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Numerical Investigation of Heat Transfer in Car Radiation System Using Improved Coolant

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ABSTRACT

In this study, numerical analysis of heat transfer in the radiation system of the car has been investigated by using pure water and water with nanofluid. ANSYS fluent version 16.1 has been conducted to carry out the simulation process using Computational Fluid Dynamic (FCD) approach. This study has been validated with experimental results and based on the simulation results the error was 8% when applying the same boundary condition. And the validation process was carried out for the flow rate with Nusselt number in both concertation 0.7 % and 1 %. Based on numerical analysis, the Nusselt number has been increased by increasing nano particle concertation. Increased number of Nusselt causes the enactment of the heat exchanger. The previous experimental data show that the heat transfer of the nanofluids was based highly on the concentration of nano particles, the flux conditions and the weak temperature-dependent heat transfer conditions.

1. Introduction

In recent years, intensive research has been underway on nanofluids (metal or metal oxide parts usually smaller than 100 nm suspended within a base fluid) and their role in the heat transfer. As a vehicle engine coolant, one major use for nanofluids [1]. The very high surface area of nanoparticles increases thermal conductivity, even at low concentrations. The significant increase in nanofluid thermal properties has attracted scientific interest in recent years. For fluids with suspended nanoparticles [2] first used the word "nanofluid"; these kinds of fluids have been studied by various experiments in different fields. In car radiators, liquid-cooled computers and cold-water air conditioners, the main use of EG is as a tool for convective heat transfer. The combined water and EG were employed because water is a much more safe engine coolant [3]. The problem with water is that it freezes or boils at high temperatures. Anti-freezing agents like EG can tolerate significantly higher temperature extremes, so that we can make a concession with water [4]. Some of the water's

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strong freezing properties are preserved, but the anti-freeze benefits from the ability to survive high temperatures.

Leong *et al.,* [5] has performed a 2D numerical study in horizontal counterpower dual pipe thermal exchange of single-phase forced convective heat transfer for Al_2O_3 and TiO_2 nanofluids. They have reported that by adding nanoparticles to the base fluid, heat transfer improved. Goudarzi and Jamali [6] had hypothesized the continuous heating flow in the laminar tube wall of nanofluid heat transfer modeling CFD within tubes with circular cross sections, in a fully formed environment. Nanoparticles with medium diameters between 45 and 150 nm at concentrations of 1 percent, 2 percent and 4 percent were used in the single-phase simulation. The results showed differences of up to 10 percent in the experimental data; it was observed that heat transfer increased as the nanoparticles concentration increased.

In several experiments at the Royal Institute of Science, School of Technology and Health (KTHSTH) in Stockholm, heat output from radiators and vertical plates with natural or induced convection has been analytically measured and investigated by CFD simulations. The primary aim was to discover ways of increasing the thermal performance of radiators [7]. It has been found that Sharaf *et al.,* can improve thermal efficiency by enlarging or changing existing radiators or adding convection fins. However, the downside of such improvements has also been higher manufacturing costs. Therefore, emphasis was centered on ways to improve heat production that could be simpler and less effective, such as steering breathing air to heated radiator surfaces or pushing air between radiator panels.

The effect of convective thermal transfer of nanofluids under laminar and turbulent flow regimes was researched experimentally [8]. They used a straight circular cross section for the laminar and turbulent flow regimes of a tube with a constant walled heat flow. Subhedar *et al.,* [9] investigated the results of thermo-physical properties of the models for predicting convective heat transfer coefficients of nanofluids at low concentrations.

They found that the validity and accuracy of the experimental convective heat transfer coefficient at low nanoparticle concentrations of the base fluid relies more on the empirical calibration of the system than on nanofluid thermo-physical versions. The increase in the thermal transfer of nanofluids is based on the turbulent flow of water in a car radiator. Sharaf *et al.,* [10, 11] reported heat transfer and hydraulics under constant wall temperature conditions in a horizontal tunnel for SiO_2 nanoparticles. Measurements were taken at 20, 50 and 70 C and 200 x e10^3 Reynolds numbers. The study has demonstrated an increase in the convective heat transfer of nanofluids over pure water. This paper conducted a numerical analysis using water-based nano fluid for the automotive radiator. Ansys was used to sample the heat transfer process fluently with CFD.

2. Materials and Methods

2.1 Mechanical Properties of Nanofluid and Materials

In order to carry out simulation process, physical properties of fluid are required to perform the boundary condition of the previous work. Table 1 show the required information. Nanofluid grain size is 20nm.

Table 1
Physical properties of the employed fluid

ρ (kg/m^3)	μ (kg/m.s)	k (W/m °C)	Cp (J/kg.°C)	α (m^2 /s)
992	0.00065	0.633	4174	1.5×10^{-7}

2.2 Primary Boundary Conditions

A flow loop was included for the simulation of liquid-side heat transfer conduct in the car radiator. A centrifuge pump with a constant flow rate of 10 Liter per minute is used to flow the test fluid from the feed to the radiator from the five-layer tube (0.75 inch in diameter) [12]. The air flow rate was 0.1l per minute with an accuracy of between 45 ° C and 50 C. All these parameters were converted into data and fluently incorporated into the ANSYS for the validation processes to be set.

2.3 Meshing and Geometry

In this analysis, the geometry of the project was created by AUTOCA software. The mesh was created using mechanical ANSYS. In the complex meshed model, tri type pave mesh was used and quad type was used in the remaining meshed model [13]. ANSYS has a completed mesh as seen in Figure 1. The schematic diagram below depicts a rectangular tube with a height of 31 cm and a width of 2 cm and a thickness of 0.3 cm.

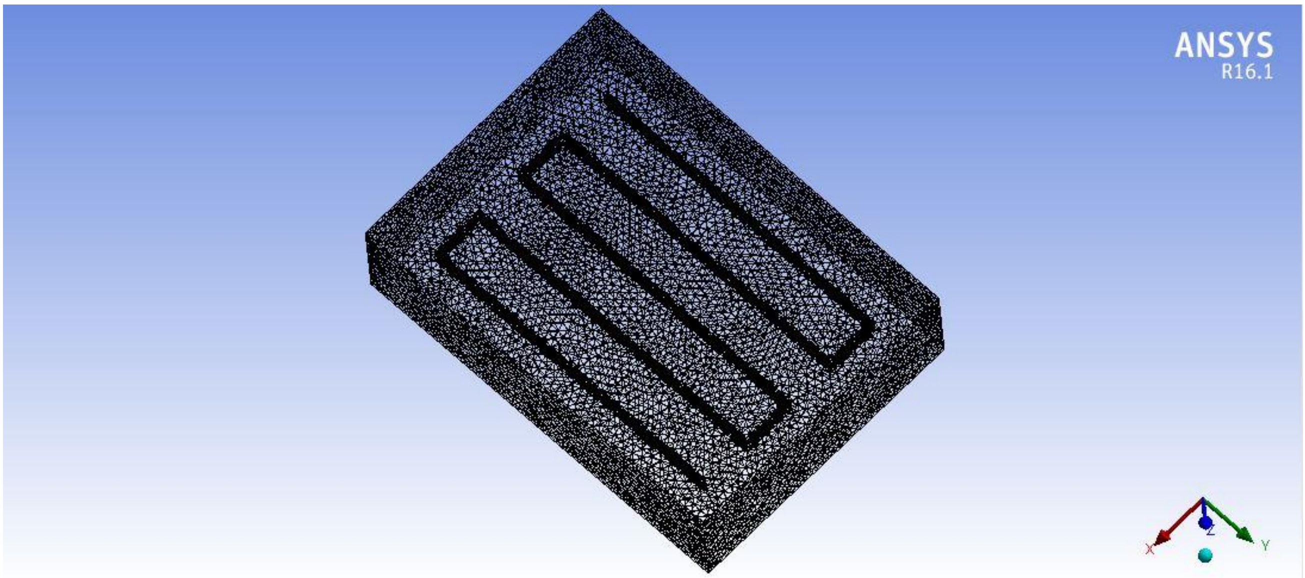

Fig. 1. The meshed model of the car radiator

3. Results and Discussion

3.1 Grid Independent Test

In the RE=15000 study, mesh was considered to be set with a T=45 C. It is shown that, depending on the results, the Nu is equal to the number of faces, and when the number of faces was 150,000, the Nu was 90. Moreover, as the number of faces increases to 160000 and up, there is no change in Nu. 160000 faces were thus programmed to conduct the simulation process as shown in Figure 2.

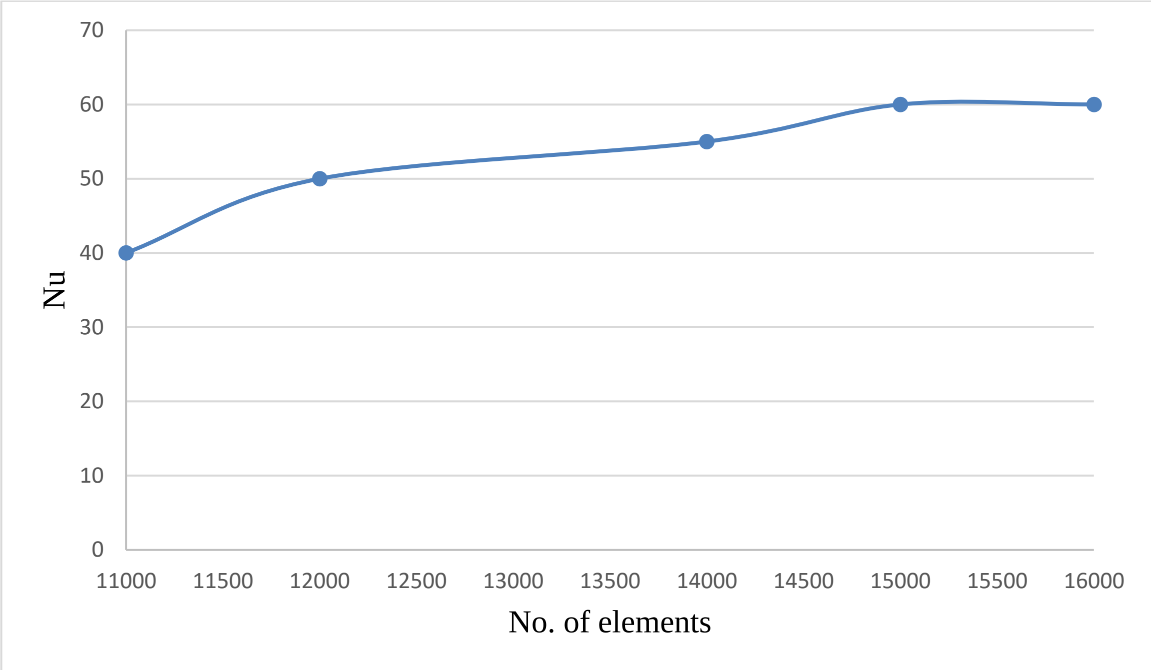

Fig. 2. Grid independent test of the current geometry

3.2 Validation

Code validation is one of the important steps taken in numerical studies to ensure that the numerical codes are accurate as in other previous studies. The code validation process also helps to test the code for running. The code validation process used in [14] was used for code validation purposes in this report. In the application of the car radiator, this group of researchers numerically investigated the effect of nano particles in the implementation of heat transfer. The findings of the comparison carried out in this study between the results of the current study and those [15, 16] have been contrasted with the experimental similarity of the numerical evidence collected in the present investigation [17].

Figure 3(a) and 3(b) compare the experimental results with the prediction of the number of nanofluids in Nusselt. The relation between the flow rate and the Nusselt number at temperature 45 °C at 1% nano particle concentration is seen in Figure 1. While the relation between the flow rate and the Nusselt number at temperature 45 °C is seen in Figure 2 at 0.7 percent nano particle concertation. In these two numbers, strong consensus can be seen [18, 19]. The computation of the absolute average error shows 7 percent to be the water-based nanofluid prediction error.

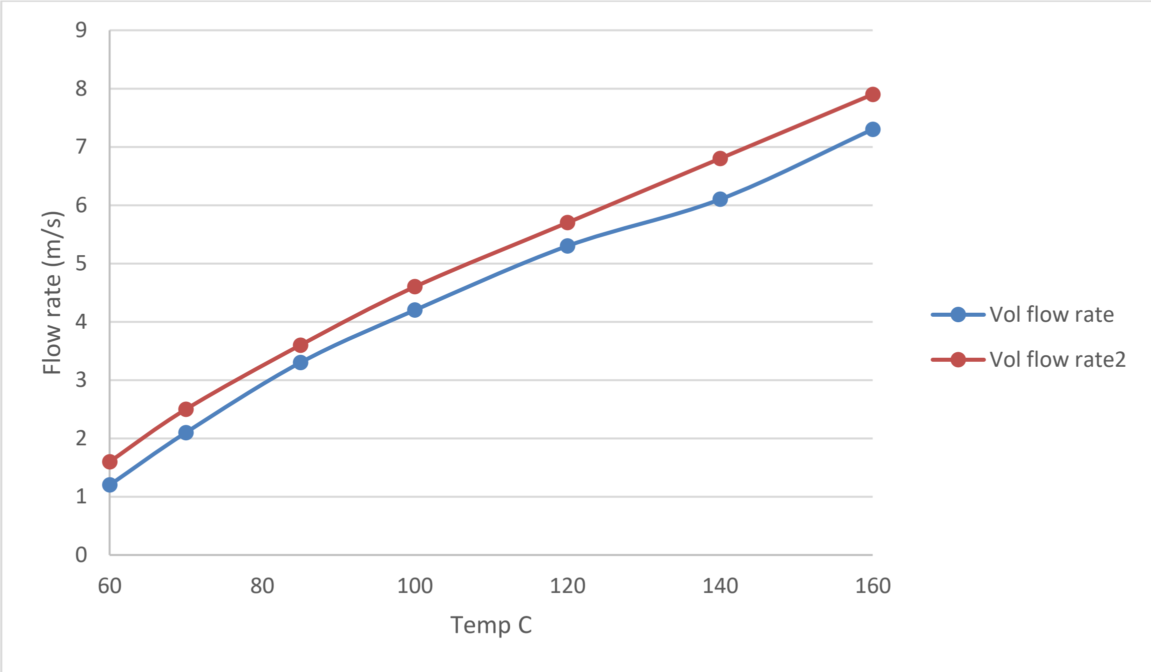

Fig. 3(a). Validation of the temperature with flow at concertation 1%

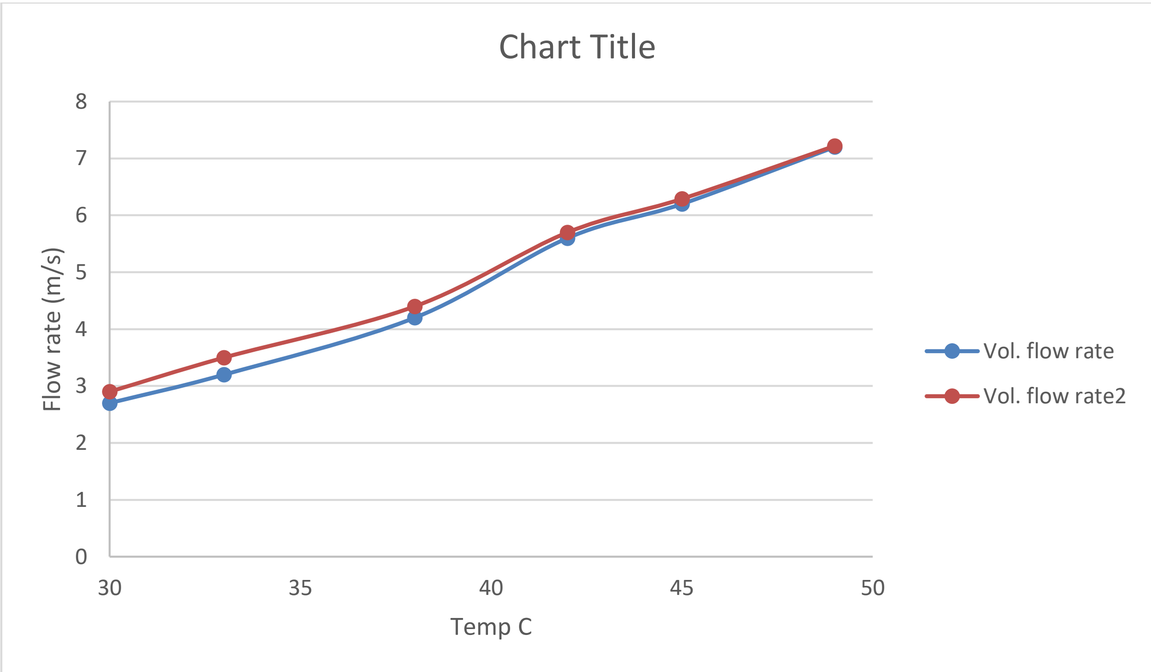

Fig. 3(b). validation of the temperature with flow Concertation 0.7

3.3 Heat Transfer to Pure Water

A number of studies with purity of water and pure EG were performed before the tests on nanofluids as a coolant for the car radiator, in order to verify the efficiency and accuracy of the experimental system. Figure 4 and 5 illustrates the experimental effects of water flow at a steady inlet temperature of 50 ° C through the radiator. The higher Reynolds number is shown to increase pure water's heat transfer coefficient. The experimental data are contrasted with the following empirical association proposed in turbulent flow.

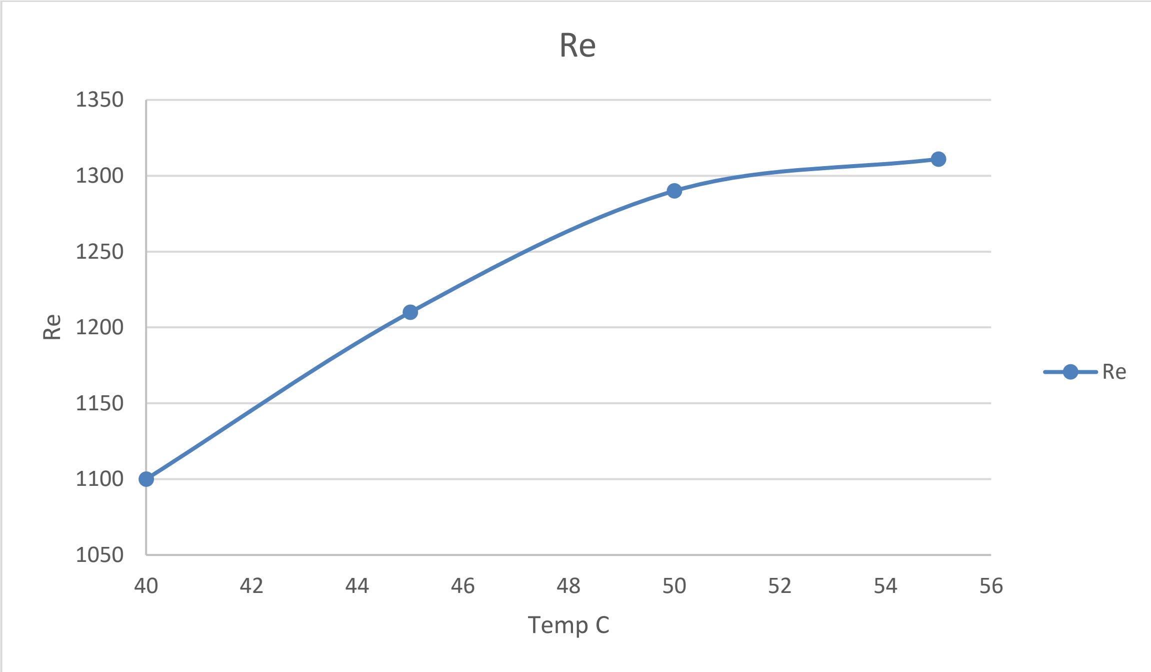

Fig. 4. Temperature with Reynolds number

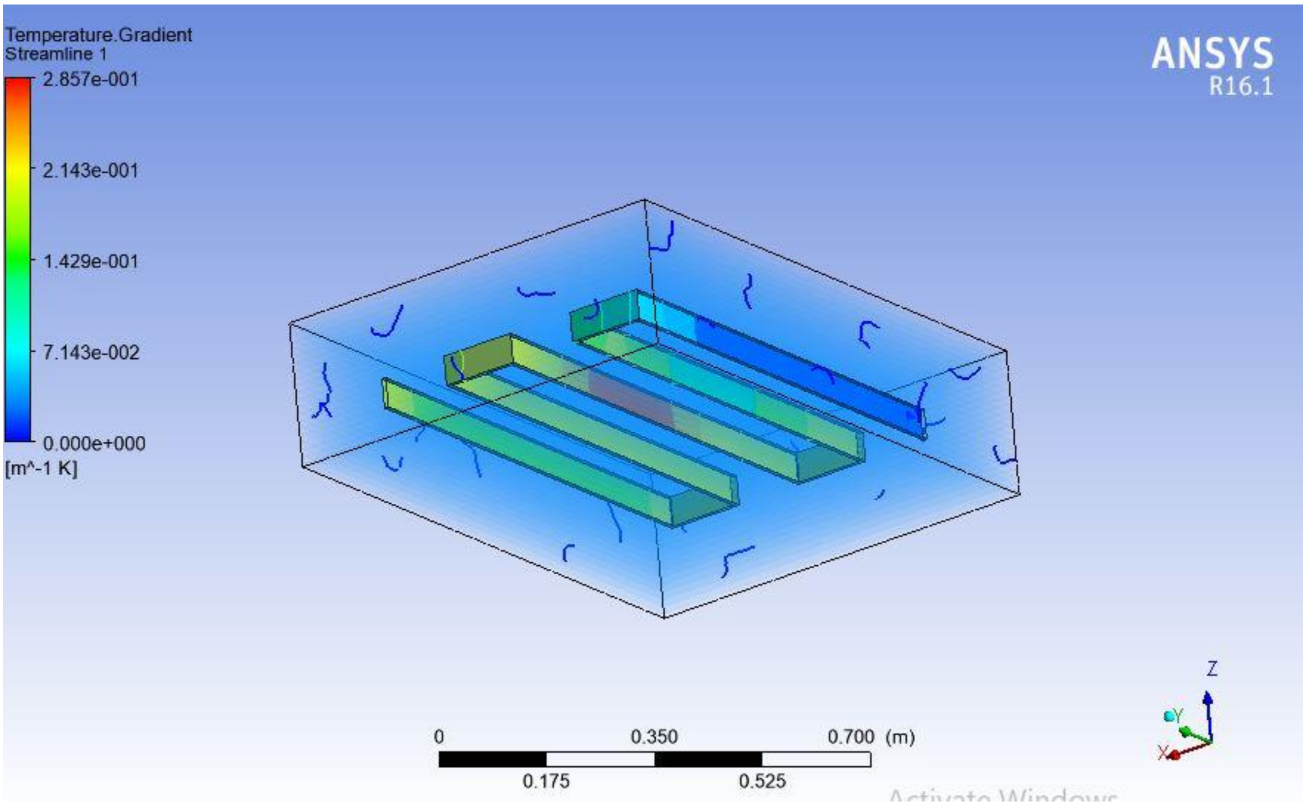

Fig. 5. Simulation heat transfer at 70 c between environment and radiator

3.4 Water-Based Heat Transfer Nanofluids

Nanofluid is added at different Al_2O_3 levels, i.e., 0.1, 0.3, 0.5, 0.7, and 1 vol. Percent and at set temperature. In order to understand the impact of the temperature on the thermal efficiency of the radiator, various inlet temperatures for each concentration have been added. Temperatures include 70 for water-based nanofluids and 70 °C for EG-based nanofluids. Figure 6 demonstrate the improvement of heat transfer as the traditional coolant by water- and EG-dependent nanofluids due to substitution of water. Through raising the nano fluid concertation to 1 vol. percent of the water's Al2O3 nanoparticle. The number of the Nusselt is increased. The mean number of Nusselt at 70 °C with a 1 percent maximum concentration is 65 and the minimum number of Nusselt at a minimum nano fluid concentration is 65.

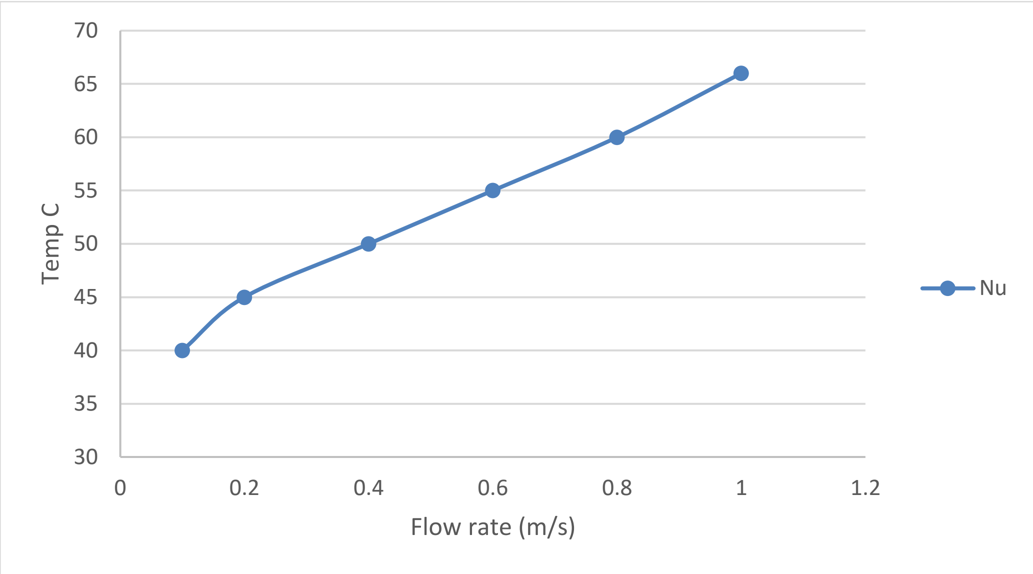

Fig. 6. Flow rate with temperature at Nu 65

This process leads to small quantities of Al2O3 nanoparticles that are being added to the basis liquid, an improvement in density and thermal conductivity, while on the other hand, Viscosity increases more dramatically than the base fluid as shown in Figure 7.

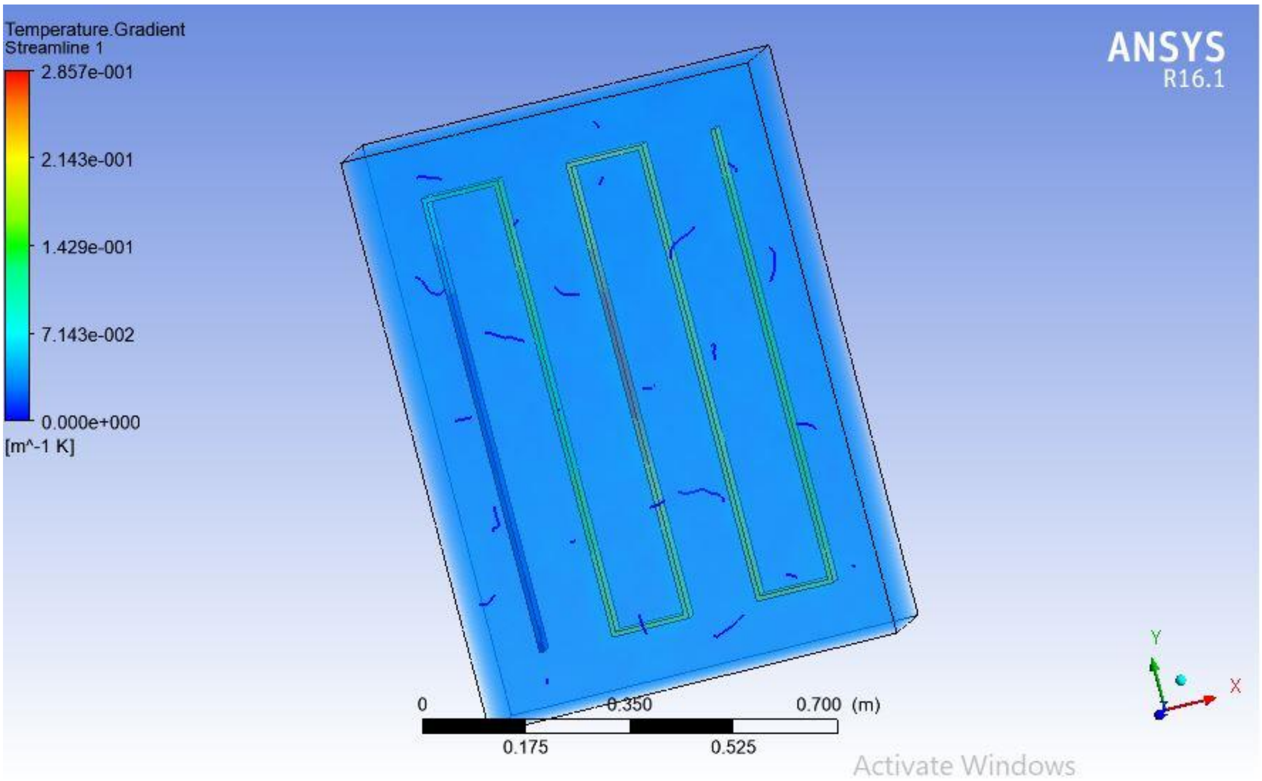

Fig. 7. Simulation of heat transfer at Nu 65

The combination of water in different quantities depending on the geographical weather is a traditional fluid commonly used in the car radiator. Based on the outcomes, there are three separate amounts of 5, 10 and 20 volts of water / EC binary mixtures. Where the results have shown that the percentage EG was prepared as basic fluids to provide additional guidance on the impact of the addition of nanoparticles to the radiator coolant as shown in Figure 8.

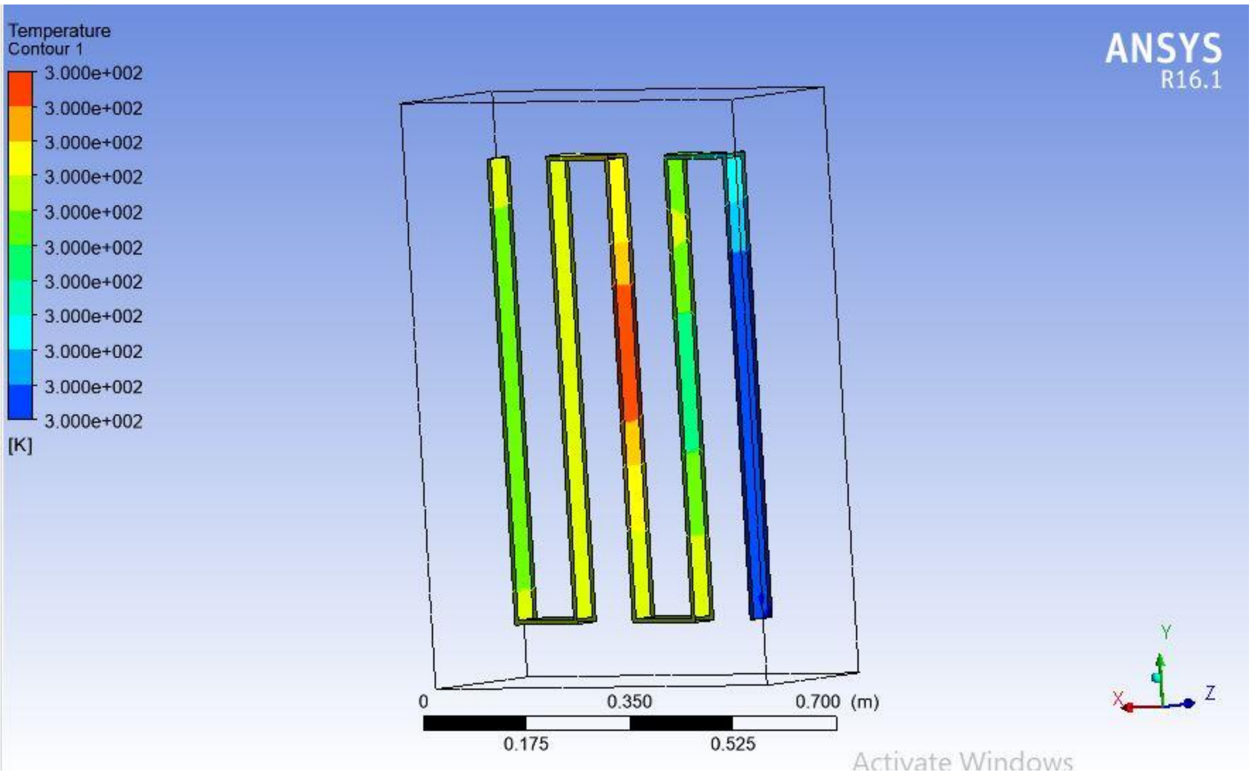

Fig. 8. Simulation of heat transfer at 20 vol.% EG

4. Conclusion

Using nanofluid, heat transfer in the car radiator was numerically observed. In order to simulate heat transfer across water and water-based nano particles and the medium, ANSYSY fluent was used. This analysis has been confirmed with experimental findings and, when adding the same boundary condition, the error was 8 percent dependent on the simulation results. The sum of Nusselt was increased by increasing the concertation of the nano particles dependent on the results of numerical analysis. The increase in the Nusselt number leads to the heat exchanger 's enactment. Previous experimental data have shown that the heat transfer of nanofluids depends heavily on the concentration and flow conditions and is weakly temperature dependent, thus calculating the flow and concentration of nano particles for thermal transfer conduct in the present study.

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