

# Effect of heat treating and analysis of mechanical characterization of cutting tool materials

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**Abstract -** For the past decades, there is a tremendous changes have been taken place in the field of metal cutting area, to evict the problems which are being associated with metal cutting operations some investigations are made. In this paper we have made an attempt to discover and eradicate the problems which are associated with different cutting tools and also we have tested the different cutting tool materials by means of different testing machines, in the mean time we have analyzed and depicted results which are obtained by means of suitable heat treating operations. In this respect cutting tool materials are those which are used to perform cutting action over any type of metal. Here we have probed and looked attentively over Stainless Steel of Grade 440C, SS316C (Chromium-Nickel steel) and titanium alloy (Ti- 6Al- 4V).

**Keywords:** Cutting Tool, Heat Treatment, Aluminum, Mild steel.

## I. INTRODUCTION

In light of growing technology there are different facilities can able to acquire directly and indirectly from available resources. Earlier century, people were facilitated traditional technology to do desirable task but now it is wholly replaced by new modern technology daily human beings are fully depending on technology. Technology not only satisfies ethical task but it gives an idea how to discover new thing and how we need to take a control over new system. As far as newly discovered product rate of material is concerned the demanded product would have highest package in market as compared to exist one. So in this connection as we know that there are various materials would have known for their best properties. In view of current technological aspects what we observed in the late nineties that were limited to certain extent. But now due to faster rate of growing technology our engineers are well known across the world for their keen interest to take bold step to discover something. In the area of mechanical engineering several manufacturing systems have been developing since very long time those manufacturing process played vital role to enhance the value of product both in qualitatively and quantitatively. An effective way of explanation is needed to disclose the mechanical properties of any metal or alloys. In order to alter the mechanical characteristics there are various and several methods could be seen those are alloying process, Recrystallization Process and Heat Treatment process. However, some hindrances could be seen to achieve desirable mechanical characteristics. Many industrialists made investigation over cutting tool materials, Thereby attaining desired properties over cutting tool materials heat treatment operations have been carried out. These operations have been made impact over cutting materials in increasing the hardness, toughness, tensile strength and other properties. When we talk about machining there are non evicted things commonly encountered. Thus the ratio of product outcome to product income may give us lesser productivity as we do not eradicate these problems. Before we met technology our ancestors were used to bring sharp tools which were being used to cut the materials and also used to kill the animals to lead the life. As technology grows, the human has facilitated different technological items which are used in engineering area. While performing machining over any metal or alloy by means of cutting tool at shear zone an enormous amount heat may be generated. As a result cutting will take place. There are some factors shall consider into our account to perform cutting action. In machining era there are cutting speed, feed, depth of cut, the direction of cutting operation, type of metal, type of cutting tool material and other factors will be considered deeply. Some other aspects shall also be considered in order to out root the wearing of tool and machined surface. There are various machine tools are available in order to perform machining operation over any material those are Lathe Machine tool, Milling, Drilling, Grinding, boring, planning, and shaping etc... So in this connection being an engineer we have to take a keen and attentive look over cutting material rather than the type of work piece used for machining operation. Cutting tool is an integral part of machine tool where it performs machining function very smoothly and nicely. As a part of our research works that we are tackling with cutting tool materials which are encompassed by various metallurgical elements. And the behaviour of cutting at required temperature depends upon the composition of the known material. Often several investigators were tried to avoid the problems encountered during machining operation. So as far machining knowledge is concerned, though some cutting tool materials are performing good at elevated temperature during machining operation, still some unavoidable things could not be eradicated so far. In the views of mechanical engineering aspects, there are some unavoidable problems commonly encountered. Those problems are commonly being associated with type of material being used, type of machine tool, type of cutting tool material. As we know that to cut any metal, whether it falls under ferrous or non ferrous or other materials a mechanical tool is needed to perform aforementioned matter that tool commonly named as cutting tool with sharp edges. Thus, in traditional machining process without considering cutting tool total work shall be invalid and idle, in this respect here we have take a keen interest over metal removing process by employing known and basic tool, in which material

can ability to take required shape and size. Firstly, to perform cutting operation some suitable factors are to be taken into our account so it makes the metal cutting processes becomes smooth, in this regard the type of work piece composition, type of cutting tool and Machinability conditions are considered to perform cutting operation.

## II. EXPERIMENTAL PROCEDURE

### A. Tool material selection

For being cut of any metal the selection of cutting tool is must. So while selecting cutting tool materials some factors are to be considered. Those are type of workpiece, cutting tool properties, type of cutting tool, type of Machinability conditions and many more. While recounting the selection of a material there are some factors which would tell about characteristics of cutting tool during metal cutting operation. Those principal characteristics are hardness, wear resistance, toughness of a material. Based on these selection of cutting would be done. So in this regard we considered initially all the materials, those are stainless steel of grade 440C, stainless steel with molybdenum of grade SS316, Titanium alloy (Ti-6Al-4V), Invar 3, Ferrite stainless steel. Amongst all materials three materials have been considered into account for their better properties. The following tables which give the nominal chemical compositions and material properties of different grades of stainless steel and titanium alloy. And in this study aluminum and mild steel were considered as workpiece material where cutting action was made over aluminum metal.



Fig. 1 SS440C raw material

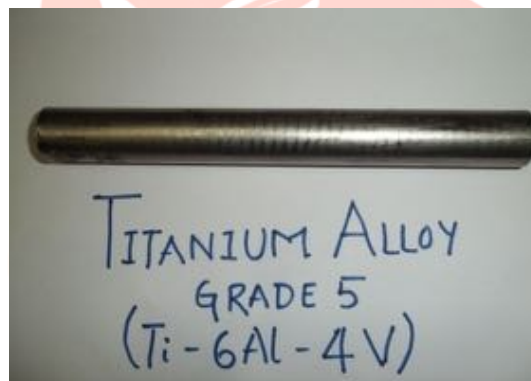


Fig.2 Ti-6Al-4V raw material

Table.1 Nominal chemical composition of SS440C and 316 alloys

Material	C	Mn	Si	Cr	P	Ni	S	Mo
Stainless Steel 440C	1.07	1.00	1.0	18.0	0.04	0.03	0.75	1.07
Stainless Steel 316	0.08	2.00	1.00	18.0	0.045	12.0	0.03	3.0

Likewise, the chemical composition of titanium alloy (Ti-6Al-4V) are mentioned below table 2

Table.2 Nominal chemical composition of Titanium alloy

Material	Al	V	Ti
Titanium	6.0	4.0	Balance

### B. Heat treatment

As we know that heat treatment involves operations of cooling and heating of an object or alloy is called heat treatment. After selecting tool materials which shall be subjected to heat treatment process where enhancement of mechanical properties takes place by means of annealing, hardening operations. The heat treated finished tool of aforementioned materials have been depicted in fig.1.3, 1.4, 1.5. thus as long as aforementioned cutting tool is kept in a muffle furnace it gets heated out above transformation temperature, where changes in properties shall takes place and during cooling back a hardness shall also increases.

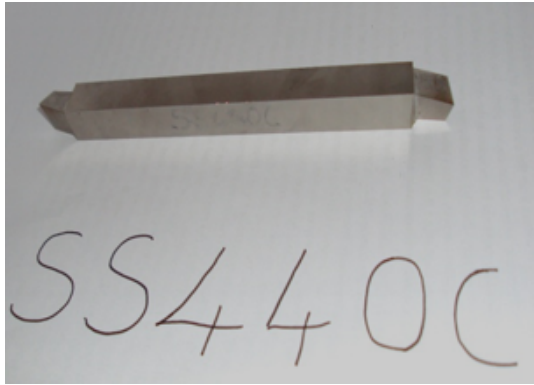


Fig.3 SS440C Heat Treated Finished Tool



Fig.4 SS316 Heat Treated Finished Tool



Fig.5 Ti-6Al-4V Heat Treated Finished Tool

### III. MATERIAL CHARACTERIZATION

#### A. Hardness test



Fig.6 Rockwell Hardness Testing Machine

To check hardness of a finished heat treated material a known hardness device Rockwell hardness machine was employed where hardened steel ball or diamond cone indenter was made to force onto the surface (both before heat treatment and after heat treatment), due its low cost and simplicity Rockwell hardness test shall be used for routine hardness checking components. In this present work Rockwell hardness on tool samples was measured as per ASTM standards ASTM D785. In this test the minor load of 150 kg applied over tested specimen. An indicating device, which follows the movements of the indenter and so responds to changes in depth of penetration of the indenter, is set to a datum position. In order to increase the depth of penetration a major load was applied when it attained equilibrium conditions the major load was removed. Removal of the additional major load allows a partial recovery, so reducing the depth of penetration. The permanent increase in depth of penetration, resulting from the application and removal of the additional major load is used to calculate the Rockwell hardness number. The obtained Rockwell hardness test results have been mentioned in Table 3.

Tool material	Hardness Number(HRC) (before hardening)	Hardness Number(HRC) (after hardening)
SS440C	51	58
Titanium Alloy(grade 5) Ti-6Al-4V	40	51
SS316	38	38

Table.3 Hardness Values of Selected Cutting Tools

#### IV. RESULTS AND DISCUSSIONS

##### A. Hardness

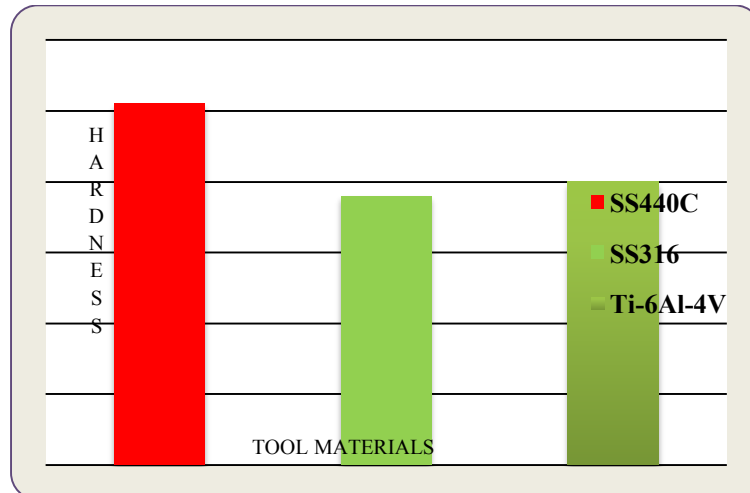


Fig.7 Hardness before Heat Treatment

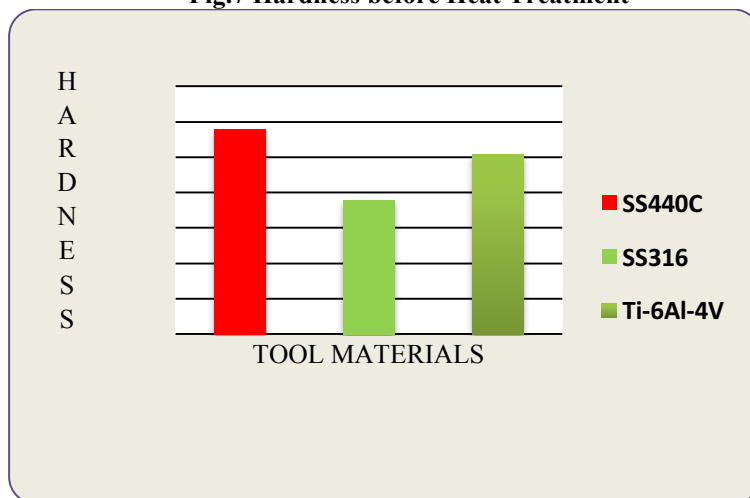


Fig.8 Hardness after Heat Treatment

From Figure 7 and 8 it is easily noticed that before heat treatment the stainless grade of SS440C Has low hardenability compared with when the same cutting was subjected to heat treatment. Same case took place in case of Titanium alloy of Grade (Ti-6Al-4V) has very low hardness compared with heat treated Titanium alloy. But in this case one can notice that the hardness of stainless steel of grade SS316 has same hardness rate before and after heat treatment process. Amongst all cutting tool materials the stainless steel of grade SS440C has high hardness compared to remained cutting tools.

##### B. Tool Wear

As far as machining knowledge is concerned, tool wear depends upon the cutting speed and time which takes to perform cutting operation. Here we analyzed that as long as machining time passes the greater the flank wear rate. So in this respect one can notice that flank wear rate of SS440C and Ti-6Al-4V almost same as compared to stainless steel of grade SS316 of wear rate was  $1.08 \times 10^{-4}$  m/min. Eventually the tool wear rate for heat treated stainless steel of grade SS316 which has lowest wear rate. As cutting speed proceeds cutting gradual wearing of metal shall takes place periodically. In figure 9 for stainless steel grade of SS440C flank wear rate increased by increasing the time rate. At 14 min the maximum wear rate was found. In figure 10 the maximum flank wear rate was found at 17.5 min. In figure 11 the maximum wear rate was found at 27.33 min.



Fig.9 Rate of flank wear on SS440C  
(Max. Wear rate  $1.35 \times 10^{-4}$  m/min)

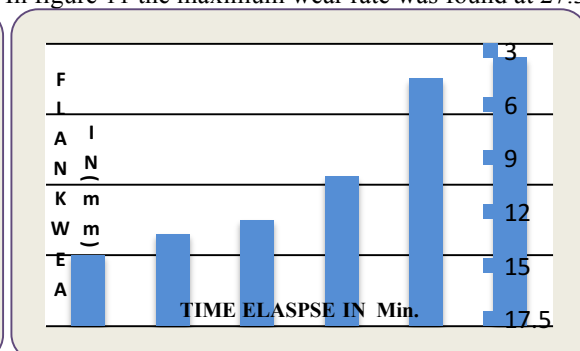


Fig.10 Rate of flank wear on SS316  
(Max. Wear rate  $1.08 \times 10^{-4}$  m/min)

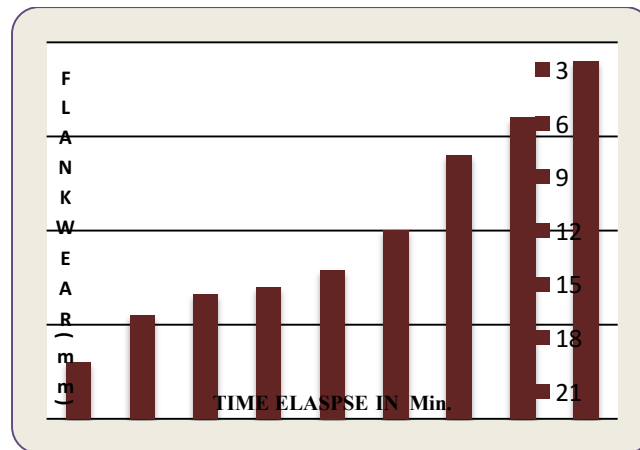


Fig.11 Rate of flank wear on Ti-6Al-4V (Max. Wear rate  $1.35 \times 10^{-4}$  m/min)

## CONCLUSIONS

Based on the experimental observations of present study following conclusions were drawn.

1. Stainless steel of Grade has low flank wear rate as compared to SS440C and Titanium alloy (Ti-6Al-4V).
2. For Aluminum workpiece material, at low cutting speed SS316 has greater shear force than Titanium alloy.
3. At high cutting speed the Titanium alloy was found that it has high shear force than SS316.
4. For aluminum workpiece material, SS316 was found to be cost effective as compared to Titanium alloy(Ti-6Al-4V)
5. Diffusion of material was occurred and deposited on the flank and crater over titanium alpha material deposited more on the rake face especially on the crater. This was due to high heat concentration by chips. These acted like shield & reduce further crater formation.

## FUTURE SCOPE

1. Comparison of study results with FEM analysis.
2. By means of variation of rake angle, the machining parameters shall be influenced.
3. By employing various coating methods it may avoid to flank wear and crater wear problem over cutting tool.
4. Making of heat treatment process further it can able to increase the hardness of the study material.

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