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Review of Composite Asymmetric Spur Gear

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***Abstract:**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. Design of gears with asymmetric teeth enables to increase load capacity, reduce weight, size and vibration level. This article includes a summary of asymmetric gear design parameters, new developments of asymmetric spur gear and their application in various fields of engineering applications.*

Keywords: Gears, Composite gears, asymmetric spur gear, pressure angle, contact ratio

I. INTRODUCTION

Gears are the mechanical elements which are basically used for various power transmission applications such as automobiles, industrial equipments, air planes and marine vessels. In an automobile industry, lighter weight gears with high reliability are necessary as lighter weight automobiles are continued in demand. New gear designs are needed because of increasing requirements, such as high load capacity, high endurance, low cost, long life, and high speeds in significant industries such as automobile, aerospace, and wind turbine. But all the conventional gears are designed with symmetric tooth side surfaces. These gears may be loaded in only one direction in some applications, e.g., lift machines and wind turbines. There has been an increase in demand for industrial gears for power transmission that are used under oil-less conditions in clean manufacturing factories. Engineering plastics have attracted attention as gear materials for use in such facilities [i]. Composite gears are being manufactured by injection molding process, which are reinforced by carbon, short glass fibers, or fillers. These composite gears also have several advantages such as light weight, reduced noise, and high degree of freedom in gear geometry, in comparison with conventional gears. Composite materials are preferred in places where lighter materials are desired or required without sacrificing strength. They have even become essential for many applications.

Conventional metallic gears are been manufactured by gear hobbing and shaping, the gear blanks are mounted in-line with the machine tool axis and hence obtaining concentric features in metal gears is not difficult. This is not the case in the injection molding process, which is widely employed in manufacturing polymer-based gears [ii]. This becomes bit difficult case in the injection molding process, in manufacturing composite based gears. In the case of injection molded polymer gears, module correction and pressure angle correction methods are widely followed to provide shrinkage compensation. Geometrical accuracy of an injection-molded component is decided by many parameters such as material shrinkage characteristics, molding parameters, gating and cooling systems [ii].

II. ASYMMETRIC GEAR DESIGN

Symmetric gears are being designed with standard procedures, whereas in the asymmetric gears, decision of suitable pressure angles at coast side and drive side are more crucial [iii]. The asymmetric spur gears profile mean use of different pressure angles for the driving and coast side of gear and pinion. Due to use of different pressure angles for pinion and gear on two sides, the corresponding profiles of base circles will have different diameters. Thus gears having asymmetric gears are best suitable for cases where the torque is transmitted mainly in one direction. Fig.1 shows meshing of asymmetric spur gear.

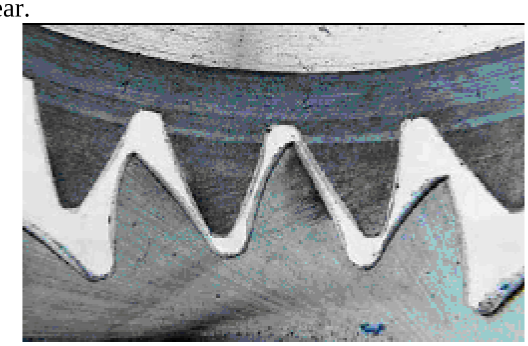

Fig. 1 Meshing of asymmetric spur gear [xi]

The increase in pressure angle increases bending strength of the gear however, with increase in pressure leads to phenomenon peaking of tooth. The peaking limit sets a boundary to the maximum magnitude of pressure angle. Gear standard procedure such as IS, recommended that tip thickness should be greater than equal to 0.2 times the module for the hardened gears. On the other hand, tooth flank becomes more curved as the pressure angle increases. Fig. shows the decrease in top land width with increase in pressure angle up to the upper limit [iii].

There are several articles about involute gears with asymmetric, or so-called, buttress teeth. They consider the low pressure angle profile (as a rule 20^0) for the drive side and high pressure angle profile for the coast side teeth. Such an approach enables to decrease the bending stresses and keeps contact stresses on the same level as for symmetric teeth with equal pressure angle [iv]. Fig. 2 shows the decrease in top land width with increase in pressure angle up to upper limit.

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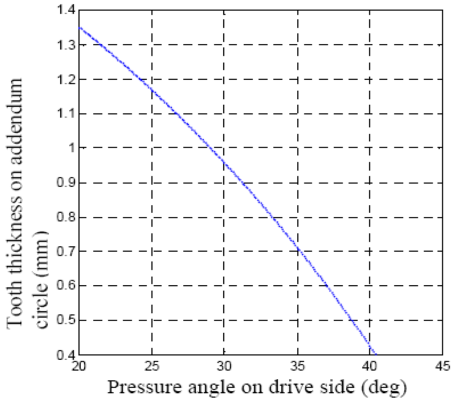

Fig. 2 Influence of pressure angle on tooth width at top land and flank region [iv]

Increase in pressure angle on drive side profile may lower the limiting number of teeth to avoid undercutting; however the contact ratio of a gear pair significantly reduces. Contact ratio is a measure of the average number of teeth in contact during the period in which a tooth comes and goes out of contact with the mating gear. Due to this behavior, uniform transmission of angular motion may not be possible. Fig. 3 indicates that behavior of contact ratio with the increase in pressure angle [iii].

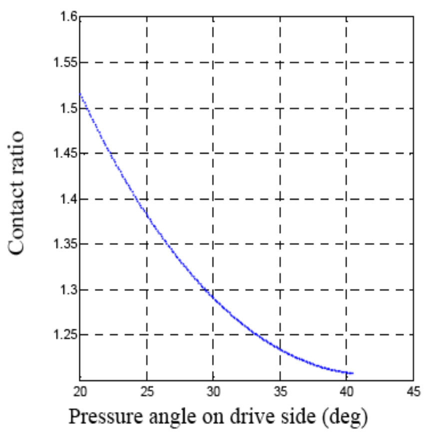

Fig. 3 Influence of drive side pressure angle over contact ratio [iii].

The difference between symmetric and asymmetric tooth is defined by two involutes of two different base circles D_{bd} and D_{bc}. The common base tooth thickness does not exist in the asymmetric tooth. The circular distance (tooth thickness) Sp between involute profiles is defined at some reference circle diameter Dp that should be bigger than the largest base diameter [ix]. Asymmetric spur gear with different base circles is as shown in Fig. 4.

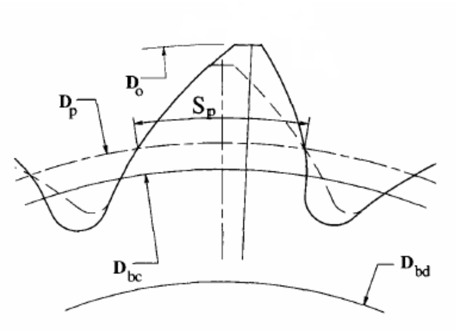

Fig. 4 Asymmetric spur gear with different base circles [ix].

New developments of asymmetric spur gear drives include:

1. Basic geometric relations for an asymmetric spur gear drive with a larger pressure angle for the driving side.
2. Modification of pinion geometry that enables:
   i. To reduce the level of transmission errors and provide a more favorable shape for the function of transmission errors, and
   ii. Localize and stabilize the bearing contact.
3. Determination of contact and bending stress and comparison with the stresses determined for a symmetric spur gear drive. It is proven that an asymmetric gear drive enables to reduce the stresses for the driving side of profiles [v].

III. 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 [vi].

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 [x]. 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 [viii].

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 fiber-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 fiber-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 [xi].

Injection molded composite gears made by blending poly-ether-ether-ketone (PEEK) with three kinds of PAN type carbon fibers (CFs) and two kinds of pitch type CFs. A composite gear reinforced with CF of the highest density indicated the highest load capability irrespective of the test conditions, due to the lowest abrasive property of the CF as well as the excellent affinity between PEEK and CF [xii]

Polyamide12/ carbon fiber (PA12/CF) gear had an excellent wear property under the condition that grease exists at the engagement region. PA12/CF gear indicated the highest load capability, excellent noiseless property, and the lowest water absorption among all polyamides investigated [viii]

IV. APPLICATIONS OF ASYMMETRIC GEARS

1. Plastic gears are now widely used for the parts of copy machines, facsimiles and printers, since they have several advantages such as being lightweight, reduced noise, anticorrosion and a high degree of freedom in design in comparison with metal gears [vii].
2. Polymer composite gears have been used with success in the automotive industry, office machines, in food and textile machinery as well as a host of other applications areas.
3. High load capacity, high endurance, low cost, long life, and high speeds becomes significant in industries such as automobile, aerospace, and wind turbine.
4. Composite gears have been widely used because of their success in the automotive industry, aircrafts, chemical equipments, transformer tubes, mine sweepers, boats and textile machinery and other allied applications areas. Some transmission gears make use of plastic materials in many places such as watches, instruments, types of washing machines, gear pumps etc. [xi].

CONCLUSION

Involute spur gears with asymmetric teeth could provide greater flexibility in designing of gears for different application areas due to non-standard design procedures. It allows to analyse a wide range of parameters for all possible gear combinations in order to find the most suitable solution for a particular application. The asymmetric tooth geometry allows for an increase in load capacity while reducing weight and dimensions for some types of gears. It becomes possible by increasing of the pressure angle and contact ratio for drive sides [iv].

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