

ABSTRACT

In the global economy, gears play a major role because of their vast application in the power transmission area, such as, industrial equipments, automobiles, aircrafts etc. The time-based competition and new-product development in the above-said fields have forced the manufacturers of gears to make an improvement with gear systems that can be manufactured faster than ever before. It is found that two-thirds of gears manufactured worldwide are spur gears. Even a small improvement in their design or in manufacture will have a wider economic impact. Spur gear is one of the simplest and main types of gears having teeth parallel to the axis of its shaft, and it has an operating efficiency of 98-99%.

In gear manufacturing, about 60% of manufacturing costs is spent for the machining and finishing process. Factors like, energy consumption during gear transmission, noise, vibration, cost of warranty, etc. are critical in this competitive manufacturing era. Therefore, quick production of gears with low cost has become the main criteria. The necessity for a cheaper, quieter and lighter machinery paved way for improvement in gear designing. Therefore, there is a high demand for gears to have a high strength with reliability, low energy consumption with low weight, low noise and vibration. According to a survey conducted by manufacturers of gears, 75% to 80% of noise and vibration in the gearboxes arise from the gears and remaining from bearing, shaft and others. Therefore, in order to increase load carrying capacity and to make the gear operate with less noise, vibration and other similar properties, innovations have emerged in the field of gear modification in terms of design and materials.

The novelty of work in this research is that, face width of gear has been split into a number of plies, and all the plies are stacked and fastened with the



aid of fasteners and the relative motion between adjacent plies is arrested with dowel pins. The advantage of these kind of stacked gears is that, it can be fabricated by press working operations like blanking / stamping, or by fine blanking when there is a need for higher accuracy. Therefore, the manufacturing time (lead time) can be reduced and obviously productivity can be improved. Another main advantage of this type of gear is that, we can substitute only the damaged ply instead of replacing the whole gear and if a crack is initiated, the propagation of crack will not pass on to the adjacent ply. The disadvantage of stacked metal gear (laminated) is that, while replacing a single damaged ply with a new one, it requires adequate working cycles to match with other plies. Plies can be manufactured by various process like stamping, fine blanking, laser cutting, thin plate forging, wire cut Electrical Discharge Machining (EDM), etc. The process of cutting depends upon the material and cost.

To understand the behaviour of above said stacked gear concept, an investigation was carried out on three categories of gears. First one is laminated spur gear where, all the plies are made of 20MnCr5 material. Second one is bimetallic gear where, plies with the combination of 20MnCr5 and Cast iron grade-35 are assembled to make single spur gear so as to reduce noise and vibration and the third one is sandwich gear where, plies with the combination of 20MnCr5 and hylam are assembled to make single spur gear so as to reduce the weight of the gear.

In any type of gear design, the bending and contact stresses are the most important criteria to be considered. In this work, the proposed gears are subjected to bending and contact stress analysis using the analysis software. Finally, the theoretical results of bending and contact stresses have been compared with finite-element results. Based on the result of finite element analysis, laminated 20MnCr5 gear is recommended as a replacement of conventional 20MnCr5 solid gear. Bimetallic and sandwich gears are



recommended for the application where the load is less by 13% and 24%, respectively, when compared with the load applied to solid 20MnCr5 gear.

To conduct the experimental work, a separate gear test rig has been developed. The developed test rig consists of a 3 phase 50 HP AC Induction motor with speed controller and a loading device (pump). The developed test rig used the Power Take-Off (PTO) gearbox with a single gear pair which is chosen for investigation. In this work, gears were investigated at various speed levels starting from 100 rpm to 1400 rpm with pump pressure load of 10 kg/cm² to 50 kg/cm². The developed test rig is used for measuring gear box oil temperature, vibration, noise radiating from the gearbox and speed of the pinion (test gear) shaft at various loading conditions are carried out.

From the experimentation work conducted on laminated 20MnCr5 gear and solid 20MnCr5 gear, it is inferred that, in laminated 20MnCr5 gear the average noise and vibration is not more than 5% when compared to solid 20MnCr5 gear. The average wear rate observed at 1.9×10^7 cycle is 0.89 mm, which is 2.2% higher and the surface roughness measured at 2.4×10^6 cycle is 2.75% higher when compared to solid 20MnCr5 gear. It is also observed that the propagation of crack acquired at 1.9×10^7 cycles is restricted because of the lamination. From the observation, it is clear that the variations in measured parameters are not more than 5%. Therefore, the proposed laminated gear can be used as a replacement for solid 20MnCr5 gear.

In the case of bimetallic gear, the average noise and vibration level is reduced to 5.04% and 11.5% respectively when compared to solid 20MnCr5 gear. The average wear is also observed to be 23.3% less. However, based on the tooth bending stress the proposed bimetallic gear is suggested for 13% less load when compared to the load applied on solid 20MnCr5 gear.

In the case of sandwich gear, weight reduction of 28.6% is achieved when compared to solid 20MnCr5 gear. The average wear rate observed at 2.4



$\times 10^6$ cycle is 0.437 mm, which is 34% higher when compared to solid 20MnCr5 gear. However, based on the tooth bending stress, the proposed sandwich gear is suggested for low load application, i.e. it is suitable for the application where the applied load is 24% less when compared to the load applied on 20MnCr5 solid gear. Further, the future work on the present study is also discussed.

