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# The role of sustainable oil maintenance on lubrication system reliability

**Zahra Fatemi**[a*]

[a]*School of Engineering, Department of Industrial Engineering, Iran University of Science and Technology, Tehran, Iran*

C H R O N I C L E

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A B S T R A C T

This article discusses the value of sustainable oil maintenance by using submicron high-tech offline filtration based on oil condition monitoring to reduce wear particles and improve system reliability. These activities incorporate broader goals of establishing a proactive maintenance approach, defined as continuous monitoring and controlling of the root causes of machine failure. Among these causes, contamination is the industry's most severe, popular, and most recognized failure cause. In order to ensure all necessary proactive maintenance activities, this paper uses practical analysis for oil contamination monitoring based on ISO 4405. The author applied a 0.1-micron high-tech offline filtration for lubrication systems of ball mills in the Sungun copper mine as an oil maintenance activity to control the system lubrication contamination as a root cause of failures.



## 1. Introduction

Proactive maintenance is motivated by failure root causes rather than early signs and symptoms of failures like predictive maintenance. While the root causes of failure are many, ten percent of the failure causes are responsible for ninety percent of the occurrences. Proactive maintenance keeps equipment serviced and in working order focusing on eliminating the root causes of failures based on condition monitoring. Proactive monitoring of the lubricant is an ideal method of determining lubricant level of contamination and the need for oil filtration or replacement (Muller et al., 2008). Three steps are necessary to ensure its benefits are achievable whenever a proactive maintenance strategy is applied. The first step is to set a target, or standard, associated with each root cause. The second step includes all necessary activities in order to achieve the target. The third step is based on continuous control activities on monitoring and controlling (Canito et al., 2017). The most significant root causes of Sungun lubrication system problems were contamination and oil additive level decreasing. The proactive maintenance approach applied to the root causes of system failures in Sungun copper mine lubrication is explained in the following. Implementing sustainable oil maintenance to make lubrication systems eco-friendlier, more economical, and reliable is a complicated topic that has piqued the interest of the industrial sector for many years. Equipment plays a vital role in the open pit mining industry. The application of specific oil filtration technology is investigable to minimize equipment breakdowns, downtimes, lubrication costs, and wastes in the Sungun copper mine as a proactive maintenance activity. The best controls, and least expensive in the long run, are practices that focus on prevention rather than treatment. It is always easy and less expensive to prevent breakdowns and downtimes to solve if, after being created, research concentrated on filtration as a promising prevention technique. Using filtration can increase the value in the processing level of mining and save changing oil costs.

## 2. Literature review

This paper mostly spans across three streams in the related literature: (i) sustainability, (ii) lubrication management, and (iii) maintenance.

* Corresponding author.
E-mail address: z_fatemi@ind.iust.ac.ir (Z. Fatemi)

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*2.1. Sustainability*

*Sustainability* is some specifications that maintain or enhance the condition and availability of desired materials or equipment over the long run, considering social, environmental, and economic aspects (Hernández-Diaz et al., 2021; Trautwein, 2021; Ramos et al., 2021; Behravesh et al., 2022; Horne & Fichter, 2022). Based on empirical data from Chinese and New Zealand company partnerships, Chen et al. (2021) investigate sustainability conflicts among businesses in business partnerships and how managers make sense of them. Silva (2021) investigates how businesses manage their legitimacy by addressing their contribution to the United Nations Sustainable Development Goals (SDGs). Gonzalez-Ramirez and Rodriguez-Gonzalez (2021) present a non-cooperative game as a case study of decision-making in establishing an acetic acid factory. Sebestyén and Abonyi (2021) use a data-driven comparison technique to assess each country's progress toward reaching sustainable development objectives. Coffay et al. (2022) combine RRI, living labs, and the effectuation concept with the effects of sustainability. Liu and Ren (2022) propose a methodological framework based on game theory and a multi-criteria decision-making (MCDM) approach to handling the decision-making issue for sustainable sludge management with competing interests of multiple stakeholders.

*2.2. Lubrication management*

Lubricating oil, in addition to being a finite resource, creates waste oil, presenting a hazard to both human health and the environment; as a result, substantial work on lubrication management has lately been conducted (Mishra et al., 2021). Zzeyaniet al. (2019) use Electron Paramagnetic Resonance (EPR) and Fourier Transform Infrared spectroscopy (FTIR) methods to assess the impact of Chamaerops Humilis L. (EEG) and Amposta red onion (EET) antioxidant extracts on the regeneration of waste lubricating oils. Sleiti (2020) investigates the use of Polyalpha-Olefin (PAO) oil in combination with hexagonal Boron Nitride (hBN) to create a new class of nanofluids for heat transfer and lubricating applications. Osman et al. (2020) use analysis of variance and response surface methods to evaluate the effects of a minimal amount of lubrication with varying concentrations of hexagonal boron nitride nanoparticles on the surface roughness and cutting force of slot-milled titanium alloy.

Gupta et al. (2021) discuss the environmental and economic impact of sustainable cooling and lubrication techniques in Inconel-800 machining. Kim et al. (2021) utilize a pilot combustion test furnace to evaluate the combustion and emission properties of a reprocessed used lubricating oil (RULO) to assess the viability of utilizing it as a fuel for boiler cold start-up operation. Ross et al. (2021) use a hybrid cooling lubrication system for long-term and improved machining of Ni-based industrial alloys. Tao et al. (2021) investigate the Chinese ship lift's ultra-large modulus heavy-duty open gear-rack drive mechanism, in which lubrication design and maintenance play a crucial role in the mechanism's safe operation and service life extension.

*2.3. Maintenance*

Inappropriate maintenance practices constitute a barrier to long-term growth; hence, researchers need to offer practical solutions to this problem (Au-Yong et al., 2022; Orošnjak et al., 2021). Hoang et al. (2017) discuss the need for traditional maintenance decision-making processes in the industry to evolve to include the energy efficiency indicator. Torres-Mach et al. (2017) provide a tool for the best planning of sustainable planned maintenance with limited budgets. Lin et al. (2018) provide an empirical top-down statistical methodology for thoroughly evaluating energy usage determinants for a stock of buildings, focusing on operation and maintenance. Ruparathna et al. (2018) provide a risk-based multi-period maintenance planning and asset management system for public buildings to reduce life cycle costs and achieve climate action targets. Zhou et al. (2020) examine a serial production system with intermediate restricted buffers utilizing a proactive preventive maintenance technique and an energy-saving opportunity window. Ingemarsdotter et al. (2021) present condition-based maintenance as a practical approach in the circular economy as a framework incorporating technical, organizational, and user-related factors. Chang et al.(2021) concentrate on service-oriented maintenance decision-making and present a new collaborative knowledge-sharing architecture and multi-channel distributed blockchain network.

## 3. Proactive maintenance in Sungun copper mine

Sungun copper deposit is in east Azerbaijan. Max temperature in summer is 33 °, and the minimum is -20 ° in winter. There is an open-pit method with 384 million tons or reserve with a grade of 0665% for 31 years in 4 phases with a total overburden of 680 million tons (w/o=1.8), annual production is 7 million tons for the first five years, and 14 million tons for the re-maining years. The concurrent pre-stripping operation started, and from 1999, other parts of mine like road building, refinery factory, dam building, and pre-stripping advanced faster. Mobin, from 1998 to now, is working there as an overburden removal contractor that from 1998 to 2006, has excavated 81 million tons[1] (Fig. 1).

[1] http://www.mobinco.com/en/projects/sungun/

Fig 1. Sungun copper mine plant-concentration department.

A classic type of fine grinder is the ball mill. A slightly inclined or horizontally rotating cylinder filled with balls, typically stone or metal, grinds material to the required fineness by friction and impact with the tumbling balls. Ball mills usually operate with an estimated ball charge of 30%. Ball mills' specification is their smaller (comparatively) diameter and longer length. The feed is at one end of the cylinder, and the discharge is at the other. The Sungun ball mill and its lubrication system are in Fig . 2 and Fig. 3.

**Fig. 2.** Sungun ball mills

**Fig. 3.** Ball mill lubrication system

As illustrated in Fig. 3, the Sungun ball mill's lubrication system includes reservoirs, pumps, filters, valves, and coolers. There are three sections in the ball mill lubrication system; high pressure, low pressure, and pinion bearing circuits. There are three high-pressure circuits, two low-pressure circuits, and two pinion circuits, in a way that in which section one line is standby. Pumps supply conditioned high-pressure oil to the trunnion bearings for hydrostatic lift & lubrication. There is a 180µm online filter in each high-pressure line. High-pressure filters protect the trunnion bearings in the event of high-pressure pump failure. Pinion pumps supply conditioned oil to the pinion bearings for lubrication. Low-pressure (L.P.) oil pumps circulate reservoir oil through L.P. filters & coolers for oil conditioning. Each low-pressure line has a 420µm strainer and one 10μm online filter for each low-pressure pump. It means that dirty oil passes low-pressure pumps, which causes low-pressure pump failures. Therefore, the application of offline filtration before low-pressure pumps is needed to clean the entering oil into the pump. The reservoir with four compartments receives dirty oil, holds oil before & after conditioning, and contains clean oil to be pumped to the trunnion & pinion bearings. Level switches maintain the proper oil levels in the reservoir. The lubrication reservoir capacity is 2200 liters, and the oil used in this system is Shell Omala 150.

The ISO Cleanliness Code, ISO 4406, is the most widely used international standard for representing the contamination level of lubricating fluids. This standard uses a code system to quantify contaminant levels by particle size in micrometers (μm) and to establish the relationship between particle counts and cleanliness in lubrication fluids. Since its introduction in 1987, it has been revised twice, in 1996 and 1999. According to the first version, ISO 4406 classification was a two-number code, e.g., 14/12, based on the number of particles greater than five μm and 15 μm, respectively. It was expanded to three numbers in ISO 4406 in 1996 by adding a code number representing the number of particles greater than two μm. The new ISO 4406:1999 standard provides a 3-part code to represent the number of particles per milliliter fluid greater than or equal to 4 μm, six μm, and 14 μm, respectively. The Particle pyramid shows that 70% of all the particles by weight are under 1 micron and are the primary cause of oxidation in the oil. If these tiny particles are removed, oxidation can be minimized, and the oil can be maintained clean. Resulting in lower costs as oil and online filter changes no longer are necessary. This super cleaned oil, in addition, improves the life span of the machine. Since the mass of particles under 1-micron size is high. Because of the submicron contamination's adverse effects on oil oxidation, their hardness, and problems with equipment clearances, the Gravimetric patch test is a more effective oil analysis method. As the name implies, the gravimetric analysis uses a laboratory scale to weigh particles and sediment on a membrane (typically 0.45 microns). No attempt is made to count, size, or visibly characterize the particles. Often, the particles on the membrane are dominated by organic soft particles such as resins from oxidation, sludge, and additive degradation. Some laboratories use a series of solvent washes of various polarities to extract soluble fractions from the membrane to approximate composition. Typical solvents used for this purpose include pet ether, toluene, and methanol. Fig. 4 illustrats the instrument for the gravimetric patch test.

**Fig. 4.**Gravimetric patch test.

## 4. Contamination root cause analysis

The leading cause of mechanical wear is particle contamination. *Contamination* is any unwanted substance or energy that enters or contacts the oil. Contaminants enter a lubrication system in a variety of ways. If not properly flushed out, contaminants from manufacturing and assembly will be left in the system. These contaminants include dust, welding slag, rubber particles from hoses and seals, sand from castings, and metal debris from machined components. Also, adding fluid to the system often comes with a certain amount of contamination. Typically, this contamination includes various kinds of solid particles and water. During system operation, various particles enter through breather caps, imperfect seals, and other openings. System operation also generates internal contamination, as components wear debris and chemical byproducts from fluid and additive breakdown due to heat or chemical reactions. Such materials then react with component surfaces to create even more contaminants.

Contaminants can harm system operation, safety, service life, and reliability. In addition to causing direct wear, contaminants act as catalysts in component and fluid deterioration processes. Some are highly destructive to the oil, additives, and machine surfaces. It is often overlooked as a source of failure because its impact is usually slow and imperceptible, yet, given time, The damage is analogous to eating the machine up from the inside out. Particles, moisture, soot, heat, air, glycol, fuel, detergents, and process fluids are commonly in industrial lubricants and hydraulic fluids. However, particle contamination is the most destructive to oil and machine. The central strategy to its success in reducing maintenance costs and increasing machine reliability is offline filtration.

Submicron high-tech offline filtration is an offline filter suitable for proactive oil maintenance. The filter captures particles down to 0.1 microns. As it is an offline filtration system, regular operation of the machinery is not interrupted. When oil is clean, the capacity to lubricate, wash and other properties will remain. They can only disappear when oxidation occurs. When oil is ultra-cleaned, oxidation ceases.

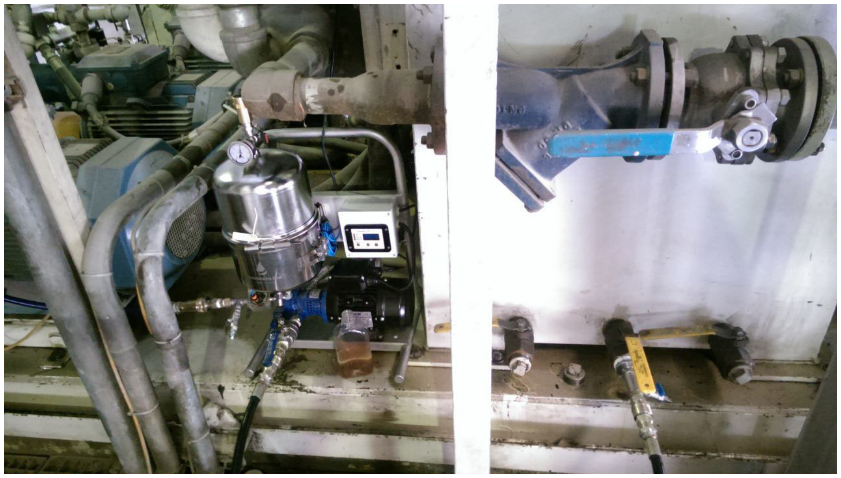
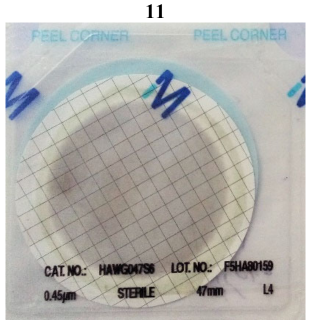
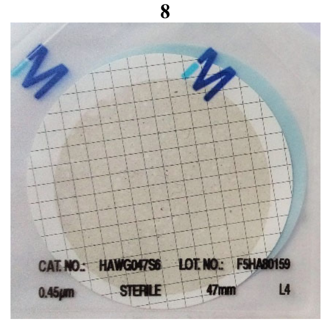


**Fig. 5.** Installation of submicron high-tech offline filtration on ball mill lubrication system

**Table 1**

Comparing the oil cleanliness after and before cleanliness

| Date | Start Time of Filtration<br>07/03/2016 | End Time of Filtration<br>10/22/2016 |
|---|---|---|
| **NAS** | **11** | **8** |
| **Patch Test** |   |   |
| **GPT (kg)** | **0.902** | **0.044** |

Contamination as a root cause of failure in Sungun copper mine was controlled by submicron hi-tech offline filtration in three following steps respectively: the first step was to set a target, or standard, associated with each root cause, and in the case of industrial oils, it is cleanliness levels based on results of gravimetric patch test. The second step, including all necessary activities for purification and protection of industrial oils to achieve target cleanliness, was applied using submicron high-tech offline filtration. The third step was based on continuous contamination activities on monitoring and controlling achieved fluid cleanliness based on standard cleanliness test and concentrating on gravimetric patch test.

Oil filtration, based on oil analysis, is possibly the most valuable method in a proactive maintenance approach. This paper has introduced basic facts about proactive maintenance and its implementation in the lubrication system of the Sungun mine ball mill. Table 1 mentions the results of this proactive maintenance on the Sungun lubrication system improvement. Note that, the new oil NAS 1638 cleanliness class was 10. The Filtration activity improved the oil cleanliness level to less than the used oil cleanliness level and less than new oil, which means super cleaned oil. Furthermore, based on the gravimetric patch test, the contamination weight of used oil decreased from 902 gr to 44 gr.

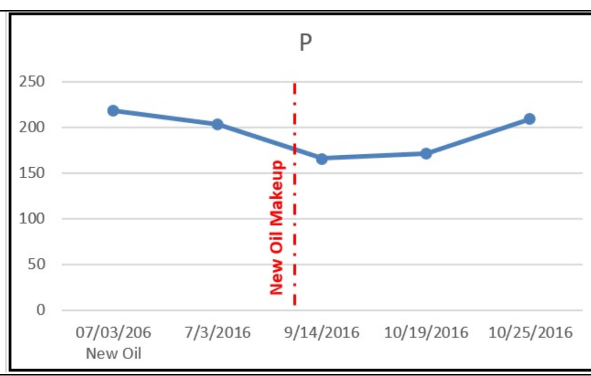
## 5. Oil Additive Decreasing Root Cause

The study of trunnion bearing lubrication has been devoted to understanding the critical operating parameters of the bearing, namely the machined clearance and the film thickness needed for proper operation. The primary function of a trunnion bearing is generally to support a shaft. Three basic lubrication regimes apply in trunnion-bearing lubrication: hydrodynamic or entire film, mixed film, and boundary. It is important to note that imperfections still exist regardless of how well a metal surface is machined. These minor peaks and valleys are known as asperities. The three lubrication regimes essentially refer to the amount of contact between these asperities. In short, boundary lubrication is the regime where metal-to-metal contact occurs, and the most significant portion of wear is generated. These asperities carry the vast majority of the load, with very little, if any, being carried by the lubricant. It typically takes place upon equipment startup. In most slow and highly loaded applications (ball mill pinion/trunnion bearings), a lubricating condition is ultimately responsible for most failures due to adhesive wear. The function of extreme pressure (EP) additive is to prevent this adhesive wear and protect the components when the lubricating oil viscosity can no longer provide the necessary film thickness.

EP additives are polar molecules. Imagine a molecule with a "head" and a "tail." The head of the molecule is attracted to the metal surface, while the tail is compatible with the lubricant carrier (Oiliofilic). As the conditions under which metal-to-metal interactions become more severe due to higher temperatures and pressures (greater loads), the lubricant film becomes more stressed. The distance between the metal surfaces has decreased to the point where rubbing occurs, and welding (adhesion) becomes very likely. Traditional boundary lubrication additives (e.g., antiwear additives) cannot adequately prevent wear and damage to the machinery seen under these conditions. Extreme pressure additives are required to enable the specific application operating under these conditions to continue. There are two main types of extreme pressure additives: those that are temperature dependent and those that are not. Boron, chlorine, phosphorus, and sulfur EP additive types are the most common temperature dependent. They are activated by reacting with the metal surface when the temperatures are elevated due to extreme pressure. The chemical reaction between the additive and the metal surface is driven by the heat produced from friction. Much like rubbing hands together, heat is generated by friction and pressure as the metal surfaces come in contact with one another. In reacting with the metal surface, these additive types form new compounds such as iron chlorides, iron phosphides, and iron sulfides (dependent on which compound is used). The metal salts produce a chemical (soap-like) film that acts as a barrier to reduce friction, wear, and metal scoring and eliminate the possibility of welding. The non-temperature-dependent, over-based sulfonate operates by a different mechanism. It contains a colloidal carbonate salt dispersed within the sulfonate. During the interaction with iron, the colloidal carbonate will form a film that can act as a barrier between metal surfaces, much like the temperature-dependent. However, it does not need elevated temperatures to start the reaction. EP additives protect from wear when the lubricant viscosity can no longer separate the working surfaces (Saini et al., 2021). As illustrated in Table 2, phosphor as an EP component decreased, and by making up a few new oils, it improved to near a new oil level.

**Table 2**
Phosphor trend in oil based on elemental aanalysis.

| Date | 07/03/2016 New Oil | 07/03/2016 | 09/14/2016 | 10/19/2016 | 10/25/2016 |
|---|---|---|---|---|---|
| P (ppm) | 219 | 204 | 166 | 172 | 210 |




## 6. Conclusion

There was contamination in the lubrication system of Sungun; second, the oil additive level decreased. Three necessary proactive steps were taken to solve these problems: first, Setting a target; second, applying controlling activities; third, monitoring based on oil analysis. The project results focused on developing and implementing submicron high-tech filtration and condition monitoring. After implementing the improvements, the mill reduced the level of oil contamination from a NAS cleanliness class of 11 to 8 in such a way that the new oil NAS cleanliness class is ten, which means that proactive maintenance activities improved the oil to super-cleaned oil. Furthermore, 80% of oil changing, flushing, and related person-hour costs were saved. Offline filtration guarantees low-pressure pumps' reliability and saves the cost of their failures, fixing, and replacement. Plant personnel recognized the importance of lubrication and changed their thinking about maintenance, especially oil maintenance. The reliability of the mill's lubrication system also improved, making the company's relatively small investment well worthwhile.

The Submicron high-tech offline filtration based on a gravimetric patch test (ISO 4405) was the core of the Oil Management System in this research. It offers a tool for proactive planned maintenance operations. Operational efficiency is enhanced by reduced downtime and higher productivity. As the oil remains clean, the wear and tear are lower, which enhances the machine's lifetime and reduces costs. Key benefits can be summarized as follows:

- Less disruption of operations is equal to fewer new spare parts.
- There is less disruption in the operation of production.
- Longer service life
- The oil does not need to be replaced.
- The system's online oil filter does not need to be changed.
- The oxidation disappears, and there would be no need to clean the oil reservoirs (hours).
- Production stopped due to oil issues.
- Clean oil washes the system and enhances the machine's lifetime.

## References

Au-Yong, C. P., Azmi, N. F., & Myeda, N. E. (2022). Promoting employee participation in operation and maintenance of green office building by adopting the total productive maintenance (TPM) concept. *Journal of Cleaner Production, 352*, 131608.

Behravesh, S. A., Darnall, N., & Bretschneider, S. (2022). A framework for understanding sustainable public purchasing. *Journal of Cleaner Production*, 134122.

Canito, A., Fernandes, M., Conceição, L., Praça, I., Santos, M., Rato, R., & Marreiros, G. (2017, June). An architecture for proactive maintenance in the machinery industry. *In International Symposium on Ambient Intelligence* (pp. 254-262). Springer, Cham.

Chang, F., Zhou, G., Zhang, C., Ding, K., Cheng, W., & Chang, F. (2021). A maintenance decision-making oriented collaborative cross-organization knowledge sharing blockchain network for complex multi-component systems. *Journal of Cleaner Production, 282*, 124541.

Chen, M. S., Eweje, G., & Kennedy, J. C. (2021). Managerial sensemaking of tensions in sustainability: Empirical evidence from Chinese and New Zealand business partnerships. *Journal of Cleaner Production, 319,* 128699.

Coffay, M., Coenen, L., & Tveterås, R. (2022). Effectuated sustainability: Responsible Innovation Labs for impact forecasting and assessment. *Journal of Cleaner Production*, 134324.

Gonzalez-Ramirez, M. G., & Rodriguez-Gonzalez, P. T. (2021). Game theory in sustainable decision-making: A new acetic acid plant as a case study. *Journal of Cleaner Production, 321*, 128962.

Gupta, M. K., Song, Q., Liu, Z., Sarikaya, M., Jamil, M., Mia, M., ... & Pimenov, D. Y. (2021). Environment and economic burden of sustainable cooling/lubrication methods in machining of Inconel-800. *Journal of Cleaner Production, 287*, 125074.

Hernández-Diaz, P. M., Polanco, J. A., Escobar-Sierra, M., & Leal Filho, W. (2021). Holistic integration of sustainability at universities: Evidences from Colombia. *Journal of Cleaner Production, 305,* 127145.

Hoang, A., Do, P., & Iung, B. (2017). Energy efficiency performance-based prognostics for aided maintenance decision-making: Application to a manufacturing platform. *Journal of Cleaner Production, 142*, 2838-2857.

Horne, J., & Fichter, K. (2022). Growing for sustainability: Enablers for the growth of impact startups–A conceptual framework, taxonomy, and systematic literature review. *Journal of Cleaner Production*, 131163.

Ingemarsdotter, E., Kambanou, M. L., Jamsin, E., Sakao, T., & Balkenende, R. (2021). Challenges and solutions in condition-based maintenance implementation-A multiple case study. *Journal of Cleaner Production, 296*, 126420.

Kim, H. H., Park, Y. H., Han, K., Jang, J. H., Park, H. Y., & Seo, Y. S. (2021). Combustion and emission characteristics of a reprocessed used lubricating oil as a renewable fuel for boiler cold start-up operation. *Energy, 222*, 119784.

Lin, M., Afshari, A., & Azar, E. (2018). A data-driven analysis of building energy use with emphasis on operation and maintenance: A case study from the UAE. *Journal of Cleaner Production, 192*, 169-178.

Liu, Y., & Ren, J. (2022). Developing a sustainability-oriented multi-criteria game theoretical decision analysis framework: A case study of sludge management. *Journal of Cleaner Production, 354*, 131807.

Mishra, A., Siddiqi, H., Kumari, U., Behera, I. D., Mukherjee, S., & Meikap, B. C. (2021). Pyrolysis of waste lubricating oil/waste motor oil to generate high-grade fuel oil: A comprehensive review. *Renewable and Sustainable Energy Reviews, 150*, 111446.

Muller, A., Suhner, M. C., & Iung, B. (2008). Formalisation of a new prognosis model for supporting proactive maintenance implementation on industrial system. *Reliability engineering & system safety*, *93*(2), 234-253.

Orošnjak, M., Jocanović, M., Čavić, M., Karanović, V., & Penčić, M. (2021). Industrial maintenance 4 (. 0) horizon Europe: consequences of the iron curtain and energy-based maintenance. *Journal of Cleaner Production, 314*, 128034.

Osman, K. A., Yılmaz, V., Ünver, H. Ö., Şeker, U., & Kılıç, S. E. (2020). Slot milling of titanium alloy with hexagonal boron nitride and minimum quantity lubrication and multi-objective process optimization for energy efficiency. *Journal of Cleaner Production, 258,* 120739.

Ramos, T. B., Domingues, A. R., Caeiro, S., Cartaxo, J., Painho, M., Antunes, P., ... & Huisingh, D. (2021). Co-creating a sustainability performance assessment tool for public sector organisations. *Journal of Cleaner Production, 320*, 128738.

Ross, N. S., Mia, M., Anwar, S., Manimaran, G., Saleh, M., & Ahmad, S. (2021). A hybrid approach of cooling lubrication for sustainable and optimized machining of Ni-based industrial alloy. *Journal of Cleaner Production, 321,* 128987.

Ruparathna, R., Hewage, K., & Sadiq, R. (2018). Multi-period maintenance planning for public buildings: A risk based approach for climate conscious operation. *Journal of Cleaner Production, 170,* 1338-1353.

Saini, V., Bijwe, J., Seth, S., & Ramakumar, S. S. V. (2021). Interfacial interaction of PTFE sub-micron particles in oil with steel surfaces as excellent extreme-pressure additive. *Journal of Molecular Liquids, 325*, 115238.

Sebestyén, V., & Abonyi, J. (2021). Data-driven comparative analysis of national adaptation pathways for Sustainable Development Goals. *Journal of Cleaner Production, 319*, 128657.

Silva, S. (2021). Corporate contributions to the Sustainable Development Goals: An empirical analysis informed by legitimacy theory. *Journal of Cleaner Production, 292*, 125962.

Sleiti, A. K. (2020). Heat transfer measurements of Polyalpha-Olefin-boron nitride nanofluids for thermal management and lubrication applications. *Case Studies in Thermal Engineering, 22*, 100776.

Tao, J., Wen, A., Liu, Z., & Yu, S. (2021). Lean lubrication of ultra large modulus open gear and rack pair: A case study of the gear-rack drive mechanism of the Chinese "Three Gorge Dam" ship lift. *Journal of Cleaner Production, 282*, 124450.

Torres-Machi, C., Pellicer, E., Yepes, V., & Chamorro, A. (2017). Towards a sustainable optimization of pavement maintenance programs under budgetary restrictions. *Journal of cleaner production, 148*, 90-102.

Trautwein, C. (2021). Sustainability impact assessment of start-ups–Key insights on relevant assessment challenges and approaches based on an inclusive, systematic literature review. *Journal of Cleaner Production, 281*, 125330.

Zhou, B., Qi, Y., & Liu, Y. (2020). Proactive preventive maintenance policy for buffered serial production systems based on energy saving opportunistic windows. *Journal of Cleaner Production, 253*, 119791.

Zzeyani, S., Mikou, M., Naja, J., Bouyazza, L., Fekkar, G., & Aiboudi, M. (2019). Assessment of the waste lubricating oils management with antioxidants vegetables extracts based resources using EPR and FTIR spectroscopy techniques. *Energy, 180*, 206-215.