International Journal of Engineering, Science and Mathematics
Vol.6 Issue 8, Decmber2017 (Special Issue)
ISSN: 2320-0294 Impact Factor: 6.765
Journal Homepage: http://www.ijesm.co.in, Email: ijesmj@gmail.com Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

Determination of Thermophysical Properties of Nano Hybrid Refrigerants to be used in Commercial Refrigeration System

UppadaVenkataRamana*
YaravaUday Kumar**
A.S.B Prasanna***
Dr. C.V.Gopinath****

Abstract

In present scenario, the need of increased cooling rate in commercial applications of a Refrigeration system is high. However, the complications in power consumption and lesser COP are still challenges to the researchers. Further, environmental impacts of refrigerant is also need to be considered. Hence, suitable refrigerant with increased thermophysical properties is need to be identified for increasing the performance of commercial refrigeration system. From the literature, it is reported that the use of mixed refrigerants in refrigeration system can enhance cooling capacity. However, mixed refrigerants with nano particles are yet to be studied in commercial refrigeration applications. In this context, the thermophysical properties of nano hybrid refrigerants are investigated by using R-22 and R-12 with a mass fraction of 50% each by volume concentration of nano particle TiO_2 from 1% to 5%. Different mathematical correlations which are developed in the past are used to determine the thermophysical properties of hybrid nano refrigerants. The thermo-physical properties of hybrid refrigerants such as Specific heat, Density, Thermal conductivity and Viscosity are determined by varying temperature from 300-350K with an temperature increment of 5K. From the results, it is observed that by nano particles dispersions in mixed refrigerants increased the thermo-physical properties. Hence, it is concluded that nano hybrid refrigerants can enhance the cooling capacity of commercial refrigeration system.

Keywords:

Nano Mixed Refrigerants;
Thermophysical Properties;
VapourCompression Refrigeration System;
Nano Particles;
Volume Concentration.

Author correspondence:

UppadaVenkataRamana,
Assistant Professor
Department of Mechanical Engineering, BITS, VIZAG, INDIA

1. Introduction

*Assistant Professor, Department of Mechanical Engineering, BITS, VIZAG, ANDHRA PRADESH ,INDIA
**Assistant Professor, Department of Mechanical Engineering, AITS, KADAPA, ANDHRA PRADESH, INDIA
***Department of Mechanical Engineering, BITS, VIZAG, ANDHRA PRADESH ,INDIA
****Department of Mechanical Engineering, BITS, VIZAG, ANDHRA PRADESH ,INDIA

The need of refrigeration increased drastically from few decades. Refrigerator is a device which produces cooling effect by reducing the temperature below ambient temperature. Refrigerant is the medium used in refrigerator which carry heat and undergo phase change to produce cooling effect. This cooling effect is used for domestic appliances, industrial purposes, hospitals, theatres etc. however the conventional refrigerants used in refrigeration system having fever COP as well as increasing GDP and ODP. R717, R290, R600a, R744, R11, R123, R134a [1]–[5]are the refrigerants used to produce refrigeration effect. In the past, conventional refrigerants are replaced by using mixed refrigerants [6]–[8]. In the recent past, conventional refrigerants are dispersed with nano particles to increase the heat transfer rate [9]–[12]. However, the demand for cooling capacity with decreased environmental pollution is still challenging. Motivated by this, the present work aims at investigating the thermopyhsical properties of mixed refrigerants R-12 (dichloro-diflouro methane) and R-22 (Chlorodiflouro methane) dispersed with changing volumetric concentration of 1-5%. From the investigation, the use of nano mixed refrigerants in domestic refrigeration can enhance the heat transfer rate.

Figure 1 shows the properties of nano particles and mixed refrigerants. The process involved are isentropic compression (1-2), isobaric heat rejection (2-3), isenthalpic expansion (3-4) and isobaric heat addition (4-1).

Table 1.Properties of nano particle and mixed refrigerants

Properties	Thermal Conductivity (W/m-K)	Viscosity(μPa-s)	Specific Heat(J/kg-K)	Density (kg/m³)
R-12 (100%)	0.066474	184.87	993.42	1304.3
R-22 (100%)	0.082639	161.04	1265.3	1183.4
R-12/R-22 (50% each)	0.065333	160.28	1139.1	1222.7
TiO_2 (1-5%)	13	---------	0.71	4157

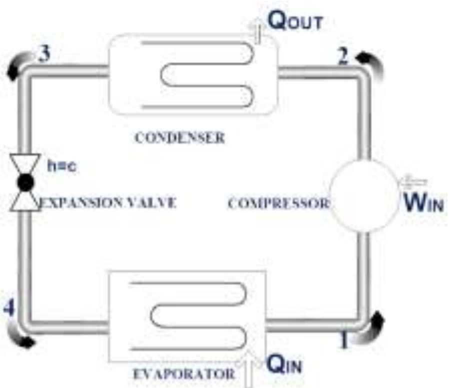

Figure 1 Schematic of Domestic Refrigeration System

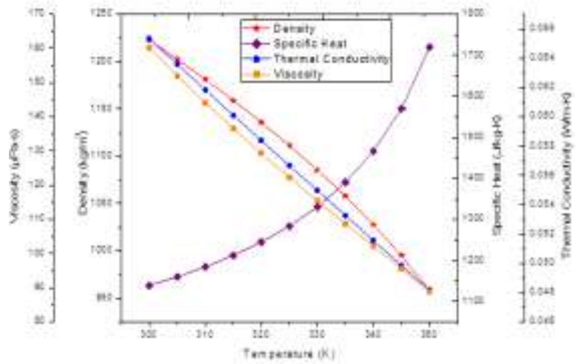

Figure 2Thermophysical properties of R12/R22 mixed refrigerants

2. Research Methodology

The thermopyhsical properties of nano mixed refrigerants such as Density, Viscosity, Thermal Conductivity and Specific heat are investigated by using various mathematical correlations which are developed in the past. The assumptions considered for analyses are nano particle is circular having an average size of 20nm and neglect the effect of surfactants. **Error! Reference source not found.** shows the thermopyhsical properties of R12/R22 mixed refrigerant with a molar mass of 50% each.

A. Specific heat

The Specific heat of nano mixed refrigerants are calculated using Pak and Cho model [13]

$$(C_p)_{eff} = \frac{(1-\phi)(\rho C_P)_{ref} + \phi(\rho C_P)_{NP}}{(1-\phi)\rho_{ref} + \phi\rho_{NP}} \tag{1}$$

Where,

$(C_P)_{eff}$ = Effective specific heat of nano mixed refrigerant

$(C_P)_{ref}, (C_P)_{NP}$ = Specific heat of mixed refrigerant, nano particle

ρ_{ref}, ρ_{NP} = Density of mixed refrigerant, nano particle

B. Density

Xuan and Roetzel model [14] is used to determine the effective density of nano mixed refrigerant

$$\rho_{eff} = (1-\phi)\rho_{ref} + \phi\rho_{NP} \tag{2}$$

Where,

ρ_{eff} = Effective density of nano mixed refrigerant

ϕ = Volume concentration of the nano particles

ρ_{ref}, ρ_{NP} = Density of mixed refrigerant, nano particle

C. Thermal conductivity

The overall thermal conductivity is the parameter which determines the heat transfer enhancement in refrigeration system. The thermal conductivity of nano particles are higher compared to refrigerants. Hence, in order to improve the overall thermal conductivity nano particles are dispersed in refrigerants. For the heterogeneous dispersion of colloidal nano particles in refrigerants is proposed by Maxwell [15]. This model is used to determine the effective thermal conductivity of the nano mixed refrigerants.

$$\frac{K_{eff}}{K_{ref}} = \frac{2K_{ref} + K_P + 2\phi(K_P - K_{ref})}{2K_{ref} + K_P - \phi(K_P - K_{ref})} \tag{3}$$

Where,

K_{eff} = Effective thermal conductivity of nano mixed refrigerant

K_P, K_{ref} = Thermal conductivity of mixed refrigerant, nano particle

The non spherical shaped colloidal nano particles dispersed in mixed refrigerants effective thermal conductivity can be calculated by using Hamilton and Crosser [16]

$$\frac{K_{eff}}{K_{ref}} = \frac{(n+1)K_{ref} + K_P - (n-1)\phi(K_{ref} - K_P)}{(n+1)K_{ref} + K_P + \phi(K_{ref} - K_P)} \quad (4)$$

Where, n= shape factor = (3/Ψ)

ψ = sphericity or non spherical edge

Buongiorno model [17] is an experimental correlation used to determine Thermal conductivity as follows

$$\frac{K_{eff}}{K_{ref}} = 1 + 2.92\phi - 11.99\phi^2 \quad (5)$$

The theory of effective medium dispersion in mixed refrigerant is given by Timofeeva model [18]

$$\frac{K_{eff}}{K_{ref}} = (1 + 3\phi) \quad (6)$$

D. Viscosity

The pumping power and pressure drop vary with respect to the viscosity. Hence, viscosity is the parameter need to calculate. The correlations used to determine the viscosity are as follows

To determine the effective viscosity, Einstein model[19] is used given by following relation

$$\frac{\mu_{eff}}{\mu_{ref}} = 1 + 2.5\phi \quad (7)$$

Where,

μ_{eff} = Effective viscosity of nano mixed refrigerant

μ_{ref} = Viscosity of mixed refrigerant

The nano mixed refrigerant viscosity can be determined by using Brinkman model[20]

$$\frac{\mu_{eff}}{\mu_{ref}} = \frac{1}{(1-\phi)^{2.5}} \quad (8)$$

Gherasim model[21] of viscosity is determined by using relation as follows

$$\frac{\mu_{eff}}{\mu_{ref}} = 0.904e^{14.8\phi} \quad (9)$$

Wang model [22] of viscosity is determined by using relation as follows

$$\frac{\mu_{eff}}{\mu_{ref}} = (1 + 7.3\phi + 123\phi^2) \quad (10)$$

To determine the viscosity Pak and Cho model [13] is used and given as follows

$$\mu_{eff} = 1 + 2.5\phi + 6.2\phi^2 \quad (11)$$

3. Results and Analysis

A. Specific heat

Pak and Cho model is used to determine the viscosity of the nano mixed refrigerant. FromFigure 3,it is evident that specific heat increases with the increase in temperature. However, as the volume concentration of nano particle (TiO_2) gradually increases the gradient curve decreases compared to mixed refrigerant (R-12 / R-22) . Furthermore, specific heat at 5% is very low and is desirable for domestic refrigeration.

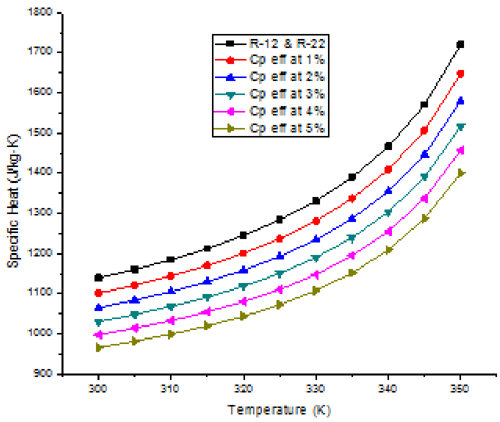

Figure 3 Variations of specific heat as a function of temperature and volume concentrations

B. Density

Xuan and Roetzel model is used to calculate the density of nano mixed refrigerants. Figure 4 shows the variations of density as a function of temperature and volume concentrations. From the figure, it is evident that density is increasing with increase in volume concentration. Moreover, with the increase in temperature density of nano mixed refrigerant is decreasing.

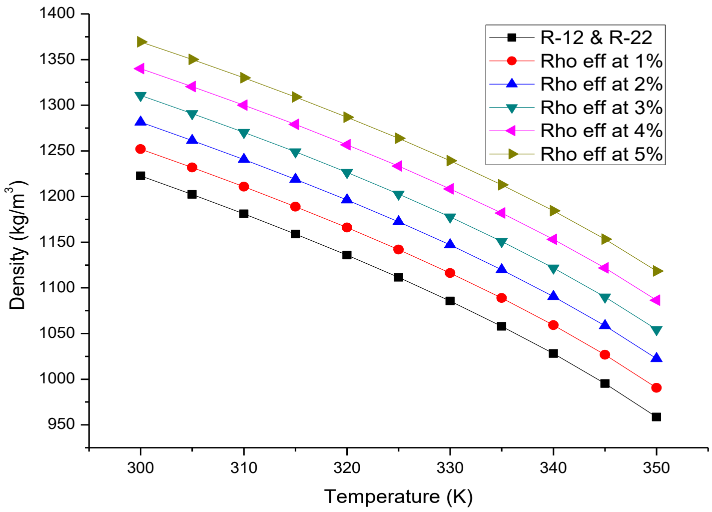

Figure 4Variation of density w.r.t varying temperatures and volume concentrations

C. Thermal conductivity

The heat transfer rate is dependent on thermal conductivity. Hence, it is necessary to calculate the thermal conductivity for nano mixed refrigerants. From the literature, the higher thermal conductivity refrigerant is better for domestic refrigeration. Figure 5 shows the effective thermal conductivity variation as a function of temperature and volume concentration of TiO_2. From the figure, it is evident that thermal conductivity of nano mixed refrigerants are increasing with increase in dispersion of nano particles in mixed refrigerants. Further, thermal conductivity is decreasing with increase in the temperature.

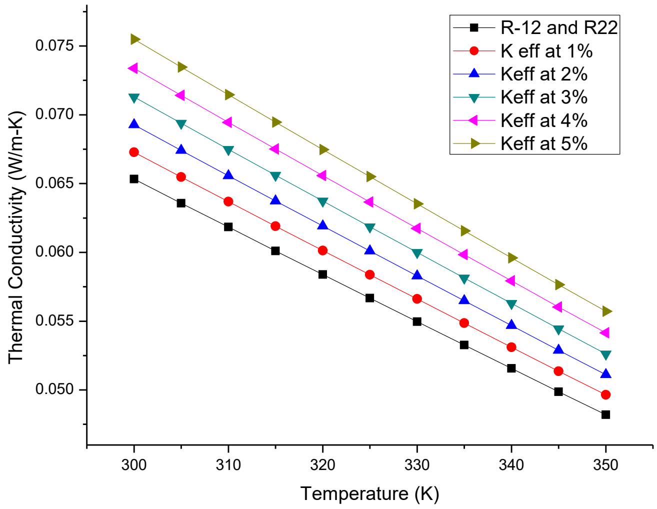

Figure 5 Effective thermal conductivity of R12/R22+TiO_2 with temperature and volume concentration

Figure 6 shows the variation of effective thermal conductivity with respect to temperature at 3% volume concentration of TiO_2 for different models. It is observed that, thermal conductivity is decreasing with the increase in temperature for different models. Further, it is observed that Hamilton and Crosser model is having an increase in 3.44% compared to Timofeeva and 2.09% compared to Maxwell at 300K.

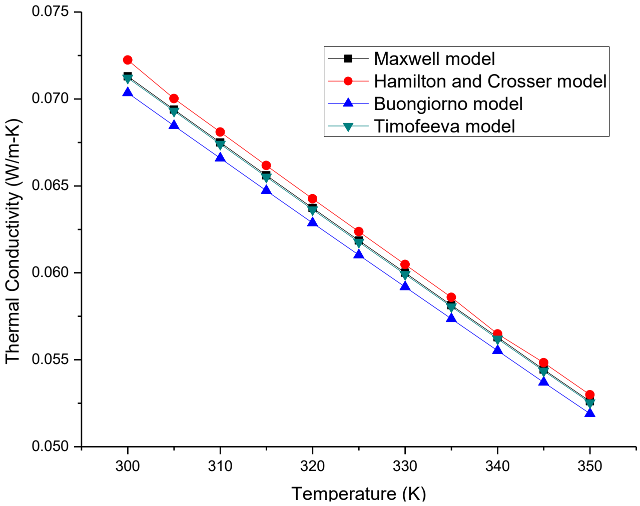

Figure 6 Variation of effective thermal conductivity by temperature for various correlations

Figure 7 shows that the effect of volume concentration over thermal conductivity for various correlations at 325K. From the figure, it is evident that with increase in volume concentration, thermal conductivity is increasing for all models. Further, it is observed that Hamilton and Crosser model is having an increase in 1.69% compared to other models, 1.51% compared to Maxwell and 4.54% compared to Buongiorno at 5% of TiO_2 dispersion.

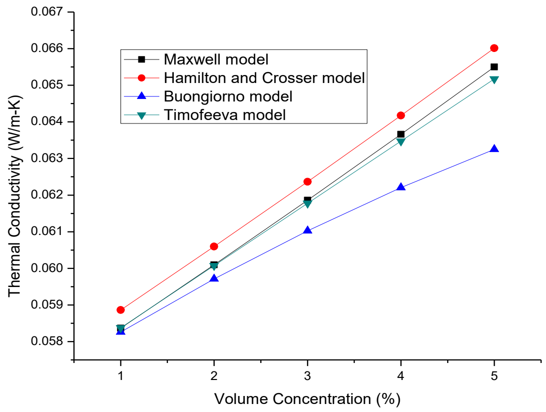

Figure 7 Effect of volume concentration over effective thermal conductivity for various correlations

D. Viscosity

The pumping power and pressure drop vary with respect to the viscosity. Hence, viscosity is the parameter need to calculate. Figure 8 shows the effect of temperature and volume concentration over effective viscosity. From the figure, it is evident that with increase in volume concentration viscosity is increasing. Furthermore, Viscosity is decreasing with increase in temperature.

Figure 9 shows the effect of volume concentration over effective viscosity for various correlations at 325K. From the figure, it is observed that Gherasim model is having higher viscosity followed by Wang model. Moreover, the viscosity has an increment of 47.91% compared with Einstein model and an increment of 12.5% compared with Wang at 5% of nano particle dispersion

Figure 10 shows the variation of viscosity as a function of temperature at 3% of TiO_2 dispersion for various correlations. From the figure, it is observed effective viscosity is decreasing with the increase in temperature. Moreover, Gherasim model having higher viscosity compared to other models. Furthermore, Gherasim model having an increment of 26.08% followed by Wang 20.93% compared with the other models at 300K.

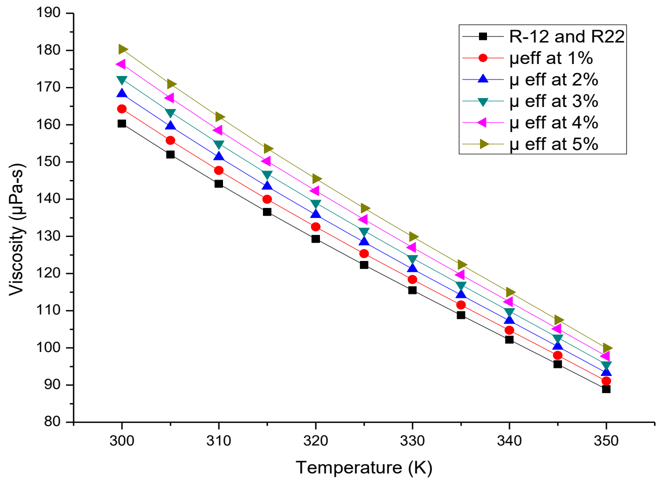

Figure 8 Effect of temperature and volume concentration over effective viscosity

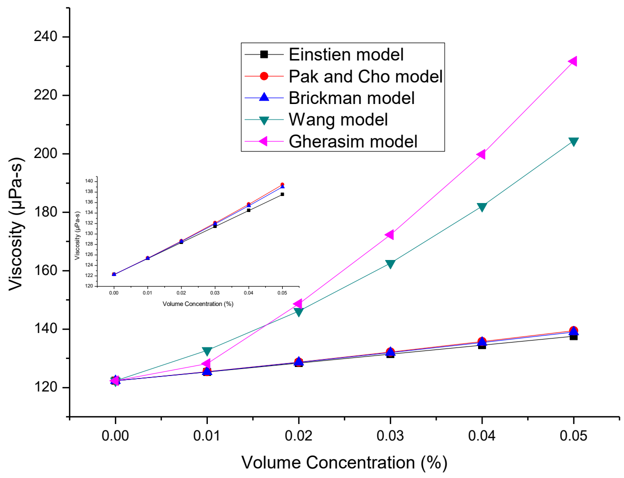

Figure 9 Effect of volume concentration over effective viscosity for various correlations

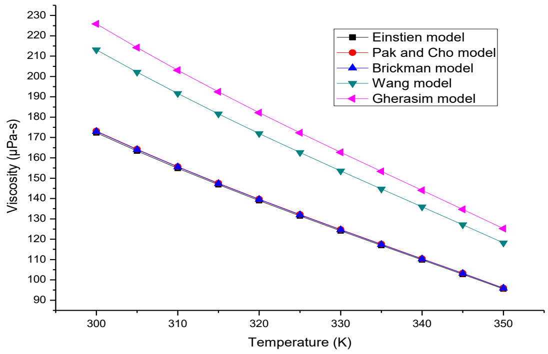

Figure 10 Effect of temperature over effective viscosity for various correlations .

4. Conclusion

The investigation on thermopyhsical properties of nano mixed refrigerant (R12/R22+TiO_2) to be used domestic refrigeration. From the investigation, it is observed that specific heat increases with the increase in temperature and with increase in volume concentration of nano particle gradually increases the gradient curve and decreases compared to mixed refrigerant (R-12 / R-22). Furthermore, specific heat at 5% is very low and is desirable for domestic refrigeration.

Density is increasing with increase in volume concentration. Moreover, with the increase in temperature density of nano mixed refrigerant is decreasing.

Thermal conductivity of nano mixed refrigerants are increasing with increase in dispersion of nano particles in mixed refrigerants and decreasing with increase in the temperature. Furthermore, thermal conductivity decreases with the increase in temperature for different models. Moreover, increase in volume concentration, thermal conductivity is increasing for all models.

Viscosity increases with increase in volume concentration and Viscosity is decreasing with increase in temperature. Gherasim model is having higher viscosity followed by Wang model. viscosity is decreasing with the increase in temperature.

References

[1] V. Jatav and R. C. Gupta, "EXPERIMENTAL INVESTIGATION OF DOMESTIC REFRIGERATOR WITH MICROCHANNEL CONDENSER USING 134A AND HYDROCARBON REFRIGERANT," *Glob. J. OFENGINEERINGSCIENCE ANDRESEARCHES*, vol. 2, no. 5, pp. 22–28, 2015.

[2] M. A. Akintunde, "Validation of a vapour compression refrigeration system design model," *Am. J. Sci. Ind. Res.*, vol. 2(4), no. 1989, pp. 504–510, 2011.

[3] A. H. D. H. M. Dange, "INVESTIGATION OF INFLUENCE OF THE VARIOUS EXPANSION DEVICES ON THE PERFORMANCE OF A REFRIGERATOR USING R407C REFRIGERANT," *Int. J. Adv. Eng. Technol.*, vol. 5, no. 2, pp. 96–99, 2014.

[4] R. K. Gond, R. P. Chaudhary, M. A. Khan, and G. Jain, "Performance and exergy analysis of vapour compression refrigeration system using various alternative of R134a .," *Int. Res. J. Eng. Technol.*, vol. 03, no. 05, p. 2016, 2016.

[5] M. K. Agrawal and A. G. Matani, "Evaluation of Vapour Compression Refrigeration System Using Different Refrigerants-A Review," *Int. J. Eng. Innov. Technol.*, vol. 2, no. 4, pp. 39–43, 2012.

[6] N. S. Walimbe, K. G. Narayankhedkar, and M. D. Atrey, "Experimental investigation on mixed refrigerant Joule – Thomson cryocooler with flammable and non-flammable refrigerant mixtures," *Cryogenics (Guildf).*, vol. 50, no. 10, pp. 653–659, 2010.

[7] D. S. Kumar and R. Elansezhian, "Investigation of R152a / R134a Mixture in Refrigeration System," *Int. J. Eng. Innov. Technol.*, vol. 2, no. 6, pp. 207–210, 2012.

[8] K. Vicknesh, "PERFORMANCE TEST ON VAPOUR COMPRESSION REFRIGERATION SYSTEM USING R290 & R134a MIXTURE," *Int. J. Sci. Res. Publ.*, vol. 6, no. 6, pp. 470–476, 2016.

[9] H. D. Asif, Faizan, "Thermophysical Property and Heat transfer Analysis of R245fa/Al2O3 Nanorefrigerant," *Int. J. Eng. Sci.*, vol. 5, no. 4, pp. 45–53, 2016.

[10] I. M. Mahbubul, S. A. Fadhilah, R. Saidur, K. Y. Leong, and M. A. Amalina, "International Journal of Heat and Mass Transfer Thermophysical properties and heat transfer performance of Al 2 O 3 / R-134a nanorefrigerants," *HEAT MASS Transf.*, vol. 57, no. 1, pp. 100–108, 2013.

[11] S. A. Fadhilah, R. S. Marhamah, and A. H. M. Izzat, "Copper Oxide Nanoparticles for Advanced Refrigerant Thermophysical Properties : Mathematical Modeling," *J. Nanoparticles*, vol. 2014, pp. 2–7, 2014.

[12] S. Bi, L. Shi, and L. Zhang, "Application of nanoparticles in domestic refrigerators," *Appl. Therm. Eng.*, vol. 28, pp. 1834–1843, 2008.

[13] Y. I. C. Bock Choon Pak, "Hydrodynamic and Heat Trasfer Study of Dispersed fluids with Submicron Metallic Oxide Particles," *Exp. Heat Transf. an Int. J.*, vol. 11.2, pp. 151– 170, 1998.

[14] Y. Xuan and W. Roetzel, "Conceptions for heat transfer correlation of nano fluids," *Int. J. Heat Mass Transf.*, vol. 43, pp. 3701–3707, 2000.

[15] J. C. Maxwell, "A treatise on electricity and magnetism," in *Dover*, 1954.

[16] R. L. Hamilton and O. K. Crosser, "Thermal Conductivity of Heterogeneous Two-Component Systems," *Ind. Eng. Chem. Fundam.*, vol. 1, no. 3, pp. 187–191, Aug. 1962.

[17] J. Buongiorno, "Convective transport in nanofluids," *J. Heat Transfer*, vol. 128, no. March 2006, 2015.

[18] J. Selinger, K. State, E. V Timofeeva, A. N. Gavrilov, and J. M. Mccloskey, "Thermal Conductivity and Particle Agglomeration in Alumina Nanofluids : Experiment and Theory," *Phys. Rev.*, vol. 76, no. 6, 2007.

[19] A. Einstein, "EINE NEUE BESTIMMUNG DER MOLEKüLDIMENSIONEN," *Ann. Phys.*, vol. 324.2, pp. 289–306, 1905.

[20] H. C. Brinkman, "The Viscosity of Concentrated Suspensions and Solutions," *J. Chem. Phys.*, vol. 20, no. 4, p. 571, Apr. 1952.

[21] I. Gherasim, G. Roy, C. T. Nguyen, and D. Vo-Ngoc, "Experimental investigation of nanofluids in confined laminar radial flows," *Int. J. Therm. Sci.*, vol. 48, no. 8, pp. 1486–1493, 2009.

[22] X. Wang and X. Xu, "Thermal Conductivity of Nanoparticle – Fluid Mixture," *J. Thermophys. HEAT Transf.*, vol. 13, no. 4, pp. 474–480, 1999.