

CHAPTER 7

CONCLUDING REMARK AND FUTURE SCOPE

7.1 Conclusions

Experimental as well as numerical studies on the minichannel heat sink are conducted using water-based hybrid (both mixture and composite) nanofluids and ribbed channels. The effects of nanoparticle combination, nanoparticle concentration, fluid inlet temperature, heat flux, particle mixing ratio and channel aspect ratio on hydrothermal characteristics are experimentally investigated. The effect of rib topology in the channel is numerically investigated as well.

From present investigations, the main inferences can be summarized as:

- Al_2O_3 +carbon allotropes (MWCNT and graphene) mixture dispersed hybrid nanofluids are better in terms of heat transfer effectiveness as compared to other studied hybrid nanofluids.
- Oxide-nitride (Al_2O_3 +AlN) mixture dispersed hybrid nanofluid is overall best in minichannel heat sink within studied hybrid nanofluids in terms of hydrothermal performances (comparison factor, COP, FOM and PEC).
- From both economic and relative hydrothermal performances (comparison factor, COP, FOM and PEC) points of view, higher particle concentration is not preferable for minichannel heat sink.
- Different particle shape combinations (i.e., spherical-nanotube) show optimum particle ratio for best hydrothermal performance.
- Inlet temperature and heat flux have a positive effect on the heat transfer coefficient and Nusselt number and a negative effect on the pressure drop and friction factor.

- The comparison factor improves significantly with inlet temperature. However, the effect on FOM and PEC is insignificant.
- The heat transfer coefficient and pressure drop increase with a decrease in channel aspect ratio due to the increase in velocity for the low aspect ratio.
- The use of PCM is beneficial if there is phase change during the process (i.e., the melting point of PCM is between inlet and outlet temperature).
- Dispersion of Composite (rGO-ZnO) in base fluid yields maximum heat transfer coefficient and pressure drop for low aspect ratio. The heat transfer coefficient increases and pressure drop decreases with an increase in the heat flux.
- The multi-phase mixture model is better than the homogeneous model for hybrid nanofluids in minichannel heat sink.
- A combination of semi-circular rib and $\text{Al}_2\text{O}_3\text{-Cu}$ hybrid nanofluid yields maximum heat transfer coefficient and Nusselt number. However, ribs are not favorable in terms of the comparison factor.
- The semi-circular rib is most favorable in terms of hydrothermal performance as compared to other considered ribs in minichannel.

7.2 Future scope

- New base fluid should be considered other than water in future research, such as thermal oil, refrigerant, molten salt, etc.
- Some other challenges are involved as the selection of nanoparticles to create mixture-based and composite-based hybrid nanofluid and its complex operation; and lack of appropriate models for thermophysical properties of hybrid

nanofluids. Based on these challenges, many fields are waiting for future research work.

- More studies to be needed for various base fluid-based allotropes of carbon (CNTs and graphene) dispersed hybrid nanofluids.
- Stability is one of the significant factors that affect the exhibition of hybrid nanofluids. Long-term stability is required for the use of nanofluid in heat sink commercially and hence more researches are required.
- More application-oriented experimental studies are needed using both hybrid nanofluid and ribbed channels. Multi-parameters optimization may be required to get a cost-effective solution for the heat sink.

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