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Evaluation of the Wear Characteristics of Different Cold Tool Steels

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Abstract **–** Cold work tool steels are steels containing high carbon and chromium. It has good machinability when hard and pre-treated. Heat treatment was carried out in selected tool steels. The effect of heat treatment on structure and wear behavior of different tool steels was investigated. Heat treated samples were examined with optical microscopy (OM) and XRD analysis. Test materials were subsequently tested wear test by using pin on disk. The best wear performance was obtained from the sample having the smallest and homogenous distributed carbides. The rise in wear strength was accredited to the softer retained austenite to the harder martensite phase and metal structure in the form of fine carbide. The wear resistance of S1 steel was minimum.

Keywords – Cold Work Tool Steels, Microstructure, Wear Resistance.

I. INTRODUCTION

Excellent hardness and toughness is compelled to increase tool lifetime. Various tool steels have been developed by alloying to meet the needs of the production sector. Cold work tool steels are the first choice for the production of punching tools and different types of dies [1], [2]. Cold work steels containing different alloying elements and high carbon show low deformation when quenched, perfect hardness and ease of machining in the annealed condition [3]. This tool steel belongs to the D series category and contains 1.5% to 2.35% carbon and up to 12% chromium. Heat treatment techniques have been applied since ancient times to improve the properties of metal products. In heat treatment, the microstructure changes if the metal is heated to a critical temperature and cooled. Annealed tool steels are soft and easy to machine. It can be hardened by heat treatment. The industrial heat treatment covers quenching or austenitizing, tempering after quenching [4], [5]. Heat treatment begins with austenitization. At the austenitizing temperature, the ferrite phase transforms into austenite. Austenite is a coarse-grained irregular and martensite is a fine-grained hardened structure. The austenitic structure hardens and turns into martensite. This transformation occurs at a temperature known as the MS or martensitic initial temperature. This phase transformation is isothermal and stops when the MF or martensitic final temperature is reached. After the steel has hardened, a certain amount of austenite remains in the matrix, called austenite. The carbon level in the steel determines hardness and the martensite start - end temperatures. The starting and ending temperatures also vary according to the grain measure [6], [7]. The austenitization temperature varies for different grades in D-series cold work tool steels. Wear is a serious problem for tool materials. Adhesive and abrasive wear may occur depending on the surface hardness of the tool material [8]. Torkamani and et al. reported the structure and

mechanical performance of D2 steel after hardening and oil quenching. The hardened samples exhibited higher hardness and toughness than the oil quenched samples [9].

In this study, the wear performance of dissimilar cold tool steels was experimentally assessed.

II. Materials and Method

The casting AISI D2, Udeholm Calmax, Böhler K340L were used for study. The chemical of the steels are given in Table 1. Heat treatment of steels is given in Table 2. The samples were etched in Nital etchant. The microstructural changes of the samples was obswerved by a optical microscope. The phases in samples were detected by a Rigaku X-ray diffractometer with Cu Ka radiation. The wear tests were performed under loads of 10, 20, 30, 40 N with a pin-on-disk in the hardness of 68 HRC. The weight loss of the samples was determined with an electronic balance.

Table 1. Chemical contents of steels (wt.%).

No	Samples	C	Si	V	Mo	Mn	Cr
S1	Böhler K340L	1.10	0.90	0.50	2.10	0.40	8.30
S2	Udeholm Calmax	0.60	0.35	0.20	0.50	0.80	4.50
S3	Casting D2	2.10	-	-	1.50	0.50	12.00

Table 2. Heat treatment of steels.

	K340L	Calmax	Cast D2
Austenitising	820 °C, 30 min	820 °C, 30 min	850 °C 30 min
Quenching	Oil 50 °C	Oil 50 °C	Oil (50 °C)
First tempering	250 °C, 2 h	250 °C, 2 h	250 °C, 2 h
Quenching	Oil 50 °C	Oil (50 °C)	Oil (50 °C)
Second	230 °C, 2 h	-	-
Quenching	Oil 50 °C	-	-

III. Results

3.1. Microstructure

SEM views of the S1-S3 samples are presented in Figs. 1. The microstructure of S1-S3 steels consisted of tempered martensite with large primary M_7C_3 carbides and secondary carbides. The carbides occurred from the martensitic matrix during annealing and were uniformly dispersed. XRD pattern of S3 sample is demonstrated in Fig. 2. The basic difference between samples was the size of primary carbides, the type and distribution of secondary carbides. The structure consisted of 5 to 20 mm primary carbides, little carbides, and an annealed martensitic matrix. At low temperatures, martensite withstands a high quantity of shrinkage, which impellent the saturated carbon atoms to splash to nearby imperfections, including dislocations and quenched voids. Martensite separates at low temperatures due to structure instability. This circulating carbon is prior zones for carbide during annealing [10]. The raw martensite contains lesser saturated structure due to the occur of martensite at lower temperatures. As the structure shrinks, it fills the octahedral spaces less. The newly formed martensite contains less carbon per unit cell and a distorted structure. The untreated martensite is further stable than the early occurred martensite. The shrinkage in the martensite creates the instability in the structure [11]. The carbon atoms in metastable martensite display lesser spatter due to a less saturated structure. The carbide intensity is reduced in defects in virgin martensite.

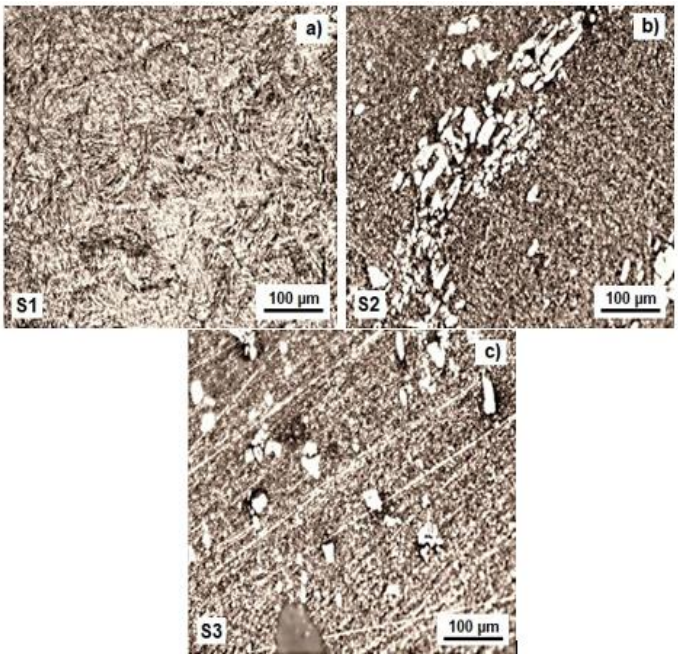


Fig. 1. Optic micrographs of the samples a) S1, b) S2, c) S3.

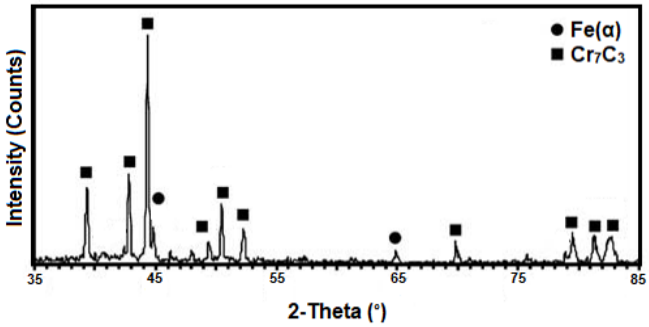
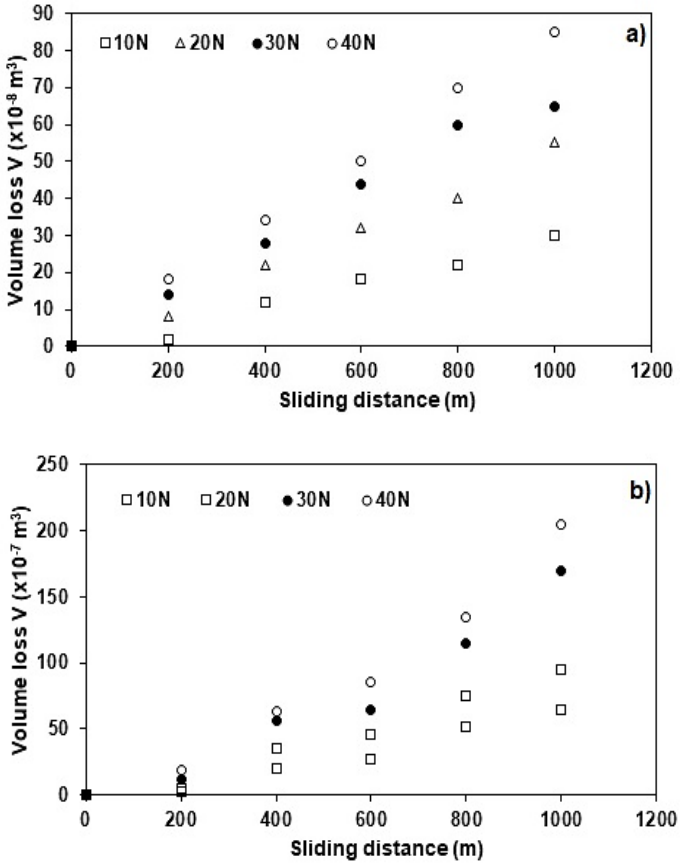


Fig. 2. XRD pattern of sample S3.

3.2. Wear test

The wear rate results of the heat-treated S1-S3 samples are presented in Fig. 3a-c. Sample S1 exhibited the excellent wear performance due to the

highest secondary carbide level and homogen carbide disperse. Removal of the retained austenite affected the carbide wear behavior [12], [13]. The wear rate is related to the nano-sized secondary carbide level and disperse (Fig. 3). Micro cracking and thermal degradation are remissible in small sized samples [14]. Different wear rates were obtained for different chemical analyses. The load and slip speed affected the wear quantity [15], [16]. The wear rates of S1-S3 are presented in Fig. 3a-c. Increasing the load increased the wear rate linearly. Increasing the load increased the wear rate. Up to 20N, the wear rate was not changed considerable. Increasing the load over 20 N load resulted in a significant decline in the wear level to the least. Then, the wear rate increased due to severe oxidation. The wear rates were detected fort the speed of 0.6 m/s.



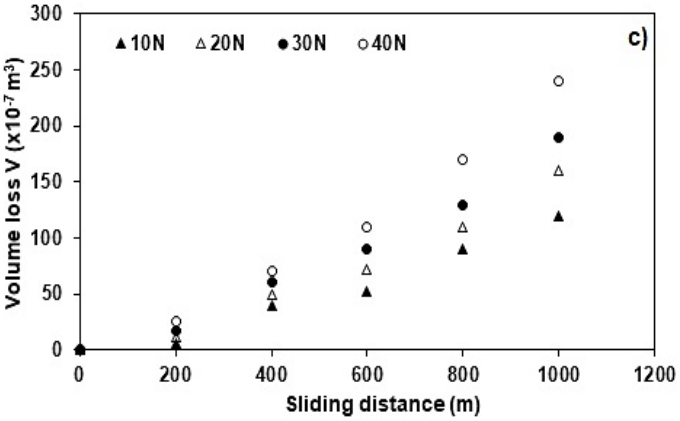


Fig. 3. Wear rates of a) S1, b) S2, c) S3 samples.

Wear morphologies of S1 and S2 tool steel showed grooves from plastic deformation at low speeds (Fig. 4a). It had large cavities formed by the protrusion of metallic debris. At faster sliding speeds, the pin-on the disc was partly oxidized (Fig. 4b) [16]. The oxide deposit was quite fine and translucent. Wear residues contained major metallic scales with grooved surfaces.

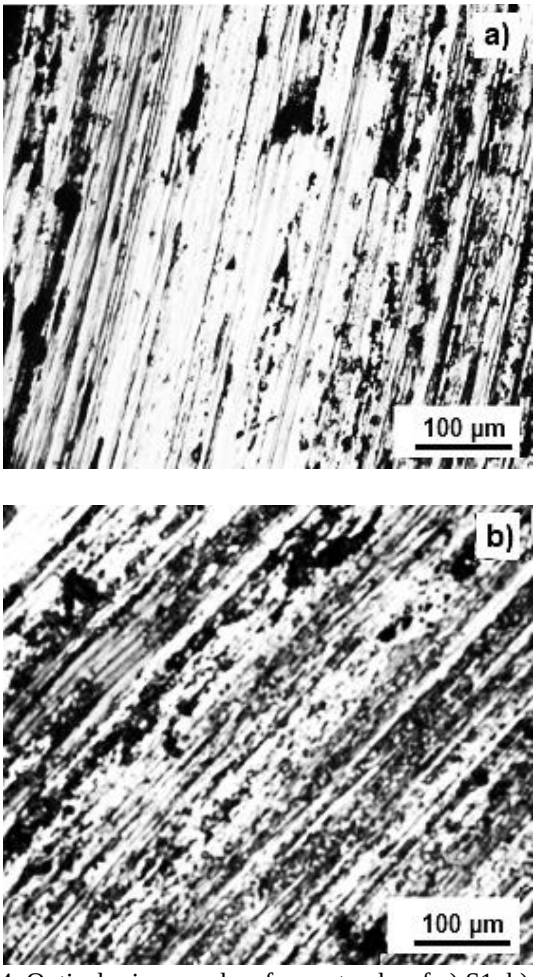


Fig. 4. Optical micrographs of wear tracks of a) S1, b) S2 samples.

4. Conclusion

The results obtained from the study are summarized.
1. Increasing the quenching intensity declined the retained austenite. This situation reduced the percentage of unworked martensite converted from residual austenite to martensite, increased the percentage of carbide, and occurred a more uniform carbide disperse.
2. The wear style in samples was abrasive wear.
3. The wear rate of all tool steels was proportional to the applied load.
4. Wear residues contained major metallic scales with grooved surfaces.

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REFERENCES

[1] L. Bourithis, G. D. Papadimitriou and J. Sideris, ‘‘Comparison of wear properties of tool steels AISI D2 and O1 with the same hardness’’, *Tribol. Int*., vol. 39(6), pp. 479–489, 2006.

[2] Y. M. Rhyim, S. H. Han, Y. S. Na and J. H. Lee, ‘‘Effect of deep cryogenic treatment on carbide precipitation and mechanical properties of tool steel’’, *Solid State Phenom*., vol. 118, pp. 9–14, 2006.

[3] D. Das, A. K. Dutta and K.K. Ray, ‘‘Optimization of the duration of cryogenic processing to maximize wear resistance of AISI D2 steel’’, *Cryogenics*, vol. 49(5), pp. 176–184, 2009.

[4] S. Zhirafar, A. Rezaeian and M. Pugh, ‘‘Effect of cryogenic treatment on the mechanical properties of 4340 steel’’, *J. Mater. Proess. Tech*., vol. 186(1-3), pp. 298–303, 2007.

[5] A. Molinari, M. Pellizzari, S. Gialanella, G. Staffelini and K. H. Stiansy, ‘‘Effect of deep cryogenic treatment on the mechanical properties of tool steels’’, *J. Mater. Process. Technol*., vol. 118(1-3), pp. 350–355, 2001.

[6] N. B. Dhokey and S. Nirbhavne, ‘‘Dry sliding wear of cryotreated multiple tempered D-3 tool steel’’, *J. Mater. Process. Tech*., vol. 209(3), pp. 1484–1490, 2009.

[7] A. Akhbarizadeh, A. Shafyei and M. A. Golozar, ‘‘Effects of cryogenic treatment on wear behavior of D6 tool steel’’, *Mater. Des*., vol. 30(8), pp. 3259–3264, 2009.

[8] C. H. Surberg, P. Stratton and K. Lingenhole, ‘‘The effect of some heat treatment parameters on the dimensional stability of AISI D2’’, *Cryogenic*s, vol. 48(1-2), pp. 42–47, 2008.

[9] H. Torkamani, S. Raygan and J. Rassizadehghani, ‘‘Comparing microstructure and mechanical properties of AISI D2 steel after bright hardening and oil quenching’’, *Mater. Des*., vol. 54, pp. 1049–1055, 2014.

[10] S. Kheirandish, H. Saghafian, J. Hedjazi and M. Momeni, ‘‘Effect of heat treatment on microstructure of modified cast AISI D3 cold work tool steel’’, *J. Iron Steel Res*., vol. 17(9), pp. 40–45, 2010.

[11] M. Ahmadi, O. Mirzaee, M. Azadi and H. Biukani, ‘‘Effects of various double-quenching treatments on the microstructure and corrosion properties of D2 tool steel’’, *Int. J. Pressure Vessels Piping*., vol. 202, pp. 104915, 2023.

[12] V. Leskovsek, M. Kalin and J. Vizintin, ‘‘Influence of deep cryogenic treatment on wear resistance of vacuum heat-treated HSS’’, *Vacuum*., vol. 80(6), pp. 507–518, 2006.

[13] D. M. Lal, S. Renganarayanan and A. Kalanidhi, ‘‘Cryogenic treatment to augment wear resistance of tool and die steels’’, *Cryogenics*, vol. 41(3), pp. 149–155, 2001.

[14] D. F. J. Silva, S. D. Franco, A. R. Machado, E. O. Ezugwu and A. M. Souza, ‘‘Performance of cryogenically treated HSS tools’’, *Wear*., vol. 261(5-6), pp. 674–685, 2006.

[15] D. Das, A. K. Dutta and K. K. Ray, ‘‘Influence of varied cryotreatment on the wear behavior of AISI 1.2080 steel’’, *Wear*., vol. 266(1-2), pp. 297–309, 2009.

[16] A. Y. L. Yong, K. H. W., Seah and M. Rahman, ‘‘Performance evaluation of cryogenically treated tungsten carbide tools in turning’’, *Int. J. Mach Tools Manuf.*, vol. 46, pp. 2051–2056, 2006.