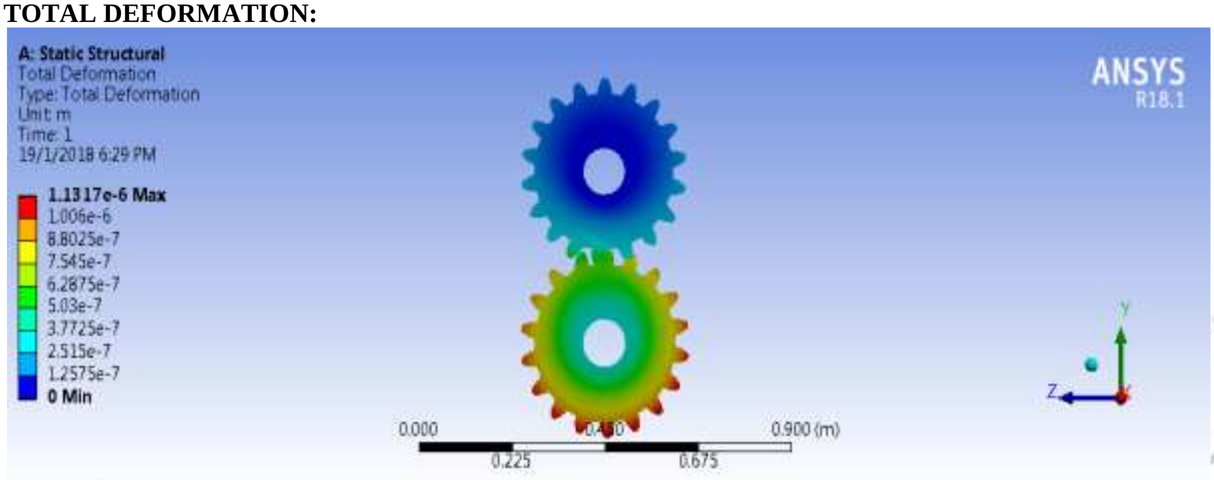
FRICTIONAL STRESS:



ANALYSIS RESULT OF GREY CAST IRON SPUR GEAR SET:
EQUIVALENT STRESS:



TOTAL DEFORMATION:



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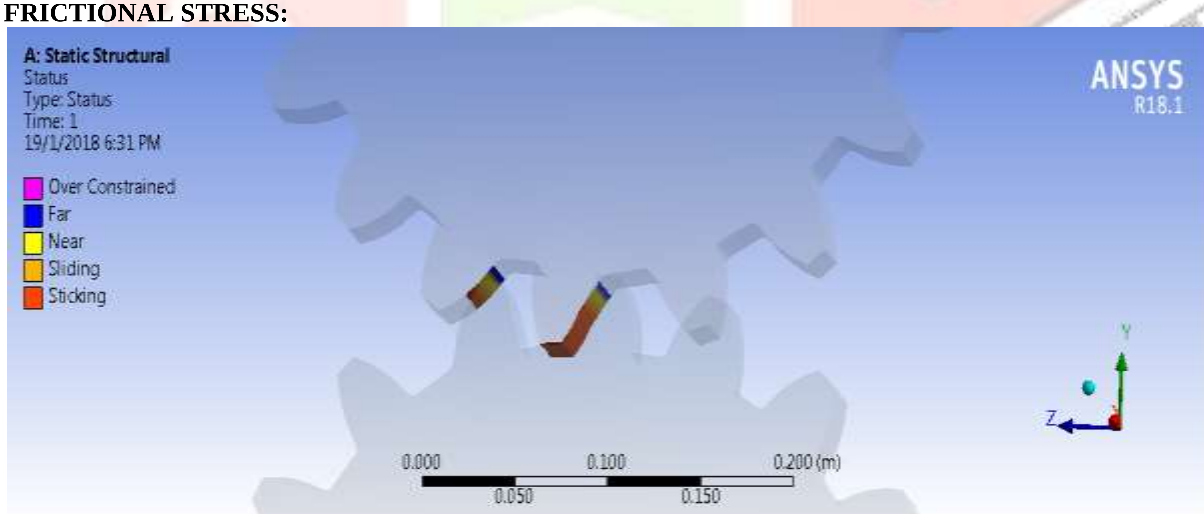
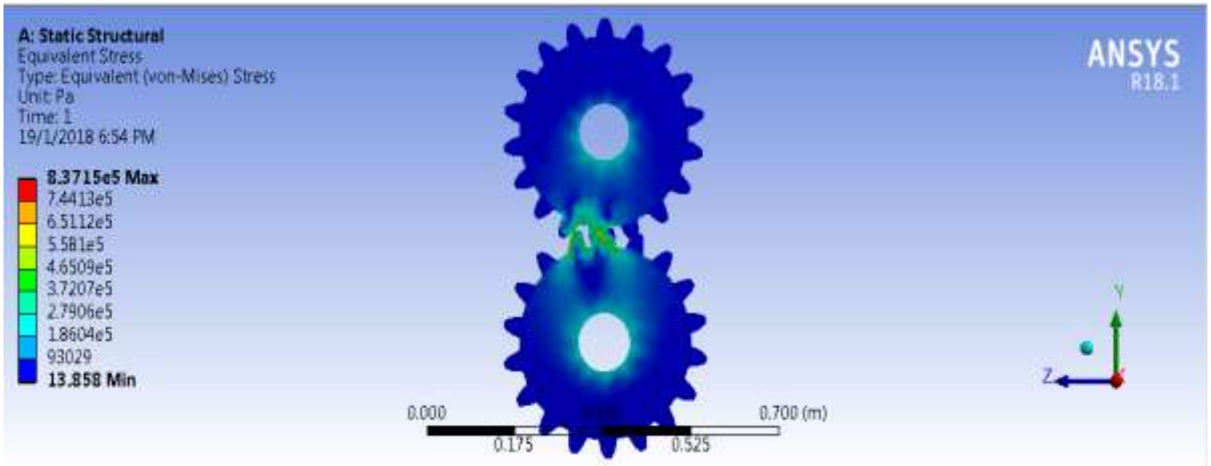
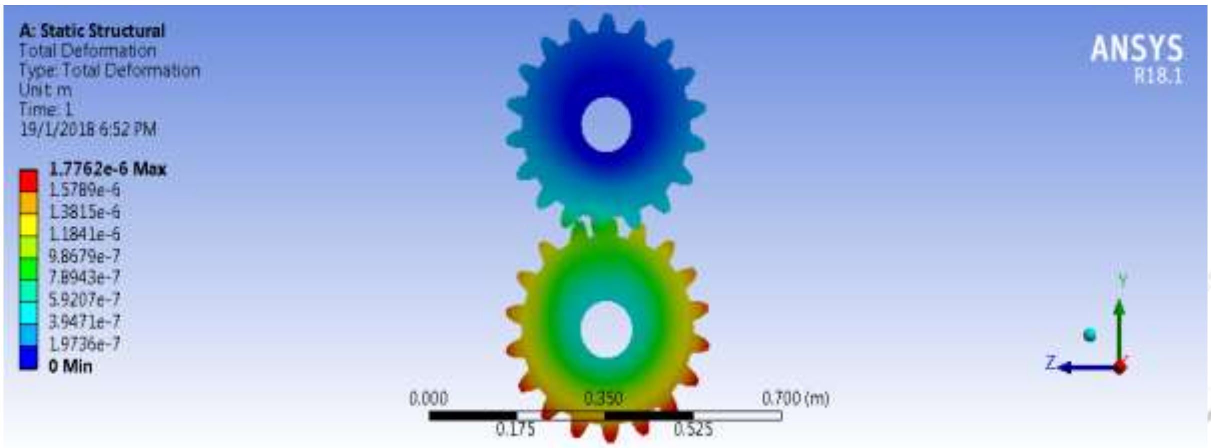


ANALYSIS RESULT OF ALUMINIUM ALLOY SPUR GEAR SET:
EQUIVALENT STRESS:



TOTAL DEFORMATION:



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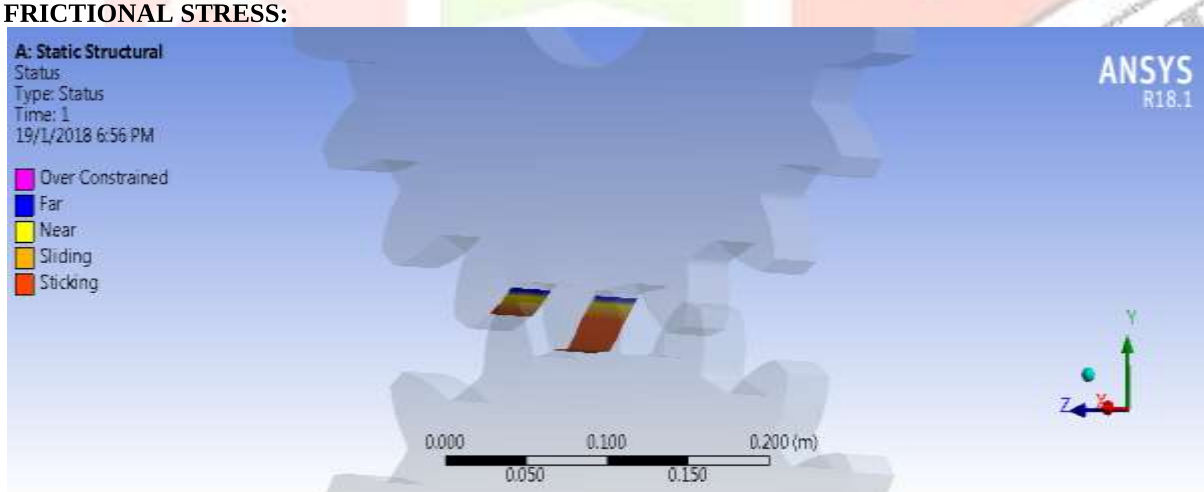
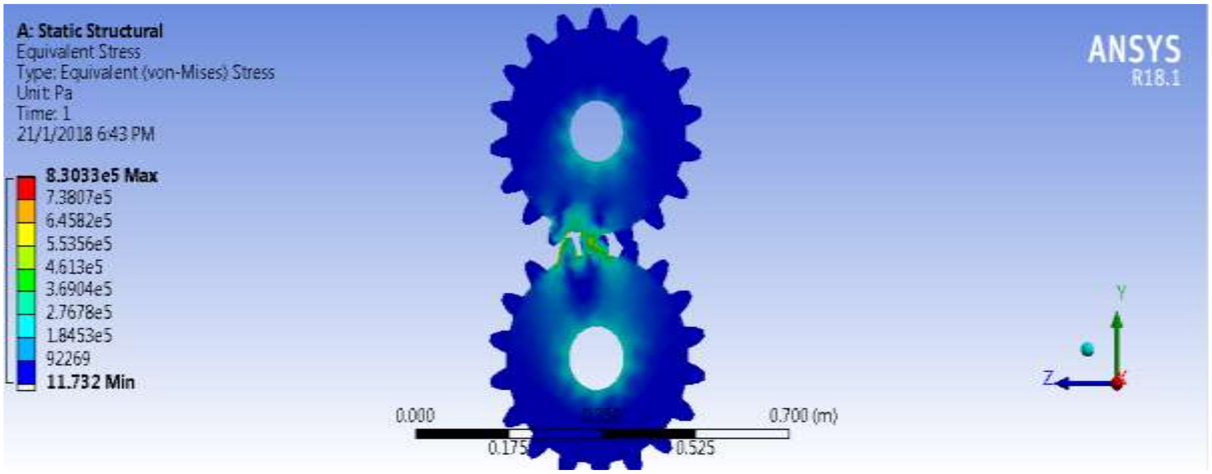
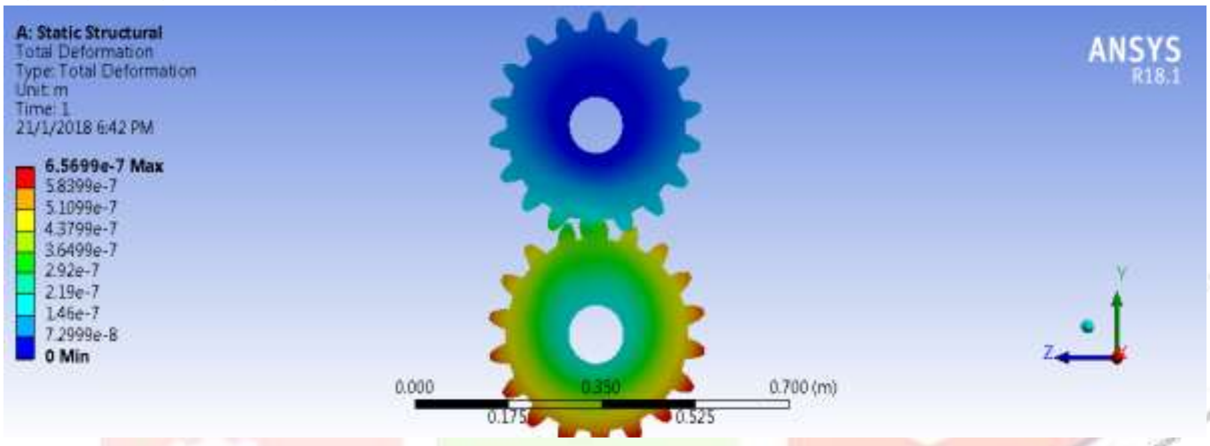


ANALYSIS RESULT OF ASTM A572 GRADE 50 HSLA STEEL SPUR GEAR SET:
EQUIVALENT STRESS:



TOTAL DEFORMATION



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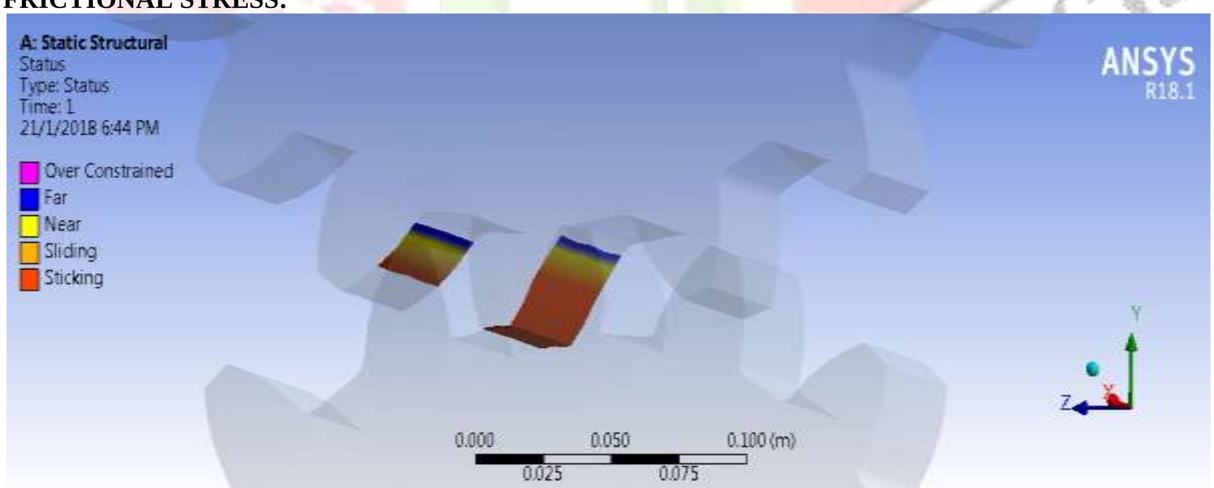

VI. CONCLUSION

Here the theoretical maximum contact stress is calculated by Hertz equation. Also the finite element analysis of spur gear is done to determine the maximum contact stress by ANSYS Workbench 18.1. It was found that the results from both Hertz equation and Finite Element Analysis are comparable. From the deformation pattern of steel, grey cast iron, aluminium alloy and ASTM A572 Grade 50 HSLA steel, it could be concluded that difference between the maximum values of steel and grey cast iron, aluminium alloy, ASTM A572 GRADE 50 HSLA steel gear deformation is very less.

The following conclusions can also be made from the analysis conducted in this study. It was concluded that the stress values are calculated for ASTM A572 Grade 50 HSLA is approximately same as compared to the structural steel, gray cast iron and aluminium alloy. So from these analysis results, we conclude that, the stress induced, deformation and weight of the ASTM A572 Grade 50 HSLA spur gear is almost same as compared to the structural steel spur gear, gray cast iron spur gear and aluminium alloy spur gear. So, ASTM A572 Grade 50 HSLA are capable of using in automobile vehicle gear boxes instead of existing cast steel gears with better results.

COMPARISION OF VALUES OF MAXIMUM CONTACT STRESS EVALUATED USING HERTZ EQUATION AND ANSYS WORKBENCH FOR STEEL,GREY CAST IRON,ALUMINIUM ALLOY,ASTM A572 GRADE 50 HSLA STEEL:

Gear	Σa (HERTZ) (pa)	σa (ANSYS) (pa)	Difference
Structural steel	**8.19e5**	**8.32e5**	**0.13**
Grey Cast Iron	**8.107e5**	**8.287e5**	**0.18**
Aluminium alloy	**8.2215e5**	**8.3715e5**	**0.15**
ASTM A572 Grade 50 HSLA Steel	**8.133e5**	**8.3033e5**	**0.17**

COMPARISION OF MAXIMUM CONTACT STRESS BETWEEN STRUCTURAL STEEL, GREY CAST IRON.ALUMINIUM ALLOY, ASTM A572 HSLA STEEL:

Gear	Torque	Total Deformation	Equivalent (von-mises) stress
Structural steel	**135 N-m**	**6.2579e-4 mm**	**8.32e5 pa**
Grey Cast Iron	**135 N-m**	**1.1317e-3 mm**	**8.287e5 pa**
Aluminium alloy	**135 N-m**	**1.7762e-3 mm**	**8.3715e5 pa**
ASTM A572 Grade 50 HSLA Steel	**135 N-m**	**6.5699e-4 mm**	**8.3033e5 pa**

VII. REFERENCES

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