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EFFECT OF CUTTING METHODS ON PROPERTY OF PURE TITANIUM

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ABSTRACT

In present study the effect of various cutting methods on the Rockwell hardness of titanium alloys SB265 is investigated. To ensure the repeatability of the experiments and to find confident results for each condition, at least 3 specimens were prepared. Six various cutting methods are investigated in this study: laser cutting in two power levels, cutting by milling machine, water jet cutting, cutting by grinding tool and plasma arc cutting. After cutting, hardness of specimens was measured and non-affected length was found for each item. The results demonstrate the best and worst methods of cutting Titanium.

Keywords: Titanium Alloy SB265, Cutting, Rockwell Hardness.

INTRODUCTION

In the continuing era of rapid industrial revolution and economic growth, noticeable advances in the domains of basic sciences, engineering and related technologies emphasized on the development, emergence and use of traditional metal cutting. Various cutting methods have been devised depending on the metals which resist cutting differently. One such metal is titanium which has grown in stature, preferential use and need during the last three decades, i.e., since the early 1970s (ASM Metals Handbook, 1990).

Titanium has been increasingly used in some special heat exchangers because of its excellent property such as high strength/ weight ratio, high ductility, adequate mechanical properties and particularly high corrosion resistance (Wang, 1993., Ohkubo, 2000., Zinelis, 2000., Jang et. al, 2001, Sicknan, 2006). The SB265 is introduced as a pure Ti in ASME BPVC (ASME, 2010).

High chemical reactivity of Ti causes complexity of its application in the industrial purposes. Hence its welding and casting procedures are different from many metals. Now that Ti has to be cut in controlled way to limit chemical reactions, the recognition of

cutting method and its effect on the specimen is strongly required.

At room temperature, Ti has a hexagonal close-packed crystal structure, which is referred to as the “alpha” phase. At 883°C, this structure transforms into the “beta” phase which is a body-centered cubic crystal structure. These phase changes directly influences its properties. The families of Ti alloys are essentially categorized as being corrosion resistant or structural. The structural Ti alloys are classified into three categories, denoted as α , $\alpha + \beta$ and the β phase alloys. The alpha- phase is relatively weak in strength but offers a combination of good corrosion resistance, good weldability, creep resistance, receptive to heat treatment and also it is easy to process (ASM Metals Handbook, 1990). The beta-phase is receptive to forging and has excellent fracture toughness. The dual phase, i.e., $\alpha + \beta$ offers a combination of excellent ductility and strength in case of applied proper heat treatment. Kuruvilla et al have discussed on the hardness, tensile properties and final fracture behavior of the alloy are discussed in light of test specimen orientation, intrinsic microstructural features, nature of loading,

local stress state and deformation characteristics of the alloy microstructure (Kuruvilla et. al. 2008). Sui Yan-wei et al, have investigated the effects of Ti casting modulus on the Vickers hardness, as well as the relationships between Vickers hardness, grain size and thickness of lamellar $\alpha+\beta$ phase (Yan-wei et. al. 2008).

The large heat gradient due to cutting process can cause alteration in Ti mechanical properties (Danielson et. al, 2004). The complexity of changing the microstructure can be compounded by contaminating with impurities from the ambient environment (oxygen, nitrogen). In small amounts, these elements do not change the HCP crystal structure. However because these elements are small, they locate on interstitial sites in the crystal lattice and prevent the movement of dislocations (Robert et.

al. 1994) . Thereby they significantly increase hardness and strength, and also cause embrittlement of cut edges. Furthermore, titanium readily oxidizes when heated in an air environment. This investigation aims to evaluate transformation of Ti hardness due cutting process and to determine the size of the affected zone.

MATERIAL AND METHODS

The specimen

Ti specimens which have used in this study are 6 mm thickened plates of SB-265 according to ASME code (Figure 1). In this study, specimens were cut using 6 methods to compare their Rockwell hardness. Figure 1 demonstrates effect of cutting process on Ti edge can be observed visually.



Fig. 1 Titanium plate and the cut edge



Figure 2 a) Used laser beam cutting machine b) Water jet setup c) Cutting by grinder wheel d) cutting by plasma arc machine

Cutting methods

Figure 2-a shows the laser beam cutting machine. Laser cutting works by directing the output of a laser

power at the material to be cut. The laser beam was carried out in two power levels, one in high power (10000 W) and another in low power (250 W). The

material then melts and vaporizes away. Specimens also were cut by milling machine. Although mechanical properties are affected by this method, chemical and physical alteration of specimens is negligible (Lautenschlager, Monaghan, 1993). The spindle axis is vertically oriented. Milling cutters are held in the spindle and rotated on its axis. It has a stationary spindle and the table is moved both perpendicular and parallel to the spindle axis to accomplish cutting.

Figure 2-b shows the water jet setup used in this investigation. Water jet is another capable tool for slicing into metal or other materials using a jet of water at high velocity and pressure.

The most important characteristic of handy grinder in cutting is Mobility. Although it is not designed to cut, it is useful in some aims such as providing test plate from heavy plates. Figure 2-c shows the Ti plate cut by a stainless steel grinder wheel.

Plasma arc cutting produces a high temperature, high velocity stream of ionized gas to melt and blow metal from the line of cut. Figure 2-d shows used plasma arc machine during cutting Ti plate while it was matched on 400 A current.

Hardness measuring

Rockwell scale B (HRB) hardness method was used to measure the hardness. The hardened steel ball indentured by applying 100kg force on the sample in an accurately controlled test force. The full load was normally applied for almost 20 seconds. Measuring hardness of specimens by HRB method has been depicted in Figure 3. Since the measured values are used especially for comparative purposes, they can be measured in any scale.



Fig. 3 Hardness Measuring

Metallographic sample preparation

The mounted specimens were ground and polished then they were immersed in the etched solution from 15 to 20 seconds to reveal the microstructural features. Solutions for etching titanium included: 100 ml water, 2 ml HF and 5 ml HN03.

RESULT AND DISCUSSION

Figure 4 demonstrates the measuring results in 6 graphs. Cutting methods are divided in two categories; cold and hot.

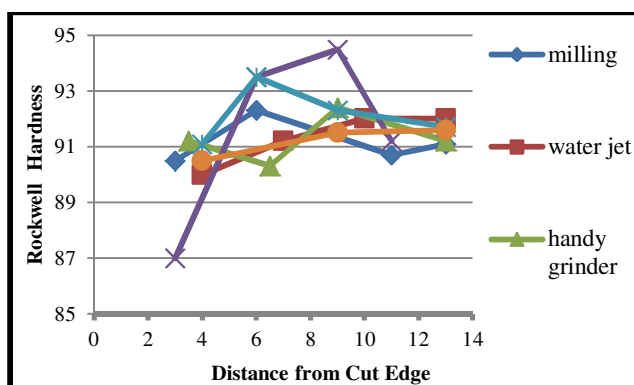


Fig. 4 Measured Rockwell hardness

Water jet has shown best result between all the mentioned processes.

The cutting process has affected hardness only through 9 millimeter from the cut edge. Also against other processes, water jet graph has a monotonous trend which is rising through the measured width. In this graph, constant value is observed after 9 mm width.

Cutting process by milling machine resulted in a reduction in hardness tendency along plate width.

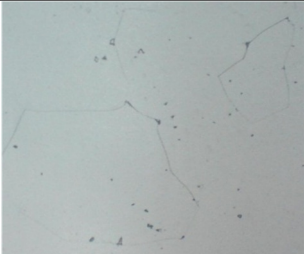
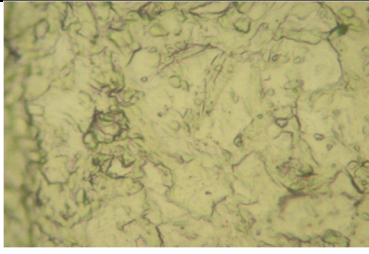
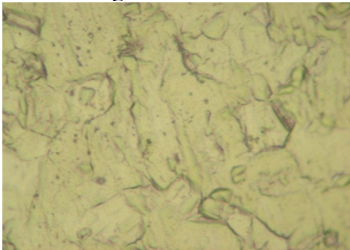
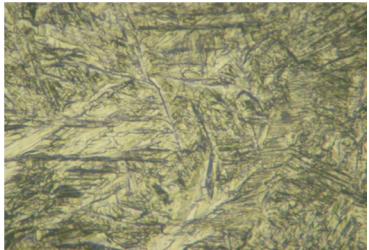
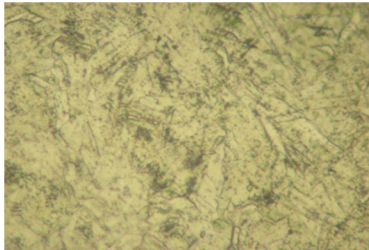
Handy grinder decreased hardness of the specimen in a larger part of measured width. Although fluctuation exists in this graph, good result has been observed. Plasma arc graph gently rises through the measured width.

Lower energy power affected the specimens too and the hardness graph fluctuates. This cutting process increased hardness of the Ti plate in larger part of measured width across cutting line.

High power laser graph demonstrates most fluctuation among other processes. At the cut edge, the hardness was decreased to minimum recorded hardness in the study.

The graph sharply rises to the peak measured hardness value. Table 1 shows alteration of microstructures in result of cutting methods.

Table: 1. Microstructures

Reference (Metals Handbook 1992)	Water Jet	Handy Grinder
		
265-2 commercial-purity unalloyed titanium, hydrogenated to 20 ppm	This is closest microstructure to Reference figure These figure shows a greater amount of TiH was produced.	The gray part may appear in result of composition of handy grinder's material and Ti.
High Power Laser	Low Power Laser	Plasma
		
Irregular alpha particles are most important feature in this case.	Intense changes were occurred in the sample.	According to recrystallization of primary alpha, the microstructure contained acicular alpha (transformed beta).

CONCLUSION

Conclusively water jet has affected a least part of titanium plate and the microstructure has been close to intact microstructure. So the best method for cutting Titanium is that to use water jet cutter. Also plasma arc has caused limited effect on the hardness of Ti plate.

Hardness has decreased in result of using the processes which hadn't used any heat source as are shown in water jet, handy grinder and milling graphs. Laser cutting process causes rising hardness in most part of affected zone. Also because of harshness, the edges need to be finished.

Although base on hardness, laser cutting method seems suitable for Ti plates in low power energy, the microstructure shows deeply changes were occurred in the metal.

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