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 2, February 2017

A Review on Design & Analysis with Weight Optimization of Two Wheeler Gear Set

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Abstract: Simplest type of gear is well known as spur gear. Spur gears have a wide variety of applications. These are most commonly applicable in auto motives. The failure of gears occurs 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 project intends to identify the magnitude of the stresses for a given configuration of a two wheeler 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 needs 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 two wheeler gear set, keeping the torque transmitting capacity intact, thus reducing the material cost of the gear.

Keywords: GFRP, Composite Material, Weight Reduction, Vibration Frequencies.

I. INTRODUCTION

A. Gear System for Two Wheeler:
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 1st to 5th 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.

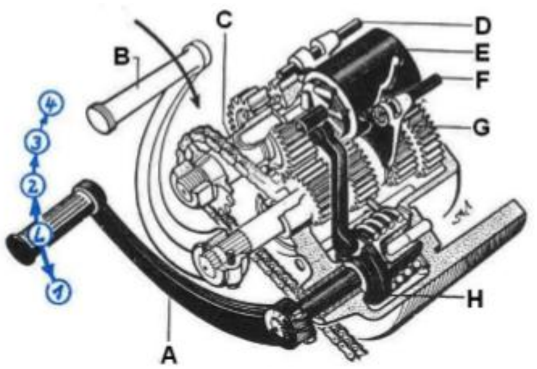

Fig 1: Foot Pedal Operated Gear Transmission System of Two Wheeler

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

• Manual System
Most manual transmission two-wheelers use a sequential gearbox. Most modern motorcycles (except scooters) change gears (of which they increasingly have five or six) by foot lever. On a typical motorcycle either first or second gear can be directly selected from neutral, but higher gears may only be accessed in order – it is not possible to shift from second gear to fourth gear without shifting through third gear. A five-speed of this configuration would be known as "one down, four up" because of the placement of the gears with relation to neutral. Neutral is to be found "half a click" away from first and second gears, so shifting directly between the two gears can be made in a single movement.

• Shift control
In earlier times (pre-WWII), hand-operated gear changes were common, with a lever provided to the side of the fuel tank (above the rider's leg) British and many other motorcycles after WWII used a lever on the right (with brake on the left), but today gear-changing is standardized on a foot-operated lever to the left.

• Clutch
The clutch in a manual-shift motorcycle transmission is typically an arrangement of plates stacked in alternating fashion, one geared on the inside to the engine and the next geared on the outside to the transmission input shaft. Whether wet (rotating in engine oil) or dry, the plates are squeezed together by a spring, causing friction build up between the plates until they rotate as a single unit, driving

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the transmission directly. A lever on the handlebar exploits mechanical advantage through a cable or hydraulic arrangement to release the clutch spring(s), allowing the engine to freewheel with respect to the transmission.

Automatic and semi-automatics typically use a centrifugal clutch which operates in a different fashion. At idle, the engine is disconnected from the gearbox input shaft, allowing both it and the bike to freewheel (unlike torque converter automatics, there is no "idle creep" with a properly adjusted centrifugal clutch). As the throttle is opened and engine speed rises, counterweights attached to movable inner friction surfaces (connected to the engine shaft) within the clutch assembly are thrown gradually further outwards, until they start to make contact with the inside of the outer housing (connected to the gearbox shaft) and transmit an increasing amount of engine power. The effective "bite point" is found automatically by equilibrium where the power being transmitted through the (still-slipping) clutch is equal to what the engine can provide. This allows relatively fast full-throttle takeoffs (with the clutch adjusted so the engine will be turning near its maximum-torque rpm) without the engine slowing or bogging down, as well as more relaxed starts and low-speed maneuvers at lower throttle settings and rpm.

Above a certain engine speed - when the bike is properly in motion, so the gearbox input shaft is also rotating quickly and so allowing the engine to accelerate further by way of clutch slip - the outward pressure of the weighted friction plates is sufficient that the clutch will enter full lock-up, the same as a conventional plate-clutch with a fully released lever or pedal. After this, there is no clutch slip, and the engine is locked to and providing all of its available power to the transmission; engine rpm is now dependent on the road speed and the current gear ratio (under either user control in a semi-auto, or reliant on road speed (and sometimes load/throttle position) in a CVT setup).

In a typical CVT, the gear ratio will be chosen so the engine can reach and maintain its maximum-power speed as soon as possible (or at least, when at full throttle, in a partially load-dependent system), but in a semi-auto the rider is responsible for this choice, and they can ride around all day in top gear (or first) if they so prefer. Also, when the engine is turning fast enough to lock the clutch, it will stay fully engaged until the RPMs fall below that critical point again, even if the throttle is fully released. Below the lock-up point, partially or fully releasing the throttle can lead to the RPM falling off rapidly, thanks to the feedback loop of lower engine speed meaningless friction pressure. This toggle-like mode of operation can lead to certain characteristic centrifugal-clutch-automatic behavior, such as being able to freewheel rapidly downhill from a standstill, with engine braking only being triggered by turning the throttle briefly (and not then cancellable without braking to quite a slow, gear-dependent pace), and lockup triggering at a lower speed with full versus minimal throttle.

II. LITERATURE REVIEW

According to research paper on “A review on design, analysis and material optimization of high speed helical gear by changing different design parameters using FEA approach” by Mr. Bhatt Parth Jitendrabhai[1] Gears are one of the most critical components in mechanical power transmission systems. The bending and surface strength of the gear tooth are considered to be one of the main contributors for the failure of the gear in gear set. The three dimensional solid model generated in pro E. This model is imported in ANSYS and then contact stress and bending stress calculated in ANSYS for deferent face width and helix angle. Contact stress and bending stress can calculate by hertz, Lewis and AGMA equation. Bending stress occurs in the root of gear and contact stress can be occur between meshing of two gear. Finally these two methods, bending and contact stress results both are compared with each other for deferent face width and helix angle Different material can also be tried for weight and cost optimization.

In the research paper on “Mass Reduction of Involute Spur Gear under Static Loading”, Mr. Sarfraz Ali N. Quadri and Mr. Dhanajay R. Dolas[2] showcased a general view of mass optimization of spur gear under static loading. It states Finite Element analysis method for the spur gear tooth using ANSYS. Author further studied the mass of spur gear with inclusion of different geometries. The results show the effect of different geometries on stresses produced and it gives the best geometry which gives safer results with optimized mass of the spur gear.

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 [3] Gear is a mechanical device that transfers the 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.

In research paper by Mr. Sa'id Golabi, Mr. Javad Jafari Fesharaki, Maryam Yazdipoor [4]on “Gear train optimization based on minimum volume/weight design” by using the Matlab program, the overall volume of one, two and three-stage gear trains is minimized. Next by considering some values for transmission power, hardness of material and gearbox ratio as input data for gearbox parameters, the results from the optimization program have been presented in the form of practical curves. The practical curves are used to specify all the necessary parameters of gearbox such as number of stages, gear modules, face width of gears and shaft diameters.

Paper on “A practical approach to the optimization of gear trains with spur gears” by Mr. Nenad Marjanovic, Mr. Biserka Isailovic, Mr. Vesna Marjanovic, Mr. Zoran Milojevic, Mr. Mirko Blagojevic, Mr. Milorad Bojic [5] presents one practical approach to optimization of gear trains with spur gears, which was the basis for the development of GTO software. It shows the optimization of position of shaft axes for the purpose of reducing the volume occupied by the gear train with spur gears. The results show that the volume of the gear train with spur gears is reduced by 22.5%. Software GTO accomplishes needed results in a very short time. The process of designing of gear trains with spur gears is performed by using two operations. Versions of concepts of gear trains with spur gears are developed within the first operation and the selection of optimal concept and their optimal parameters are selected within the second operation.

One more paper on “Bending Stress Analysis & Optimization of Spur Gear”, by Mr. Ram Krishna Rathore and Abhishek Tiwari [6]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 “Analysis of composite material spur gear under static loading condition” by P B Pawar and Abhay A Utpat [7] focuses on finding alternate material for spur gear manufacturing. Spur gears are the simplest and widely used in power transmission. In recent years it is required to operate machines at varying load and speed. Gear teeth normally fail when load is increased above certain limit. Therefore it is required to explore alternate materials for gear manufacturing. Composite materials provide adequate strength with weight reduction and they have emerged as a better alternative for replacing metallic gears.

In this work metallic gears of steel alloy and Aluminum Silicon carbide composite have been manufactured. Composites provide much improved mechanical properties such as better strength to weight ratio, more hardness, and hence less chances of failure. So this work is concerned with replacing metallic gear with composite material so as to improve performance of machine and to have longer working life. Efforts have also been carried out for modeling and finite element analysis of gears using ANSYS 14.0.Composite gears have been manufactured by stir casting, which is economical method. Composite gears offer improved properties over steel alloys and these can be used as better alternative for replacing metallic 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 [8]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. CONCLUSION

If we observe the literature survey above, we can clearly see that the study on optimization of gears is done solely on the spur gears and helical gears. But very little literature is available on the gears of a two wheeler automobile. This widens the area of optimizing the gears of two wheeler gears which is unexplored. With respect to above points we will bring forward below study objectives.

- 3D Modelling and Finite element analysis of stresses in the gears using ANSYS.

- Modifying the 3D model for weight reduction and again performing FEA on the gears.
- Experimental analysis of gears for torque transmitting capacity.
- Comparison of theoretical, FEA and experimental results for the two wheeler gears.

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