# Design and Analysis of Reduction Spur Gearswith Composite Material using Static Structural Analysis Technique

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***ABSTRACT:Mechanical power transmission systems and industrial rotational machines rely heavily on gears. If the spur gear is meshing with another tooth, it is susceptible to two kinds of stresses: bending stresses and contact stress. Spur gears are the easiest and most common form of power transmission. Modern machines must be operated with variedloads and speeds. Normal failure of gear teeth occurs when the load exceeds a particular limit.As a result, it is necessary to seek alternative materials for gear manufacturing. A superior alternative to metallic gears is composite materials, which combine strength and weight reduction. An important goal of this work is to determine what the optimal result of composite material use in reduction gears looks like. In automobile components, composite materials have been employedbecause of their high specific stiffness, low weight, high specific stiffness, corrosion-free, ability to construct complex shapes, high specific strength and high impact energy absorption, among other qualities and advantages. Composites provide many improved mechanical properties such as better strength to weight ratio, more hardness, and hence fewer chances of failure. Efforts have also been carried out for modelling using 3D modelling software called SOLIDWORKS 2018 and finite element analysis of gears using ANSYS WORKBENCH R 2016.***

***Keywords:Spur gear; Centre distance; Constraints Materials, bending stress,Static Structural, finite element analysis, composite material.***

## 1. INTRODUCTION

It is a positive drive that maintains a constant velocity ratio and has great transmission efficiency. The spur gear with an involute profile is the simplest gear type in terms of design and manufacturing cost [1]. An analysis of the spur gear of an automobile gearbox has been presented in this paper. When it comes to modern power transmission systems, highly efficient gears are essential [2]. Straight-cut gears or Spur gears are the most basic type of gear. Basically, they're made out of a cylinder or disc with radial teeth on the surface.The edge of each tooth is straight and oriented parallel to the axis of rotation, despite the teeth not being straight-sided (although usually of a specific form to provide a constant drive ratio, mainly involute but less commonly cycloidal)They only mesh correctly when mounted on parallel shafts[3]. They do not generate any axial thrust. Although spur gears perform well at moderate speeds, they can be loud at higher speeds. For motion and energy transmission, spur gears are utilised to generate motion. Using a spur gear, you can rotate shafts that are aligned parallel to one anotherSpur gear has the advantage of being simple and compact in design, and the manufacturing process takes less time, which is its major advantage.It was low-maintenance and economical to maintain. Current technology makes spur gears indispensable, notably for gear pumps and drive shafts. The spur gears offer good mechanical features such as lubricant-free, noise-free, very high strength-to-weight ratio, corrosion-resistant, etc [4]. Composite material (also known as a composition material or shortened to composite) is the material made from two or more constituent elements with considerably distinct physical or chemical properties which, when combined, produce a material with characteristics that differ from the individual components. As a finished structure, the different components stay separate and distinct from each other. New Materials that are stronger, lighter, or less expensive than traditional materials may be favoured for a variety of reasons. Recently, researchers have begun to actively incorporate sensing, actuation, computing, and communication into composites, which are referred to as Robotic Materials by researchers. Finite Element Analysis plays a significant part in durability studies since the forecast of life and the location of the damage is critical. FEA was originally created to solve complicated problems in solid mechanics by using numerical methods.

Simulation of deformable solids using FEA is the most extensively used and adaptable technique.

## 2. LITERATURE REVIEW

**Vivek Karaveer et al (2013)** exhibited the pressure investigation of mating teeth of the footing apparatus to discover greatest contact worry in the rigging tooth. The outcomes got from limited component investigation are contrasted and hypothetical Hertz condition esteems. The footing gear are displayed and amassed in ANSYS DESIGN MODELER and stress examination of footing gear tooth is finished by the ANSYS 14.5 programming. It was discovered that the outcomes from both Hertz condition and Finite Element Analysis are practically identical. From the distortion example of steel and dim cast press, it could be reasoned that distinction between the most extreme estimations of steel and dim CI adapt mishapening is less [5].

**K. Daoudi and E. M. Boudi, (2018)**was reduced in weight and centre distance of one pair of spur gears. This goal was achieved using the GA while adhering to certain constraints, such as bending strength, contact stress, and gear dimension requirements. The results are estimated using Matlab's Genetic algorithm tools and four different materials: normal steel, stainless steel, grey cast iron, and alloy copper [6].

**A. Pavan et al (2019)**proposed a novel spur gear with reduced transmission error and longer life for electric/hybrid vehicles, adapted to strong initial torque and reverse loads during braking. The teeth of the spur gear profile have been micro- geometrically modified for the application in the issue. Contact analysis is used to develop profile modified spur gears with preferred running characteristics, as well as experiment design to optimise the gears' running characteristics and optimization [7].

**Bachir et al (2019)** examined the effect of modifying the addendum factor on the contact ratio factor as well as the contact stress produced on the zone action of spur gear teeth during meshing. There were three different addendum factors used in this study: 1, 1.15 and 1.25 with the contact stress calculated according to the ISO formula & compared to the results from the finite element approach. SolidWorks was used to create and build the 3D model, which was then subjected to ANSYS Workbench's stress analysis to obtain the results (FEM) [8].

**Amadane, et al (2020)**is being studied in relation to the root bending stress created by spur gear teeth pair, in order to decrease stress and optimise design, the Profile Shift Factor (x). Profile Shift Factor x = 0; x =0.1; and x =0.2 are selected in this work. Based on LEWIS theory, ISO standard equations are used to determine bending stress, which is then verified using ANSYS Workbench software's Finite Element Method (FEM). They were created three geometry models using Solidworks [9].

**Sahi, et al (2020)** proposed that an aluminium alloy material be used in the gear train design in Solid works at a certain parameter. Ansys 18.0 is used for the next step of the analysis, which involves applying various loading conditions. Two types of simulation analysis are performed: vibration analysis and stress analysis. In a gear train, 500 N-m of the moment is supplied. The tooth and shaft stresses are measured in order to verify if the result analysis produced is in compliance with the yield tensile limit of the used materials [10].

## 3. OBJECTIVES

- Check the comparative effect of produced stress in conventional metallic material of spur gears using a static finite element method.
- Check the metallic material using static finite element analysis.
- Check the stress analysis of gear parameters like face width and module under loading conditions.
- Check the possibility to replace metallic gear with other materials like polymer, composite or hybrid material for spur gear.

## 4. PROPOSED METHODOLOGY

The aim of this work is to optimize the quality of Reduction gear as the ratio of 3:1. For that, we are utilizing diverse composite materials and contrasting them and ordinary material demonstrating that composite material will help in enhancing the quality of apparatus. the MMC (Metal matrix composite materials) Al-SiC The composite Al-SiC selected have AL 6061 matrix with reinforcements materials of 18% SiC. High strength, stiffness, thermal stability, corrosion and wear resistance, and fatigue life are all features of aluminium alloy composite materials. According to the research, composite materials such as aluminium silicon carbide are one of the options for power transmission gears. 50% cabon fibre reinforcement in epoxy resin. High strength epoxy adhesives are used in fabrication of carbon fiber composite drive shafts for cars. The metal inserts provide support for bearings, shafts, gears and other metal components of the gearbox.The Reduction gear is demonstrated in "SOLIDWORKS 2018" and imported to "ANSYS 2016" for basic investigation and modular examination.

### 4,1 Design of Reduction Gear Using Solidworks

Design of Reduction Gear using Solidworks is performed by 3d Part Modelling. Solidworks is a modern CAD/CAE/CAM software used to design complex designs in a very quick way. Design of Reduction gears is done by two interferences i.e.,first, we create the 2D sketch of the gear usingGear Parameters and then convert it into 3Dmodelling using EXTRUDE command

### I. Gear 1 Design Parameters

Equations, Global Variables, and Dimensions

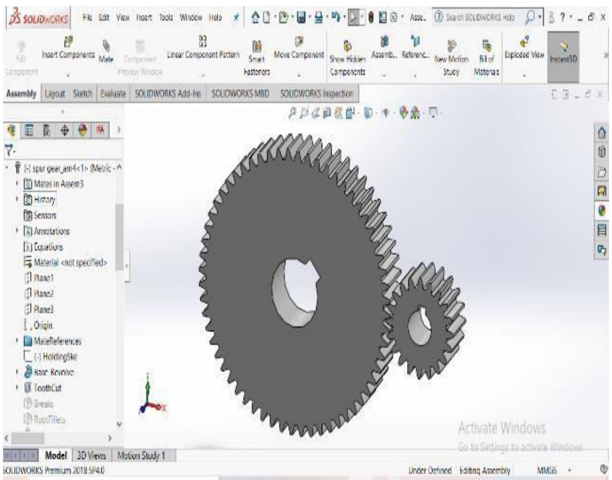
| Name | Value / Equation | Evaluates to |
|---|---|---|
| Global Variables | | |
| "Teeth" | = 60 | 60 |
| "Module" | = 2 | 2 |
| "PCD" | = "Teeth" * "Module" | 120 |
| "Circular pitch" | = "PCD" * pi / "Teeth" | 6.28319 |
| "diameteral pitch" | = 1 / "Module" | 0.5 |
| "Addendum" | = "Module" | 2 |
| "Addendum circle diameter" | = "PCD" + 2 * "Addendum" | 124 |
| "clearence" | = "Circular pitch" / 60 | 0.10472 |
| "dedendum" | = "Addendum" + "clearence" | 2.10472 |
| "dedendum circle diameter" | = "PCD" - 2 * "dedendum" | 115.791 |
| "Pressure angle" | = 20 | 20 |
| "Gear thickness" | = 20 | 20 |
| "Shaft Diameter" | = 40 | 40 |

### II. Gear 2 Design Parameters

Equations, Global Variables, and Dimensions

| Name | Value / Equation | Evaluates to |
|---|---|---|
| Global Variables | | |
| "Teeth" | = 20 | 20 |
| "Module" | = 2 | 2 |
| "PCD" | = "Teeth" * "Module" | 40 |
| "Circular pitch" | = "PCD" * pi / "Teeth" | 6.28319 |
| "Diametrical Pitch" | = 1 / "Module" | 0.5 |
| "Addendum" | = "Module" | 2 |
| "AddendumCircleDia" | = "PCD" + 2 * "Addendum" | 44mm |
| "Clearence" | = "Circular pitch" / 20 | 0.314159mm |
| "Dedendum" | = "Addendum" + "Clearence" | 2.31416mm |
| "DedendumCircleDia" | = "PCD" - 2 * "Dedendum" | 35.3717mm |
| "Pressure angle" | = 20 | 20 |
| "Gear thickness" | = 20 | 20 |
| "Shaft diameter" | = 20 | 20 |

### III. 3D Model of Reduction Gear Assembly.



**Composite Material Properties.**

**1) Grey Cast Iron**

| Properties | Value | Units |
|---|---|---|
| Mass Density | 7.85 | g/cm^3 |
| Poisson Ratio | 0.28 | |
| Young Modulus | 1.1E+005 | PA |
| Bulk Modulus | 8.333E+10 | PA |
| Shear Modulus | 4.296E+10 | PA |

**2) Aluminium Silicon Carbide (20% SIC)**

| Properties | Value | Units |
|---|---|---|
| Mass Density | 2.81 | g/cm^3 |
| Poisson Ratio | 0.3 | |
| Young Modulus | 1.5E + 11 | PA |
| Bulk Modulus | 1.25E + 11 | PA |
| Shear Modulus | 5.7E + 10 | PA |

**) Mild Steel (EN 8)**

| Properties | Value | Units |
|---|---|---|
| Mass Density | 7.80 | g/cm^3 |
| Poisson Ratio | 0.28 | |
| Young Modulus | 1.9E + 11 | PA |
| Bulk Modulus | 1.4E+11 | PA |
| Shear Modulus | 7.4E + 10 | PA |

**4) Carbon Epoxy**

| Properties | Value | Units |
|---|---|---|
| Mass Density | 1.8 | g/cm^3 |
| Poisson Ratio | 0.30 | |
| Young Modulus | 4.5E + 11 | PA |
| Bulk Modulus | 3.75E + 11 | PA |
| Shear Modulus | 1.73E + 11 | PA |

### Finite Element Analysis Method

Finite element analysisis one of the most essential methods for evaluating the gear material in a loading state. By using an analysis package called Ansys, this section examines how gear material bends under tension. SOLIDWORKS is used to create a 3D model with the necessary geometry properties, which is imported into ANSYS as an Initial Graphic Exchange System (IGES) file. In ANSYS, an automatic mesh generation tool is used to divide the geometry into a desired number of elements.

### Static Structural Analysis Module

We use the FEA method in Ansys using the Static Structural Analysis module to analyse and simulate various Composite Materials used in reduction material. Structural Analysis is the method in which a structure or a solid model is considered in static condition and applied various parameters on that to find various stress concentrations and total deformation.

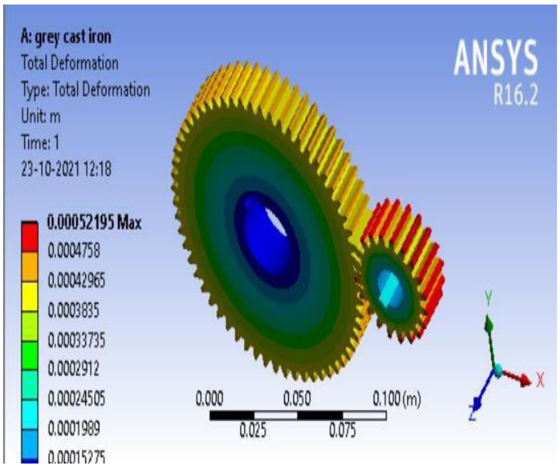
## 5. RESULT & ANALYSIS

The structural analysis module is performed in various phases

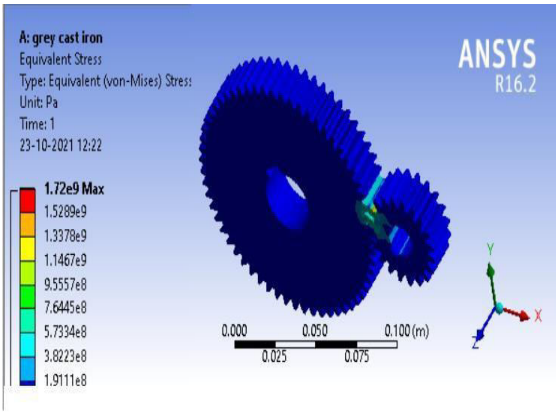
- Mesh the model
- Apply Structural features
- Frictional Forces on both gears
- Consider Torque 350 Nm at 400rpm

**1) Grey Cast Iron**

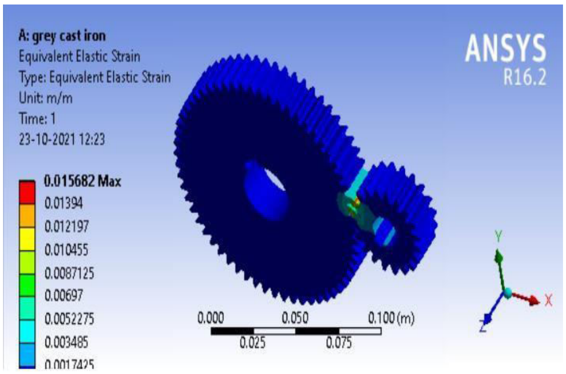
**a) Total Deformation**




**b) Equivalent Stress**

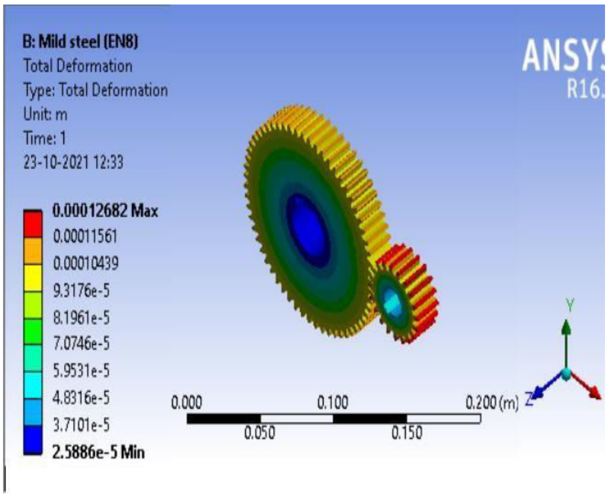



**c) Equivalent Elastic Strain**

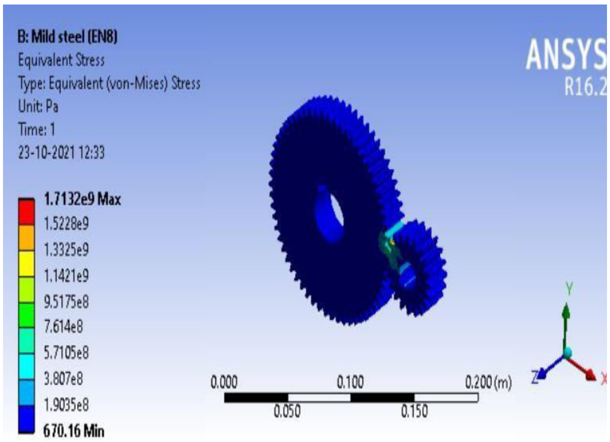


2) **Mild steel (EN8)**

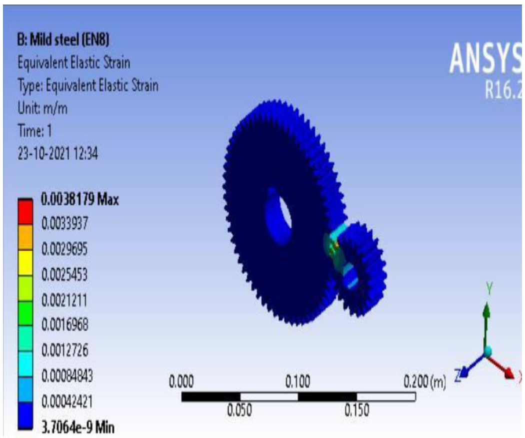
a) **Total Deformation**




b) **Equivalent Stress**



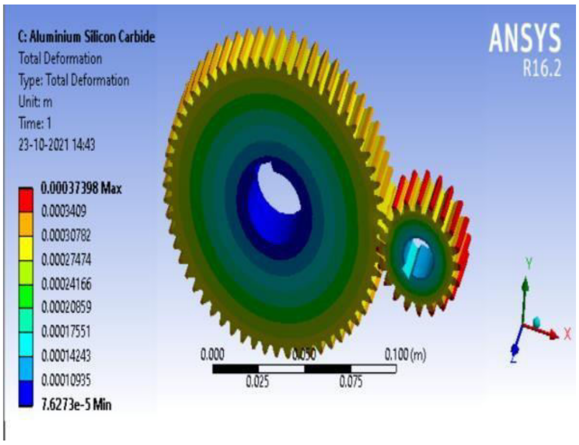

c) **Equivalent Elastic Strain**



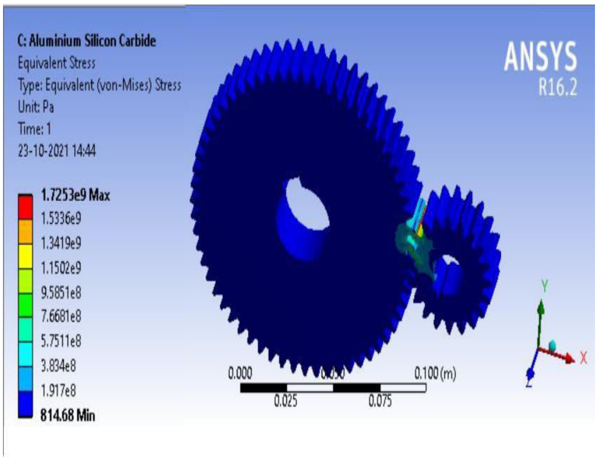

3)

**Aluminium Silicon Carbide**

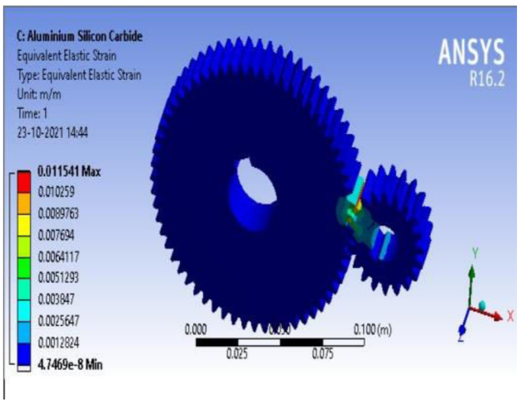
a) **Total Deformation**




b) **Equivalent Stress**




c) **Equivalent Elastic Strain**



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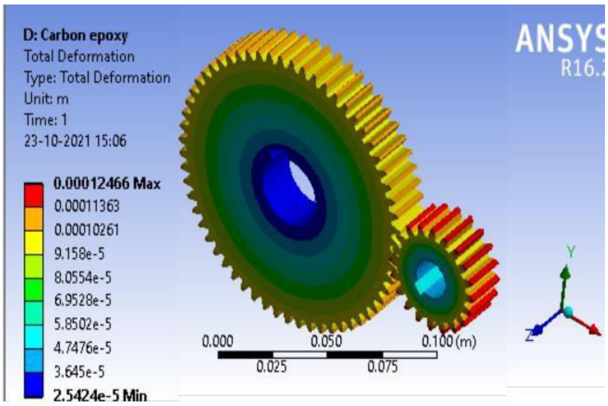
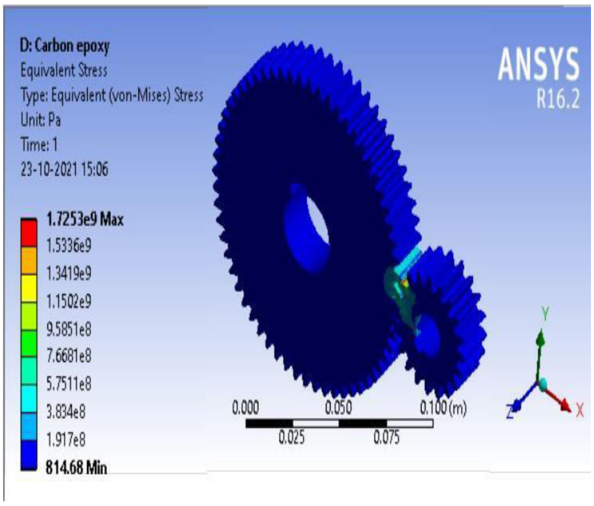
### 4) Carbon Epoxy

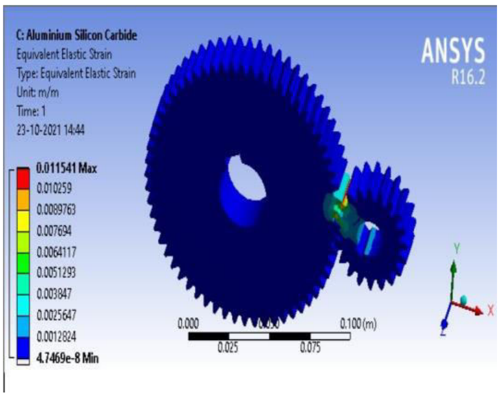
#### a) Total Deformation




#### b) Equivalent Stress




#### c) Equivalent Elastic Strain




**Result Parameters**

| Material | Total Deformation | Equivalent Stress | Equivalent Elastic Stress |
|---|---|---|---|
| Grey Cast Iron | Min 0.166 mm Max 0.521 mm | Min 649.78 PA Max 1.72E+009 PA | Min 1.3E-008 Max 1.5E-002 |
| Mild Steel (EN8) | Min0.026 mm Max 0.126 mm | Min 670.1 PA Max1.713E+009PA | Min 3.7E-009 Max 3.8E-003 |
| Aluminium Silicon Carbide | Min 0.076 mm Max 0.383 mm | Min 2357.6 PA Max1.719E+009PA | Min 4.9E-008 Max 1.1E-002 |
| Carbon Epoxy | Min 0.025 mm Max 0.124 mm | Min 814.68 PA Max1.725E+009PA | Min 1.5E-008 Max 3.8E-003 |

## 6. CONCLUSION

Different materials are used in spur gear production, resulting in a variety of contact stresses. The kit's crucial component has been determined, and ANSYS software has been used to conduct a stress analysis. The maximum shear stress and total deformation of grey cast iron, aluminium silicon carbide, Mild steel, and carbon epoxy with reduction spur gears as a substitute in the gear manufacturing industry were compared in this process, and the software was programmed in SOLIDWORKS 2018 and ANSYS 16.2 Workbench to achieve the best possible result. Ansys' Static Structural Study module was used to analyse and simulate various Composite materials utilising the stress distribution obtained inthe FEA analysis approach.

- The examination of aluminium silicon carbide, carbon epoxy, cast iron, and mildsteel EN8 in the application of gear boxesused in transmission systems is based on that study.
- Carbon epoxy was discovered to offer good resistance qualities when comparedto other materials.

## FUTURE SCOPE

Numerous investigations on spur gears that use composite materials as the gear material have been undertaken. The roots of the gear tooth have been subjected to a great deal of stress. This means that instead of using composites throughout the structure while keeping the core the same, it's best to concentrate on these critical areas. As a result, the gear will be less expensive, as new materials like composites are fairly costly. This form of structure, on the other hand, will be suitable for precision applications. In addition to the materials listed, many types of composite materials can be used to improve outcomes, increase gear strength and life, and be used in other industries for betterresults.

## REFERENCES

1. V.B. Bhandari, Design of machine elements, 2nd ed. New Delhi, India, McGraw Hill Education, ISBN: 0-07-061141-6, 2009, Ch. 17, sec. 17.5, pp. 656-657
2. Vikash Chauhan, A review on the effect of some important parameters on the bending strength and surface durability of gear, International journal of science and research (IJSR) Publications, Vol 6, Issue 3, March 2016 289 ISSN 2250- 3153.
3. 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 (IJMER), Vol.2, Issue.4, July-Aug 2012 pp-2862- 2866, ISSN: 22496645
4. K. Mao, ―A new approach for polymer composite gear design‖, Mechanical Engineering, School of Engineering and Design, Brunel University, Uxbridge, Middlesex UB8 3PH, UK, accepted 14 June 2006
5. Vivek Karaveer, Ashish Mogrekar and Preman Reynold Joseph T (2013), "Modeling and Finite Element Analysis of Spur Gear", International Journal of Current Engineering and Technology, ISSN 2277-4106.
6. K. Daoudi and E. M. Boudi, "Genetic Algorithm Approach for Spur Gears Design Optimization," *2018 International Conference on Electronics, Control, Optimization and Computer Science (ICECOCS)*, 2018, pp. 1-5, doi: 10.1109/ICECOCS.2018.8610520
7. A. Pavan S., S. Periyasamy, V. Karthik S.S. and A. Gopalakrishnan, "Microgeometry Optimization of Spur Gear for Electric and Hybrid Vehicle Applications," *2019 IEEE Transportation Electrification Conference (ITEC-India)*, 2019,pp. 1-5, doi: 10.1109/ITEC-India48457.2019.ITECINDIA2019-155
8. B. Samya, A. Bachir, E. M. Boudi and I. Amarir, "The Effect of Addendum Factor on Contact Ratio Factor and Contact Stress for Spur Gears," *2019 7th International Renewable and Sustainable Energy Conference (IRSEC)*, 2019, pp. 1-6, doi: 10.1109/IRSEC48032.2019.9078205
9. B. Samya, E. M. Boudi, A. Bachir and Y. Amadane, "Analysis of Profile Shift Factor's Effect on Bending Stress of Spur gears Using The Finite Element Method," *2020 IEEE 6th International Conference on Optimization and Applications (ICOA)*, 2020, pp. 1-6, doi: 10.1109/ICOA49421.2020.9094486
10. A. Kumar, Y. Sahi, S. Chandan and P. Suresh, "Modal Analysis of Helical Gear Train using Ansys," *2020 International Conference on Computational Performance Evaluation (ComPE)*, 2020, pp. 604-607, doi: 10.1109/ComPE49325.2020.9200162