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# Investigation on SS316, SS440C, and Titanium Alloy Grade-5 used as Single Point Cutting Tool

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## ABSTRACT

The main objective of this work is to find alternative materials for the cutting tools used in turning operations. The conventional materials like tungsten carbide(WC), titanium carbide(TiC), cubic boron nitride (CBN) and diamond used as cutting tools for turning operations on lathe are expensive.

Titanium grade 5 (Ti-6Al-4V), SS440C/AISI440C and SS316 are some of the materials which satisfy the necessary requirements for turning metals and polymer materials. These materials are machined as per the standard tool signature of high-speed steel tool (HSS) and are subjected to necessary heat treatment for hardening and then finish ground. The machined tools thus prepared were used to turn mild steel and aluminium workpieces.

The cutting forces at play are determined using lathe tool dynamometer and plotted on a MCD (Merchant's Circle Diagram). The cutting tools are also subjected to tests to determine tool life, wear and work hardening. It is found that the performance and tool life of SS440C is better and cost effective compared to existing tools. Even though Ti-6Al-4V is comparatively costly it could be used for obtaining good surface finish.

***Keywords*** - Cutting forces, surface finish, Titanium grade 5, tool life, wear

## I. INTRODUCTION

The tool used in a lathe is known as a single point cutting tool which has one cutting edge or point. The lathe tool shears the metal rather than cuts and it can only do so if there is relative motion between the tool and the work piece. For efficient cutting, a tool must have good strength, resistance to shock, hot hardness, resistance to wear and low coefficient of friction. Along with this, the tool material must be easily available and economical one, so the materials can be used for a wider range of applications preferably.

Some of the conventional tool materials like tungsten carbide, titanium carbide, cubic boron nitride (CBN) and diamond are expensive. Even for machining softer materials like aluminium, brass and copper expensive tools like TiC & WC are used. The range of cutting tool types is extensive. The selection of correct tool for a particular application depends especially on the tool geometry and the cutting tool material, if the operation is to be done in a cost-effective (i.e. productive) way.

The cutting parameters like cutting speed, feed and depth of cut affect different cutting forces exerted on tool and work piece during any metal cutting action. These forces in turn derive the quality and the dimensional accuracies of the metal surface. Hence it is very important to accurately measure the cutting forces and control them to obtain required degree of surface or dimensional accuracy on the surface, Electronic Dynamometers are used to measure these forces.

Gradual wearing of certain regions of the face and flank of the cutting tool can terminate the life of a cutting tool. Tool wear is a time dependent process. As cutting proceeds, the amount of tool wear increases gradually. The most important wear type from the process point of view is the flank wear; therefore, the parameter which has to be controlled is the width of flank wear land. This parameter must not exceed an initially set safe limit. The safe limit is referred to as allowable wear land (wear criterion). The cutting time required for the cutting tool to develop a flank wear land of a specified width is called tool life (T), a fundamental parameter in machining.

When the tool wear reaches an initially accepted level, there are two options - one is to resharpen the tool on a tool grinder and the other is to replace the tool with a new one. This second possibility applies only when the resource for tool resharpening is totally exhausted and/or the tool does not allow for any further resharpening. Gradual wearing of certain regions of the face and flank of the cutting tool can terminate the life of a cutting tool, therefore the life of a cutting tool is determined by the amount of wear that has occurred on the tool profile and which reduces the efficiency of cutting to an unacceptable level, or eventually causes tool failure.

Gradual wear occurs at three principal locations on a cutting tool Crater Wear, Flank Wear and Corner Wear. The tool wear can be measured by various methods

(A) By loss of tool material in volume or weight, in one lifetime –This method is crude and is generally applicable for critical tools like grinding wheels.
(B) By grooving and indentation method – In this approximate method, wear depth is measured indirectly by the difference in length of the groove or the indentation outside and inside the wear area.
(C) Using optical microscope fitted with micrometer - A very common and effective method (Magnification 8X).
(D) Using scanning electron microscope (SEM) – This method is used generally for detailed study - both qualitative and quantitative
(E) Talysurf – Used especially for shallow crater wear.

The work pieces were machined on the lathe using the services of an experienced lathe operator to ensure uniformity of cutting speed, feed, depth of cut as well as skill. The work pieces were machined on the lathe using the services of an experienced lathe operator to ensure uniformity of cutting speed, feed, depth of cut as well as skill.

## II. MATERIAL SELECTION

The properties of various materials are collected and studied in detail with reference to the requirements of existing cutting tool materials. Below are few candidate materials that can substitute today's expensive tool material. Tool materials selected based on hardness, toughness and wear properties.

- SS440C
- SS316
- Titanium alloy (G5)

The single point cutting tools are prepared according to the standard by using HSS tool as reference. Fig.1 shows the final cutting tools obtained. The workpiece materials used are as follows;

- Mild Steel (for HSS and SS440C)
- Aluminium (for SS316 and Titanium alloy)


Figure1: Test Specimens

After the preparations of the cutting tool, heat treatment processes were carried out for improving the hardness of the material.

## III. EXPERIMENTATION

Once the cutting tool is fabricated the next step is to subject these tools to various standard tests to determine the tool performance for the intended application.

### 3.1 DETERMINATION OF CUTTING FORCES


Figure 2. Electronic Dynamometer a) Digital panel b) Tool post

The lathe tool dynamometer shown in Fig.2 b) can be directly fixed on to the tool post using the hole provided on dynamometer. The tool post has been provided with output socket for two forces in mutually perpendicular directions. i.e., Horizontal/ Vertical. The strain gauges are employed in such a way that the independent bridge senses the mutually perpendicular / angular forces and the digital panel shows the corresponding readings.

Using the readings obtained from the experiment, various other forces that are acting on the tool and workpiece material during the machining operation are determined using Merchant Circle Diagram.

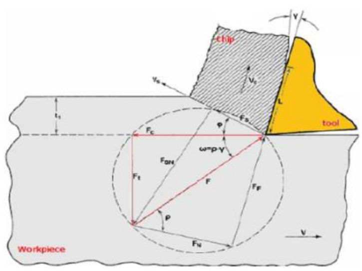


Figure 3: Merchant's Circle Diagram

Advantageous use of Merchant's circle diagram

1. Easy ,quick and reasonably accurate determination of several other forces from a few known forces involved in machining
2. Friction at chip-tool interface and dynamic yield shear strength can be easily determined
3. Equations relating the different forces are easily developed.

### 3.2 HARDNESS TEST

The Rockwell hardness test was performed on the tool samples as per ASTM standards (ASTM D785).

Figure 4: Rockwell hardness tester

### 3.3 TOOL WEAR

Figure 5: Optical microscope

In this work the tool flank wear is determined by operating the tool samples at constant speed, feed and depth of cut and the flank wear is measured at different time intervals and after this operation the wear on the flank of the tool samples is measured using optical microscope fitted with micrometer (refer Fig. 5). It is a very common and effective method (Magnification 8X).

### 3.4 TOOL LIFE

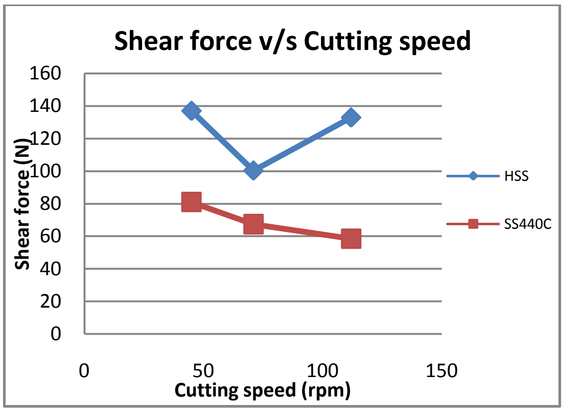
For R & D purposes, tool life is always expressed by span of machining time in minutes whereas, in industries besides machining time in minutes some other means are also used to assess tool life, depending upon the situation, such as

- No. of pieces of work machined
- Total volume of material removed
- Total length of cut.

From the above options the total length of cut method has been used to find out the tool life. This method is similar to tool wear method but here we are considering how much material is removed per minute.

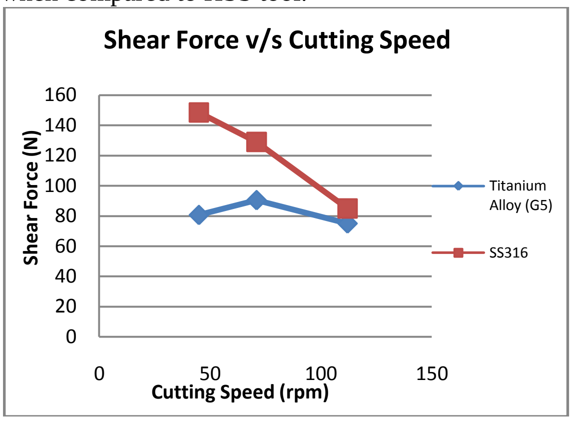
## IV. RESULTS AND DISCUSSION

### 4.1 CUTTING FORCES




Graph 1: Shear force v/s Cutting speed

From Graph 1 it can be observed that the shear force for machining of mild steel is lower in SS440C when compared to HSS tool.




Graph 2: Shear force v/s Cutting speed

From Graph 2 it can be observed that the shear force for machining of Aluminium workpiece is lower in SS316 when compared to titanium alloy.

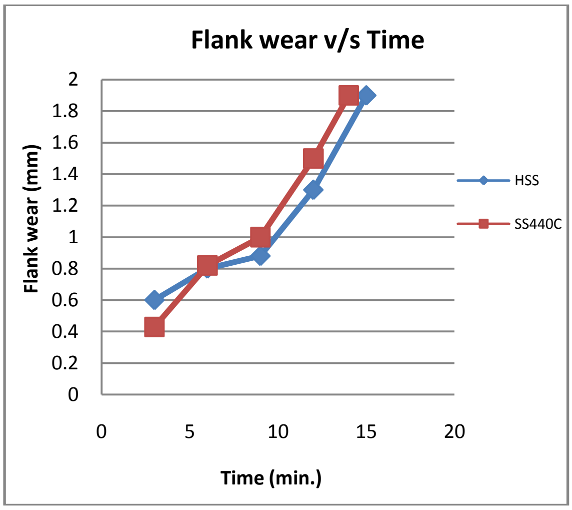
### 4.2 HARDNESS

Table 1: Hardness Number

| Tool material | Rockwell C scale Hardness Number (before hardening) | Rockwell C scale Hardness Number (after hardening) |
|---|---|---|
| High Speed Steel | 60(heat treated) | 60 |
| SS440C | 51 | 58 |
| Titanium Alloy(G5) Ti-6Al-4V | 40 | 51 |
| SS316 | 38 | 38 |

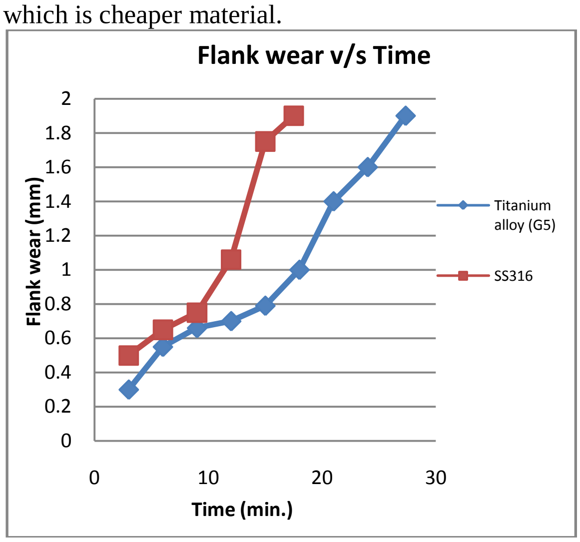
From the above hardness table observations we can conclude that, the SS440C material will have hardness very nearer to HSS material.

### 4.3 TOOL WEAR




Graph 3: Flank wear v/s Time

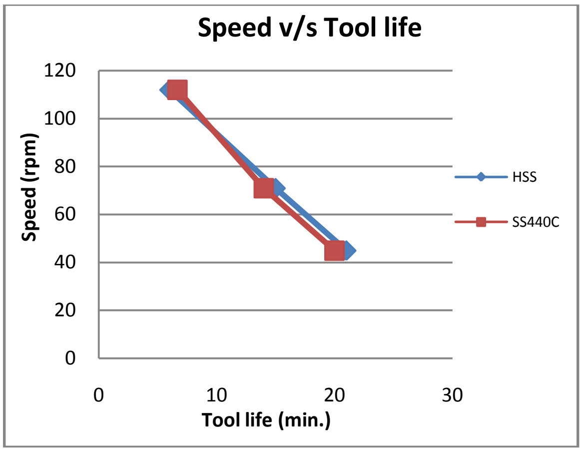
Graph 3 it shows that the flank wear of the SS440C material is parallel to flank wear of the HSS material With respect to time so that instead of using HSS which is costly material we can use SS440C which is cheaper material.




Graph 4: Flank wear v/s Time

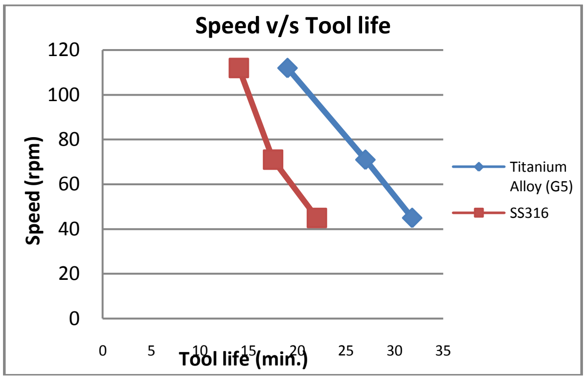
From Graph 4 we can observe that the flank wear of titanium alloy is relatively lower than the SS316 material.

### 4.4 TOOL LIFE




Graph 5: Speed v/s tool life

From the Graph 5, we conclude that the SS440C material has a tool life very nearer to HSS material.




Graph 6: Speed v/s tool life

From the Graph 6, we conclude that the Titanium Alloy has a better tool life compared to SS316.

## V. CONCLUSION

For mild steel workpiece material At low cutting speed the Shear force of the SS440C material is high as compared to the HSS tool.

At all cutting speeds tool life of HSS and SS440C were found to be relatively close.

- SS4
- 40C materials were found to be cost effective, compared HSS material.

o SS440C tool can be replaced with HSS tool for mild steel workpiece.

- For aluminium workpiece material

o SS316 were found to be cost effective as compared to Titanium alloy (Ti-6Al-4V)

o At lower cutting speed SS316 has a greater Shear force than the Titanium alloy (Ti-6Al-4V), but at higher cutting speeds Titanium alloy (Ti-6Al-4V) were found to have higher Shear force than SS316.

- o At all speeds Titanium alloy (Ti-6Al-4V) were found to be having longer tool life than SS316.
- o SS316 will produce low surface finish rather than the titanium alloy material.

- The performance of the tools can be furthur improved by employinf different heat treatment process, coating methods and changing the rake angles of the tool.

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