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Study of Force Convection Nanofluid Heat Transfer in The Automotive Cooling System

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Abstract **- The results revealed that the nano fluid (Ag/HEG) with highest concentration of volume 4% has the highest friction factor at all Reynolds numbers. This solution provides promising ways for engineers to develop highly compact heat exchangers and automobile radiators. When adding nano particles to the base fluid, such as water, the potential enhancement of car engine cooling rates could entail more engine heat being removed or a reduction in size of the cooling system. Smaller cooling systems would lead to smaller and lighter radiators, which would benefit almost every aspect of car performance and increase fuel economy.**

Keywords**- Nano fluid, Friction factor, heat transfer, Reynolds numbers.**

I. INTRODUCTION

Nano technology is a revolutionary concept introduced in 21st century that has a potential to improve the characteristics of a material in many fields. Nano sized material have an emerged as a new additive alternate in coolants. A recent advancement in nanotechnology has been the introduction of nanofluids. Nanofluids are colloidal mixtures of nano metric metallic or ceramic particles in a base fluid, such as water, ethylene glycol or oil.

In nanotechnology, a particle is defined as a small object that behaves as a whole unit in terms of its transport and properties. On the other hand, ultrafine particles are sized between 1 and 100 nanometers. Nano particles may or may not exhibit size-related properties that differ significantly from those observed in fine particles or bulk materials. Although the size of most molecules would fit into the above outline, individual molecules are usually not referred to as nano particles. Nano particle research is currently an area of intense scientific interest due to a wide variety of potential applications in mechanical, biomedical, optical and electronic fields.

II. METHODOLOGY

Physical Model

Fig.1 shows the automobile radiator used in this study, which consists of a flat tube with a length (L=500 mm) and hydraulic diameter (Dh = 4.5 mm). The Reynolds number was calculated based on the hydraulic diameter (Dh):

$$D_h = \frac{4 \times Area}{Perimeter}$$

$$D_h = \frac{4 \times [\frac{\pi}{4}d^2 + (D - d) \times d]}{\pi \times d + 2 \times (D - d)}$$

Reynolds number (Re) is determined as:

$$Re_D = \frac{\rho \times D_h \times u}{\mu}$$

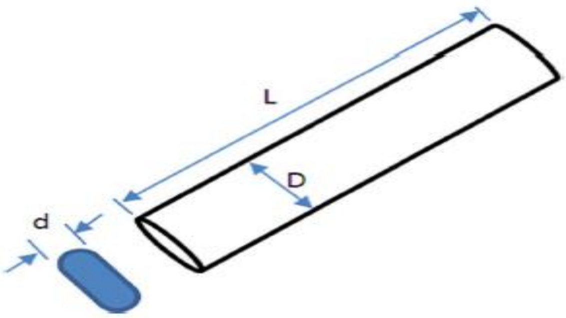

Fig.1. Flat tube of radiator [Hussein et. al. (2017)].

Assumptions Assumed In Study

Several assumptions were made on the operating conditions of the automotive cooling system, [13, 14]:
Steady-state, incompressible and Newtonian turbulent fluid flows with constant thermophysical properties of the nanofluid assumed.
Additionally, heat conduction in the axial direction and wall thickness of the tubes was neglected.

Governing Equations

Using infinitesimal (less than 100 nm) solid particles, the single-phase approach can be used, and thus, the single-

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phase approach was adopted for nanofluid modelling. The thermal properties of the nanofluid can be estimated by the equations below:

$$\rho_{nf} = \left(\frac{\phi}{100}\right)\rho_p + \left(1 - \frac{\phi}{100}\right)\rho_f$$

$$C_{nf} = \frac{\frac{\phi}{100}(\rho C)_p + (1 - \frac{\phi}{100})(\rho C)_f}{\rho_{nf}}$$

$$k_{nf} = (1 + 3\Phi)k_f$$

$$\mu_{nf} = (1 + 2.5\Phi)\mu_f$$

where ρ, C, k and μ are the density, specific heat capacity, thermal conductivity and viscosity, respectively, and the subscripts, nf, f,and p, represent the nanofluid, fluid and solid properties, respectively. For all assumptions, the dimensional governing equations at steady state are the continuity, momentum and energy equations [16]:

$$\nabla \cdot V = 0$$

$$V_x\frac{\partial V_z}{\partial x} + V_y\frac{\partial V_z}{\partial y} + V_z\frac{\partial V_z}{\partial z} = -\frac{1}{\rho}\frac{\partial P}{\partial z} + \upsilon\frac{\partial^2 V_z}{\partial z^2} + g_z$$

$$V_x\frac{\partial T}{\partial x} + V_y\frac{\partial T}{\partial y} + V_z\frac{\partial T}{\partial z} = \alpha\frac{\partial^2 T}{\partial z^2}$$

III. RESULT

1.Effect of Nano Fluid Concentration

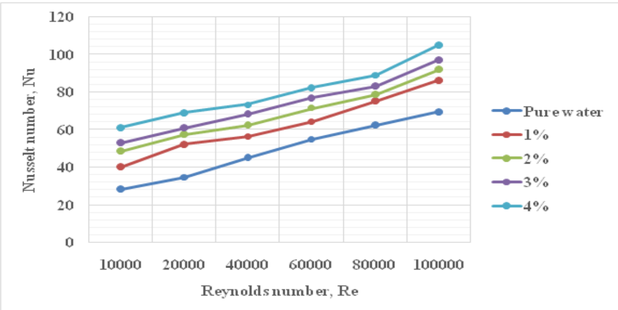

Fig.2. Nusselt number at different nano concentration for TiO2.

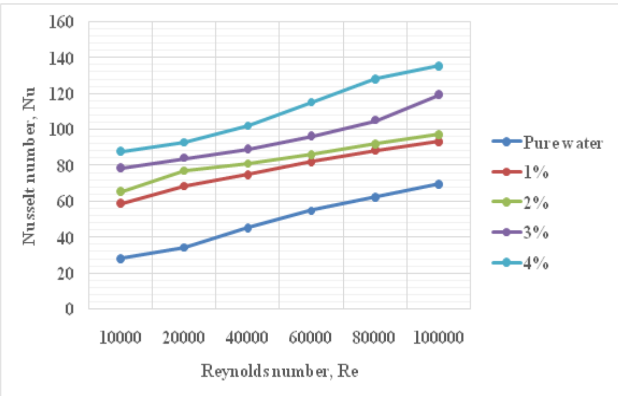

Fig.3. Nusselt number at different nano concentration for Ag/HEG.

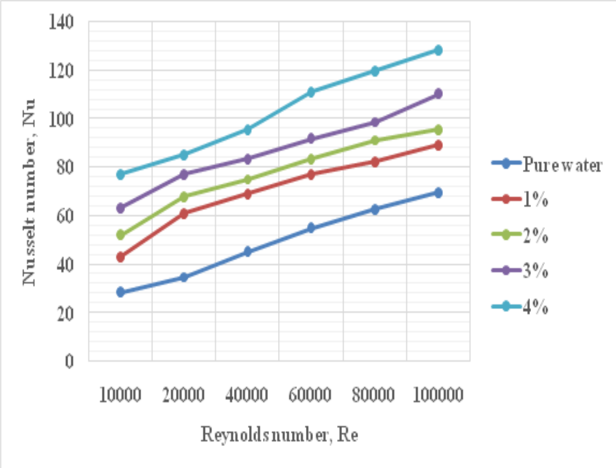

Fig.4.Nusselt number at different nano concentration for SiO2.

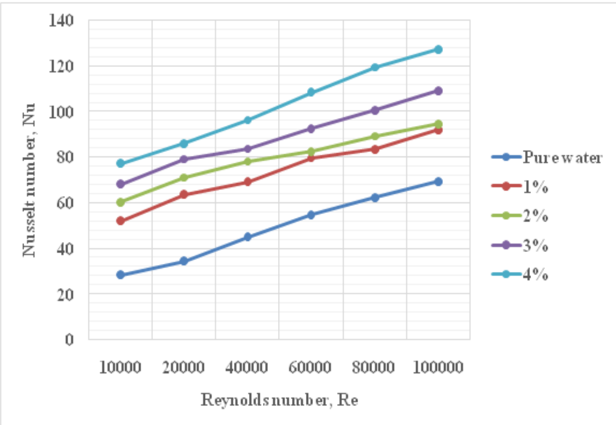

Fig.5. Nusselt number at different nano concentration for Al2O3.

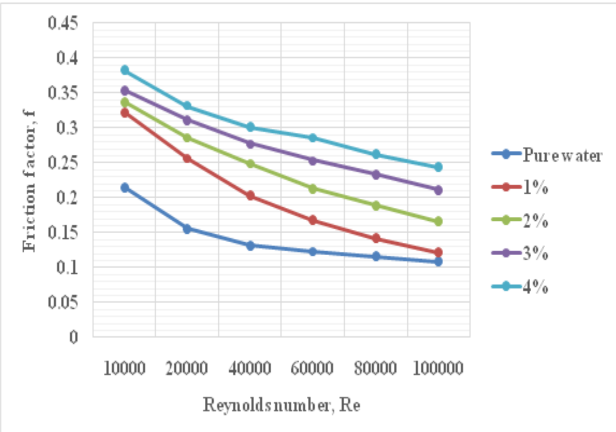

Fig.6. Variation of friction factor at different nano concentration for TiO2.

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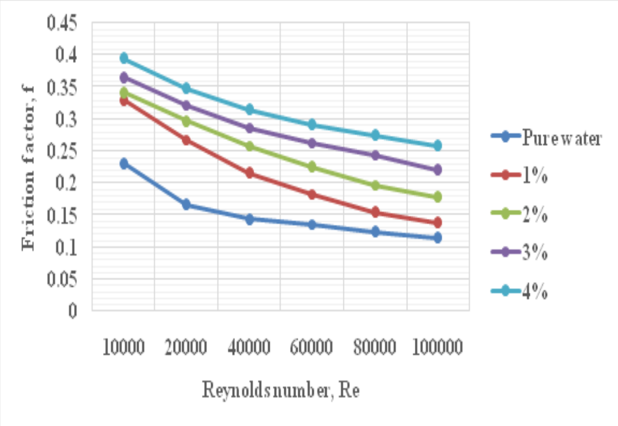

Fig.7. Variation of friction factor at different nano concentration for Ag/HEG.

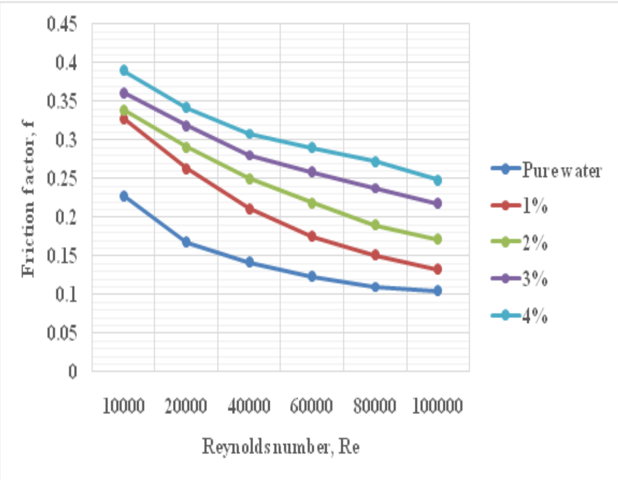

Fig.8. Variation of friction factor at different nano concentration for SiO2.

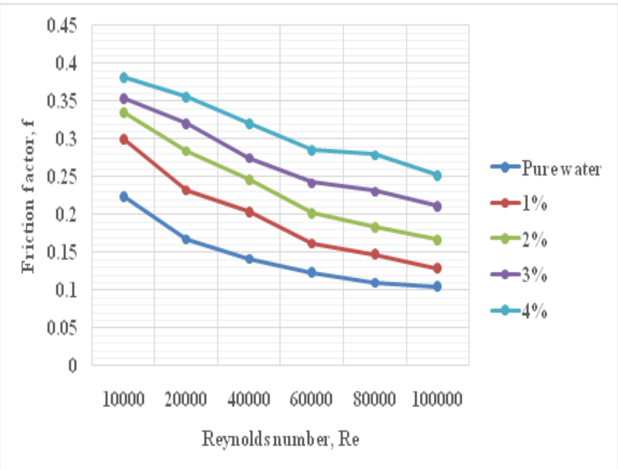

Fig.9. Variation of friction factor at different nano concentration for Al2O3.

Effect of the Wall Temperature

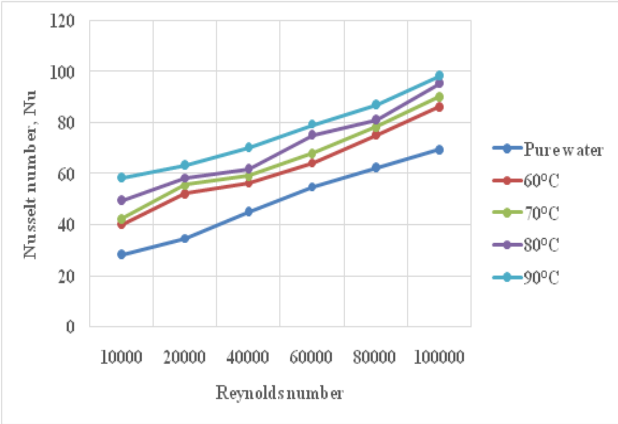

Fig.10. Variation of Nusselt number at different wall temperature for TiO2.

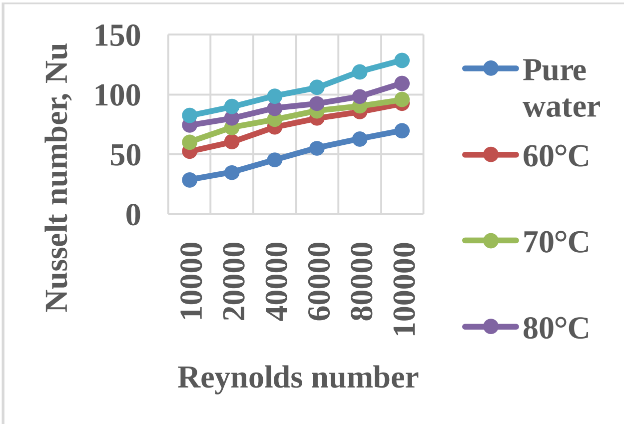

Fig.11. Variation of Nusselt number at different wall temperature for Ag/HEG.

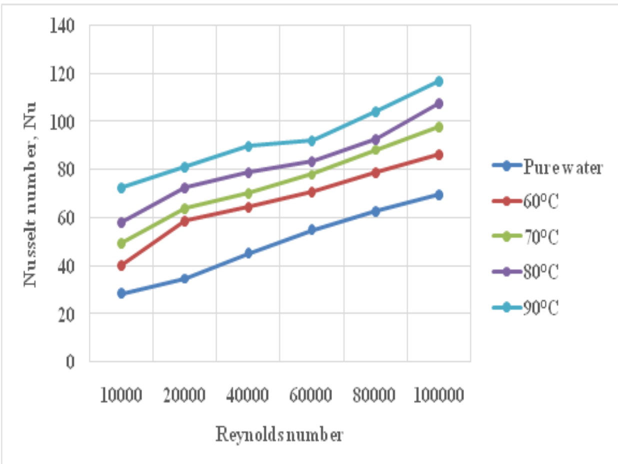

Fig.12. Variation of Nusselt number at different wall temperature for SiO2.

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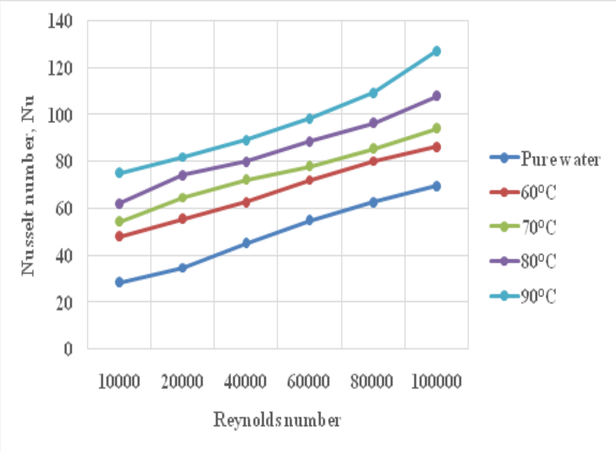

Fig.13. Variation of Nusselt number at different wall temperature for Al_2O_3.

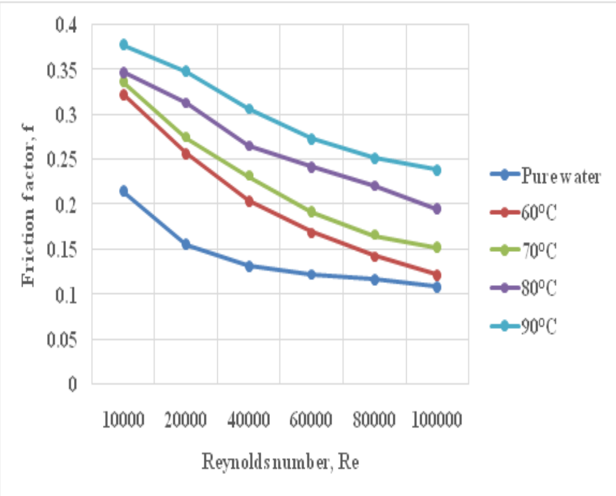

Fig.14. Variation of friction factor at different wall temperature for TiO_2.

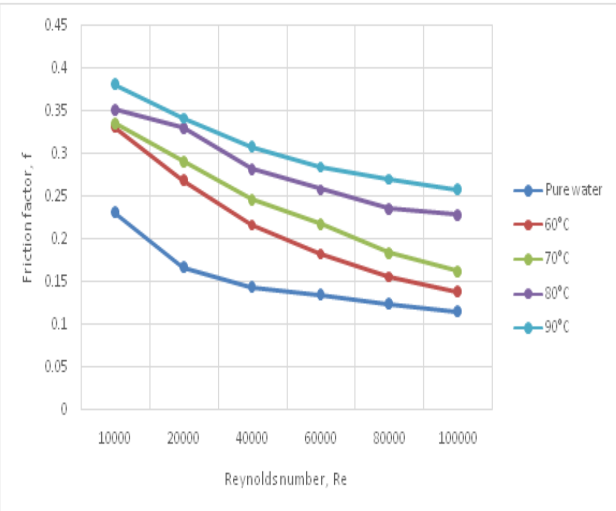

Fig.15. Friction factor at different wall temperature for Ag/HEG.

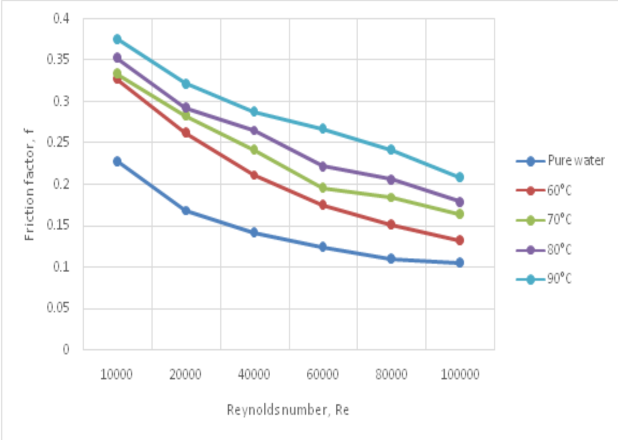

Fig.16. Variation of friction factor at different wall temperature for SiO_2.

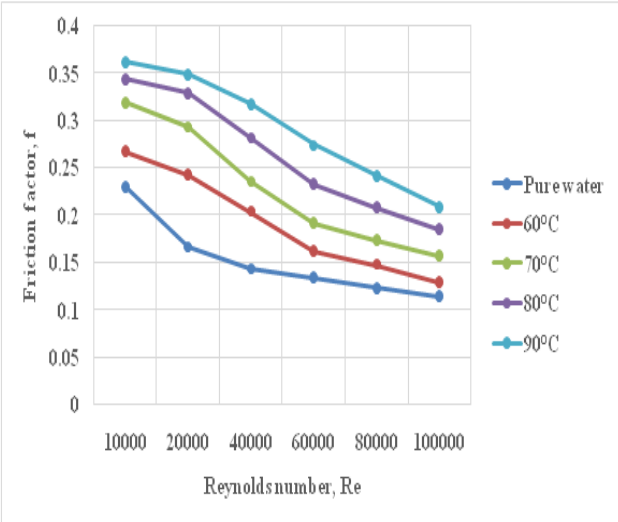

Fig.17. Variation of friction factor at different wall temperature for Al_2O_3.

IV. CONCLUSION

The following conclusion can be drawn from following studies:

1. The friction factor and forced convection heat transfer enhancement of different nanoparticles suspended in water were determined.
2. Significant increases in friction factor and heat transfer enhancement were observed when nanoparticles at different volume concentrations were added to the base fluid.
3. The simulation results showed that the friction factor and Nusselt number behaviour of the nanofluids were highly dependent on the volume concentration, inlet temperature and Reynolds number.
4. The results revealed that the nanofluid (Ag/HEG) with highest concentration of volume 4% has the highest friction factor at all Reynolds numbers.

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5. This solution provides promising ways for engineers to develop highly compact heat exchangers and automobile radiators. When adding nanoparticles to the base fluid, such as water, the potential enhancement of car engine cooling rates could entail more engine heat being removed or a reduction in size of the cooling system.
6. Smaller cooling systems would lead to smaller and lighter radiators, which would benefit almost every aspect of car performance and increase fuel economy.

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