CHAPTER 8

CONCLUSION AND FUTURE WORK

8.1 CONCLUSION

The following inferences can be derived from the present study:

1. Coordinates for the involute profile of the tooth should come from a kinematic analysis of the cutting process. Approximation methods to present the involute are not recommended because of the sensitivity of the involute and its effects on the static and dynamic stresses.

2. An approach has been proposed and a computer programme has been developed. This approach can plot and design the spur gear tooth profile with more efficiency and can deal with the irregular cases related with base and root radius.

3. Another approach has been submitted for doing an inverse design on actual cases of spur gears based on tooth thickness measurement at an arbitrary radius of the actual gear sample. A programme has been developed based on this approach and it gives as good results for nonstandard cases as for standard cases.

4. Most bending stresses occur in the fillet portion of the tooth root, which is represented by a trochoid curve. Trochoid curve should come from rack cutter formulation because it is
a trochoidal path of the rack cutter during cutting operation. It is not correct to assume that the trochoid is an arc of a circle.

5. Pressure angle noticeably affects on the profile of tooth, the thickness of the base of tooth is increased when the pressure angle has been increased, and similarly the flank space of tooth is decreased when the pressure angle is increased which will affect the central distance between the mating gears. For the selected case the bending stress in the fillet portion of the tooth is decreased when the pressure angle has been increased, but for other modules and number of teeth, stress concentration region will occur between the teeth which might cause increase in bending stress after exceeding pressure angle of 25° and especially at pressure angle of 30°.

6. The bending stress in the fillet portion of the tooth is decreased when the profile shift factor has been increased. The thickness of the base of tooth is increased when the profile shift factor has been increased, and similarly the flank space of tooth is decreased when the profile shift factor is increased. This theoretically and practically affects the center distance between the mating gears and also the tip thickness of the tooth which will decrease until reaches a critical case that might cause increasing in pitting.

7. Number of the teeth is a significant parameter in all gear relations and its formulations. Its effect is on the size of the tooth and on the overall size of the gear. The exceeding of the minimum number of teeth will cause the undercut in the tooth, which will require a correction on this gear. The
bending stress decreases when the number of teeth is increased, but at a critical number of teeth the increase in the number of teeth will increase the bending stress, and it is important to know this critical value of number of teeth for each module.

8. Rack cutter tip radius directly affects the forming of trochoid curve. The bending stress in the fillet portion of the tooth is decreased when the rack cutter tip radius has been increased, but when it is decreased a sharp angle will be produced in the fillet of the tooth root which causes a stress concentration region and that in turn will increase the stress. This work recommends at least (0.25 module) as a value for rack cutter tip radius.

9. The effect of rim thickness on bending stress has been studied in two paths (sector path and full ring rim path). Both paths of analysis have showed the same behavior of bending stress when the rim thickness and back up ratio are varied. The bending stress results for both of these paths are compared, and found to be particularly close. At back up ratios above 1.4, no appreciable change occurred in the maximum tensile bending stress on the base of the loaded gear tooth. The maximum bending stresses in the tooth root increased with decreases in the rim backup ratio. These increases were not significant until the back up ratio dropped to values below 1.4. The general trends of increasing tensile bending stresses with decreasing backup ratio agree with the published literature. Differences in the reported backup ratio at which the increases become measurable were seen to depend primarily on rim support geometry.
10. It is found that the increase in the rim thickness and back up ratio will decrease the natural frequency of spur gear. Therefore the rim thickness parameter is very important to control the stiffness and vibrations of the gear and in turn the entire system in which this gear operates. The rim thickness and back up ratio can be used to control the effects of the dynamic stress because of its influence on the natural frequency.

11. It is not accurate to calculate the compressive stress from the equations, which is based on Hertz theory alone. Gear design should be considered an exact contact problem between two teeth. The contact finite element analysis presented good results to simulate the actual condition during the contact operation. The potential load and the point of contact should be calculated carefully and fed to the finite element analysis where all the relative motions of the two teeth should be under the consideration. Suitable size should be given to the target and contact regions on both the mating teeth.

12. It is found from the finite element contact analysis that a sliding case occurs after the point of contact exceeding the single tooth contact region and before reaching the point of separation. During this stage the contact stress concentration regions in the pinion tooth and gear tooth sides will be affected and show a very small shifting in this regions from the theoretical locations which have been calculated from the theory of gear tooth contact.

13. A programme has been developed to plot a case of contact between any pair of teeth of two mating gears. This
programme depends on the formulation of Chapter 5, and it is so useful to give the geometrical situation of these mating teeth at any angular location of contact.

14. It is found from the dynamic analysis of gear tooth for the moving load that the dynamic stresses are varying periodically (the period is coinciding with the period of fundamental bending vibration of gear tooth). It is also observed that the time period is invariant with rotational speed of the gear. The analysis should be based at least on the third frequency.

15. It is found from the applying of finite element method in transient analysis of spur gear by using of mode superposition technique which gives more confident and accurate results than the other methods.

16. Referring to section 14.8 (Dynamic Factor) of (Shigley and Charles 2003), dynamic stress is obtained by multiplying by the Lewis form factor $c_v$ (Equation 14.27) of (Shigley and Charles 2003):

- This factor does not take into account gear face width (F).
- It assumed the static stress is multiplied by a factor involving peripheral velocity of the gear.
- It is well known that when the face width is increased the gear tooth becomes stronger and, hence the magnitude of dynamic stress is smaller than the gear with smaller face width, but this has not been taken into account in this formula.
• During the transient phase the gear tooth is expected to vibrate in one or more of its natural frequencies, which has not been assimilated taken into account in the existing code.

In the present approach of this work these aspects have been taken into account.

17. Modal super position technique assumes that any transient disturbance of member is the sum totals of the disturbance due to the first few modes of vibration. In reality the contribution from the higher modes die down very fast in comparison with the first mode. This has been experimentally observed to be true. This is the basis of subsections 6.4 to 6.7 in Chapter 6.

18. It is found that as the rotational speed of gear increases, the bending stress of dynamic stress also increases. For the moving load, the ratio of maximum dynamic bending root stress to maximum static bending root stress is increases gradually as the rotational speed of gear increases.

8.2 FUTURE WORK

This project work has been enlightening and fulfilling in ways more than one to me. Since my understanding has assumed new dimensions, I am concerned and confident of taking this study to newer levels of comprehension. I would love to extend my vistas in the following areas:
1. Extend this work to include the helical and hypoid gears concentrating on the dynamic effects on these gears.

2. Using the self damping material and other materials (such of composite materials) in spur gears, and try to know how many of these materials can reduce the vibrations, which might lead to a formula based on curve relation or a table that gives the natural frequency and damping ratio for each type of the selected material.

3. Using the Boundary Element Method instead of the finite element method to find out the dynamic stress curve with the time for spur gear teeth and compare these results with that of finite element method.

4. Study the dynamic contact stress in relation to new assumptions for contact and target regions in gear teeth.

8.3 NUMERICAL SUMMARY

Table 8.1 Work Summary

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