A study of various geometric inclusions on Effective Thermal Conductivity estimation of Two-Phase Materials

ABSTRACT

The two-phase materials such as ceramics, porous materials, etc play a vital role in engineering applications. The prediction of the effective thermal conductivity of such two-phase materials is, therefore, essential. The two- phase materials comprise of natural and chemical structures and combined with the formation of continuous and which when dispersed phases supports their attributes. The geometry dependent resistance models are employed to approximate the effective thermal conductivity of two-phase materials. In this work, algebraic equations are derived based on isotherm approach for various asymmetric geometry such as triangle and pentagon models by contemplating the influence of basic parameters are concentration, conductivity ratio and contact resistance. For any range of a conductivity ratio, the Maxwell equation and Hashin-Shtrikman equation are considered for the concentration varying from 0 to 0.1 and 0.9 to 1, respectively and the proposed equation is valid for the concentration ranging from 0.11 to 0.89 for approximating the effective thermal conductivity of the two-phase materials. The proposed models and standard models are compared with experimental data for diverse kinds of two phase materials for validation. The developed models are in good agreement with investigational and traditional representations results. All the developed models are predicting ETC with the highest deviation of

±20% from the experimental data and conventional data for the broad array of two-phase systems. The present models can be broadly employed for predicting the ETC of two-phase materials with asymmetric configuration employed in the engineering applications.

To study the heat transfer characteristics a numerical model was built up to predict the effective thermal conductivity of two-phase materials for asymmetric geometry (triangle and pentagon cylinder) using the conductivity

ratio, concentration and contact ratio. The simulation entails a broad array of conductivity ratio and a broad spectrum of concentration. The precision of predicting the effective thermal conductivity employing the developed relation is extremely good and it is validated by comparing it with the experimental results. The correspondence would be of direct

employement in industrial applications of two-phase materials because of its straight-forward nature.

The model is tested at diverse conductivity ratios (5 to 1000) and diverse concentrations (0.1 up to 0.6) beyond that it is invalid. The effective thermal conductivity of the two-phase materials can be precisely calculated in the course of the array, employing the straight-forward relation.

Nano-fluids are becoming increasingly popular owing to their utility in the modern high performance systems. Nano-particles of size (<100nm) is dispersed into conventional two phase materials has proven considerable heat transfer enhancements. Hence studying the nano-fluids characteristic and their thermal behavior inside conventional with nano-fluids systems will be useful.

The build-up of Effective Thermal Conductivity (ETC) of two- phase materials with nano-fluids has an appropriate solution till date. Determination of the ETC with maximum accuracy and reliability poses considerable problem. A readily available solution is an analytical model. In this work, the analytical model has been developed to approximate the Effective Thermal Conductivity of two-phase materials with nano-fluid rooted in the unit cell method by considering the concentration, conductivity ratio and contact resistance. The prediction of algebraic equations for standard square geometry model was developed based on parallel isotherm approach. The conclusions based on the developed study are that the geometry dependent

analytical models based on unit cell approach are used for approximating the effective thermal conductivity of two-phase materials with nano-particles. The influences of concentration, conductivity and contact ratios on the effective thermal conductivity was examined.The inclusion of Al_2O_3 nano- particles in conventional two-phase system has shown an average of ±6.17% enhancement in the thermal conductivity value.The developed analytical models are also applied to two phase systems without considering the nano- particles and are compared with the conventional and experimental model. The results showed that the developed analytical models corresponding to various concentration [ν =0.05 to 0.67] and contract ratio [λ = 0.001 to 0.01] has an average deviation of ±7.40 from the experimental results for a broad variety of systems considered. This was done to verify the model. The thermal conductivity of the two-phase nano material, Al_2O_3(nano)/EG/Water with a known experimental value for various concentrations [ν = 0.005 to 0.01] are compared with the values of our developed model and ±11.10% was the obtained average deviation.