PERFORMANCE OF POLYVINYL ETHER BASED NANOLUBRICANTS IN RESIDENTIAL AIR CONDITIONING

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We hereby declare that We have checked this thesis, and, in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Doctor of Philosophy.

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I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Penyaman udara kediaman (RAC) adalah salah satu peralatan rumah yang menyumbang kepada penggunaan tenaga yang tinggi. Usaha ke arah RAC yang cekap adalah penting dalam memenuhi tujuan penggunaan tenaga yang cekap. Satu teknik unik untuk menghadapi cabaran ini ialah menyebarkan zarah nano dalam pelincir RAC, iaitu pelincir nano. Aplikasi pelincir nano dalam sistem RAC boleh meningkatkan sifat pelincir asal dan meningkatkan prestasi sistem RAC. Kajian ini bertujuan untuk mengkaji sifat termo-fizik dan tribologi pelincir nano berasaskan Polyvinyl ether (PVE) yang dimasukkan zarah nano SiO_2 dan TiO_2 ke dalamnya, menilai prestasi RAC yang dikendalikan dengan pelincir nano tunggal dan hibrid, dan menyiasat keadaan optimum prestasi sistem RAC menggunakan pelincir nano. Zarah nano telah disebarkan ke dalam pelincir PVE dengan kepekatan isipadu yang berbeza sehingga 0.1% menggunakan kaedah penyediaan dua langkah. Kestabilan pelincir nano dinilai dengan kaedah kualitatif dan kuantitatif. Sifat reologi pelincir nano diukur pada suhu 30 hingga 100 °C manakala sifat kekonduksian terma dikaji sehingga suhu 80 °C. Sifat tribologi pelincir nano telah diuji menggunakan kaedah empat bola yang mematuhi piawaian ASTM D4172. Penyiasatan eksperimen untuk prestasi RAC telah dijalankan dalam pelantar ujian RAC yang disesuaikan bersama-sama dengan bilik kawalan haba. Pengoptimuman telah dijalankan menggunakan metodologi permukaan tindak balas manakala model regresi untuk parameter operasi juga dirumuskan. Parameter input sistem RAC telah dioptimumkan untuk suhu luar dan julat kepekatan masing-masing pada 31 hingga 39 °C dan 0 hingga 0.007%. Penilaian kestabilan menunjukkan bahawa semua pelincir nano mempunyai sifat kestabilan yang sangat baik dengan pemendapan terhad diperhatikan dalam tempoh 30 hari. Keputusan spektroskopi ultraungu boleh dilihat mendedahkan bahawa pelincir nano TiO_2/PVE menunjukkan hasil kestabilan terbaik dengan nisbah kepekatan 95% sehingga 30 hari. Nilai potensi zeta untuk semua jenis pelincir nano adalah lebih daripada 60 mV. Kelikatan dinamik dan kekonduksian terma pelincir nano mono dan hibrid meningkat dengan kepekatan isipadu tetapi menurun dengan suhu. Kelikatan meningkat tidak lebih daripada 2% untuk semua pelincir nano pada semua suhu. Penemuan menarik berlaku pada suhu 30 °C di mana kelikatan pelincir nano telah menurun berbanding dengan PVE tulen. Kenaikan kekonduksian terma maksimum 2.7% didapati pada kepekatan 0.01% pelincir nano TiO_2/PVE. Keputusan tribologi yang baik diperolehi daripada pelincir nano dengan kepekatan masing-masing pada 0.005% dan 0.015% untuk SiO_2/PVE dan TiO_2/PVE, dengan penurunan pekali pengurangan geseran sehingga 15%. Peningkatan prestasi didapati untuk hampir semua sampel yang diuji apabila pelincir nano digunakan dalam sistem RAC. Pelincir nano telah menyumbang kepada pengurangan kerja pemampat, peningkatan kapasiti penyejukan, dan pengurangan penggunaan kuasa sistem RAC. Pekali maksimum prestasi dan peningkatan nisbah kecekapan tenaga dicapai masing-masing pada 39.25% dan 52.74% untuk pelincir nano SiO_2-TiO_2/PVE pada kepekatan 0.005%. Keputusan pengoptimuman untuk pelincir nano SiO_2-TiO_2/PVE menghasilkan kerja pemampat optimum, kapasiti penyejukan dan penggunaan kuasa masing-masing sebanyak 29.322 kJ/kg, 4.564 kW dan 0.774 kW, pada kemahuan tertinggi 0.913. Aktiviti pengoptimuman mendapati bahawa 0.043% adalah kepekatan optimum untuk pelincir nano SiO_2-TiO_2/PVE. Kesimpulannya, pelincir nano meningkatkan sifat pelincir PVE dan meningkatkan prestasi sistem RAC yang beroperasi dengan bahan pendingin R32. Pelincir nano SiO_2-TiO_2/PVE dengan kepekatan 0.043% disyorkan untuk prestasi optimum sistem RAC.

ABSTRACT

Residential air conditioning (RAC) is a home appliance that contributes to high energy consumption. The endeavour toward efficient RAC is vital in fulfilling the purpose of utilising the energy effectively. One unique technique to encounter this challenge is by dispersing nanoparticles in the RAC lubricant, namely nanolubricant. Nanolubricant application in the RAC system can improve the properties of pure lubricants and enhance the performance of RAC systems. The present study aims to examine the thermo-physical and tribological properties of Polyvinyl ether (PVE) based nanolubricants dispersed with SiO_2 and TiO_2 nanoparticles, evaluate the performance of RAC operated with mono and hybrid nanolubricants, and investigate the optimum condition of RAC system performance using nanolubricant. The nanoparticles were dispersed in the PVE lubricant with up to 0.1% concentrations using the two-step method preparation. The stability of nanolubricants was evaluated by qualitative and quantitative methods. The rheological property of nanolubricants was measured at temperatures of 30 to 100 °C, while the thermal conductivity property was investigated up to 80 °C. The tribological property of nanolubricants was tested using the four-ball method that conforms to the ASTM D4172 standards. The experimental investigation for the RAC performance was conducted in a customised RAC test rig together with a thermal control room. The optimization was carried out using response surface methodology while regression models for the operating parameters were formulated. The RAC system input parameters were optimised for the outdoor temperature and concentration range of 31 to 39 °C and 0 to 0.007%, respectively. Stability evaluation showed that all nanolubricants have excellent stability attributes with limited sedimentation observed within 30 days. The ultraviolet-visible spectroscopy results revealed that the TiO_2/PVE nanolubricants showed the best stability results with 95% concentration ratio up to 30 days. The zeta potential values for all types of nanolubricants were more than 60 mV. Dynamic viscosity and thermal conductivity of the mono and hybrid nanolubricants increased with volume concentration but decreased with temperature. The maximum viscosity was increased by 2% for all nanolubricants at all temperatures. An exciting finding happened at 30 °C, where the viscosity of nanolubricants was decreased compared to pure PVE. A maximum 2.7% thermal conductivity increment was found at 0.01% concentration of TiO_2/PVE nanolubricant. Promising tribological results were obtained from nanolubricants with the concentration of 0.005% and 0.015% for SiO_2/PVE and TiO_2/PVE, respectively, with the coefficient of friction reduction up to 15%. Performance improvements were found for almost all tested samples when nanolubricants were applied in the RAC system. Nanolubricants have contributed to compressor work reduction, cooling capacity enhancement, and power consumption reduction of the RAC system. The maximum coefficient of performance and energy efficiency ratio enhancement were achieved at 39.25% and 52.74%, respectively, for SiO_2-TiO_2/PVE nanolubricant at 0.005% concentration. The optimization results for the SiO_2-TiO_2/PVE nanolubricants yield optimum compressor work, cooling capacity and power consumption of 29.322 kJ/kg, 4.564 kW and 0.774 kW, respectively, at the highest desirability of 0.913. The optimisation exercise found 0.043% was the optimum concentration for SiO_2-TiO_2/PVE nanolubricants. In conclusion, nanolubricants enhanced the properties of PVE lubricant and improved the performance of the RAC system operating with R32 refrigerant. The SiO_2-TiO_2/PVE nanolubricant with a concentration of 0.043% is recommended for the optimum performance of the RAC system.

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