SKRIPSI

ANALISIS DAN UJI SIFAT TRIBOLOGI BIOPELUMAS DARI LIMBAH MINYAK GORENG

Diajukan untuk Memenuhi dan Melengkapi Salah Satu Syarat dalam Menempuh Ujian Sarjana Program Studi Teknik Industri pada Fakultas Teknik Universitas Islam Sumatera Utara

MUHAMMAD FAQIH
71220911054

PROGRAM STUDI TEKNIK MESIN
FAKULTAS TEKNIK
UNIVERSITAS ISLAM SUMATERA UTARA
MEDAN
2024

HALAMAN PENGESAHAN

ANALISIS DAN UJI SIFAT TRIBOLOGI BIOPELUMAS DARI LIMBAH MINYAK GORENG

Diajukan untuk Memenuhi dan Melengkapi Salah Satu Syarat dalam Menempuh Ujian Sarjana Program Studi Teknik Industri pada Fakultas Teknik Universitas Islam Sumatera Utara

MUHAMMAD FAQIH
71220911054

Menyetujui
Pembimbing

Pembimbing I	**Pembimbing II**
(M.Rafiq Yanhar, S.T., M.T.)	**(Khairul Suhada, S.T., M.T.)**

Disetujui Oleh,

Ketua Program Studi Teknik Mesin,

(Ahmad Bakhori, S.T., M.T.)

PROGRAM STUDI TEKNIK MESIN
FAKULTAS TEKNIK
UNIVERSITAS ISLAM SUMATERA UTARA
MEDAN
2024

HALAMAN PENGESAHAN SKRIPSI

ANALISIS DAN UJI SIFAT TRIBOLOGI BIOPELUMAS DARI LIMBAH MINYAK GORENG

Diajukan untuk Memenuhi dan Melengkapi Salah Satu Syarat dalam Menempuh Ujian Sarjana Program Studi Teknik Industri pada Fakultas Teknik Universitas Islam Sumatera Utara

MUHAMMAD FAQIH
71220911054

Menyetujui
Pembimbing

Pembanding I	Pembanding II	Pembanding III
(Ir. H. Abdul Haris Nasution, M.T.)	(Ir. Suhardi Napid, M.T.)	(Ahmad Bakhori, S.T., M.T.)

Disetujui Oleh,

Ketua Program Studi Teknik Mesin,

(Ahmad Bakhori, S.T., M.T.)

PROGRAM STUDI TEKNIK MESIN
FAKULTAS TEKNIK
UNIVERSITAS ISLAM SUMATERA UTARA
MEDAN
2024

PERNYATAAN KEASLIAN

Saya yang bertanda tangan di bawah ini :

Nama : Muhammad Faqih

NPM : 71220911054

Prodi : Teknik Mesin

Fakultas : Teknik

Judul Skripsi : **ANALISIS DAN UJI SIFAT TRIBOLOGI BIOPELUMAS DARI LIMBAH MINYAK GORENG**

Dengan ini menyatakan bahwa hasil penelitian Skripsi yang telah saya buat ini merupakan hasil karua sendiri dan benar keasliannya. Apabila ternyata dikemudian hari penulis Skripsi ini merupakan hasil plagiat terhadap karya orang lain, maka saya bersedia mempertanggung jawabkannya sekaligus bersedia menerima sanksi akademis berdasarkan aturan dan tata tertib Universitas Islam Sumatera Utara.

Medan, 14 Oktober 2024

Muhammad Faqih

KATA PENGANTAR

Assalamu'alaikum Warahmatullahi Wabarakatuh

Alhamdulillahirabbil'alamin, puji syukur kepada Allah SWT yang telah memberikan rahmat dan karunia-Nya, sehingga dapat menyelesaikan penulisan Skripsi berjudul " Produksi dan Uji Sifat Tribologi Biopelumas dari Limbah Minyak Goreng" ini dengan baik.

Adapun tujuan penulisan skripsi ini adalah sebagai syarat untuk mencapai derajat Strata 1 (S1) pada program studi Teknik Mesin di Universitas Islam Sumatera Utara. Dalam Penelitian ini penulis banyak mendapatkan bantuan dari berbagai pihak, oleh karena itu pada kesempatan ini penulis menyampaikan ucapan terimakasih kepada :

1. Orang Tua tersayang selalu memberikan dukungan baik moral maupun materi, do'a, dan kasih sayang. Dan kepada seluruh keluarga penulis yang telah memberi do'a dan dukungan;

2. Bapak Ir. Muksin R Harahap, S.Pd., M.T, Selaku Kepala Prodi Teknik Mesin Universitas Islam Sumatera Utara;
3. Bapak M. Rafiq Yanhar, S.T., M.T. selaku dosen Pembimbing I penulis yang telah memberikan pengarahan serta dukungan dalam penyelesaian penulisan skripsi ini. Semoga Allah SWT selalu memberikan kesehatan dan membalas semua kebaikan yang telah diberikan;
4. Bapak Khairul Suhada, S.T., M.T. selaku Pembimbing II penulis yang telah memberikan pengarahan serta dukungan dalam penyelesaian laporan skripsi ini. Semoga Allah SWT selalu memberikan kesehatan dan membalas semua kebaikan yang telah diberikan;
5. Semua rekan-rekan mahasiswa UISU dan POLMED yang telah banyak memberikan bantuan dan motivasi kepada penulis dalam penyelesaian laporan skripsi ini.

Penulis juga menyadari dalam penulisan laporan skripsi ini masih terdapat banyak kekurangan, untuk itu penulis sangat mengharapkan saran dan kritik yang membangun dari pembaca. Penulis berharap semoga laporan skripsi ini dapat bermanfaat untuk menambah pengetahuan dan wawasan bagi pembaca.

Wassalam

Penulis,

Muhammad Faqih

DAFTAR ISI

Halaman

DAFTAR TABEL

Halaman

DAFTAR GAMBAR

Halaman

DAFTAR SINGKATAN

WCO	: *Waste Cooking Oil*
ASTM	: *American Standard Testing and Material*
KOH	: *Pottasium Hidroxide*
H_2SO_4	: *Sulfurid Acid*
H_3PO_4	: Asam Fosfat
TMP	: *Trimethylolpropane*
CH_3NaO	: Sodium methoxide
TWCOE	: *Trimethylolpropane Waste Cooking Oil Ester*

DAFTAR PUSTAKA

Aboelazayem, O., & Alayoubi, R. (2021). Sustainable Valorization of Waste Cooking Oil into Biofuels and Green Chemicals: Recent Trends, Opportunities and Challenges. Sustainable Solutions for Environmental Pollution: Waste Management and Value-Added Products, 1, 199-227. doi:https://doi.org/10.1002/9781119785439.ch5

Almasi, S., Ghobadian, B., Najafi, G., & Soufi, M. D. (2021). A review on bio-lubricant production from non-edible oil-bearing biomass resources in Iran: Recent progress and perspectives. *Journal of Cleaner Production, 290*, 125830. doi:https://doi.org/10.1016/j.jclepro.2021.125830

Annisa, A. N., & Widayat, W. (2018). *A review of bio-lubricant production from vegetable oils using esterification transesterification process.* Paper presented at the MATEC Web of Conferences.

Appiah, G., Tulashie, S. K., Akpari, E. E. A., Rene, E. R., & Dodoo, D. (2022). Biolubricant production via esterification and transesterification processes: Current updates and perspectives. *International Journal of Energy Research, 46*(4), 3860-3890. doi: https://doi.org/10.1002/er.7453

Aravind, A., Joy, M., & Nair, K. P. (2015). Lubricant properties of biodegradable rubber tree seed (Hevea brasiliensis Muell. Arg) oil. *Industrial crops and products, 74*, 14-19. doi:http://dx.doi.org/10.1016/j.indcrop.2015.04.014

Attia, N., El-Mekkawi, S., Elardy, O., & Abdelkader, E. (2020). Chemical and rheological assessment of produced biolubricants from different vegetable oils. *Fuel, 271*, 117578. doi:https://doi.org/10.1016/j.fuel.2020.117578

Bahadi, M., Salimon, J., & Derawi, D. (2021). Synthesis of di-trimethylolpropane tetraester-based biolubricant from Elaeis guineensis kernel oil via homogeneous acid-catalyzed transesterification. *Renewable Energy, 171*, 981-993. doi:https://doi.org/10.1016/j.renene.2021.02.163

Bahari, A., Lewis, R., & Slatter, T. (2018). Friction and wear response of vegetable oils and their blends with mineral engine oil in a reciprocating sliding contact at severe contact conditions. *Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology, 232*(3), 244-258. doi:https://doi.org/10.1177/1350650117712344

Cao, D., Matsakas, L., Zhang, J., Dong, L., Shi, Y., Zhu, J., . . . Mu, L. (2024). Biolubricant. *Sustainable Production Innovations: Bioremediation and Other Biotechnologies*, 1-56.

Cao, Y., Wang, N., Fu, H., You, F., & He, L. (2020). Technologies for Conversion Bio-Lubricant Production in Fatty Acids. *Industrial Oil Plant: Application Principles and Green Technologies*, 175-200. doi:10.1007/978-981-15-4920-5_7

Cavalcanti, E. D., Aguieiras, E. C., da Silva, P. R., Duarte, J. G., Cipolatti, E. P., Fernandez-Lafuente, R., . . . Freire, D. M. (2018). Improved production of biolubricants from soybean oil and different polyols via esterification reaction

catalyzed by immobilized lipase from Candida rugosa. *Fuel*, *215*, 705-713. doi:https://doi.org/10.1016/j.fuel.2017.11.119

Chowdary, K., Kotia, A., Lakshmanan, V., Elsheikh, A. H., & Ali, M. K. A. (2021). A review of the tribological and thermophysical mechanisms of bio-lubricants based nanomaterials in automotive applications. *Journal of Molecular Liquids*, *339*, 116717. doi:https://doi.org/10.1016/j.molliq.2021.116717

Crown, O. (2023). Fuels and lubricants -hydraulic fluids. In: https://www.crownoil.co.uk/guides/hydraulic-oil-guide/.

ESDM. (2023). *Handbook Of Energy & Economic Statistics Of Indonesia*: Kementerian Energi dan Sumber Daya Mineral.

Farfan-Cabrera, L. I., Gallardo-Hernández, E. A., & Pérez-González, J. (2017). Compatibility study of common sealing elastomers with a biolubricant (Jatropha oil). *Tribology International*, *116*, 1-8. doi:http://dx.doi.org/10.1016/j.triboint.2017.06.039

Garlapati, V. K., Mohapatra, S. B., Mohanty, R. C., & Das, P. (2021). Transesterified Olax scandens oil as a bio-additive: Production and engine performance studies. *Tribology International*, *153*, 106653. doi:https://doi.org/10.1016/j.triboint.2020.106653

Gul, M., Zulkifli, N. W. M., Kalam, M. A., Masjuki, H. H., Mujtaba, M. A., Yousuf, S., . . . Noor, S. (2021). RSM and Artificial Neural Networking based production optimization of sustainable Cotton bio-lubricant and evaluation of its lubricity & tribological properties. *Energy Reports*, *7*, 830-839. doi:https://doi.org/10.1016/j.egyr.2021.01.033

Guo, H., Adukure, A. R., & Iglesias, P. (2019). Effect of ionicity of three protic ionic liquids as neat lubricants and lubricant additives to a biolubricant. *Coatings*, *9*(11), 713. doi:https://doi.org/10.3390/coatings9110713

Gupta, S., Zaid, M., Kumar, A., & Singh, Y. (2020). Effect of Jojoba oil based biolubricant additive on the friction and wear characteristics of the Al-7Si alloy. *Materials Today: Proceedings*, *26*, 2681-2684. doi:https://doi.org/10.1016/j.matpr.2020.02.564

Hotha, K. K., Roychowdhury, S., & Subramanian, V. (2016). Drug-excipient interactions: case studies and overview of drug degradation pathways. *American Journal of Analytical Chemistry*, *7*(1), 107-140.

Hussein, R. Z., Attia, N. K., Fouad, M. K., & ElSheltawy, S. T. (2021). Experimental investigation and process simulation of biolubricant production from waste cooking oil. *Biomass and Bioenergy*, *144*, 105850.

imarcgroup. (2024). Used Cooking Oil Market Report by Source (Household Sector, Commercial Sector), Application (Biodiesel, Oleo Chemicals, Animal feed, and Others), and Region 2024-2032. Retrieved from https://www.imarcgroup.com/used-cooking-oil-market

ISO. (2023). In.

Jason, Y. J. J., How, H. G., Teoh, Y. H., & Chuah, H. G. (2020). A study on the tribological performance of nanolubricants. *Processes*, *8*(11), 1372. doi:https://doi.org/10.3390/pr8111372

Joshi, J. R., Bhanderi, K. K., & Patel, J. V. (2023). A review on bio-lubricants from non-edible oils-recent advances, chemical modifications and applications. *Journal of the Indian Chemical Society*, *100*(1), 100849. doi:https://doi.org/10.1016/j.jics.2022.100849

Joshi, J. R., Bhanderi, K. K., Patel, J. V., & Karve, M. (2023). Chemical modification of waste cooking oil for the biolubricant production through transesterification process. *Journal of the Indian Chemical Society, 100*(3), 100909. doi:https://doi.org/10.1016/j.jics.2023.100909

Kamalakar, K., Manoj, G. S., Prasad, R., & Karuna, M. (2015). Influence of structural modification on lubricant properties of sal fat-based lubricant base stocks. *Industrial crops and products, 76*, 456-466. doi:https://doi.org/10.1016/j.indcrop.2015.07.050

Kamyab, B., Beims, R. F., Chio, C., Qin, W., Chambers, D. W., & Xu, C. C. (2024). Synthesis of TMP esters as a biolubricant from canola oil via a two-step transesterification–transesterification process. *The Canadian Journal of Chemical Engineering, 102*(1), 35-52. doi:10.1002/cjce.25024

Karmakar, G., Ghosh, P., & Sharma, B. K. (2017). Chemically modifying vegetable oils to prepare green lubricants. *Lubricants*, *5*(4), 44. doi:https://doi.org/10.3390/lubricants5040044

Kurre, S. K., & Yadav, J. (2023). A review on bio-based feedstock, synthesis, and chemical modification to enhance tribological properties of biolubricants. *Industrial crops and products*, *193*, 116122. doi:https://doi.org/10.1016/j.indcrop.2022.116122

Liu, S., Nie, K., Zhang, X., Wang, M., Deng, L., Ye, X., . . . Tan, T. (2014). Kinetic study on lipase-catalyzed biodiesel production from waste cooking oil. *Journal of Molecular Catalysis B: Enzymatic*, *99*, 43-50. doi:https://doi.org/10.1016/j.molcatb.2013.10.009

Lubrication, M. (2023). International Standard Organization Viscosity Grade Retrieved from https://www.machinerylubrication.com/Read/213/iso-viscosity-grades

Malik, M. A. I., Kalam, M., Mujtaba, M., & Almomani, F. (2023). A review of recent advances in the synthesis of environmentally friendly, sustainable, and nontoxic bio-lubricants: Recommendations for the future implementations. *Environmental Technology & Innovation*, 103366. doi:https://doi.org/10.1016/j.eti.2023.103366

McNutt, J. (2016). Development of biolubricants from vegetable oils via chemical modification. *Journal of industrial and Engineering Chemistry*, *36*, 1-12. doi:https://doi.org/10.1016/j.jiec.2016.02.008

Mobarak, H., Mohamad, E. N., Masjuki, H. H., Kalam, M., Al Mahmud, K., Habibullah, M., & Ashraful, A. (2014). The prospects of biolubricants as

alternatives in automotive applications. *Renewable and sustainable energy reviews, 33*, 34-43.

Mohadesi, M., Aghel, B., Maleki, M., & Ansari, A. (2019). Production of biodiesel from waste cooking oil using a homogeneous catalyst: Study of semi-industrial pilot of microreactor. *Renewable Energy, 136*, 677-682.

Mohamed, N., Hamidon, M. L. H., Jumadi, R., Khalid, A., Jaat, N., Salleh, H., & Samion, S. (2022). Analysis of the Biodegradable Lubricant in Internal Combustion Engine. *Journal of Automotive Powertrain and Transportation Technology, 2*(1), 47-55.

Moreira, D. R., Chaves, P. O. B., Ferreira, E. N., Arruda, T. B. M. G., Rodrigues, F. E. A., Neto, J. F. C., . . . Ricardo, N. M. P. S. (2020). Moringa polyesters as eco-friendly lubricants and its blends with naphthalenic lubricant. *Industrial crops and products, 158*, 112937. doi:https://doi.org/10.1016/j.indcrop.2020.112937

Muhammad, C., Usman, Z., & Agada, F. (2018). Biodiesel production from Ceiba pentandra seed oil using CaO derived from snail shell as catalyst. *Pet. Sci. Eng, 2*, 7-16. doi:10.11648/j.pse.20180201.12

Negi, R. S., Singh, R. K., Atray, N., & Singh, S. K. (2023). Potential valorization of used cooking oil into novel biolubricating grease through chemical modification and its performance evaluation. *Industrial crops and products, 205*, 117555. doi:https://doi.org/10.1016/j.indcrop.2023.117555

Njuguna, J., Siddique, S., Kwroffie, L. B., Piromrat, S., Addae-Afoakwa, K., Ekeh-Adegbotolu, U., . . . Moller, L. (2022). The fate of waste drilling fluids from oil & gas industry activities in the exploration and production operations. *Waste Management, 139*, 362-380. doi:https://doi.org/10.1016/j.wasman.2021.12.025

Otabor, G., Ifijen, I., Mohammed, F., Aigbodion, A., & Ikhuoria, E. (2019). Alkyd resin from rubber seed oil/linseed oil blend: A comparative study of the physiochemical properties. *Heliyon, 5*(5), e01621.

Paar, A. (2023). ISO viscosity classification ISO 3448. In: https://wiki.anton-paar.com/en/iso-viscosity-classification/.

Paar, A. (2024). ISO Viscosity Classification - ISO 3448. Retrieved from https://wiki.anton-paar.com/en/iso-viscosity-classification/

Panchal, T. M., Patel, A., Chauhan, D., Thomas, M., & Patel, J. V. (2017). A methodological review on bio-lubricants from vegetable oil based resources. *Renewable and Sustainable Energy Reviews, 70*, 65-70. doi:http://dx.doi.org/10.1016/j.rser.2016.11.105

Pariffin. (2023). Paraffin Gear Oil H1 Elkalub. Retrieved from https://www.komori.de/static/default/files/documents/pdf/K-Supply/KS_Paraffin_Gear_Oil_H1_ISO_VG_68_LR.pdf

Pariffin. (2024). Pariffin ISO VG 95. Retrieved from http://www.paraffinlubricants.com/hydraulic-oil/

Perera, M., Yan, J., Xu, L., Yang, M., & Yan, Y. (2022). Bioprocess development for biolubricant production using non-edible oils, agro-industrial byproducts and wastes. *Journal of Cleaner Production, 357*, 131956. doi:https://doi.org/10.1016/j.jclepro.2022.131956

Prasannakumar, P., Sankarannair, S., Bose, C., Santhakumari, R., & Jyothi, S. N. (2023). Influence of techniques on synthesizing cashew nut shell oil as a prospective biolubricant on its physicochemical, tribological, and thermal behaviors. *Journal of Cleaner Production, 401*, 136717. doi:https://doi.org/10.1016/j.jclepro.2023.136717

Putra, M. D., Nata, I. F., & Irawan, C. (2020). Biodiesel production from waste cooking oil using heterogeneous catalyst: Biodiesel product data and its characterization. *Data in brief, 28*.

Reeves, C. J., Siddaiah, A., & Menezes, P. L. (2018). Tribological study of imidazolium and phosphonium ionic liquid-based lubricants as additives in carboxylic acid-based natural oil: Advancements in environmentally friendly lubricants. *Journal of Cleaner Production, 176*, 241-250. doi:https://doi.org/10.1016/j.jclepro.2017.12.099

Shankar, S., Manikandan, M., Raja, G., Priyadharashini, G. S., & Pramanik, A. (2021). Experimental studies on viscosity, thermal and tribological properties of vegetable oil (kapok oil) with boric acid as an additive. *Micro & Nano Letters, 16*(5), 290-298. doi:10.1049/mna2.12045

Shell. (2018). Helix HX5 15W-40. Retrieved from https://www.shell-livedocs.com/data/published/en-PH/761115b0-5bc8-430c-9830-e5f727419b44.pdf

Shell. (2020). Quaker State SAE0W-20 Motor Oil Full Synthetic Motor Oil. Retrieved from https://www.shell-livedocs.com/data/published/en/12f1955d-0457-4745-9fab-41a16ced3dd0.pdf

Silitonga, A., Mahlia, T., Kusumo, F., Dharma, S., Sebayang, A., Sembiring, R., & Shamsuddin, A. (2019). Intensification of Reutealis trisperma biodiesel production using infrared radiation: Simulation, optimisation and validation. *Renewable Energy, 133*, 520-527. doi:https://doi.org/10.1016/j.renene.2018.10.023

Soni, S., & Agarwal, M. (2014). Lubricants from renewable energy sources–a review. *Green Chemistry letters and reviews, 7*(4), 359-382.

Sun, G., Li, Y., Cai, Z., Teng, Y., Wang, Y., & Reaney, M. J. (2017). K2CO3-loaded hydrotalcite: a promising heterogeneous solid base catalyst for biolubricant base oil production from waste cooking oils. *Applied catalysis b: environmental, 209*, 118-127. doi:https://doi.org/10.1016/j.apcatb.2017.02.078

Syahir, A., Zulkifli, N., Masjuki, H., Kalam, M., Alabdulkarem, A., Gulzar, M., . . . Harith, M. (2017). A review on bio-based lubricants and their applications. *Journal of Cleaner Production, 168*, 997-1016. doi:http://dx.doi.org/10.1016/j.jclepro.2017.09.106

Syaima, M., Ong, K., Noor, I. M., Zamratul, M., Brahim, S., & Hafizul, M. (2015). The synthesis of bio-lubricant based oil by hydrolysis and non-catalytic of palm oil mill effluent (POME) using lipase. *Renewable and Sustainable Energy Reviews, 44*, 669-675. doi:https://doi.org/10.1016/j.rser.2015.01.005

Thapar, S. (2024). Energy and Climate Change. In *Renewable Energy: Policies, Project Management and Economics: Wind and Solar Power (India)* (pp. 1-11): Springer.

Ude, C. N., Igwilo, C. N., Nwosu-Obieogu, K., Nnaji, P. C., Oguanobi, C. N., Amulu, N. F., . . . Omenihu, U. C. (2023). Optimization of dual transesterification of jatropha seed oil to biolubricant using hybridized response surface methodology (RSM) and adaptive neuro fuzzy inference system (ANFIS)-genetic algorithm (GA). *Sustainable Chemistry for the Environment, 4*, 100050. doi:https://doi.org/10.1016/j.scenv.2023.100050

Vigneshwaran, S., Sundarakannan, R., John, K., Johnson, R. D. J., Prasath, K. A., Ajith, S., . . . Uthayakumar, M. (2020). Recent advancement in the natural fiber polymer composites: A comprehensive review. *Journal of Cleaner Production, 277*, 124109. doi:https://doi.org/10.1016/j.jclepro.2020.124109

Wang, E., Ma, X., Tang, S., Yan, R., Wang, Y., Riley, W. W., & Reaney, M. J. (2014). Synthesis and oxidative stability of trimethylolpropane fatty acid triester as a biolubricant base oil from waste cooking oil. *Biomass and Bioenergy, 66*, 371-378. doi:https://doi.org/10.1016/j.biombioe.2014.03.022

Zaid, M., Singh, Y., Kumar, A., & Gupta, S. (2020). Development of the Calophyllum inophyllum based biolubricant and their tribological analysis at different conditions. *Materials Today: Proceedings, 26*, 2582-2585. doi:https://doi.org/10.1016/j.matpr.2020.02.546

Zainal, N., Zulkifli, N., Gulzar, M., & Masjuki, H. (2018). A review on the chemistry, production, and technological potential of bio-based lubricants. *Renewable and Sustainable Energy Reviews, 82*, 80-102. doi:https://doi.org/10.1016/j.rser.2017.09.004

LAMPIRAN