CHAPTER 8

CONCLUSION

8.1 INTRODUCTION

This chapter presents a list of major conclusions drawn from the results of Finite Element Analysis (FEA) and experimental work. The work has been subdivided into four modules as indicated below.

Module-1: Selection of gears based on Finite Element Analysis. Observing the bending and contact stress behavior of the selected gears.

Module-2: Manufacturing of selected gears.

Module-3: Development of gear test rig for conducting experimental investigation.

Module-4: Conducting experimental investigation on parameters like noise, vibration, surface roughness and wear performance of gears.

The reliability of FEA result was proved by comparing it with calculation result obtained from lewis equation and hertz equation. The performance of each gear is compared and analysed based on the above said parameters.

The following inferences were derived from the present study.

8.1.1 Conclusion on Laminated Gear

i. From the Finite Element Analysis, it is inferred that, when compared to solid 20MnCr5, the bending and contact stress of laminated
20MnCr5 gear is 6.2% and 1.8% lesser respectively. This difference is because of the geometry of laminated 20MnCr5 gear; there is a considerable improvement in bending and compressive strength. The result recommends that laminated 20MnCr5 Gear can be used as a replacement for solid 20MnCr5 Gear.

ii. Considering noise and vibration, the average noise level observed in the case of 20MnCr5 solid gear is 82.93 dB and for the 20MnCr5 laminated gear is 83.98 dB. The difference is only 1.05 dB and the vibration in terms of average acceleration is 80.95 m/s². The percentage of increase in acceleration when going for laminated 20MnCr5 gear is 4.7%. This rise in acceleration is because of the assembled structure of laminated gear. However, it depends on the number of plies and type of assembly.

iii. From the result of wear measurement, the average wear rate observed in the worst condition (recommended by the manufacturer) is 0.87 mm in the case of 20MnCr5 solid gear. For laminated 20MnCr5 gear, the average wear rate observed is 0.89 mm. From the result, it is inferred that the difference in average wear rate is 0.11 mm i.e. 2.2%. However, the wear rate can be reduced by choosing proper lubricant oil.

iv. The chordal thickness of 20MnCr5 solid gear observed at 1.9 x 10⁷ cycle is 5.82 mm and for laminated 20MnCr5 gear, observed chordal thickness is 5.7 mm. The difference between the observed chordal thickness of solid and laminated 20MnCr5 gear is 0.12 mm. The percentage of the increase in surface roughness ‘Ra’ of laminated gear when compared to 20MnCr5 solid gear at 2.4 x 10⁶ cycle is 2.75%. However, the chordal thickness strongly
depends on wear phenomenon, therefore steps taken to reduce the tooth wear will results in improvement of chordal thickness with respect to cycles.

v. From the above results, there is no major difference observed between laminated and solid gear. It is also observed that the propagation of crack is restricted because of the lamination. Therefore, the laminated gear is recommended as a replacement for solid gear.

In this work, the developed laminated 20MnCr5 spur gear is used as a replacement for solid 20MnCr5 spur gear in the Power Take Off gear box unit. Based on the conclusion of laminated 20MnCr5 spur gear as discussed above, it is inferred that, the laminated gear can be applied in the place of conventional solid gears. The laminated spur gears are strongly recommended for the following applications.

- Power Take Off units used in fire engines
- Jet vac machines
- Road sweeping machines
- Construction equipments
- Agricultural equipments like planters, transplanter, Bale lifter etc.
- Rice huller
- Mixer-wagon, etc.
8.1.2 Conclusion on Bimetallic Gear

i. The bimetallic gear proposed here is for the reduction of vibration and noise. Therefore, cast iron grade-35 is chosen because of its good vibration damping and noise absorption property.

ii. From the result of noise analysis, it is inferred that by using the proposed bimetallic gear, average noise level is reduced by 5.04% when compared to 20MnCr5 solid gear. The vibration result also shows that the average acceleration level is reduced by 11.5% when compared to 20MnCr5 solid gear. This reduction in both noise and vibration is because of the presence of cast iron plies which has a good vibration damping and noise absorption property.

iii. From the result of wear measurement, the average wear observed along this path of contact is 0.618 mm which is 23.3% less when compared to 20MnCr5 solid gear. This reduction is because of the graphite structure of cast iron plies which acts like a lubricating film and reduces the wear.

iv. However, compared to 20MnCr5 ply, the strength of cast iron ply is low. At $1.9 \times 10^7$ cycle, severe damage was observed in cast iron plies when compared to 20MnCr5 plies. The result of FEA also confirms that bimetallic gear can withstand or perform better when the applied load is 13% less when compared to the load applied to 20MnCr5 solid gear.

From the above discussed conclusion, it is inferred that, bimetallic gears are strongly recommended as a replacement for conventional solid gears which are used in medium load applications where the reduction of noise and
vibration is essential. Some of the recommended applications are mentioned below:

- Conveyors
- Construction equipments
- Flour mill machinery
- Mills mixers
- Gas and oil industry
- Water treatment plants, etc.

8.1.3 Conclusion on Sandwich Gear

i. In the proposed sandwich gear, weight reduction of 28.6% is achieved when compared to 20MnCr5 solid gear. This reduction in weight percentage is achieved because of the hylam plies which have a low density. However, the weight depends on number of hylam plies used.

ii. From the result of FEA in bending stress, the sandwich gear is proposed for low load application. In the present study, it is observed that the sandwich gear can withstand the load which is 24% less than the load applied to 20MnCr5 solid gear.

iii. When the applied pressure is increased to 40 Kg/cm² and above, hylam plies were not able to withstand more than $6 \times 10^5$ cycles, tooth breakage of hylam ply was observed. The sandwich gear proposed here withstands pressure load of 30 Kg/cm² and 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, the wear rate depends on the material of mating gear also.

iv. When compared to noise and vibration of 20MnCr5 gear, noise and vibration observed in sandwich gear is reduced by 3.8% and 7.2% respectively.

v. Compared to solid hylam gear, tooth deflection of sandwich gear is reduced by 43.5%. However, the strength can be increased or decreased based on the number of steel plied added to the gear.

Based on the conclusions arrived from the investigation of sandwich gears, it is inferred that, the sandwich gears can be applied for weight reduction in medium load applications. Sandwich gears are recommended for the following applications.

- Food Processing
- Washing Machines
- Material Handling
- Office Machines
- Packaging machinery
- Paper Processing
- Broadcast spreader (agricultural equipment), etc.
8.2 SCOPE FOR THE FUTURE WORK

i. As a future work, these types of stacked gears can be made from various combinations of materials based on the requirement of a particular application. Cost benefit analysis can be carried out to find the economy of manufacturing such gear.

ii. For the fabrication of laminated gears, each ply can be produced from metal plates using laser cutting, wire cutting, etc. An accurate profile can be obtained when going for such unconventional machining process.

iii. In the case of sandwich gears, the study was carried out for a particular material combination i.e. 20MnCr5 and hylam. However any other soft material can be chosen as sandwich material instead of hylam, for e.g. nylon, plastics etc. and investigation can be carried out on it.

iv. Advanced test rigs like FZG make, can be used for accurate measurement of different parameters like wear, noise and vibration.