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EFFECT OF ADDITIVES ON THE TRIBOLOGICAL BEHAVIOR OF GLYCERIN-MOTOR OIL BLENDS

Al-Kabbany A. M.[1], M. M. Youssef[2] and Ali W. Y.[1]

[1]Department of Production Engineering and Mechanical Design, Faculty of Engineering, Minia University, Minia 61519, Egypt.
[2]Automotive and Tractors Engineering Department, Faculty of Engineering, Minia University, Minia 61519, Egypt.

ABSTRACT
Oil additives are some of the most important products since they greatly improve the performance of motor oils and other types of lubricants. This is why the oil additive industry is valued at 14 billion US dollars. One of the types of oil additives is anti-wear additives. Which are used to decrease wear and friction between contacting parts separated by an oil. In this work, the effect of adding talc, graphite and polytetrafluoroethylene (PTFE) with different particle sizes to a blend of glycerin and motor oil on the coefficient of friction and scratch width when a steel ball is in contact with a steel surface is investigated.

It was found that adding talc at 2 wt. % showed the lowest value of scratch width at 0.1 mm. Increasing particle size of the graphite additive had a minimal effect on the scratch width but increased the coefficient of friction. The lowest value of the coefficient of friction was found to be at the oil with 3 wt. % graphite at a particle size of 0.012 mm. Increasing the percentage of PTFE additive decreases the scratch width but increases the coefficient of friction.

KEYWORDS
Glycerin, graphite, polytetrafluoroethylene, Talc.

INTRODUCTION
It was well known that all oils consist of a base oil which has multiple additives added to it, [1, 2]. Oil additives are compounds that give special properties to the oil, [3 – 14] . Multiple types of oil additives exist, such as detergent additives, [15 – 17], anti-rust additives, [18, 19], anti-foam additives, [20, 21], viscosity improver additives, [22 – 24], and anti-wear additives, [25, 26].

Multiple materials can be used as anti-wear additives. Talc is a common material that can be used as a solid lubricant and anti-wear additive, [27, 28]. PTFE is also a common material that is used as a solid lubricant, it also works as an anti-wear

additive due to the ability of PTFE layers to slide on one another with a minimal coefficient of friction [29]. Another material that is commonly used as a solid lubricant and an anti-wear additive is graphite, which works in a way similar to PTFE with layers of graphite (or graphene) slide on one another which normally has a lower coefficient of friction than whatever materials are contacting each other, [30, 31]. The anti-wear properties of talc and graphite were compared, and talc was found to give a neater microstructure on a bronze workpiece being tested with steel when compared to graphite, [32].

The particle size of the added additives is also an important factor in determining the behavior of the additive. Usually the lower the particle size, the better. This is due to the ability of smaller particles to enter into tight areas of contact between moving parts and provide lubrication in them. The increased surface area-to-volume ratio also imparts excellent mechanical properties on the materials, [2, 33]. Nanomaterials are also usually used as lubricant additives, [34, 35].

In this study, the effect of using graphite of different particle sizes, talc, and PTFE on a glycerin-motor oil blend as a base oil is investigated. The oil was added in a system with a steel ball sliding on a steel surface and the scratch width on the steel surface after sliding and the coefficient of friction between the two surfaces were measured.

EXPERIMENTAL

A pin-on-plate reciprocating scratch test was performed in order to determine the coefficient of friction and the wear scar width generated from friction of a steel 16 mm diameter steel ball and a steel plate with an oil sample separating them after 5 strokes of 1cm length were performed. The device is shown in fig. 1. It could measure the friction force using a load cell and scratch width was measured using a microscope. since all tests were done at a normal force of 6 N, the coefficient of friction can be calculated by dividing the friction force by the normal force. The tested oil was a mixture of glycerin and motor oil.

The effect of three additives on the behavior of the oil was tested. The first was talc powder, the second was graphite powder, and the third was PTFE powder with an average particle size of 0.26 mm. The tests were done with these powders added to the starting oil at different percentages. The results of this experiment are shown in Figs. 3 - 5.

The effect of the particle size of the graphite additive on the coefficient of friction and the wear scar width was also investigated. 3 different graphite powders were prepared. The first one had an average particle size of 0.56 mm, the second one had an average particle size of 0.3 mm, and the third had an average particle size of 0.012 mm. Photomicroscopic pictures of the the powders are shown in Fig. 2. They were all added to the oil at a weight percentage of 3 %. The results of this experiment are shown in Fig. 6.

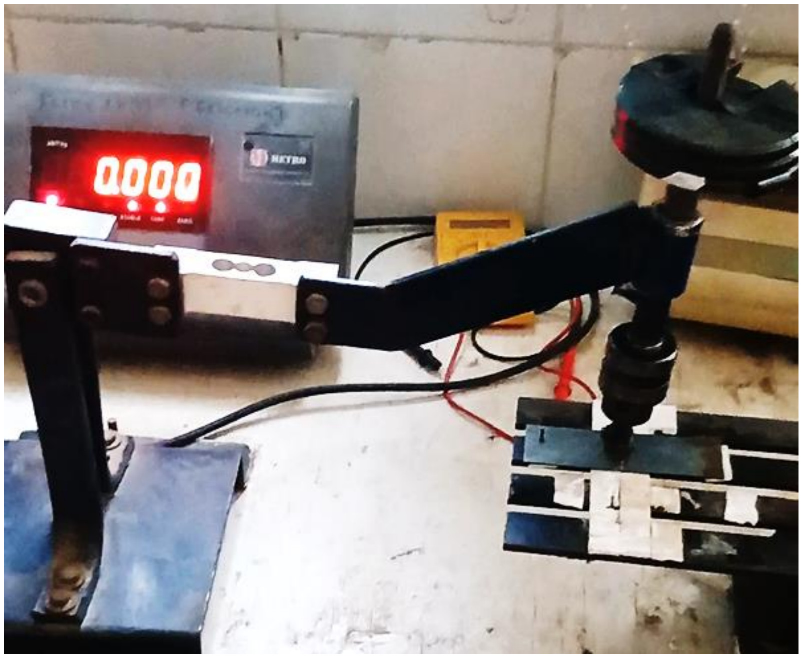
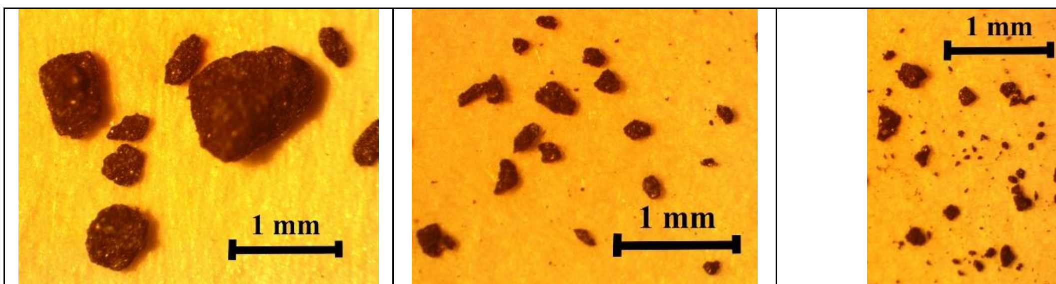


Fig. 1. The scratch testing device.



a	b	c

Fig. 2. Microscopic image of, (a) First graphite additive, (b) Second graphite additive, (c) Third graphite additive.

RESULTS AND DISCUSSION

The results for coefficient of friction and scratch width for the oil with different percentages of talc are shown in Fig. 3. The optimal percentage of talc was 2 wt. % for optimizing scratch width at 0.1 mm and 4 wt. % for optimizing coefficient of friction at 0.033. The scratch width value for the oil with 2 wt. % talc was the lowest value for scratch width for all tests. This is because the entire weight of the steel ball value is going to be concentrated on one talc particle (which is similar to a ball in shape), this causes the indentation width to be reduced to the width of the talc particle at low normal loads. This also decreases the indentation at higher loads. This effect can be seen in Fig. 7.

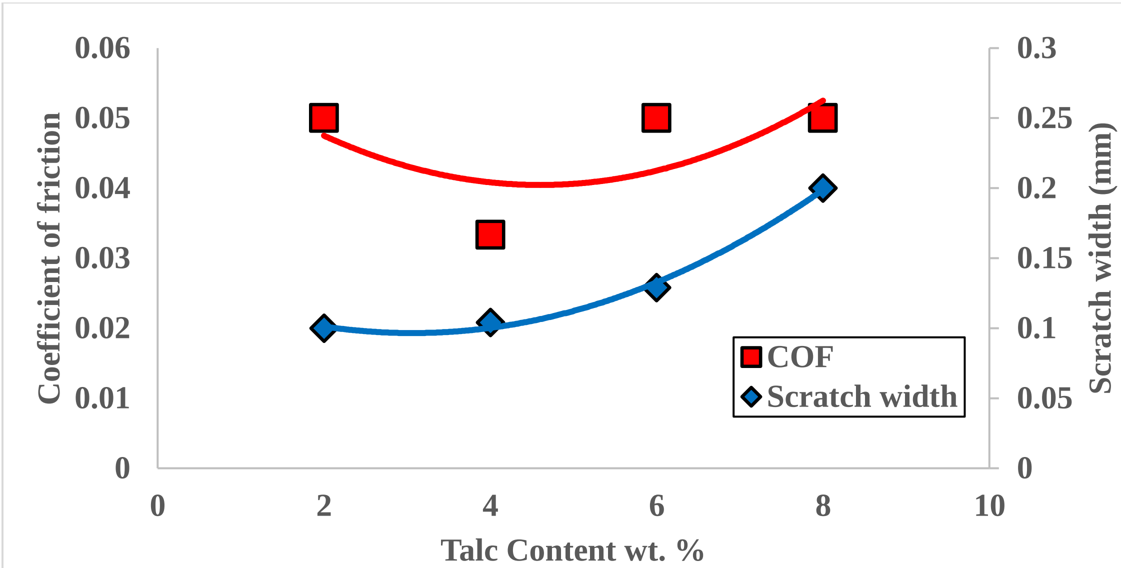


Fig. 3 Effect of the percentage of talc on the coefficient of friction and scratch width shown by the oil.

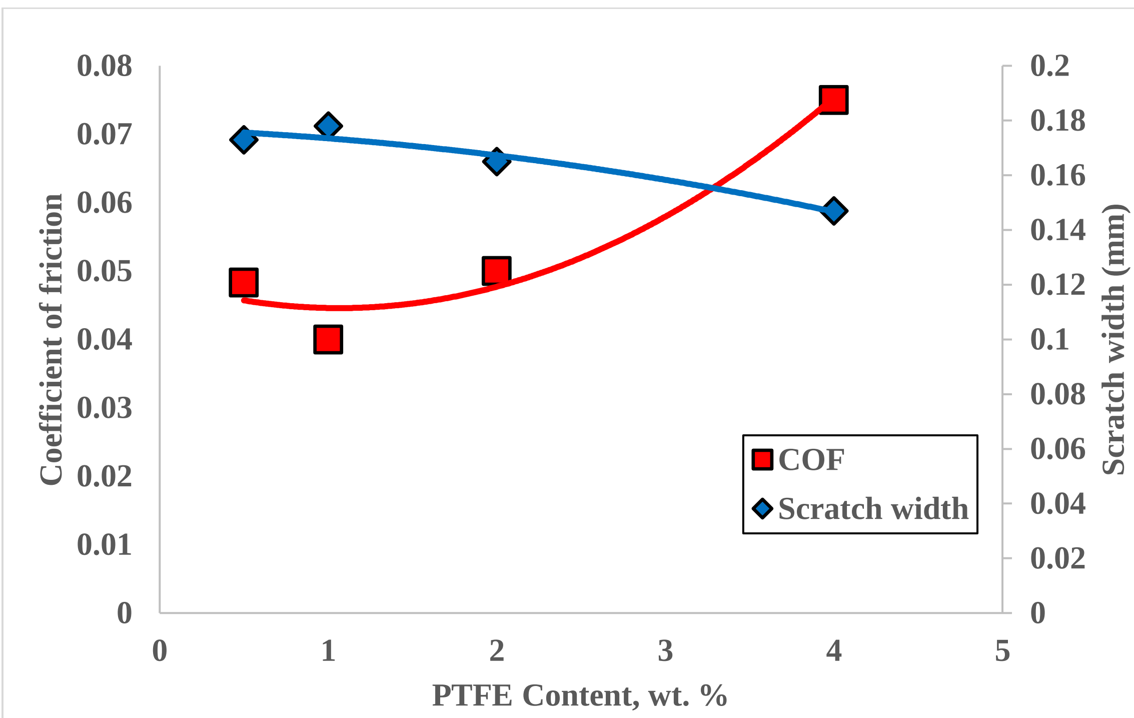


Fig. 4 Effect of the percentage of PTFE on the coefficient of friction and scratch width shown by the oil.

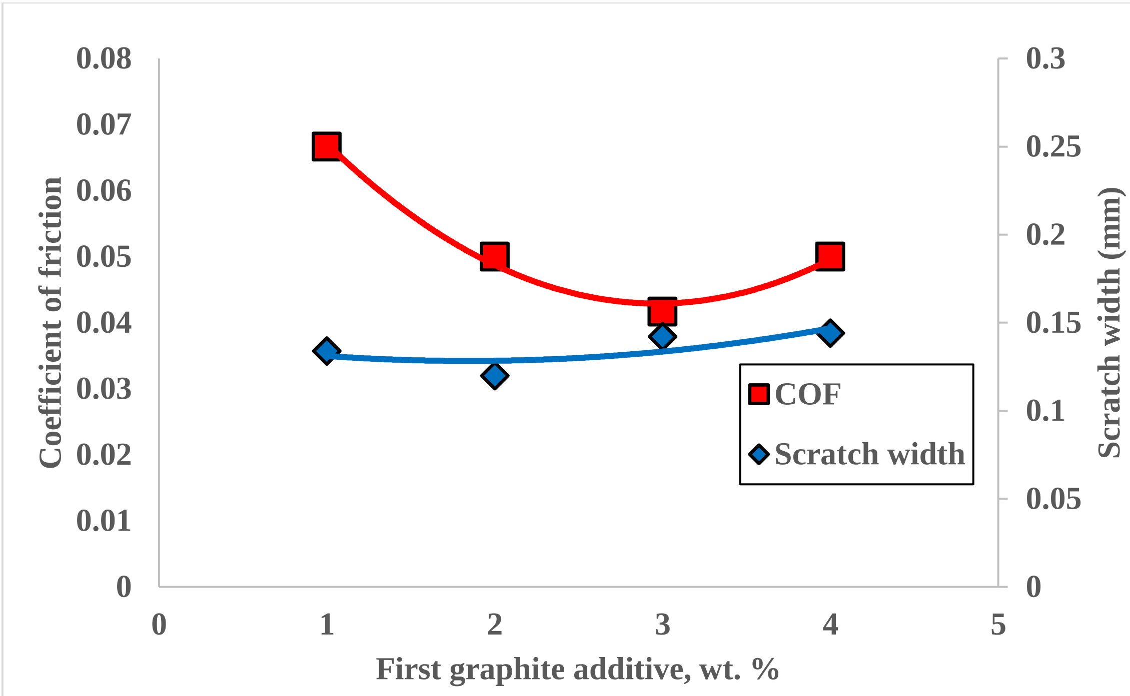


Fig. 5. Effect of the percentage of graphite on the coefficient of friction and scratch width shown by the oil.

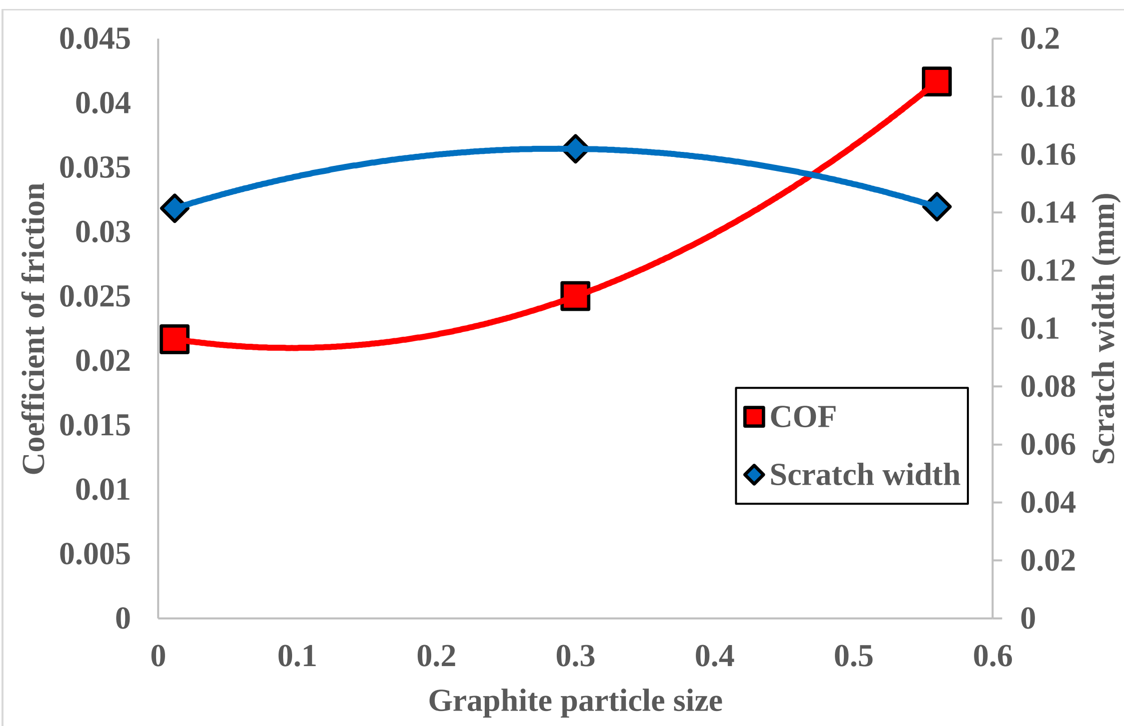


Fig. 6 Effect of the graphite particle size on the coefficient of friction and scratch width shown by the oil.

PTFE showed minimum coefficient of friction of 0.04 at 1 wt. % and a minimum scratch width of 0.147 at 4 wt. % PTFE mostly works via sliding of PTFE layers on top of each other. These results are shown in Fig. 4. The effect of adding the first graphite powder to the oil is shown in fig. 5. The lowest value of the coefficient of friction displayed was 0.046 at 4 wt. % graphite and the lowest value for scratch width was 0.12 mm. Slight change in the scratch width was seen when varying the particle size of the graphite, staying the same at around 1.45 mm. However, the coefficient of friction decreased to 0.0216 at a particle size of 0.012 mm as shown in Fig. 6, that was the lowest value of the coefficient of friction of all tests. This is due to graphite eliminating steel on steel sliding and replacing it with sliding of graphite layers on top of one another. Decreasing the particle size of graphite increases the likelihood of graphite getting in between the two contacting surfaces.

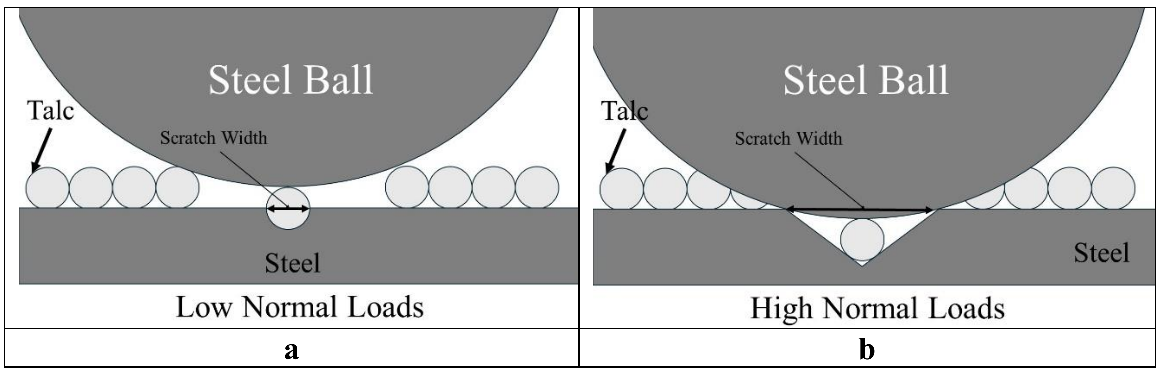


Fig. 7 Scratch width in case of adding talc, (a) under low normal load, (b) under high normal load.

CONCLUSIONS

1. Adding talc at 2 wt. % of a motor oil and glycerin mixture gave the lowest value of scratch width.
2. Decreasing the particle size of the graphite additive had a minimal effect on the scratch width but decreased the coefficient of friction.
3. Increasing the percentage of PTFE additive decreases the scratch width but increases the coefficient of friction.
4. The lowest value of the coefficient of friction was found to be at the oil with 3 wt. % graphite at a particle size of 0.012 mm.

REFERENCES

1. Adhvaryu A., Liu Z., and Erhan S. Z., "Synthesis of novel alkoxylated triacylglycerols and their lubricant base oil properties", Industrial Crops and Products, Vol. 21, No. 1, pp. 113–119, (Jan. 2005), https://doi.org/10.1016/J.INDCROP.2004.02.001.

2. Wang J., Zhuang W., Liang W., Yan T., Li T., Zhang L., and Li S., "Inorganic nanomaterial lubricant additives for base fluids, to improve tribological performance: Recent developments", *Friction*, Vol. 10, No. 5. Tsinghua University, pp. 645–676, (May 01, 2022). https://doi.org/10.1007/s40544-021-0511-7

3. Ali W. Y. and Balogh I., “The Role of Lubricant Additives in Reducing Abrasive Wear”, 4th Tribology Conference, GTE, Budapest, September 22 - 24, (1987).
4. Hakim K. A. and Ali W. Y., “Application Of Ferrography In Condition Monitoring”, VI Int. Seminar On New Development In Engine And Industrial Oils, Fuels And Additives, Misr Petroleum Co., Cairo, Egypt, March 7 - 10, (1988).
5. Mousa M. O., Balogh I. and Ali, W. Y., “Effect Of Lubricant Additives On Wear And Friction Caused By Lubricant Abrasive Contaminants”, Proceedings of XXI Bus Meeting, Budapest, September 3 - 6, 1990, pp. 197 - 204, (1990).
6. Ali W. Y., “Solid Lubricant Dispersion In Lubricating Greases”, Proceedings of the VIII Int. Seminar On New Development In Engine And Industrial Oils, Fuels And Additives, Cairo, Egypt, Feb. 24 - 27, (1992).
7. Ali W. Y., Khattab A. A. and Hashem A., “Effect Of Externally Applied Voltage On Lubricant Additives Behaviour”, Proceedings of the VI. Budapest Tribology Conference, Budapest Technical University, June 6 - 7, pp. 188 - 198, (1996).
8. Khashaba, M. I., Ezzat, F. H. and Ali, W. Y., “Friction and Wear of Epoxy Composites”, Smart Advances in Tribology: Advanced Additives and Structured Coatings, Zurich, Switzerland, 12 – 14 September (2003).
9. Rasha A. H., Bastaweesy A. M. and Ali W. Y, “Effect of Preheating Lubricating Oil and Sulphur Containing Additives on the Wear Resistance of Steel”, Journal of the Egyptian Society of Tribology, Vol. 2, No. 4, Jnuary, pp. 15 – 24, (2005).
10. Zaini H., Alahmadi A., Ali W. Y. and Abdel-Sattar S., "Influence of Magnetic Field on the Action Mechanism of Lubricant Additives", Journal of the Egyptian Society of Tribology Vol. 9, No. 2, April 2012, pp. 15 – 28, (2012).
11. Abdel-Jaber G. T., Mohamed M. K., Al-Osaimy A. S. and Ali W. Y., "Effect of Magnetic Field on the Performance of Lubricant Additives", September 27 – 29, 2011, Tribologie Fachtagung, Göttengen, Germany, (2011), Journal of Applied and Industrial Sciences, April, 2013, 1 (1), pp. 25 – 31, (2013).
12. Marzouk M. E., Khashaba M. I., Ali W. Y., "Effect of Lubricating Additives on the Performance of Rolling Bearings", EGTRIB Journal, Vol. 12, No. 3, July 2015, pp. 15 – 27, (2015).
13. Touny A. R. M., Mahmoud M. M. and Ali W. Y., “Tribological Performance of Antiwear Additive Dispersed in Hydraulic Oil”, Journal of the Egyptian Society of Tribology, Vol. 19, No. 3, July 2022, pp. 53 – 67, (2022).
14. Touny A. R. M., Mahmoud M. M. and Ali W. Y., “Investigation of the Influence of Antiwear Additives Dispersed in Hydraulic Oil on Friction and Wear”, Journal of the Egyptian Society of Tribology, Vol. 19, No. 3, July 2022, pp. 68 – 79, (2022).
15. Gulmez C., Altinkaynak C., Özdemir N., and Atakisi O., "Proteinase K hybrid nanoflowers (P-hNFs) as a novel nanobiocatalytic detergent additive", International Journal of Biological Macromolecules, Vol. 119, pp. 803–810, (Nov. 2018), https://doi.org/10.1016/J.IJBIOMAC.2018.07.195.
16. Al-Ghanayem A. A. and Joseph B., "Current prospective in using cold-active enzymes as eco-friendly detergent additive", Applied Microbiology and Biotechnology, Vol. 104, No. 7, pp. 2871–2882, (Apr. 2020), https://doi.org/10.1007/S00253-020-10429-X/FIGURES/2.
17. Ktari N., Ben Khaled H., Nasri R., Jellouli K., Ghorbel S., and Nasri M., "Trypsin from zebra blenny (Salaria basilisca) viscera: Purification, Characterisation and

Potential Application as a Detergent Additive", Food Chemistry, Vol. 130, No. 3, pp. 467–474, (Feb. 2012), https://doi.org/10.1016/J.FOODCHEM.2011.07.015.

18. Wang J., Hu W., Li J., Wang J. ;, Hu W. ;, and Li J., "Lubrication and Anti-Rust Properties of Jeffamine-Triazole Derivative as Water-Based Lubricant Additive", Coatings 2021, Vol. 11, Page 679, Vol. 11, No. 6, p. 679, (Jun. 2021), https://doi.org/10.3390/COATINGS11060679.

19. Watanabe S., Kawahara H., and Kuramochi T., "Adducts of cyclic acid anhydrides and fatty amines as anti-rust additives in water-based cutting fluids", Journal of the American Oil Chemists' Society, Vol. 68, No. 2, pp. 92–94, (Feb. 1991), https://doi.org/10.1007/BF02662324.

20. Ross S., "Inhibition of Foaming. II1,2A Mechanism for the Rupture of Liquid Films by Antifoaming Agents", Journal of Physical and Colloid Chemistry, Vol. 54, No. 3, pp. 429–436, (Mar 1950), https://doi.org/10.1021/J150477A018/ASSET/J150477A018. FP. PNG_V03.

21. Centers P. W., "Behavior of Silicone Antifoam Additives in Synthetic Ester Lubricants", Tribology Transactions, Vol. 36, No. 3, pp. 381–386, (1993), https:// doi.org /10.1080/10402009308983173.

22. Souza De Carvalho M. J., Rudolf Seidl P., Pereira Belchior C. R., and Ricardo Sodr J., "Lubricant viscosity and viscosity improver additive effects on diesel fuel economy", Tribology International, Vol. 43, No. 12, pp. 2298–2302, (Dec. 2010), https://doi.org/10.1016/J.TRIBOINT.2010.07.014.

23. Martini A., Ramasamy U. S., and Len M., "Review of Viscosity Modifier Lubricant Additives", Tribology Letters, Vol. 66, No. 2, pp. 1–14, (Jun. 2018), https://doi.org/10.1007/S11249-018-1007-0/FIGURES/7.

24. Dandan M. A., Samion S., Azman N. F., Mohd Zawawi F., Abdul Hamid M. K., and Musa M. N., "Performance of polymeric viscosity improver as bio-lubricant additives", International Journal of Structural Integrity, Vol. 10, No. 5, pp. 634–643, (Sep. 2019), https://doi.org/10.1108/IJSI-04-2019-0028/FULL/PDF.

25. Bakry M., Samy A. M., Nabhan A., and Rashed A., "Tribological Behaviour of Steel Lubricated by Grease Filled by Polymeric Additives", Journal of the Egyptian Society of Tribology, Vol. 18, No. 3, pp. 11–12, (Jul. 2021), https://doi.org/ 10.21608/JEST.2021.189026.

26. Badran A., Hamdy K., and Rashed A., "Hardness and Tribological Properties of PMMA Composite Reinforced by Hybrid Graphene and TiO_2 Nanoparticles used in Dental Applications", Journal of the Egyptian Society of Tribology, Vol. 19, No. 2, pp. 36–47, (Apr. 2022), https://doi.org/10.21608/JEST.2022.231178.

27. Rudenko P. and Bandyopadhyay A., "Talc as friction reducing additive to lubricating oil", Applied Surface Science, Vol. 276, pp. 383–389, (Jul. 2013), https://doi.org/10.1016/j.apsusc.2013.03.102.

28. de Castro V. V., dos Santos L. M., Antonini L. M., Schroeder R. M., Mattedi S., Souza K. S., Pereira M. B., Einloft S., dos Santos C. A., and de Fraga Malfatti C., "Water-based lubricant containing protic ionic liquids and talc lubricant particles: Wear and corrosion analysis", Wear, Vol. 518–519, (Apr. 2023), https://doi.org/ 10.1016/j.wear.2023.204633.

29. Rico E. F., Minondo I., and Cuervo D. G., "The effectiveness of PTFE nanoparticle powder as an EP additive to mineral base oils", Wear, Vol. 262, No. 11–12, pp. 1399–1406, (May 2007), https://doi.org/10.1016/J.WEAR.2007.01.022.
30. Huang H. D., Tu J. P., Gan L. P., and Li C. Z., "An investigation on tribological properties of graphite nanosheets as oil additive", Wear, Vol. 261, No. 2, pp. 140–144, (Jul. 2006), https://doi.org/10.1016/J.WEAR.2005.09.010.
31. Zhang Z. J., Simionesie D., and Schaschke C., "Graphite and Hybrid Nanomaterials as Lubricant Additives", Lubricants 2014, Vol. 2, Pages 44-65, Vol. 2, No. 2, pp. 44–65, (Apr. 2014), https://doi.org/10.3390/LUBRICANTS2020044.
32. Chinesta Francisco., Chastel Yvan., and Mansori M. El., International conference on advances in materials and processing technologies : AMPT2010, 24-27 October 2010, Paris, France. American Institute of Physics, (2010).
33. Anand G. and Saxena P., "A review on graphite and hybrid nano-materials as lubricant additives", in *IOP Conference Series: Materials Science and Engineering*, Institute of Physics Publishing, Oct. 2016. https://doi.org/10.1088/1757-899X/149/1/012201
34. Rashed A. and Nabhan A., "Friction and Vibration Analysis of Sliding Surfaces Lubricated by Engine Oils Dispersed by Aluminum Oxide Nanoparticles", Journal of the Egyptian Society of Tribology, Vol. 17, No. 1, pp. 14–26, (Jan. 2020), https://doi.org/10.21608/JEST.2020.78805.
35. El-Abden S. Z., "Effect of Silica Nanoparticles and Multiwall Carbon Nanotubes Dispersing Lubricating Grease in Metal Forming", Journal of the Egyptian Society of Tribology, Vol. 16, No. 4, pp. 13 - 24, (Oct. 2019), https: //doi.org/.21608/JEST. 2019.79186.