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Experimental analysis of effect to friction of commercial oil additive used in automobiles

Otomobillerde kullanılan ticari yağ katkı maddesinin sürtünmeye etkisinin deneysel analizi

Yazar(lar) (Author(s)): *Mithat ŞİMŞEK[1], Özlem SALMAN NTEZIYAREMYE[2], Emrullah Hakan KALELİ[3] Recai Fatih TUNAY[4] Ertuğrul DURAK[3]*

ORCID[1]: 0000-0002-0534-1133

ORCID[2]: 0000-0001-7609-1795

ORCID[3]: 0000-0001-7586-918X

ORCID[4]: 0000-0002-9877-9379

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Experimental Analysis of Effect to Friction of Commercial Oil Additive Used in Automobiles

Highlights

- *Real engine parts were used in the experiments*
- *Experiments were run with commercial 20W50 motor oil and 5% additive added commercial 20W50 motor oil and additive oil.*
- *Using additives in the commercial oil lubricant showed a little reduction under the lower load. When the applied load increased commercial oil showed better friction coefficient performance in the experimental study.*

Graphical Abstract

In this study, cylinder and piston ring sample materials were used in the reciprocating test rig. Six different speeds and three loads were used in the experiments. Experimental studies of 60 minutes were carried out with additives. The effect of the additive on the coefficient of friction was investigated experimentally.

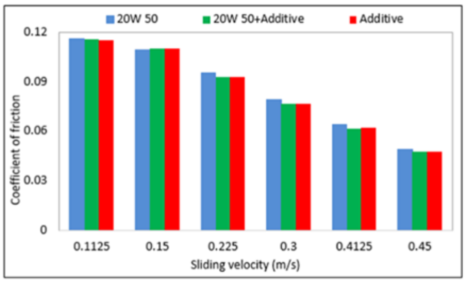

Figure. Friction coefficient and sliding speed under 50 N load

Aim

The aim of this study is to investigate the effect of additive to engine oil on tribological properties.

Design & Methodology

Experiments were conducted in the reciprocating test rig with 50, 100, and 150 N constant loads, 0.1125, 0.150, 0.225, 0.300 0.4125, and 0.450 m/s sliding speeds, and 60 minutes at 25°C (±3) environment temperature. Used motor cylinder and piston ring samples used in the reciprocating experiments. Samples were used having the same material, surface properties, and size in the experimental studies.

Originality

The tests are of the original value as real engine parts are used.

Findings

-All lubricants showed similar and so close friction coefficient values in the experimental results.

-The reason for the similarity in the results may be the most possible reasons such as the short sliding time, and other test parameters. These results show that all lubricant types are suitable for the experimental conditions in this study.

-Using additives in the commercial oil lubricant showed a little reduction under the lower load. When the applied load increased commercial oil showed better friction coefficient performance in the experimental study.

-As for the expected results, the friction coefficient reduced with increasing sliding speeds under all conditions.

Conclusion

In general, commercial oil fortifiers didn't highly affect to reduce the friction coefficient when all the results were evaluated, in these experimental conditions.

Declaration of Ethical Standards

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Experimental Analysis of Effect to Friction of Commercial Oil Additive Used in Automobiles

(This study was presented at TURKEYTRIB 15 conference.)

Araştırma Makalesi / Research Article

Mithat ŞİMŞEK[1*], Özlem SALMAN NTEZIYAREMYE[2], Emrullah Hakan KALELİ[3], Recai Fatih TUNAY[4], Ertuğrul DURAK[4]

[1]Faculty of Engineering and Architecture, Department of Mechanical Engineering, Gaziosmanpaşa University, Tokat, Turkey
isar Meslek Yüksek Okulu, Makine Bölümü, Manisa Celal Bayar Üniversitesi, Türkiye
[2]Lam Research, Fremont, CA, USA
[3]Faculty of Mechanical Engineering, Department of Mechanical Engineering, Yıldız Technical University, Istanbul, Turkey
[4]Faculty, Department of Mechanical Engineering, Süleyman Demirel University, Isparta, Turkey

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ABSTRACT

With the development of automotive technology, long life, high power, and low fuel consumption performance are expected from the internal combustion engine. This study investigated the effects of commercial oil additives on friction under different experimental conditions. In order to examine the friction effect, the samples prepared from the piston ring and cylinder were tested with the Reciprocating Test Rig at different speeds and loads. Using additives in the commercial oil lubricant showed a little reduction under the lower load. When the applied load increased commercial oil showed better friction coefficient performance in the experimental study. As for the expected results, the friction coefficient reduced with increasing sliding speeds under all conditions. In general, it was found that the commercial oil supplement did not have much effect on reducing the coefficient of friction when all the results were evaluated under these experimental conditions

Keywords: Additive, oil fortifier, lubrication, friction coefficient.

Otomobillerde Kullanılan Ticari Yağ Katkı Maddesinin Sürtünmeye Etkisinin Deneysel Analizi

Otomotiv teknolojisinin gelişmesiyle birlikte içten yanmalı motordan uzun ömür, yüksek güç ve düşük yakıt tüketimi performansı beklenmektedir. Bu çalışmada, farklı deneysel koşullar altında ticari yağ katkı maddelerinin sürtünme üzerindeki etkileri araştırılmıştır. Sürtünmeye etkisini incelemek için piston segmanı ve silindirden hazırlanan numuneler Gidip-Gelme deney seti ile farklı hız ve yüklerde test edilmiştir. Ticari yağlayıcıda katkı maddelerinin kullanılması, düşük yük altında küçük de olsa bir azalma göstermiştir. Uygulanan yük arttığında ticari yağ deneysel çalışmada daha iyi sürtünme katsayısı performansı göstermiştir. Beklenen sonuçlara gelince, her koşulda artan kayma hızları ile sürtünme katsayısı azalmıştır. Genel olarak, tüm sonuçlar bu deneysel koşullar altında değerlendirildiğinde, ticari yağ katkısının sürtünme katsayısını düşürmede çok büyük bir etkisinin olmadığı tespit edilmiştir.

Anahtar Keklimeler: Katkı maddesi, yağ takviyesi, yağlama, sürtünme katsayısı.

1. INTRODUCTION

Large amounts of energy can be lost during the friction process as a result of heat generation and dissipation. Surface damage decreased device performance, and reliability is all consequences of friction-induced wear. For instance, friction and wear waste around one-third of the energy used in passenger cars. From conventional bearings, pistons, and gears to micro-scale devices and bio-related devices like teeth and implants, friction and wear have a significant impact on a wide range of applications [1].

The most important role of the lubricating oil is to reduce energy loss and minimize surface wear and prevent the build-up of the edge surface of materials to improve the friction characteristics of the lubricant [2]. Besides it, the lubricating oil has some required second-function properties such as deterioration prevention and anti-rust resistance in metals. Therefore, many functions in the base oil are insufficient, provided by special additives soluble in the base oils [3-5]. In general, an additive is referred to as a post-added agent to lubricants to give some new properties to the lubrication oil, to improve the current characteristics of the oil, and to eliminate undesirable features or minimize them [6]. At a specific

**Sorumlu Yazar (Mithat ŞİMŞEK)*
e-posta : mithat.simsek@gop.edu.tr

normal load, the lubricant additives can readily create tribofilm with low shear strength and decrease the interfacial contact area [7].

Some specific topics such as longevity in internal combustion engines, high power, and low fuel consumption have been the main subject of scientific studies with the advancement of technology. Today, the most effective way shows that to reduce engine oils and fuel consumption might be able the use proper engine lubrication and additives to minimize friction and wear [8, 9]. The need to enhance engine oil lubricants' performance has been growing steadily. Since a few decades ago, performance-improving additives have been added to engine oil lubricants for that reason [10]. Lubricant additives complement the natural properties of necessary lubricating fluids, improving field service performance or expanding their use in already known applications. These are also referred to as additives or enhancers.

Generally, lubricant additives are divided into three categories.

• Designed to prevent chemical deterioration or change in order to safeguard the finished lubricant in use,

• Protecting the machine from harmful fuel combustion byproducts that accumulate in lubricants or from inefficient fuel and/or oil operation,

• Those that enhance or supplement already-present physical characteristics.

Lubricating oils and lubricants are produced via cleansing and manufacturing procedures as well as by adding specific chemical compounds or additives. For a variety of reasons, additives are added to lubricants, greatly enhancing the lubricating oils created by nature and refineries. Modern lubricating oil additives are now required in many applications since they are based on years of scientific research, created for the extreme demands of contemporary equipment, and optimized for performance under actual working conditions. In order to increase the scope for operational safety, the automobile industry and manufacturers of machinery and equipment have developed additive-based lubricants whose limitations go far beyond the lubrication requirements required by even the strictest machine maintenance standards [11, 12].

The performance of the engine oil is evaluated according to some abilities such as friction reduction, oxidation resistance, minimizing the formation of residues, corrosion and wear prevention capabilities. Engine oil additives uses in the engines for enhance existing properties of the base oil and improve specific properties that are required in modern engines. In order to bring in the required engine performance uses many additives such as anti-wear additive (AW), friction modifier (FM), viscosity index improver (VI), anti-foam agents, pour point depressant, detergent and dispersant, antioxidant, extreme pressure additives (EP), corrosion inhibitor [9-20]. Crankcase oils contain friction modifiers that are intended to lessen friction in mixed or boundary lubrication regimes. These friction-reducing additives work by creating a slippery layer on the surfaces; this layer's shear strength is extremely low, resulting in a low friction coefficient [21].

In this study, cylinder and piston ring sample materials were used in the reciprocating test rig. The six different speeds and three loads were used in the experiments. Experimental studies of 60 minutes were carried out with additives. The effect of the additive on the coefficient of friction was investigated experimentally.

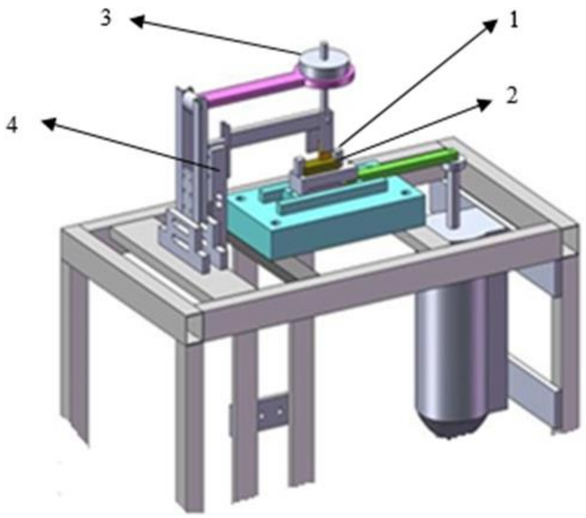
2. MATERIAL and METHOD

In this study, experiments were run with commercial 20W50 motor oil and 5% additive added commercial 20W50 motor oil and additive oil. All these oils are used as lubrication substances, respectively. Experiments were conducted in the reciprocating test rig with 50, 100, and 150 N constant loads, 0.1125, 0.150, 0.225, 0.300 0.4125, and 0.450 m/s sliding speeds, and 60 minutes at 25°C (±3) environment temperature. Experiments were carried out with used cylinder and piston ring samples. Samples were used having the same material, surface properties, and size in the experimental studies.

Tests were carried out the reciprocating test rig. On a sliding platform that reciprocates horizontally beneath a stationary tool holder, test specimens are mounted. An electric motor powers the sliding platform (1.5 kW, 1390 rpm). Adjustable test parameters include stroke length, speed, and load. The load cell is used to determine the frictional force and coefficient of friction during testing. The tests can be performed in the boundary, mixed, and hydrodynamic lubrication regime on the test bench and under different running conditions on this test bench [22, 23]. Fig. 1. shows the reciprocating test rig and Fig. 2. shows the cylinder and piston ring samples for this study. Also, the properties of the commercial motor oil (20W50) and additive used in the experiment are given in Table 1 [24].

Table1. Properties of the commercial motor oil (20W50) and additive

	Motor Oil (20W50)		Additive
Kinematic viscosity 40 °C cSt 100 °C cSt	IP 71	157.0 19.0	39.45 -
Viscosity index	IP 226	137	-
Density 15°C kg/l	IP 365	0.888	1.019
Flash point (PMCC) °C	IP 34	215	176
Pour point,°C	IP 15	-27	9



1-Piston ring test specimen, 2-Cylindric test specimen, 3-Load, 4- Load-cell

Figure 1. Reciprocating test rig [23]

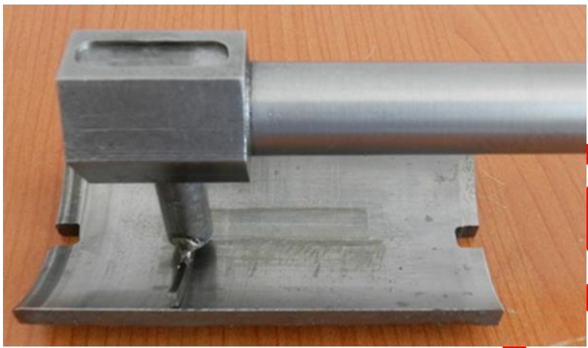


Figure 2. View of the piston ring and cylinder test specimens (used)

3. RESULTS AND DISCUSSION

The results of the experimental study show the friction coefficients in Figure 3-8. The measured friction coefficient values were close to each other when the lower load of 50 N was applied with 0.1125 and 0.15 m/s sliding speeds. All the experimental results are given in Figures 3-20, respectively.

The coefficient of friction values obtained during the experiments were determined to be close to each other in Figure 3-8. Under 50 N load and 0.1125 m/s sliding speed condition, it appears to be inconsistent with the other sliding speeds. Except 50 N and 0.1125 m/s condition friction coefficient measurements were stable. It is thought that the reason for this inconsistency was interactions between surfaces. And then, the friction coefficient became stable after covered surfaces by lubricant mixtures. Kaleli H. and Berthier Y. said that "in order to obtain additive layers on the sliding surfaces, chemical and mechanical surface reaction needs to be occurred between sliding pairs under boundary lubrication conditions" [25]. The highest friction coefficient value was measured under 100 N load and 0.1125 m/s condition using with commercial motor oil 20W50. Add the additive agent improved this result and detected a decreasing trend in friction coefficient. Condition with 150 N load and two sliding speeds 0.150 m/s and 0.225 m/s performed inconstant friction coefficient trend. Furthermore, Tonk noted that adding significant amounts of friction modifiers does not ensure that oil will improve. It might even worsen the situation occasionally [10]. There may not always be any further benefit as more additive is incorporated into the oil, and occasionally, performance may even worsen. In other situations, the service life extends but the additive's performance is unchanged. One feature of oil may be improved while another deteriorates when the proportion of a particular addition is increased. The overall quality of the oil may be impacted if the prescribed additive concentrations of the additives fall out of balance [26]. Two kinds of lubricants, 5% additive mixed lubricant and additive, showed the best friction coefficient performance with sliding speed increases compared to 20W50 motor oil performance. The friction coefficient decreased with the sliding speed increases in all lubricant samples [3, 27].

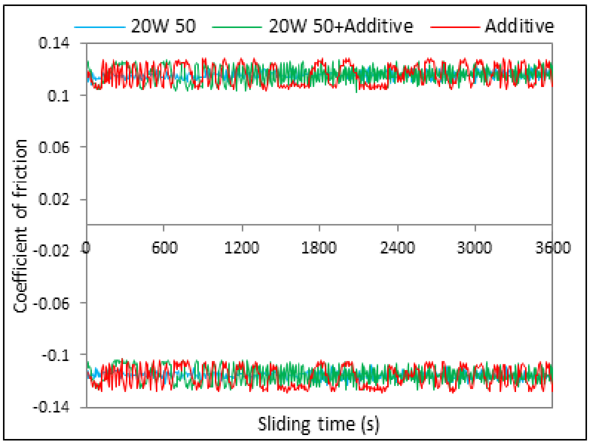


Figure 3. μ- sliding time changes (50 N, 0.1125 m/s)

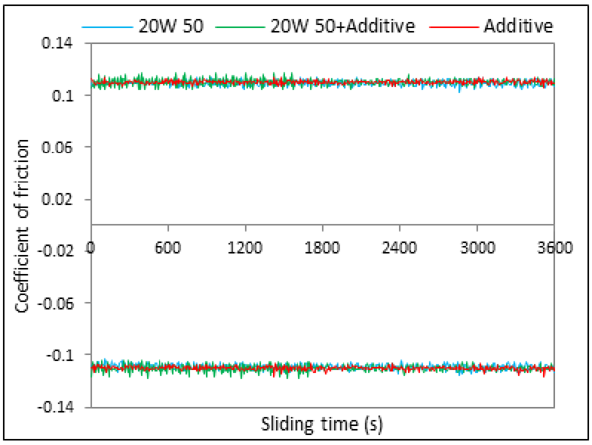


Figure 4. μ- sliding time changes (50 N, 0.150 m/s)

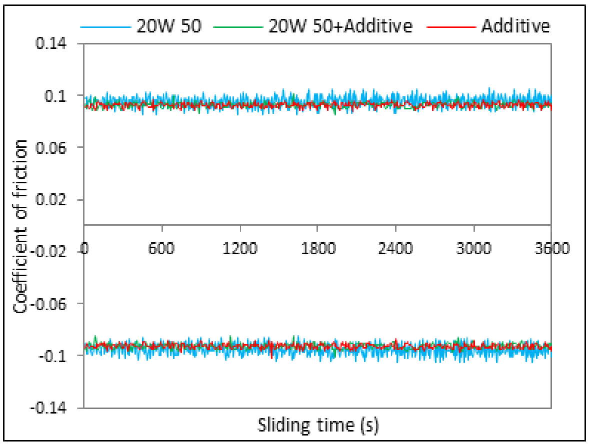


Figure 5. μ- sliding time changes (50 N, 0.225 m/s)

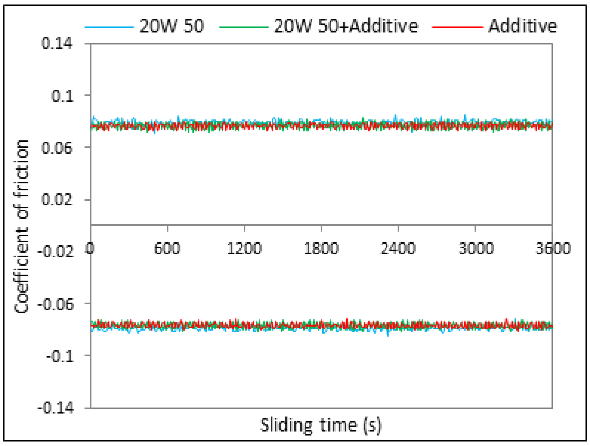


Figure 6. μ- sliding time changes (50 N, 0.300 m/s)

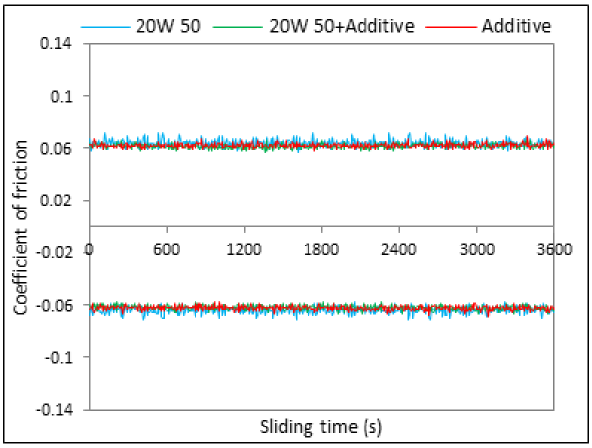


Figure 7. μ- sliding time changes (50 N, 0.4125 m/s)

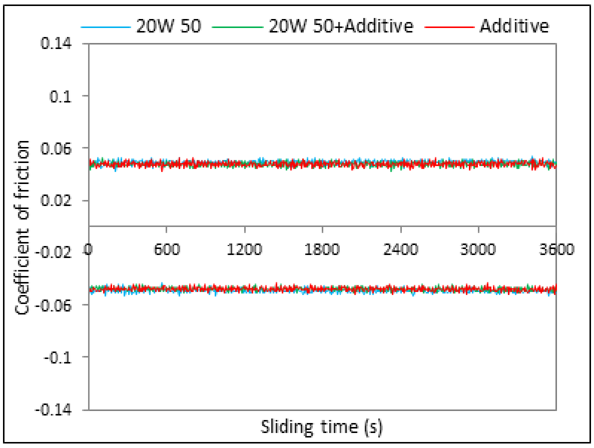


Figure 8. μ- sliding time changes (50N, 0.450 m/s)

Commercial motor oil (20W50) showed the highest coefficient of friction under 100 N load and 0.1125, 0.150, 0.225, and 0.300 m/s sliding speed conditions in Figure 9-14 [3]. With a sliding speed increase, a 5% additive mixture of commercial motor oil and additive lubricant performed the highest friction coefficient values Figure 22. According to the findings of the tribological tests, lubrication with nano-additives decreased the wear rate and friction coefficient in comparison to 5W-30 by 25%–30% and 26.5%–32.6%, respectively. The findings indicated that this is a potential strategy for enhancing the toughness and longevity of frictional sliding components as well as fuel efficiency in car engines [28].

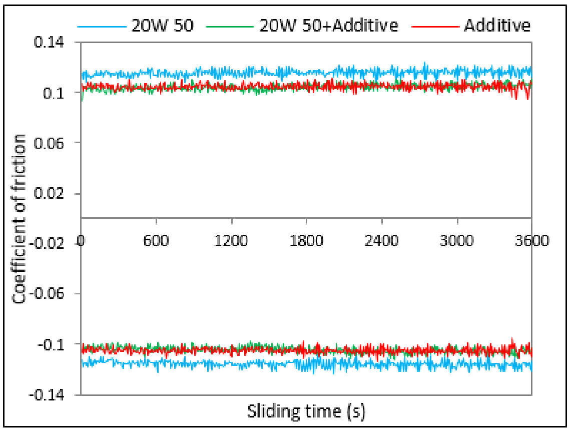


Figure 9. μ- sliding time changes (100 N, 0.1125 m/s)

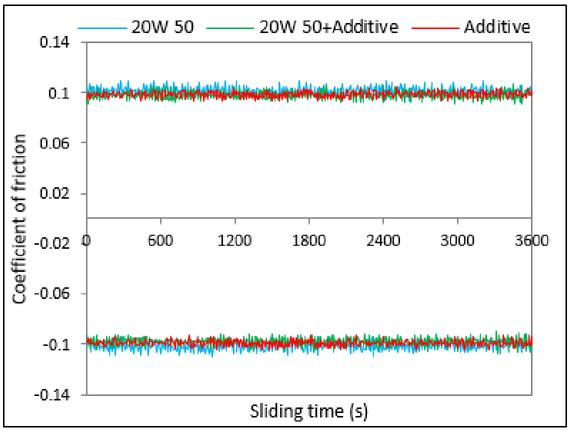


Figure 10. μ- sliding time changes (100 N, 0.150 m/s)

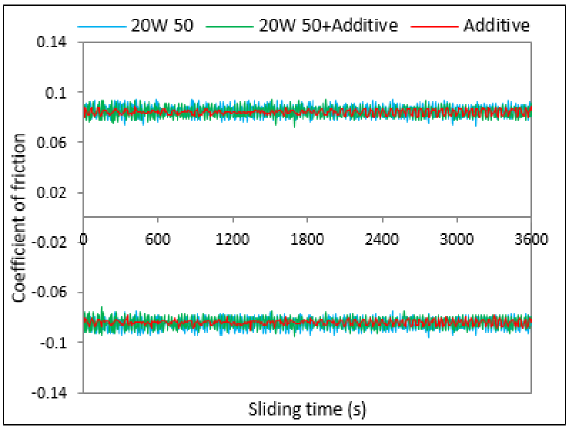


Figure 11. µ- sliding time changes (100 N, 0.225 m/s)

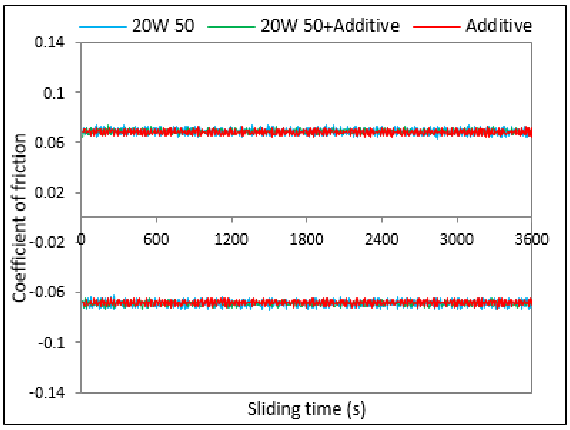


Figure 12. µ- sliding time changes (100 N 0.300 m/s)

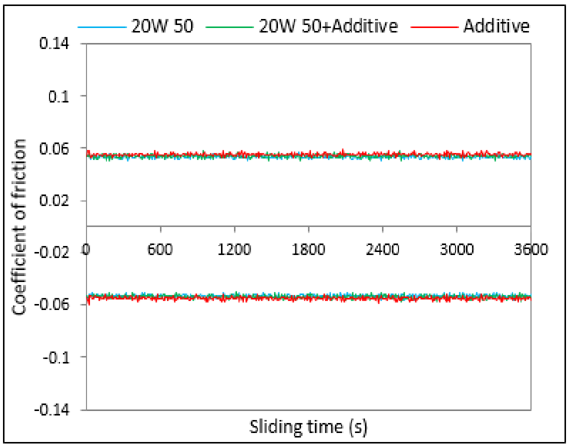


Figure 13. µ- sliding time changes (100 N, 0.4125 m/s)

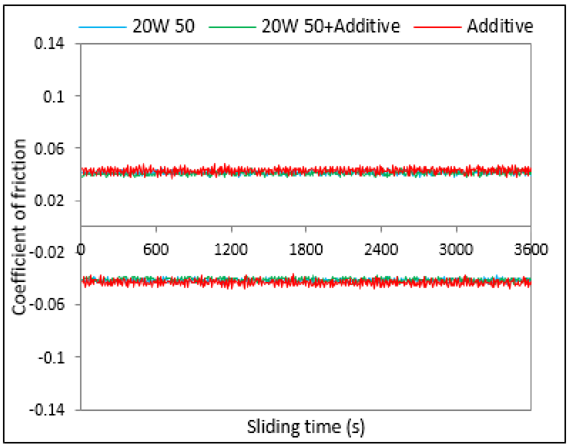


Figure 14. µ- sliding time changes (100 N, 0.450 m/s)

Commercial motor oil showed the lowest friction coefficient values under 150 N load and all sliding speeds experimental conditions Fig. 15-20. Additionally, when the sliding speed increased, the friction coefficient increased with all experimental conditions Fig. 23. Test results in Figures15-20 show that all experimental results have lower friction coefficients using with commercial oil under 150 N load. It was considered to be an increase in the obtained coefficient of friction except for the commercial motor oil tests. For some reason; it didn't occur enough lubricant layer thickness under 150N load

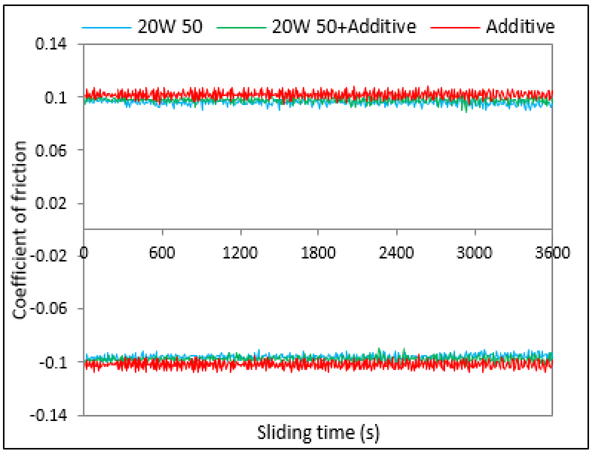


Figure 15. µ- sliding time changes (150 N, 0.1125 m/s)

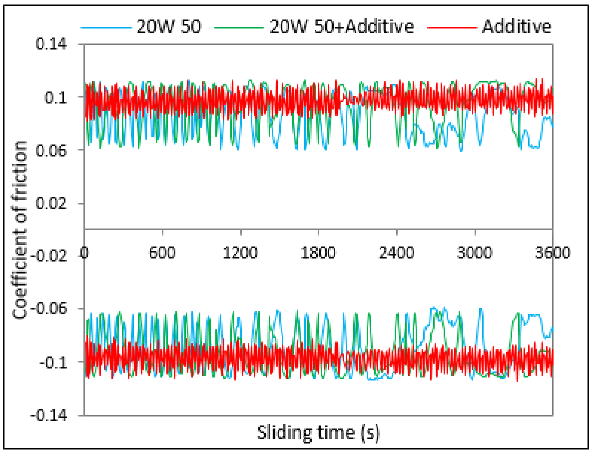


Figure 16. µ- sliding time changes (150 N, 0.150 m/s)

because of the low viscosity of the additive agent so it caused mechanic contact between surfaces.

Viscosity values of the commercial motor oil and additive were shown in Table 1. It was determined that the friction coefficient decreases with increasing the sliding speeds in all experimental conditions. Tunay used the same reciprocating test rig to investigate the friction properties of pure soybean oil and 5% boric acid-added soybean oil under boundary lubrication conditions. He observed that the friction coefficient decreases with increasing sliding speed [29].

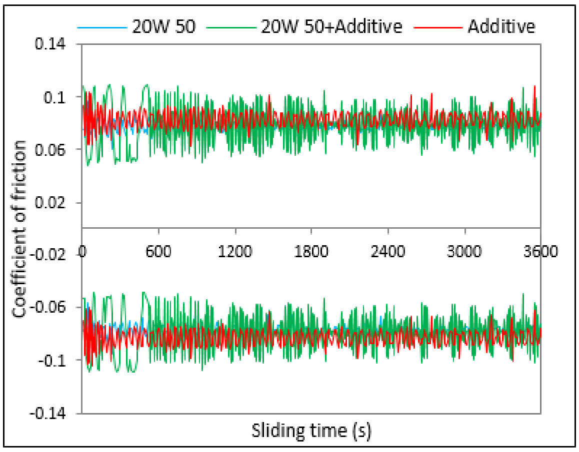


Figure 17. μ- sliding time changes (150 N, 0.225 m/s)

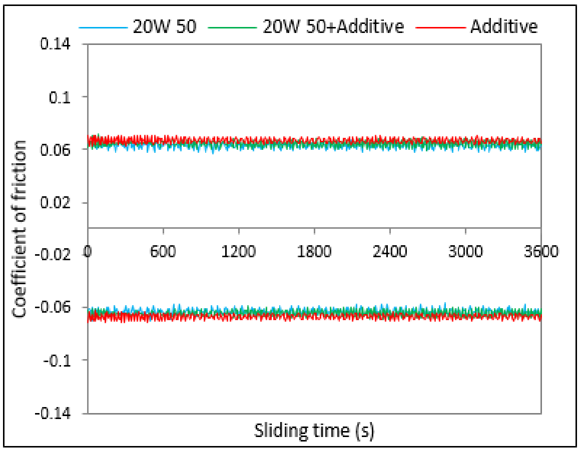


Figure 18. μ- sliding time changes (150 N, 0.300 m/s)

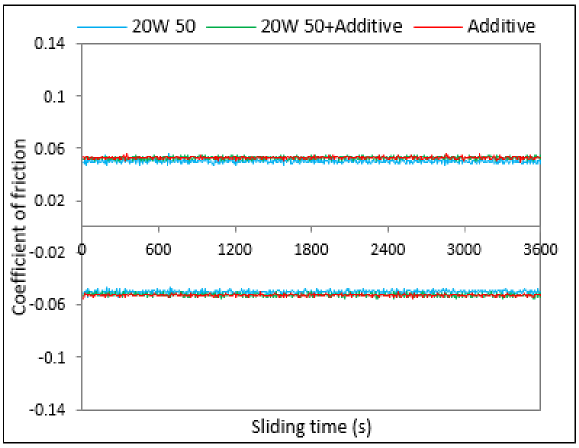


Figure 19. μ- sliding time changes (150 N, 0.4125 m/s)

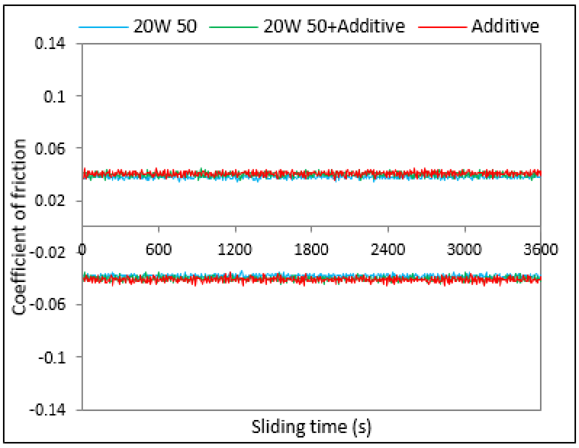


Figure 20. μ- sliding time changes (150 N, 0.450 m/s)

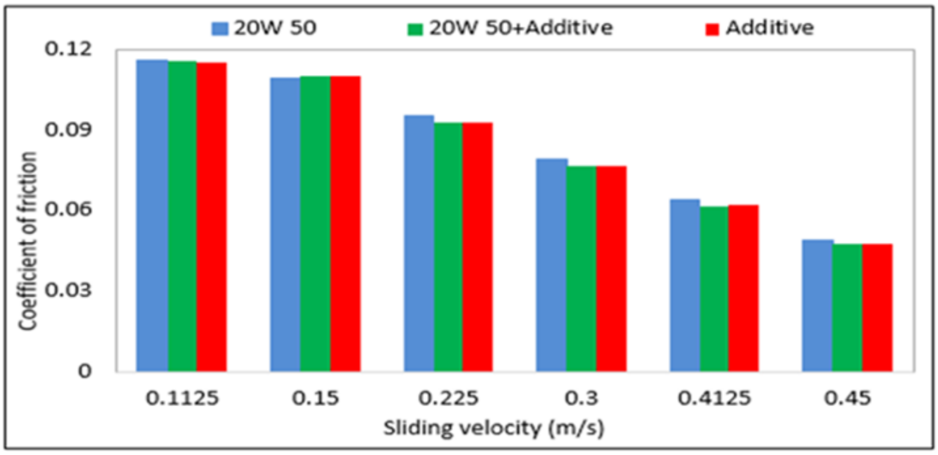


Figure 21. Friction coefficient and sliding speed under 50 N load

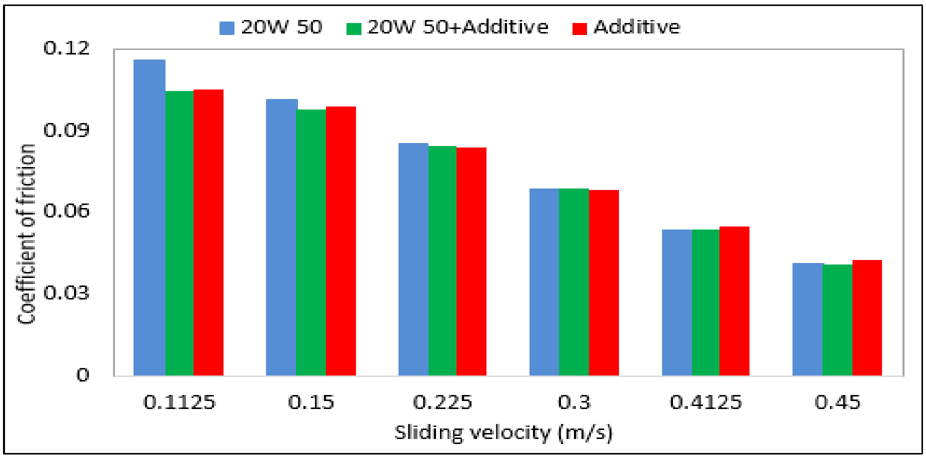


Figure 22. Friction coefficient and sliding speed under 100 N load

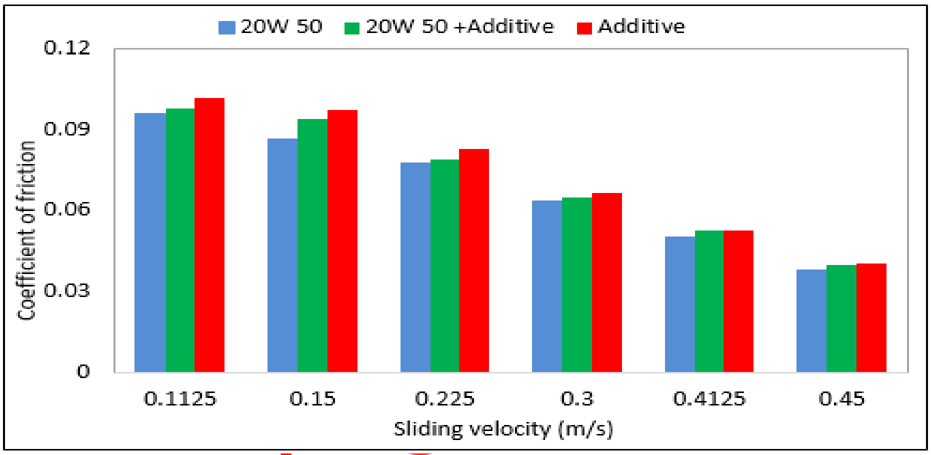


Figure 23. Friction coefficient and sliding speed under 150 N load

According to a general overview of the results as test conditions (time, speed, and load) and a high coefficient of friction considered to be obtained, though reciprocating friction test apparatus has a small oil tank, boundary lubrication and/or mixed lubrication regimes. A boundary lubrication regime is essential to have adsorbed layers, chemisorbed films, or films (additive layers) formed by chemical reaction rather than fluid film or hydrodynamic lubrication. Additive layers or the response with the surface of the lubricant containing additives is formed under chemical and mechanical mechanisms. The mechanical surface reaction between the lubricant and sliding pairs needs surface degradation [25].

Internal combustion engines experience power disasters from rubbing due to the lubricant's thick, viscous drag and contact catastrophes caused by warming up under mixed and boundary-pushing situations. The former can be lessened by reducing oil thickness, but only to the degree where a lubricant coating is maintained, keeping moving parts apart. Boundary lubrication takes place in many targeted areas of the engine. The oil film created during this type of lubrication or greasing is insufficient to keep moving parts apart. The amount that these surfaces move past one another determines how much drag is produced by the limited oil. Using rubbing modifiers is one way to reduce energy losses while maintaining a limit film. By definition, the base liquid itself acts as a friction/grating modifier, but the need for efficiency has led to the addition of additional contact modifiers. In the way of activity, friction modifiers are clearly distinguished from antiwear added compounds [30].

4. CONCLUSION

The reciprocating test rig was used in this experimental study to measure the coefficient of friction between the used motor cylinder and piston ring using three different lubricants. Test specimens lubricants, were commercial motor oil, 5% additive with commercial motor oil, and only additive agent.

-All lubricants showed similar and so close friction coefficient values in the experimental results.

-The reason for the similarity in the results may be the most possible reasons such as the short sliding time, and other test parameters. These results show that all lubricant types are suitable for the experimental conditions in this study.

-Using additives in the commercial oil lubricant showed a little reduction under the lower load. When the applied load increased commercial oil showed better friction coefficient performance in the experimental study.
-Coefficient of friction reduced with increasing load under all sliding speeds.

-As for the expected results, the friction coefficient reduced with increasing sliding speeds under all conditions.

-In general, commercial oil fortifiers didn't highly affect to reduce the friction coefficient when all the results were evaluated, in these experimental conditions.

ACKNOWLEDGEMENT

This study was published as a summary paper at the 1st International Conference on Tribology - TURKEYTRIB 15 conference.

DECLARATION OF ETHICAL STANDARDS

B The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

AUTHORS' CONTRIBUTIONS

Mithat ŞİMŞEK: Conceptualization, performed the experiments and analysis the results.
Özlem SALMAN N TEZIYAREMYE: Conceptualization performed the experiments and analysis the results.
Emrullah Hakan KALELİ: Review the manuscript.
Recai Fatih TUNAY: Review the manuscript.
Ertuğrul DURAK: Conceptualization, review of the manuscript, and supervision administration.

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