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Dry sliding friction and wear behaviour of hardened AISI D2 tool steel with different hardness levels

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ABSTRACT

The influence of the sliding speed and hardness on the friction and wear performance, and their related mechanisms of hardened tool steel AISI D2 with different hardness levels were investigated. Friction and wear tests of the estimated specimens with different hardness levels versus Si_3N_4 balls were carried out under dry sliding friction condition in ball-on-disc tester. The results showed that the influence of the hardness on the friction coefficient at the sliding speeds of 0.05 and 0.5 m/s is more prominent than that at 0.10 m/s, while the wear rate shows great sensitivity to the sliding speed and hardness.

1. Introduction

In manufacturing of components, a large number of tool steels are applied in milling, drilling, sawing and the measuring tool as well as mold. In their work, they have to undergo great tension-compression stress and friction-wear, which exert great influence on their service life. Therefore, the properties of high hardness, strength and wear resistance are required for tool steel in the manufacturing industry.

In recent years, a considerable number of papers about the wear performance of the tool steel AISI D2 have been investigated by many scholars. Bourithis et al. [1] have investigated the wear properties of two commercial tool steels (AISI D2 and O1) with the same hardness of 60 HRC by using pin-on-disk tester. They have obtained the results that the tool steel microstructures play the most important role in determining the wear properties. The sliding wear resistances of ZrN and (Zr, 12 wt%Hf) N coating deposited on a hardened tool steel AISI D2 were studied by Atar et al. [2]. After the tool steel AISI D2 were subjected to the different heat treatments, the relationship between the hardened-and-tempered condition of the tool steel and its abrasive wear resistance were tested and studied by Gorscak et al. [3]. Besides Omer and Muammer [4], who have studied and compared the wear performances of seven different, uncoated die materials (AISI D2, Vanadis 4, Vancron 40, K340 ISODUR, Caldie, Carmo, 0050A) by using a newly developed wear testing device, Sen et al. [5] have investigated the tribological behavior of Alumina and AISI 52100 steel in a ball-on- disc tester. In these tests, the molybdenum boride coated tool steel AISI D2 was used as the mating sliding surface. The results showed that the friction coefficient decreases with the increase of sliding speed, while the wear rate drops. Some researchers [6–9] have also investigated the wear behavior and resistance of the tool steel AISI D2 by deep cryogenic and sub-zero treatment under the condition of different sliding speeds and normal loads. They considered that the wear behavior can be clearly correlated with the reduction in the retained austensite content and the increase in the amount of secondary carbide particles of the microstructure.

Up to now, very few studies have only been reported on the influences of the hardness and sliding speed on the wear performance and mechanism of the hardened tool steel AISI D2. In this paper, the influences of different hardened levels (51 ± 1, 55 ± 1, 58 ± 1, 62 ± 1, and 65 ± 1 HRC) of the tool steel AISI D2 and sliding speeds (0.05, 0.10, and 0.50 m/s) at the normal load of 5 N on the friction coefficient, wear rate, and related mechanisms were investigated. Friction-wear tests were conducted on a ball-on-disc tester at room temperature under dry sliding friction condition.

2. Experimental procedures

2.1. Material

The material chosen in this investigation was a commercial tool steel AISI D2 (Cr12MoV, China) bar. Its chemical composition is presented in Table 1.

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Table 1
Chemical composition of the tool steel AISI D2 (wt%).

C	Cr	Mo	Mn	Si	P	S	V
1.55	11.25	0.45	0. 35	0.35	0.025	0.025	0.20

2.2. Heat treatment

Earlier results showed that the tool steel AISI D2 could get fine-needle martensite, high-diffusion, and uniform distribution fine-grain carbide by using the quenching temperatures of 1000–1040 °C[10]. According to the methods of heat treatment in the literature [11], the specimens were inserted into an electrical resistance furnace at 1000–1040 °C, then quenched in oil, and finally tempered at various low temperatures.

2.3. Hardness measurement

The hardness values of the differently treated specimens were estimated by Rockwell hardness tester. At least three readings have been taken to estimate the average hardness value of hardness of every specimen. The obtained hardened specimens were in different hardness levels of 51 ± 1, 55 ± 1, 58 ± 1, 62 ± 1, and 65 ± 1 HRC.

2.4. Microstructure of the hardened tool steel AISI D2 with different hardness levels

After mounting, grinding, polishing, and etching (etchant used: 4% Nitric acid alcohol solution for 40 s), microstructure examination of the hardened specimens were carried out utilizing a scanning electron microscope (SEM).

The polishing has been carried using a semi-automatic grinding and polishing machine from Buehler. The processes are as follows:

1. Grinding: using Ultra prep (9 μm) Metal-bonded disc at a normal load of 20 N and rotate speed of 120 rev/min (Rotating direction is the same.) for 5 min.
2. Polishing: using surface of preparation with the TriDent polishing cloth (3 μm) and MetaDi polishing liquid at a normal load of 25 N and rotate speed of 120 rev/min (Rotating direction is the same.) for 10 min. Fig. 1 is the finished specimens.

2.5. Dry sliding wear tests

2.5.1. Testing systems

Dry sliding wear testing systems are made up of THT friction-wear tester and 2206 surface roughometer. THT friction-wear tester made in CSM in Switzerland shown in Fig. 2 was utilized to measure the friction coefficient and wear rate of the hardened specimens and a 2206 surface roughometer was utilized to measure the cross-section profile of the worn surface.

2.5.2. Experimental details

The experimental details are described in Table 2. Schematic diagram of the ball-on-disc wear test rig is shown in Fig. 3. Dry sliding friction and wear tests were conducted on a ball-on-disc tester at a room temperature of about 22 °C, and relative humidity of about 40%.

The hardened tool steel AISI D2 (51 ± 1, 55 ± 1, 58 ± 1, 62 ± 1, and 65 ± 1 HRC) discs of 28 mm diameter, 8 mm length, and a surface roughness of 0.336 μm Ra were tested against the N_3Si_4 balls with a diameter of 3.0 mm. The friction and wear tests were carried out at a normal load of 5 N and different sliding speeds of 0.05, 0.1, and 0.5 m/s. The wear volumes were obtained from track cross-section

Fig. 1. Finished specimens.

Fig. 2. THT friction-wear testing machine.

Table 2
Experimental details.

Condition of experiment	Method of contact	Temperature	Relative humidity	Normal load (N)	Sliding distance (m)
	Ball-on-disc	Room temperature (22 °C)	40%	5	100
	Mating material	Hardness of estimated specimens (±1 HRC)	Sliding speeds (m/s)		
Scheme of the wear test	Si_3N_4 ball	51	0.05	0.10	0.50
		55	0.05	0.10	0.50
		58	0.05	0.10	0.50
		62	0.05	0.10	0.50
		65	0.05	0.10	0.50

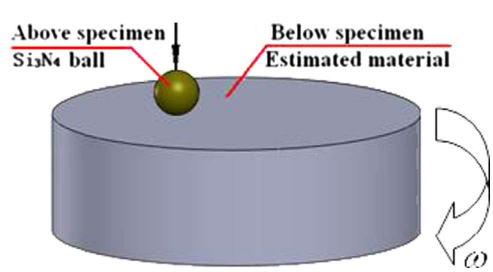

Fig. 3. Schematic diagram of the wear test rig.