ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com
International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 3, Special Issue 19, April 2016

OPTIMISATION OF MERCEDES BENZ GEARBOX INTERMS OF STRESS AND WEIGHT REDUCTION USING TAGUCHI METHOD

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ABSTRACT:

The main objective of this project is to design analyses and optimize a composite gear box using modelling and analyzing software's to reduce the weight and improve its performance. A gearbox 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 gear box. 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 modelled using modelling software. The various stresses, displacement and strain for the gearbox are 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.

1. INTRODUCTION:

A gearbox is a mechanical method of transferring 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.

2. GEAR CLASSIFICATION:

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

2.1. SPUR GEAR:

Spur gears are the most commonly used gear types. 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.

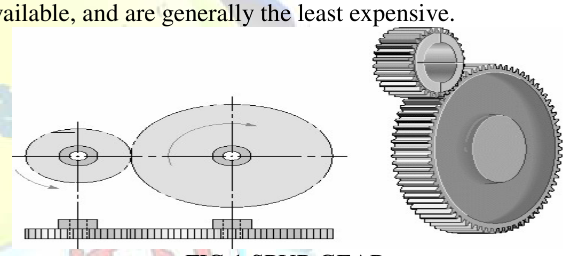

FIG.1.SPUR GEAR

2.2. HELICAL GEAR:

Helical gears may be used to mesh two shafts that are not parallel, although they are still primarily used 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.

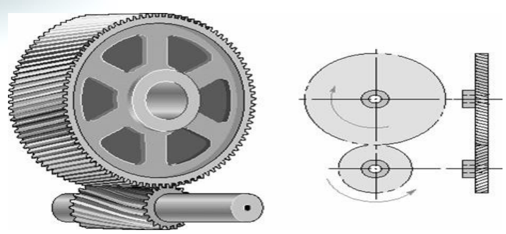

FIG.2.HELICAL GEAR

3. GEAR BOX:

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

- To provide high torque at the time of starting, vehicle acceleration, climbing up a hill.

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- To provide more than forward speeds by providing more than one gear ratio. In modern cars, five forward gears and reverse gear is provided. For given engine speed, higher speed can be obtained by running in higher (4^{th} and 5^{th}) gears.
- Gear box provides a reverse gear for driving the vehicle in reverse direction.

3.1. TYPES OF GEAR BOXES

a) Selective type gear boxes

- Sliding mesh gear box
- Constant mesh gear box
- Synchromesh gear box

b) Progressive type gear box

c) Epicyclical type gear box.

3.1.1. SLIDING MESH GEAR BOX:

It is the simplest type of gearbox out of the available gear boxes. In this type of gearbox, gears are changed by sliding one gear on the other. This gear box consists of three shafts; main shaft, clutch shaft and a counter shaft. In a four speed gear box (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 on 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 countershaft drive gear.

3.1.2. SYNCHROMESH GEAR BOX:

This type of gearbox 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 synchromesh 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.

4. COMPOSITE MATERIAL:

4.1. INTRODUCTION:

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 fibre-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, bathtubs, storage tanks, imitation granite and cultured marble sinks and counter tops. The most advanced examples perform routinely on spacecraft in demanding environments.

4.2. SOFTWARES USED:

Some of the software's that are used for modelling and analysing the above mentioned composite gear box are

- Solidworks Software
- Ansys Software & Minitab

4.2.1. SOLIDWORKS:

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.

- Defined by 3d design
- Based on components

5. 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 of 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.

6. ANALYSIS OF VARIANCE:

The purpose of product or process development is to improve the performance characteristics of

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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.

7. 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 analysing research data.

7.1. 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.

8. 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.

8.1. DESIGN OF EXPERIMENTS:

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

Table.1:

8.3. DESIGN OF EXPERIMENTS:

EXP.	FACEWIDTH (mm)	HELIX ANGLE (degree)	MATERIALS
1.	20	15	Alloy Steel
2.	20	17	Cast carbon steel
3.	20	19	Malleable Cast Iron
4.	20	21	Glass filled polyamide
5.	20	23	Carbon Epoxy
6.	25	15	Cast carbon steel
7.	25	17	Malleable Cast Iron
8.	25	19	Glass filled polyamide
9.	25	21	Carbon Epoxy
10.	25	23	Alloy Steel
11.	30	15	Malleable Cast Iron
12.	30	17	Glass filled polyamide
13.	30	19	Carbon Epoxy
14.	30	21	Alloy Steel
15.	30	23	Cast carbon steel
16.	35	15	Glass filled polyamide
17.	35	17	Carbon Epoxy
18.	35	19	Alloy Steel
19.	35	21	Cast carbon steel
20.	35	23	Malleable Cast Iron
21.	40	15	Carbon Epoxy
22.	40	17	Alloy Steel
23.	40	19	Cast carbon steel
24.	40	21	Malleable Cast Iron
25.	40	23	Glass filled polyamide

Table.2:

8.4. MODE FOR DESIGN PARAMETERS OF GEARBOX:

As per the above mathematical calculation, the design parameter of gearbox is calculated and designed. As per the calculated design parameters, a gearbox is modelled using modelling software, Solidwork. The below mentioned figure shows the model 3D diagram of the gearbox.

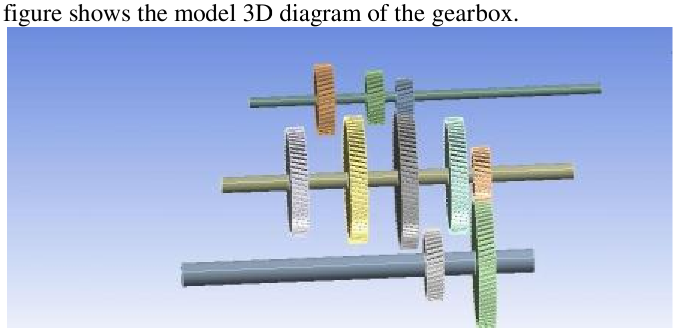

FIG.3:3d model

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8.5. STEPS INVOLVED IN ANSYS WORKBENCH:

1. Modelling
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

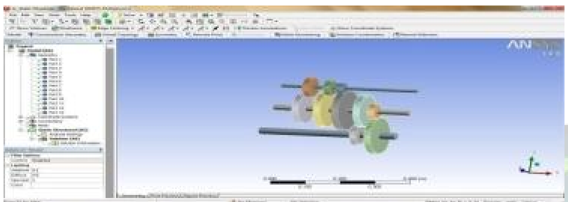

FIG.4:ANSYS

9.RESULT FOR MASS AND VON MISES 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

Table.3

9.1.ANOVA VERIFICATION FOR MASS :

FIG.5:MASS

9.2.ANOA VERIFICATION FOR VON MISES STRESS:

FIG.6:STRESS

9.3.ANOVA TABLE

SUM OF VARIANCE	SUM OF SQUARE	DEGREES OF FREEDOM	MEAN SUM OF SQUARE	Fcal	Ftable at α=0.05	REMARKS
A	0.029732774	4	0.007433	4.78		SIGNIFICANT
B	0.00884765	4	0.002211	1.42	3.26	INSIGNIFICANT
C	0.200932041	4	0.0502330	32.34		SIGNIFICANT

Table.4

In factor **'A&C' Fcal > Ftable** i.e. It is clear that the factor A and factor B have significant effect on the mass. Since

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F_{cal} for the factors A and B is greater than the F_{table}. Hence factor A and factor B is the best factor among the three factors available to us.

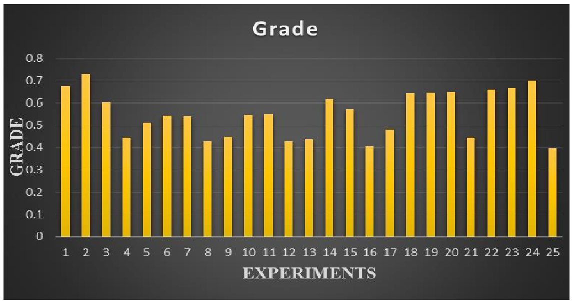

FIG.7 :GRADE

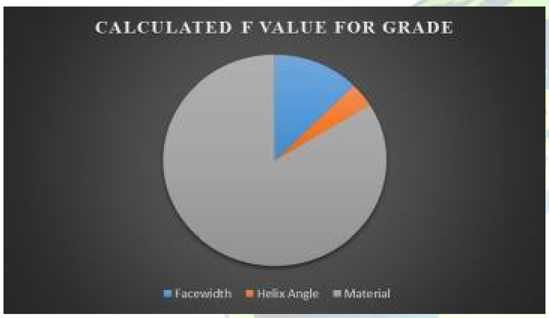

FIG.8: VALVE

10. RESULTS:

MATERIAL	VON-MISES STRESS (Mpa)	MASS (kg)
Cast Carbon Steel (Existing)	67.2	15.52
Glass Filled Polyamide	59.5	6.48

Table.5

11. ANALYSIS OF RESULTS FOR DESIGN OF MERCEDES BENZ GEARBOX:

11.1 Design of Mercedes Benz Gearbox:

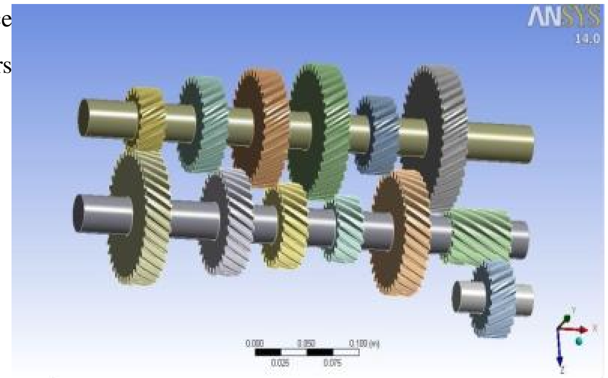

FIG.9 DESIGN

11.2 MATERIAL ANALYSIS:
(Changes in material only)

FOR STRESS: CASTCARBON STEEL & GLASS FILLED POLYAMIDE:

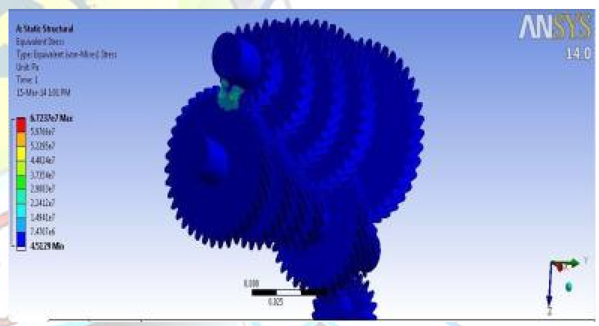

FIG.10 DESIGN

(Changes in all the factors)

FOR STRESS: CASTCARBON STEEL & GLASS FILLED POLYAMIDE:

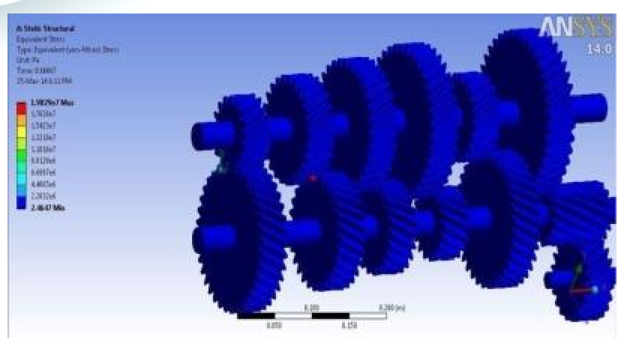

FIG.11 DESIGN

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ISSN 2394-3785 (Online)
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11.2.1 COMPARISON I

(CHANGES IN MATERIAL ONLY)

MATERIAL	VON-MISES STRESS (Mpa)	MASS (kg)
Cast Carbon Steel (Existing)	67.237	15.52
Glass Filled Polyamide	59.541	6.48

Table.6

The above table shows the comparison result of Cast carbon steel and Glass filled polyamide materials which are applied in an existing gear box. Here, we have just changes the optimised material alone. For an effective performance, the gearbox should have minimum stress and mass. Among these materials, the Glass filled polyamide has minimum stress and mass. It clearly shows that 58% of the mass can be reduced using the optimised composite material than the existing one without much changes in Von-Mises stress both helps to improve the efficiency of the gearbox performance.

11.2.2 COMPARISON II

(CHANGES IN ALL THE FACTORS)

MATERIAL	VON-MISES STRESS (Mpa)	MASS (kg)
Cast Carbon Steel (Existing)	**19.89**	**51.38**
Glass Filled Polyamide	**18.53**	**12.36**

Table.7

The above table shows the comparison result of Cast carbon steel and Glass filled polyamide materials which are applied in the existing gear box. Here, we have substitute the face width, material and helix angle in the existing gear box. For an effective performance, the gearbox should have minimum stress and mass. Among these materials, the Glass filled polyamide has minimum stress and mass. It clearly shows that 58% of the mass can be reduced using the optimised composite material than the existing one without much changes in Von-Mises stress both helps to improve the efficiency of the gearbox performance.

12. CONCLUSION:

While concluding our project, we feel that it is all a team work to achieve the aim lot of things like design, mathematical modelling & analysis have been studied lot of difficulties in selection of our project by visiting various industries in our locality. This project work has an excellent opportunity and experience to use our limited knowledge gained a lot of practical knowledge regarding designing and modelling

while doing this project work we feel that the project work is a good solution to bridge the gates between institution and industries.

The efficiency and the lifetime of the gear box 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.

LIST OF SYMBOLS:

S.NO	DESCRIPTION	SYMBOLS	UNITS
1	SPEED	N	r.p.m
2	MASS	m	kg
3	STRESS	σ	mpa
4	HELIX ANGLE	β	degree
5	DIAMETER	D	mm

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