DESIGN AND DEVELOPMENT OF AN INNOVATIVE INSTRUMENT TO MEASURE CONSISTENCY AND USEFUL LIFE IN GREASES

Greases are complex substances that are prone to deprivation in their performance due to their operation under severe operating conditions and contaminations due to water and particles. Therefore, they demand testing at regular intervals, to understand the condition of the grease and henceforth, take necessary maintenance actions. As of now, the available test methodologies require a large collection of samples from the components and testing in the laboratory, which leads to a longer waiting time for the decision-making. To overcome these difficulties, a new state-of-the-art contact angle instrument is proposed and developed that abides the latest ASTM requirements. This instrument determines the condition of the grease by measuring the contact angle values of a water droplet on the grease surface. The key feature of the instrument is portability, requiring a lesser amount of grease for testing, and a minute of testing time.

All greases are susceptible to both physical and chemical degradation. Physical degradation primarily prevails due to: shearing of grease at higher shear-rate, evaporation off of base oil, contamination by particles and/or water or combination above three processes, all occurring below 50° C [4]. The chemical degradation of greases is due to the oxidation reactions, which result in significant alterations to the chemical composition of the base oil and thickener [5].

Clearly, the testing of grease to ensure proper functionality is crucially important. Therefore, the development of testing instruments to understand and improve grease quality has a very high scope in numerous industries [6]. The commonly used testing methods for testing greases are by using a rheometer or penetrometer. Utilizing a combination of these two instruments has proven to be effective, but due to the requirement of large amounts of grease required to perform a test with a penetrometer, the intensive expertise required to use a rheometer along with the high pricing of both instruments, makes these methods undesirable [3]. Further, these instruments are for laboratory purposes and are not portable.

With the expertise from Louisiana State University, Koehler Instrument Company is manufacturing a new state-of-the-art contact angle instrument that abides by the latest ASTM requirements. The technique of the instrument leverages the chemistry behind the interaction of the water droplet with the surface-active components within the grease structure to assess the behavior of the grease [7]. The instrument analyses the interactions to determine the grease properties such as: water resistance, consistency, degradation of grease due to oxidation etc. By determining the consistency change, the useful life of the grease can be predicted [8]. The development and utilization of a contact angle instrument will enable accurate and cost-effective on-field testing of the greases using a small quantity of grease (0.1 gm of NLGI grade 2 grease).

The contact angle is the angle between the surface of the grease and the gradient of the tangent of the droplet edge (see Figure 1). Figure 2 depicts the qualitative relationship between the contact angle and wetting properties. A larger contact angle often implies the grease is hydrophobic/pristine/higher grade/non-oxidized grease, while a smaller contact angle often means the grease is hydrophilic/degraded/lower grade/oxidized.

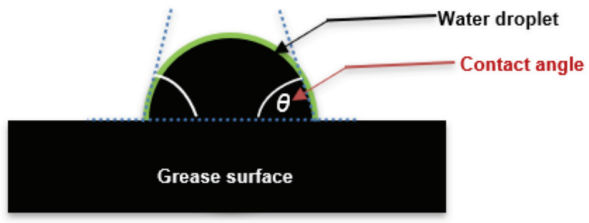

Figure 1. Visual Representation of the contact angle

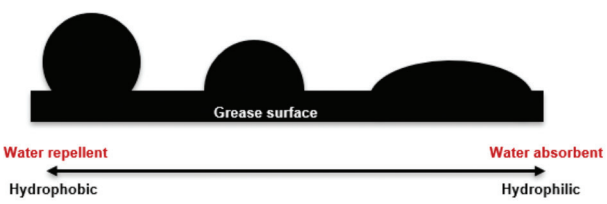

Figure 2. What the contact angle can tell us about the material [9]

The contact angle instrument is operated by dispensing a water drop onto the semi-solid grease surface and capturing the video of the water droplet [6]. The software deployed in the Raspberry pi (a basic barebones micro-processor for the prototype model) is used to determine the contact angle of the water droplet.

Figure 3. Raspberry Pi board

The contact angle instrument includes five major components that all work in unison to produce an efficient and accurate result. The components are: dispensing system, the stage, the viewing system, grease holder, and the measurement system. The dispensing system consists of a micro-syringe to hold and dispense the liquid and can be operated manually or by a micro-pump [6]. The stage is the part of the instrument that holds the solid surface still. The viewing system consists of a camera to capture and a lens to magnify the image of the water drop on the grease surface. The viewing system also includes a monochromatic light source to illuminate the samples and enhance the visibility of the outline of the drop [6]. The viewing system assembly can be seen in Figure 4. Grease samples are placed on the grease holder.

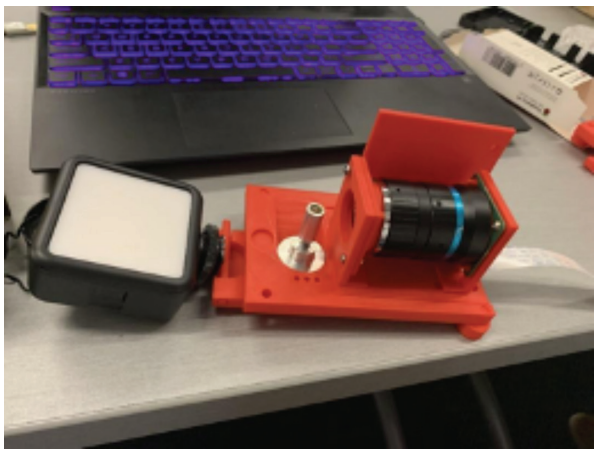

Figure 4. Contact angle instrument viewing system

Lastly, the system measures the contact angle from the image captured by the viewing system. It is important to note that the measurement system is not a physical part of the instrument. This is done using a software program set up to trace the grease surface, droplet edge, and gradient to calculate the contact angle. These programs can provide additional information like drop volume and contact area with the correct calibrations [6]. A considerable proposition is often brought up to challenge the contact angle method. This is because greases are a semi-solid substance, and when a liquid droplet is placed on a greased surface, the liquid spreads and gets absorbed by the grease; therefore, the droplet size and the contact angle values change with time. This instrument, to address this issue, includes a droplet video recording at three frames a second with the images at different intervals, which are analyzed for the contact angle [6]. The option to view all the contact angle measurements is available in the instrument's software.

The contact angle instrument is the perfect solution for the industry in dire need of a portable and faster testing approach. The concept of determining grease wetting properties by measuring the contact angle can potentially change the lubrication industry. The immense knowledge and data obtained through this instrument allow users to become aware of any significant problems with their grease and take necessary maintenance action. Be sure to check for the flaws in your grease products upon next use to potentially save your system from failing.

References

[1] Engineers Edge, L. L. C. (n.d.). Application of grease review. Engineers Edge - Engineering, Design and Manufacturing Solutions. Retrieved January 3, 2022, from https://www.engineersedge.com/lubrication/application_grease.htm

[2] Dhiman, C., Reddy, M., Gulati, K., & Khan, M. (2014). Detection of elemental composition of lubricating grease using laser induced breakdown spectroscopy. Lubricants, 2(4), 223–236. https://doi.org/10.3390/lubricants2040223

[3] Wright, J. (2019, June 21). Grease Basics. Machinery Lubrication. Retrieved January 3, 2022, from https://www.machinerylubrication.com/Read/1352/grease-basics .

[4] Lijesh, K. P., Khonsari, M. M., & Miller, R. A. (2020). Assessment of water contamination on grease using the contact Angle Approach. Tribology Letters, 68(4). https://doi.org/10.1007/s11249-020-01339-0

[5] Rezasoltani, Asghar & Khonsari, M. (2016). On Monitoring Physical and Chemical Degradation and Life Estimation Models for Lubricating Greases. Lubricants. 4. 34. 10.3390/lubricants4030034.

[6] Bharadwaj, S. (2021). |Project Management| |Capstone Project|. Retrieved December 20, 2021.

[7] Lijesh & Miller, Roger & Shah, Raj. (2021). Evaluating Grease Degradation through Contact Angle Approach. Lubricants. 9. 11. 10.3390/lubricants9010011.

[8] Lijesh, K. P., and M. M. Khonsari. "On the assessment of mechanical degradation of grease using entropy generation rate." Tribology Letters 67, no. 2 (2019): 1-13.

[9] Contact Angle: A Guide to Theory and Measurement. Ossila. (n.d.). Retrieved January 3, 2022, from https://www.ossila.com/pages/contact-angle-theory-measurement

Authors

Lijesh Koottaparambil is a post doctorate student at Louisiana State University, US. In the year 2018, he joined LSU as a Indo-US postdoctoral fellow. He completed his doctoral degree from Indian Institute of Technology, Delhi, India. He has coauthored 60 peer reviewed publications. He holds five patents and two project grants in his name. His research interests includes wear, friction, lubrication, magnetic bearings and MR fluids.

Professor M. M. Khonsari holds the Dow Chemical Endowed Chair in Rotating Machinery and Professor of Mechanical Engineering at Louisiana State University (LSU). Prof. Khonsari earned his B.S., M.S., and Ph.D. all in Mechanical Engineering from The University of Texas at Austin. Prior to joining LSU, he spent a number of years as a faculty member at The Ohio State University, University of Pittsburgh, and served as the Chairman of the Department of Mechanical Engineering and Energy Processes at Southern Illinois University. Professor Khonsari has also served as a Research Faculty Fellow at NASA Glenn (Formerly Lewis) Research Center, Wright-Patterson Air Force laboratories, and the U.S. Department of Energy.

He is the holder of 8 US patents, has authored 494 archival papers, 50 book chapters and special publications, 3 technical books and delivered over 180 invited lectures, seminars, and plenary presentations. Professor Khonsari is the recipient of several research awards including the ASME Mayo Hersey Award, Burt Newkirk Award, the STLE Presidential Award, ALCOA awards for his contributions to tribology, and is the recipient of the LSU College of Engineering Outstanding Research Award. He is the Editor-in-Chief for ASME Journal of Tribology and serves on the editorial board of eight other journals. Professor Khonsari is a fellow of American Society of Mechanical Engineers (ASME), Society of Tribologist and Lubrication Engineers (STLE), American Association for the Advancement of Science (AAAS) and a Senior Member of the National Academy of Inventors (NAI).

Dr. Raj Shah is a Director at Koehler Instrument Company in New York, where he has worked for the last two decades. He is an elected Fellow by his peers at IChemE, CMI, STLE, AIC, NLGI, INSTMC, Institute of Physics, The Energy Institute and The Royal Society of Chemistry. An ASTM Eagle award recipient, Dr. Shah recently coedited the bestseller, "Fuels and Lubricants handbook", details of which are available at

ASTM's Long-Awaited Fuels and Lubricants Handbook 2nd Edition Now Available - Jul 15 2020 - David Phillips - Petro Industry News Articles - Petro Online (petro-online.com)

A Ph.D in Chemical Engineering from The Penn State University and a Fellow from The Chartered Management Institute, London, Dr. Shah is also a Chartered Scientist with the Science Council, a Chartered Petroleum Engineer with the Energy Institute and a Chartered Engineer with the Engineering council, UK. Dr. Shah was recently granted the honourific of "Eminent engineer" with Tau beta Pi, the largest engineering society in the USA. He is on the Advisory board of directors at Farmingdale university (Mechanical Technology), Auburn Univ (Tribology) and Stony Brook University (Chemical engineering/ Material Science and engineering).

An adjunct professor at the Dept. of Material Science and Chemical Engineering at State University of New York, Stony Brook, Adjunct Professor in Engineering Management at Hofstra University, Hempstead, NY, Raj also has over 450 publications and has been active in the petroleum field for 3 decades. More information on Raj can be found at

Koehler Instrument Company's Director elected as a Fellow at the International Institute of Physics Petro Online (petro-online.com)

Mr. Anthony Schevon is a student of Chemical engineering at SUNY, where Dr. Raj Shah is the chair of the external advisory board of directors. Anthony is also part of a thriving internship program at Koehler instrument company. Anthony is the founder of the newly established SBU Energy Club at Stony Brook University where Dr. Shah helps as an advisor.

Shashank Bharadwaj completed graduate school at Hofstra University in engineering management. He is an entrepreneur at heart with a background and few years of industrial experience in in computer science and Engineering and is currently working at Koehler instrument company in Holtsville, NY as a product development intern

Author Contact Details

Dr. Raj Shah, Koehler Instrument Company • Holtsvile, NY 11742 USA
• Email: rshah@koehlerinstrument.com • **Web: www.koehlerinstrument.com**

Lijesh Koottaparambil • Louisiana State University

Michael M. Khonsari • Louisiana State University

Anthony Schevon • Koehler Instrument Company

Shashank Bharadwaj • Koehler Instrument Company

Lijesh Koottaparambil

Michael M. Khonsari

Anthony Schevon

Shashank Bharadwaj

Raj Shah