Machinability With Different Cutting Parameters of Sintered Steels

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Abstract

Powder metallurgy (PM) is known for producing of complex parts with near-net shape. However, many PM components require surface finish machining to reach final tolerance or shapes not possible to achieve in the compaction step. This study deals with the quantitative evaluation of the machinability of sintered steels during turning operation. Sintered parts were prepared with (MnS and MnX) and without additives for machinability evaluations. All parts were machined in a CNC lathe using a face turning operation which performed using two different cutting inserts. These were uncoated WC-Co cermet and solid carbide. The cutting speeds and feed rates used were with different values while the depth of cut was kept constant. The results showed that the effect on the machinability of MnS addition remarkably positive and enables extended tool life for all inserts. The performance of MnX was found less effective. The tool life of uncoated WC-Co insert is better than the solid carbide at identical cutting condition. Also, the feed rate has a significant effect on the machined surface.

1. Introduction

As a metal-working technology, powder metallurgy (PM) has the advantage compared to other processes, that it can produce complex parts of high quality with close tolerances, in an economical way [1]. However, many parts require machining afterwards because of intricate design. Thus, there is a renewed interest in machinability characteristics of PM parts. Turning and drilling are the most widely used cutting methods in machining of PM parts [2]. The machinability of a PM component is dependent on the workpiece and tool material properties, cutting conditions, and machine and cutting tool parameters [3]. Chemical composition, porosity, free machining additives, and production process parameters such as compaction and sintering methods, also collectively influence machinability [1]. Guidelines for insert choice and effect from additives are needed to improve the performance in the machining operation [4]. PM parts are often considered to be difficult to machine, especially compared to conventional standard steels. However, by choosing a proper combination of tool material and insert geometry together with optimized cutting data, and additives if necessary, it is in many cases possible to achieve a productivity level of machining PM parts equal to that of machining standard steels [5-6]. The details of the machining properties should be further examined in order to use PM steel parts in a large scale. However, there are not enough studies on the machinability of PM parts in the literature. It is clear that wear data and tool life relationships in wrought can not be expected to be valid for PM material because of the porous structure mostly of the different composition [7]. It was therefore necessary to study the effect of many machining parameters on the machinability of PM parts.

Machining of Cu-Ni-Mo pre-alloyed Distaloy AB steels has been studied by a few researchers, and they emphasized the importance of these steels in the PM industry [2, 8]. In order to widen the use of these steels a better understanding of the different factors influencing the machinability of these steels are required. This study describes the machinability of Cu-Ni-Mo based Distaloy AB workpieces. The influence of tool grades, additives and cutting dates, when machining this type of PM parts, has been discussed in this study.

2. Experimental Procedure

In this study, water atomized low alloyed steel powder commercially known as Distaloy AB obtained from Höganäs Company were used for workpiece material production. The chemical composition of the steel powder was Fe-1.5 Cu-1.75 Ni-0.5 Mo. The powder premix consisted of 0.8% Zn-stearate as lubricant and 0.5% carbon added as fine graphite. The machibability of parts was evaluated with and without additives, where MnS and MnX were added in the premixes. The powder mixes use in this study is shown in Table 1.

Table 1. Powder mixes.

PM workpiece	Powder composition
Workpiece 1	Distaloy AB + 0.5 C + 0.8 Zn-stearate
Workpiece 2	Distaloy AB + 0.5 C + 0.8 Zn-stearate + 0.5 MnS
Workpiece 3	Distaloy AB + 0.5 C + 0.8 Zn-stearate + 0.4 MnX

The workpiece for the turning tests were produced by convection with cylindrical geometry: inner diameter 30 mm, outer diameter 60 mm and height of about 60 mm, reaching a green density of 7.0 g/cm^3. All the specimens were sintered at 1120 ºC for 30 minutes in an industrial continuous pusher furnace under 25% N_2-75% H_2 atmosphere, and cooled with a cooling rate of 0.5 °C/sec for convectional sintering. Turning tests were carried out by conventional CNC lathe using a face turning operation in a dry condition without any coolant. The turning operation was performed using two different types of inserts. These were grades CT5015 (uncoated WC-Co cermet) and GC3215 (solid carbide, coated with TiCN, Al_2O_3 ad TiN) according to Sandvic Coromant guide lines [9]. The inserts, from Sandvik Inc., were clamped on the same tool holder used for the tool life tests. The cutting speeds (V_c) and feed rates (f) used were with different values while the depth of cut (a_p) was kept constant in order to relevant setting and to meet tool life. The cutting conditions used in the experiments are listed in Table 2, and each treatment is replicated three times.

Table 2. The cutting conditions.

Inserts	V_c (m/mim)	f (mim/rev)	a_p (mm)
CT5015	150 - 300	0.1 - 0.3	0.5
GC3215	150 - 300	0.1 - 0.3	0.5

The hardness of the workpiece was measured, and optical microscopy studies were carried out. Three different locations were selected on the as-sintered and as-machined surface of the specimens and the average of those values was used as the hardness measure of samples. The surface roughness value on each of the workpieces was measured with a Mitutoyo SJ-210 surface roughness tester. The measurements were taken on the same day of the experiment in order to prevent oxide films from depositing on the machined surface.

3. Results and Discussion

The machinability of a PM component is dependent on the microstructural characteristic of the workpieces [1]. The microstructures of sintered specimens with and without additives were examined. All the specimens consist of ferrite, pearlite, bainite, austenite and less bainite phases. Since the cooling step of sintering cycle was slowly done in a controlled way, less bainite and martensite phases were formed in the microstructure. There is no effect on the microstructure when the MnS and MnX additives are added.

The as-sintered and as-machined surface hardness values of the workpieces with or without additives are given in Table 3, and significant work hardening of the as-machined surface compared to the as-sintered was determined. The cutting speed and feed rate of grades CT5015 were 300 m/min and 0.15 min/rev, respectively. The microhardness is less influenced with additives. The as-machined surface hardness values are bigger compared with the as-sintered for all workpieces. According to Šalak et al., [2] the cutting process caused significant work hardening of the machined surface linked to the deformation of the subsurface area. It means that for the hardness of as-machined surfaces the effect of porosity was significantly lower compared to as-sintered.

Table 3. The microhardness of the specimens.

PM workpiece	**Microhardness (HV10)**	
	As-sintered surface	As-machined surface
Workpiece 1	215	332
Workpiece 2	211	328
Workpiece 3	209	324

The tool life of inserts when turning workpieces with or without additives is shown in Figure 1. The cutting speed and feed rate of grades CT5015 were 150 m/min and 0.15 min/rev, respectively. Machinability is strongly improved with MnS additive, but less influenced with MnX additive, shown by dramatically increased tool life of the grade CT5015. In many studies were reported to improve the machinability of PM parts with additives such as MnS and MnX [10]. The additives influence can be observed in terms of a minor reduction in hardness of the parts. Engström [11] explained that MnS improved the machinability of sintered parts 5-10 times without influencing dimensional change and mechanical properties. One of the reasons for improved machinability was attributed to the lubricating effect of the additives, which formed a uniform coating on the tool surface. This coating reduced the friction between the material and the tool, thereby decreasing the interface temperature and wear [12]. Tool life is the same for the workpieces with MnX and without when the GC3215 grade is used. The overall best performance was obtained by the grade CT5015 for all workpieces. CT5015 uncoated cermet carbide grade provides hardness for high wear resistance. It also prevents a built-up edge, resulting in a higher quality surface finish and longer too life than provided by other grades. Also, WC-Co cermet grade results in a less friction between and chip, improved chemical inertness and less sensitivity to the cutting speed [9].

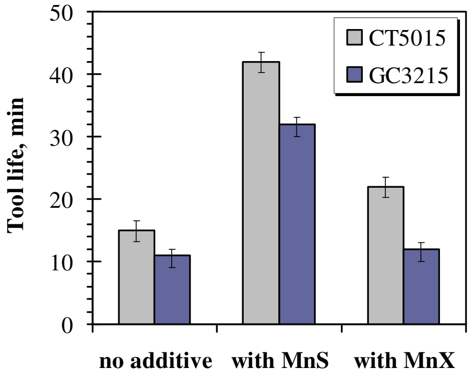

Figure 1. The tool life of inserts for all workpieces.

In an attempt to increase tool life, the cutting speed was reduced from 150 m/min to 300 m/min for grades CT5015 and GC3215. The tool life of insert grades at different cutting speed of groups with MnX additive is shown in

Figure 2. The feed rate of grades was 0.15 min/rev. The tool life of grade CT5015 was increased by 35% and of grade GC3215 by 14% with decreasing the cutting speed. Tool life of cemented carbides can be increased by reducing cutting speed [5]. The cause of this is lower the cutting heat at low cutting speed, and decrease tool wear. All obtained tool wear was formed by normal abrasion.

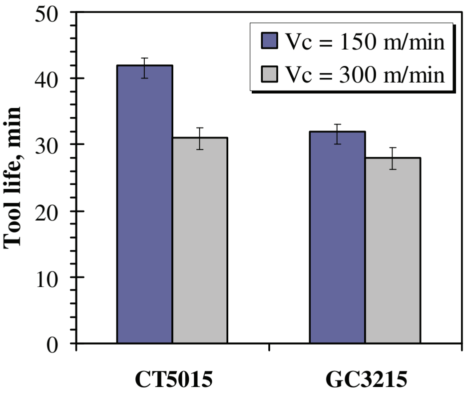

Figure 2. The tool life of inserts at different cutting speeds.

Figure 3 shows the surface roughness at different feed rates of groups without additive. The cutting speed of grades was 300 m/min. The results indicated that the investigated insert type used in this study has no a significant effect on the machined surface. Surface roughness increases with increased feed rate for both cutting inserts. The machined surface in higher feed rate was smoother than lower feed rate, which is thought to be a consequence of less smearing during machining.

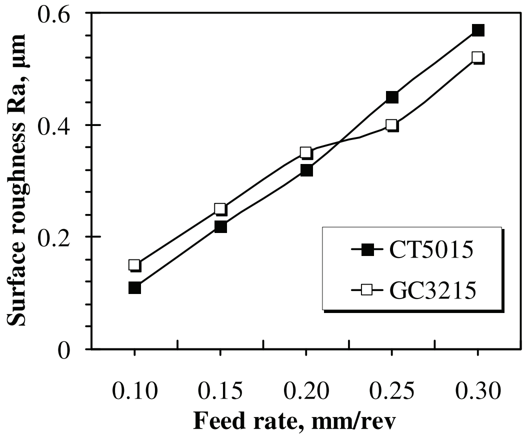

Figure 3. Surface roughness at different feed rates.

Cutting interval is large for PM material [1]. This study clearly shows that machinability is strongly dependent on tool material, cutting condition and machining additives.

4. Conclusion

Turning tests were performed to find how machinability of Cu-Ni-Mo based PM workpieces was influenced by choice of cutting conditions, insert type and additives. The following conclusions can be drawn:

- There are no significant differences in hardness and dimensional changes between the workpieces with and without additives.
- The increase in hardness of as-machined surface in all the specimens was achieved with work hardening caused by the cutting process.
- Effect on the machinability of MnS addition remarkably positive and enables extended tool life for all inserts. The performance of MnX was found less effective when the GC3250 grade is used.
- Tool life with grade CT5015 is bigger compared with grade GC3215 for all workpieces. In order to better understand the status of tool wear should be examined.
- The best machining performance is achieved when the cutting speed is reduced.
- The feed rate has a significant effect on the machined surface, but the surface quality can be obtained independent from the investigated insert.

Acknowledgment

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