Chapter 7: Conclusions and future scope

7.1 Conclusions

This thesis includes both numerical and experimental investigations to evaluate the thermo-hydraulic behavior and energetic and exergetic performances of VHHC SPNCL using water and oil and their mono and hybrid nanofluids. Firstly, the one-dimensional steady state and transient performances of VHHC SPNCL using water-based binary and ternary hybrid nanofluids and thermal oils are numerically investigated. The effect of tube diameter, loop height, loop aspect ratio (height to width), loop inclination, nanoparticle shapes, and power input on the energetic and exergetic performance of SPNCL are studied. Secondly, a detailed investigation of the effect of different assumptions related to Boussinesq approximation, property variation, bends effect, heat loss, axial fluid and wall conduction on the transient and steady-state characteristics is done for different working fluids (water, brines, and hybrid nanofluids). The effect of different heat flux distributions, like the uniform, linear, non-linear, sinusoidal, and Gaussian, applied to the heater is also explored. Lastly, an experimental investigation is performed to evaluate the transient and steady-state performance of SPNCL using Water, Therminol VP1 and Soyabean oil, and their based mono and binary hybrid nanofluids. The effect of power input, and loop inclination (Counter- clockwise and clockwise), and coolant inlet temperature on the performance parameters, i.e., mass flow rate, effectiveness of the heat exchanger, and total entropy generation rate, has been investigated. The important conclusions drawn from the obtained results for the present investigations are as follows:

- Energetic and exegetic performances of hybrid nanofluid are better (effectiveness increases and entropy generation decreases) than base fluid for SPNCL. However,

the mass flow rate can decrease or increase depending on the type and shape of nanoparticles.

- The time required to attain a steady state is reduced with hybrid nanofluids than with water. This is beneficial when the heat removal rate is a major concern. The flow stabilizes at an early instant for higher heating power and lower tube diameter and loop height.
- The mass flow rate increases with heating power, tube diameter and loop height. Whereas effectiveness and entropy generation increase with decreasing tube diameter and loop height. Entropy generation increases with heating power
- Increasing the loop aspect ratio decreases the steady-state effectiveness, total entropy generation rate and upsurges the mass flow rate at specified input power. The optimum value of the height to width ratio can be different for different types of fluids.
- Using Boussinesq approximation, the error in the performance parameter is higher for EG and PG brines, which restricts the implication of Boussinesq approximation for SPNCL with all the working fluids.
- Non-Boussinesq with temperature-dependent properties (considering conduction effect, bend effect, and heat loss) predicts the close agreement with the experimental result for both steady and transient behavior of SPNCL.
- Wall conduction has a significant effect while simulating the transient behavior of the SPNCL as it imparts a time delay for the initiation of transient flow conditions.
- The Gaussian heat flux distribution shows the highest mass flow rate at a given power input. The fluctuation in the mass flow rate and the time required to attain a steady-state is highest for non-linear decreasing heat flux.

- ❖ For higher temperature applications (above 100 ^{o}C), Therminol VP1 shows better performance than soyabean oil. Al_2O_3+CNT nanoparticle-based hybrid nanofluid shows the best performance among other hybrid nanofluids.
- ❖ Increasing coolant inlet temperature increases the mass flow rate and total entropy generation rate and decreases the effectiveness.
- ❖ The loop inclination decreases the mass flow rate, whereas it increases the effectiveness and total entropy generation rate. However, clockwise and counter-clockwise inclinations have a different effect on performance.

The study will be beneficial in the following ways:

- **a.** The modelling tool can be used for design and assessment of natural circulation look, using oil or water as heat transfer fluids. Moreover, such loops can be utilized for cooling of nuclear reactor core, electronic circuits, Automobile engine cooling. Also, the findings will be useful for operating an evacuated tube collector (ETC) in the natural circulation mode for solar thermal applications.
- **b.** The reported findings will enable addressing the issues related to the instability/stability of natural circulation loop, and to enhance the reliability of the loop. Thus, selecting an appropriate design and operating conditions for the desired temperature range. These are especially relevant for the cooling of nuclear reactor core.
- **c.** The investigations will enable selecting a suitable heat transfer fluid, including nano-oils, for enhancing heat dissipation from a source in the medium temperature range (30 ^{o}C – 250 ^{o}C).

7.2 Future scope

- ❖ For the medium temperature range of applications, more numerical and experimental investigations are needed to perform using other thermal oil like Dowtherm, Paratherm CR, and Vegetable oil, i.e., Sunflower oil, canola oil in SPNCL.

- A more experimental investigation is required for hybrid nanofluids (mono, binary and ternary), and to generate a generalized Nusselt and friction factor correlation for the SPNCL system, which can be employed in solving the 1-D SPNCL system.
- Investigation can be performed using some geometric modifications such as Variable area, Wavy surface, spiral tube, and noncircular cross-section tube.
- Economic analysis can be carried out by comparing SPNCLwith the force circulation for the same mass flow rate and also comparing base fluid with the nanofluids.