6.1 Summary and conclusions

Heat pipes charged with DI water and Cu–water nanofluids are fabricated. Nanofluids with different weight percentages are prepared and tested. Thermal performances of heat pipe operated with two different wicks are analyzed. Also, thermal performances of an anodized and non-anodized TPCT are compared. A porous structure with an average thickness of 20 µm and pore size of 150 nm on the inner wall of the aluminum tube is achieved in anodized TPCT. A mathematical model is developed to map the pressure, velocity and temperature variations inside the heat pipe when nanofluid is used as a working fluid. The following important conclusions are arrived at from the current work:

As the volume percentage of the copper in the nanofluid increases, the efficiency of the heat pipe also increases, which results in an increase in the heat transfer capability of the heat pipe. At the Cu wt% of 0.1, the maximum efficiency rise of 14% was obtained when the DI water is replaced with nanofluid. Further, as the nanoparticles present in the nanofluid sit on nucleation sites, they probably could create more active nucleation sites by splitting a single nucleation site into multiple ones and enhancing the boiling heat transfer. Thus a low temperature profile is obtained.

The thermal resistance of heat pipe at the evaporator section is reduced by around 40% at the test condition due to the coated wick. The coated wick reduces the wall temperature at the evaporator and condenser of the heat pipe. It decreases the thermal resistance of the evaporator whereas it increases the thermal resistance of the condenser. The reduction in the thermal resistance of the evaporator is higher
than the increase in the thermal resistance of the condenser and hence the Thermal resistance of the heat pipe operated with coated wick is lower than that of conventional one and is comparable to the heat pipe operated with nanofluids.

The thermal resistance and heat transfer coefficient of the evaporator of the TPCT respectively are reduced and enhanced by a maximum of 15% due to the porous coating in the inner wall of TPCT. However, the effects of porous coating on the thermal resistance and heat transfer coefficient of the condenser are negligible. The total thermal resistance of the anodized TPCT is lower than that of the non-anodized TPCT due to the reduction in the thermal resistance of the evaporator. Thermal stability test confirms the feasibility of use of porous coating in the TPCT. Though aluminum heat pipes are of light weight, their thermal resistance is larger than that of commonly used Copper heat pipes. A simple anodization of the inner wall of the aluminum TPCT can overcome this drawback. These light weight heat pipes with porous structure are more suitable for heat transfer applications in space.

A two-dimensional numerical model is developed and the effect of Cu-water nanofluid on the performance of heat pipe is studied. The temperature distribution, operating pressure, liquid and vapor velocity profiles and thermal resistance variations are predicted. Also, the pressure distribution at the liquid/vapor interface is simulated. The addition of nanoparticles to the working fluid leads to reduction in evaporator wall temperature, operating pressure, total resistance and increase in liquid and vapor velocity. By calculating the pressure drop between the vapor and liquid, the capillary head required to pull the liquid from the condenser to the evaporator is calculated. The capillary head generated by the wick structure is higher when the DI water is replaced with nanofluid. Based on the capillary head, the wick pore size is calculated for both working fluids and found that pore size is reduced when nanofluid is used as the working fluid.
6.2 Recommendations for future work

In the present study, the heat transfer characteristics of heat pipe using nanofluids with coated wick and coated wall are reported. The use of nanofluid as the working fluid in heat pipes finds a wide variety of applications appears promising. But the development of the heat pipe with nanofluid field is hindered by (i) the particle deposition in the wick region; (ii) poor characterization of suspensions; and (iii) lack of theoretical understanding of the mechanisms responsible for changes in properties. Therefore, more experimental studies related to the performance study of heat pipe with nanofluids are needed. Many issues, such as thermal conductivity, the Brownian motion of particles, particle migration, and thermophysical property change with temperature, must be carefully considered in heat pipes when nanofluids are used. The use of nanofluids in heat pipes has shown an enhancement in the performance characteristics and considerable reduction in thermal resistance. However, the particle aggregation and deposition in heat pipe are big challenges for the stable operation of heat pipe.

Further study is required in these areas to identify the reasons for deposition and the effects of particle deposition on the performance of heat pipe. From the present investigation, it is observed that the thin porous deposition present in the heat pipe influences the pool boiling heat transfer leading to the enhancement in the heat transfer characteristics of the heat pipe. Also a cost effective thin porous coating developed on the inner wall of thermosyphon is promising and enhances the heat transfer capability of the same. Finally, there appears to be hardly any research in heat pipes or thermosyphons with thin porous coating operated using refrigerant as the working fluid. Hence nanoparticles - refrigerant dispersions in heat transfer devices can be studied to explore the possibility of improving the heat transfer performance of the commercial devices.