Experimental of friction characteristic properties of TiN coating

Okka Adiyanto[1,2], Effendi Mohammad[1,*], Wonsik Choi[3], Rosidah Jaafar[1]

[1)] Fakulti Kejuruteraan Pembuatan, Universiti Teknikal Malaysia Melaka,
Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.
[2)] Department of Industrial Engineering, Universitas Ahmad Dahlan,
Bantul, 55191 Yogyakarta, Indonesia.
[3)] Department of Bio Industrial Machinery Engineering, Pusan National University,
Miryang campus, 50463, South Korea.

[*]Corresponding e-mail: effendi@utem.edu.my

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ABSTRACT – Friction that arises in the piston ring and cylinder linear is an important part that occurs in Internal Combustion (IC). This friction will cause wear around the piston and cylinder linear. To reduce wear, coatings are needed to reduce wear that occurs. One type of coating that can be used is Titanium Nitride (TiN). This study aims to study the friction characteristics of the Titanium Nitride (TiN) coating. The friction coefficient is measured using a pin on disk tribometer. Based on the results of the study it was found that TiN has a friction coefficient range of 0.007-0.040. The lowest coefficient of friction occurs at lower loads. and increases with increased loads.

1. INTRODUCTION

Friction piston rings and linear cylinders are an important part of the Internal Combustion (IC) because more than 30% of energy consumption in IC engines is caused by piston ring-cylinder liner systems [1]. Power generating parts on the engine requires good performance to improve vehicle performance and to increase the efficiency of IC performance [2]. The researchers examined that the main factors affecting engine performance were temperature, coefficient of friction (COF), and friction [3]. This friction is a common phenomenon and is accompanied by energy conversion. This friction energy will be converted into heat energy [4].

To prevent friction, a layer is needed on a material to be able to withstand the friction. Various types of coatings are used to reduce wear on the piston ring. One of the coatings that can be used is Titanium Nitride (TiN). TiN exhibits stable characteristics in wear resistance, corrosion resistance, and hardness [5]. TiN material is widely used as a material in auto parts. TiN coating has a high level of hardness and is resistant to wear. TiN coatings are widely used as industrial components such as auto parts and other engine part. However, there are no studies related to the characteristics of TiN friction in the piston. This research will discuss the TiN friction characteristics using a pin-on-disc procedure.

2. METHODOLOGY

2.1 Materials

Pin use TiN and disk use SCM 440 carbon steel, pin have a thickness of 1 mm, and diameter = 4 mm. The disk specimen is SCM 440 which is 60 mm diameter and 5 mm thickness. Chemical composition and mechanical structure from the disk and pin are shown in Table 1 and Table 2. The test sample is prepared as ASTM G99-05 standard (Standard test method for wear tests with a Pin on Disk machine).

Table 1 Chemical composition of SCM 440.

Element (%) Material	C	Si	Mn	P	S	Cu	Ni	Cr	Mo
SCM440	0.38 ~ 0.40	0.15 ~ 0.35	0.60 ~ 0.9		0.03		0.02 ~ 5	0.90 ~ 1.20	0.15 ~ 0.30

Table 2. Mechanical properties of the pin and disk

Element Material	Tensile Strength (kgf/mm²)	Yield Strength (kgf/mm²)	Elongation	Hardness (HB)
SCM440	75	90	14%	255-321

2.2 Experiment conditions

Friction tests were conducted with a pin-on-disk tester. Pin and disk were ultrasonically cleaned in acetone for 15 min. After cleaned put pin and disk in the plate. The lubricant used in this experiment is paraffin oil. The test condition from the experiment can see in Table 3.

Table 3 Test conditions.

Parameters	Conditions
Pin material	TiN
Disk Material	SCM 440 carbon steel
Load range (N)	2, 4, 6, 8, 10
Pressure range (MPa)	0.25-2.05
Speed range (m/s)	0.06-0.34

2.3 Friction test

In this study, we consider a traditional pin-on-disc tribometer, a ball attached to a rotating sample [6]. Normal Load (W) is applied at constant angular velocity (ω). The normal load exerted on the pin surface defined by (r) from the center of the disc. The torque on the disc is noted as F_{app}. The value of F_{app} is equal to F_T. The static friction force Fc acts in the opposite direction. The difference between F_T and F_C is the net force F_{Net}.

$$F_T = F_{app} \quad (1)$$

$$F_C = \mu_s W \quad (2)$$

$$F_T - F_C = F_{Net} \quad (3)$$

$$F_{Net} = \mu_d W \quad (4)$$

$$F_{Net} = F_{tf} \quad (5)$$

$$\mu = \frac{F_{tf}}{W} \quad (6)$$

3. RESULTS AND DISCUSSION

3.1 Friction coefficient

Figure 1 shows the friction coefficient of the TiN test with 5 different loads. Based on the graph on the image, the 4-friction coefficient will start constantly after the velocity is 0.10 m / s to 0.35 m / s. TiN has a friction coefficient range of 0.007-0.040. The friction coefficient decreases and the bigger the load and velocity gets faster so the friction coefficient will be smaller [7].

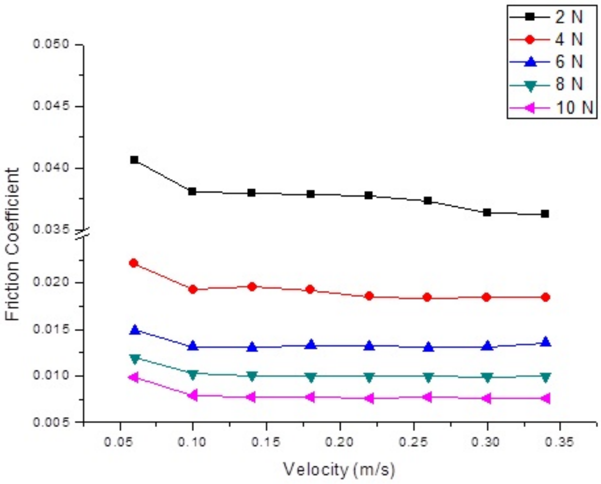

Figure 1 Friction coefficient of a load as a function of velocity with pin TiN.

3.2 Microstructure

The appearance of SCM after the test can be seen on Figure 2 and Figure 3 wear is found on SCM 440 patterns.

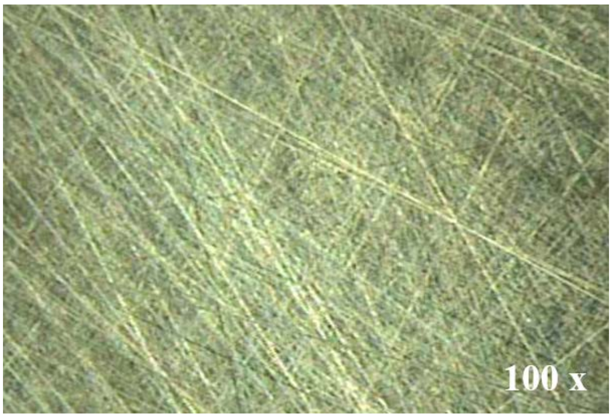

Figure 2 appearance before testing.

4. CONCLUSIONS

Design of pin on disc type tribometer has been carried out in this study. In this study the friction test on SCM 440 carbon steel with TiN. Based on the results of the study it was found that when the speed increases the friction coefficient will increase. Given the greater load, the friction coefficient will be smaller. Load 2 N has a friction coefficient higher than other loads, and Load 10 N has a friction coefficient smaller than other loads. TiN has a friction coefficient range of 0.007-0.040.

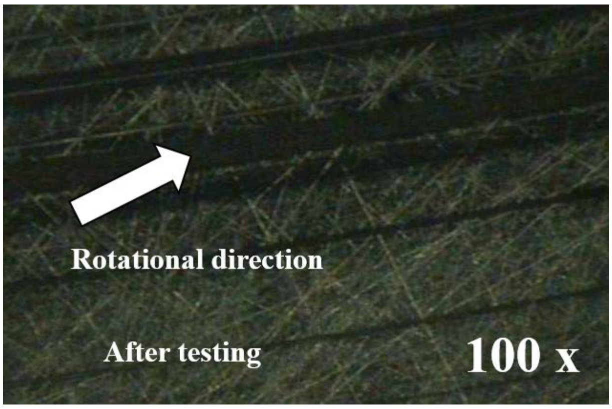

Figure 3 The track left by tribometer on the workpiece.

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REFERENCES

[1] Holmberg, K., Andersson, P., Nylund, N. O., Mäkelä, K., & Erdemir, A. (2014). Global energy consumption due to friction in trucks and buses. *Tribology International*, *78*, 94–114.

[2] Tyagi, A., Pandey, S., Murtaza, Q., Walia, R. S., & Tyagi, M. (2020). Tribological behavior of carbon coating for piston ring applications using Taguchi approach. *Materials Today: Proceedings*, *25*, 759–764.

[3] Liu, Q., Song, Y., Yang, Y., Xu, G., & Zhao, Z. (1998). On the Laser Quenching of the Groove of the Piston Head in Large Diesel Engines. *Journal of Materials Engineering and Performance*, *7*(3), 402–406.

[4] Ying, S., & Yupeng, Y. (2017). Temperature field analysis of pin-on-disk sliding friction test. *International Journal of Heat and Mass Transfer*, *107*, 339–346.

[5] Zhang, M., Liu, X., Shang, H., & Lin, J. (2019). Comparison of TiN and CN x coatings on orthodontic stainless steel: Tribological and biological evaluation. *Surface and Coatings Technology*, *362*, 381–387.

[6] Adiyanto, O., Pratama, P. S., & Choi, W. (2018). Tribological characteristics of SCM 440 bearing steel under gas and oil lubricant in the cylinder block tractor engine. *Industrial Lubrication and Tribology*, *70*(8), 1361–1366.

[7] Lyu, Y., Bergseth, E., Wahlström, J., & Olofsson, U. (2019). A pin-on-disc study on the tribology of cast iron, sinter and composite railway brake blocks at low temperatures. *Wear*, *424–425*, 48–52.