Chapter 12

Conclusion and Future Scope

12.1 Concluding Remarks

Owing to the practical applications (like biomedical imaging, targeted drug delivery, hyperthermia, biosensors, medical instruments, pharmaceuticals, bio-chromatography, theranostic, microchip pump, biomedical science, and cancer therapy), nine fluid flow problems (over a flat surface, cylinder and disk) are modelled and investigated in this thesis. The transport phenomena of Newtonian and non-Newtonian fluids (Carreau and Casson fluids) considering various effects like MHD, EMHD, radiation, multiple slip, stratification, geometric effects of nanoparticles, heat source, viscous dissipation, chemical reaction, Stefan blowing, convective heating and passive control of nanoparticles have been investigated. The salient features of the current theoretical/numerical exploration can be summarized as below:

- The augmenting volume fraction of single-wall carbon nanotube and magnetite nanoparticles raises the nanofluid temperature. Addition of gold-nanoparticles and an increase in the inter-particle spacing of gold-nanoparticles descends the velocity profile. However, a reverse trend is observed when the radius of gold-nanoparticles is augmented. The addition of gold-nanoparticles and an increase in the inter-particle spacing of gold-nanoparticles ascends the thermal field.
- Velocity and induced magnetic field profiles are least affected by spherical-shaped silver nanoparticles and highly affected by cylinder-shaped silver nanoparticles. Blade shaped silver nanoparticles contribute the most whereas cylinder-shaped silver nanoparticles contribute the least towards the

nanofluid temperature. Blade shaped silver nanoparticles offer an increased heat transfer rate over the other nanoparticle shapes and cylinder-shaped silver nanoparticles exhibit the highest mass transfer rate. A significant rise in the surface drag is brought out by the spherical-shaped silver nanoparticles followed by blade, platelet, and cylinder-shaped nanoparticles.

- Per unit increase in the electric-field parameter augments the drag coefficient and heat transfer rate by 21.28% and 8.49%, respectively. Per unit increase in the volume fraction of gold nanoparticles augments the heat transfer rate by 81.71% and reduces the surface drag by 163.51%. Per unit increase in the inter-particle spacing of gold nanoparticles augments the drag coefficient by 85.92%. Per unit increase in the radius of gold nanoparticles reduces the surface drag by 49.71%.
- The magnetic field parameter exhibits a negative impact on the velocity profile which helps in improving the biomedical imaging capabilities by manipulating the transference of nanomaterial to the preferred location. Descending electric field parameter retards the velocity profile, which helps in improving the efficiency of targeted drug delivery and biomedical imaging.
- Ascending Biot number intensifies the nanomaterial temperature that serves a crucial role in the termination of cancerous cells or tumors. An increase in the chemical reaction parameter consumes more nanoparticles and hence concentration decreases. Biologically, consumption of more nanoparticles is directly proportional to improved medication and biomedical imaging.
- Increasing Weissenberg number improves the velocity of dilatant fluids and reduces the velocity in the case of pseudo-plastic fluids. The nanofluid velocity is observed to descend with an increase in the Casson parameter.
- The thermal field of the nanomaterial when using the modified Buongiorno model is higher than when the traditional Buongiorno model is used. Further, the velocity field is lower in the case of the modified Buongiorno model than in the conventional Buongiorno model.
- Augmenting Stefan blowing parameter curtails the velocity and nanomaterial temperature profiles. The maximum drag coefficient is experienced for lower

values of the magnetic field parameter and Stefan blowing parameter. The heat transfer rate is an increasing function of the Stefan blowing parameter and Biot number. Further, the optimum level of heat transport is estimated to be 0.4304 which occurs when Stefan blowing and Biot number are maintained at the high levels and magnetic field is kept at the low level.

- The second-order hydrodynamic-slip parameter ascends the nanofluid velocity whereas the first-order hydrodynamic-slip parameter descends the velocity profile. Moreover, the drag coefficient is maximum for higher values of electric field parameter and lower values of magnetic field parameter.

- A decline in nanofluid temperature, microorganism concentration and nanofluid concentration profiles is observed due to ascending thermal, motile density and solutal stratification parameters, respectively.

- The maximum drag coefficient (when stretching parameter is less than 1) is experienced for higher values of the magnetic parameter and lower volume fraction of single-wall carbon nanotube and magnetite nanoparticles. However, the maximum drag coefficient (when stretching parameter is greater than 1) is experienced for lower values of the magnetic parameter and higher volume fraction of single-wall carbon nanotube and magnetite nanoparticles.

- Hartmann number and thermal slip parameter exhibit negative sensitivity towards heat transfer rate whereas radiation parameter showcase positive sensitivity towards heat transfer rate. The heat transport in the nanomaterial is more positively sensitive to thermal radiation and most negatively sensitive to the exponential heat source.

- It is noted that the curvature parameter is directly proportional to axial velocity. The magnetic field parameter has a destructive effect on the radial and azimuthal velocity profiles. Furthermore, increments in the velocity ratio parameter tend to escalate and curtail the radial velocity and the azimuthal velocity profiles, respectively.

12.2 Future Research Work

The use of mathematical modelling to elucidate the biological variations in body fluids due to the application of nanofluids is a growing field with lot of demand on the application scenario. There is a lot of work to be done in this area and the work presented in the thesis only considers a few of these application-oriented sense. It is only natural that this topic can be extended upon to incorporate diverse geometries and more advantageous effects. The use of ternary-hybrid nanofluids and various non-Newtonian (shear thinning) fluids will benefit the future explorations. Entropy generation of a modelled flow and the significance of nanoparticle density on the flow profiles can also be examined. Furthermore, the use of artificial neural networking to optimize the physical quantity of choice can also advance the present work.

List of Publications

1. Sujesh A.S., J. Mackolil, B. Mahanthesh, and Alphonsa Mathew; "Bulirsch-Stoer computations for bioconvective magnetized nanomaterial flow subjected to convective thermal heating and Stefan blowing: a revised Buongiorno model for theranostic applications", *Waves in Random and Complex Media* (Taylor & Francis), 2022. DOI: 10.1080/17455030.2022.2102692

2. Alphonsa Mathew, Sujesh A.S., and A.S. Sabu; "Significance of magnetic field and stratification effects on the bioconvective stagnation-point flow of ferro-nanofluid over a rotating stretchable disk: Four-factor response surface methodology", *Journal of the Indian Chemical Society* (Elsevier), 99(8), 100615, 2022. DOI: 10.1016/j.jics.2022.100615

3. Sujesh A.S., J. Mackolil, B. Mahanthesh, Alphonsa Mathew, and P. Rana; "A study on nanoliquid flow with irregular heat source and realistic boundary conditions: A modified Buongiorno model for biomedical applications", *ZAMM - Journal of Applied Mathematics and Mechanics / Zeitschrift für Angewandte Mathematik und Mechanik* (Wiley), 102(3), e202100167, 2022. DOI: 10.1002/zamm.202100167

4. Alphonsa Mathew, Sujesh A.S., and A.S. Sabu; "Sensitivity analysis on radiative heat transfer of hydromagnetic Carreau nanoliquid flow over an elongating cylinder using Bulirsch-Stoer algorithm", *Thermal Science and Engineering Progress* (Elsevier), 25, 101038, 2021. DOI: 10.1016/j.tsep.2021.101038

5. Sujesh A.S., A.S. Sabu, Alphonsa Mathew, and B. Saravanan; "Statistical analysis on the stratification effects of bioconvective EMHD nanofluid flow past a stretching sheet: Application in theranostics", *Heat Transfer* (Wiley), 50(7), 6680-6702, 2021. DOI: 10.1002/htj.22198

6. Alphonsa Mathew, Sujesh A.S., A.S. Sabu, and S. Saleem; "Significance of multiple slip and nanoparticle shape on stagnation point flow of silver-blood nanofluid in the presence of induced magnetic field", *Surfaces and Interfaces* (Elsevier), 25, 101267, 2021. DOI: 10.1016/j.surfin.2021.101267

7. Sujesh A.S., F. Mabood, A.S. Sabu, Alphonsa Mathew, and I.A. Badruddin; "Dynamics of water conveying single-wall carbon nanotubes and magnetite nanoparticles subject to induced magnetic field: A bioconvective model for theranostic applications", *International Communications in Heat and Mass Transfer* (Elsevier), 126, 105484, 2021. DOI: 10.1016/j.icheatmasstransfer.2021.105484

8. Sujesh A.S., A.S. Sabu, R. Kumar, and Alphonsa Mathew; "Triple stratification effects on bioconvective stagnation point flow pertaining carbon nanotubes due to induced magnetic field", *ZAMM - Journal of Applied Mathematics and Mechanics / Zeitschrift für Angewandte Mathematik und Mechanik* (Wiley), 101(11), e202000375, 2021. DOI: 10.1002/zamm.202000375

List of Presentations

1. Presented the paper entitled “Significance of ESHS and LHS on the MHD hybrid nanofluid flow towards a stagnation point on a stretching/shrinking cylinder" in the 2nd Online International Conference on Advances in Physical, Mathematical and Computational Sciences organized by the Faculty of Physical Sciences, St. Aloysius’ College (Autonomous), Jabalpur; during 23 - 24 July 2021.

2. Presented the paper entitled “Thermal Radiation and Chemical Reaction Effects on Three Dimensional MHD Hybrid Nanofluid Flow past a Stretching Sheet" in the 28th International Conference (Virtual) of Forum for Interdisciplinary Mathematics jointly organized by FIM, SSN & Stella Maris College, Chennai, during 23 - 27 November 2020.