10. Conclusions from Surface structural physical properties of Lanthanum and Praseodymium Zirconate:

Some of the structural properties of La$_2$Zr$_2$O$_7$ and Pr$_2$Zr$_2$O$_7$ were studied and the powder was prepared by Agate jar mixing and planetary high energy 4-jar wet ball milling. Based on the overall results experimental investigation, the following conclusions are drawn.

1. In the first agate jar method; there is no formation of Lanthanum Zirconate because stabilization of Zirconia is very less due to large particle size and high calcinations temperature of 1625° C.

2. In the planetary high-energy 4-jar wet ball mill method used for powder preparation from this method Lanthanum Zirconate was formed because the particles are very fine due to well grinded by ball mill (i.e. 1 to 5 microns) and it has been shown that pure 98%La$_2$Zr$_2$O$_7$ powders can be formed by the reaction of Lanthanum oxide and Zirconia dioxide, at a calcined temperature at 1430° C, 1550° C. and 1595° C. Hence planetary high-energy 4-jar wet ball mill method is most suitable to get 98% of stabilized Zirconate, where smaller powder particles sizes are essential. The same method used for all selected different zirconate material compositions at the optimum calcinations temperature of 1595° C. The final plasma sprayable Zirconate TBC powder attains a flowability of 38 g/min, powder tap density of 2.89 g/cc. similar rends of results obtained for Pr$_2$Zr$_2$O$_7$.

3. Results of La$_2$Zr$_2$O$_7$ TBC powder and coating made using on metal substrates indicate that 99% stabilization of stable cubic phase occurs, this can be evident from XRD results and majority of high intensity peaks of XRD Exactly matched with ICDD peaks, and it is clear that no destabilization of c/t phase was evident even after severe thermal shock tests. But the coatings failed after 1450° C at 1000 TSRT cycles; with regard to coatings adhesive strength of 48 MPa, is achieved and the coating could with stand at 1450° C for 1000 TSRT cycles.
4. (Ni-Cr-Al) has a significant improvement in hardness before and after TSRT when compared to Ni-Cr bond coat,

5. From the experimental results it was evident here that the VHN of 57%La$_2$O$_3$-ZrO$_2$ was found to be 555. And there no such large variation of hardness values has been noticed in specimen coated with 57%La$_2$O$_3$-43 ZrO$_2$ and it may be due to very good dense coating surface of base metal and very negligible % of defects.

6. It has been observed from the overall wear results of experimental investigations of Ni30CrAl bond coating AISI SS304 steel shows significantly higher wear resistance when compared to uncoated AISI SS304 steel and MG Al-124 base material.

10.1. Conclusions from Engine performance:

From experimental investigations conducted on 4-stroke single cylinder, air cooled, direct injection diesel engine with two thermal barrier coatings viz La$_2$Zr$_2$O$_7$ and Pr$_2$Zr$_2$O$_7$, and standard engine and by comparison of results following conclusions are drawn:

1. By thermal shock testing, it is found that La$_2$Zr$_2$O$_7$ coating withstand upto the temperature of 1450°C for about 1000 cycles, where Pr$_2$Zr$_2$O$_7$ coating can withstand upto the temperature of 1400°C for about 800 cycles. Therefore, it can be concluded that new advanced La$_2$Zr$_2$O$_7$ and Pr$_2$Zr$_2$O$_7$ of best selected compositions of TBC coatings are much suited for high performance low heat rejection engines in the longer period.

2. The coatings were found to be exhalent adhesive strength (well adherent) to the engine components even after 350hours of rigorous test of advanced Zirconate Thermal Barrier Coated engines.

3. From the Experimental investigations it is found that, in the case of TBC coated engines, volumetric efficiency reduces at every operating load compared to that of standard un-coated diesel engine. Among the two advanced zirconate coatings considered for the analysis, there was a negligible % variation of the volumetric efficiency noticed at every operating load.
4. It is found that there is marginal of about 3% decrease in bsfc for the coated engines compared to that of standard un-coated diesel engine. Therefore it is concluded that the usage of the zirconate thermal barrier coatings in LHR engines are going to affects on the fuel economy for the longer period.

5. It is found that there is great reduction in smoke density especially at Maximum operating loads (about 3% opacity) in the case of coated engines compared to that of standard un-coated diesel engine. Therefore from the envinamental pollution point of view, the use of Zirconate thermal barrier coatings in diesel engines have a great potential in the future to meet stringent emission norms which are going to come.

6. By comparison of performance characteristics and emissions of coated engine with that of existing coatings like PSZ, etc. the advanced zirconate coatings developed in this research work have almost comparable achievements and also these two advanced zirconate coatings are indigenously developed and tested successfully at lower costs. Therefore, it can be concluded that these advanced zirconate coatings are very much useful for the cost effective LHR diesel engines combustion zone, for large extent

7. From the experimental investigation, it has been identified that among the two zirconate coatings developed and tested in this work, La$_2$Zr$_2$O$_7$ coating clearly shows better performance compared to Pr$_2$Zr$_2$O$_7$ coating in internal combustion engine applications. But both the above zirconate coating has better performance compare to standard un-coated diesel engine.

The observation made from over all results of Experimental investigation, Finally, it can be concluded that, the cost effective environmental friendly advanced Zirconate thermal barrier coated engines performance are high by consuming less amount fuel and reducing pollution rate by increasing engine combustion chamber and exhaust gas temperature, to standard un-coated diesel engine, hence the advanced Lanthanum and Praseodymium Zirconate Thermal barrier coating(TBC) material are most suitable for high temperature diesel, gas turbine, aero space, marine engine applications, above 1350ºC.
10.2. Scope for Future Work:

1. Thermal conductivity and thermal expansion coefficient to be conducted at various temperatures for different compositions of Zirconate materials.
2. Scratch indentation test required on bond coat and top coat.
3. High temperature corrosion and wear test require both top and bottom coat.
4. Performance test can conduct on Zirconate Thermal barrier coating (TBC) by using various other coating techniques.