UGC Approved Journal

IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

ISO 3297:2007 Certified

Vol. 4, Issue 7, July 2017

# Design & Analysis with Weight Optimization of Two Wheeler Gear Set

**Yuvraj P. Mali[1], E.R. Deore[2]**

PG Student, Mechanical Engineering Department, S.S.V.P.S.'s, B.S.D. College of Engineering, Dhule, India [1]

Associate Professor, Mechanical Engineering Department, S.S.V.P.S.'s, B.S.D. College of Engineering, Dhule, India [2]

**Abstract**: Gears have a wide variety of applications. Gears generally fail when the working stress exceeds the maximum permissible stress. Contact stress analysis between two spur gear teeth was considered in different contact positions representing a pair of mating gears during rotation. These stresses are proportional to the amount of power transmitted while the design could offer favorable or adverse conditions for generation of the same. This paper intends identify the magnitude of the stresses for a given configuration of a gear transmitting power while trying to find ways for reducing weight of the gear. The philosophy for driving this work is the lightness of the gear for a given purpose while keeping intact its functionality. The process constraints for manufacturing the gear also need to be considered while recommending alternative/s. Ease of incorporating the new feature for weight reduction over the existing process of manufacturing and the magnitude of volume of mass (or weight) reduced could be considered as the key parameters for assessment for this work. This study will focus on the weight optimization of the gear, keeping the torque transmitting capacity intact, thus reducing cost of the gear. In this work, the gear will be modeled in modeling software Catia and analyzed in ANSYS. The results obtained from FEA will be validated by modifying the standard gear and then practically testing torque transmitted and stresses in the gear.

**Keywords**: Contact stress, FEA, ANSYS, Spur Gear

## I. INTRODUCTION

In order to design, build and analysis gear drive systems it is necessary to understand the terminology and concepts associated with gear systems. Fig 1 shows the assembly for complete gear transmission system for automobile two wheeler pedal operated system. It uses 5 pairs of spur gear system. From 1$^{st}$ to 5$^{th}$ continuously speed of the vehicle is increased. Gear shift pedal is used to shift the gears and sequence of gear changing is shown in the image.

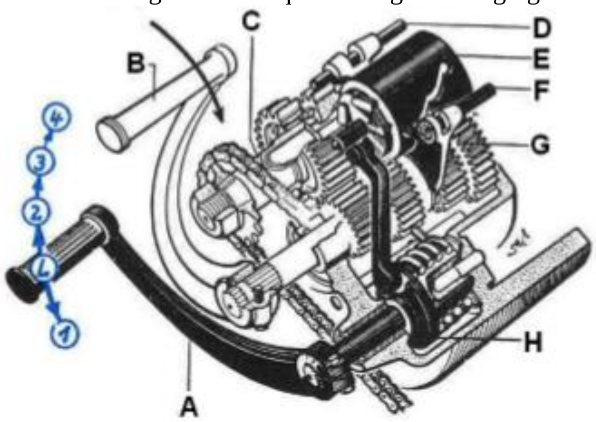


Fig 1: Foot Pedal Operated Gear Transmission System of Two Wheeler

A - Gear Shift Pedal
B - Kick Starter
C - Main and clutch shaft
D & F - Shift forks
E - Shift cam
G - Start and counter shaft
H - Cam shaft with linkage for shift cam

## II. LITERATURE REVIEW

In the research paper on "Gear Pair Design Optimization by Genetic Algorithm and FEA", Mr. M. Chandrasekaran, Mr. S. Padmanabhan, Mr. S. Ganesan, Mr. V. Srinivasa Raman [2] Gear is a mechanical device that transfers the

IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified
Vol. 4, Issue 7, July 2017

rotating motion and power from one part of a machine to another. Gear optimization can be divided into two categories, namely, single gear pair or Gear train optimization. The problem of gear pairs design optimization is difficult to solve because it involves multiple objectives and large number of variables. Therefore reliable and robust optimization techniques will be helpful in obtaining optimal solution for the problems. In this paper an attempt has been made to optimize spur gear pair design using Genetic Algorithm (GA) and analytical tool MITCalc. A combined objective function which maximizes the Power, Efficiency and minimizes the overall Weight, Centre, distance has been considered in this model. Finite Element Analysis (FEA) was carried out and results were compared with the allowable limit.

One more paper on "Bending Stress Analysis & Optimization of Spur Gear", by Mr. Ram Krishna Rathore and Abhishek Tiwari [5] focuses on fatigue failure of gear teeth. Author explained a minor drop in the root bending stress results in enormous enhancement in the bending fatigue life of a spur gear. If gear fails in tensile fatigue condition the results are cataclysmic and arise with modest or no notification. Up till now the gear design has been enhanced by using better material, surface hardening and carburization, and shot penning for surface finish etc. Some extra efforts have been completed to enhance the durability and strength by changing the various parameters i.e. pressure angle, by asymmetric teeth, by root fillet curve alteration and so on. The majority of these techniques do not provide assurance for the interchangeability of the existing gear design. This work shows the potential by means of the stress concentration methods by inserting the stress relieving features at the most stressed area for the reduction of root fillet or bending stress in spur gear. In this work, circular and elliptical stress relieving holes are employed and better results are obtained than using circular stress relieving holes, which were employed in previous researches. A finite element model of spur gear is considered for analysis and compared with the analytical method and stress relieving features of various sizes are inserted on gear teeth at root area. In this work the optimum size and location of the stress relief features for Spur gear are proposed, which help in reducing the fatigue failure in gears.

One paper on "Investigation of load carrying capacity of asymmetric high contact ratio spur gear based on load sharing using direct gear design approach "by P Marimuthu , G. Muthuveerappan [7] says that the direct design approach is one of the many gear designing methods available to improve load carrying capacity of the gear pairs. For customized gear pairs, the direct gear design approach is more advantageous over conventional design. In this paper, a parametric study is carried out for asymmetric high contact ratio spur gears based on load sharing method to determine the improvement in load carrying capacity. A finite element model for multi-pair contact is adopted to determine the non-dimensional fillet and contact stresses which quantify the load carrying capacity of the gear pairs. The results of direct designed symmetric and asymmetric high contact ratio spur gears are compared with the conventional symmetric high contact ratio spur gears. Also, the influence of gear parameters such as addendum pressure angle, gear ratio, teeth number and backup ratio of non-dimensional stresses is analyzed in detail. The results show significant improvement in gear pair performance for all parameters analyzed.

## III. NECESSITY

Vehicle weight reduction saves energy, minimizes brake & tyre wear and cuts down emissions. Weight reduction of vehicles is directly linked to lower $CO_2$ emissions and improved fuel economy. The benefits of even modest vehicle weight reduction are significant. Optimizing the two wheeler gear set will help reducing weight of vehicle.

## IV. PROBLEM FORMULATION

The combustion of fossil fuels such as gasoline and diesel to transport people and goods is the fourth largest source of CO2 emissions, accounting for about 12.9 % of total $CO_2$ emissions in India according to study published in 2008. $CO_2$ emission by human activities is one of the major reasons for excessive greenhouse gases in earth's environment, which is causing global warming. To reduce $CO_2$ emission due to transportation our focus should be on increasing fuel efficiency of the vehicle used for transportation. One of the ways of achieving it is reducing the weight of the vehicle.

Our focus will be on reducing the weight of the gear set of Hero Splendor which will contribute in reduction of weight of the vehicle eventually.

## V. FINITE ELEMENT METHOD

The Finite Element Method (FEM) is a numerical technique to find approximate solutions of partial differential equations. In a structural simulation, FEM helps in producing stiffness and strength visualizations. It also helps to minimize material weight and its cost of the structures. FEM allows for detailed visualization and indicates the distribution of stresses and strains inside the body of a structure. FEM allows entire designs to be constructed, refined and optimized before the design is manufactured.

IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified
Vol. 4, Issue 7, July 2017

Basic Steps in Finite Element Analysis:

*A) Idealizing the Continuum*

Modelling or design of the object may be carried out in very fine details as per requirements of the manufacturing operatives and other departments which will be referring the models for the study purpose. While performing finite element analysis it is required to simplifying that geometry or generally referred to as idealizing the continuum.

*B) Discretization of Model*

The need of finite element analysis arises when the structural system in terms of its either geometry, material properties, boundary conditions or loadings is complex in nature. For such case, the whole structure needs to be subdivided into smaller elements. The whole structure is then analyzed by the assemblage of all elements representing the complete structure including its all properties.
Figure below shows a finite element mesh of a continuum using triangular and quadrilateral elements. The assemblage of triangular elements in this case shows better representation of the continuum. The discretization process also shows that the more accurate representation is possible if the body is further subdivided into some finer mesh.

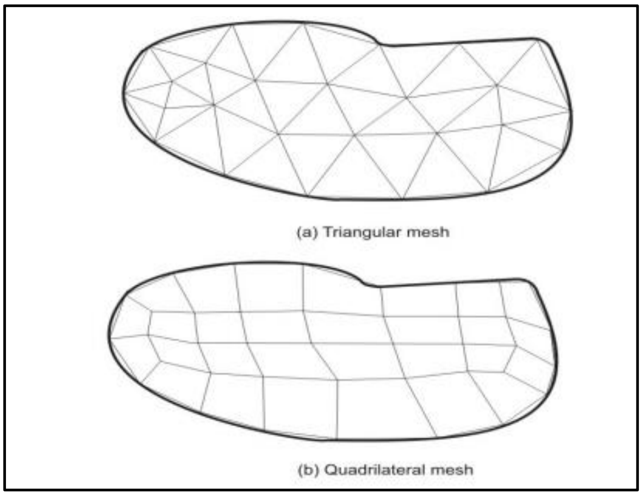


Fig 2: Discretization of Continuum

*C) Finite Element Modelling*

FEA consists of a computer model of a continuum that is stressed and analyzed for specific results. A continuum has infinite particles with continuous variation of material properties. Therefore, it needs to simplify to a finite size and is made up of an assemblage of substructures, components and members. Discretization process is necessary to convert whole structure to an assemblage of members/ elements for determining its responses. Figure below shows the process of idealization of actual process to a finite element form to obtain the response results. The assumptions are required to be made by the experienced engineer with finite element background for getting appropriate response results. On the basis of assumptions, the appropriate constitutive model can be structured.

*D) Post Processing*

Post processing is the process of obtaining the meaningful data like values and graphs of stress, strain, life, frequencies etc. from the solved analysis. We obtain the desired output from the FEA analysis to verify different acceptance criteria.
It also important step in FEA to interpretation of the results and comparing them with the either analytical solution or practical testing results. This is the part where we validate the FEA procedure. Only FEA results are not enough for predicting acceptance or rejection of any design concept due to idealized assumptions used while performing FEA analysis.

## VI. STATIC ANALYSIS

Static analysis deals with the conditions of equilibrium of the bodies acted upon by forces. A static analysis can be either linear or non-linear. All types of non-linearity allowed such as large deformations, plasticity, creep, stress stiffening, contact elements etc. Basic dimensions of gears are calculated using basic design formulae and CAD tool CATIA is used to create 3D models of the gears. FEA is performed on the gears by calculating the torque on the gear

IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified
Vol. 4, Issue 7, July 2017

and applying the load resulting from that torque to one individual teeth of the gear. Stresses at the gears are observed and are confirmed to be within the limit which is considered as 321 MPa as per design standards.

Iterations of fourth gear for Design and optimization using FEA.

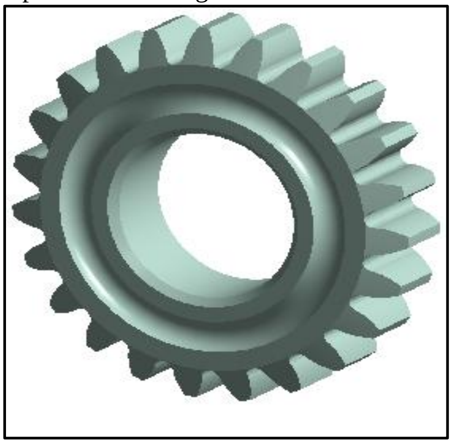

Fig 3: Fourth Gear Actual Model

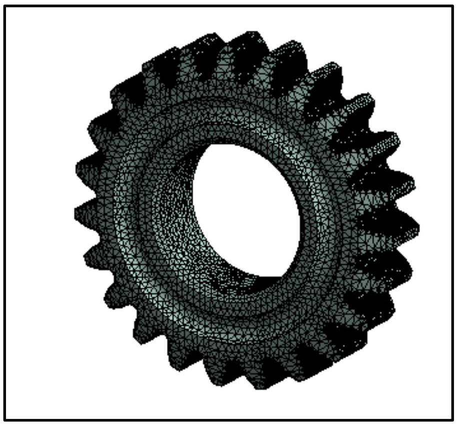

Fig 4: Meshed Model Actual Fourth Gear

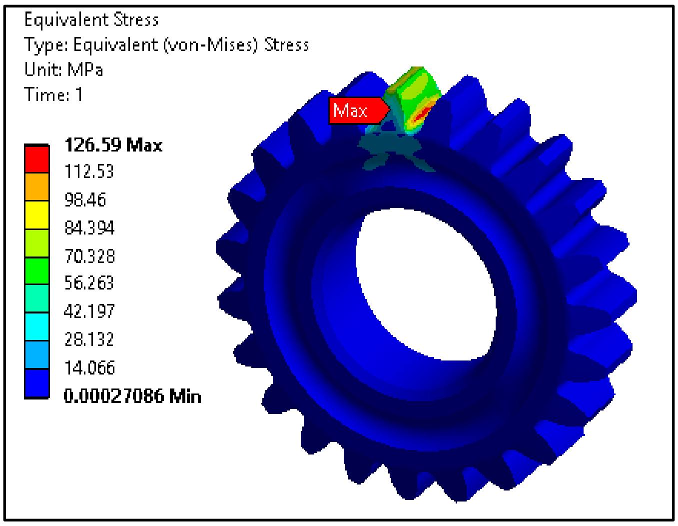


Fig 5: von Mises stress plot Actual Forth Gear

UGC Approved Journal

IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

ISO 3297:2007 Certified

Vol. 4, Issue 7, July 2017

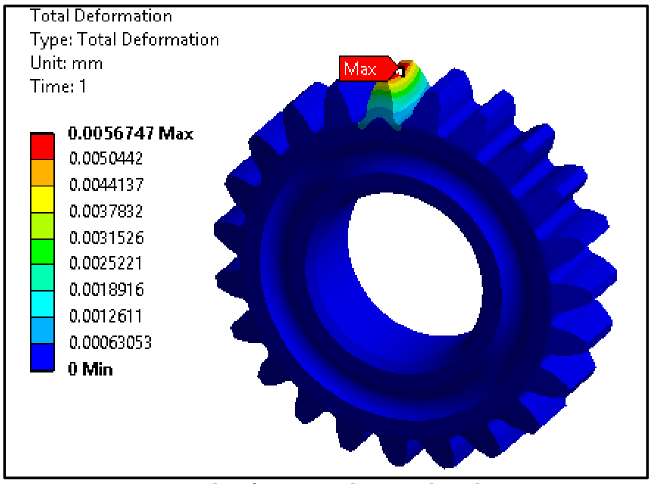


Fig 6: Total Deformation Plot Actual Forth Gear

In the baseline results of Actual model of Gear 4 FEA analysis it is observed that maximum stress that is observed in the gear due to torque at one tooth is 126.59 MPa and Total deformation of 0.00567 mm. Maximum stress is well within the acceptance criteria for the gear material of 318 MPa. Weight of the fourth gear is observed from the FEA model is 0.104kg. It can be seen from the Stress and deformation plot that there is huge possibility of removing material without harming the FEA results and gear's capacity to withstand the torque. Iteration 1 design is generated by removing some material from the recess which was there on the original gear. Figure for the design concept is given below.

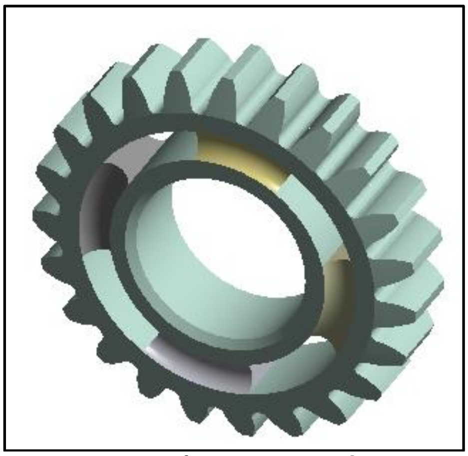

Fig 7: Design for Iteration 1 Fourth Gear

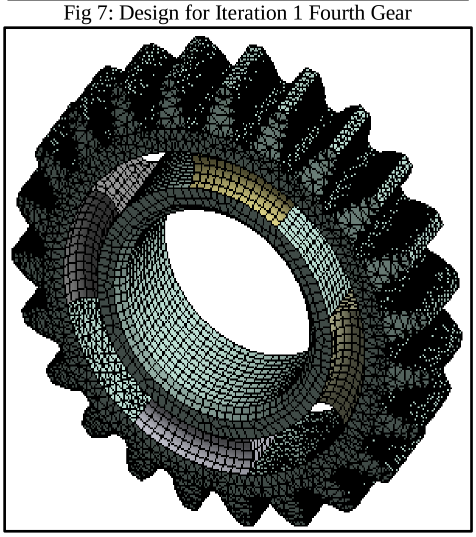

Fig 8: Meshed Model for Iteration 1 Fourth Gear

UGC Approved Journal

IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

ISO 3297:2007 Certified

Vol. 4, Issue 7, July 2017

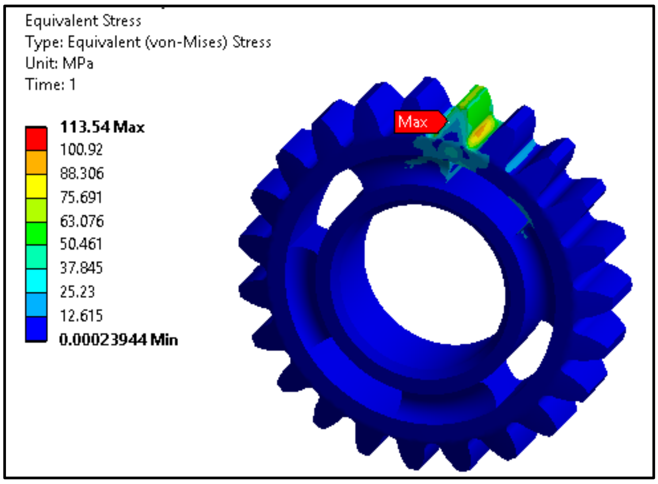


Fig 9: von Mises stress plot at Iteration 1 Fourth Gear

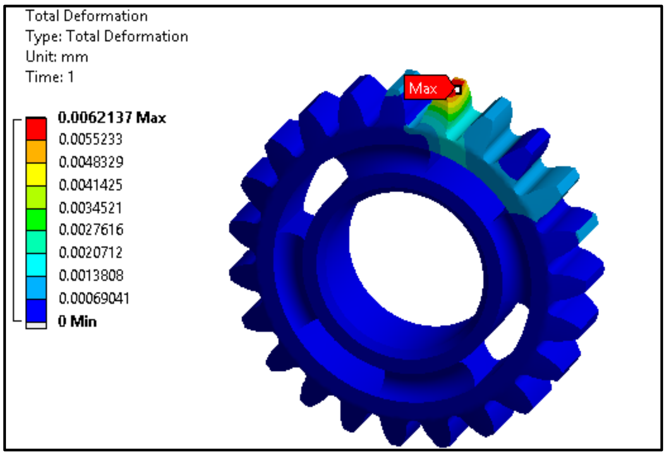


Fig 10: Deformation plot at Iteration 1 Forth Gear

From the Iteration 1 maximum stress observed at the gear is 113.54 MPa and Maximum Total deformation observed in the gear is 0.0071 mm. Mass of the design is 0.090 kg. As it can be seen in the gear design of iteration 1 there is not more space to remove further material from the gear without hurting the assembly purpose and safely engaging gear teeth. So we will not further reduce material from this gear.

## VII. EXPERIMENTAL VERIFICATION

### *A) Original and Optimized Gears:*

The gears were machined as per the optimization done in the FEA chapter. The images of the original and optimized gears are given below**.**

Fig. 11: Original and Optimized Fourth Gear of Hero Splendor

UGC Approved Journal

IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

ISO 3297:2007 Certified

Vol. 4, Issue 7, July 2017

*B) Torque Test Setup:*

In torque testing, the relationship between torque and degree of rotation is graphically presented and parameters such as ultimate torsional shearing strength (modulus of rupture), shear strength at proportional limit and shear modulus (modulus of rigidity) are generally investigated. Moreover, fracture surfaces of specimens tested under torsion can be used to determine the characteristics of the materials whether it would fail in a brittle or a ductile manner.

In this case, the gears are tested for torque transmission capacity and not subjected to destructive testing.

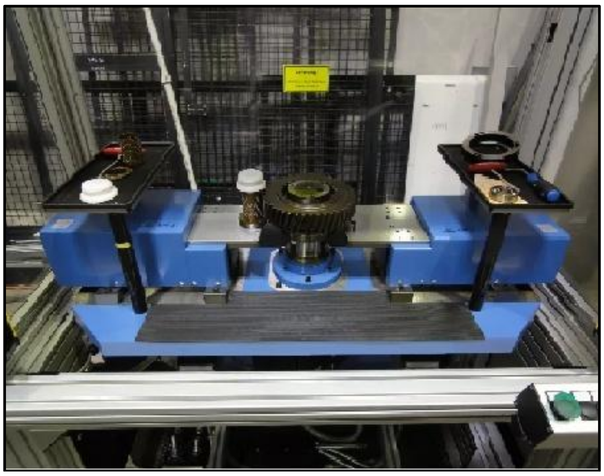

Fig. 12: Close view of the torque testing machine

*C) Equipment Used:*

1. Test specimens (Gear Set)
2. Gear Torque testing machine

*D) Experimental Procedure:*

The first thing that was done, was mounting the gear in the torque testing machine. The step by step procedure is as follows:

1. Grip the test specimen on to the torque testing machine and make sure the specimen is firmly mounted and block the movement of the gear with the help of attachment.
2. Set reading on the torque meter to zero.
3. Start applying the torque to the gear until the value of required torque is achieved.
4. Remove the gear from the machine and check the gear for fractures or cracks or any other deformation.
5. Mount another gear and repeat the same procedure.
6. Discuss and conclude the obtained experimental results.

*E) Test Results:*

The static torque capability of the gears was tested in the torque testing machine. The torque was to be applied by a knob. So there was a possibility that the torque would minutely be excess to the required torque. The values of the torque transmitted by different gears are as follows:

Table 1: Torque applied and angle of Twist

| Gear | Torque Transmitted (Nm) |
|---|---|
| Actual 1st | 10.36 |
| Actual 2nd | 10.35 |
| Actual 3rd | 10.39 |
| Actual 4th | 10.36 |
| Optimized 2nd | 10.36 |
| Optimized 3rd | 10.37 |
| Optimized 4th | 10.35 |

IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified
Vol. 4, Issue 7, July 2017

From the result table, it is proved that the torque transmitting capacity of the gears exceeds the required torque transmitting capacity. Thus the design is safe and the gears can be successfully applied for the application.

## VIII. RESULTS AND DISCUSSION

Table 2: Comparative results for stress between Original and Optimized Design

| Gear | Actual Stress (MPa) | Optimized Stress (MPa) |
|---|---|---|
| 1st | 52.67 | - |
| 2nd | 102.67 | 190.71 |
| 3rd | 70.349 | 89.287 |
| 4th | 126.59 | 113.54 |
| Total | 354.16 | 387.33 |

Table 3: Comparative results for weight between Original and Optimized Design

| Gear | Actual Weight (Kg) | Optimized Weight (Kg) | % Reduction |
|---|---|---|---|
| 1st | 0.263 | 0.263 | 0 |
| 2nd | 0.2 | 0.175 | 12.5 |
| 3rd | 0.133 | 0.106 | 20.3 |
| 4th | 0.104 | 0.090 | 13.46 |
| **Total** | **0.7** | **0.634** | **9.428** |

As can be seen from results tables, there is significant weight reduction is possible on gear 2, 3 & 4 under the application of static loading without much affecting the functionality of the gear and keeping the stresses within the acceptable limit

## IX. CONCLUSION

1. Designed a two-wheeler gear set for Hero Splendor as per the engine specifications. There is a possibility for reduction in the weight of the gears of Hero Splendor.
2. After doing the FEA and experimental testing, it can be said that the weight of the gears can be reduced up to 9.428%.
3. The gears successfully withstood the torque which will be applied in the application.

## X. FUTURE SCOPE

1. The gears can be manufactured and used in the current vehicle.
2. Also, alternate material can be thought of for manufacturing low weight gears.
3. Composite materials such as glass fiber and carbon fiber can be tried and tested for manufacturing gears.

## REFERENCES

1. Mr. Bhatt Parth Jitendrabhai "A Review on Design, Analysis and Material Optimization of High Speed Helical Gear by Changing Different Design Parameters Using FEA Approach", International Journal of Engineering Sciences & Research Technology.
2. Mr. M. Chandrasekaran, Mr. S. Padmanabhan, Mr. S. Ganesan, Mr. V. Srinivasa Raman, "Gear Pair Design Optimization by Genetic Algorithm and FEA", Department Of Mechanical and Production Engineering, Sathyabama University, Chennai, India.
3. Mr. Sa'id Golabi, Mr. Javad Jafari Fesharaki, Mrs. Maryam Yazdipoor "Gear Train Optimization Based On Minimum Volume/Weight Design by Using the Matlab Program" Mechanism And Machine Theory 73 (2014) 197–217.
4. Mr. Nenad Marjanovic, Mr. Biserka Isailovic, Mr. Vesna Marjanovic, Mr. Zoran Milojevic, Mr. Mirko Blagojevic, Mr. Milorad Bojic "A Practical Approach To The Optimization Of Gear Trains With Spur Gears" Mechanism And Machine Theory 53 (2012) 1–16.
5. Mr Ram Krishna Rathore And Mr. Abhishek Tiwari, "Bending Stress Analysis & Optimization Of Spur Gear", International Journal Of Engineering Research & Technology (IJERT), Vol. 3 Issue 5, May – 2014, Issn: 2278-0181 Vol. 3 Issue 5.
6. P B Pawar, Abhay A Utpat "Analysis of Composite Material Spur Gear under Static loading Condition", SVPM's ITE Malegaon (BK), Baramati.
7. P Marimuthu , G. Muthuveerappan "Investigation of load carrying capacity of asymmetric high contact ratio spur gear based on load sharing using direct gear design approach" Mechanism and Machine Theory, Volume 96, Part 1

IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

ISO 3297:2007 Certified

Vol. 4, Issue 7, July 2017

8. Yallamti Murali Mohan, T. Seshaiah "Spur Gear Optimization by Using Genetic Algorithm", Department of Mechanical Engineering QIS College of Engineering & Technology Ongole, Andhra Pradesh
9. Anjali Gupta, "Design Optimization of The Spur Gear Set", U.I.E.T Panjab University Chandigarh, India
10. Bernd- Robert Hohn, Klaus Michaelis And Michael Hinterstoiber, "Optimization of Gearbox Efficiency", GOMABN 48, 4, 441-480 Original Scientific Paper
11. Mohd. Muzammil, Prem Pal Singh and Faisal Talib, "Optimization of Gear Blank Casting Process by Using Taguchi's Robust Design Technique", Department of Mechanical Engineering, Aligarh Muslim University, Aligarh, India.
12. Spur-Gear Optimization Using SPUROPT Computer Program, NASA Technical Memorandum, 104394.
13. Sarfraz Ali N. Quadri, Dhanajay R. Dolas "Mass Reduction of Involute Spur Gear under Static Loading "American Journal of Mechanical Engineering and Automation.
14. Yuvraj P. Mali, E.R. Deore "A Review on Design & Analysis with Weight Optimization of Two Wheeler Gear Set"