L. DAHIL, İ. DAHIL, A. KARABULUT

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COMPARISON OF ADVANCED CUTTING TECHNIQUES ON HARDOX 500 STEEL MATERIAL AND THE EFFECT OF STRUCTURAL PROPERTIES OF THE MATERIAL

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Purpose of this study is to determine the most advantageous cutting method for a better competition chance. By presenting high hardness, high strength and superior toughness Hardox 500 steel. This sample was cut by plasma, laser, wire erosion and abrasive water jet (AWJ) methods from advanced cutting technologies. By taking micro structure photos of surface of the sample cut by different cutting methods, effects of different cutting methods on metallurgical structure of material were compared.

Key words: Hardox 500, advanced cutting techniques, micro structure, hardness

INTRODUCTION

Conventional methods have different disadvantages that could cause decrease of importance shown to them in market. In recent years, there are manufacturing methods called as developed advanced cutting techniques. These manufacturing methods are wire erosion, laser, plasma and abrasive water jet. In the environment where national and international competition have been increasing every passing day, it has become more and more important to make proper selection required minimum process.

In the optimization study made for the selection of processing parameters of wire erosion, important factors affecting processing performance were determined by using Taguchi experiment design method and analysis of variance [1]. Processing with wire erosion allows mould members to be processed in high-measurement precision, after being exposed to heat treatment, because hard materials, which are manufactured very difficult according to classic processing methods, could be processed provided that being conductive [2]. In wire erosion, generally, a hard layer and hair cracks occur on the surface of work piece depending on performed processing conditions and thermal features of material [3]. With wire erosion, chip is removed from work piece through electro thermal energy, for this reason, machining ratio depends on electrical conductivity and heat of melting of work piece [4]. Gas parameters, power supply parameters and cutting speed are important parameters for plasma cut [5]. Surface roughness is defined by fluctuation on the surface and size of the fluctuation is proportional to diameter of jet [6]. When rate of feed of jet is decreased, it was determined that abrasive particles lose partially their accuracies in the deformation abrasion zone and the particles separating from the cutting material increase hole depths by touching the surface [7]. Water jet has been becoming more and more effective than the other methods competing with it, because it has no thermal effect especially on cutting material [8]. An surface roughness that increases depending on cutting depth is inevitable likewise laser cutting, plasma, underwater plasma and oxygen flame [9]. Due to cutting process with water jet is provided by water, it is totally proper to health conditions needed in food sector [10]. Water jet is a cutting tool, which is non-abrasive, with non-apparent turning, don't leave burrs at corners, generates powers that will deform the material during cutting, without temperature influence and therefore occurrence of structural defect, tarnish, distortion, melting, dropping and burning problems don't come into question, can cut even the most complicated shapes by its high sensibility and very clean surface properties [11]. While laser cutting and plasma cut, structural alterations, which possessed high hardness degree and processed with difficulty, occur on cutting surfaces because of the used thermal energy [12].

In this study, examination of hardness and micro structure changes, which occur on the surface of shear of cutting sample and on backwards areas from cutting surface because of the non-conventional different cutting methods, and determination of the most advantageous cutting method, were proposed.

MATERIALS AND METHODS

In experimental studies done, Hardox 500 steel sample, which is commonly used in heavy industry and

L. Dahil, Istanbul Aydın University, Department of Mechanical and Metal Technologies, Turkey. A. Karabulut, Afyon Kocatepe University, Faculty of Technology, Mechanical Engineering, Turkey
İ. Dahil, Ministry of Education, Istanbul Provincial Administration of Education, Turkey

manufacturing and many phases about manufacture and keep high hardness, high strength and superior toughness together, was used. Size of sample is been 20x20x15 mm. Prepared sample was cut by plasma, laser, wire erosion and abrasive water jet (AWJ) methods of advanced cutting technologies.

By comparing micro structure photos of the sample cut by different cutting methods with micro structure photos of the original sample, effects of different cutting methods on metallurgical structure of the material were evaluated. In addition, on the sample cut by different methods, effects of hardness variation were examined on the graphics obtained by making hardness measurements from cutting edge towards the core.

Plasma cutting

Cutting method for CNC plasma machines is the thermal processing method that takes the electric energy from power supply and transmits it to the material to be processed, under the guidance of torc and protection of substitute gases, and during this process, that uses an ionized and electric transmitter gas as transfer media [13]. State of the sample cut by plasma, is shown on Figure 1.

Laser cutting

Laser cutting method can be defined as transmission of photon energy to the material to be processed by thermal or photochemical ways, "atom-atom" processing of the material to be processed by melting or evaporation and revulsion of melted material by the help of using gases.

State of the sample cut by plasma, is shown on Figure 2.

Figure 1 Photo of surface of shear of the sample cut by plasma

Figure 2 Photo of surface of shear of the sample cut by laser

Figure 3 Photo of surface of shear of the sample cut by wire erosion

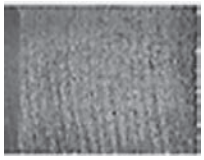


Figure 4 Photo of surface of shear of the sample cut by abrasive water jet

Wire erosion cutting

Wire erosion is the method of cutting with the help of a wire on which high-density flow is passed. On these looms, when wire electrode connected to different electrical poles is approximated to work piece, a high temperature occurs with high discharges and chip is removed by local metal defrosting way [14]. State of the sample cut by plasma, is shown on Figure 3.

Cutting by abrasive water jet

Cutting technology by Water Jet is based upon that obtained beam of water jet at high speeds by crossing the pressure increased water (4000 bar) through a narrow range discharges particles from the material by impact effect, and as a result of this, processing of the material. It is a method that can cut all kinds of materials with thickness from 0,1 mm to 200 mm [15].

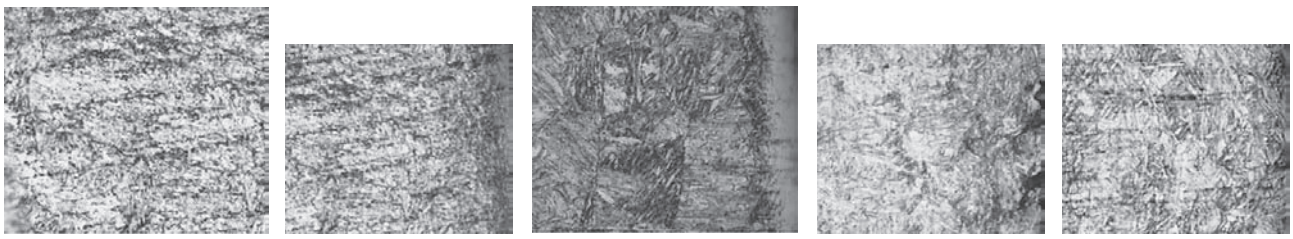
While cutting the materials by abrasive water jet, QMAX Abrasive Water Jet was used. Among GMA Garnet, Garnet and Power Garnet, abrasives which are commonly used, GMA Garnet was used in this study. State of the sample cut by abrasive water jet, is shown on Figure 4.

Hardness of the cut surfaces was measured by "HV0.5" value in "SHUMAZU" hardness measuring instrument. Photos of cut surfaces were taken by zooming their micro structures 500 times by the help of "OLYMPUS BX-60 Model" microscope and TV tuner and software on "Inter Core 2 Duo PC".

In order to examine variable hardness values of materials cut by different cutting methods and structural defect and alterations in microstructures and on surface caused by cutting method, edges neighboring on surface of shear of cut samples were cleaned by 240 - 1 200 papers consisting of SiC granules in different granule sizes and placed on rotating disk. The reason why cleaning and polishing operations are applied on borders neighboring on surface of shear is to examine hardness alteration from the border of surface of shear to inward. The process was carried out until the base is parallel to the surface on which examinations will be made.

For polishing process, aluminum powder and diamond paste were used as abrasive. After providing the gloss completely, the surface to be seared and examined was cleaned by washing with water and alcohol.

These operations were carried out until the desired surface is obtained for metallurgical examinations. Each polished material was seared by 3 % nital for 6 seconds in order to find out surface structures. After searing operation, the surface to be examined was cleaned by



a) Before cutting b) Cut by water jet c) Cut by plasma d) Cut by laser cutting e) Cut by wire erosion

Figure 5 Micro structure photos of cutting border and surfaces of the sample cut by different cutting methods

washing pure water and alcohol. Seared materials were zoomed 500 times by examining under optical microscope and then their micro structure photos were taken.

The micro structure is at a point, which is non-affected by cutting method, and the structure is formed at cutting edge were examined comparatively in order to observe alterations in micro structures of material.

In order to find differences resulted in examination, a large number of photos were taken three different points from material surface and deformation in the structure of material caused by cutting method and hardness changes were determined as a result of examining all of these photos.

Hardness measurements of materials, which their micro structures were examined, were carried out by Vickers hardness measuring device and the obtained results were transmitted on graphics. On the same sample, by measuring hardness at intervals of two each millimeters from cutting border to core, hardness changes were determined from cutting border towards core and effects of different methods were evaluated depending on these alterations.

DISCUSSION

During different cutting operations applied on prepared sample, it was observed that temperature changes would cause what kind of changes on external structure of piece and then the results were compared with micro measurements. Neighboring surfaces of surfaces obtained as a result of cutting were subjected to micro structural examination by polishing.

After micro film and hardness measurement operations, hardness and structural changes that occur depending on cutting methods on material, were evaluated. On figure 5(a), 5(b), 5(c), 5(d) and 5(e) illustrate micro structure photos of cutting border and surfaces of the sample cut by different cutting methods.

Cut surface with different methods of hardness changes % resulted in these comparisons are illustrated on Table 1. As seen on Table 1, there isn't a significant change on surface, micro structure and cutting edge of the material, only in cutting by water jet among these cutting methods.

In order to determine these changes coming into existence on these cut materials, original hardness value of the sample that was not subjected to cutting operation was determined primarily. In order to carry out determination and comparison of the changes after cutting operations, hardness values in Vickers (HV) were measured at 2, 4, 6 mm distances on neighboring surface from cutting edges towards centre. Graphic, which have been formed to figure out what kind of a change is presented towards inside of material by hardness values on the cut surfaces of the sample subjected to different cutting methods and to make comparison to before and after the operation, are given on figure 6.

Table 1 **Depending on the original hardness of the material cut, the cut surface with different methods of hardness change**

Cutting Method	Hardox 500	
	Hardness / HV	Change / %
Core	600	-
Water Jet	602	0,33
Wire Eroison	638	6,34
Laser	655	9,16
Plasma	672	12,10

When these graphics are examined, it is seen that hardness values change depending on microstructure of material in different cutting methods. It is clearly noticed that cutting method with maximum change is plasma cutting and cutting method with minimum change is abrasive water jet cutting.

By seeing different hardness values of different materials, it has been seen that water jet cutting provides superior advantage and completes the operation without causing any internal strain for materials. As for the other cutting methods, wire erosion, laser and plasma cuttings follow grading of water jet in terms of advantage.

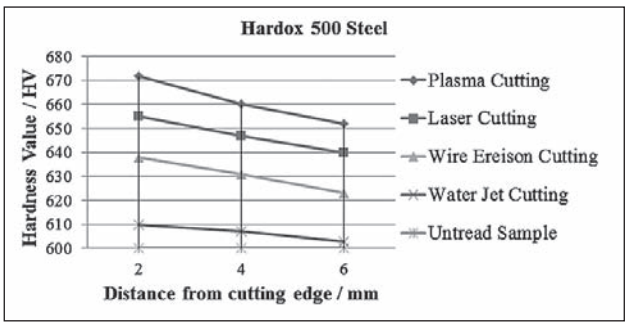


Figure 6 HV 0.5 Hardness measurement graphics

CONCLUSIONS

On the surfaces cut by method of abrasive water jet, because any thermal treatment didn't occur on the field touched by jet beam, material didn't have any microstructure change and hardness differences depending on cutting.

When effects of different cutting methods on metallurgical properties of cut surface are taken into consideration, it is seen that method of AWJ cutting, which gives the most positive results, comes into prominence.

While different temperature and cooling effects that exist during advanced cutting methods have an important impacts on metallurgical properties of the examined materials, a zone affected by temperature doesn't occur on cut surfaces and there won't be a defect in original structure of the material, because temperature is not too high in AWJ cutting. This situation means that there cannot be a change for mechanic properties depending on the metallurgical properties.

Among four different method examined in consequence of experiment, if an evaluation is made by taking into consideration micro structural changes of the zone affected by temperature, it is seen that the most negative method is " Plasma cut" and the most positive method is "AWJ cutting".

Methods in which advanced cutting methods are applied, mechanic properties of the material also change depending on the effect of material on metallurgical effects after cutting. In consequence of experimental studies conducted, this situation is verified because hardness values measured on the surfaces cut by different methods are more different than original values of the materials.

Since all the applied cutting methods apart from water jet contain heat treatment, they cause a significant change for hardness of material. Hardness changes are been different depending on the properties of cutting methods. This difference changes depending on heat and temperature formed during cutting and cooling conditions.

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Note: The responsible translator for English language: Gülsen Bozdemir, Ankara, Turkey