# DESIGN, ANALYSIS AND OPTIMIZATION OF COMPOSITEGEAR BOX

**R. JEREMIAH[1], S. BALU[2] I. JOB GAMALIE[3]**

[1,2,3]Dept. of Mechanical Engineering, Kings Engineering College, Chennai- 602 117

**Abstract-**

The main objective of this project is to design analyses and optimize a composite gear box using modeling and analyzing software's to reduce the weight and improve its performance. A gear box is used to vary the speed of a system which is run by using a prime mover such as motor, engine. For attaining different speed these types of gearboxes are used.

In recent days they are using hardened steel or iron in the manufacture of gears that are used in the gearbox. These types of materials have high mass and stress. This causes a poor performance of the system. To improve the performance of the system, there must be a minimum stress and mass in the transmission system. Some composite materials can satisfy these conditions.

A gearbox is designed with various design parameters and is modeled using modeling software. The various stress, displacement and strain for the gear box is identified by applying various materials using analyzing software. by using an optimization technique, suitable material for the gearbox is identified and applying it to the existing gearbox for comparison of the lifetime and performance.

## I. INTRODUCTION

A gearbox is a mechanical method of transfer ring energy from one device to another and is used to increase torque while reducing speed. Torque is the power generated through the bending or twisting of a solid material. This term is often used interchangeably with transmission located at the junction point of a power shaft, the gearbox is often used to create a right angle change in direction, as is seen in a rotary mower or a helicopter. Each unit is made with a specific purpose in mind, and the gear ratio used is designed to provide the level of force required. This ratio is fixed and cannot be changed once the box is constructed. The only possible modification after the fact is an adjustment that allows the shaft speed to increase, along with a corresponding reduction in torque.

## II. LITERATURESURVEY: GEAR CLASSIFICATION

Some of the types of gears are as follows:

- Spur Gear
- Helical Gear
- Bevel Gear
- Worm Gear
- Rack and Pinion.

### *A. Spur gear*

Spur gears are the most commonly used gear type. They are characterized by teeth which are perpendicular to the face of the gear. Spur gears are by far the most commonly available, and are generally the least expensive.

### *B. Helical gear*

Helical gears may be used to mesh two shafts that are not parallel, although they are still primarily use in parallel shaft applications. A special application in which helical gears are used is a crossed gear mesh, in which the two shafts are perpendicular to each other. The basic descriptive geometry for a helical gear is essentially the same as that of the spur gear, except that the helix angle must be added as a parameter.

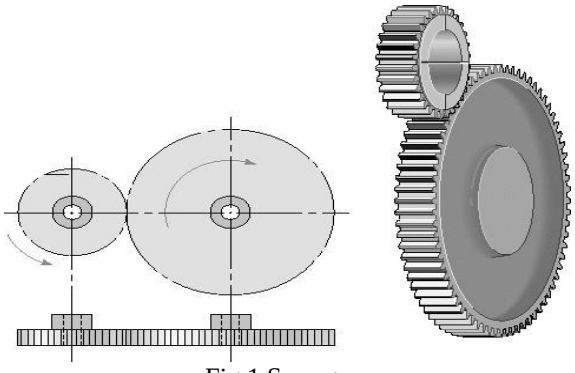

Fig.1 Spur gear

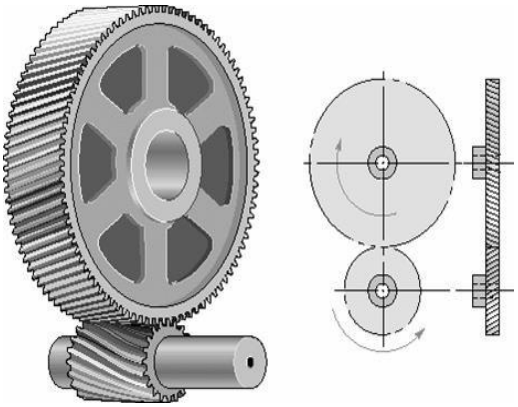

Fig.2 Helical gear

*C. Gearbox*

An automobile is able to provide varying speed and torque through its gear box. Various functions of a gearbox are listed below:

- To provide high torque at the time of starting, vehicle acceleration, climbing up a hill.
- To provide more than forward speeds by providing more than one gear ratios. In modern cars, five forward gears and reverse gear is provided. For given engine speed, higher speed can be obtained by running in higher (4th and5th) gears.
- Gear box provides a reverse gear for driving the vehicle in reverse direction.

*D. Types of Gearboxes*

**a)** Selective type gear boxes
- Sliding mesh gearbox
- Constant mesh gear box
- Synchro mesh gear box

**(b)** Progressive type gearbox

**(c)** Epicyclical type gear box.

*E. Sliding Mesh Gearbox*

It is simplest type of gear box out of the available gearboxes. In this type of gearbox, gears are changed by sliding one gear on the other. This gearbox consists of three shafts; main shaft, clutch shaft and a counter shaft. In a four speed gearbox (which includes one reverse gear) ,the counter shaft has four gears which are rigidly connected to it. Transmission shaft has one gear and main shaft has two gears. The two gears on the main shaft can slide in the horizontal direction along the splines of the main shaft. However, the gears on the counter shaft cannot slide. The clutch gear is rigidly fixed to the clutch shaft. It is always connected to the counter shaft drive gear.

*F. Synchro Mesh Gearbox*

This type of gear box is similar to the constant mesh type in that all the gears on the main shaft are in constant mesh with the corresponding gears on the lay shaft. The gears on the lay shaft are fixed to it while those on the main shaft are free to rotate on the same. Its working is also similar to the constant mesh type, but in the former there is one definite improvement over the latter. This is the provision of synchro mesh device which avoids the necessity of double declutching. The parts which ultimately are to be engaged are first brought into frictional contact which equalizes their speed, after which these may be engaged smoothly.

*G. Composite Material*

Composite materials (also called composition materials or shortened to composites) are materials made from two or more constituent materials with significantly different physical or chemical properties, that when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure. The new material may be preferred for many reasons: common examples include materials which are stronger, lighter or less expensive when compared to traditional materials.

Typical engineered composite materials include:
- Composite building materials such as cements, concrete
- Reinforced plastics such as fiber-reinforced polymer
- Metal Composites
- Ceramic Composites (composite ceramic and metal matrices) Composite materials are generally used for buildings, bridges and Structures such as boat hulls, swimming pool panels, race car bodies, shower stalls, bath tubs, storage tanks, imitation granite and cultured marble sinks and counter tops. The most advanced examples perform routinely on space craft in demanding environments.

*H. Software's Used*

Some of the software's that are used for modeling and analyzing the above mentioned composite gearbox are

- Solid works Software
- Ansys Software

*I. Solid works*

The Solid Works CAD software is a mechanical design automation application that lets designers quickly sketch out ideas, experiment with features and dimensions, and produce models and detailed drawings.

- Definedby3Ddesign
- Basedoncomponents

## III. TAGUCHI'S METHOD DESIGN OF EXPERIMENTS

1. Define the process objective, or more specifically, a target value for a performance measure of the process. The target of a process may also be a minimum or maximum. The deviation in the performance characteristic from the target value is used to define the loss function for the process.

2. Determine the design parameters affecting the process. Parameters are variables within the process that affect the performance measure that can be easily controlled. The number of levels that the parameters should be varied at must be specified

3. Create orthogonal arrays for the parameter design indicating the number of and conditions for each experiment. The selection of orthogonal arrays is based on the number of parameters and the levels of variation for each parameter, and will be expounded below.

4. Complete data analysis to determine the effect of the different parameters on the performance measure. The pictorial depiction of Taguchi method and additional possible steps, depending on the complexity of the analysis is given in the form of a flow chart.

## IV. ANALYSIS OF VARIANCE

The purpose of product or process development is to improve the performance characteristics of the product or process relative to customer needs and expectation. The purpose of experimentation should be to reduce and control variation of a product or process and decide which parameter affects the performance of the product or process. Analysis of variance (ANOVA) is a statistical method used to interpret experimented data and make decisions about three parameters.

A. Minitab

Minitab is a general purpose statistical package designed for easy interactive use. Minitab was originally designed as a tool to be used in teaching statistics. Its interactive features make it well suited to instructional applications, and Minitab's greatest popularity remains as a teaching tool. However, Minitab is sufficiently powerful that it is also used by many people in analyzing research data.

B. Uses of Minitab

Data and File Management – spread sheet for better data analysis. Tables and Graphs, Multivariate Analysis - includes factor analysis, cluster analysis, correspondence analysis, etc, Analysis of Variance - to determine the difference between data points.

C. Selection of Control Factors

The control factors can be identified using different tools. Characteristics that you can control in the product or process you are designing. Factors (or control factors) are the design parameters of a concept or technology that need to be optimized.

Table.1: Selection of control factors

| LEVELS / FACTORS | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| A Face width (mm) | 20 | 25 | 30 | 35 | 40 |
| B Helixangle (degree) | 15 | 17 | 19 | 21 | 23 |
| C Materials | Alloy steel | Cast carbon steel | Malleable castiron | Glass filled polyamide | Carbon epoxy |

Table.2: Design of Experiments

| EXP. | FACEWIDTH (mm) | HELIXANGLE (degree) | MATERIALS |
|---|---|---|---|
| 1 | 20 | 15 | AlloySteel |
| 2 | 20 | 17 | Castcarbonsteel |
| 3 | 20 | 19 | Malleable CastIron |
| 4 | 20 | 21 | Glassfilledpolyamide |
| 5 | 20 | 23 | CarbonEpoxy |
| 6 | 25 | 15 | Castcarbonsteel |
| 7 | 25 | 17 | Malleable CastIron |
| 8 | 25 | 19 | Glassfilledpolyamide |

| | | | |
|---|---|---|---|
| 9 | 25 | 21 | CarbonEpoxy |
| 10 | 25 | 23 | AlloySteel |
| 11 | 30 | 15 | Malleable CastIron |
| 12 | 30 | 17 | Glassfilledpolyamide |
| 13 | 30 | 19 | CarbonEpoxy |
| 14 | 30 | 21 | AlloySteel |
| 15 | 30 | 23 | Castcarbonsteel |
| 16 | 35 | 15 | Glassfilledpolyamide |
| 17 | 35 | 17 | CarbonEpoxy |
| 18 | 35 | 19 | AlloySteel |
| 19 | 35 | 21 | Castcarbonsteel |
| 20 | 35 | 23 | Malleable CastIron |
| 21 | 40 | 15 | CarbonEpoxy |
| 22 | 40 | 17 | AlloySteel |
| 23 | 40 | 19 | Castcarbonsteel |
| 24 | 40 | 21 | Malleable CastIron |
| 25 | 40 | 23 | Glassfilledpolyamide |

## V. MODEL FOR DESIGN PARAMETER OF GEARBOX

As per the above mathematical calculation, the design parameter of gearbox are calculated and designed. As per the calculated design parameters, a gearbox is modeled using modeling software, Solid work. The below mentioned figure shows the model 3D diagram of gearbox.

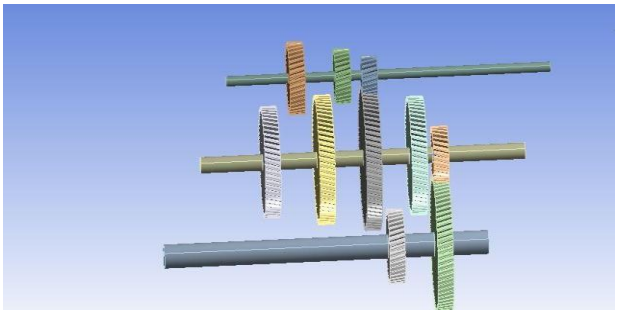

Fig.3 3D modeling of gear trains

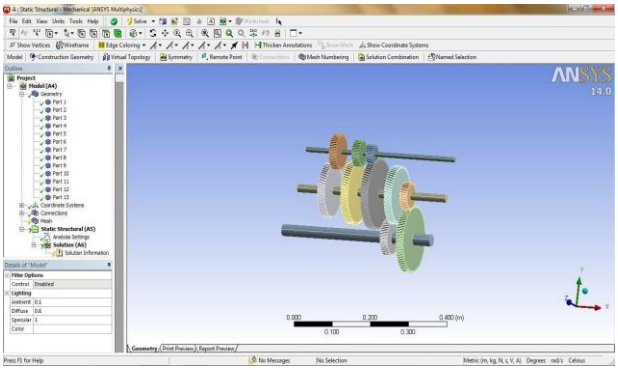

Fig.4 Isometric view of gear trains

Table.3:Result for mass and vonmises stress

| EXP. | MASS (kg) | VON MISES STRESS (Mpa) |
|---|---|---|
| 1 | 18.51 | 107.44 |
| 2 | 19.36 | 124.48 |
| 3 | 18.037 | 81.053 |
| 4 | 5.11 | 46.010 |
| 5 | 7.25 | 64.973 |
| 6 | 33.70 | 42.483 |
| 7 | 32.33 | 43.270 |
| 8 | 6.75 | 35.340 |
| 9 | 10.848 | 35.210 |
| 10 | 36.40 | 42.000 |
| 11 | 52.72 | 28.053 |
| 12 | 9.13 | 30.95. |
| 13 | 16.05 | 24.838 |
| 14 | 59.15 | 47.779 |
| 15 | 61.52 | 29.118 |
| 16 | 12.39 | 18.617 |
| 17 | 23.41 | 31.254 |
| 18 | 90.15 | 32.212 |
| 19 | 93.42 | 30.405 |
| 20 | 90.08 | 34.509 |
| 21 | 32.46 | 12.727 |
| 22 | 130.4 | 10.701 |
| 23 | 134.78 | 10.075 |
| 24 | 129.54 | 22.570 |
| 25 | 18.35 | 10.820 |

A. Steps Involved in Ansys Workbench:

1. Modeling
2. Defining element type
3. Defining real constant
4. Adding material properties
5. Meshing
6. Specifying contact
7. Setting initial condition
8. Setting constraints
9. Specifying loading options
10. Setting global data
11. Setting time and frequency controls
12. Solving
13. Viewing and interpolating results

B. Anova Verification for Mass Anova Verification for Vonmises Stress

General Linear Model : Mass (kg) versus General Linear Model: Vonmises stress versus Face width (mm),helix Face Width (mm), HelixAngle (degree), Material, Angle (degree), Material

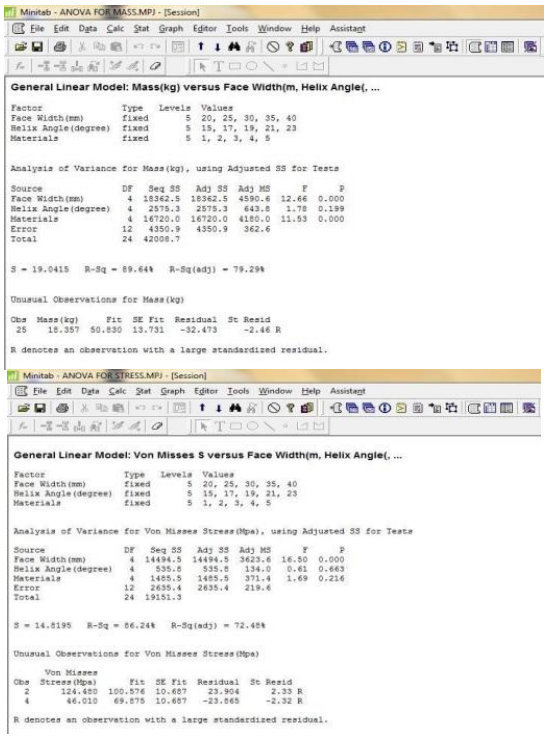


Fig.5 Title Gear parameters

## VI. RESULTS

Table:4 Comparison.

| MATERIAL | VON-MISES STRESS (Mpa) | MASS (kg) |
|---|---|---|
| **Cast Carbon Steel (Existing)** | 67.237 | 15.52 |
| **GlassFilled Polyamide** | 59.541 | 6.48 |

The above table shows the comparison result of Cast carbon steel and Glass filled polyamide materials which are applied in an existing gearbox. Here, we have just changes the optimized material alone. For an effective performance, the gearbox should have minimum stress and mass.

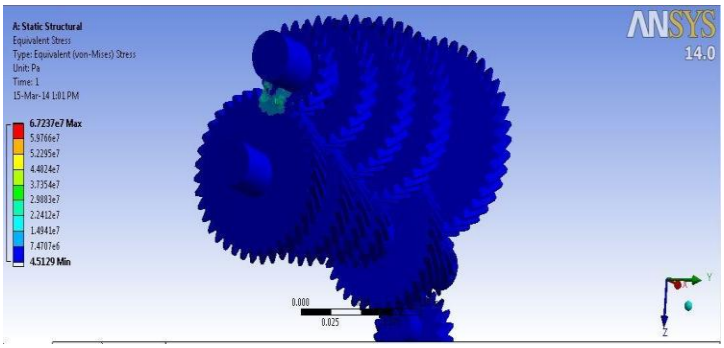


Fig:6 Analysis of Results for Design of Mercedes Benz Gearbox

## VII. CONCLUSION

The efficiency and the lifetime of the gearbox can be improved by reducing the equivalent stress acting on the gearbox and the mass of the gearbox. From the above results, it is clear that glass filled polyamide has minimum mass and stress than the other existing materials and other suitable composite materials. Moreover the life span of glass filled polyamide is also high compared to the other materials.

Thus we concluded that the glass filled polyamide is the best material to manufacture the gear box which can give a long life time and improved performance of the gear box and the whole system.

## REFERENCES

[1] Vera Nikolic,‘ Dynamic model for stress and strain analysis of a spur gear transmission’ ,Journal of Mechanical Engineering2009.

[2] Dearn K Dand Walton D,’Acoustic Emissions from Polymeric Gears’,

[3] Proceedings of the World Congress on Engineering.

[4] Madhury a Baruah and HARakshin,’ Design and Fabrication of a Gear Box Motor Current Analysis System’, thesis submitted Department of Mechanical Engineering National Institute of Technology, Rourkela,2010.

[5] MarciaKurcz, Burak Baser Harri Dittmar, Joachim Sengbuschand Hans Pfister:‘ Replacing Steel with Glass-Mat Thermoplastic Composites in Automotive Spare-Wheel Well Applications’, SAE paper

[6] Ajuwa,C.I. and H.M.Sheidi,’ Design of high performance vehicle composite fly wheel. ’Res. J. AppliedSci.

[7] ChungHaePark, Abdelghani Saouab, Joel Breard, WooSuck Han, Alain Vautrin and WoolILee,‘ An integrated optimization for the weight, the structural performance and the cost of composite structures’, Composites Science and Technology.

[8] Jaroslav Mackerle and LudvıkPrasil, ’Finite element analyses and simulations of gears and gear drives, International Journal for Computer- Aided Engineering and Software.