20th Science Council of Asia Conference

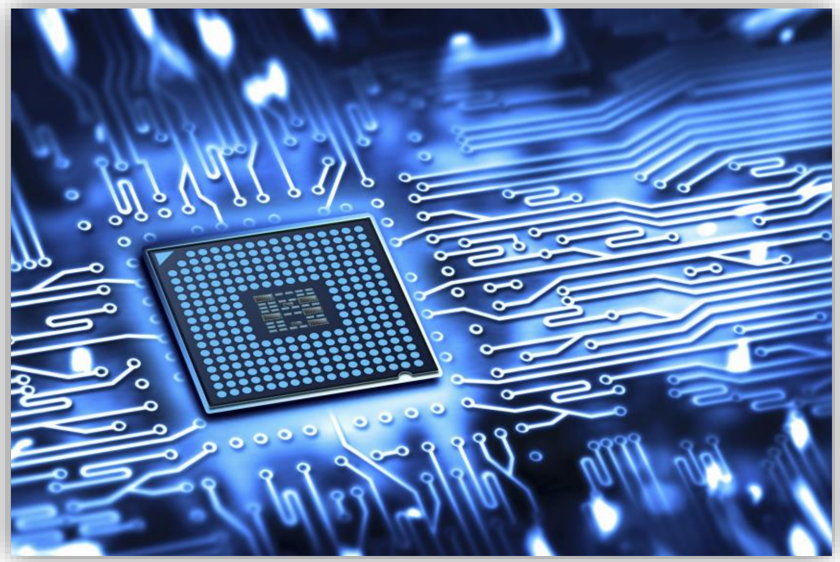
New Frontiers for Materials Design (14 May 2021)

Heat Transfer Performance of Hybrid Nanofluid by Varying Mixing Ratio

Hong Wei Xian[1], Nor Azwadi Che Sidik[1]

[1] Malaysia – Japan International Institute of Technology (MJIIT),
Universiti Teknologi Malaysia Kuala Lumpur,
Jalan Sultan Yahya Petra (Jalan Semarak), 54100 Kuala Lumpur, Malaysia.

Background



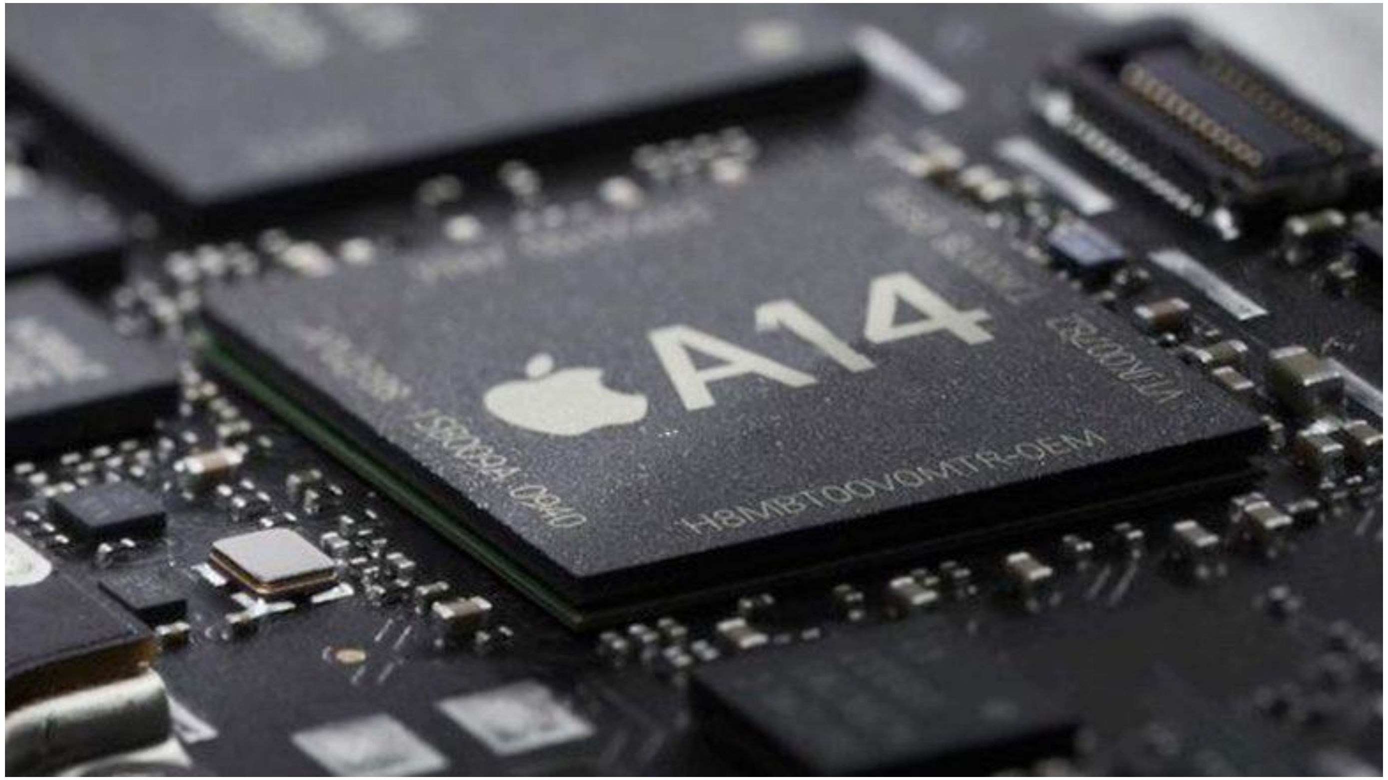
Nanotechnology

- Biomedical
- Energy storage
- Photovoltaic
- Electronics
- Molecular science

1. Active method
2. Passive method

Passive method

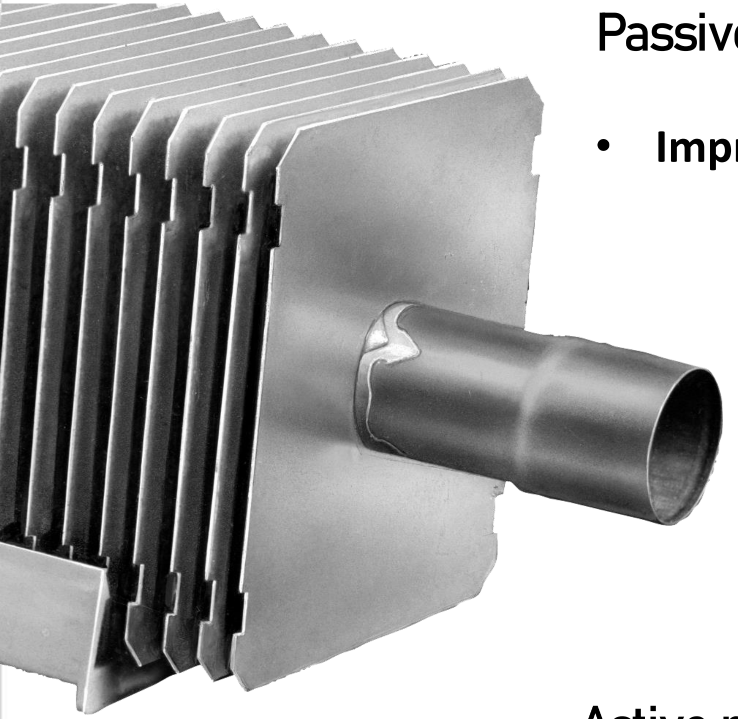
7 nm → 5 nm



Area reduction of 45%

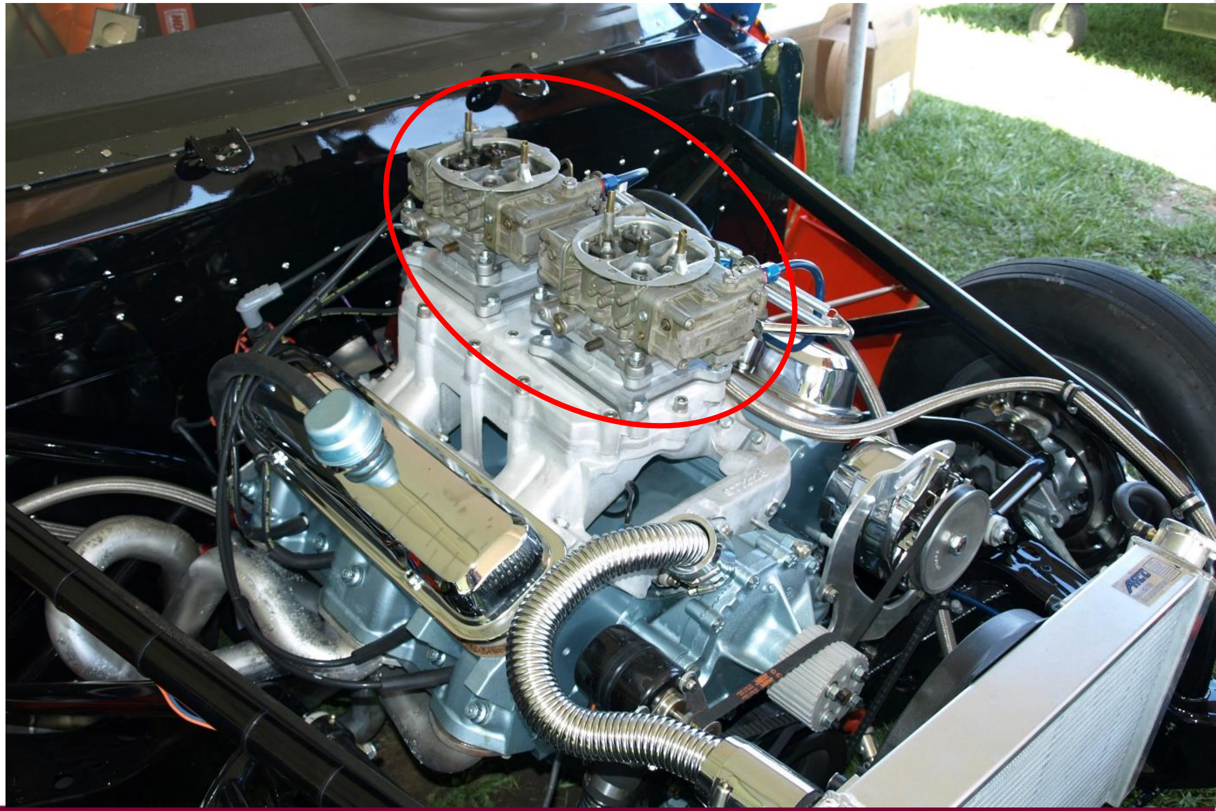
↓

8.5 billion to 11.8 billion transistors



Passive method

- **Improve radiator body (material and fin configuration)**

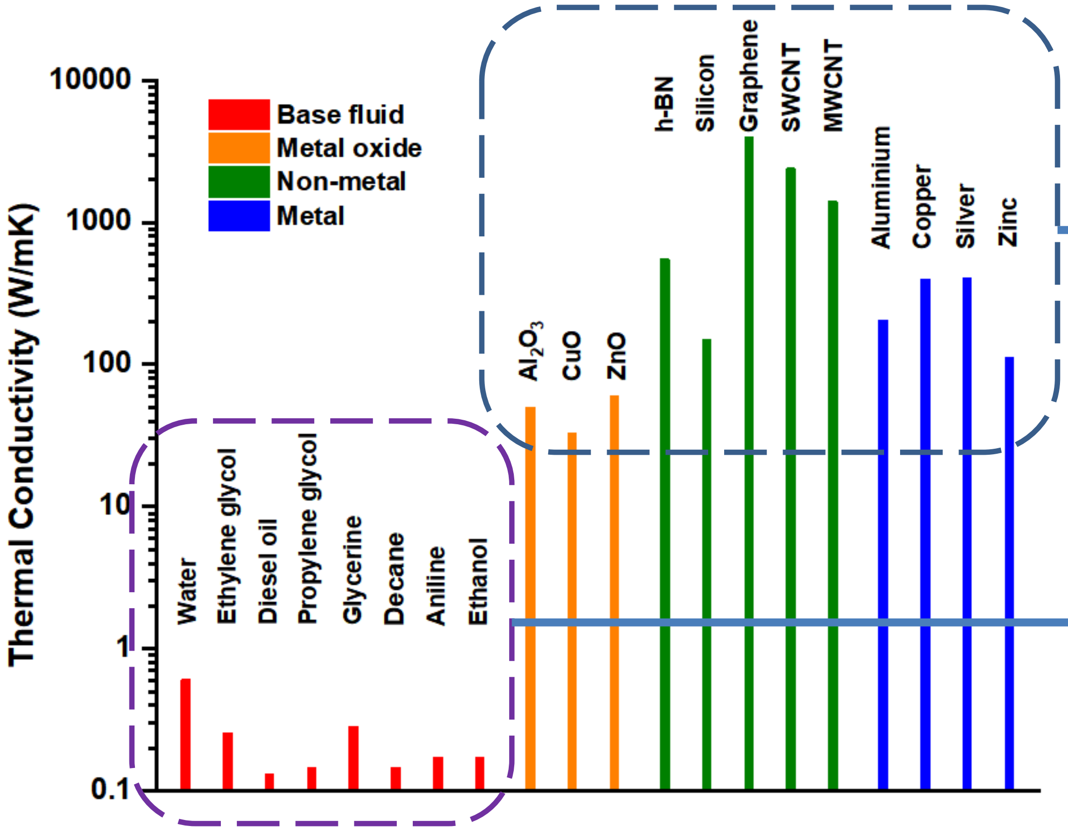


Active method

- **Cooling device such as external fan**

Problem Statement

There are variety of heat exchangers and coolants to transfer heat away to surrounding.



Milled into nano-sized powder

+

Act as base fluid

= Nanofluid

Composition

Properties of base fluid	Findings
Thermal conductivity	↑
Viscosity	↑
Density	↑
Specific heat capacity	↓

Base fluid

- Water
- Ethylene glycol
- Oil and lubricants
- Bio-fluids
- Polymer solutions

+

Nanoparticles

- Metals
- Metallic oxides
- Non-metallic oxides
- Functionalized nanoparticles

Mono – Single type of nanoparticles

Hybrid – At least two types of nanoparticles

Literature Review

Type of heat exchanger	Nanoparticle concentration	Base fluid	Enhancement on base fluid	References
Cross-flow	0.3 vol% Al_2O_3	DW/EG (50:50)	Nusselt number (24.21%)	[1]
	0.5 vol% Al_2O_3	DW/EG (50:50)	Smaller frontal surface area (15%)	[2]
	0.65 vol% Fe_2O_3 0.65 vol% Al_2O_3	Water	Heat transfer enhancement: Fe_2O_3 (9%), Al_2O_3 (7%)	[3]
	0.02 wt% hybrid carbon (20-30 nm)	Water	Heat exchange capacity (13%) System efficiency factor (11.7%)	[4]
Shell and tube	0.3 vol% γ-Al_2O_3	Water	Nusselt number (29.8%) Overall heat transfer coefficient (19.1%)	[5]
	4 vol% Al_2O_3 (20 nm)	Water	Average heat transfer coefficient (11.94%)	[6]
Double pipe	4 vol% AlN	EG	Thermal performance (35%)	[7]
	1 vol% Al_2O_3 (20 nm)	Water	Nusselt number (20%)	[8]
	1 vol% TiO_2 (21 nm)	Water	Heat transfer coefficient (26%)	[9]
	0.2 vol% γ-Al_2O_3 (20 nm)	Water	Heat transfer rate (7.32%)	[10]
	0.15 vol% γ-Al_2O_3 (20 nm)	Water	Heat transfer coefficient (25%)	[11]
Double pipe U-bend	0.06 vol% Fe_3O_4 (36 nm)	Water	Heat transfer enhancement (14.7%) Effectiveness (2.4%)	[12]
Counter	0.45 vol% Ag (30-90 nm)	Water/EG (70:30)	Convective heat transfer coefficient (42%)	[13]
Cone helically coiled tube	0.5 vol% MWCNT (50-80 nm)	Water/EG (70:30)	Nusselt number (52%)	[14]

There are only few papers compared the properties of hybrid nanofluid with different mixing ratio.

Authors	Nanocomposite	Base fluid
Vicki et al., 2020	Al_2O_3-CuO	Water + ethylene glycol
Bhattad et al., 2020	Al_2O_3-TiO_2	Deionized water
Ma et al., 2020	Al_2O_3-CuO	Water + ethylene glycol
Hamid et al., 2018	TiO_2-SiO_2	Water + ethylene glycol

Thermal conductivity increases with higher ratio of material with high conductance.

Objectives

1. To evaluate thermal performance of the novel hybrid nanofluid experimentally.
2. To identify the effect of mixing ratio on the thermal performance of hybrid nanofluid.

Research Scope

I. Two different nanoparticles were tested in this research:

Titanium dioxide and carboxyl functionalized graphene nanoplatelets dispersed in water/ethylene glycol.

II. Two-step method was used as preparation method.

III. Cross-flow heat exchanger was used as radiator.

IV. Working parameters: Nanoparticle concentration (0.025 – 0.1 wt%), hybrid mixing ratio (100:0, 70:30, 50:50, 30:70), coolant volume flow rate (100 – 600 L/hour) and inlet air velocity (1.7 – 2.1 m/s).

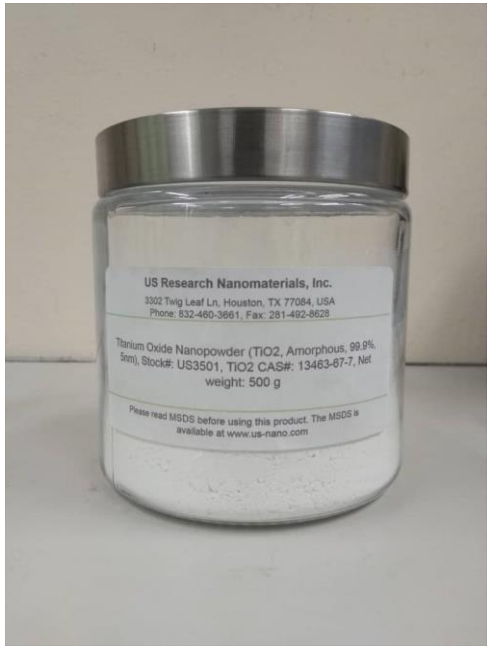
Methodology

UTM UNIVERSITI TEKNOLOGI MALAYSIA

Sample Preparation

Two step method (Direct mixing)

1. Addition of surfactant into base fluid (water/ethylene glycol - 60:40) and stirred for 10 min.
2. Addition of nanoparticles powder into the previous mixture and stirred for 30 min.
3. Ultra-sonication of the final mixture.



Titanium dioxide(TiO_2)

- 5 nm
- Amorphous
- 99.9% purity

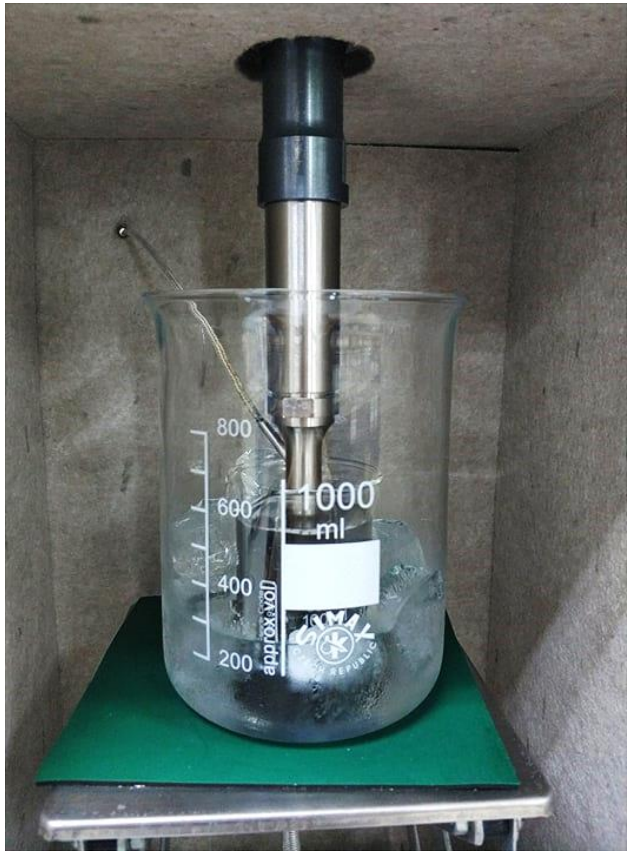
+

Graphene nanoplatelets (COOH-GnP)

- 2 µm length
- < 4 nm thickness
- 99 wt% purity

+

Surfactant



Ultrasonication

Test Rig

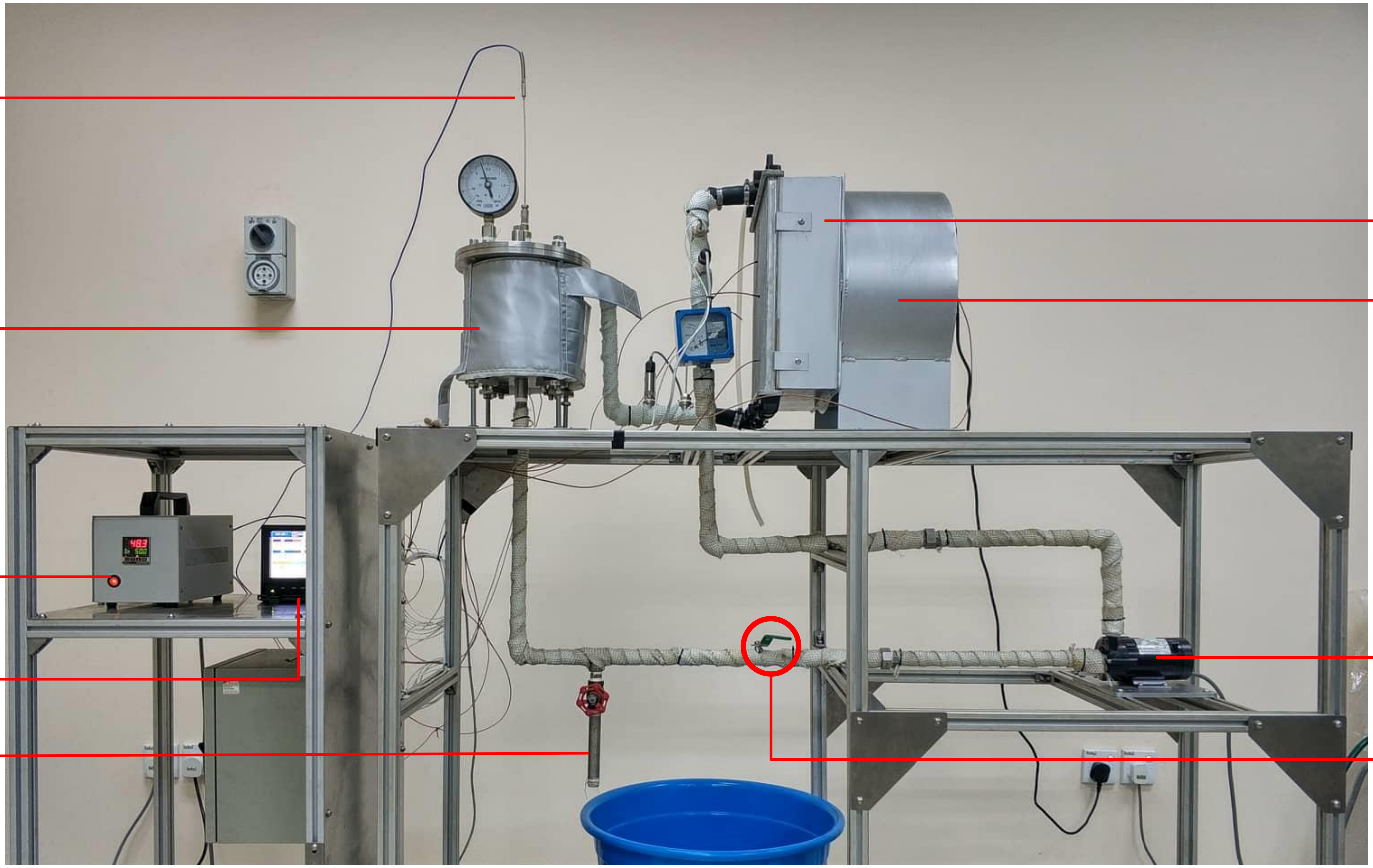
Sheath thermocouple (k-type)

Heating tank

Temperature controller

Data recorder

Drainage pipe



Radiator

Cooling fan

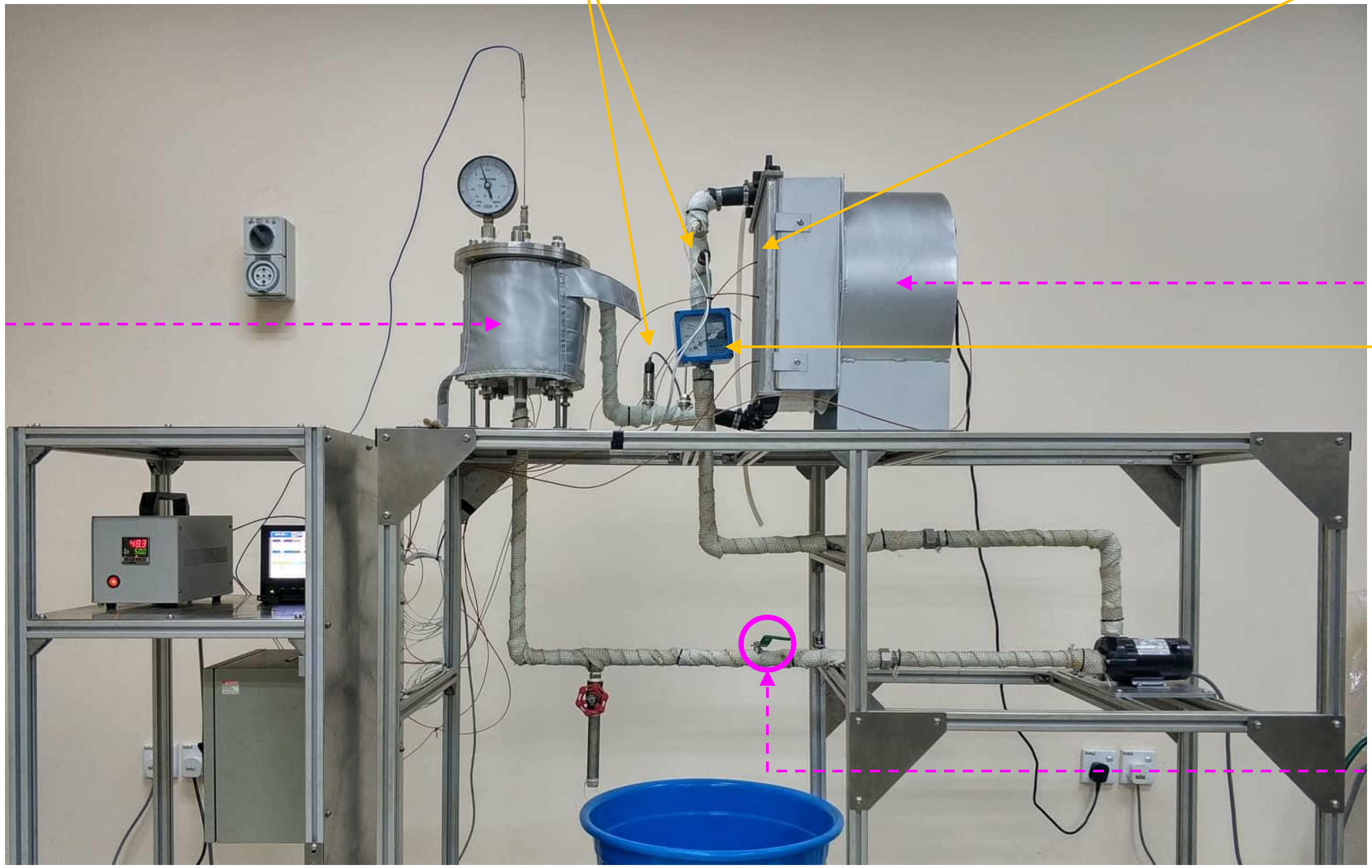
Pump

Ball valve

RTD Pt-100 thermocouple for T_{in} and T_{out}

5 k-type thermocouples for radiator surface temperature

Fixed at 35 °C



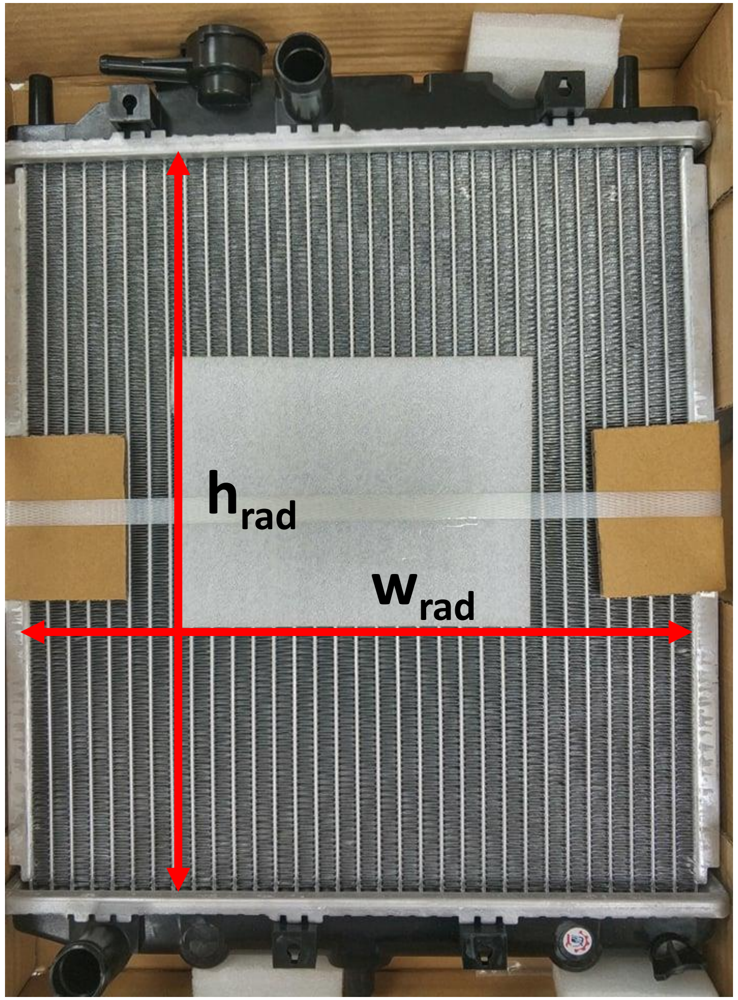
Air velocity (1.7 – 2.1 m/s)

Rotameter

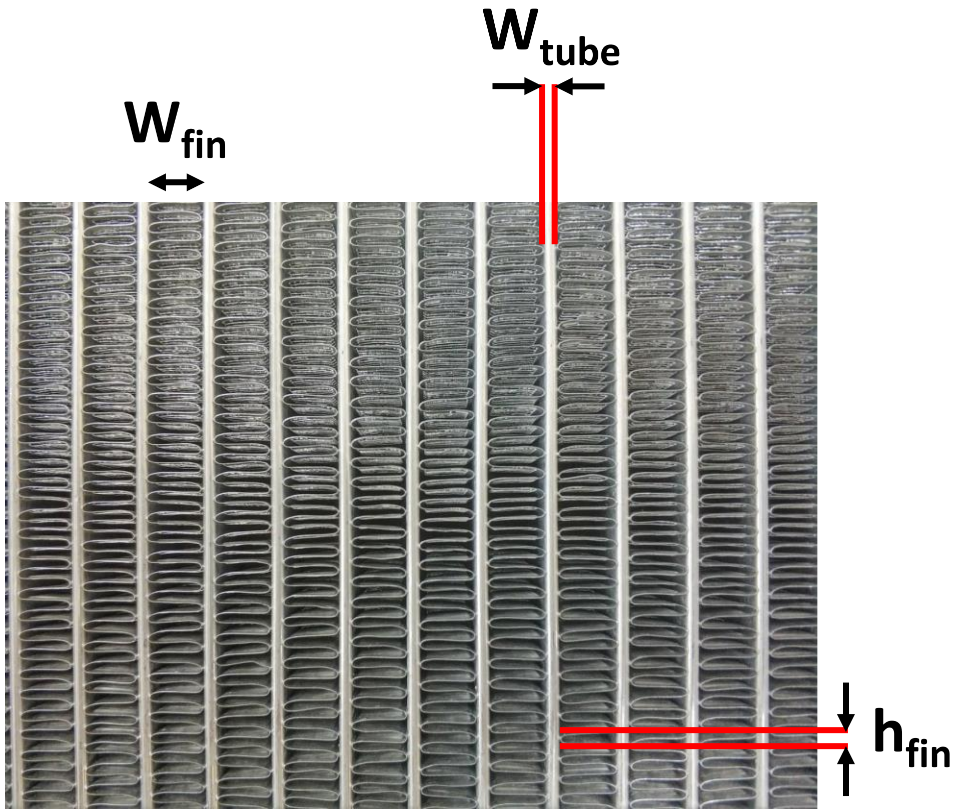
Coolant flow rate (100 – 600 L/hour)

1. Adjust desired coolant flow rate and air velocity.
2. Allow the coolant to flow for 30 minutes.
3. Record data for 10 minutes.

Geometrical Properties



Perodua Kancil radiator

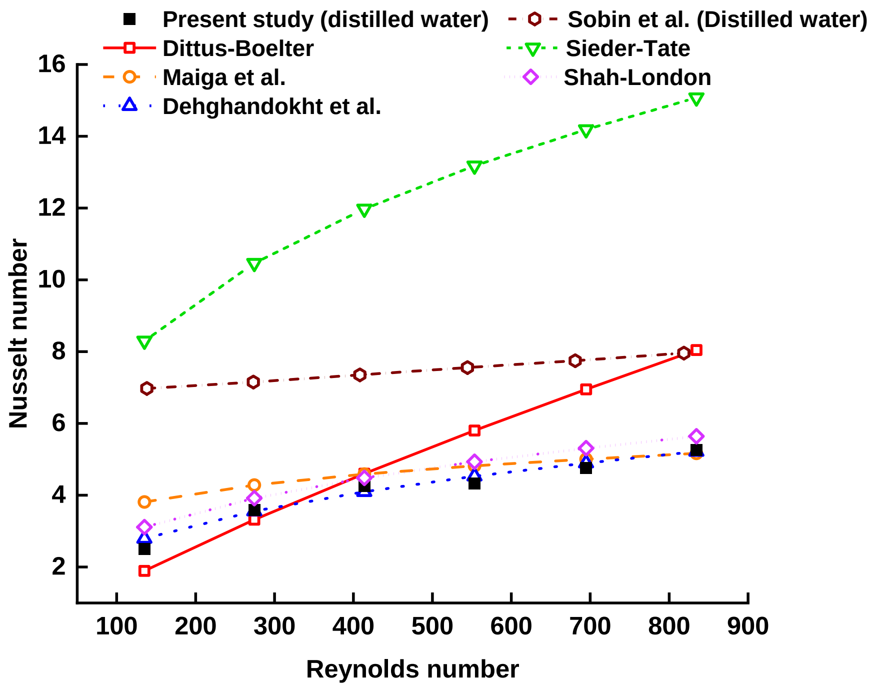


Serpentine fins

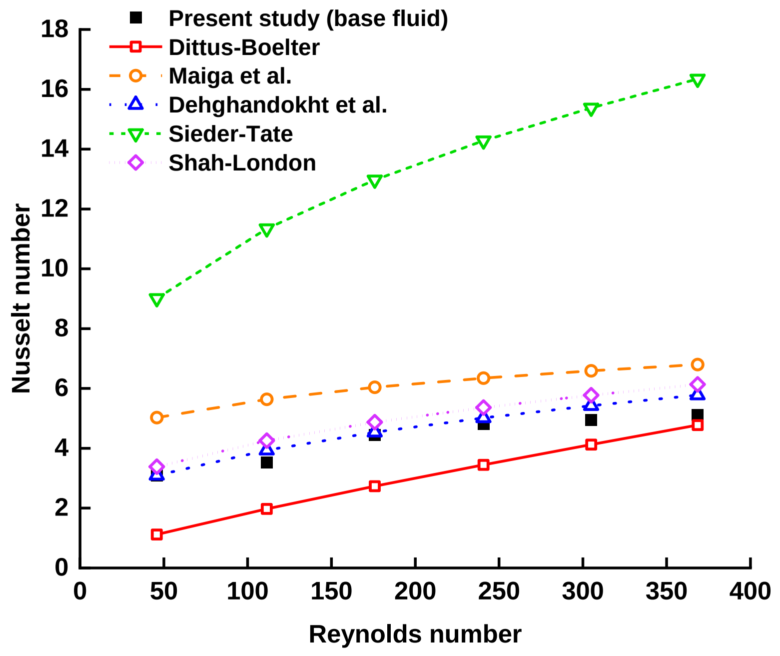
Results and Discussion

Verification

Tested at T_{in} = 35 ºC , v_{air} = 1.7 m/s



Distilled water

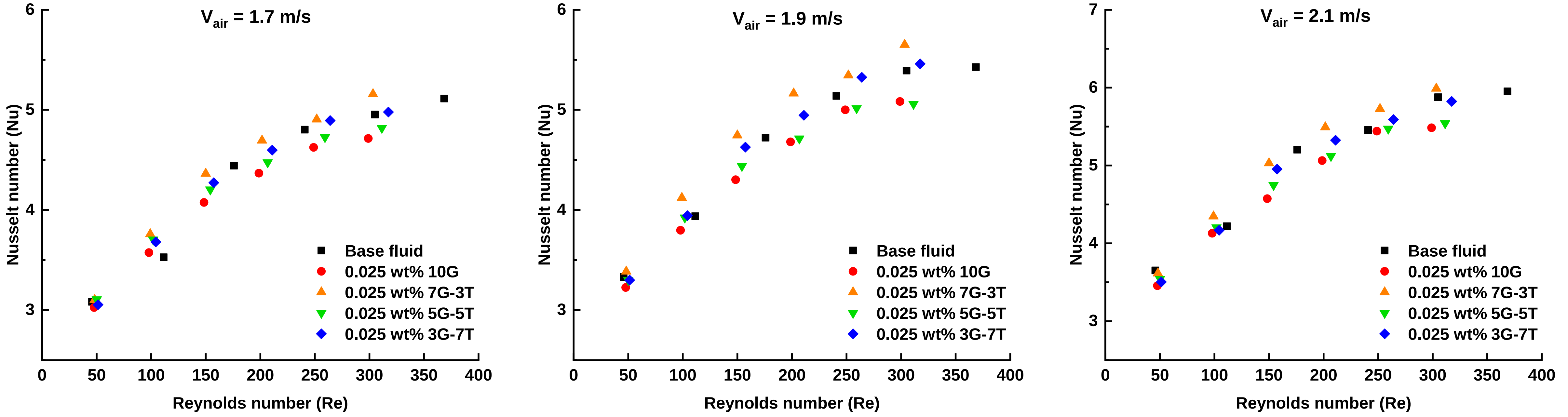


Base fluid (DW/EG)

Correlation	Average deviation	Mean absolute deviation (MAD)	Standard deviation
Dehghandokht et al.	6.163%	0.7752	0.9949
Shah-London	12.65%	0.7932	1.019

Heat Transfer Performance

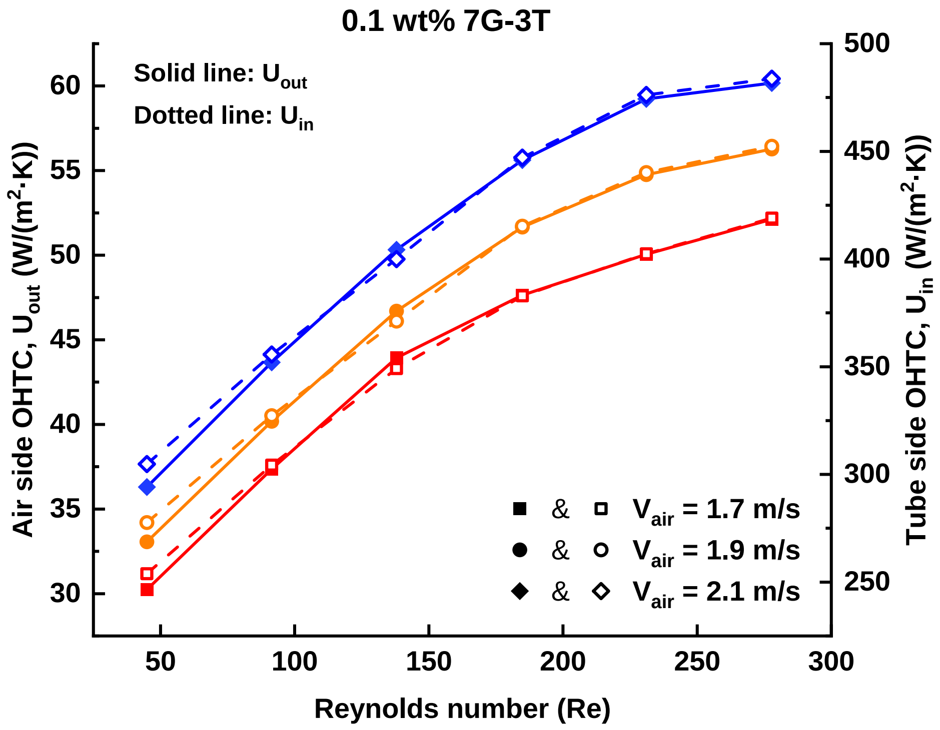
Nusselt number

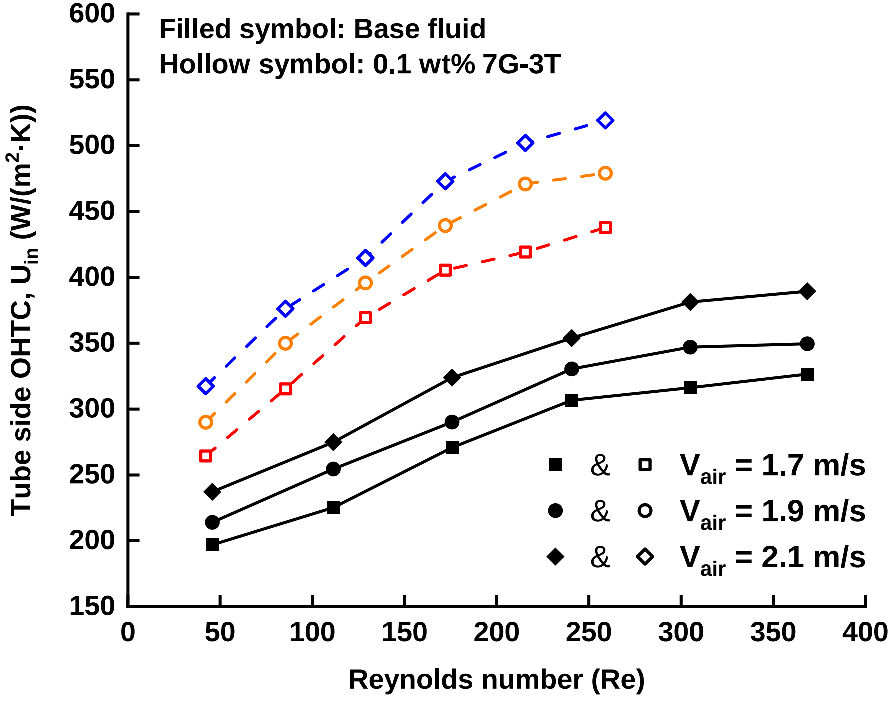


Mixing ratio of 50:50 and 100:0 of GnP-TiO_2 at 0.025 wt.% showed deterioration due to the poor thermal conductivity.

Overall heat transfer coefficient (OHTC)

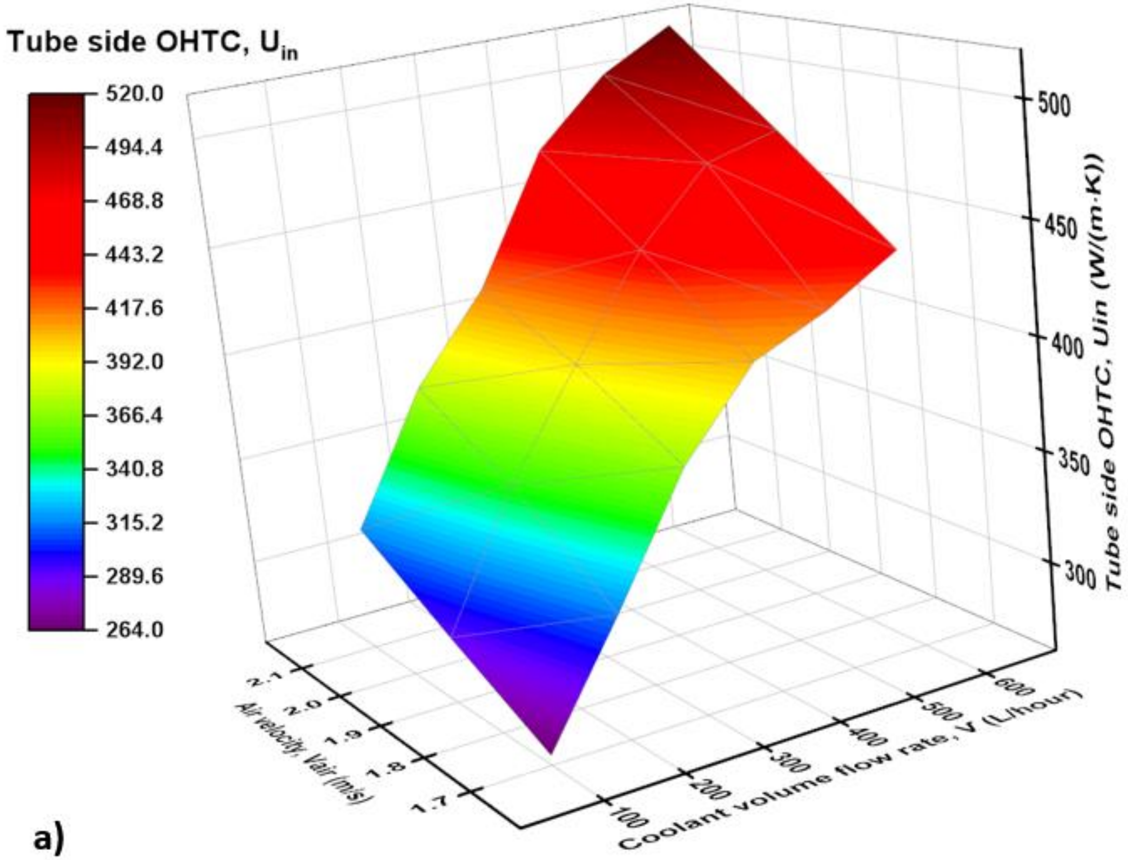
70% COOH-GnP
30% TiO_2



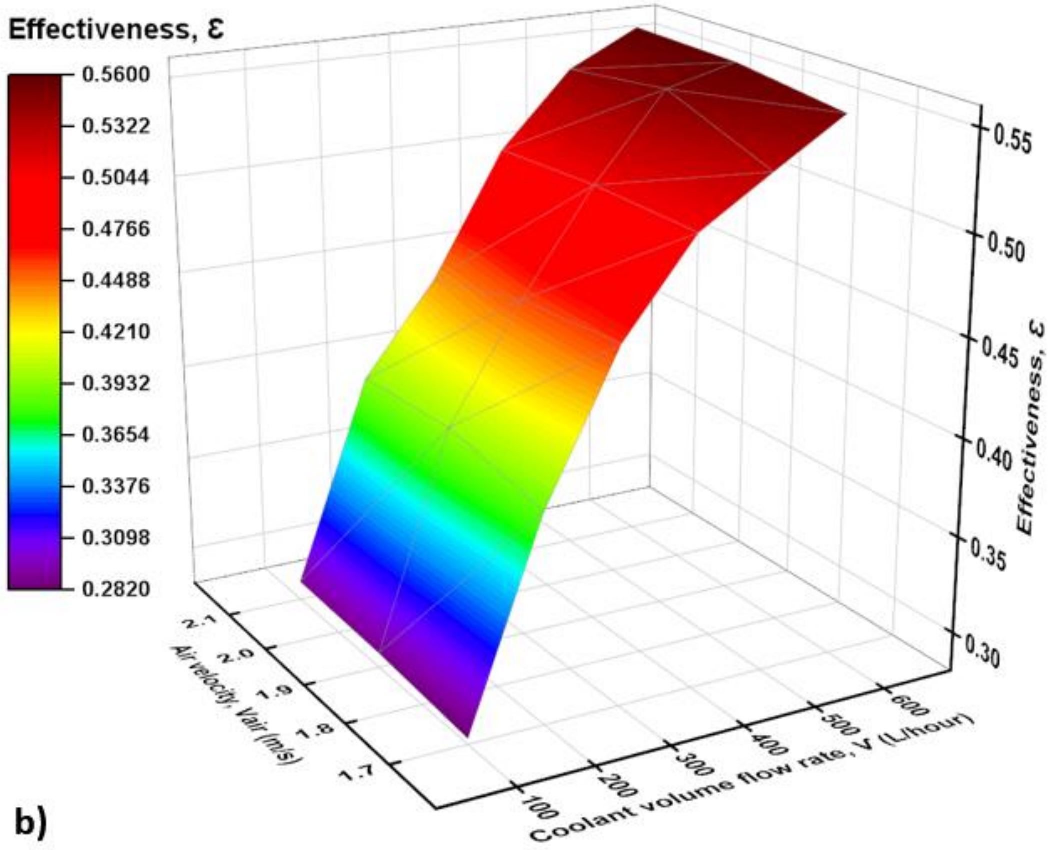


Combined effect

Fixed at 0.1 wt% 7G-3T nanocoolant

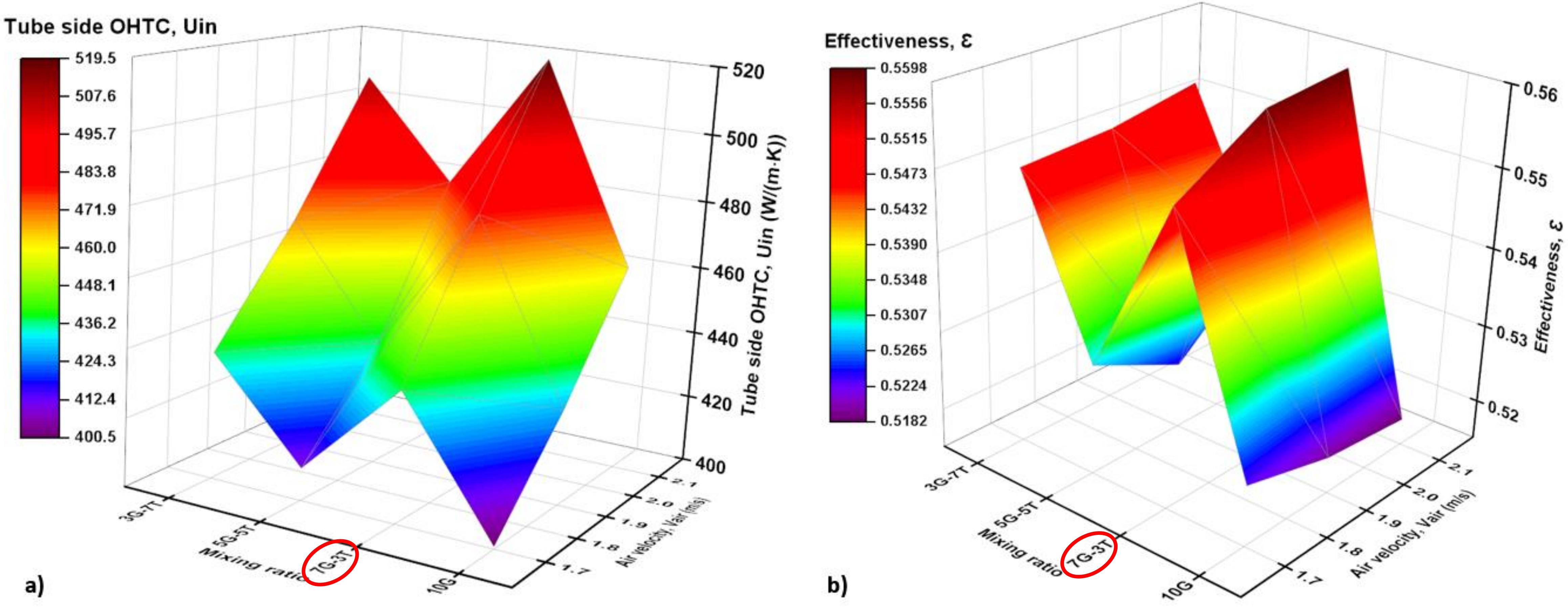


a)



b)

Fixed at V̇ = 600 L/hour, concentration of 0.1 wt%



Conclusion

1. The addition of nanoparticles increased thermal performance.

2. Hybrid nanocoolant improved overall heat transfer coefficient and effectiveness of radiator up to 33.31% and 20.74% respectively, when compared to base fluid.

3. Mixing ratio of 70% COOH-GnP + 30% TiO_2 exhibit the best heat transfer performance. It is not necessary that thermal performance increases with higher amount of material with greater thermal conductivity.

References

1. Said, Z., et al., *Enhancing the performance of automotive radiators using nanofluids.* Renewable and Sustainable Energy Reviews, 2019. **112**: p. 183-194.
2. Topuz, A., et al., *Experimental investigation of pressure drop and cooling performance of an automobile radiator using Al 2 O 3-water+ ethylene glycol nanofluid.* Heat and Mass Transfer, 2020. **56**(10): p. 2923-2937.
3. Peyghambarzadeh, S.M., et al., *Experimental study of overall heat transfer coefficient in the application of dilute nanofluids in the car radiator.* Applied Thermal Engineering, 2013. **52**(1): p. 8-16.
4. Hung, Y.-H., et al., *Performance evaluation of an air-cooled heat exchange system for hybrid nanofluids.* Experimental Thermal and Fluid Science, 2017. **81**: p. 43-55.
5. Barzegarian, R., A. Aloueyan, and T. Yousefi, *Thermal performance augmentation using water based Al2O3-gamma nanofluid in a horizontal shell and tube heat exchanger under forced circulation.* International Communications in Heat and Mass Transfer, 2017. **86**: p. 52-59.
6. Jafari, S.M., et al., *Heat Transfer Enhancement in Thermal Processing of Tomato Juice by Application of Nanofluids.* Food and Bioprocess Technology, 2017. **10**(2): p. 307-316.
7. Hussein, A.M., *Thermal performance and thermal properties of hybrid nanofluid laminar flow in a double pipe heat exchanger.* Experimental Thermal and Fluid Science, 2017. **88**: p. 37-45.
8. Darzi, A.A.R., M. Farhadi, and K. Sedighi, *Heat transfer and flow characteristics of AL2O3–water nanofluid in a double tube heat exchanger.* International Communications in Heat and Mass Transfer, 2013. **47**: p. 105-112.
9. Duangthongsuk, W. and S. Wongwises, *An experimental study on the heat transfer performance and pressure drop of TiO2-water nanofluids flowing under a turbulent flow regime.* International Journal of Heat and Mass Transfer, 2010. **53**(1): p. 334-344.
10. Aghayari, R., et al., *Effect of nanoparticles on heat transfer in mini double-pipe heat exchangers in turbulent flow.* Heat and Mass Transfer/Waerme- und Stoffuebertragung, 2014. **51**(3): p. 301-306.
11. Raei, B., et al., *Experimental study on the heat transfer and flow properties of γ-Al2O3/water nanofluid in a double-tube heat exchanger.* Journal of Thermal Analysis and Calorimetry, 2017. **127**(3): p. 2561-2575.
12. Ravi Kumar, N.T., et al., *Heat transfer, friction factor and effectiveness of Fe3O4 nanofluid flow in an inner tube of double pipe U-bend heat exchanger with and without longitudinal strip inserts.* Experimental Thermal and Fluid Science, 2017. **85**: p. 331-343.
13. Selvam, C., et al., *Convective heat transfer characteristics of water–ethylene glycol mixture with silver nanoparticles.* Experimental Thermal and Fluid Science, 2016. **77**: p. 188-196.
14. Palanisamy, K. and P.C.M. Kumar, *Heat transfer enhancement and pressure drop analysis of a cone helical coiled tube heat exchanger using MWCNT/water nanofluid.* Journal of Applied Fluid Mechanics, 2017. **10**(SpecialIssue): p. 7-13.

THANK YOU

HONG WEI XIAN
Malaysian-Japan International Institute of Technology
Universiti Teknologi Malaysia