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INVESTIGATION OF MACHINABILITY IN Co AND Cr CONTAINING HARD MATERIALS HEATED BY PLASMA ARC

Halis ÇELİK
Fırat University, Faculty of Technical Education, Elazığ, Turkey

ABSTRACT

Turning soft materials is not a problem in these days. But machinability of hard materials have been necessary. A lot of research has been done on machinability of difficult-to-cut materials. The aim of the present study is to investigate the machinability of three of hard materials after heating and softening. In this study for machining difficult-to-cut materials, different heating processes were applied and for heating, lately developed plasma heating method was used. To cut the hard material heated by plasma arc, tungsten carbide cutting tool was used. In the study, three different hard materials have been used. These were ferritic steel with 14 % Cr, Ti added cast iron, 8.5 % Cr cast steel and Co-Cr-W alloyed steel which is called stellite 6 and used in the textile industry and at power stations. In this study cutting forces, wear of cutting tool and surface roughness were investigated.

Key Words: Hot machining, Machinability, Plasma arc heating, High chromium steel

Co ve Cr İÇEREN SERT MALZEMELERİN PLAZMA ARKI İLE ISITILARAK TALAŞLI İŞLENEBİLİRLİKLERİNİN ARAŞTIRILMASI

ÖZET

Günümüzde yumuşak malzemelerin tornalanması problem olmamakla beraber, sert malzemelerin talaşlı üretimi bazı durumlarda teknolojik bakımdan zorluk çıkarmaktadır. Bu zorlukların giderilmesi hususunda araştırmacılar çalışmalarını halen sürdürmektedirler. Bu çalışmanın amacı yüksek sertlikteki üç adet malzemeyi ısıtarak yumuşatmak ve hemen ardından da bu malzemelerin işlenebilirliğini araştırmaktır. Malzemelerin ısıtılma işlemi, ileri ısıtma metodlarından "plazma arkı ısıtma metodu" kullanılarak yapılmıştır. Isıtılan yüzeyden talaş kaldırmak için tungsten karbür kesici takımlar kullanılmıştır. Tornalama deneylerinde iki çeşit malzeme kullanılmış olup bunlar sırasıyla, Titanyum ilaveli %14 Cr içerikli dökme çelik, %8,5 Cr içerikli dökme çelik ve bir tane de gerek otomotiv gerekse kuvvet santralleri, tekstil ve kağıt endüstrisinde çok kullanılan ve stellite 6 olarak bilinen Co-Cr-W alaşımıdır. Deneylerde kesici takımların aşınması, kesme kuvvetleri ve yüzey pürüzlülüğü hususları incelenmiştir.

Anahtar Kelimeler: Sıcak işlenebilirlik, İşlenebilirlik, Plazma arkı ile ısıtma, Yüksek kromlu çelikler.

1. INTRODUCTION

Production methods are divided into two categories as chip removal and non-chip removal. Generally the first method is used, but hardness of material is very important and cutting tool must be harder than material. Otherwise it is too difficult to cut the material. As regard to hardness of material, many of the studies have been done to improve the cutting tool hardness. In order to cut high hardness material, sintered cubic boron nitride (CBN) cutting tool is developed (Naturaki, 1983). CBN tools make high rate machining of hard materials possible, because the high temperature hardness of CBN is much better than all other HSS or carbide tools. Machining is possible as long as cutting tool materials are harder than work itself. Metal cutting is based on this principle. It is very difficult to find a cutting tool which is harder than work material, therefore a part or overall of a workpiece is heated to make it softer. As a result of that, material can be cut easily with a lower power (Chen and Lot, 1974). Workpiece is heated by special designed plasma arc apparatus which was used before by the researchers. There are several methods to heat the work material. These are electric current (Macmanus, 1968), and high frequency induction method (Kainth and Chaturvedi, 1975; Weller and Schrier, 1969). In this study Plasma arc heating method was used (Naturaki, 1983). A torch was placed opposite the cutting tool. Plasma arc made the material locally soft. After this, by a single point cutting tool the workpiece is machined.

As a result of these processes, the body of the workpiece heats (Hoffman and Haavisto, 1984; Kitagawa et. all., 1988). The heat may change the dimensions of the workpiece and its surface roughness. These were considered as a disadvantages of hot machining. Using this process two high chromium cast steel and a Co-Cr-W alloy were machined. Cutting forces, tool wear, cutting temperature and surface roughness were investigated for various cutting speeds and heating conditions.

2. MATERIALS USED IN THE EXPERIMENTS

Table 1 shows the chemical composition of the work materials. First two materials are high chromium (Cr) cast iron and they have high hardness. Their machinability is quite difficult at the room temperature when using tungsten carbide tool which is the best cutting tool compared with the others except CBN. From the table 1, stellite 6 is the wear resistant material and it sustains its hardness at the high temperatures. At the room temperature its flow stress is the lowest compared with the other materials but after 500 °C it has the highest flow stress. From the machinability point of view this is a disadvantage.

Table 1. Chemical Composition of Work Material

C	Cr	Ni	Mo	Cu	Si	Mn	P	S	Ti	W	Co
14% Cr Cast steel											
2.05	13.8	0.13	0.04	0.02	0.61	0.64	0.03	0.02	0.21		
8% Cr Cast steel											
2.5	8.1	0.07	0.25	0.04	1.1	0.45	0.02	0.03			
Co-Cr-W											
1.1	28									4	69.9

For each specimen, different temperatures were applied at the tension-compression testing machine. The relationship between temperature and yield stress was used for hot machining. Figure 1 shows the relationship between yield stress and temperature for the turned specimens.

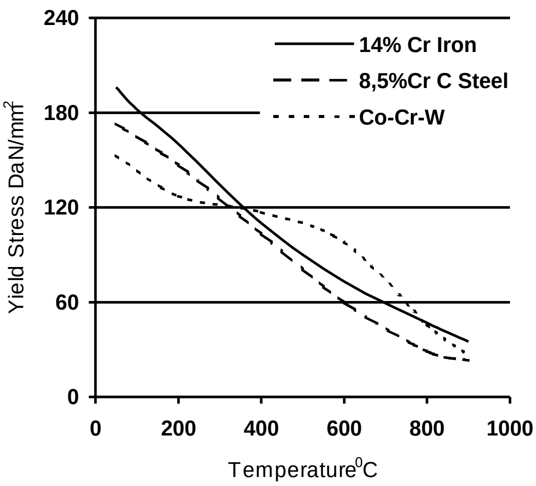

Figure 2. Relationship between yield stress and temperature for the workpiece materials

The yield stress at about 650-700 °C is possible for hot machining above three types of material. Cobalt based material sustains its hardness at the high temperatures. Therefore, hot machining temperature of the tools should be higher.

A plasma arc apparatus was designed, similar to Kitagava et.al (1988). Argon gas was used to generate plasma. Figure 2 shows the complete plasma arc heating equipment. For heating process, there are two important conditions. The first one consists of arc current, flow rate of working gas, gas mixture ratio, nozzle diameter and distance of nozzle. The second consists of work materials, cutting speed, depth of cut and feed rate. To measure the temperature of the work material, a thermocouple was placed at the position of cutting edge. For each experimental study 70x400 mm workpieces were used. Feed rate was 0.15 rev/min, and the distance between work material and torch was fixed as 5 mm. Figure 3 shows the relationship between the surface temperature and arc current. The surface temperature of workpiece is the highest for slower feed rates and at the constant arc current. A plasma arc is sprayed on the workpiece's surface to be cut, for making the part locally soft. Just after being heated and made locally soft by means of a plasma arc the material is removed by a single point cutting tool (Figure 4).

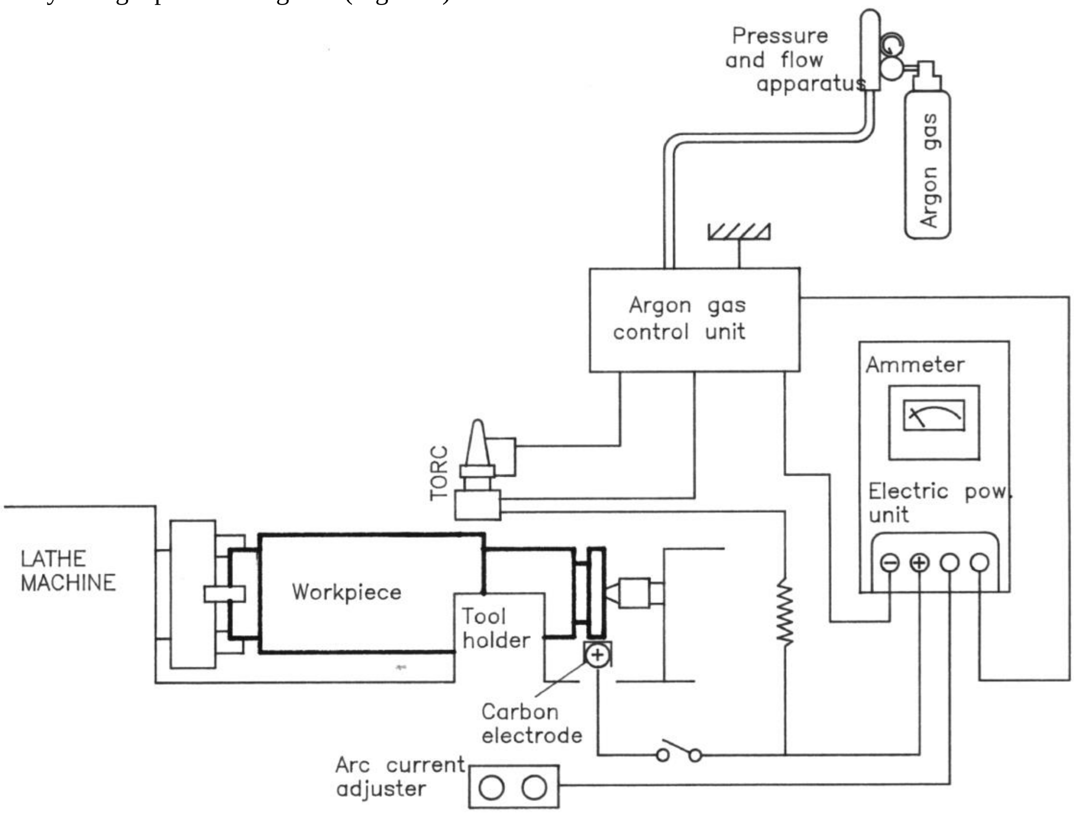

Figure 2. Plasma hot machining equipment

3. EXPERIMENTAL STUDIES

Turning experiments were carried out under the following conditions.

Cutting conditions are as follows: Toolk; P10 (0, 0, 6, 6, 15, 5, 0.8) tungsten carbide which is suitable for high temperature working. Cutting speed; 40-121 m/min, feed rate; 0.15 mm/rev, depth of cut 1.5 mm, cutting fluid was'not used (dry).

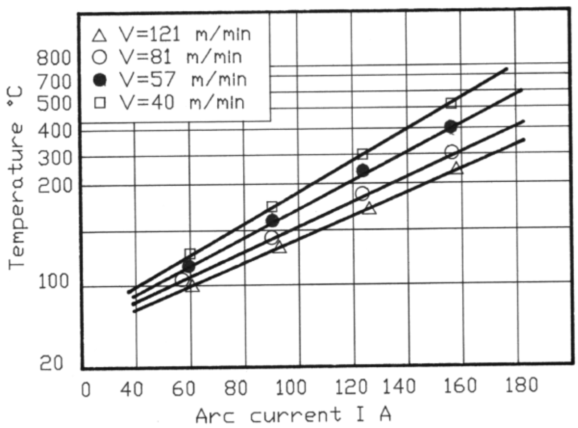

Figure 3. The relationship between plasma arc current and surface temperature

Heating conditions are: Arc current; 0-180 A, working gas; argon, flow rate; 13 l/min. The distance between nozzle and work material is 5 mm.

3.1. Hot Machining of 14 % Cr Cast Iron

Cutting forces and the wear of cutting tool was searched for each work material (Bhattacharya, 1987). Figure 5 shows the relationship between cutting speed and cutting forces. Cutting forces

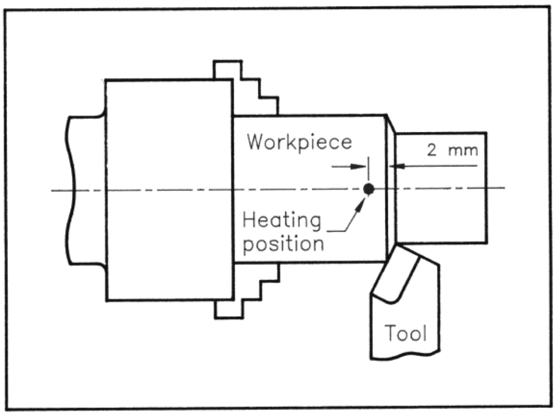

Figure 4. Cutting tool and plasma heating position

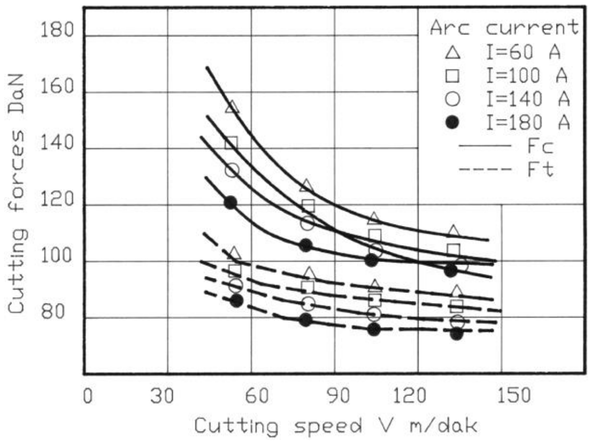

Figure 5. The relationship between cutting speed and cutting forces (14 % Cr cast iron)

consist of main component F_c and feed component F_t. Both the cutting forces F_c and F_t drop with the increase in the arc current and cutting speeds. The highest cutting force are obtained at the lowest cutting speeds such as v = 40 m/min. Increasing the arc current relatively rises the heat. At high speeds such as v = 121 m/min the tool wear increases. However decreasing the cutting speed (v = 57 m/min) the wear rate also decrease.

3.2. Hot Machining of 8.5 % Cr Cast Iron

Above, the changes of cutting forces due to cutting speeds were examined for 18% Cr cast iron. In this section the changes of cutting forces against arc current were examined. Figure 6 shows the changes of cutting forces due to different arc current. In this graph especially at lower speeds, rising plasma arc decreases the cutting forces. However at the high temperature sharp decreasing at the flow stress is not

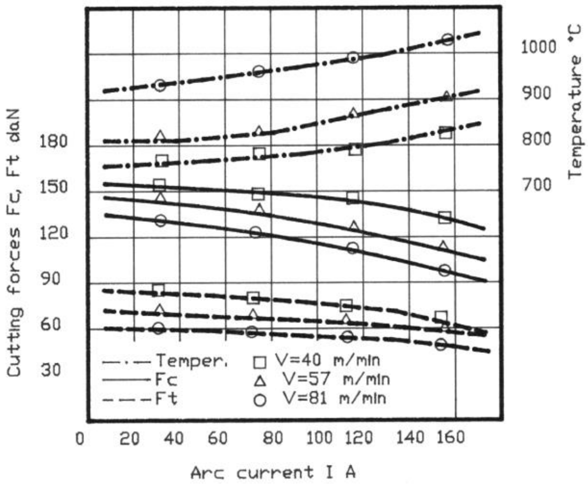

Figure 6. The change in cutting forces and cutting temperature of 8.5 % Cr cast steel with respect to arc current

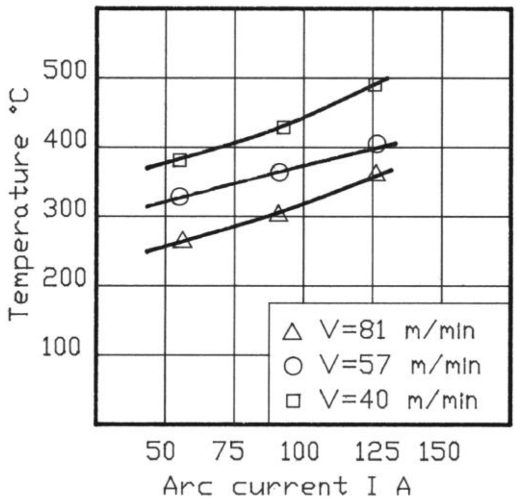

Figure 7. The surface temperature just after chip removal depending of the arc current of cast steel with 8.5 % Cr

seen here. Moreover increasing arc current does not effect a lot the heat increase. In addition, the friction distance of the chip on the tool surface increase compared with the material containing 14 % Cr due to the increase in the curve radius of the chip.

The only difference between normal cutting and plasma hot machining is the surface groove of cutting tool. For normal cutting the groove is greater than PHM.

As the arc current rises the surface roughness disappears. The surface temperature of work just after being machined was measured by a thermocouple. It was placed at the site just opposite to the cutting tool against the work material. Figure 7 shows the relationship between the arc current and surface temperature. From figure 7 at the lower speeds (v = 40 m/min) cutting speed, the surface heat rises with the increase in arc current.

3.3. Hot Machining of Cobalt Based Alloy

This alloy has less C Content and hardness compared with Cr alloyed cast irons. Cobalt based alloy (Stellite 6) sustains its hardness at high temperatures, but due to the phase transformations after 400 ºC its hardness decreases. For this material at the turning operations P10 sintered carbide tool was used. Figure 8 shows the relationship between arc current and cutting forces in the case of I = 75 A, the cutting forces decrease sharply. Since turning material gets mild around 450 ºC, from the figure 8, it is observed that at an arc current of I = 75 A the tool wear drops.

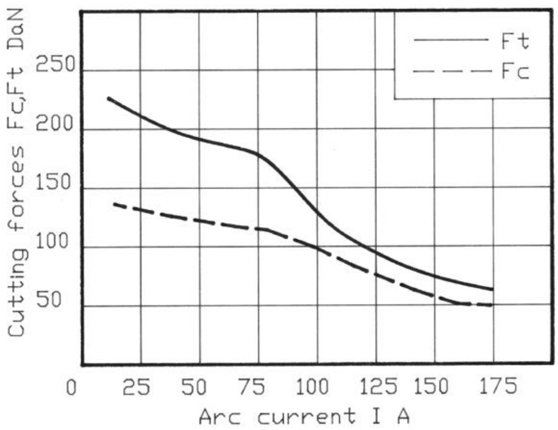

Figure 8. The relationship between the cutting forces and arc current (Cutting speed v = 81 m/min, Feed 0.15 m/min)

4. CONCLUSIONS

1. High temperature flow charesterictics of 14 % Cr, 8.5 % Cr cast iron and Co-Cr-W alloy which are typical of difficult-to-cut materials having high hardness were investigated by the bar compression test machine.
2. The application of plasma hot machining is suitable for hard materials at the normal temperature. This method spreads the heat all the surface homogeneously.
3. Cast iron 8.5% Cr comparing cast iron 14% Cr, crater which is on the surface of the tool was less than other. However flank wear increased a bit.
4. Although 14 % Cr and 8.5 % Cr and Co-Cr-W materials have high hardness, PHM makes it possible to cut it with tungsten carbide tools with less flank wear.
5. Although Co-Cr-W alloy has lower hardness compared with Cr alloyed cast irons. Co-Cr-W alloy sustains its hardness at the high temperatures but PHM temperature is the same as Cr alloyed cast irons.

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