e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:03/March-2022 Impact Factor- 6.752 www.irjmets.com

STATIC STRUCTURAL AND DYNAMIC MODEL ANALYSIS OF THE SPUR GEAR TOOTH WITH DIFFERENT MATERIALS

Nalam. Ranadeep*1, P. Syam*2

*1M. Tech Student, Department of Mechanical Engineering, Newton's Institute of Science & Technology, Macherla, Andhra Pradesh, India.

*2Assistant Professor, Department of Mechanical Engineering, Newton's Institute of Science & Technology, Macherla, Andhra Pradesh, India.

ABSTRACT

Gears have surpassed all other components in the mechanical transmission system in terms of frequency of use. With regard to applications, spur gears are commonly found everywhere, ranging from domestic items to large-scale construction projects. The of gear is used in this particular piece of craftsmanship. Polymer composite materials have a number of advantageous qualities, including high elasticity, noiselessness, and precision in power and motion transfer, as well as the absence of the requirement for lubrication, all of which have contributed to their long-term viability and survival. In this particular instance, the gear is modelled using the CAD software application CATIA V5 R18. Gears are studied using ANSYS14.5, which performs both static and model analysis. This was achieved by studying three materials: cast iron, structural steel, and carbon fiber composite. Then, using modal analysis, we can compute the stress associated with the deformations induced by applying force to the tooth in step 3. Using modal analysis in the presence of free vibration, we may obtain the frequencies and natural mode shapes that are displayed in the table below. Using the Eigen values, which were derived through problem solving, it is possible to represent frequencies and their accompanying mode shapes mathematically. The performance of cast iron, structural steel, and carbon fiber/epoxy resin composite spur gears is studied and compared.

Keywords: Spur Gear, Catia V5 R18, Ansys 14.5, Investigation, Cast Iron, Structural Steel And Carbon Fiber Composite.

I. INTRODUCTION

Spur Gear:

When it comes to gears, Spur gears are the most basic and widely used. Their structure resembles an elongated chamber or a circle. Straight-cut gears have major edges parallel to the revolution's pivot point, allowing for additional tooth extension. On the off event that these gears are mounted to parallel axles, they will only function successfully. If we analyze the power that a tooth of one device applies to another tooth of the other gear, we can determine the torque proportion. Both a spiral and a circumferential segment will be present in the power. Gears are a fairly simple machine that is quite useful. When two gears are engaged, the torque ratio is the force exerted by one gear's tooth on the other's tooth. A gear is a part of a transmission device. A worm gear can rotate another gear or device. A pulley is not a gear since a gear is a round wheel. Because they coincide with the teeth of other gears, they allow energy to be completely swapped without slippage. The development and course of action of geared devices allows them to transmit power at a variety of rates, torques, or in an alternate bearing, depending on their design and construction. Apparatuses are a fundamental machine that is quite useful. The most well-known scenario is for an apparatus to operate in conjunction with another gear nevertheless, an apparatus can operate in conjunction with any gear that has perfect teeth, such as straight moving racks. The driving apparatus's velocity can be varied by increasing or decreasing the number of teeth on the drive shaft. As a part of applications where motion control is not important, spur gears are frequently used. A nylon or non-metallic gear is ideal when greater noise levels and higher speeds are required. In rare situations, a maximum speed of 200 feet per minute is possible.

This prevents sound and vibration.

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:03/March-2022 Impact Factor- 6.752 www.irjmets.com

Figure 1: Spur Gear

Spur Gear Cutting

The Spur Gear has been cut to size. When it comes to the fabrication of the spur gears, there are a variety of options available to you. Milling, hobbing, shaping, blanking, grinding, mold-making, forming, casting, and stamping are just a few of the ways that can be used to make gears. Another relatively new approach is the wire EDM process, which is a variation on the milling process. The best manufacturing procedure depends on the product's quality, cost, quantity, gear material, and last but not least, application.

II. LITERATURE SURVEY

S. Mahendran, K.M. Eazhil, L. Senthil Kumar [1]. DESIGN AND ANALYSIS OF SPUR GEAR Steel and composite materials benefit from the spur gear's weight reduction. This study looked at impact analysis and torque loading for cast steel and composite materials. So, the composite spur gear has less distortion and weight than the cast steel spur gear. **Utkarsh. Desail, Prof.Dhaval.A. Patel [2].** MATERIAL ASSESSED FOR SPUR GEAR UNDER STABLE LOADING. Using alternate materials will improve gear performance. Composite materials outperform metallic gears in terms of strength and weight. A metallic alloy steel gear is replaced by a composite gear consisting of 30% glass filled Poly-Ether-Ether-Ketone (PEEK). As a result, these composite materials offer excellent mechanical properties, reducing failure risks. This project uses SOLIDWORKS to model spur gears and ANSYS V14 to analyse bending stress. **R. Yakut et al [3].** The study looks on PC/ABS spur gear load capability and gear damage. The FZG experiment set was used to test the applicability of PC/ABS composite plastic material as spur gear. The study concluded that PC/ABS materials outperform PA66 GFR 30 materials in terms of flame, air, and UV resistance. Low rotations and tooth loads are also optimal working conditions. Gears thrive in situations of rotation and tooth load. Prefer low tooth and high-power PC/ABS transmission gear. **V. Siva Prasad et al [4].** For sugarcane juice machines, replacing metallic gears with polymer gears will minimize weight and noise. It was created in PRO-E and imported into ANSYS 10.0 for analysis. This study compares nylon and polycarbonate gears to cast iron gears. The study concluded that well-designed and evaluated composite gears had useful properties including reduced cost, noise, weight, and vibration. Unlike cast iron spur gears, nylon gears are suitable for low-load sugarcane juice machines. **Vivek Karaveer et al [5].** The maximum contact stress is determined by measuring the tension in spur gear teeth. They are compared to theoretical Hertz equation values. ANSYS 14.5 does stress analysis on spur gear teeth. The Hertz equation and FEM produced similar results. The maximum values of steel and grey CI gear deformation are quite similar. **Mahebub Vohra et al [6].** Cast iron with nylon, metallic and non-metallic, is investigated. FEA is used to stress the lathe machine headstock gear box. It is calculated via Lewis and AGMA formulae. Comparing analytical and finite element findings validates. The stress distribution in ANSYS matched the theoretical conclusions. Non-metallic materials are less expensive, self-lubricating, quieter, and easier to manufacture than metallic materials.

III. SELECTION OF MATERIAL

Materials of Spur Gears

There is a diverse selection of materials available for the production of spur gears. Aluminum, bronze, nylon, steel, phenolic, cast iron, Bakelite, and today polymers are among the materials that can be used in this way. the following table 1 represents the properties of materials The material is modified in accordance with the type of application as well as the amount of load placed on the spur gears. The most widely utilized materials are structural steel, cast iron, aluminum, and other similar materials. A spur gear's ratio is normally between 1:1 and 1:6, but it can be greater or lower depending on the application. The pitch line can travel at speeds of up to 25 meters per second. The spur gear demonstrates that it can operate at a frequency of 98-99 percent of its maximum capacity. A spur gear's pinion is always constructed of a more durable material than the wheels it is intended to replace. Carbon fiber are very thin filaments of carbon molecules with a width of 0.0005–0.010 mm and a thickness of 0.0005–0.010 mm. Carbon fiber are 0.0005–0.010 mm wide and 0.0005–0.010 mm thick. Carbohydrate fiber is linked and strengthened in minute parts that are virtually precisely aligned with the long axis of the fiber and reinforced with carbon.

Table 1: Properties of the material

Material Identification and Physical Characteristics	Structural Steel	Cast Iron	Carbon Fiber
Young's Modulus is a type of modulus. (E)	2.5e^5 MPA	163e^3 MPA	451 GPA
Strength of the Yield(Y)	251 MPA	253 MPA	211 MPA
Poisson's Ratio (μ)	0.31	0.27	0.32
Density(ϱ)	7852 KG/M^3	7210 KG/M^3	1810 KG/M^3
Tensile Strength to the Extreme	463 MPA	352 MPA	541 MPA

STRUCTURAL STEEL:

A combination of iron and carbon results in steel, which is the most widely used material and has a wide range of properties as a result. A long time has been spent exploiting the high strength of iron-carbon composites, particularly after heat treatment, to considerable advantage. Today's steels and ferrous composites are largely the result of technological advances made after the Industrial Revolution. Carbon content in mild steel is between 0.1 and 0.2 percent. The low-cost solid steels are employed in the development of products as well as in the shipping and bundling of such products. The density and Young's modulus of all steels are quite high, as is the hardness of all steels. Cold working improves the strength of mild steel by reducing its ductility. Coatings such as paint, galvanizing, or other protective coatings can be used to protect mild steel from corrosion.

CAST IRON:

Cast irons, which are iron composites with a high carbon content, have qualities that are comparable to those of steels in that they are iron composites (2-4 percent). Many years have passed without anyone discovering the abuse of iron-carbon composites' strength, especially after heating (since the "Iron Age"). The Industrial Revolution created extensively used materials like modern steels and ferrous alloys. Cast iron is cheap and may be used to quickly cast high carbon alloys of intermediate strength. Cast iron is dense and has a high Young's modulus. They have a tendency to be of low durability; however, by applying heat to them, their strength and durability can be improved significantly. Because cast iron corrodes readily, it is recommended that painted parts be used on parts made of cast iron.

CFRP:

CFRP (Carbon Fiber Reinforced Plastic) is a composite material made up of various carbon fibres and thermosetting resins that can be used in a variety of applications. Because Nikkiso makes the best possible use of these resources, it is able to provide clients with outcomes of exceptional included quality that no one else can match. CFRP is primarily employed in situations where other materials have reached their maximum load-bearing capacity. Its light weight and resistance, above all, are extremely important characteristics. CFRP is up to five times lighter than steel and weighs only around 60 percent of the weight of aluminium, making it an excellent choice for aerospace applications. High fatigue strength, X-ray transparency, and minimal thermal expansion are among the other characteristics of this material. The exact properties of a single component can

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:03/March-2022 Impact Factor- 6.752 www.irjmets.com

be altered, managed, and maximised in a targeted manner. In our product brochure, you may learn more about the issues that we at SGL Carbon are concerned about and the opportunities that result from our portfolio.

IV. DESIGN FORMULA

Designs for spur gears are created by taking into consideration the specific velocity ratio and the distance between the central shafts, both of which are crucial considerations in the manufacturing process. When two shafts are placed together, the distance between their centres is defined by the following:

- which can be expressed by the following equations:

$$x = (d1 + d2)/2$$

- The speed or velocity ratio is computed by multiplying the two numbers together:

$$N1/N2 = d2/d1 = T2/T1$$

Where,

X = center distance between the two shafts

N1 = driver speed

T1 = Number of teeth found on the driver

d1 = Driver's Pitch circle diameter

N2 = follower Speed

T2 = Number of teeth of the follower

d2 = Pitch circle diameter of the follower

Pc = Circular pitch

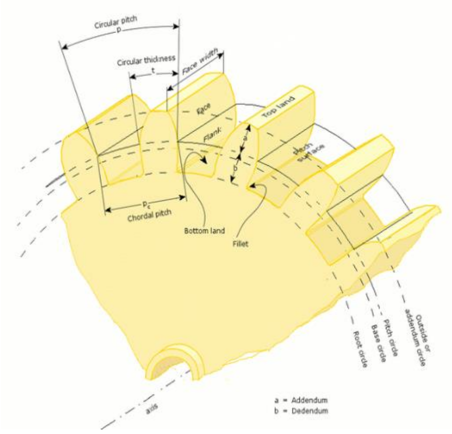

Figure 2: Spur gear main geometry

Depending on the situation, the result of T1 and T2 can be a full number or not. When the number of teeth in a gear design is a whole number, the values of x, d1, and d2 must be adjusted. This is done to ensure that the gear design's tooth count is always a whole number.

LEWIS EQUATION: The load carrying ability of toothed gears is defined by an equation (known as the *Lewis equation). For safety reasons, Lewis assumed that the load is divided among numerous teeth as it is transferred from one gear to another.

The load is considered to be at the driven teeth when contact occurs and at the driven teeth when contact ends. The weight may be spread among numerous teeth when the number of teeth in a pair of mated gears is considerable.

$$Ft=\sigma\ C_bY_m$$

Where,

C = velocity

b = face width

Y = form factor

m = module

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:03/March-2022 Impact Factor- 6.752 www.irjmets.com

σ = allowable static stress

LEWIS FORM FATOR

$$y = (0.124 - 0.684/Z) \text{ for } 14\ ½° \text{ involute system.}$$
$$= (0.154 - 0.912/z) \text{ for } 20° \text{ involute system}$$
$$= (0.175 - 0.95/z) \text{ for } 20° \text{stub teeth system}$$
$$Y = y^*\pi$$

FACE WIDTH OF GEAR IN TERMS OF MODULE $b = 9.5m \leq b \leq 12.5m$

V. MODELING AND ANALYSIS

MODELING: CATIA V5 is used for parametric 3D modelling, surface modelling, and structural simulations. It offers extensive libraries for typical parts and allows users to define libraries for repeated content. In the absence of accessible parametric gears, this study proposes a complete solution for integrating repeating gear content as an accessible function in the programmed platform. The geometry of a spur gear (Figure 2) is determined by well-known factors. thus, the generic gear will be to.

- The keyway on the shaft is only one way.
- It is used for key mounting for the involute splined joint on the shaft spur spline. Spline with helical curvature.

The Design of Generic Gears:

1. **Parameter:** The tooth's complicated geometry calls for Generative Shape Design. The teeth will be defined in a Geometrical Set — a set of definitions that relate intelligent geometric elements. The parameters are defined first: modulus, teeth number, outer, pitch, root radiuses. The geometric parameters will be based on specified rules, while the principal parameters are independent and used for user input. The involute spline curve will support the tooth profile. The curve will be rotated by ZX. These two circles will be utilized for trimming and filleting to finalize the profile of a tooth. So, the tooth profile will be arranged, joined for a sketch and extruded in Part Design mode.
2. **Parameterization of the mounting:** Specific design parameters and logical parameters for the parametric block status will be employed to solve the mounting type representation. These parameters will be used for pocket definition and square spline mounting. To acquire the spline mounting profile, the key mounting parameters are deactivated and a new pocked with the matching array is defined [3].

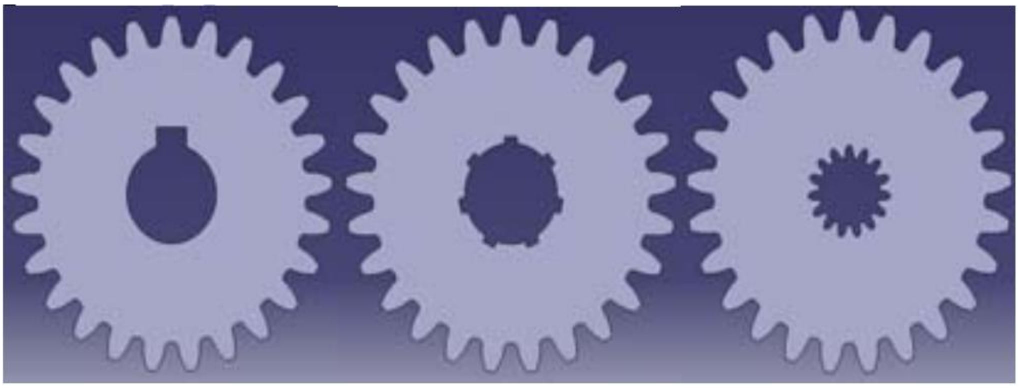

Figure 3: Spline Mounting Profile

3. **Parameterization of the tooth type:** To derive the helical gear from the generic spur gear pad, all extrusion definitions must be disabled, from the original Pad definition to the first plane sketch. The supporting rail is a parameterized helix. With the linked plane drawn structure, the tooth is obtained as a RIB feature. This will be the generic helical gear basis.

ANLYSIS: The ANSYS programme is a general-purpose finite element programmed that is self-contained and easy to use. Swason analysis systems Inc. is responsible for the development and maintenance ANSYS finite element analysis software enables following tasks:

- Design performance conditions or additional operating loads should be applied.

- Make a computer model of a building, component, good, or system for simulation.
- Testing prototypes in environments where it would be difficult or undesirable to do so in any other way.
- Temperature distributions, stress levels, and electromagnetic fields are studied.
- Optimizing design early in the development process might help you save money on your production costs.

PRE-PROCESSOR

The preprocessor is responsible for preparing the input data for ANSYS analysis. Preprocessor 7 (PREP 7) is a general-purpose preprocessor that includes solid modelling and mesh generating capabilities. It also creates all other analytical data and has data base definition and manipulation capabilities. Aside from the parametric input, user files, macros, and extensive online documentation are available to help the analyst identify the issue more precisely. For example, ANSYS provides isometric, perceptive, and sectional views of three-dimensional structures, as well as edge and hidden-line representations of input numbers and results.

The preprocessor stage involve:

- Specify the title, which should match the issue's title. This is a useful optional feature, especially if numerous configuration cycles are required on the same base mode.
- Thermal analysis, modal analysis, harmonic analysis, and other types of analysis are available.
- To create the model, follow these steps: The model can also be built in a pre-processor or imported from another design software by changing the file format.
- Defining element type: these are the elements selected from the element library.
- The Young's modules, the Poisson's ratio, and density of a material, as well as its thermal conductivity, damping effect, and specific heat, among other things, are all influenced.
- Use meshing to your advantage: Nothing more than the process of dividing a huge region into a small number of discrete particles can be described as meshing.

SOLUTION PROCESSOR

The environment of the model is constructed in this step, which involves the addition of restrictions and loads. There are several issue-solving strategies that can be used to solve the problem at this phase of the analysis, which is the most crucial phase of the process. There were three important steps:

- The solution type (static, modal, or transitory) is chosen.
- Loads are defined as follows: Surface loads and point loads are possible; thermal loads such as temperature, as well as fluid pressure and velocity, are also possible.
- Solve The FE solver has three basic steps: pre-solver, solution, and post-solver. After the pre-processor develops an arithmetical representation of the model, the mathematical-engine calculates the answer. The strains, stresses, and other parameters for each node inside the component or continuum are calculated in the post solver.

POST PROCESSOR:

Post-processing refers to the results of an analysis. As a result, we are trying to understand how the applied loads affect the design and how the meshing is achieved. It analyses the data and presents stress and strain contours, distorted geometries, flow fields, safety factor contours, and potential field results contours. The vector field displays mode forms and time graphs. The post processor can also conduct algebraic operations, database manipulation, and differentiation and integration of calculated results.

REVIEW THE RESULTS:

After calculating the solution, the results can be viewed in the post processor. POST 1 and POST 26 are the current post processors. When a single sub step is executed across the entire model or a selected area of the model, the results are examined using POST 1, the general post processor. The results of the study can be studied and analysed utilizing contour displays, deform forms, and tabular listings, all of which are readily available to us for our convenience. There are numerous other characteristics in POST 1, including error estimates, load case combination, computation among results data, and path operations, to name a few. When we wish to review outcomes at certain places in the model over the duration of all time steps, we use POST 26, the time history post processor, which is available in the model's documentation. Visualisations of the results are accessible in the form of graphs, data plots against time, and table listings. POST 26 also has other features, such as the ability to perform arithmetic calculations and complex algebra, among others. As a result of the simultaneous set of equations generated by the finite element method, the computer is able to compute the solution, which yields the following results.

- The values of the nodal degree of freedom, which when added together form the fundamental solution.
- The derived values that are used to organize the component arrangement are called derived values.

MESHING:

MESHING: Before latticing or even constructing the model, consider whether a free work or mapped cross section is better for the evaluation. Unrestricted works have no restrictions on their constituent elements forms and are not based on any preconceived example. Unlike a free work, the geometry of a mapped cross section is constrained by the pattern of mesh surrounding it. An area mesh can be either quadrilateral or triangular, although a volume cross section can be either. In order to develop this type of lattice, we need to arrange volumes and/or areas that can recognize a mapping network.

STRUCTURAL STATIC ANALYSIS:

Because of the damping and inertial effects, it is possible to compute load effects on a structure without taking them into consideration. For example, using structural static analysis techniques, it is possible to compute the load effects generated by time variable loads in real time. Static analysis encompasses, among other things, the analysis of steady equivalent loads such as static inertia loads and time changing loads. Removals, burdens, strains, and powers in structures or segments that are caused by burdens that do not have considerable dormancy and damping effects or that do not cause significant dormancy and damping effects are determined using static analysis. While it is generally recognized that the stacking and reaction conditions will persist, it is also projected that the stress and the structure's reactions will change gradually over time. Static analysis can be used to apply several types of loads, including.

- Application of force and pressure on the body.
- Inertial forces in a constant state of motion.
- Displacement.
- Thermodynamic behavior.

VI. RESULTS AND DISCUSSION

This gear model can be used in assembly design and can be fully interfaced with data bases. It is also available for download. Through the use of the Generative Structural Analysis module, this study can be further developed to include the creation of geometric data and mechanical element libraries. It can also be further developed to include the editing of the graphic interface and the definition of new functions through the use of Microsoft Visual Basic, allowing for simple geometry insertion into the model space. This newly created function can incorporate automatic calculation of assembly characteristics, such as maximum torque, into the programmed. This investigation can be broadened to include bevel gears and more complex geometries (structural holes or gear base).

Gears structural analysis:

Material Type: Cast Iron

In a static structural analysis, the influence of stable (or static) loading conditions on a structure is calculated while taking into account inertia and damping effects, such as those generated by time-varying loads, are not considered. Among the loads considered in a static analysis are constant inertia loads (such as gravity and rotational velocity and accelerations) and time-varying loads that can be approximated as static equivalent loads.

This figure will depict the sequence of processes that were performed in the design of gear with cast iron material properties applied to it and the completion of ANSYS work in Catia v5.

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:03/March-2022 Impact Factor- 6.752 www.irjmets.com

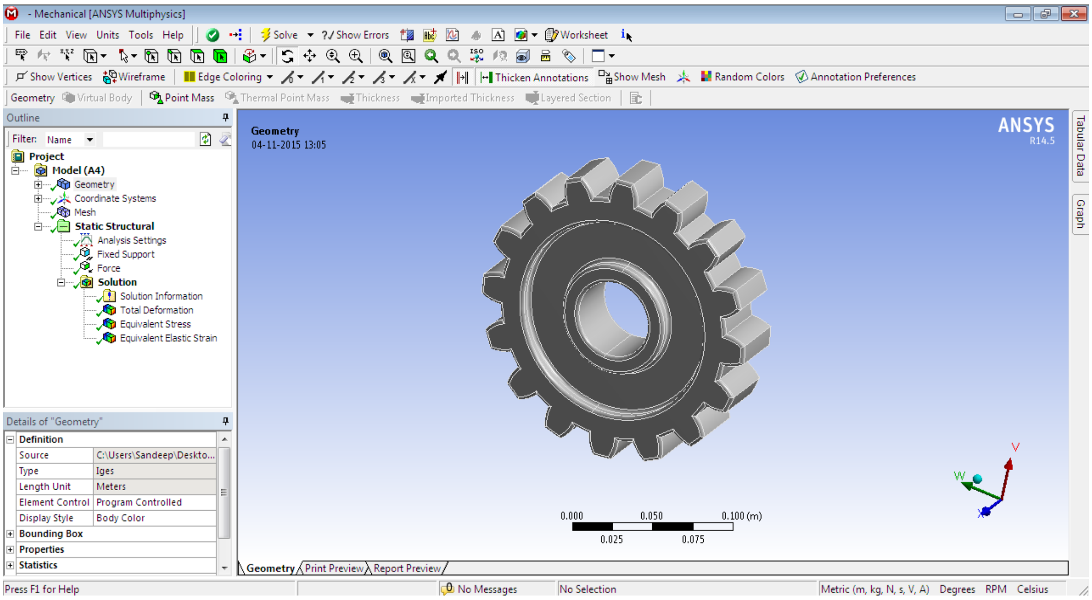

Figure 4: Gears structural analysis of gear with Cast Iron material

Meshed Model:

When two or more gears in a gear train mesh properly, the term "meshing" is used to describe the appropriate engagement of teeth between them. The gear mesh model of a gear made of cast iron is depicted in the accompanying illustration.

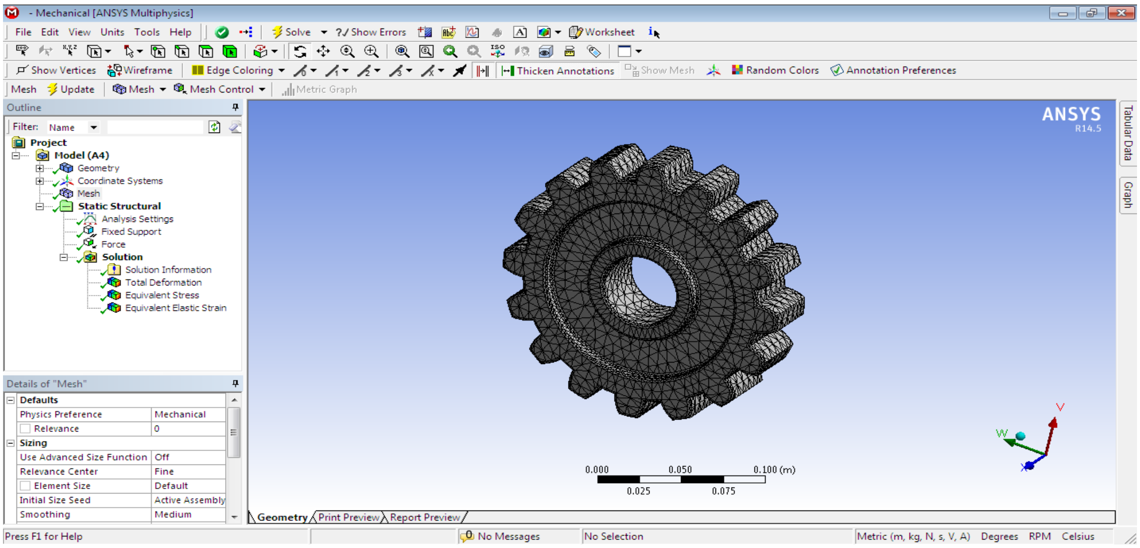

Figure 5: Gear Meshed Model of gear with Cast Iron material

Deformation in its entirety was observed:

The following figure represents Gear Deformation with Cast Iron, strainless steel and carbon fiber material.

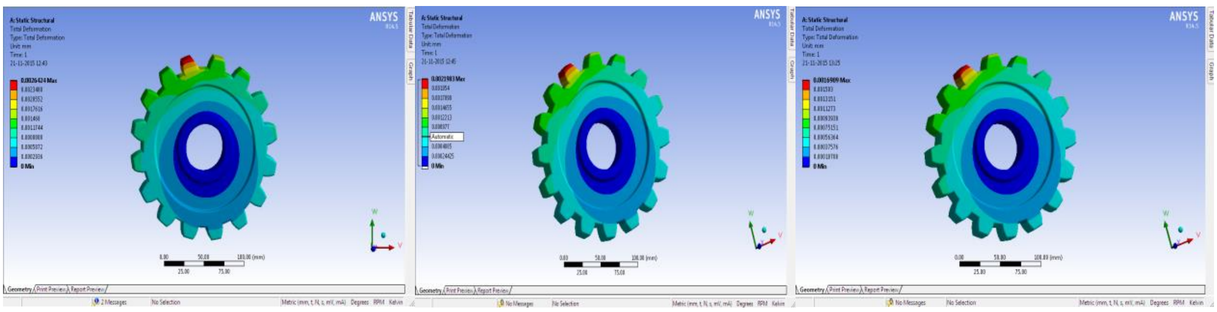

Figure 6: Deformation in its entirety Cast Iron, strainless steel and carbon fiber material

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:03/March-2022 Impact Factor- 6.752 www.irjmets.com

Von misses stress deformation of Cast Iron, strainless steel and carbon fiber spur gear:

The following figure represents Von misses stress deformation of Cast Iron, strainless steel and carbon fiber material.

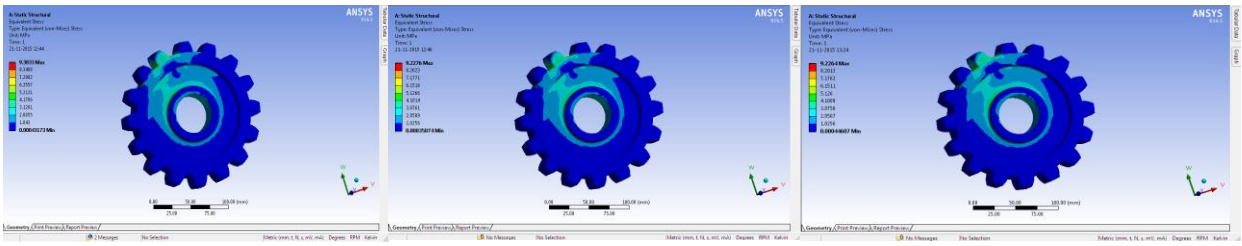

Figure 7: Von misses stress deformation of Cast Iron, strainless steel and carbon fiber spur gear

Von misses strain deformation of Cast Iron, strainless steel and carbon fiber spur gear:

The following figure represents Von misses strain deformation of Cast Iron, strainless steel and carbon fiber material.

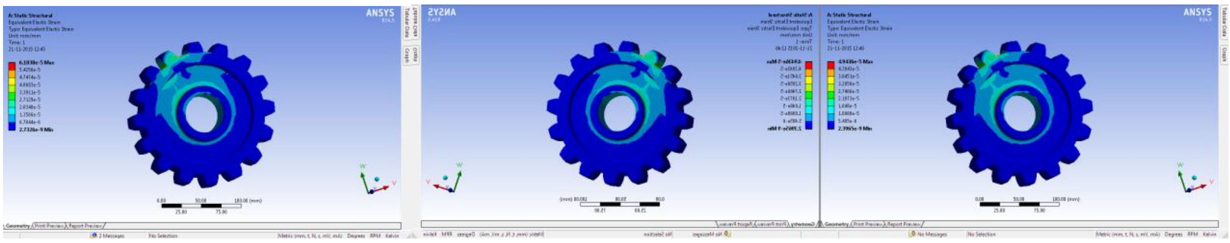

Figure 8: Von misses strain deformation of Cast Iron, strainless steel and carbon fiber spur gear

The numerical values that were collected throughout the analysis:

Table 2: Gear values discovered during the structural examination of the gear

S. No	Material type	Displacement (mm)		Von-Mises stress		Strain	
		min	Max	Min	Max	min	Max
1	CAST IRON	0	$2.642e^{-3}$	$4.31\ e^{-3}$	9.4231	2.632e-9	6.232E-5
2	STEEL	0	$2.1903\ e^{-3}$	$3.87\ e^{-3}$	9.1892	2.528e-9	4.854E-5
3	CARBON FIBER	0	$1.6909\ e^{-3}$	$4.64\ e^{-3}$	9.2145	1.112e-9	2.561E-5

Gear modal analysis results revealed the following values:

Table 3: Gear modal analysis results revealed

S. No	Material	mode 1	mode 2	mode 3	mode 4	mode 5
1	CAST IRON	3732	3733	4224	4411	4538
2	STEEL	3948	3948	4478	4604	4771
3	CARBON FIBER	8924	8921	1.00e3	1.00e3	1.07e3

- Carbon fibre composites deform far less than structural steel or cast-iron spur gear.
- The stress levels measured in the Spur gear made of carbon fibre composites are lower than other types of gears.
- The natural frequency of the carbon fibre-epoxy resin composite spur gear is much higher than the natural frequencies of steel and cast-iron spur gears, according to modal analysis of three spur gears.

VII. CONCLUSION

A spur gear is finite element analyzed in ANSYS 14.5 to determine maximum stress and deformation. When comparing total deformation in spur gears composed of cast iron, structural steel, and carbon fiber, cast iron has much less total deformation than carbon fiber. Compared to other materials, the reported three-dimensional stresses are minimal. Steel has a higher deformation value than other materials. As a result, carbon fiber may soon replace cast iron in the gearbox. Carbon fiber, which is strong, can be utilized to make other components such as drive shafts and applications requiring less power. Carbon fiber is lighter than other materials and has excellent conductivity, minimal thermal expansion, low noise, and corrosion resistance.

VIII. REFERENCES

[1] V. Siva Prasad, Syed AltafHussain, V.Pandurangadu, K.PalaniKumar. Modeling and Analysis of Spur Gear for Sugarcane Juice Machine under Static Load Condition by Using FEA. International Journal of Modern Engineering Research (2012), 2(4):2862-2866.

[2] Mahebub Vohra, Prof. Kevin Vyas "Comparative Finite Element Analysis of Metallic and non Metallic spur gear", May-June 2014, IOSR Journal of Mechanical and Civil Engineering, 11(3):136-145.

[3] Lin Tengjiao, Ou H., Li Runfang. 2007. A finite element method for 3D static and dynamic contact/impact analysis of gear drives, Computer Methods in Applied Mechanics and Engineering, 196(9-12):1716-1728.

[4] Kahraman A., Kharazi A. A., Umrani M. 2003. A deformable body dynamic analysis of planetary gears with thin rims, Journal of sound and vibration, 262:752-768.

[5] Nitin Kapoor, Pradeep Kumar, Rahul Garg and Ram Bhool. " Parametric Modeling and Weight Analysis of Glass Filled Polyamide Composite Differential Gearbox", International Journal of Science, Engineering and Technology Research, 2014,3(6).

[6] S. Kirupasankar, C. Gurunathan, R. Gnanamoorthy. Transmission efficiency of polyamide nanocomposite spur gears||, Indian Institute of Information Technology, Design and Manufacturing (IIITD&M) Kancheepuram, Melakottaiyur, Chennai 600 048, India, Materials and Design 39 (2012): 338-343.

[7] Prasil, Ludvik, Mackerle and Jaroslav. 2008. Finite element analyses and simulations of gears and gear drives. A bibliography 1997-2006, Engineering Computations: International Journal for Computer-Aided Engineering and Software, 25(3):196-219.

[8] Jesper Brauer, Soren Andersson. Simulation of wear in gears with flank interference-a mixed FE and analytical approach, Department of Machine Design, KTH, Brinellvagen 83, 100 44 Stockholm, Sweden, Wear254(2003):1216-1232.

[9] R. Yakut, H.Duzcukoglu, M.T.Demirci Mechanical Education Department, University of selcuk, Campus.