Afyon Kocatepe Üniversitesi Uluslararası Mühendislik Teknolojileri ve Uygulamalı Bilimler Dergisi

Afyon Kocatepe University International Journal of Engineering Technology and Applied Sciences

AKÜ IJETAS Vol **1**(2018) Aralık (29-34 s) AKU J.Eng.App.Sci. **Vol 1** (2018) December (29-34pp)

Araştırma Makalesi / Research Article

Effect of Change in Mechanical Properties on Machinability 30MNVS5 Steel Cooled in Sand and Air After Hot Forging

Barış Özlü[1], Halil Demir[2], Mustafa Türkmen[3], Süleyman Gündüz[4]

[1] *Department of Mechanical and Metal Technology, Vocational School of Technical Sciences, Aksaray University, 68100, Aksaray, Turkey.*

[2,4] *Department of Manufacturing Engineering, Faculty of Technology, Karabük University, 78050, Karabük, Turkey.*

[3] *Department of Metallurgy, Vocational School of Hereke, Kocaeli University, 41800, Kocaeli, Turkey.*

e-posta: mustafa.turkmen@kocaeli.edu.tr

Geliş Tarihi:03.09.2018; Kabul Tarihi:10.12.2018

Keywords

Hot Forging;
Microalloyed Steel;
Machinability

Abstract

In this study, the effect of the microstructure, hardness, and cutting parameters on cutting force and surface roughness in 30MnVS5 steel cooled in different media (sand and air) after hot forging, was examined. For this purpose, steel samples were subjected to a controlled closed die forging followed by cooling in air and sand mediums. The turning tests were carried using coated carbide cutting tool at four different feed rates of 0,04, 0,08, 0,12 and 0,16 mm/rev, at a constant cutting speed of 180 m/min and at a constant depth of cutof 0,6 mm. The Optical microscope images of samples were examined out and their hardness values was evaluated. In the experimental study, the microstructure, the hardness and feed rates of the samples cooled in different environments was seen had a significant effect on the surface roughness and cutting forces.

Sıcak Dövme Sonrası Kumda ve Havada Soğutulan 30MnVS5 ÇeliğininMekanik Özelliklerdeki Değişimin İşlenebilirlik Üzerine Etkisi

Anahtar kelimeler

Sıcak Dövme;
Mikroalaşımlı Çelik;
İşlenebilirlik

Özet

Bu çalışmada, sıcak dövme işleminden sonra farklı ortamlarda soğutulmuş (kum ve hava) 30MnVS5 çeliğinde mikroyapı, sertlik ve kesme parametrelerinin kesme kuvveti ve yüzey pürüzlülüğü üzerindeki etkisi incelenmiştir. Tornalama deneyleri, kaplamalı karbür kesici takım kullanılarak dört farklı ilerleme miktarında 0.04, 0.08, 0.12 ve 0.16 mm/dev, sabit kesme hızında 180 m/dak ve sabit kesme derinliğinde0,6 mm gerçekleştirildi. Numunelerin optik mikroskop görüntüleri incelenmiş ve sertlik değerleri değerlendirilmiştir. Yapılan deneysel çalışmada farklı ortamlarda soğutulmuş numunelerin mikroyapısı, sertlik ve ilerleme miktarlarının, kesme kuvveti ve yüzey pürüzlülüğü üzerinde önemli bir etkisi olduğu görülmüştür.

1. Introduction

Today, with the developing technology, steels have a widespread usage area. In this respect, in the improvement of microstructure and mechanical properties, heat treatment applied to steel is gaining importance increasingly important (Uzkut and Özdemir 2001). Microalloyed steels are widely used in machinery manufacturing industry. In particular, 38MnVS6 steel is preferred in the automotive industry in high-strength structural elements. Parts made of microalloyed steels is used in the automotive industry in crankshaft, piston, connection rod and steering parts (Das and Chattopadhyay 2009).

Microalloyed steels is a group of materials with superior properties such as high strength, high toughness, low ductile-to-brittle transition temperature (Lawrow 2000). The studies on microalloyed steels were conducted especially between 1970 and 1980. Great improvements have been achieved in the mechanical properties of these steels with the addition of strong carbides and nitride forming elements such as Ti, Al, Nb and V. In this process, called microalloying, the total of alloying elements does not exceed 2% in general. Usually, this value is between 0.1 and 0.2% except for manganese. The advantages of these steels are that they have low alloys, have better machinability, are faster to produce, energy efficient and lighter in weight (Bai, Al. 1998 and Li, al. 2001)

In this study, microstructure and mechanical properties were investigated in 30MnVS6 steels after hot forging at appropriate austenization temperature followed by cooling in different mediums. In addition, it is aimed to investigate the effects of the change in microstructure and hardness depending on the cooling speed on the surface roughness and cutting forces in the samples treated with cemented carbide cutting tool.

2. Materyal ve Metot

In the experimental studies, microalloyed 30MnVS5 steel, were used. The chemical compositions of 30MnVS5 steel is given in Table 1.

Table 1. Chemical compositions of Microalloyed Steel.

Materials (microalloyed Steel)	C	Si	Mn	P	S	V
30MnVS5	0,30	0,50	1,46	0,010	0,032	0,087

Before hot forging, samples are supplied with a diameter of 33 mm and a length of 240 mm. Samples other than the as-received sample were heated to 1200 °C of the induction heating system. After annealing, the samples were subjected to the hot forging process with the 1600 tons eccentric press. The temperature values after forging were measured by using infrared laser thermometer. As a result of after hot forging, the diameters of the samples were reduced from 33 mm to 25 mm and the final temperature was measured as 1150±20 °C. After forging, the samples were cooled in the sand and air in a controlled manner. The surfaces of the samples were ground and the oxides and decarburization zones formed after the heat treatment were removed. The samples were grinded sandpaper until removing all roughness on the surfaces. These surfaces were then polished with diamond pastes. Finally, all prepared samples were etched in 3% Nital solution to examine the microstructure under an optical microscope.

The microhardness measurements of the as-received samples and the samples cooled in different mediums after hot forging were made with the Buehler Micromet 5103 brand Hardness Tester. Micro hardness measurements were carried out by applying HV1 (1000 gr.) load. The microhardness values were determined by taking the average of 10 hardness measurements from each sample. Microstructure analysis were performed using a Nikon ECLIPSE L150 optical microscope with X50-X1000 magnification capacity. Grain sizes, percentage of ferrite and pearlite phases of steel specimens were measured at appropriate magnification using a Clemex Vision Lite brand microstructure analysis system.

The turning experiments were carried out by using a coated carbide cutting tool in dry processing conditions. Turning experiments were made on a Johnford TC35 CNC turning center at constant a cutting speed (Vc) of and constantdepths of cut(ap) by using four different feed rate (fn). Table 2 given the process parameters for the turning tests.

Table 2. The machining parameters for the turning tests of 30MnVS5 microalloyed steel samples in cylindrical form

Experiment No.	Materials	Cutting Speed mm/min	Feed Rate mm/rev	Depth of Cut mm
1	30MnVS5	180	0.04	0.6
2			0.08	
3			0.12	
4			0.16	

The turning tests were made using a coated carbide cutting tool, produced by Kennametal firm with the geometry of WNGA 080404T01020. The cutting tool is coated with Al2O3/TiCN-TiN by PVD method. The turning tests were made with a diameter of 25 mm and a length of 30 mm. fc measurements were made out by using a Kistler 9257A dynamometer. Mitutoyo Surftest 211 was used to measure surface roughness (Ra) values. The measurements were done at three points by rotating the samples by 120 degrees.

3. Experimental Results and Discussions

3.1. Microstructure and hardness

The optical microscope image of the as-received is given in Figure 1. As can be seen in Figure 1, the as-received microstructure of 30MnVS5 steels consisted of the ferrite and pearlite phases.

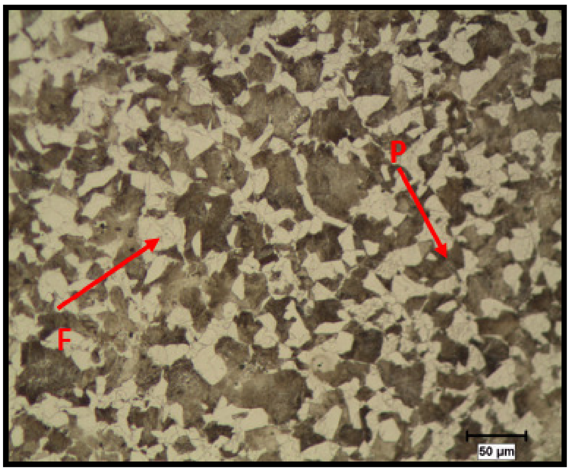

Figure 1. Microstructure of As-recieved steel (F: Ferrite, P: Perlite).

Figure 2 shows the optical microstructure image obtained from steel samples cooled in sand and airafter hot forging. As shown in Figure 2 that steel samples cooled in sand or air after hot forging showed ferrite and pearlite structures with different grain sizes (Fig. 2.a, b). The average mean linear intercept grain sizes, ferrite % and pearlite % calculated with the help of microstructure images are given in Table 3.

Since the rate of cooling in air is faster than the rate of coolin in sand, microstructures of air-cooled samples occurred of thinner ferrite and pearlite structures compared to the sand-cooled samples (Table 3). Recrystallization and even grain growth may occur before the austenite-ferrite transformation at low cooling rates such as the one in sand cooling (Jahazi and Eghbali 2001). Therefore, it was observed that pre-eutectoid ferrite had a network distribution on the grain boundaries and that the 30MnVS5 samples showed coarse grains when they were cooled in sand after closed die forging since the sand cooling rate was slower than the air cooling rate. These results are consistent with the results obtained by (Kaynar al. 2013).

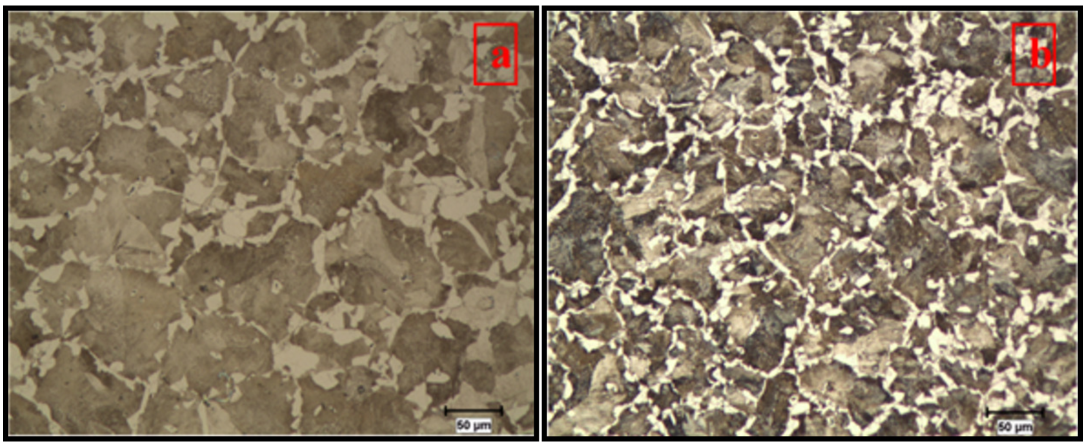

Figure 2. Microstructures of 30MnVS5 steel cooled in different mediums; (a) sand and (b) air.

Table 3. The results of the ferrite %, perlite % and grain size of the as-received, sand cooled and air cooled 30MnVS5 steel samples.

Sample	Ferrite (%)	Pearlite (%)	Ferrite Grain Size (µm)	Perlite Grain Size (µm)
As-received	38	62	11	20
Sand	25	75	9	30

Air	23	77	4	16

The hardness results of the samples cooled in the sand and air after the hot forging with the as-received are given in Fig. 3. As can be seen that the samples cooled in air found to have higher hardness values than those cooled in sand. The cause for this is the change that takes place in the microstructure images due to the different cooling rate (Demir, al. 2011 and Gündüz, al. 2006). For example, air cooled samples showed smaller ferrite and pearlite grain size and slightly higher percentage pearlite which increase the strength of the air cooled samples.

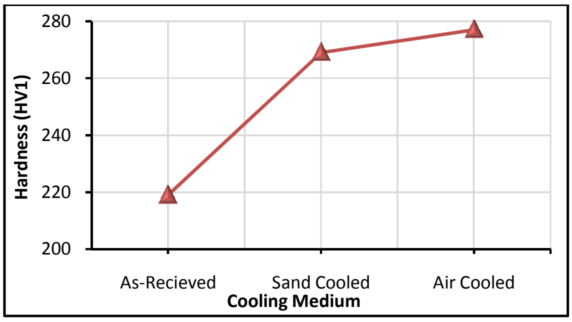

Figure 3. Hardness test results of samples (HV1)

3.1. Cutting forces

Turning tests were madeon 30MnVS5 microalloyed samples with different microstructure and hardness values which were obtained samples cooled in different environments after hot forging. Three components of the forces on the tool were measured in the turning tests. The effect of the primary cutting force (Fc) component on power consumption in machining operations is much higher than the feed force (Ff) and radial force (Fr). Therefore, the primary cutting force (Fc) was evaluated in this study. The Fc relationship depending on the fn and cooling environment is shown in Fig. 4.

The effects of the mechanical properties and fn on Fc are seen in Fig. 4. Fc were measured for four different fn (0.04, 0.08, 0.12 and 0.16 mm/rev). The Fc was measured as 129.6 N for as-received samples at 0.04 mm/rev fn. For as-received samples, as the feed rate increased up to 0.16 mm/rev, the Fc values increased at the rates of 111.7%. As can be seen from Fig. 4, sand and air cooled samples after hot forging showed higher Fc than the as-received samples. For example, Fc increased by 4.7% for sand cooled samples, 10% for air cooled samples compared with the respectively to those in the as-received samples.These can be explained by the increase in hardness of the sand and air cooled samples after hot forging. For sand and air cooled samples, as the fn increased up to 0.8 mm/rev, the Fc values increased at the rates of 49.9% in average. After this point, increasing the feed rate to 0.12 mm/rev for sand and air cooled samples decreased respectively Fc 3% and 10%.

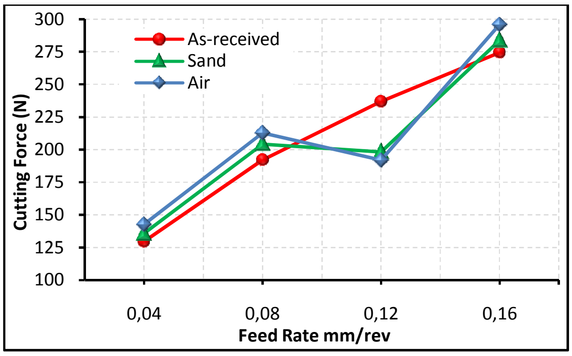

Figure 4. The change in the Fc of 30MnVS5 steel depending on the fn with the coated carbide tool.

The increase in the hardness of the hot forging applied samples also increases the resistance of the samples against cutting. In the case of 0,12 mm / rev in fn in sand and air cooled samples, Fc have been reduced due to cutting tool wear. For sand and air cooled samples is increased fn 0,16mm/rev. The Fc for the cutting tool which has lost its cutting feature has increased again. In the literature, many studies have shown that Fc values increase with the increase in the fn(Yeyen, al. 2009 and Kumar, al. 2008)

3.2. Surface roughness

The effects of the mechanical properties and fn on the Ra of the turning samples are seen in Fig. 5. Three measurements were made on sample and the arithmetic mean of these was accepted as Ra values. As shown in Fig. 5, the Ra was influenced by a significant amount of the fn. At 0.04 mm/rev fn, Ra values was measured as 1.26 µm, 0.97 µm and 0.87 µm for as-received, sand and air samples. Ra values of as-received, sand and air samples were found to be about 41–45% lower at 0.08 mm/rev fn compared to those in the samples tested at 0.04 mm/rev fn.Ra values of as-received, sand and air samples was decreased to be about 41–45% lower at 0.08 mm/rev fn compared to those in the samples tested at 0.04 mm/rev fn.At 0.08 mm/rev fn, the lowest Ra values was measured as 0.69 µm, 0.57 µm and 0.48 µm for as-received, sand and air samples. After this point, maximum Ra values were reached for all three samples with 0.16 mm / rev fn. In the literature, it is determination that there is an increasing relationship between the fn and Ra value. Depending on the increase in the fn, the increase in Ra values is an expected situation. Reducing the fn progress to improve Ra values is indicated (Lalwani, al. 2008 and Sandvik Coromant, 1994).

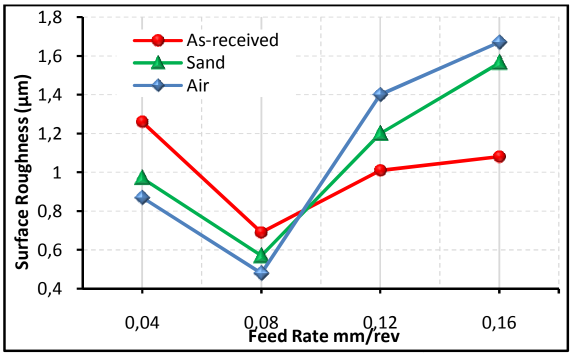

Figure 5. The change in the surface roughness of 30MnVS5 steel depending on the feed rate with the coated carbide tool.

4. Conclusions

This study investigated the microstructure and hardness values of 30MnVS5 steel quenched in sand and air after hot forging and turning tests were carried out using coated carbide cutting tool.The results of the experimental study are presented below.

- ✓ Air cooled samples were found to be consisted of thinner ferrite and pearlite phases compared to that of samples cooled in sand. This is because of air cooling which is faster than sand cooling.
- ✓ The hardness values of sand cooled samples with ferritic and perlitic structure were lower than those of samples cooled in air due to slow cooling after hot forging.
- ✓ The lowest cutting force of 0.04 mm / rev feed rate was measured at 129.6 N in the as-received. The highest cutting force of 0.04 feed rate was 142,67 N measured in the air cooled sample after hot forging.
- ✓ For all three samples, the maximum cutting force was measured at highest feed rate of 0.16 mm / rev.

5. References

Uzkut, M.,Özdemir, İ., 2001. Farklı çeliklere uygulanan değişen ısıtma hızlarının mekani,k özelliklere etkisinin incelenmesi. *DEÜ Mühendislik Fakültesi Fen ve Mühendislik Dergisi*, 3 (3), 65-73.

Das, D., Chattopadhyay, P.P., 2009. Influence of martensite morphology on the work hardening behaviour of high strength ferrite-martensite dual phase steel. *Journal of Materials Science*, 44, 2957-2965.

Lawrow, P., 2000. Welding considerations with high-strength steel.*Modern steel constructions*, August, USA.

Bai, D.O., Yue, S., Maccagno, T.M., Jonas, J.J., 1998. Effect of deformation and cooling rate on the microstructures of low carbon NB-B steels. ISIJ International, 38, 371-379.

Li, Y., Crowther, D.N., Green, M.J.W.,Mitchell, P.S., Baker, T., 2001. The effect of vanadium and niobium on the properties and microstructure of the intercritically reheated coarse grained heat affacted zone in low carbon microalloyed steel. ISIJ International, 41, 46-55.

Jahazi, M., Eghbali, B., 2001. The influence of hat forging conditions on the microstructure and mechanical properties of two microalloyed steel.*J. Mater. Process. Tech.,* 113, 594-598.

Kaynar, A., Gündüz, S., Türkmen, M., 2013. Investigation on the behaviour of medium carbon and vanadium microalloyed steels by hot forging test.*Materials and Design*,51, 819-825.

Demir, H., ÇÎftçi, İ., Türkmen, M., Gündüz, S., 2011. The Influence of Heat Treatment and Hardness on the Machinability of Alloyed and Non-Alloyed Medium Carbon Steels.*In IATS'II, 6th ınternational advanced Technologies Symposium*, 94-97.

Gündüz, S., Çapar, A., 2006. Influence of forging and cooling rate on microstructure and properties of medium carbon microalloy forging steel. *Journal of Mat. Sci. Letters,*41, 561-564.

Yeyen, H.E., Korkut, İ., Turgut, Y., Çiftçi, İ., 2009. AISI 303 östenitik paslanmaz çeliklerin işlenmesinde kesme hızı ve ilerlemenin kesme kuvvetleri ve yüzey pürüzlülüğü üzerindeki etkileri.*5. Uluslararası İleri Teknolojiler Sempozyumu (IATS'09)*, Karabük.

Kumar, K.V., Choudhury, S.K., 2008. Investigation of tool wear and cutting force in cryogenic machining using design of experiments. *Journal of Materials Processing Technology*, 203, 95-101.

Lalwani, D.I., Mehta, N.K., Jain, P.K., 2008. Experimental investigations of cutting parameters influence on cutting forces and surface roughness in finish hard turning of MDN250 steel.*Journal of Materials Processing Technology,* 206 (1-3), 167-179.

Sandvik Coromant, 1994. Modern metal cutting–A practical handbook. English Edition.*Sandvik Coromant*, Sweden, I-III.