CHAPTER 6

CONCLUSIONS

After a careful and thorough analysis, the design optimization of brake disc and pad were carried out using genetic algorithm approach. The designed cast iron brake disc was analyzed for its design performance under single stop condition using various parametric relations. The thermal performance analysis was carried out using lumped parametric model along with the thermal network model. The structural characteristics analysis of the cast iron brake disc was carried out using ANSYS Finite element software package. To find the viability, feasibility and suitability of alternate material application for the brake disc, the above integrated analysis was carried out with different materials such as silicon carbide based metal matrix composite and alumina based metal matrix composite.

Based on the above integrated design, thermal and structural performance analysis, the following conclusions were made. The conclusions were based on the braking system operating variables such as, vehicle speed, deceleration rate, deceleration time and coefficient friction and alternate material application such as silicon carbide based metal matrix composite and alumina based metal matrix composite for the brake disc. The conclusions drawn in this section based on the percentile variation of the parameters with respect to the experimental values are subjected to an error margin for the sensors for load pressure and temperature are about ±3% and for speed sensor is about 0.2%.
1. This design optimization program using genetic algorithm is proved to be one of the effective means of designing the automotive braking system components in the existing trend of design methodologies such as geometric programming and stochastic approach etc.

2. In this investigation, the design of brake disc based on the genetic programming exhibits a relatively closer dimension of the brake disc than the geometric programming based design values. This is due to the fact that, the genetic programming approach consists of finer decision making steps such as cross over, spread factor and mutation etc.

3. Using genetic algorithm approach for the brake disc design, the optimum values of the brake disc radii were arrived at a probability of 0.9 with a spread factor of \( q = 5 \) and a cross over probability of 0.99 from the randomly generated brake disc radius. The predicted design dimensions of the brake disc based on the genetic approach is better than the geometric programming based one. However, the findings from both genetic and geometric approach are well within the practical standards as seen in section 5.1. Similarly the performance trends were also absorbed during down hill deceleration as seen in the section 5.11

4. The design performance parameters such as stopping distance, pedal effort, energy generated and power absorbed during braking for the cast iron brake disc at different deceleration rates, deceleration time and coefficient of friction were synthesized and compared. In this comparison it is found that,
the performance values are lower by about 2 - 15% on various performance values for the genetically designed brake disc than the geometrically designed one. On comparing with the experimental verifications carried out under identical conditions, the synthesized design performance parameter values for the genetically designed brake disc are quite comparable than the geometrically designed one as seen in section 5.2 and 5.4

5. The thermal performance parameters such as brake disc temperature, heat flux, Reynolds number, Nusselt number, heat transfer due to conduction, convection and radiation at different deceleration rates, deceleration time, coefficient of friction and brake disc temperature were synthesized and compared. It is found from the comparison that, the computed values are higher by about 10 to 19% for the geometrically designed brake disc than the genetically designed one. The comparison between synthesized and experimental findings shows that, the synthesized thermal performance parameter values for the genetically designed brake disc are higher by about 10% which is quite comparable than the geometrically designed one as seen in section 5.3 and 5.5. Similarly the thermal performance trends were also desorbed during down hill deceleration as seen in section 5.11.

6. The comparison of design performance parameters with respect to coefficient of friction indicates that, these parameters are greatly influenced by the frictional coefficient values. Since the frictional coefficient cannot exceed a certain prescribed safe and
workable value, it's value is chosen as 0.4 for this investigation and the optimum design performance parameters were obtained at this value. However, synthesized design performance parameters values for the genetically designed brake disc higher by about 2-10%, but they are in quite agreement with the experimental trends as seen in section 5.6.

7. The comparison of thermal performance parameters with respect to coefficient friction indicates that, their Comparison is widely influenced by the frictional coefficient values, due to the fact that, the frictional energy is transformed into heat energy. Since, the frictional coefficient values greatly influence the braking energy in the form of heat, it is proposed to adopt a workable and a safe frictional coefficient value of 0.4 for the optimum thermal performance and it is also achieved at this particular value. Under these conditions, the synthesized thermal performance parameters values for the genetically designed brake disc are higher by about 3-20% but they are in quite agreement with the experimental trends as seen in section 5.7.

8. The individual comparison of design and thermal performance parameters with respect to brake disc temperature indicates that, the temperature rise in the brake disc is widely affecting both the performances. This is mainly due to the fact that, the increase in temperature in the brake disc affects its functional parameters due to change in the material properties. However the synthesized thermal performance parameters values for the genetically designed brake disc are higher by about 4-20%,
however they are in quite agreement with the experimental trends as seen in section 5.8.

9. The above design performance parameter values are significantly and sensitively varying at different speeds of the vehicle. To analyze this effect, in this investigation, the performance values were synthesized for the genetically and geometrically designed brake discs. The performance values are higher by about 2-11% for the geometrically designed brake disc than the genetically designed one. The comparison between synthesized and experimental findings shows that, the synthesized design performance parameter values for the genetically designed brake disc are quite comparable than the geometrically designed one as seen in section 5.7.

10. The thermal performance parameter values for the brake disc are quite significantly and systematically varying at different speeds. The computed values are higher for the geometrically and genetically designed brake disc when compared to those of experimental values obtained from the braking performance test carried out in the test vehicle. The synthesized thermal performance parameters values for the genetically designed brake disc are higher by about 4 - 20%, but they are in quite agreement with the experimental trends as seen in section 5.8.

11. The design and thermal performance parametric trends for the alternate materials application is similar to those of base material cast iron but their magnitudes are significantly varied due to its physical properties. It is also evident from the analysis that, the SiC Al MMC is better in performance as compared to
Al Al MMC and base material cast iron as seen in section 5.9 and 5.10.

12. The structural characteristics analysis through finite element software revealed that, for a given value of braking or clamping force, the SiC Al MMC exhibits the optimum stress, strain, overall deformation values, natural frequency and its amplitude and overall temperature rise in the brake disc when compared to Al Al MMC and base material cast iron under identical conditions of theoretical verifications as seen in section 5.12. These values are quite comparable with the permissible values for SiC Al MMC

6.1 SUGGESTIONS FOR FUTURE WORK

i Further experimental investigations can be carried out with other types of vehicles under different operating conditions to make the capability of the simulation work more realistic and practicable.

ii This work can also be further extended to predict the brake squeal, thermal stress and the corresponding strain development in the brake disc.