Chapter – 8

Conclusions and Scope for the Future Work

8.1 Conclusions

Thermophysical properties of various base fluids (water, PG, EG, sugarcane juice), nanofluids (PG brine based Ag, Al_2O_3, TiO_2,CuO nanofluids and Al_2O_3/EG brine) and hybrid nanofluids (0.5%Al_2O_3 +0.5% TiO_2/PG brine, 0.5%Al_2O_3 +0.5% CuO/PG brine and 0.5% Al_2O_3+0.5% Ag /PG brine), which are considered as coolants, have been measured and compared with the theoretical value. Within studied base fluids, water yield best heat transfer properties at lower temperature value, where as sugarcane juice seems to be best at higher temperature range (above 60^{o}C). Although, the viscosity of EG water brine increases continuously with increase EG concentration and PG brine yield lowest viscosity at about 25% PG concentration and results the similar heat transfer properties as water. As expected, nanofluid and hybrid nanofluids yield better thermophysical properties than base fluids and exhibits enhanced heat transfer characteristics for radiator coolants.

The theoretical energetic and exergetic performance analyses of various fin surfaces (wavy fin, louvered fin and rectangular fin) for above mentioned coolants reveal, sugarcane juice as base fluid, PG brine based Ag nanofluid and PG brine based (0.5%Al_2O_3+0.5% Ag) hybrid nanofluid have higher heat transfer rate, effectiveness, second law of efficiency and lower pumping power. As expected louvered fin yields better performance as compared to wavy and rectangular fin radiator. The new proposed coolant optimum PG brine (25% PG) yields nearly same performance as water at higher temperature and has better performance as compared to conventional EG brine. So, the proposed new coolant (25% PG) may be considered as a heat transfer fluid for automotive radiators in both light duty and heavy duty vehicles. For same cooling capacity and volume flow rate, the radiator size reduces by 3.2 %, by using PG brine based Ag nanofluids with comparision to PG brine or conventional coolants and also decreases by 2.1 % for Ag hybrid nanofluids as compared to 1% volume fraction Al_2O_3 nanofluid . So, it can be predicted that the use of nanofluids and hybrid nanofluid leads to reduction in radiator size, weight and cost, engine fuel consumption, embodied energy.

Also, the theoretical performance analysis for carbon and graphite foam as radiator fin materials, results in higher heat transfer rate and effectiveness as compared to conventional radiator fin materials and the performance increases with increase in frontal air velocity. For the same radiator core volume, CCFC (combination of cross and counter flow configuration) results better performance from conventional and counter flow configurations. Also, CCFC radiator yields 35.61% better cooling capacity than the conventional cross flow radiator at a vehicle speed 40 km/hr and mass flow rate coolant of 2 kg/s for heavy duty vehicles.

Experimentation for radiator performance on a wind tunnel based radiator set up results that heat transfer coefficient, heat transfer rate and effectiveness for water and optimum PG brine are nearly same with an experiment and theoretical result deviation of 5.7%, 3.5% and 3% respectively, with frontal velocity of 4.6m/s for rectangular fin radiator. However, heat transfer rate and effectiveness of optimum PG based Al_2O_3-CuO hybrid nanofluid are

7.4%, 5.2% higher respectively, as compared to Al_2O_3- TiO_2 /PG brine hybrid nanofluid and coolant pressure drop for optimum PG based Al_2O_3-TiO_2hybrid nanofluid at a inlet coolant temperature of 80^{o}C decreases 9 % as compared to Al_2O_3- CuO/PG brine hybrid nanofluid.

Experimentation on the performance evaluation of cooling system with engine load of 6 kg, results that the variation of air side heat transfer rate in radiator for PG brine increases by 4.48% and 11.78% for water and 25% EG brine respectively, with brake specific fuel consumption. However, heat transfer rate and effectiveness in radiator using mentioned coolants, gradually increases with increase in engine load. The heat transfer rate and effectiveness are higher for PG brine based (0.5%Al_2O_3+0.5%TiO_2) hybrid nanofluid coolant at a engine full load of 6 kg for both light duty and heavy duty vehicles. However, with the same full load of engine, the energy distribution analysis results, the better heat transfer performance for PG brine based hybrid nanofluid. Also, for the same heat transfer rate, the radiator core volume size deceases by 10% as compared to conventional coolant (25% EG brine), which benefits to reduce the manufacturing cost and the space occupied by radiator.

CFD simulation for the predicted 25%EG brine based silver nanofluid, results that the predicted results of EG brine based Ag nanofluid has higher pressure drop as compared to validated results of PG brine as radiator coolant. Comparison with the validated result of PG brine, the EG brine based Ag nanofluid has a deviation within 3% for the temperature distribution through tube and fins and the addition of 2% Ag nanoparticles to the EG brine based coolant has the potential to improve automotive and heavy-duty engine cooling rates.

8.2 Scope for the future work

(i) Use of Sugarcane juice as a coolant needs more research for the selection of a chemical preservative to store it for few months.

(ii) Experimental performance analysis on graphite and carbon foams radiator with different nanofluids and hybrid nanofluids as coolants.

(iii) Experimental performance analysis with cooling system (engine and radiator) for various fuels and coolants.

(iv) Theoretical analysis of CCFC radiator configuration for various nanofluid and hybrid nanofluids as radiator coolant.

(v) CFD analysis of different fin materials, coolants, heat exchanger geometries and CCFC configurations.