A STUDY OF FRICTION COEFFICIENT OF GAS SOFT NITRIDING AND SULFUR NITRIDING TREATMENT ON THE PLAIN CARBON AND ALLOY STEEL

Somsak Siwadamrongpong*, Sirijit Champee

School of Manufacturing Engineering.

Institute of Engineering. Suranaree University of Technology.

111 University Avernue, Muang District, Nakhonratchasima 30000, Thailand.

*** E-mail: somsaksi@sut.ac.th. Tel: 0-4422-4236, Fax: 0-4422-4566**

ABSTRACT

The metallurgy associated with improvement in mechanical properties tends to perform with the procedure of heat treatment one kind of well-known heat treatment is gas surface hardening method. For instance gas soft nitriding and sulfur nitriding which two technical well developed in friction and wear. This study was aimed to investigate friction coefficient and influence of steel that treated on gas soft nitriding and gas sulfur nitriding. The friction coefficient are conducted with Pin on disk under dry sliding condition which observed in this research, Pin of plain carbon and alloy stel and disk made form D2 steel were used in this experiments. First, the specimen was normalizwed by normalizing and shot blasting. Then the specimen was prepared surface and was treated by gas soft nitriding, gas sulfur nitridng. The result the microstructures, found that white layer on sulfur nitriding specimen less than soft nitriding. The worn surface distributions of specimens are examined after and before friction test. The surface phases of the treated are determined by X-ray diffraction method. $Fe_{1-x}S$ phase is obtained on the sulfur nitriding surface.

1. INTRODUCTION

In the recent plain carbon and alloy steel is the use wildly in many application of construction steel such as equipment of crankshaft piston in automotive engine , machinery, agriculture construction there have been a requirement to improve fatigue and wear resistance.

The technical of thermochemical treatment such as gas soft-nitriding and gas sulfur- nitriding are extensively used for the performance modification in term of friction coefficient and wear resistance (Industrial manual), which the gas soft nitriding process is nitempered under relatively safe conditions using a gaseous medium containing nitrogen gas to build white layer and improve mechanical properties of steel. And gas sulfur-nitriding technical process in an atmosphere of NH_3 and H_2S in endothermically derived propane carrier gas, this method suitable for steel, this has been investifated. (Osamu momose and Sosuke uchida, 1986)

By research of, Wang Lijie, Xing Yazhe, Wang Hongbo, and Hao Jianmin (2009) have studied of effect of nitriding sulfurizing composite treatment on Ti alloy and the result by nitriding sulfurizing composit treatment was covered by numerous spherical bulges while the modified layer for nitriding surface was composed of larger irregular particles. According to the results of friction and wear tests, the friction coefficient of alloy after nitriding-sulfurizing composite treatment at different loads is demonstrated the various values.

G. Nicoletto, A. Tucci, L.Esposito was studied on friction and the wear resistance of spheroidal and lamellar cast irons with treated by nitriding and nitrocarburizing after treated studied on dry sliding with pin on disk apparatus the result spheroidal cast iron almost always presents a lower wear rate than the lamellar cast iron, independently of the surface treatment.The results demonstrated that the wear rate of spheroidal part is lower than the lamellar cast irons

The aims of this study to investigate the influence of gas heat treatment by gas soft-nitriding and gas sulfur-nitriding that effect on friction coefficient of the plain carbon steel and alloy steel

2. EXPERIMENT PROCEDURES

2.1 Materials and thermochemical treatments

AISI	C	Si	Mn	P	S	Cu	Ni	Cr	Mo	V	AL	Fe
1040	0.429	0.237	0.661	0.021	0.013	0.215	0.045	0.056	0.011	0.001	0.006	Bal.
4140	0.417	0.222	0.712	0.007	0.005	0.167	0.039	1.098	0.161	0.007	0.020	Bal.
4340	0.406	0.232	0.661	0.008	0.006	0.025	0.021	1.053	0.171	0.002	0.036	Bal.

Table 1 composition of raw material (%wt) Pin specimens

The AISI 1040, AISI 4140, and AISI 4340 which were presented the chemical composition in Table 1 (ASM v.1, 2005) were turned with a lathe into a Cylindrical shape sizing 5 mm-diameter and 16.5 mm-length. All the pins were taken to the heat treatment with 870 °C for 1 hr. Normalizing process for the sake of eliminate residual stress. Subsequent the heat treatment Process, the specimens' surface were cleaned with shot blasting with ball 0.3 diameter for 45 min (ASM V.5, 1987). Followed by the surface pretreatment, silicon carbide paper grit 2000 was used for grinding the cross-section area of pins.

Another vital part, disc material AISI D2 (the chemical composition in Table 2) was machined to 30 mm-diameter and 6 mm-thickness. The crucial variable of the disc is plane grinding to 0.1 µm-roughness (R_a) (ASTM G99-05)

AISI	C	Si	Mn	Cr	Mo	V	Fe
D2	1.43	0.166	0.226	11.95	0.629	0.738	Bal.

Table 2 composition of raw material (%wt) Disc

2.2 Heat treatment

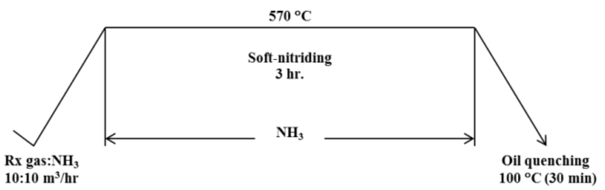

Fig. 1 Treatment conditions of soft-nitriding method

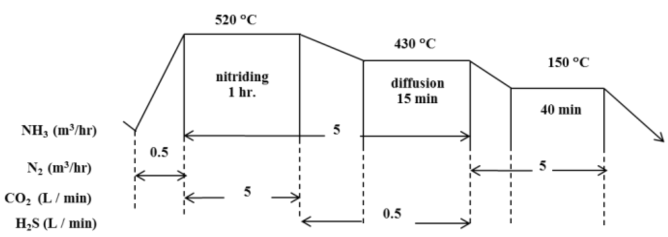

Fig. 2 Treatment conditions of sulfur-nitriding method

Upon completion of the preparation, all the specimens are separated into two groups. One for the gas soft-nitriding for 3 hr with 570 °C as shown in Fig. 1. And second group for gas sulfur-nitriding shown in Fig.2

2.3 Dry sliding (Pin-on-disk) tests

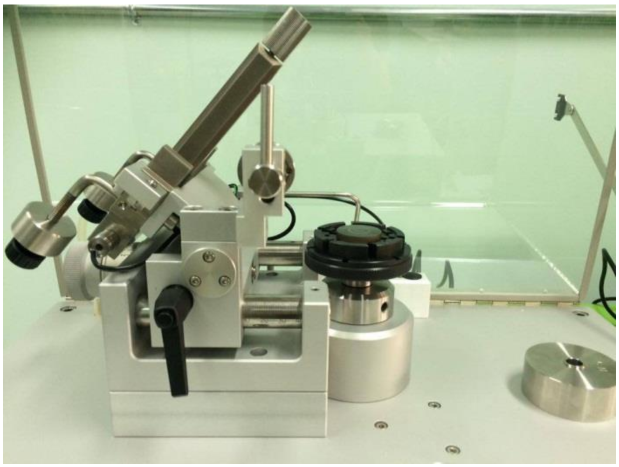

Fig. 3 Pin on disc apparatus

The experimental details Dry sliding friction were conducted on a pin-on-disc tester at a room temperature of about 23°C, and relative humidity of about 40% and disc diameter 30 mm thickness 6 mm and surface roughness (R_a) 0.1 µm were against with the steel pin diameter 5 mm. The friction test were carried out at a normal load of 5 N and sliding speed 0.1 m/s

3. Results and discussion

3.1 Surface hardness

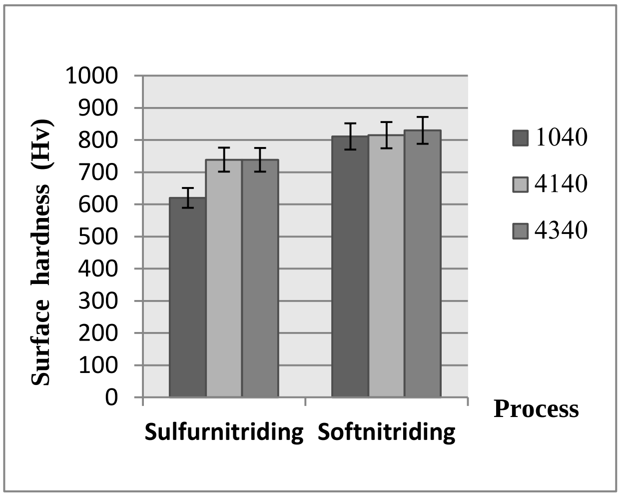

Fig. 4 Surface hardness of specimens

Fig. 4 shown surface hardness of specimens which treated by soft-nitriding and sulfur-nitriding in two process the trend of alloy steel (AISI 4140, AISI 4340) have higher surface hardness than plain carbon steel (AISI 1040). It is assumed that the chromium and molybdenum contained in the steels increased their hardness (Osamu, M., 1986) and from the result may suggest sulfur-nitriding have lower than soft-nitriding. We found from SEM report that the porous layer with irregularly shape particles was formed on the surface of gas sulfur-nitriding process. (Somsak Siwadamrongpong and Sirijit Champee, 2015) And found the compound layer thickness ($Fe_{2-3}N$, Ɛ) in sulfur-nitriding process less than soft-nitriding process.

3.2 X-ray difflaction of the specimens

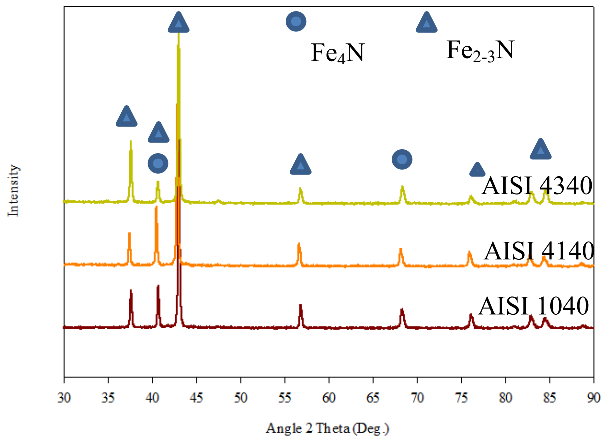

Fig. 5 X-ray diffraction patterns of sulfur-nitriding specimens

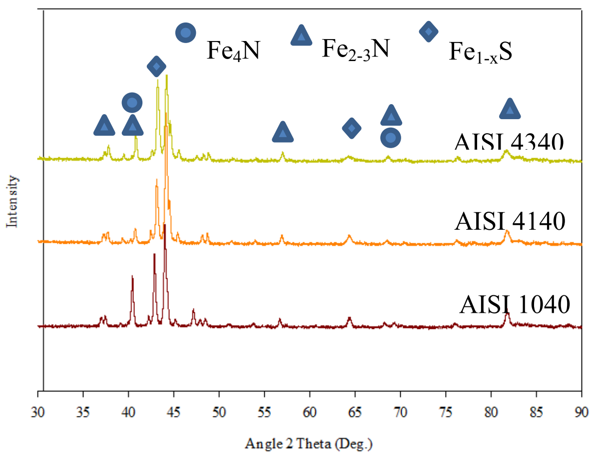

Fig. 6 X-ray diffraction patterns of sulfur-nitriding specimens

From the fig. 5-6 examination of the specimens that treated by gas soft-nitriding which analysis with XRD showed that Fe_4N (γ') and $Fe_{2-3}N$ (ε) in the Fig. 6 in the gas sulfur-nitriding process found the Fe_4N (γ') and the $Fe_{2-3}N$ (ε) too but we found $Fe_{1-x}S$ in gas sulfur-nitriding process.

3.3 Dry sliding friction

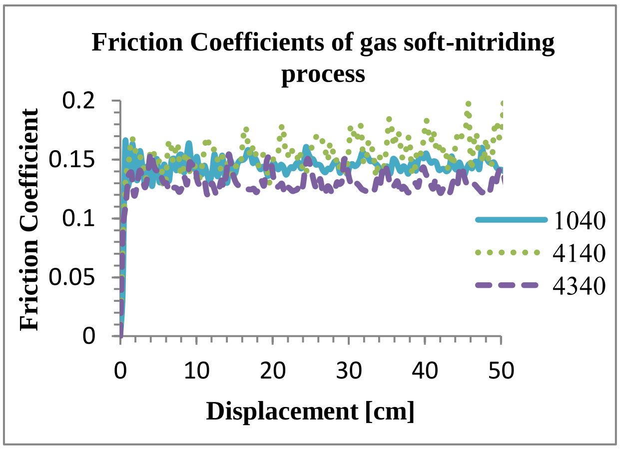

Fig. 7 Coefficients of friction against D2 disc of the soft-nitriding process

The dry sliding results of soft-nitriding as shown in Fig. 8 was found that the value of μ_k sort by ascending; AISI 4340 (0.129), AISI 1040 (0.143), AISI 4140 (0.154). Consistent with OM evidence that shows a most compound layer ($Fe_{2-3}N$) on AISI 4340 massively and X-ray diffraction indicate the compound layer consists Ɛ phase was found.

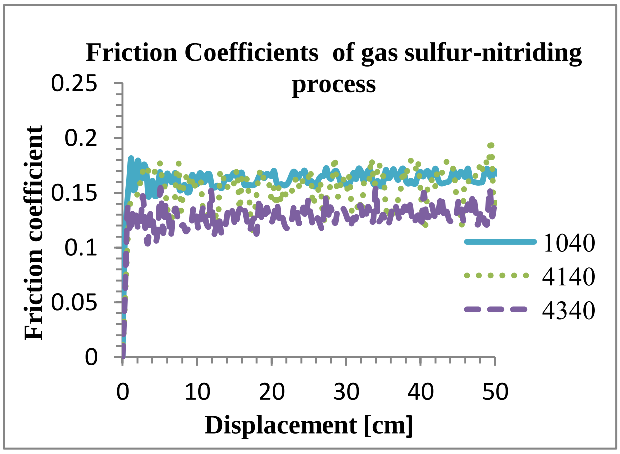

Fig. 8 Coefficients of friction against D2 disc of the sulfur-nitriding process

As well as Soft-nitriding, the Fig. 8 shown that the lowest μ_k value of AISI 4340 (0.128) is the most slippery material, and then AISI 4140 (0.152) and AISI 1040 (0.161) respectively. The AISI 4340 has most compound layer (composed of $Fe_{2-3}N$ and $Fe_{1-x}S$). For the trend of two processes AISI 4340 has most slippery material. This indicates that the Ɛ-phase ($Fe_{2-3}N$) produced on the AISI 4340 has a significant effect on sliding friction coefficient.

4. Conclusion

The specimens AISI 1040, AISI 4140 and AISI 4340 were chosen in this study and the aimed to investigated influence of two process gas soft-nitriding and gas sulfur-nitriding to friction coefficient and propertied of specimens

Surface hardness result found that the alloy steel (AISI 4140, AISI 4340) has a good trend more than plain carbon steel

XRD (X-Ray diffraction) found that gas soft-nitriding process has Fe_4N (γ') and $Fe_{2\text{-}3}N$ (ε) in specimen while gas sulfur-nitriding process has the same Fe_4N (γ') and $Fe_{2\text{-}3}N$ (ε) and we found $Fe_{1\text{-}x}S$ in the specimen

Friction coefficient result found that in two processes AISI 4340 has lowest friction coefficient more than AISI 1040 and AISI 4140

5. Acknowledgements

The authors would like to thank Suranaree University of Technology for financial support and Thai Tohken Thermo Co., Ltd

REFERENCES

Osamu Momose and Sosuke Uchida (1986). Gas sulphonitriding steels in a CS_2 and NH_3 atmosphere. Tokai University, Wear 116 (1987) pp.19-24

Wang lijie, Xing Yazhe, Wang hongbo, and Hao Jianmin (2009). Effect of nitriding-sulfurizing Composite treatment on tribological behavior of titanium alloys. Rare materials Vol.129 (2010) p.604

Y.K. Ko, et al.,(2008). Plasma nitrosulfurizing techniques for low friction coefficient with H_2S and C_3H_8 gas addition, Journal of surface Coatings Technology 202 (2008) 5501-5504

G. Nicoletto, A. Tucci, L. Esposito (1995). Sliding wear behavior of nitride and nitocarburized cast iron, Wear 197 (1996) pp. 38-44

Wang lijie, Xing Yazhe, Wang hongbo, and Hao Jianmin (2009). Effect of nitriding-sulfurizing Composite treatment on tribological behavior of titanium alloys. Rare materials Vol.129 (2010) p.604

B. Selcuk, R.Ipek, M.B. Karamis, V.Kuzucu (1999). An investigation on surface properties of treated low carbon and alloyed steels (boriding and carburizing), Journal of Materials Processing Technology 103 (2000) 310-317

ASM Handbook., Heat Treating., Material Park Ohio.ASM International., Vol. 4, (1987)

ASM Handbook., Surface engineering., Meterial Park Ohio. ASM International, Vol. 5, (1987)

ASM Handbook., Properties and Selection: Irons, Steels, and High Performance Alloys., Meterial Park Ohio.ASM International, Vol. 5, (1987)

Somsak Siwadamrongpong, Sirijit Champee (2015) Effect of gas sulfur-nitriding processes and gas soft-nitriding on the alloy and plain carbon steel.

B. Selcuk. R. Ipek, M.B. Karamis: A study on Friction and wear behavior of carburized, carbonitrided and borided AISI 1020 and 5115, Journal of Materials Processing Technology 141 (2003) 189-196

Somsak Siwadamrongpong received the B.E. (1995) degree in Mechanical Engineering from Chulalongkorn University, M.E. (2001) degree in Environmental System from Nagaoka University of Technology, and D.E. (2004) degree in Energy and Environment from Nagaoka University of Technology.

He is a Professor, Department of Manufacturing Engineering, Suranaree University of Technology.

Sirijit Champee received the B.E. (2012) degree in Manufacturing Engineering for Suranaree University of Technology. She is a 2st years of master degree in Manufacturing Engineering.