

TRIBOLOGICAL CHARACTERISTICS OF MINERAL AND PLANT OIL  
BLENDS

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A thesis submitted in fulfilment of the  
requirements for the award of the degree of  
Doctor of Philosophy (Mechanical Engineering)

Faculty of Mechanical Engineering  
Universiti Teknologi Malaysia

MAY 2016

*To:*

*My God, Allah 'azza wa jalla*

*Then to My beloved family*

## ACKNOWLEDGEMENT

Thanks to ALLAH, the Most Gracious, the Most Merciful, the Most Bountiful who gave me the courage and patience to accomplish this research work. Without his help and mercy, this would not have come into reality.

I am deeply grateful to my supervisor, Prof Ir Dr. Farid Nasir Ani for his guidance, patience, and support. I have been extremely lucky to have a supervisor who cared so much about my work, and who responded to my questions and queries so promptly. I would like also to thank my co-supervisor, Asso. Prof. Dr. Syahrullail Bin Samion for his useful advices and encouragement. Without their valuable advice, kind encouragement and trust, I would not have reached this point.

I would like to acknowledge the Malaysian Ministry of Higher Education (MOHE), Iraqi Ministry of Higher Education & Scientific Research, Universiti Teknologi Malaysia and University of Technology/ Baghdad for providing the financial support and facilities for this research.

My thanks are also due to the staff, faculty members, and technicians of the Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, who contributed to my research.

I have been very providential to have the love and support of my family throughout my academic career. I am extremely grateful to my father Haj Hassan Jabal for his constant faith in me and for always supporting my efforts.

## ABSTRACT

Due to the biodegradability, low toxicity, high viscosity index, reasonably cost to produce and environment friendly, the bio-lubricants such as vegetable oils are being commonly used as sustainable resources. However, vegetable oils are still suffering from low wear resistance (high wear scar) and low thermal stability (low flash temperature parameter), which led to limit their applications. In this research, the evaluations of tribological characteristics as a new source of bio-lubricant, namely, cactus oil besides other different types of vegetable oils that include refined, bleached, and deodorized (RBD) palm olein, castor oil and also jatropha oil were implemented. These types of oils were employed as an extensive substitute to mineral oil in the air compressors machines and with the intention to reduce the amount of mineral oil, which these are non-degradable, toxic properties, unfriendly to the environment and also high-priced in producing, the blends of vegetable oils were also applied as a partially bio-lubricant replacement for the mineral oil. According to ASTM D4172-B standard test of four-ball tribotester, the lubricity of the oils was examined in terms of kinematic viscosity, viscosity index, coefficient of friction ( $C_f$ ), wear scar diameter ( $WSD$ ), and flash temperature parameter ( $FTP$ ). The results of normal load, rotation speed, and oil temperature were also evaluated for blended and neat oils, and then the results were compared to the mineral oil. The observations of the wear surfaces were attained utilizing an image processing that considered as a new technique in the tribological field, as well as the ball volumetric losses were also calculated. To optimise the blended oils based on the computed parameters, a design of experiments (DOE) method was used. The tribological performance characteristics, such as the wear losses, cylinder surface temperature, and kinematic viscosity were evaluated using a reciprocating air compressor for 60 hours as an intermittent operating time. As a comparison between the vegetable oils, the neat cactus oil shows a satisfaction tribological behaviour due to lowest value of ball volume losses and comparable results for wear scar diameter and flash temperature parameter after being used as an abundant bio-lubricant. It was also found that the cactus oil fulfilled a significantly better tribological performance as a partial bio-lubricant, as an illustration, the wear losses was 0.058 g/l for the optimum cactus blend codes as (E44.24/CC55.76), while the mineral oil was 0.09 g/l. The results also demonstrated that the wear scar diameter for the optimum cactus blend under 600 N shows a 37.83% reduction and the wear losses for the optimum RBD palm olein blend shows a 97.55% reduction. Furthermore, it was also observed that the flash temperature parameter values increased to be 135.35% and 114.07% for the E53.11/RB46.89 and E44.24/CC55.76, respectively, which therefore it is able to conclude that the blending process contributed towards improving of the tribological characteristics and the air compressor performance. With regards to the results of viscosity, the neat and optimised blends oils exhibit an essential consistency based upon the viscosity grade requirement of ISO VG32. Moreover, the results of image processing possesses appropriately represented the surface wear characteristics and provided precise details about the distribution of wear depth and wear shape together with the ball volumetric losses.

## ABSTRAK

Disebabkan kebiodegradasian, ketoksikan rendah, indeks kelikatan yang tinggi, harga yang berpatutan untuk dihasilkan dan mesra alam sekitar, biopelincir seperti minyak sayuran lazim digunakan sebagai sumber kelestarian. Walau bagaimanapun, minyak sayuran masih mengalami rintangan hausan rendah (keparutan hausan tinggi) dan kestabilan rendah haba (parameter suhu kilat rendah), yang membataskan penggunaannya. Dalam kajian ini, penilaian ciri-ciri tribologi sebagai sumber baru biopelincir iaitu minyak kaktus di samping jenis minyak sayuran lain yang berbeza termasuk minyak sawit olein tapis, diluntur, dan dinyahbau (RBD), minyak kastor dan minyak jatropha telah dilaksanakan. Jenis-jenis minyak tersebut telah digunakan dengan meluas sebagai pengganti minyak mineral dalam mesin pemampat udara dan tujuan untuk mengurangkan jumlah minyak mineral yang tidak boleh terurai, bersifat toksik, tidak mesra alam dan juga mahal untuk penghasilannya. Campuran minyak sayuran juga digunakan sebagai penggantian separa biopelincir untuk minyak mineral. Mengikut ujian standard ASTM D4172-B penguji tribo empat bebola, kebolehpelinciran minyak telah diperiksa dari segi kelikatan kinematik, indeks kelikatan, pekali geseran ( $C_f$ ), garispusat kehausan parut ( $WSD$ ), dan parameter suhu kilat ( $FTP$ ). Keputusan beban normal, kelajuan putaran, dan suhu minyak juga telah dinilai untuk minyak campuran dan tulen, dan kemudian keputusan dibandingkan dengan minyak mineral. Pemerhatian permukaan haus telah dicapai dengan menggunakan satu pemprosesan imej yang dianggap sebagai satu teknik baru dalam bidang tribologi, juga kehilangan isipadu bebola dikira. Untuk mengoptimumkan minyak campuran berdasarkan parameter yang dikira, satu kaedah reka bentuk eksperimen (DOE) telah digunakan. Ciri-ciri prestasi tribologi seperti kehilangan (berat) haus, suhu permukaan silinder, dan kelikatan kinematik telah dinilai menggunakan pemampat udara salingan selama 60 jam sebagai masa operasi yang berkala. Sebagai perbandingan antara minyak-minyak sayuran tersebut, minyak kaktus tulen menunjukkan ciri-ciri tribologi yang memuaskan kerana nilai terendah kehilangan jumlah isipadu bebola dan keputusan yang setanding untuk diameter kesan keparutan dan parameter suhu kilat selepas digunakan sebagai biopelincir. Didapati juga minyak kaktus memenuhi prestasi tribologi yang ketara lebih baik sebagai biopelincir separa, contohnya, kehilangan (berat) hausan adalah 0.058 g/l untuk kod campuran optimum minyak kaktus sebagai (E44.24/CC55.76), manakala minyak mineral adalah 0.09 g/l. Keputusan juga menunjukkan garispusat hausan parut untuk campuran kaktus optimum di bawah 600 N mengalami pengurangan sebanyak 37.83% dan kehilangan (berat) hausan untuk campuran olein sawit RBD optimum menunjukkan penurunan sebanyak 97.55%. Tambahan pula, nilai parameter suhu kilat didapati meningkat kepada 135.35% dan 114.07% bagi E53.11/RB46.89 dan E44.24/CC55.76. Dengan itu dapat disimpulkan bahawa proses pencampuran menyumbang kepada penambahbaikan ciri-ciri tribologi dan prestasi pemampat udara. Merujuk kepada ciri-ciri kelikatan yang diperolehi oleh minyak tulen dan minyak campuran yang telah dioptimumkan, ia mempamerkan suatu konsistensi yang penting berdasarkan kepada keperluan gred kelikatan ISO VG32. Selain itu, hasil pemprosesan imej mempunyai ciri hausan permukaan yang menggambarkan ciri kehausan permukaan dan memberikan butiran yang tepat mengenai taburan kehausan dalaman serta bentuk kehausan bersama kehilangan isipadu bebola.

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