

# The material performance of HSS (high speed steel) tools and its relation with chemical composition and carbide distribution

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**Abstract.** The study aims to compare the performance of two types of material HSS (High Speed Steel) are widely used. It also will be the chemical composition and distribution of carbide particles therein. Two types of HSS are available in the market: HSS from Germany (Bohler) and HSS from China. This research employed the pure experimental design. It consists of two stages. The first, aims to test/operate lathe machines to determine the lifetime and performance of tools based on specified wear criteria. The second, characterization of microstructure using SEM-EDS was conducted. Firstly, grinding of toolss was done so that the toolss could be used for cutting metal in the turning process. Grinding processes of the two types of toolss were done at the same geometry, that is side rake angle ( $12^{\circ}$ - $18^{\circ}$ ), angle of keenness ( $60^{\circ}$ - $68^{\circ}$ ), and side relief angle ( $10^{\circ}$ - $12^{\circ}$ ). Likewise, machining parameters were set in the same machining conditions. Based on the results of the tests, it is found that to reach 0.2 mm wear point, toolss made of HSS from Germany needed 24 minutes, while toolss made of HSS from China needed 8 minutes. Next, microstructure tests using SEM/EDS were done. The results of the SEM tests indicate that the carbide particles of HSS from Germany were more evenly distributed than the carbide particles of HSS from China. Carbide compounds identified in HSS from China were  $\text{Cr}_{23}\text{C}_6$  and  $\text{Fe}_4\text{Mo}_2\text{C}$ . Oxide impurity of  $\text{Al}_2\text{O}_3$  was also found in the material. On the other hand, in HSS from Germany, no impurity and other carbide compounds were identified, except  $\text{Cr}_{23}\text{C}_6$  and  $\text{Fe}_4\text{Mo}_2\text{C}$ , also  $\text{Fe}_4\text{W}_2\text{C}$ , and VC or  $\text{V}_4\text{C}_3$ .

## 1. Introduction

In the process of forming and machining, cutting tools are used to change the shape of materials into particular desired shapes or certain products. The materials of the tools should ensure the continuity of the process of cutting/forming with optimum results. The materials used should have properties that are better or superior to the materials of workpieces to be formed into specific products [1]. The advantages of the tools can be achieved because the tools/toolss are made from materials which have certain characteristics, such as:

- Hardness: harder than the materials of workpieces, not only at room temperature but also at high temperature during machining process;
- Ductility: large enough to withstand shock loads occurring during the process of machining with termination/interruption or when cutting workpieces which have hard spots;
- Thermal shock load: required when significant temperature changes occur regularly;



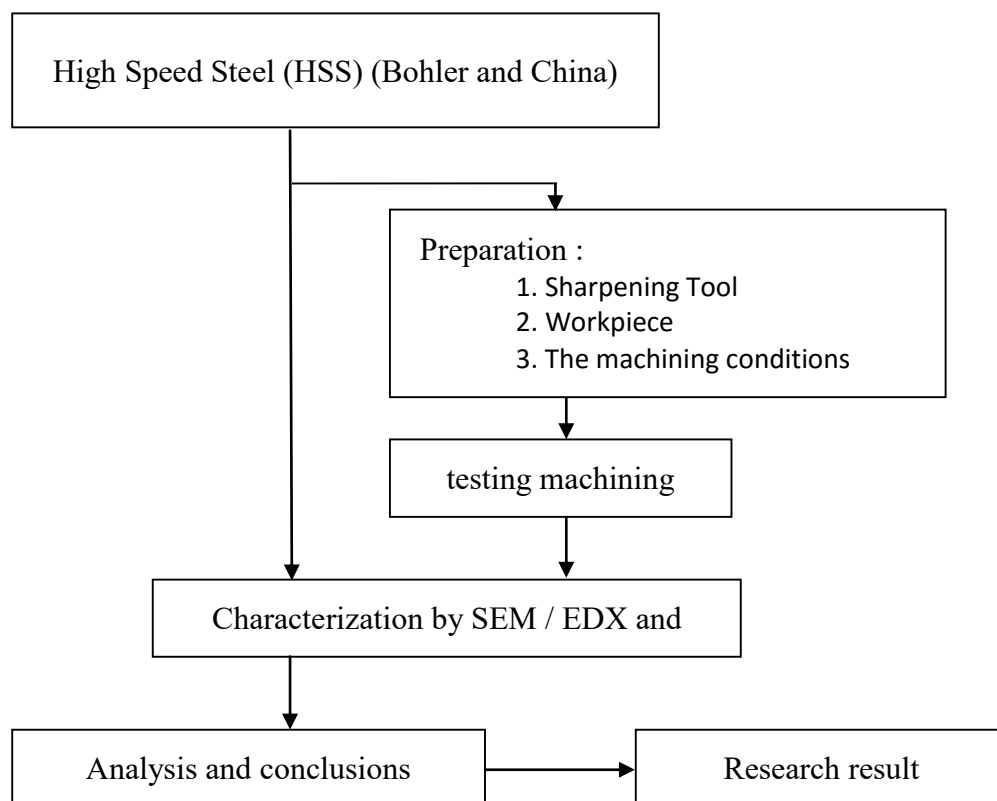
- Low adhesive properties: to reduce the affinity of workpieces against the tools/toolss, reducing the wear rate;
- Low solubility of elements or materials of the tools/toolss: required to minimize the wear rate due to diffusion mechanism.

The material which is widely used because it has the characteristics described above is High Speed Steel (HSS) [2]. This material can easily be found in the market. It is affordable and can easily be sharpened when it undergoes the process of wear and tear. There are many manufacturers producing this type of cutting tool material. They offer various prices. The various prices reflect the quality of the material. There are different characteristics in terms of material performance if the material is used in machining processes. The performance of the material can be seen from the life of toolss/tools. It is interesting to explore the different characteristics of the material, which reflect different performances, by looking at the metallurgical features of the material through a micro approach/perspective by using SEM/EDS. The purposes of this study are:

- to get a description of the performance of various types of HSS material through machine testing with specified critical wear criteria;
- to get a description of chemical composition and the distribution of carbide as well as its size through the use of SEM/EDS.

## 2. Research Methods

The method used as shown in the following diagram:



**Figure 1.** Method

### 3. Results and Discussions

#### 3.1. Machine Testing

Machining processes to identify the life of cutting tools were done by way of stoppage; for a certain length of cut, the size of edge wear (VB) was measured to determine whether the tools reach the specified critical wear. The results of the machining processes can be seen in the following table:

**Table 3.** The wear of tools – HSS ½” Bohler Germany

No	Length (mm)	Duration (min)	Wear (mm)
1	400	4	0,05
2	400	4	0,05 - 0,1
3	400	4	0,1
4	400	4	0,1 - 0,15
5	400	4	0,15
6	400	4	0,15 - 0,2
<b>Total</b>	<b>2400</b>	<b>24</b>	<b>0,2</b>

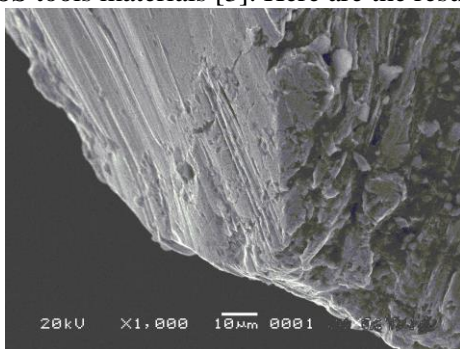
**Table 4.** The wear of tools – HSS ½” China.

No	Length (mm)	Duration (min)	Wear (mm)
1	400	4	0,1
2	400	4	0,2
<b>Total</b>	<b>800</b>	<b>8</b>	<b>0,2</b>

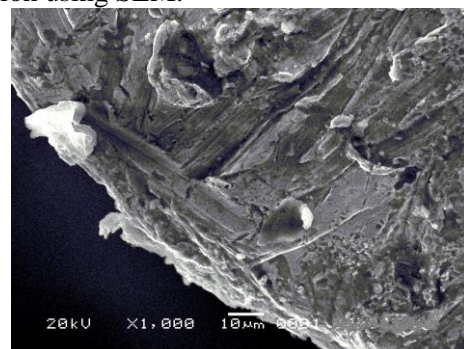
From the comparison of tool life with critical wear  $VB = 0.2$  mm, it is found that the life of the German HSS tools is longer ( $t_c = 24$  minutes), compared to that of the China HSS tools ( $t_c = 8$  minutes). The causes of this difference can be identified by looking at the metallurgical characteristics of materials of the toolss using SEM/EDS.

#### 3.2. Examination using SEM/EDS

Examination using SEM/EDS was aimed to determine the microstructure and chemical composition of the materials, as well as to identify the distribution of carbide particles which commonly emerge from HSS tools materials [3]. Here are the results of the examination using SEM.



**(a) China HSS**

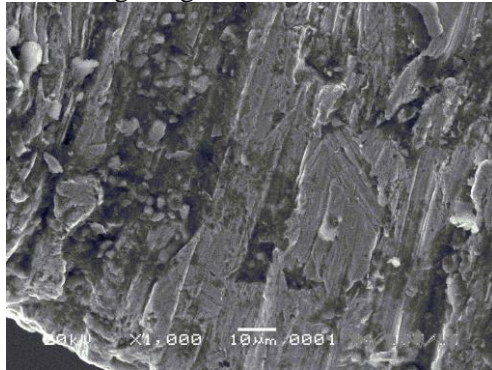


**(b) German HSS**

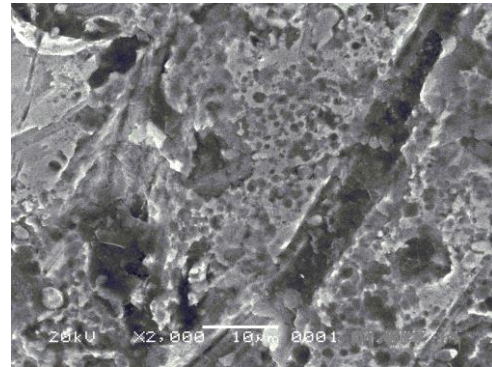
**Figure 2.** Microstructures of the wear areas of HSS tools materials

Based on the two images, it can be explained qualitatively that the spread of carbide grains in German HSS is more even than that of China HSS. Furthermore, the grains of German HSS are finer. This difference affects the life of the tools. Carbide is a very hard compound. If it is spread evenly, the hardness will also be evenly distributed, so that the tool life could be longer.

Meanwhile, in accordance with the theory of HallPetch, the small size of carbide grains will increase the strength of the material. This explains why German HSS toolss have longer service life. The following images indicate the microstructure of China HSS and German HSS.



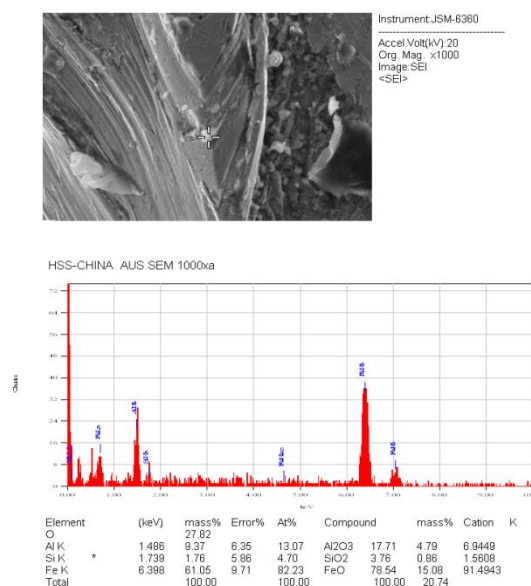
**Figure 3.** The microstructure of China HSS



**Figure 4.** The microstructure of German HSS

### 3.3. Chemical composition analysis using EDS

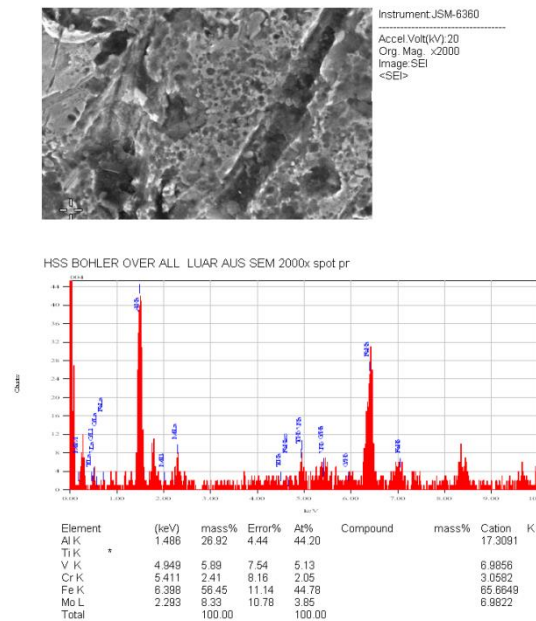
The purpose of this analysis was to determine the chemical compositions of the two types of HSS. The technique used was Energy Dispersive Spectroscopy (EDS). The chemical composition analysis was applied to the same areas, which were around the wear of the toolss and distant form the wear. The morphological image and chemical compositions of the two toolss are presented in the following figure.



**Figure 5.** Chemical composition analysis of China HSS outside wear area

Based on the above figure and with reference to the literature on the formation pattern of compounds as a result of an element, it can be estimated that there is an element of Aluminium (Al) around the wear area of the China HSS tools. The Al allowed the oxidation of Al<sub>2</sub>O<sub>3</sub>, which is a detrimental impurity (able to decrease the material strength).

It is predicted that the Al element was from the walls of the melting furnaces (refractory) during the making of HSS. While Chromium (Cr) and Molybdenum (Mo) can form carbide compound which can increase the material strength. The pattern of carbide compound from Cr is  $M_{23}C_6$ , in accordance with the references, it can be predicted that carbide compound from Cr is  $Cr_{23}C_6$ . While the pattern of carbide compound from Mo is  $Fe_4Mo_2C$ .



**Figure 6.** Chemical composition analysis of German HSS outside wear area

Different from the results of the chemical composition analysis of China HSS, German HSS contains other elements such as Vanadium (V) and Cobalt (Co), besides Chromium (Cr) and Molybdenum (Mo). Such elements will form carbides in accordance with the patterns of carbide compound: VC or  $V_4C_3$ . The addition of Cobalt (Co) to the HSS will increase the hardness of the material at high temperature and tenacity. The grains become finer; thus, the sharp end can be maintained during the heat treatment process at high temperatures.

#### 4. Conclusions

Based on the results of the performance testing of the toolss, it can be concluded that:

- German HSS toolss have longer lifetime compared to China HSS toolss under the same machining parameters and critical wear criteria;
- The difference of lifetime, which reflect their endurance, is due to the different chemical compositions of the materials. Both German HSS toolss and China HSS toolss contain carbide compound; however, they have different compositions.

#### References

- [1] Rochim T, 1993, Teori & Teknologi Proses Pemesinan, Proyek HEDS
- [2] De Garmo E Paul, 1984, Material and processes in Manufacturing, MacMillan Publishing Company.
- [3] Goldstein JI and Yakowiz H, P, 1977, Practical Scanning Electron Microscopy, Plenum Press, New York.