

PERFORMANCE EVALUATION OF VARYING NANOPARTICLES DERIVED FROM ALOE VERA PLANT FOR DOMESTIC REFRIGERATION SYSTEM

S. A. Afolalu¹, O. M. Ikumapayi^{1,✉}, O. Okwilagwe², O. O. Yusuf³
and O. R. Oloyede¹

¹Department of Mechanical and Mechatronics Engineering, Afe Babalola University, Ado Ekiti, 360101, Nigeria

²Department of Mechanical Engineering, Covenant University, KM. 10 Idiroko Road, Canaan Land, Ota, 112212, Nigeria

³Department of Microbiology, Obafemi Awolowo University, Ile-Ife, 220282, Nigeria

✉Corresponding Author: Ikumapayi.omolayo@abuad.edu.ng

ABSTRACT

The production of Zinc oxide (ZnO) nanoparticles was made from the aloe vera plant which served as the reductant and this was mixed with mineral oil to decrease compressor effort in order to raise the efficiency of a domestic vapour compression refrigeration system. The nanoparticles were dissolved in mineral oil at different proportions of 1.50 grams, 1.25 grams, 1.00 grams, 0.75 grams as well as 0.5 grams each in 250 ml. The system was monitored for about three hours forty-five minutes (225 minutes) per sample, and the parameters for comparison are the discharge temperatures, pull-down time, and net refrigeration effect. The results indicate a reduction in discharge temperature by 4-10% from 0.2 wt. %, 0.5 wt. %, and 0.6 wt. %, and a lower pull downtime of 40% from 0.2 wt. % concentration as compared to the values from the control specimen, which contained pure mineral oil.

Keywords: Nanotechnology, Nanoparticle, Refrigeration, Refrigerant, Lubricating Oil.

RASAYAN J. Chem., Vol. 15, No.3, 2022

INTRODUCTION

Long before refrigerators (fridges and freezers) came into existence, people found out that food was more preserved in the wintertime than during summer. Hence, the use of natural ice began. Large chunks of ice in polar or cold regions would be cut out and transported manually by a team over a long distance to be sold out to others who would keep the ice in their food “storage rooms” with heat-insulated walls using sawdust.¹⁻² Later on, the addition of salts like sodium nitrates and common salts were discovered to “bring down” the temperature of the water.³ Refrigeration, in thermodynamic terms, is the process of moving heat from a low-temperature reservoir to a high-temperature reservoir. Refrigeration is simply absorbing heat from a material.⁴ There are four major components in any refrigeration system: the evaporator, the compressor, the condenser, as well as the expansion valve or throttling valve.⁵ A refrigerant is a liquid or gaseous fluid that produces cooling. This substance absorbs heat at a low-temperature level in one location and rejects it at a higher temperature and pressure level in another location.⁶ Hydrocarbons and hydrofluorocarbons are common refrigerants. Another fluid used in the refrigeration system is a lubricant or lubricating oil. The lubricant is essential in lubricating the compressor and other metal components that are susceptible to rust. This, in turn, reduces the heat produced during friction and prolongs the life of the parts by reducing wear and tear. For refrigerator manufacturers, this entails developing specific blends that are suitable for the coolant, the refrigerator, and the surroundings. The lubricant uses the heat from the refrigeration process to increase its vapour pressure, allowing it to disperse to the compressor and other heated components. The lubricant to be used mainly depends on the compressor's capacity in British thermal units.⁷⁻⁸ However, in as much as there are many advantages of using lubricating oils in a refrigeration system, they pose several concerns. Among these concerns are environmental and human health issues in the disposal of used oil and production costs.⁹ After reviewing various literature using nano lubricants and nanorefrigerants experimentally, that nano lubricants can upgrade the thermal and mechanical performance

and reduce the energy consumption of a refrigeration system, as a result, the synthesis of nano lubricants has evolved into green chemistry, as defined by Paul Anastas, which entails employing safe components and avoiding harmful chemicals when creating new molecules because they have better thermal properties than the more available micro lubricants.¹⁰⁻¹¹ Nanofluids are the fluids produced by dispersing nanoparticles in a base fluid such as oil, water, ethyl, glycol, lubricating oils, refrigerants, and on. Nanofluids are fluids made up of nanoparticles and base fluid.¹² Nanofluids as mixtures of particles between 1 and 100nm and common fluids like oil and water. Nanofluids are enhanced working fluids that have been investigated to have properties in heat transfer enhancement.¹³ With respect to lubrication, nano lubricants are solid-like particles of nanometre size (typically with a diameter lying between a 1 and 100 nm) used as additives to a lubricating base oil or embedded in a coating and they have been researched and found to decrease both friction and wear rate during use in laboratory tests.¹⁴ The base oils include vegetable oils and water. Properties of good nano lubricants are chemical stability, lower toxicity than conventional lubricants, and great strength.¹⁵ This study explores the synthesis of zinc oxide from aloe vera as a lubricant additive in the area of refrigeration.

EXPERIMENTAL

The materials used in this study are zinc nitrate hexahydrate crystals [$Zn(NO_3)_2 \cdot 6H_2O$], as well as Aloe vera stalks, mineral oil as control, distilled water, and also R-134a refrigerant. The zinc oxide nanoparticles and nano lubricant fluid were prepared and characterized as described in our previous work which centered on the improvement of the thermal efficiency of a household refrigeration system, the authors developed a nano lubricant utilizing aloe vera plants and the use of SEM was employed to estimate the surface characteristics and crystal structures of the produced nanoparticles. EDS has also been employed to analyze the elemental and chemical composition of the aloe vera as well as the produced nanoparticles. The compositional analysis shows a concentration of 73.31% Zn, 20.19% O, and 6.40% C, which indicates a significant phase of ZnO.

RESULTS AND DISCUSSION

Discharge Temperature

The discharge temperature was obtained by using thermocouple K to measure the discharge temperature. As shown in Fig.-1, values obtained were plotted for each concentration against the time the system was monitored. After plotting the values, Fig.-1 indicates a steady rise in discharge temperature in all samples and the control. However, samples 1 (0.2 wt. %), 4 (0.5 wt. %), and 5 (0.6 wt. %) have lower discharge temperatures of approximately 10, 4, and 8%, respectively, than the control mineral oil. However, samples S2 and S3 have 8 and 6% higher discharge temperatures than the control sample. Nevertheless, lower discharge temperatures are more desirable because there would not be a lubricating effect loss of the compressor oils or breakdown in the chemical composition of the oils.¹⁶ Those two could cause bearings to break down and block passages from the excess sludge.

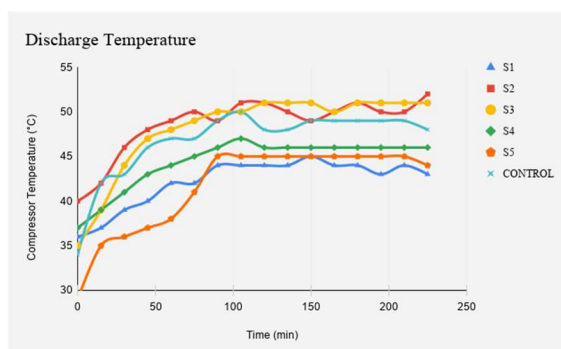


Fig.-1: Graph of Variation of Discharge Temperature against Time

Pull Downtime (PDT)

Pull downtime (PDT) is the time it takes for the refrigerator to reach the desired cooling temperature. Values of the temperature of the cabinet were obtained through a thermocouple and monitored for 225 minutes. A graph was plotted of the cabinet temperatures against time, as shown in Fig.-2 which indicates a gradual

decrease in cabinet temperatures in all samples which is desirable because low cabinet temperatures after a short time interval from the refrigerator power-up mean a faster cooling rate for the refrigerated bodies.¹⁷⁻¹⁸ Sample S3 (0.4 wt.%) shows a constant temperature after 75 minutes of 0°C. Samples 4 and 5 have cabinet temperatures of -3°C each at 195 minutes. Sample S1 (0.2 wt.%) and Sample S2 (0.3 wt.%) show the best pull-down time after 195 minutes with temperatures of -9°C compared with the control sample that effects the cabinet temperature being -6°C at the same time.

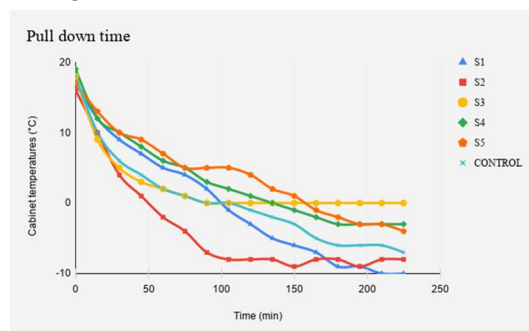


Fig.-2: Graph of Pull Downtime per Concentration of Nano lubricant

Net Refrigeration Effect

Net refrigeration effect is the quantity of heat that a mass of refrigerant absorbs from the vacuum space.¹⁹ Mathematically, it is the difference between the enthalpy of the refrigerant entering the compressor and the refrigerant entering the evaporator. Table-1 indicates the calculated net refrigeration effect per sample.

Table 1: Variation in Net Refrigeration Effect

NRE (kcal/kg)						
CONTROL	Time (min)	S5	S4	S3	S2	S1
5.229	15	5.09	2.774	4.91	3.98	5.607
6.47	30	6.045	3.891	7.5	7.994	6.797
7.926	45	6.6	4.7	8.62	8.037	7.387
8.069	60	7.254	5.78	9.02	9.257	8.417
8.369	75	9.357	7.04	9.62	10.079	8.187
9.43	90	9.357	7.951	10.22	10.393	9.646
9.43	105	9.339	8.217	10.375	11.649	9.946
9.48	120	9.49	8.142	10.375	11.649	10.503
9.019	135	9.962	8.508	10.672	11.327	10.703
9.219	150	10.262	8.742	10.672	11.199	10.721
9.8	165	10.774	9.008	10.672	11.327	11.787
10.3	180	10.974	9.142	10.375	11.327	11.821
10.763	195	11.174	9.3	10.9	11.215	11.954
10.93	210	11.174	9.3	10.9	11.327	12.221
10.52	225	11.474	9.3	10.9	11.327	12.528

Table-1 shows a trend of increasing net refrigeration effect over 3 hours. A high net refrigeration effect is desirable because the higher the quantity of heat absorbed from the refrigerating space within a short time interval, the less power will be consumed.¹⁸⁻²¹ 0.2 wt. % (Sample 1), 0.3 wt. % (Sample 2), 0.4 wt. % (Sample 3) and 0.6 wt. % (Sample S5) concentrations of the nano lubricant indicate higher NREs of approximately 19, 8, 4, and 9% respectively than the control sample. However, Sample S4 has the lowest net refrigerating effect which is 12% lower than that of the control sample.

CONCLUSION

The results of this study show a reduction in discharge temperature by 4-10% from 0.2 wt. %, 0.5 wt. %, and 0.6 wt. %, and a lower pull downtime of 40% from 0.2 wt. % concentration as compared to the values from the control sample, which contained pure mineral oil, exhibiting the maximum benefit of refrigeration after 225 minutes of operation as compared to the control sample.

ACKNOWLEDGMENT

The authors are grateful for the financial assistance provided by Afe Babalola University in Ado Ekiti in the completion of this research work for publication.

REFERENCES

1. D. S. Adelekan, O. S. Ohunakin, T. O. Babarinde, M. K. Odunfa, R. O. Leramo, S. O. Oyedepo, and D. C. Badejo, *Case Studies in Thermal Engineering*, **9**, 55(2017). <https://doi.org/10.1016/j.csite.2016.12.002>
2. N. Akev, A. Can, N. Sütülpınar, E. Çandöken, N. Özsoy, T. Y. Özden and E. Üzen, *İstanbul Üniversitesi Eczacılık Fakültesi Dergisi*, **45(2)**, 191 (2015).
3. M. Ahmaruzzaman, M, *Advances in Colloid and Interface Science*, **166**, 36(2011), <https://doi.org/10.1016/j.cis.2011.04.005>
4. O. O. Ajayi, D. E. Ukasoanya, M. Ogbonnaya, E. Y. Salawu, El. P. Okokpujie, S. A. Akinlabi, F. T. Owwoeye, *Procedia Manufacturing*, **35**, 112(2019), <https://doi.org/10.1016/j.promfg.2019.05.012>
5. K. Ali, S. Dwivedi, A. Azam, Q. Saquib, M. S. Al-said, A. A. Alkhedhairi and J. Musarrat, *Journal of Colloid and Interface Science*, **472**, 145(2016), <https://doi.org/10.1016/j.jcis.2016.03.021>
6. T. Somanathan, K. Prasad, K. K. Ostrikov, A. Saravanan and V. M. Krishna, *Nanomaterials*, **5(2)**, 826(2015), <https://doi.org/10.3390/nano5020826>
7. G. Sonnenrein, A. Elsner, E. Baumhögger, A. Morbach, K. Fieback and J. Vrabec, *International Journal of Refrigeration*, **51**, 154(2015), <https://doi.org/10.1016/j.ijrefrig.2014.12.011>
8. A.A.M. Redhwan, W. H. Azmi, M. Z. Sharif and N. N. M. Zawawi, *MATEC Web of Conferences*, **90**, (2016), <https://doi.org/10.1051/mateconf/20179001051>
9. Y. B. Pottathara, Y. Grohens, V. Kokol, N. Kalarikkal and S. Thomas, *Nanomaterials Synthesis: Design, Fabrication and Applications*, 25 pages (2019), <https://doi.org/10.1016/B978-0-12-815751-0.00001-8>
10. D. M. S. Zamare and S. S. Vutukuru, *International Journal of Engineering Applied Sciences and Technology*, **1(12)**, 85(2016).
11. X. Wu, C. Dang, S. Xu and E. Hihara, *International Journal of Refrigeration*, **108**, 209(2019), <https://doi.org/10.1016/j.ijrefrig.2019.08.025>
12. R. K. Veera and R. N. Govindha, *IOP Conference Series: Materials Science and Engineering*, **330(1)**, 012112(2018), <https://doi.org/10.1088/1757-899X/330/1/012112>
13. S. C. Thomas, Harshita, P. K. Mishra and S. Talegaonkar, *Current Pharmaceutical Design*, **21**, 6165(2015), <https://doi.org/10.2174/1381612821666151027153246>
14. G. Supriyanto, N. K. Rukman, A. K. Nisa, M. Jannatin, B. Piere, Abdullah, H. S. Kusuma, *BioResources*, **13(3)**, 4832(2018).
15. A. Sharma, *International Journal of Trend in Scientific Research and Development*, **2(3)**, 1108(2018), <https://doi.org/10.31142/ijtsrd11267>
16. A. Sebastian, A. Nangia and M. Prasad, *Journal of Agricultural and Food Chemistry*, **65(3)**, 557(2017), <https://doi.org/10.1021/acs.jafc.6b04634>
17. G. Saxena and R. N. Bharagava, *Bioremediation of Industrial Waste for Environmental Safety*, Springer Singapore, pp.207-221(2020), https://doi.org/10.1007/978-981-13-1891-7_10
18. F. M. Djuned, R.F. Adinda, H. Kamila and M. Faisal, *Rasayan Journal of Chemistry*, **15(2)**, 1028(2022), <http://dx.doi.org/10.31788/RJC.2022.1526658>
19. E. N. Sabiiti, *African Journal of Food, Agriculture, Nutrition and Development*, **11(6)**, 1(2011).
20. O. M. Ikumapayi, E. T. Akinlabi, A. O. M. Adeoye, O. S. Fatoba, *Material Today: Proceedings.*, **44(1)**, 1162(2021), <https://doi.org/10.1016/j.matpr.2020.11.233>
21. M. C. Agarana, E. T. Akinlabi, O. M. Ikumapayi, *Trends in Mechanical and Biomedical Design, Lecture Notes in Mechanical Engineering*, pp. 223-229(2021), https://doi.org/10.1007/978-981-15-4488-0_20
22. C. Veeravel, K. Rajasekar, S. Balasubramaniyan and R. Selvarani, *Rasayan Journal of Chemistry*, **14(4)**, 2285(2021), <http://doi.org/10.31788/RJC.2021.1446672>

[RJC-6807/2021]