CHAPTER 8

CONCLUSIONS AND SCOPE FOR FURTHER WORK

8.1 INTRODUCTION

This chapter presents a list of major conclusions drawn from the investigations carried out to evaluate the dynamic behavior of transmission and gear housings. The following section presents the salient features and contributions of research work reported in the thesis. The future trends and scope for future work have also been identified and the same listed in the subsequent sections.

8.2 CONCLUSION

The dynamic analysis for transmission and gear housing in kW range 30 to 4500 was carried out. The influence of various parameters like length, breadth, height and thickness on the natural frequencies of housings were analysed. It was observed that the fundamental natural frequency obtained for various cases are in the range of 20 to 60 cps which is excitable range of frequencies for systems considered in this research work. In the case of gear housing, the influence of shoulders and cylindrical bosses of anti-friction bearings with specific reference to housing natural frequencies is presented. Besides, it is indicated that the critical speeds in torsion and bending may also lie in the range of natural frequencies of housings. It is possible to increase the fundamental natural frequency of transmission and
gear housings by using standard unequal angles of appropriate sizes at the corners and standard stiffeners with appropriate spacing.

The important conclusions that are arrived at are discussed below.

- Finite element analysis carried out on transmission housing without ribs, stiffeners and cutout indicated fundamental natural frequency to be 31.6 cps. Experimental works carried out also resulted in the same value. Validation is also done by energy method, assuming the vertical plates to have approximately sinusoidal mode shape along any horizontal plane whereas along any vertical plane they behave like cantilever. Introducing ribs at four corners and stiffeners at the middle is found to increases the natural frequency to 35.2 and 178.2 cps respectively. The housing with ribs at four corners increases the natural frequency by 10%. There is approximately five times increase in natural frequency for housing with ribs and stiffeners. It may be observed that an increase of 10% in natural frequency amounts to increase of 6cps in natural frequency. This is around 360 rpm which is substantial from the point of view of requirements in industries. Hence it is concluded that in the design of such housings, addition of ribs and stiffeners will avoid near resonance condition of operation.

- Providing a large size cutout on transmission housing reduces the fundamental natural frequency drastically and the value is 14.4 cps. The drastic reduction in fundamental natural frequency has been explored through torsional analysis of the housing. The results are also verified with experiment. From the point of view of dynamic behavior of the housing, it is concluded that the introduction of either rectangular or circular
cutout of substantial size (in relation to housing) is to be avoided to keep the natural frequency of the housing, away from the possible exciting frequencies.

- In case of gear housing, provision of axial constraint along the axis of the shaft on the side plates stiffened it and made the top plate alone more flexible. Introduction of ribs, stiffeners and bearing blocks marginally increased the fundamental natural frequency of gear housing due to flexibility of top plate.

- The mode shape for transmission housing obtained experimentally indicates bulging of large size side plates which is similar to the results obtained through finite element analysis. The beam assumption used in energy method implies the four rectangular side plates bend in such way that the rectangular cross section is preserved while bending. But the deformed shape obtained by finite element method and experimental indicates bulging of the plates. Flexibility of the individual plates is overlooked in the beam model. From this observation, it is concluded that the beam approach is found to overestimate the natural frequency. Hence use of energy approach for plate model with modified boundary condition is found to be valid.

Most research papers in the area of vibration, normally deal with formulation of new differential equations, sometimes non-linear and discussions on limit cycles and singularities. These reports involving mathematical models may focus on theoretical interpretation. The present work deals with real time field problems that were prompted by investigation of site failures. It uses well-known energy method, finite element method and free and forced vibration experiments. The present research addresses the dire necessity to look at some aspects of vibration from an industrial perspective.
This line of thinking is borne out of reported failures during the last ten years in five different places largely due to overlooking of near resonant conditions of operation and consequent losses.

The results presented in this thesis, can be conveniently used to tide over near resonant conditions of operation and to arrive at a safe housing design. Determination of natural frequencies of housings appears to be apparently simple. But, in reality, it is more involved. Large housings made of reinforced concrete are erected without considering the dynamics. This has led to severe vibrations of support bearings. Once the housing is fabricated, it is extremely difficult to implement any modifications if the structure is of reinforced concrete. The design guidance including the angles at the corners and channels is highlighted. Designing housings, without paying attention to the dynamic behavior, results in huge loss of production if the housing is in the zone of excitable range. It is imperative that this aspect is taken into account in the design stage itself.

8.3 PRESENT TRENDS

At present the researchers employ mostly finite element method for analysis. In most cases, details of software used are not highlighted in the work. Experimental modal analysis, noise measurement and condition monitoring of the performance of units are also presented. But, by and large, the research work reported falls under the category of analysis and not synthesis.

Synthesis is partially heuristic and partly analytical. The synthesis of gearboxes, essentially centers around developing exhaustive output data (natural frequency, thickness of gearbox and total weight of gearbox for chosen input like net speed reduction, horsepower transmitted, leading dimensions like length, breadth and height for gear boxes with and without
ribs and stiffeners). With this data available and with the speeds of operation known one makes a preliminary selection of gearbox closest to the requirement and then fine tuning of the leading dimension is done. Many industries are carrying out these exercises in house but these investigation results are not available in public domain.

Three decades ago, it was not possible either to determine the thickness or the first few natural frequencies of a gear box scientifically since the gear box with complicated shape and loading is a statically indeterminate structure. But, today with the advent of finite element method, this has become a reality. With modern tools available for analysis and experiments, the demands of the user have gone up. The user looks for trouble free gear box, probably one which has absence of near resonant condition of operation (vibration), absence of noise level above specific dB (acoustics), minimum weight (structural optimization) and a limit on the temperature rise due to gear meshing (heat transfer). A designer cannot satisfy all these requirements simultaneously. Certainly future trend in research, in our opinion, would be an attempt to answer these questions scientifically through synthesis.

8.4 SCOPE FOR FUTURE WORK

The present work could be extended to achieve the following

(i) Development of the most economical design of transmission and gear housings knowing the range of exciting frequencies that the system is likely subjected to.

(ii) Development of methodology for obtaining the best design of housing, using reverse engineering, for higher operational speeds in the range of 10,000 to 20,000 rpm.
(iii) Development of schemes to quantify the range of speeds at which existing drive housing can be safely operated.

(iv) The influence of angular misalignment, flexible coupling, co-axial shafts, gear meshing frequencies have not been taken into consideration in present study. Hence there is the scope for studying the influence of these parameters on the drive housings.