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# THE INFLUENCE OF MOLYBDENUM DISULPHIDE-FRICTION MODIFIER (FM) ADDITIVE INCREMENT ON THE FRICTION AND WEAR PREVENTION BEHAVIOUR OF HVI 60 BASE OIL

## PENGARUH PENAMBAHAN ADITIF PEMODIFIKASI GESEKAN JENIS MOLIBDENUM DISULFIDA TERHADAP KARAKTERISTIK GESEKAN DAN PERLINDUNGAN KEAUSAN MINYAK LUMAS DASAR HVI 60

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### ABSTRAK

*Gesekan selalu ada dalam suatu sistem mekanikal. Oleh karena itu diperlukan langkah-langkah untuk meminimalkan gesekan, sehingga pemakaian energi menjadi lebih efisiensi.Makalah ini membahas pengaruh penambahan aditif pemodifikasi gesekan serbuk MoS2 ukuran 1,5 µm dengan jumlah mulai 0,05%; 0,1%; 0,5%; 1% dan 2% berat dan ukuran 90 nm sebesar 0,05% 0,1%; 0,5% pada minyak lumas dasar mineral HVI 60, terhadap karakteristik gesekan dan perlindungan keausannya. Aditif ukuran 90 nm dan minyak lumas dasar dicampur dan diaduk menggunakan magnetik stirrer selama enam puluh menit pada suhu 50oC setelah itu dimasukkan ke dalam ultrasonic homogenizer selama satu jam, sedangkan aditif ukuran 1,5 µm pada suhu 75oC tanpa menggunakan ultrasonic homogenizer. Campuran yang dihasilkan diuji karakteristik gesekan dan perlindungan keausannya menggunakan mesin uji four-ball dan mesin uji SRV. Analisis dilakukan pada goresan permukaan bola uji menggunakan scanning electron microscope (SEM). Hasil penelitian menunjukkan bahwa penambahan aditif meningkatkan perlindungan keausan dengan dosis optimal sebesar 0,1% berat dengan rincian ukuran 1,5 µm perbaikannya sebesar 23% dan ukuran 90 nm sebesar 11%. Pengamatan permukaan goresan menunjukkan mekanisme keausan terjadi secara adesif dan abrasif. Data yang diperoleh dari penelitian ini bisa digunakan sebagai dasar dalam pembuatan minyak lumas yang bisa meningkatkan kinerja mesin.*

***Kata Kunci:*** *aditif, gesekan, keausan, molibdenum disulfida,* four-ball

### ABSTRACT

Friction will always be found in a mechanical system. It is therefore necessary to minimize friction, so it becomes a more efficient use of energy. This paper discusses the influence of $MoS_2$ friction modifier (FM) additive in the form of powder with two different mesh sizes, i.e. 90 nm and 1.5 um, on the friction and wear characteristic of HVI 60 base oil. The variation of $MoS_2$ were 0,05%; 0,1%; 0,5% weight whereas $MoS_2$ 1.5 um were 0,05%; 0,1%; 0,5%; 1% and 2% weight. $MoS_2$ additive 90 nm was mixed with base oil and stirred with magnetic stirrer for 60 minutes at 50°C and homogenized in an ultrasonic homogenizer for 1 hour. For the $MoS_2$ 1.5 um, the additive was mixed with base oil and stirred with magnetic stirrer for 60 minutes at 75$^o$C without using an ultrasonic homogenizer. Friction and wear characteristics of these mixtures were tested using four-ball and SRV test-rig. The wear scars were analyzed by using a scanning electron microscope (SEM). The results of the tests showed that the addition of 0.1% weight $MoS_2$ additive, both in 90 nm and 1.5 um, resulted in an optimum increase in friction and wear characteristic of 23% and 11%, respectively. Observation on the wear scar showed that adhesive and abrasive wear mechanisms were involved in the wear process. The results of this research could be applied in the production of lubricating oils that can improve engine performance. Keywords: additive, friction, wear, molybdenum disulfide, four-ball

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## I. INTRODUCTION

Loss of mechanical energy in a system is partly contributed by the energy used to overcome friction. For example, the balance of energy that has been supplied by fuel in a car, 50% will be wasted in the form of heat, 8.3% is lost to overcome the friction in the engine, 4.17% is lost in overcoming friction in the transmission system, and 37.5% is used for moving (Pirro & Wessol 2001).

In addition to a decline in efficiency, friction generated heat causes wear and tear that could lead to faulty equipment. Friction and wear is the dominant factor in energy efficiency and mechanical durability of equipment. In the automotive engine components, friction is primarily derived from a series of piston (59.5%), bearings (8.8%), the valve mechanism (23.7%), and other parts (7.9%) (Dresel 2007).

In the majority of Tribology system applications, liquid lubricants and lubricating grease is used to overcome friction and wear. But in a variety of conditions, such as very high or low temperatures, vacuum conditions, the effect of radiation, extreme pressure, and in other cases, an alternative could be solid lubricants. The combination of liquid lubricants with solid lubricants are also suitable and have beneficial synergies against friction performance and wear and tear on the sliding contact (Kenneth 2001).

A thin layer with low shear strength of gases, liquids, and solids placed between two surfaces will improve the smoothness of the movement from one surface to the other surface and prevent damage. This layer is usually very thin with a thickness between 1-100 µm therefore its existence was difficult to observe, but the layers can still be found. Knowledge related to the strengthening or diagnosis of the effectiveness of coating that prevents damage to the solids touch point is generally referred to as lubrication (Stachowiak & Batchelor 2005).

Research which has been undertaken to reduce friction and wear using solid lubricants can be divided into two major parts; the utilization of solid lubricant material in a manner superimposed on the surface of the specimen through both physical and chemical processes, and as an additives mixed into lubricating oil.

W. Jiang has conducted research on the solid lubricant coating of nano particles through electrostatic spray coating (ESC) (Jiang et al. 2004). J. Lou and colleagues investigated the effect of $MoS_2$ solid lubricant coating on the surface of the steel against rotational fretting wear of the angular variation of displacement amplitude, constant normal load, and speed of rotation. Analysis of test results was by using the SEM, EDX, XPS, optical microscopy and profilometer. Results of studies have shown that a decline in the coefficient of friction and wear was relatively smaller (Luo et al. 2011).

Research on the use of solid lubricants as an additive carried out by M. Kalin and colleagues, focused on the mechanisms and increase in the performance of lubricating oil base with nanotubes $MoS_2$ additive on the behaviour of friction and its wear characteristics. The results of these experiments have shown that the friction coefficient of lubricating oil dropped two-fold and wear rate fell 5-9 times lower when nanotubes MoS2 additives were added than if just using lubricating oil base (Kalina et al. 2012). J. Kogovsek and his colleagues have examined the effect of roughness surfaces of steel coated with lubricating oil in which there were nanotubes $MoS_2$ all over the lubrication areas. The results showed the friction coefficient down 40-65% depending on the surface roughness of the metal when using lubricating oils containing nanotubes $MoS_2$, rather than when only using lubricating oil base. Meanwhile, the friction coefficient did not vary much for a wide range of surface roughness, if using lubricating oils containing nanotubes $MoS_2$ (Kogovsek et al. 2013).

Some of inorganic materials (such as molybdenum disulfide, graphite, hexagonal boron nitride and borides acid) can provide better lubrication. (Dresel 2007). Most of these materials have their own lubrication properties due to lamellar crystal or crystal terraced structures as well. A small part such as a soft metal, polytetrafluoroethylene, polyimide, specific oxides and rare-earth Fluorides, diamond and diamond-like carbons, and fullerenes can also provide good lubrication, despite not having a lamellar crystal structure (Dresel 2007).

The development of engine design can affect the lubricant needs. Modern engines are made with greater precision with smaller gaps between the components, higher engine speed, higher compression pressure, the ratio between engine capacity and larger power output, and more efficient fuel consumption. These factors require a lubricant with low viscosity characteristics which is able to withstand large loads. $MoS_2$ additive has a very important role in improving the performance of lubricants. In a very small gap in engine components, lubricating liquid will be easily thrown out of the surface, but that is not the case with $MoS_2$ solid lubricant. This solid lubricant will adhere well, which will protect the metal surface and lead to a lower friction levels, so that the machine is expected to be durable and fuel consumption will be decreased.

This study focused on the effect of friction modifier powdered $MoS_2$ additive on the mineral lubricating oil HVI 60. The reason for using $MoS_2$ additives is because of the widespread availability in the market of a variety of types, which are cheaper and are suitable for applications in engine lubricants. This study has observed whether these additions will affect the friction characteristics and wear protection of lubricating oil base and optimal dosage of the additive. The selection of HVI 60 as the research object was because this type is included in a group of lubricating oil base with low quality that comes from domestic refineries, so that the implementation of this research is expected to increase the sale value of the lubricating oil base, in particular HVI 60 and lubricating oil base mineral types in general.

## II. METHODOLOGY

This study begins with the preparation of tools and materials to formulate lubricating oils and additives. A mixture consisting of lubricating base oils and additives with a specific composition is blended while heated in order to form an homogenous mixture. The resulting mixture was then tested to obtain the characteristics data of its protection wear and friction coefficient. The data obtained from the testing process was then analyzed to arrive at any conclusions.

Materials used in this study consisted of a base lubricating oil HVI 60 and powdered $MoS_2$ as friction modifier additive. HVI 60 is a lubricating base oil derived from crude oil that has been processed in RU IV Cilacap oil refinery with a range of values of kinematic viscosity at a temperature of 100°C between 4.4 up to 4.9 cSt and categorized as Group I based on grouping by API. Powdered MoS2 could be obtained from the finished products and sold freely in the market. There are two types of powdered $MoS_2$; the first production Kingxin Limited has an average size 1,5µm with a purity of 98.83% , and the production of M. K Impex Corp. which has a size of 90 nm with 99% purity.

Additives with a size of 90 nm, as much as 0.05%; 0.1% and 0.5% by weight of the lubricating base oil, is then mixed and stirred using a magnetic stirrer for one hour at 50°C, and after that it is put into an ultrasonic homogenizer for one hour and the resulting mixture was coded as N0,05 ; N0,1 and N0,5. Additives with a size of 1.5 µm dose of the additive was 0.05%; 0.1%; 0.5%; 1% and 2% by weight, stirring using a magnetic stirrer for one hour at a temperature of 75$^o$C without being homogenized in ultrasonic homogenizer and the resulting mixture was coded as M0,05; M0,1; M0,5; M1; and M2 respectively.

The resulting mixture was tested on its friction characteristics and wear protection using a four-ball test machine and SRV test machine then analyses were performed on a spherical surface scratch test using the scanning electron microscope (SEM). A four-ball test, involves using a four-ball tester by rotating a ball tester against a stationary three balls tester. As a result, the three stationary balls will wear out with the wear profile of a circle or ellipse in accordance with the ASTM D 4172 test method. Friction characteristics testing was conducted according to ASTM D-6425 using a test machine Brand Optimol SRV Series III in Product Development Laboratory Pertamina for 120 minutes. The Friction surface of the four-ball tester was observed using a scanning electron microscope (SEM) after cleaning using toluene and acetone. An SEM test was performed in the laboratory of SEM Department of Metallurgy and Materials Engineering, at the University of Indonesia. Testing SEM SEM LEO 420i was conducted by using the property of the Department of Metallurgy and Materials.

## III. RESULTS AND DISCUSSION

Analysis of test results was conducted on the characteristics of wear protection, friction coefficient, the surface scratch profile, the former lubricating oil testing and the material testing ball.

### A. Characteristics of wear protection.

Characteristics of protection against wear is indicated from the large diameter scratches (scar diameter) ball test of the testing process using a four-ball then the average value was calculated as shown in Figure 1 as one sample of test results.

After an assessment, the amount of diameter scratches of HVI 60 is 1449 µm or 1.449 mm. Four-ball test results of this sample are shown in Figure 2

Figure 2 shows that the addition of $MoS_2$ into HVI 60 leads to a lowering of the stroke diameter. This happened on samples M0,05; M0,1; M0,5; M2 and N1.

However, there are several samples, namely M1; N0,05 and N0,5 diameter of the stroke which

(a) 1st Ball, R=730.8µm (b) 2nd Ball, R=740.4 µm (c)3rd Ball, R=702.40 µm

**Figure 1**
**Four- ball test results HVI 60.**

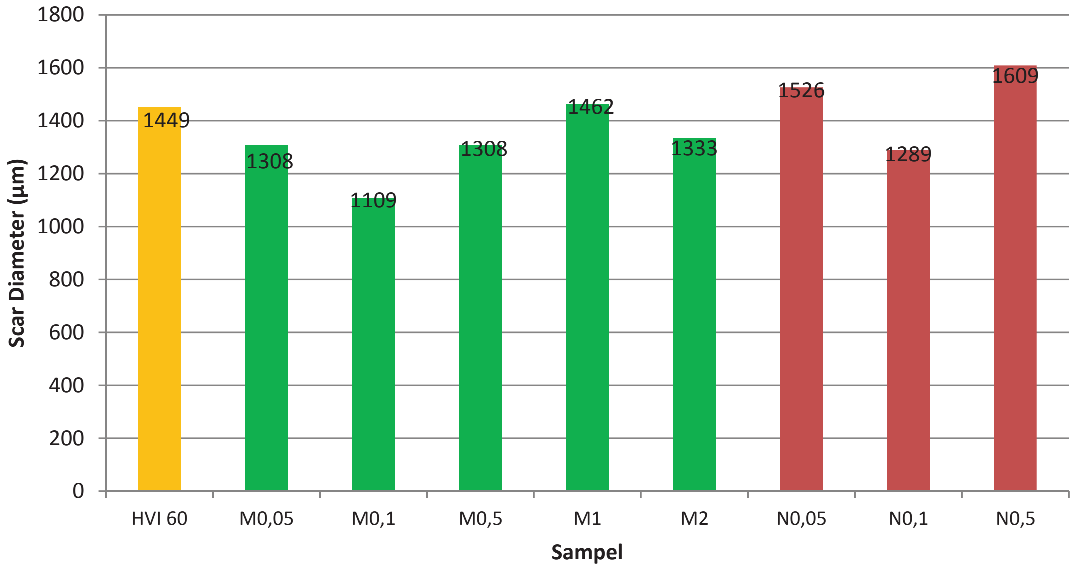

**Figure 2**
**Graphs the results of scar diameter four- ball test.**

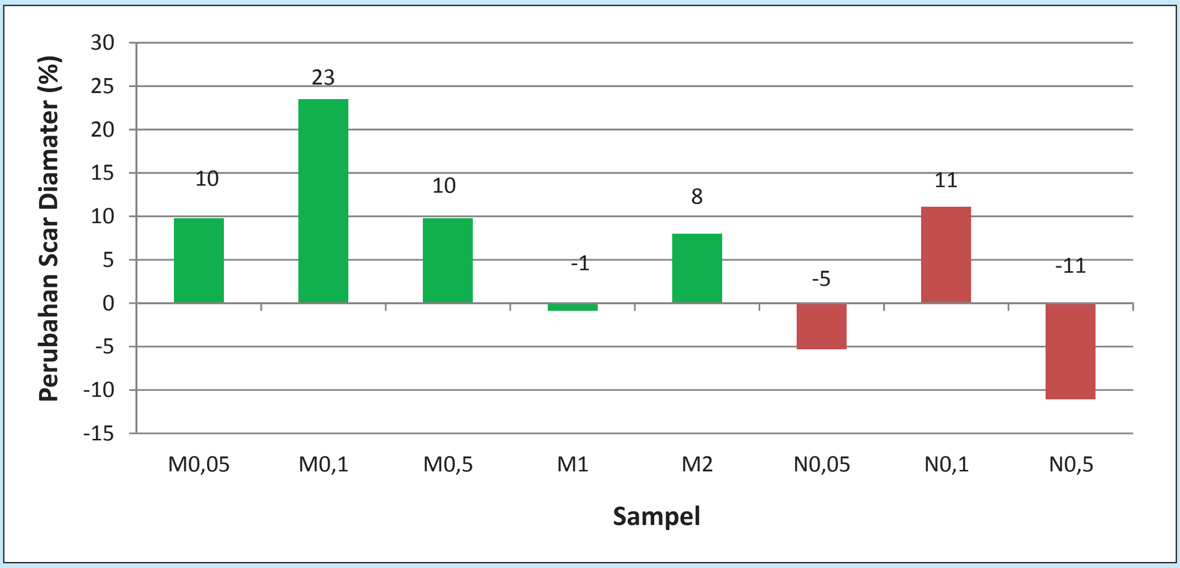

**Figure 3**
**Charts of the precentage of scar diameter changes.**

are higher than HVI 60. In samples M1 and M2 the change in the diameter of the stroke was not significant and contradictory, with that possibly because the dose exceeds the ability to dissolve lubricating oil additives. It can also be due to the additives not being mixed perfectly resulting in the deposition of additives. Although it has been avoided by means of an ultrasonic homogenizer and the mixture which is inserted is tested immediately afterwards, but based on visual observations, the precipitation began to occur about 5 minutes after the mixing process.

M0,1 samples showed the best results with the addition of $MoS_2$ dose size of 1.5 µm of 0.1% by weight. Based on this research, the optimum dose addition of $MoS_2$ size of 90 nm is equal to 0.1% by weight represented by the sample N0,1. The optimum dose addition of $MoS_2$ size of 1.5 µm of 0.1% by weight as well, which is indicated by the sample M0,1

The factors that influence the effectiveness of the $MoS_2$ additive were working temperature, environmental conditions, especially moisture, size, and degree of purity (Leslie 2003). The most influential factor in our research is the size of the MoS2 additive. This is because other factors are considered similar because it was conducted on the premises, tools and purity are approximately equal. Four-ball test results indicate that $MoS_2$ with the size of 1.5 µm showed better performance compared to the size of 90 nm.

$MoS_2$ effectiveness will increase when there is greater contact force against the lubricated components. It can be achieved by increasing the surface area of $MoS_2$, which means making a smaller particle size. However, when it is getting smaller the $MoS_2$ particle size will be more easily oxidized into $MoO_3$ abrasive, especially if the environmental conditions of high humidity and high temperatures. When the level of oxidation is increasing, there are more products $MoO_3$ that will be formed which will increase the abrasive wear as well as the coefficient of friction of the lubricant (Leslie 2003). The optimum size of $MoS_2$ cannot be known yet from this study because it only uses 2 types of sizes of 90 nm and 1.5 µm.

The addition of $MoS_2$ size of 90 nm, with a dose of 0.05% and 0.5% by weight, was indicating that abrasive products $MoO_3$ resulted in scratches that are bigger in diameter than HVI 60 (without additive), which is shown from the observation surface scratches four ball - test results using SEM. The concentration of small nano particles additive, instead of a rolling forming, it was forming a sliding friction, which will cause the larger amount of friction. If there is an over concentration, the nano particles will tend to be agglomerated to form aggregates with a larger particle size and chemical precipitation will occur (Jiao et al. 2011). In the experiment using nanocomposite additives $Al_2O_3$/$SiO_2$ with a size of 70 nm and with a dose of 0.05%; 0.1%, 0.5% and 1% by weight of the mineral base lubricating oils, obtained optimum dose of 0.5%, mean the optimum dose addition is 0.1%. This could be due to differences in the type of material, size, mixing methods, amongst others factors.

On the addition of $MoS_2$ size of 1.5 µm with a dose of less than 0.1% by weight showed the larger scar diameter as indicated at a dose of 0.05% by weight. This is because there is an insufficient number of particles required to form a protective layer. Meanwhile, the addition of a dose of larger than 0.1% by weight, the amount of particles added was in excess of what is needed and it becomes abrasive, resulting in a larger scar diameter.

The impact of varying percentage levels of $MoS_2$ additive is shown in Figure 3. The best performance of 23% was obtained by adding 0.1% $MoS_2$ additives size of 1.5 µm.

On the addition of MoS2 size of 1.5 µm with a dose of less than 0.1% by weight showed the larger scar diameter as indicated at a dose of 0.05% by weight. This is because the number of particles required to form a protective layer is not sufficient. Meanwhile, the addition of a dose of larger than 0.1% by weight, the amount of particles added was in excess of what is needed and it becomes abrasive so the scar diameter becomes larger.

The percentage of $MoS_2$ additive effect is shown in Figure 3. The increasing of the best performance of 23% was obtained by adding 0.1% $MoS_2$ additives size of 1.5 µm

The addition of $MoS_2$ additive did not provide overall improvement in the quality of its wear protection. Improvement occurred with samples of 0.05; 0.1; 0.5; M2 and 0.1. There was a detrimental effect with negative results for samples M1; N0,05 and N0,5. Worst affected was N0,5 sample of 11% (adding a dose of 0.5% by weight of additives $MoS_2$ size of 90 nm).

### B. Characteristic coefficient of friction

The friction characterics test was carried out on HVI 60; M0,05; M0,1; M0,5 and M1 samples. The four-ball test results showed indications of protection against wear $MoS_2$ additives was better by adding a dose of 0.1% by weight for size of 1.5 µm, so that the coefficient of friction testing was focused on the sample by the addition of additives of micron size.

HVI 60 friction coefficient as base lubricant without additive showed a smooth graph and stable trend that indicates existing barriers for movement back and forth on the test ball test disc is relatively

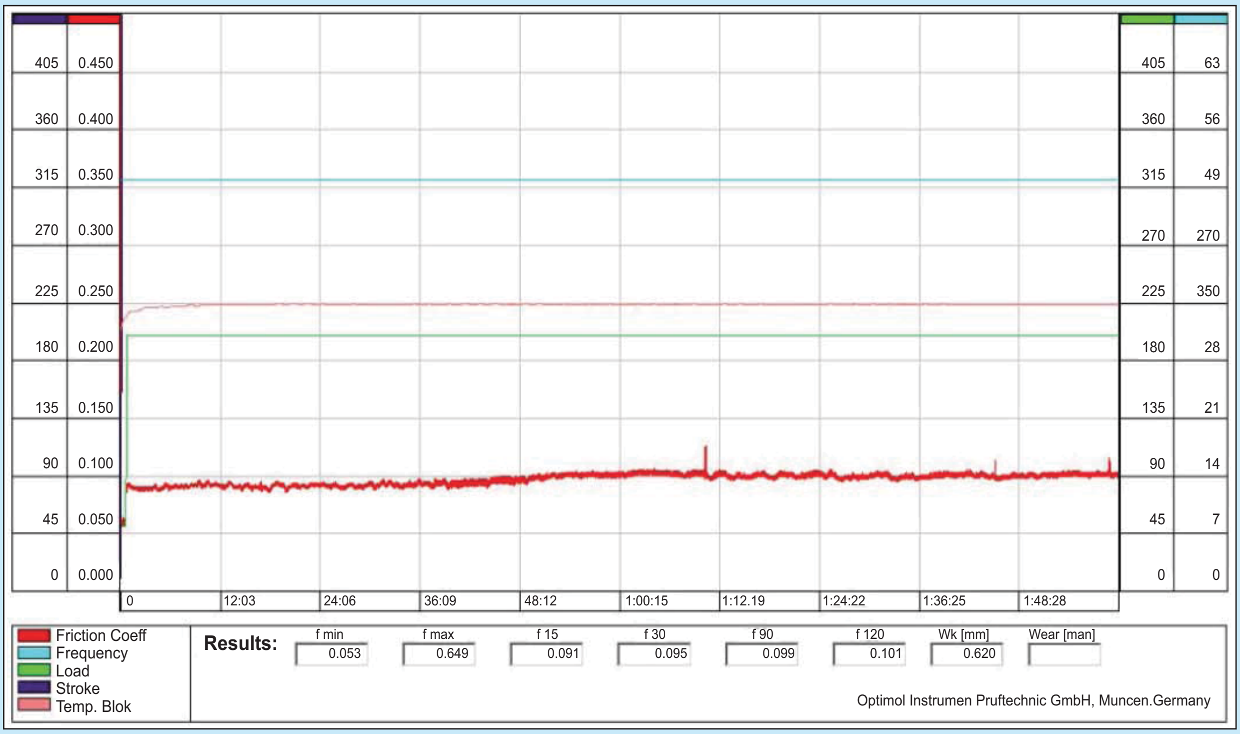

**Figure 4**
**Chart of samples HVI 60 friction coefficient.**

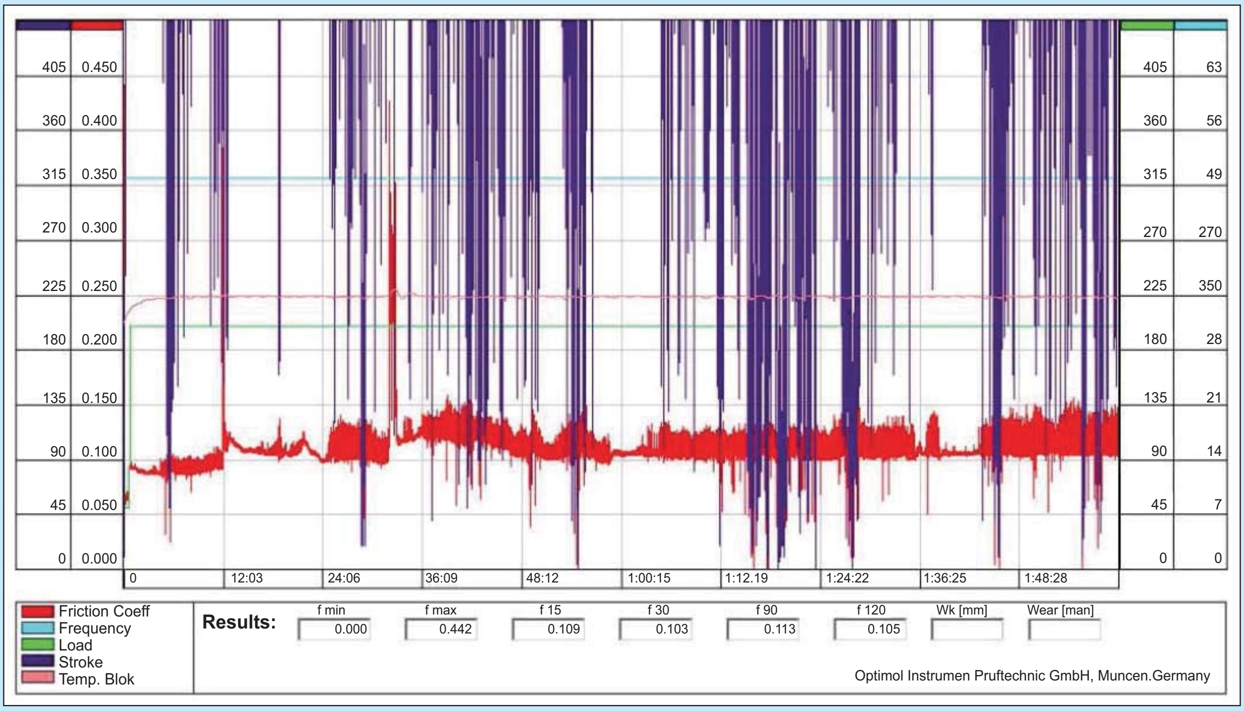

**Figure 5**
**The Chart of M0,05 sample friction coefficient.**

small. The profile coefficient of friction of HVI 60 as shown in Figure 4.

Minimum friction coefficient of 0.058 occurred at the beginning of the test and a maximum of 0.649. There was a low coefficient of friction at the beginning of the test and it continued to rise until the end of the test. In the 15th minute, the coefficient of friction was 0.091 (F15), at the 30th minute it rose to 0.095 (F30), at the 90th minute it was 0.099 (F90) and 0.102 at the end of the test at the 120th minute (F120). It can be explained by the fact that at the beginning of the test there has not been a lot of wear and tear so that the barrier to metal products tended to be smaller. The obstacle was caused by the metal surface profile test. Worn metal products will increase the barriers to the movement of the test specimen, a trend that increases when tests are carried out for a longer period, which is indicated by the increase in the coefficient of friction.

M0.05 sample friction coefficient (a dose increase of 0.05% by weight) was showing a rough chart and tends to be unstable which indicates the obstacles that exist for movement back and forth on the test ball test disc are relatively large. The coefficient of friction of at least 0,000 occurred at the beginning of the test and immediately rose to about 0,100 in the first minute and to a maximum of 0.442 after about 32 minutes of testing. The coefficient of friction at the beginning of the test is high compared to HVI 60 at the beginning of the test, then rose to 0,103 at the 30th minute and tends to increase until the end of the test when it was 0,105.

The coefficient of friction of M0.1 samples (adding a dose of 0.1% by weight) shows a rough chart and tends to be unstable at the beginning of the test until about forty minutes. This condition is probably caused by the formation of a protective layer $MoS_2$ which has not been formed optimally, so that conditions such as on the M0,05 sample testing will occur. The coefficient of friction of at least 0,000 occurred at the beginning of the test and immediately rose to about 0,100 in the first minute of the friction coefficient, even at a maximum of 1,376, in about 10 minutes of testing. The coefficient of friction after forty minutes tends to be stable until the end of the test at 0.1000. This is most likely caused by the equilibrium between the formation of protective coatings, abrasive wear products, and the rate of its wear characteristics that is able to be achieved. The profile coefficient of friction of the M0.1 sample shown in Figure 6.

The coefficient of friction of 0.5 M samples (dosage increase of 0.5% by weight) has a smooth graph and tends to be stable as the coefficient of

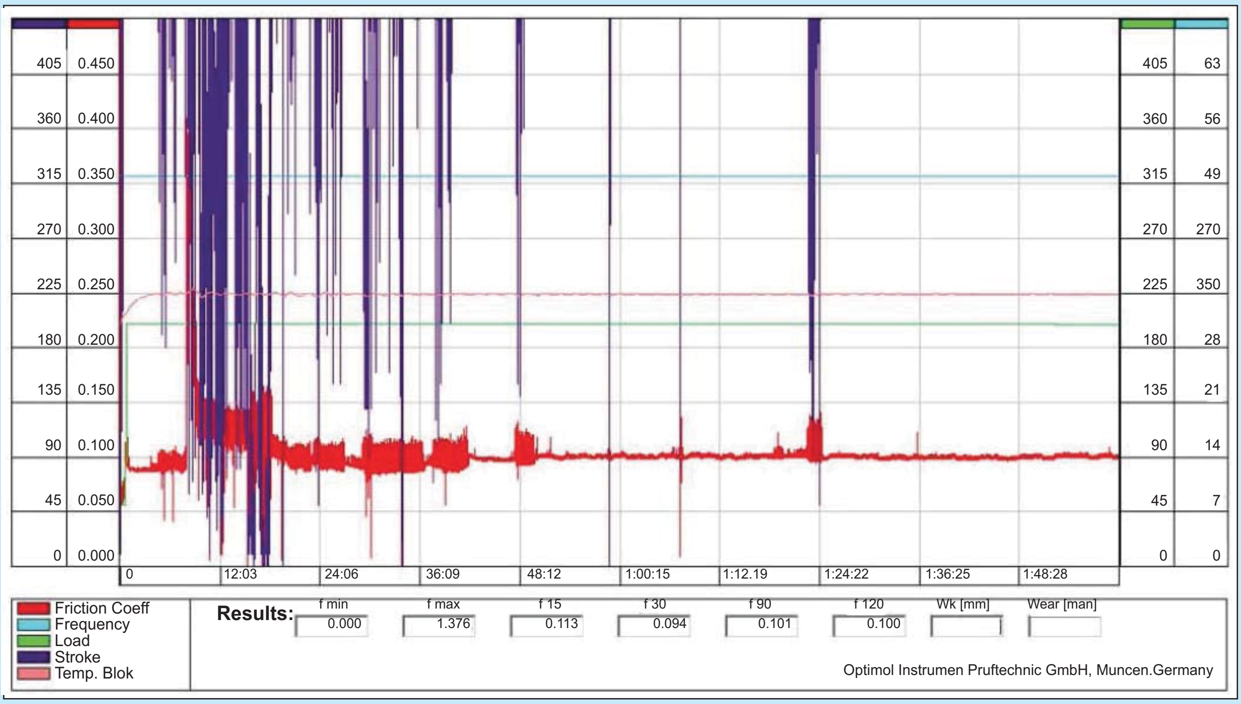

**Figure 6**
**Chart of sample M0,1 friction coefficient.**

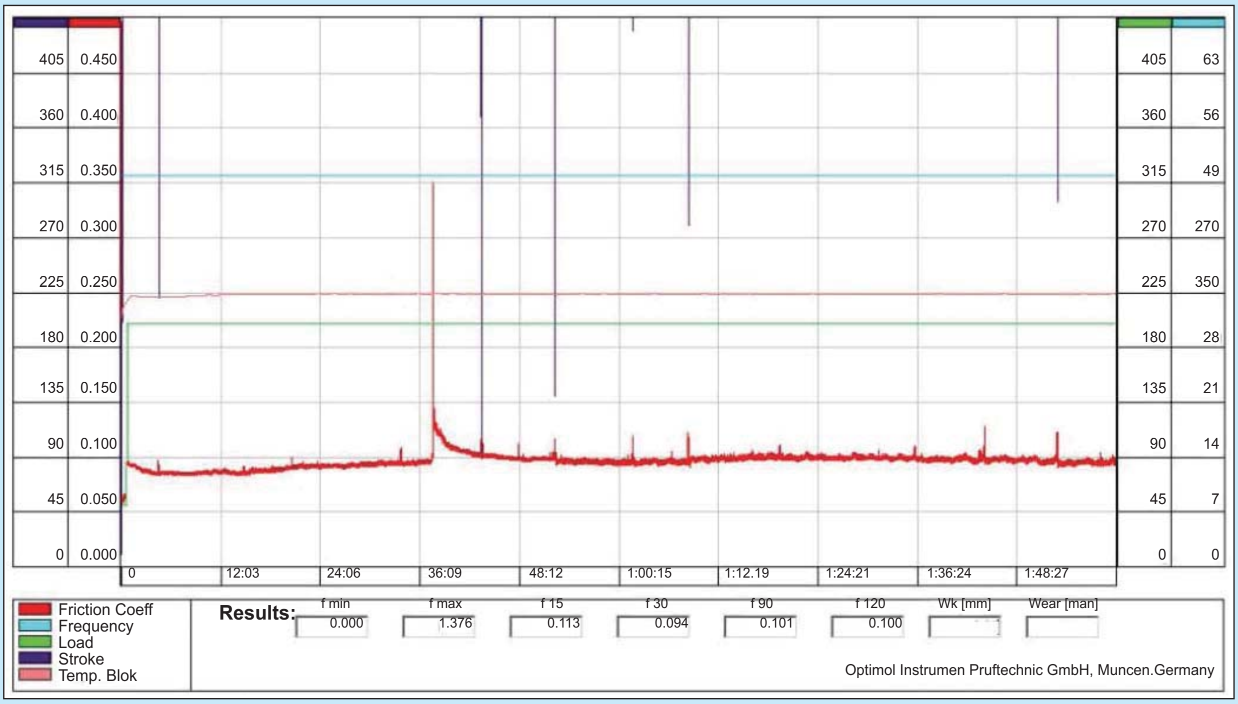

**Figure 7**
**Chart of M0,5 sample friction coefficient.**

friction sample profile HVI 60. The profile coefficient of friction of the M0,5 sample is shown in Figure 7.

The coefficient of friction of M1 samples (dose addition of 1% by weight) shows a rough chart and tends to be unstable which indicates a large obstacle for movement back and forth on the test ball against test disc. Although the friction profile is unstable, the results are still better than the M0,05 sample. A minimum friction coefficient of 0.000 occurred at the beginning of the test and immediately rose to more than 1,000 in the first minute and to a maximum of 1,282 in about ten minutes of testing. This is due to the addition of large doses of additives, so that there was friction between molecules $MoS_2$ in addition to friction between its asperitis, mainly in the initial thirty minutes of testing. After thirty minutes of equilibrium between the formation of protective coatings, abrasive wear products, and the rate of its wear characteristics the friction coefficient is stable at 0.1000 until the 48th minute. At about the 70th minute to the 100th minute, the friction profile is not unstable anymore, which is due to the equilibrium obtained already having shifted. The profile coefficient of friction of the M1 samples is shown in Figure 8.

Overall, these results is equal with the results of rOverall, these results are the same as the results of research related to the use of $MoS_2$ additives in the case of a decrease in wear and tear, however, there are not any differences in the magnitude. Decrease in wear and tear in this research is a maximum of 23% and there was no significant change to the coefficient of friction. Research by Kalin M et al shows the friction coefficient of lubricating oil dropped two-fold and wear rate fell 5-9 times lower if MoS2 nanotubes additives with a size of 100-500 nm were added into synthetic lubricating oil base , rather than if just using a lubricating oil base.

## C. SEM Analyses

Figure 9 shows surface SEM photograph of the test sample at a magnification of 250 times. The surface of profile HVI 60; M 0.05 and N0,05 look smoother than others because there is almost no additive effect. According to the theory mechanism of wear, wear and tear that occurs is predominantly by adhesive wear, although it is also possible that there was a slight influence by abrasive wear. When the $MoS_2$ additive is added by more than the optimum dose and thereby exceeds the limit, then the possibility of the formation of oxidation products $MoO_3$ abrasive will be even greater, so that the surface profile becomes more rugged and forms patterns such as the elongated trench. There is a trench shape instead of a straight line, but in the form of an arch due to the movement of four-ball test with circular movements. Scratches on the surface can be seen in the short irregular wear of metals as in HVI 60 and small elongated shape as in sample M2. Irregular short form is usually caused by wear adhesive while the elongated shape is due to abrasive wear.

Wear metal particles and scratches on the surface profile can be seen more clearly on higher magnification as presented in Figure 10.

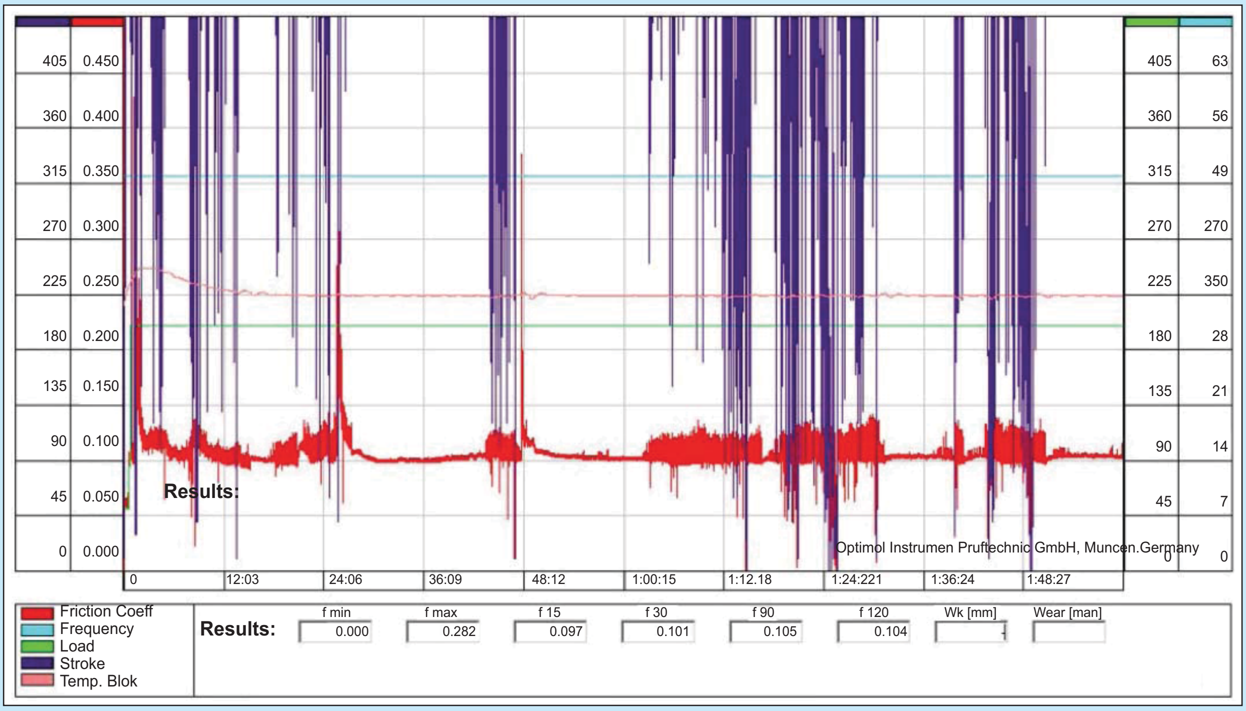

**Figure 8**
**Chart of M1 samples friction coefficient.**

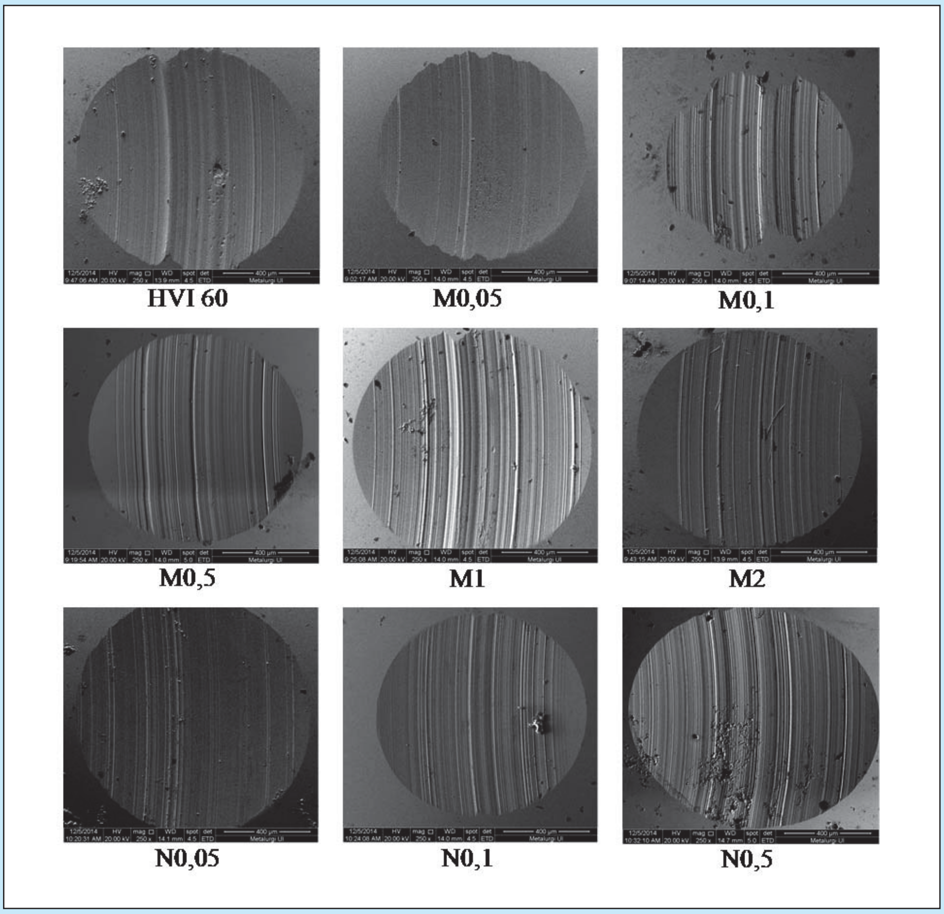

Figure 9
SEM photos spherical surface test with 400 μm bar scale.

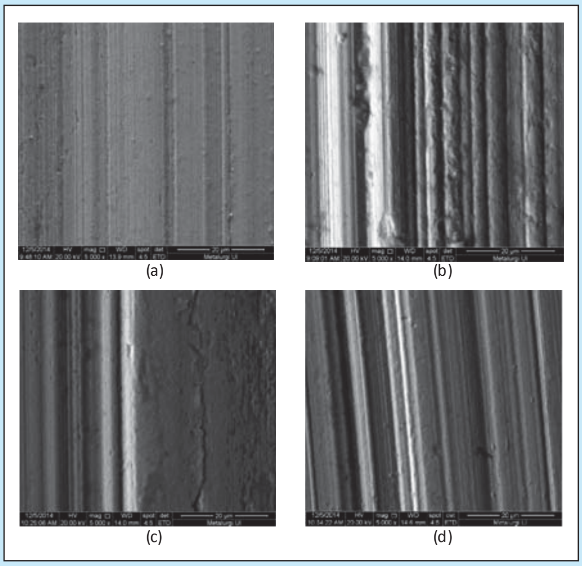

Figure 10
EM photos spherical surface test with 20 μm bar scale: ( a) HVI 60 ( b ) M0,1 ( c ) N0,1 ( d ) N0, 5.

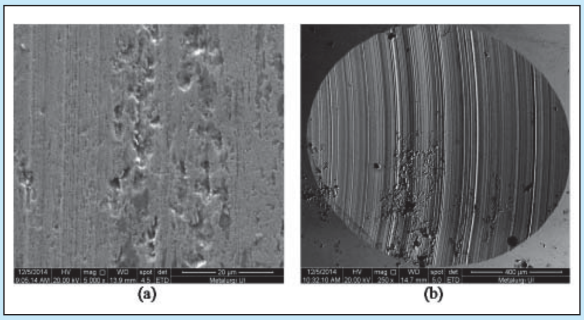

Figure 11
SEM photos spherical surface test:
(a) M0,05 with 20 μm bar scale,
(b) N0,5 with 400 μm bar scale

In Figure 10 ( a) , the number of trenches formed was less than the others, with tiny wear particles with irregular shape due to adhesive wear , and no visible scratches. A bright white color indicates the formation of a protective layer of $MoS_2$. Shades of light and dark are also a picture of the surface contour of the stroke. Bright colors indicate a higher level surface than its surrounding in a darker area.

In Figure 10 (b) and (c), it is clear that trenches were formed by abrasive wear. There are also previous deprived metal particles of the parent metal due to adhesive wear that look like holes with irregular shapes and layers to be peeled off. Although the dose of the addition of the similar additives, that is 0.1 % by weight , scratch the surface profile 1.5 µm and is more abrasive than 90 nm size. This relates to the effectiveness of the protective layer. The smaller the additive particle size, it will more easily form into a solid protective layer. However, the results of the analysis of the four- ball wear test showed an additive with a size of 1.5 µm has a better performance which is indicated by a smaller scar diameter value.

In Figure 10 (c) and (d), each of which represents a dose increase of 0.1 % and 0.5 % $MoS_2$ additive measuring 90 nm, it can be seen that both form a protective layer and trenches due to abrasive wear. The difference is in intensity. At N0.5 there is a more rough surface profile due to the number of trenches that are formed a lot more than figure 10 (a) and (b) . Four- ball test results also showed greater wear due to the amount of abrasive wear.

To achieve better results of the study required accuracy in the analysis. On the results of the SEM observation of the M0,05 and N0,5 samples, they had a cursory similar wear profile, but it is actually very much different. The M0,05 sample showed obvious wear profile due to adhesive wear profile, while sample N0, 5 showed wear caused by the corroded ball test indicated by the similar wear profile, but are beyond the four- ball test scratches. The surface profile is presented in Figure 11.

Scar diameter at N0,5 sample is 1,609 mm while on the N0,05 sample it is 1,525 mm. The existence of a corroded defect in the ball test for N0,5 sample could be caused by the four- ball test, and is worse than sample N0,05.

Surfaces that are moving between the two objects will be exposed to high pressure and local stress. As a result, deformation and the local fracture will cause high temperatures. The high temperatures will accelerate the chemical reaction on the surface, resulting in local melting. These conditions not only damage the surface, but it is necessary for the formatting a new compound, called tribofilm. The new compound layer (tribofilm) will lead to new tribologikal nature of the surface, due to topography, chemical and mechanical characteristic changes. Jacobson and Hogmark divide tribofilm establishment into two parts; transformation tribofilm and deposition tribofilm types. Type tribofilm transformation include transformation of initial surface by plastic deformation, phase transformation, diffusion, and others. The deposition tribofilm Type formed by molecular feedback of counter surface, the environment, or by the wear particles (Olofjon 2011). Based on tribofilm layer formation theories, formation mechanism is possibly through both of its combination.

## IV. CONCLUSION

The conclusion that can be drawn from this research is the addition of $MoS_2$ additives into lubricating base oil HVI 60 had an affect on the coefficient of friction and wear protection characteristics. In this study, the addition of MoS2 optimum dose to obtain the effect of minimum wear is 0.1% by weight, both of the size 1.5 µm and size of 90 nm.. Four-ball test results show that the performance of an additive MoS2 measuring 1.5 µm would be better and resulted in characteristic improvement of 23% when compared to the size of 90 nm, which is only increased by 11%.

Scratches the surface observation using SEM showed that the mechanism of wear has been occured in adhesive and abrasively; while the surface wear profile is finer when using $MoS_2$ additive with a size of 90 nm when compared with the size of 1.5 µm, although the magnitude scar diameter showed opposite results.

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