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Review on Design Optimization of Sprocket Wheel Using Different Techniques

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Abstract

Sprockets are most widely used in automobile sector and in machinery. These are used in two wheelers and four wheelers such as bikes, cycles, cars and other mechanism either to transmit revolving motion between two shafts wherever gears are incompatible or to communicate undeviating motion to a pathway etc. They exist in various dimensions, teeth number and are made of different materials. Sometimes faulty chains quickly wear the sprocket. Possible causes of this problems are significant overload, breakage, high impact pressure, excessive chain wear far beyond replacement level, combination of worn chain with new sprockets etc. To ensure efficient power transmission chain sprocket should be properly designed and manufactured. There is a possibility of weight reduction in chain drive sprocket. In this paper, a study of design optimization of sprocket using different processes and techniques is studied. This paper reviews the designing of chain sprocket, analysis using FEA and using the results from FEA how the optimization of sprocket for weight reduction has been done. Mostly researchers have used different grades of steel as their base material and re-designed the sprocket by using different CAD software, few have used composite materials like Carbon Fiber or Nylon66GF30 also as an alternative to steel and compared to earlier research. Some has given heat treatment and other types of chemical treatment to the sprocket to enhance its mechanical properties. From the review, it is concluded that no work is done in re-designing of chain sprocket and optimizing its weight and performance using different alternative materials like Metal Matrix Composite.

Keywords: Chain sprocket, FEA, CAD, Composite Materials

I. Introduction

A sprocket or sprocket-wheel is a profiled wheel with teeth that meshes with a chain or track. They are generally used in bicycles, motorcycles, cars, tracked vehicles, and other machinery to transmit rotary motion between two shafts where gears are unsuitable or to impart linear motion to a track, tape etc. The most common form of sprocket is found in the bicycle where the pedal shaft carries a large sprocket-wheel, which drives a chain, which, in turn, drives a small sprocket on the axle of the rear wheel. Early automobiles were also largely driven by sprocket and chain mechanism and that concept was adapted from bicycles. Sprockets are of various designs, dimensions, teeth number and are made of different materials. Sprockets typically do not have a flange. Some sprockets used with timing belts have flanges to keep the timing belt centered. Sprockets and chains are also used for power transmission from one shaft to another where slippage is not admissible.

Fig.1 Uses of sprockets in different areas

Within international standards sprockets are conceptually basic mechanical devices. However, their versatility leads to many contrasting style. Sprockets can be supplied in various materials and styles, depending upon the application and severity of service requirements. Generally, there are two major ways of categorizing sprockets; by general form and form of the hub. Fig.2 show sprocket classification by general form while Fig.3 shows classification based on hub form. For most applications, fabricated steel sprockets are recommended as offering the best combination of performance, availability, and price. Fabricated steel sprockets can be provided for every chain tooth combination and are readily available.

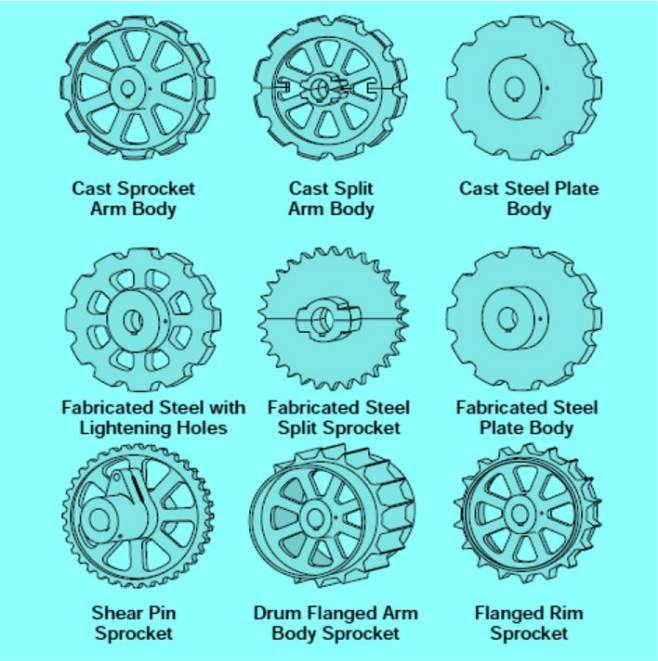


Fig.2 General Form of Sprocket (Source: Rexnord Sprocket Catalog)

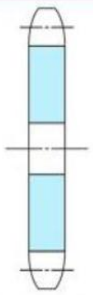
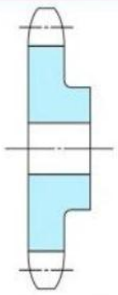
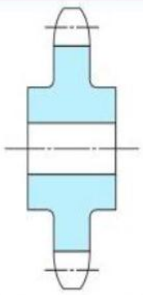
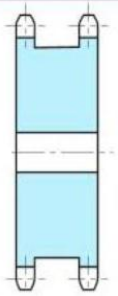
Type symbol	Type A (flat)	Type B (single hub)	Type C (both hubs)	Type SD (Single dual)
Construction				
Specifications	Flat structure with no hub (boss).	Flat structure with a hub (boss) on a single side.	Flat structure with hubs (bosses) on both sides.	Structure where two single-strand chains can be put.

Fig.3 Classification based on hub (Source: Rexnord Sprocket Catalog)

II. Problem Arises in Sprocket

The sliding motion between chain roller and sprocket tooth causes friction wear and wear occur in pin hole of chain rollers making the chain to elongate and so that chain becomes slack. Chain sprocket has problems like breaking of bushings and/or rollers, breaking of plates and pins (unusual cracks), quickly wear of sprockets, Worn rollers, etc. Possible causes of these problems are significant overload breakage, high impact pressure, combination of worn chain with new sprockets, excessive chain wear far beyond replacement level etc. Also there is a wear on sprocket tooth and outer surface

becomes rough affecting the transmission of motion in motorcycle. According to survey after approx. 20000 km of motorcycle drive chain sprocket assembly needs to be replaced.

III. Discussion

Based on Literature Review, different design optimization processes and techniques was used by different researchers. Some of them re-designed the chain sprocket, analysis using FEA and using the results from FEA they optimized the weight of sprocket. Mostly researchers have used different grades of steel as their base material and re-designed the sprocket by using different CAD software, few have used composite materials like Carbon Fiber or Nylon66GF30 also as an alternative to steel and compared to earlier research. Some has given heat treatment and other types of chemical treatment to the sprocket to enhance its mechanical properties. For this review, many international and national papers were helpful. Worldwide researchers have applied the efforts to design and tried to optimize the weight of chain sprocket as,

[1] Tushar S. Hingve, Y. A. Kharche and N.A. Kharche, "Diagnosis for the Failure of Sprockets and Chain Drive", In this study they found the faults by using the various faults detection techniques and analyzed them. They tried to diagnose the faults by using the simple techniques. They found out the major breakdowns in mechanisms due to sprockets failure causing production losses to the company and suggested counter measures by which these problem can be reduced. They identified the root causes of breakdowns using cause and effect diagram. Finally, they studied diagnosis of the faults for eliminating causes. By using the design sprockets for the particular causes, it would help to reduce the defects like wear in the sprockets, reduction of Noise in the drive by using the proper chain for the alignments, reduction of vibration in the sprockets using modal analysis, 26 tooth were preferred according to the polygonal action found in the sprockets and chain can be maintained, by considering design parameter chain climbing on the sprocket can be eliminated.

[2] Sagar N. Vasoya, P. L. Koradiya and B. J. Patel, "Development of Sprocket to Improvement the Torque for Off Road Bike", In this paper, the process of development in sprocket was studied and gear ratio between them was investigated. They discussed four types of materials which will be best suited for sprocket namely Mild Steel, Chromoly Steel, Carbon Fiber and Aviation Grade Aluminium Alloy. They developed the Sprocket using 15/41 Teeth into the 13/39 Teeth and found that torque has increased by 9.91% by using the developed sprocket ratio.

[3] Nikhil P. Ambole and Prof. P. R. Kale, "Design and Analysis of Carbon Fiber Sprocket", In this research, carbon fiber was introduced as a replacement for conventional mild steel. They have done CAD through reverse engineering and analysis was carried out using Hypermesh and ANSYS. Finite element analysis was then carried out by using Mild Steel (IS 2062) and Carbon fiber. To validate the FEA analysis with the Experimental analysis, both steel and carbon fiber sprocket were tested on UTM for experimental results. From results of finite element analysis, they observed that stresses

are maximum at joint locations. It was also observed that both the materials have stress values less than their respective permissible yield stress values. Hence their design was safe. From analysis results and comparison of properties of all the materials, they found that carbon fiber was the material which was having the least density and it was easily available and cheap as compared to other alternate materials. Also machining cost for carbon fiber was less. Hence it was the best suited alternate material for sprocket and was expected to perform better with satisfying amount of weight reduction.

[4] Parag Nikam and Rahul Tanpure, ”Design Optimization of Chain Sprocket Using Finite Element Analysis”, In this research, the chain sprocket was designed and analyzed using Finite Element Analysis for safety and reliability. ANSYS software was used for static and fatigue analysis of sprocket design. Using these results optimization of sprocket for weight reduction have been done. As sprocket undergo vibration, modal analysis was also performed. The design of sprocket has been successfully optimized with weight reduction of 15.67%. Also von-mises stress of modified design was lesser than preliminary design with little increase in deformation, which ultimately results in the safety and reliability of design.

[5] Nikhil P. Ambole and Prof. P. R. Kale, “Finite Element Analysis Carbon Fiber Sprocket using ANSYS”, In this paper, the stress of chain drive was studied and the existing sprocket of Bajaj Pulsar 180 motorcycle was compared with the sprocket of carbon fiber material. They have achieved this by using ANSYS 13, by applying torque in to the model of sprocket. Sprocket of mild steel (MS) was considered as an object and input variables have been taken from standard conventional rear wheel sprocket model of Bajaj Pulsar 180. Sprocket have been designed as per standard design procedure with input data of Bajaj Pulsar 180. From results of finite element analysis, they observed that stresses are maximum at joint locations and both the materials have stress values less than their respective permissible yield stress values. From analysis results and comparison of properties of all the materials, they found that carbon fiber is the material which is having the least density and also it is easily available and cheap as compared to other alternate materials. Also machining cost for carbon fiber was less. Hence it was the best suited alternate material for sprocket.

[6] Tushar S. Hingve and Dr. A. V. Vanalkar, “Faults Detection and Diagnosis of the Sprockets Failure”, In this paper, the main objective was to find out the major breakdowns in mechanisms due to sprockets failure causing production losses to the company and to suggest counter measures by which these problems can be reduced. They conducted a root cause analysis to find the root cause of breakdowns and they identified some parallel improvement opportunities for implementation so as to reduce the downtime and studied the diagnosis of the faults. They suggested that one can eliminate the faults occurred in sprockets by designing new sprocket tooth profile and same parallel improvements.

[7] Yasir Afzal, Vandana Jha and Anil Mohapatra, “A Comparative Study Based on ANSYS Analysis of Existing Sprocket’s Material with High Performance Engineering

Plastic Materials", In this paper, a comparative Study was done based on ANSYS analysis of existing sprocket's material with high performance engineering plastic materials. They used CATIA and ANSYS for designing and analyzing the result respectively. They determined the equivalent stress and strain using base material like SS304, then changed the material and tests on PEEK, PI and PPS material was taken results were compared. They found that those high performance engineering plastic materials can be used in the manufacturing of Sprocket in the viewpoint of equivalent stress and equivalent elastic strain. The main thing was cost, and they found that the cost of PPS is very lesser than other plastic material even much lesser than the cost of SS 304. Therefore, PPS was one of the best Alternate material for SS 304.

[8] Kavit M. Shah and Prof. Dhruv U. Panchal, "Experimental Investigation on Effect of Plasma Nitriding on Wear of Chain-Sprocket Assembly Used in Motorcycle", In this research, effect of plasma nitriding on wear of chain-sprocket was studied. Two sets of chain-sprocket assemblies were placed on the test-rig. The conditions of the experiment were kept similar for both the chain drives. The no. of cycles has been operated during the experiment. Each cycle was of 4 hours. The setup ran for 540 hours; which included both untreated and plasma nitrided sprockets. From the readings and condition of sprockets they concluded that plasma nitrided sprocket has greater wear resistance than the normal (untreated) sprocket.

[9] Swapnil Ghodake, Prashant Deshpande and Shrikant Phadatare, "Optimization of Excavator Sprocket and its Validation by Test Rig Concept", In this research, the weight of excavator sprocket was optimized by reducing material to get optimized design which could perform well under torque condition keeping same constraints. For this purpose, they used an FEM tool for analyzing existing and optimized sprocket with different types of FEA techniques. Strain Gauging was done for correlation with FEA virtual strain to confirm the loadings. Conceptual Test rig was also proposed to validate the optimized sprocket.

[10] Ebhota Williams S, Ademola Emmanuel and Oghenekaro Peter, "Fundamentals of Sprocket Design and Reverse Engineering of Rear Sprocket of a Yamaha CY80 Motorcycle", In this paper the fundamentals of sprocket design and manufacturing of a rear sprocket of Yamaha CY80 motorcycle through reverse engineering approach was studied. The eight steps that was to be followed sequentially in the reverse engineering approach were discussed. They manufactured the sprocket by universal milling machine from the blanked mild carbon steel (AISI 1045) with chemical composition of C=0.45%, Mn=0.75%, P=0.03% max, S=0.04%. Induction heat treatment was applied to enhance the material hardness from 13 HRC to 45 HRC.

[11] Pooja R Phule and Shyam P Mogal, "Design and Performance Evaluation of Chain Wheel Drive of Bicycle by Using Alternate Material", In this paper, performance of chain wheel drive of bicycle was studied by using alternative material. The plastic material chosen was a composite of Nylon 66 and Glass filled i.e. Nylon66GF30. The model of the plastic wheel was developed using Pro/E and analyzed using the ANSYS

software. Their analysis showed that the physical and mechanical properties of the plastic chain wheel were comparable to a steel chain wheel and therefore, plastic can be used to replace steel. From the obtained results they had concluded that, there was some dimensional changes and change in manufacturing process for Nylon 66 chain wheel as results shows more displacement in Nylon 66 chain wheel than the Steel chain wheel. The Nylon 66 + glass filled chain wheel was manufactured by SLS Rapid prototyping process. With this manufacturing process, product was manufactured layer by layer form so that this Nylon 66 chain wheel shows the some more deflection.

III. Conclusion

It is interesting to observe that mostly researchers have chosen Finite Element Analysis to optimize the sprocket. Mostly they have chosen different grades of steel as their base material. Few have tried to substitute the steel with composite material also. As compared to steel, composites are not so easy to be machined using traditional machining processes. Few of the researchers have optimized the sprocket using FEA software without performing the experiment validation. Hence, it can be concluded that more weight reduction can be achieved by re-designing the sprocket geometry like teeth profile, hub, bolt holes, pockets etc. and more torque can be achieved. Since metals will be going to deplete someday, researchers are searching for more alternative materials. Polymer composites are slowly finding its place as a replacement to steel. Re-designing of sprocket can be done by using the different compositions of polymer matrix composites and more weight can be optimized without reducing the power transmission. Metal-Matrix composite can be also used as a substitute to steel for manufacturing of sprocket. Cost of material is an another factor which restricts the use of alternate materials in place of existing materials for sprocket manufacturing for automobiles and machineries. New manufacturing techniques can also be introduced or the existing methods can also be optimized for fast and precision manufacturing of the sprockets. So the above techniques can be used for further development of chain sprocket and more efficiency can be achieved during power transmission.

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