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Analysis of Spur Gear by using Composite Material

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Abstract—
Gearing is one of the most critical components in a mechanical power transmission system, and in most industrial rotating machinery. It is possible that gears will predominate as the most effective means of transmitting power in future machines due to their high degree of reliability and compactness. In addition, the rapid shift in the industry from heavy industries such as shipbuilding to industries such as automobile manufacture and office automation tools will necessitate a refined application of gear technology. but still we need to improvise the life of gear that's why we can design the spur gear model using designs software. For that we have to study the weight reduction and stress distribution for cast steel and composite materials. To study the impact analysis and torque loading of cast steel and composite materials. Finally, comparing and analyzing of the composite gear with existing cast steel, carbon fiber and cast iron gear is to be done
Keywords—cast steel, carbon fiber and cast iron.

I. INTRODUCTION

Overview of Gear

Gearing is one of the most critical components in a mechanical power transmission system, and in most industrial rotating machinery. It is possible that gears will predominate as the most effective means of transmitting power in future machines due to their high degree of reliability and compactness. In addition, the rapid shift in the industry from heavy industries such as Shipbuilding to industries such as automobile manufacture and office automation tools will necessitate a refined application of gear technology. A gearbox as usually used in the transmission system is also called a speed reducer, gear head, gear reducer etc., which consists of a set of gears, shafts and bearings that are factory mounted in an enclosed lubricated housing. Speed reducers are available in a broad range of sizes, capacities and speed ratios. Their job is to convert the input provided by a prime mover (usually an electric motor) into an output with lower speed and correspondingly higher torque. In this, analysis of the characteristics of involute spur gears in a gearbox was studied using nonlinear FEM. Gears are toothed members which transmit power motion between two shafts by meshing without any slip. Hence, gear drives are also called positive drives. In any pair of gears, the smaller one is called pinion and the larger one is called gear immaterial of which is driving the other. Gears are necessary as lighter automobiles continue to be in demand. In addition, the success in engine noise reduction promotes the production of quieter gear pairs for further noise reduction. Noise reduction in gear pairs is especially critical in the rapidly growing field of office-automation equipment as the office environment is adversely affected by noise, and machines are playing an ever widening role in that environment. Ultimately, the only effective way to achieve gear noise reduction is to reduce the vibration associated with them. Designing highly loaded spur gears for power transmission systems that are both strong and quiet requires analysis methods that can easily be implemented and also provide information on contact and bending stresses, along with transmission errors. The finite element method is capable of providing this information, but the time needed to create such a model is large. The prime source of vibration and noise in a gear system is the transmission error between meshing gears. Transmission error is a term used to describe or is defined as the differences between the theoretical and actual positions between a pinion (driving gear) and a driven gear. It has been recognized as a main source for mesh frequency excited noise and vibration Spur Gear

II. LITERITURE REVIEW

The review mainly focuses on replacement of a metallic gear of Alloy Steel with the Cast iron, Carbon fiber and cast steel within the application of Luna TFR. The gear stress analysis, the transmission errors, and the prediction of gear dynamic loads, gear noise, and the optimal design for gear sets are always major concerns in gear design. The polymer gear wear rate will be increased, when the load reaches a critical value for a specific geometry. The gear surface will wear slowly with a low specific wear rate if the gear is loaded below the critical one. The possible reason of the sudden increase in wear rate is due to the gear operating temperature reaching the material melting point under the critical load condition. Actual gear performance was found to be entirely dependent on load. A sudden transition to high wear rates was noted as the transmitted torque was increased to a critical value. This is to be associated with the gear surface temperature of the material reaching its melting point. That is for a given geometry of actual gear, a critical torque can be decided from its surface temperature calculation. [K. Mao, 2006]

III. SPUR GEAR

The spur gear is simplest type of gear manufactured and is generally used for transmission of rotary motion between parallel shafts. The spur gear is the first choice option for gears except when high speeds, loads, and ratios direct towards other options. Other gear types may also be preferred to provide more silent low-vibration operation. A single spur gear is generally selected to have a ratio range of between 1:1 and 1:6 with a pitch line velocity up to 25 m/s. The spur gear has an operating efficiency of 98-99%. The pinion is made from a harder material than the wheel. A gear pair should be selected to have the highest number of teeth consistent with a suitable safety margin in strength and wear. The minimum number of teeth on a gear with a normal pressure angle of 20 degrees is 18.

Fig.1-spur gear

Description of project: This project is for manufacturing composite gear using several materials. Gears are generally used in power and motion transmission work under different loads and speeds. Due to advantages of noiseless running, light weight, resistance to corrosion, ease of mass production, lower coefficients of friction, and the ability to run without external lubrication, the use of composite gears is continually increasing. These gears are especially preferred and successfully used in office machines, household utensils, in the food and automotive industries, and in textile machinery because of the above- mentioned advantages. Gearing is an essential component of many machines, and the defect of gear is the important factor causing machinery failure. According to statistics, 80% of transmission machinery failure was caused by the gear, and gear failure was about 10% of rotating machinery failure, so gearbox monitoring for fault detection and diagnosis is one of the important tasks in industrial maintenance.

In this work, a metallic gear of Alloy Steel is replaced by the composite gear of cast steel, carbon fiber and cast iron. Such Composites material provides much improved mechanical properties such as better strength to weight ratio, more hardness, and hence less chances of failure. In this work, an analysis is made with replacing gear material with composite material such as cast steel, carbon fiber and cast iron so as to increase the working life of the gears to improve overall performance of machine. Finally the Modelling of spur gear is carried out using SOLID WORK and bending stress analysis of spur gear is carried out using ANSYS V14.

Fig.2 -spur gear in Ansys V14

IV. DESCRIPTION OF VEHICAL

Fig.3 –Kinetic Luna TFR Model

Model: Kinetic Luna TFR
Type: scooterette
Displacement: 49.8cc
Maximum Power: 1.2 bhp@4500rpm
Max. Torque: 2.94Nm@3000rpm
Engine description: Air Cooled
Transmition:
Gear Box: Automatic.
Dimension,Weight,Capacity
Ground Clearence:120mm
Wheel Base:1100mm

V. COMPOSITE GEAR

Gears made from composite materials are widely used in many power and motion transmission applications. Due to lower weight to stiffness ratio, composite gears may be replaced by conventional material gears in power transmission systems. Present day plastics have attracted the attention as gear material for use in such facilities. These composite gears are usually manufactured by process of injection molding, which are reinforced by carbon, short glass fibers, or fillers. Geometrical accuracy of an injection-molded component is decided by many parameters such as material shrinkage characteristics, molding parameters, gating and cooling systems. Complex geometry of gear causes different flow and shrinkage rates and affects the gear accuracy [ii]. Polymeric composite gears materials suffer from poor mechanical strength and thermal resistance compared with metals. Reinforced polymers offer high mechanical strength and thermal resistance and are suitable for structural load bearing applications. the basic weakness of plastic spur gear teeth is tooth fracture brought on by the accumulation of stress at the root of the tooth and by the geometry of the tooth . Polymer composite gears can fail in two ways: one by fatigue, the other by wear. Fatigue can be measured directly by life tests, but wear needs to be continuously recorded . According to the recent works it has been reported that short glass fiber-reinforced gears also show unacceptable wear under power transmission conditions, and only carbon fibre reinforced gears have efficient capacity for high torque. Carbon fiber-reinforced material has been used in an application for the flexspline of harmonic drive gears. However, the problem is that carbon fibre-reinforced gears are expensive [i]. Gear rotational speed influences the performance of composite gears. Increasing the rotational speed considerably increases the loading frequency and increases the surface temperature of gears, which leads to the reduction of gear life .

VI. COMPOSITE MATERIAL

A composite material can be defined as a combination of two or more materials that results in better properties than those of the individual components used alone. In contrast to metallic alloys, each material retains its separate chemical, physical, and mechanical properties. The two constituents are reinforcement and a matrix. The main advantages of composite materials are their high strength and stiffness, combined with low density, when compared with bulk materials, allowing for a weight reduction in the finished part. The reinforcing phase provides the strength and stiffness. In most cases, the reinforcement is harder, stronger, and stiffer than the matrix. The reinforcement is usually a fiber or a particulate. Particulate composites have dimensions that are approximately equal in all directions. They may be spherical, platelets, or any other regular or irregular geometry. Particulate composites tend to be much weaker and less stiff than continuous fiber composites, but they are usually much less expensive. Particulate reinforced composites usually contain less reinforcement (up to 40 to 50 volume percent) due to processing difficulties and brittleness. A fiber has a length that is much greater than its diameter. The length-to-diameter ratio is known as the aspect ratio and can vary greatly. Continuous fibers have long aspect ratios, while discontinuous fibers have short aspect ratios. Continuous-fiber composites normally have a preferred orientation, while discontinuous fibers generally have a random orientation. Fibers produce high-strength composites because of their small diameter; they contain far fewer defects (normally surface defects) compared to the material produced in bulk. As a general rule, the smaller the diameter of the fiber, the higher its strength, but often the cost increases as the diameter becomes smaller. In addition, smaller-diameter high-strength fibres have greater flexibility and are more amenable to fabrication processes such as weaving or forming over radii. Typical fibres include glass, aramid, and carbon, which may be continuous or discontinuous. The continuous phase is the matrix, which is a polymer, metal, or ceramic. Polymers have low strength and stiffness, metals have intermediate strength and stiffness but high ductility, and ceramics have high strength and stiffness but are brittle. The matrix (continuous phase) performs several critical functions, including maintaining the fibers in the proper orientation and spacing and protecting them from abrasion and the environment. In polymer and metal matrix composites that form a strong bond between the fiber and the matrix, the matrix transmits loads from the matrix to the fibers through shear loading at the interface. In ceramic matrix composites, the objective is often to increase the toughness rather than the strength and stiffness; therefore, a low interfacial strength bond is desirable. There is a practical limit of about 70 volume percent reinforcement that can be added to form a composite. At higher percentages, there is too little matrix to support the fibers effectively. Common fiber reinforced composites are composed of fibers and a matrix. Fibers are the reinforcement and the main source of strength while the matrix which glues all the fibers together in shape and transfers stresses between the reinforcing fibers. Sometimes, fillers or modifiers might be added to smooth manufacturing process, impart special properties, and/or reduce product cost. Primary functions of the matrix are to transfer stresses between the reinforcing fibers (hold fibers together) and protect the fibers from mechanical and/or environmental damages. A basic requirement for a matrix material is that its strain at break must be larger than the fibers it is holding. The primary functions of the additives (modifiers, fillers) are to reduce cost, improve workability, and/or impart desired properties. Design choices, especially the complex shape and hollow cross-section parts.

VII. MATERIAL SELECTION

A. Cast steel

Cast steel was the first type of steel that allowed alloys to be added to the iron. Prior to this method, manufacturers had not been able to get steel hot enough to melt. By heating blister steel in a clay crucible placed directly into a fire, Huntsman allowed the metal to reach up to 2900°F (1600°C). Melting allowed other elements, such as nickel, to be mixed into the metal, thus strengthening the steel. Cast steel has a rough finish. It often has surface holes created by gas bubbling during the heating process. An elastic metal, this type of steel is very tough, having four times the tensile strength of cast iron. Tensile strength is how much pressure, created by pulling, an object can withstand before it breaks. One concern when using cast steel is whether the surface holes extend into the interior of the metal. If so, these holes could create weaknesses that affect the soundness of the steel. Measuring the volume of water that can be poured into the holes will give a good indication of whether the holes extend far into the metal.

Properties of Cast Steel

Hardness
The hardness of cast steel varies depending on the mixture of carbon and other ingredients. The heat levels used when mixing the metal also affect the hardness of the finished metal product. Typically, lower levels of carbon and high alloy content result a softer metal. Higher levels of carbon with fewer added allows achieves a cast steel with greater hardness but lower yield strength, which is the flexibility of the metal.

Durability
Several tests are used to determine the strength and durability of cast steel before it starts to break down. These tests include impact tests, drop tests, tear tests and fracture tests. In this area, high carbon and low allow concentrations are actually detrimental.

Ductility
The ductility of steel is the measurement of how much molding or shaping it can take and how small the sheets can become without breaking down. This is determined largely by the material mixture of the cast steel and how it is formed. In general, quenched or tempered steel has higher ductility levels, or the ability to deform without breaking, than traditional annealed steel, which produces a softer metal.

Fatigue
The fatigue properties of cast steel represent how much pressure and use the steel can take before breaking down. The fatigue test of cast steel shows its predicted life.

Advantage and Disadvantage of Cast Steel

One of the advantages of cast steel is the design flexibility, the designer of the casting have the greatest freedom of Cast steel has the metallurgy manufacturing flexibility and strongest variability; you can choose a different chemical composition and control, adapted to the various requirements of different projects. By different heat treatment choice in the larger context of the mechanical properties and performance, and good weldability and workability.
Cast steel is a kind of isotropic material and can be made into the overall structural strength steel castings, thereby improving the reliability of the project. Coupled with the design and weight the advantages of short delivery time, price and economy has a competitive advantage.
The weight range of steel castings is larger. Little weight can be only a few dozen grams of molten mold precision castings, and the weight of large steel castings up to several tons, dozens of tons or hundreds of tons. Steel castings can be used for a variety of working conditions, and its mechanical properties superior to any other casting alloys, and a variety of high-alloy steel for special purposes.

Mechanical Properties of Cast Steel

Density = 7870 kg/m3
Young modulus = 200 GPa
Poisson's ratio = 0.29
Tensile strength = 518.8 MPa
Ultimate Tensile Strength = 540 MPa Yield Tensile Strength = 415 MPa
Bulk modulus = 140 GPa

B. Carbon fiber
The principal purpose of the reinforcement is to provide superior levels of strength and stiffness to the composite. In a continuous fiber-reinforced composite, the fibers provide virtually all of the strength and stiffness. Even in particle reinforced composites, significant improvements are obtained. Carbon fibers display linear stress-strain behavior to failure, the increase in strength also means an increase in the elongation-to-failure. The commercial fibers thus display elongations of up to 2.2%, which means that they exceed the strain capabilities of conventional organic matrices. Carbon fibers are available from a number of domestic and foreign manufacturers in a wide range of forms having an even wider range of mechanical properties. The earliest commercially available carbon fibers were produced by thermal decomposition of rayon precursor materials. The process involved highly controlled steps of heat treatment and tension to form the appropriately

ordered carbon structure. Carbon fibers are also manufactured from pitch precursor for specialty applications. Pitch fiber properties typically include high modulus and thermal conductivity.

Advantages & Disadvantages of carbon fiber

Carbon fiber is now common use in everything from tennis rackets to bicycle frames. It is Light weight, flexible, high strength in tension, high resilience (can be deformed thousands of times without fatigue), easy shaping, low thermal expansion. One of the great benefits of carbon fiber is that it can be applied to existing composite materials as reinforcement and corrosion resistant. Carbon fiber are 70% lighter weight than steel, and 40% lighter weight than aluminum. It is highly corrosion resistant.
The disadvantages of Carbon fiber are Sensitivity to shock, less strength in compression, cost (although cost has been falling). it is Imbalance An issue with any prop, many don't come balanced. If you don't balance them, they'll be worthless.

C. Cast iron

Cast iron is made when pig iron is re-melted in small cupola furnaces (similar to the blast furnace in design and operation) and poured into molds to make castings. Cast Iron is generally defined as an alloy of Iron with greater than 2% Carbon, and usually with more than 0.1% Silicon All types of cast iron - from gray to ductile reduce noise because of the inherent sound damping properties of the metal. This is due to the graphite content of cast iron, which gives it optimal noise reduction capacity. Precipitated graphite particles absorb noise vibration; therefore, the relative damping capacity of ductile iron is twice that of steel. Gray cast iron has twice the damping capacity of ductile iron. Cast iron is well known for being highly machinable, but is often neglected as an engineering material because of the misconception that it is weak and brittle. While it's true that the gray irons are relatively brittle, ductile iron is not. Gray iron contains graphite in the form of flakes, while ductile iron contains graphite in the form of small, rounded nodules in a metal matrix. Ductile iron's mechanical properties are similar to those of carbon steels with a pearlite-toferrite ratio influences strength, hardness and machinability in cast irons and steels.

Mechanical Properties of cast iron

Graphite morphology and matrix characteristics affect the physical and mechanical properties of gray cast iron. Large graphite flakes produce good dampening capacity, dimensional stability, resistance to thermal shock and ease of machining. While on the other hand, small flakes result in higher tensile strength, high modulus of elasticity, Resistance to crazing and smooth machined surfaces.
Mechanical Properties can also be controlled through heat treatment of the gray cast iron. For example, as quenched gray cast iron is brittle. If tempering is accomplished after quenching, the strength and toughness can be improved, but hardness decreases. the tensile strength after tempering can be from 35-45% greater than the as-cast strength.

VIII.CONCLUSION

The review mainly focuses on replacement of metallic gear of Alloy Steel is Replaced by the composite gear of cast steel, carbon fiber and cast iron.
The literature survey of composite spur gear was performed. Then the study in weight reduction and stress distribution and noise reduction of spur gear for cast steel and composite materials has been done.
On the basis of that study, the analysis of both cast steel and composite materials are analyzed in the application of gear box which is used in automobile vehicles.
So, Composite materials are capable of using in automobile vehicle gear boxes in the application of model instead Kinetic Luna TFR of existing cast steel gears with better results.

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