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Enhanced Machinability of Sinter-hardenable PM Steels

Bruce Lindsley[a], Chris Schade[b] and George Fillari[c]

Hoeganaes Corporation, 1001 Taylors Lane
Cinnaminson, NJ 08077, USA
[a]Bruce.Lindsley@hoeganaes.com, [b]Chris.Schade@hoeganaes.com, [c]George.Fillari@hoeganaes.com

Abstract

Machining of sinter-hardened PM steels provides a challenge for part makers. To facilitate machining of these materials, a new additive (MA) has been developed to increase tool life during the machining process. Hard turning tests were performed to evaluate the effect of this new additive. Sintered compacts with the MA additive were compared to compacts without a machining aid and to compacts that contained the MnS additive. This paper discusses the improvement in machinability with this new additive in sinter-hardenable PM steels.

Keywords : machinability, sinterharden, machining additives

1. Introduction

Ferrous PM is generally considered a net or near net shape process. Nevertheless, many pressed and sintered parts are machined prior to final assembly. The machinability of PM steels is generally considered more difficult than that of wrought steel due to the presence of porosity and an often heterogeneous microstructure. PM, however, has the advantage of being able to admix materials into ferrous alloys, and both powder producers and part makers have taken advantage of this ability by incorporating machinability additives, such as MnS, into the steel. With the advent of sinter-hardening alloys, the machinability of these materials in the as-sintered condition is considerably more challenging. The hard, martensitic microstructure is more difficult to machine, and requires advanced tooling that can withstand higher forces and increased wear tendencies. In addition, traditional machining additives may not work effectively under these conditions. A new machining additive (MA) has been developed to enhance the machinability of sinter-hardened PM steels. The benefit of this additive will be discussed in both sinter-hardening alloys and in an iron-copper-carbon steel.

2. Experimental and Results

The three alloys studied were FC-0208 (Ancorsteel® A1000B + 2% Cu + graphite), FLC2-4808 (Ancorsteel 737 + 2% Cu + graphite) and FLN4C-4005 (Ancorloy® 4 + graphite). The compositions are listed below in Table I. The chemical composition of Alloy 3 is equivalent to FD-0405. To each of these alloys, three conditions were tested: no additive, 0.35% MnS, and 0.3% MA.

Table 1. Nominal compositions (in wt.%)

Alloy	Designation	Ni	Mo	Mn	Cu	C
1	FC-0208	-	-	0.1	2	0.8
2	FLC2-4808	1.4	1.25	0.4	2	0.8
3	FLN4C-4005	4	0.5	0.1	1.5	0.5

The mixes were compacted into rings measuring 25.4 mm ID, 44.5 mm OD and 28 mm high at a density of 7.0 g/cm^3. The rings were then sintered in a 90% nitrogen –10% hydrogen atmosphere at 1120 °C for 15 minutes at temperature. A typical furnace cooling rate of 0.6 °C/sec was used; no accelerated cooling was employed. Alloys 2 and 3 were tempered at 205 °C for 1 hour after sintering.

The machinability testing was conducted with a depth of cut of 1.25 mm (0.05 in.) per pass at various cutting speeds. A coated carbide tool with a chip breaker design was used for the FC-0208 composition. The same coated carbide without the chip breaker along with a boron nitride tool was used for Alloys 2 and 3 at a constant cutting speed of 2.5 m/s (500 sfm). The tool wear data has been assigned a value of zero after the first 5 cuts to eliminate the effects of the break in period. Thereafter, tool wear was measured after every fifth cut on the flank of the tool.

The main advantage of MA additive is found in sinter-hardening materials. The microstructures for sinter-hardenable Alloys 2 and 3 are shown in Figure 1. The cooling rate of 0.6 °C/sec produced a nearly fully martensitic microstructure with some bainite in Alloy 2 and a mixed microstructure consisting of pearlite, bainite,

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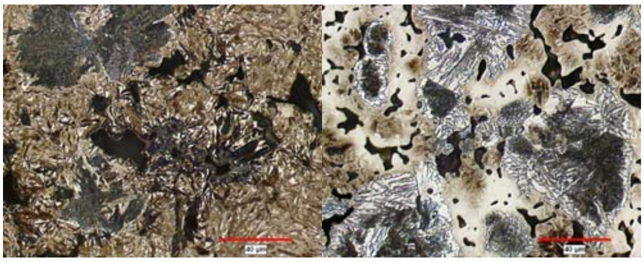

(a) (b)

Fig. 1. Microstructures of the sinter-hardenable alloys at 0.6 °C/sec (a) Alloy 2 (FLC2-4808) and (b) Alloy 3 (FLN4C-4005).

martensite and nickel-rich austenite regions in Alloy 3. When the martensitic Alloy 2 was cut with the coated carbide tool (Figure 2), both MnS and MA reduced tool wear; the MA additive was, however, much more effective. Surface finish also improved with the MA additive. Interestingly, under these cutting conditions, when Alloy 2 was cut with the boron nitride tool, there was little effect of the machining additives. When Alloy 3 was cut with the carbide tool, MnS increased tool wear, whereas MA showed improvement. MA showed the greatest improvement over MnS when Alloy 3 was cut with the boron nitride tool. Overall, the MA additive provided consistently low wear for all conditions.

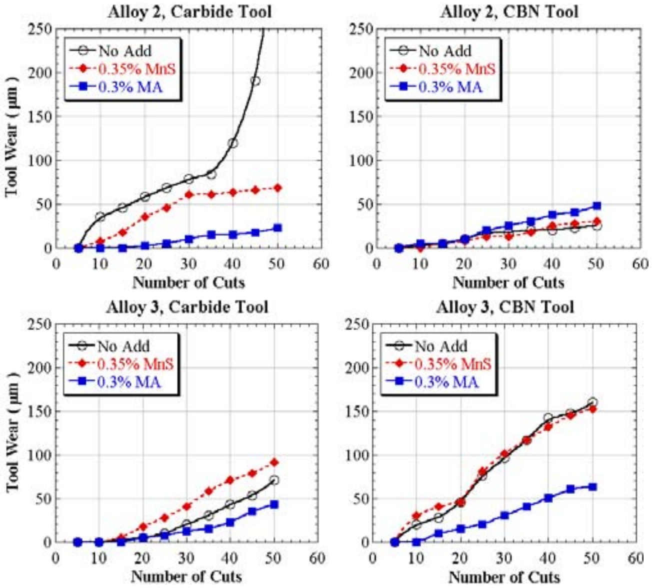

Fig. 2. Tool flank wear with different additive conditions. Alloys 2 (FLC2-4808) and 3 (FLN4C-4005) machined with coated carbide and boron nitride (CBN) tools.

The effect of MA additive on machinability in a non-sinterhardening system (FC-0208) was also investigated, Figure 3. At slower speeds, the MA additive resulted in significantly less wear than the MnS additive. The tool catastrophically failed after 10 cuts in the no additive condition. However, at higher speeds, the MnS resulted in virtually no wear and is superior to both the MA and no additive. Customer trials on alloy FC-0208 with these three additive conditions showed that MA was effective with much higher speeds. A smaller depth of cut was used and MA was more effective than MnS at cutting speeds up to 3 m/s (600 sfm). Under select conditions, MA additive can greatly reduce tool wear in this alloy system.

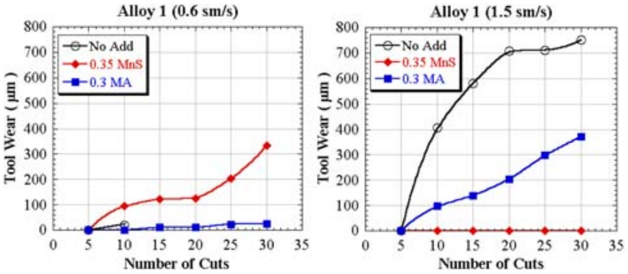

Fig. 3. Tool wear during machining of Alloy 1 (FC-0208) at two surface speeds and the three additive conditions.

The mechanical properties of sinter-hardenable alloys with the three additive conditions were tested to determine if the additives had any effects on behavior. Standard mechanical test specimens were prepared similarly to the machining samples. A small decline in density (<0.05 g/cm^3) occurred with the addition of the machining additives and less dimensional growth was found with MA compared with MnS. It was found that the green strength, apparent hardness, and impact resistance were relatively unchanged with the additives. The small decrease in sintered strength due to the addition of machining additives was similar between MA and MnS. In addition, axial fatigue testing found no measurable differences between the no additive condition and the mixes with either MnS or MA.

Finally, sintered bars were tested for corrosion (rusting) resistance. FC-0208 and FD-0405 bars with either no additive, 0.35% MnS or 0.3% MA were placed in a controlled, humid environment. Compared with no additive, MnS greatly increased the amount of rust on both alloy samples, whereas the MA additive had no effect.

3. Summary

The benefits of a newly developed machining additive (MA) have been presented. This additive is particularly effective in PM alloy systems that contain mixed to fully martensitic microstructures. Tool wear rate decreased with the use of the MA additive compared with both the MnS additive and no additive. The addition of the MA additive resulted in very consistent, low tool wear across the board for sinter-hardenable alloys and different tool materials. MA additive was also effective at select speeds in the iron-copper-carbon system, and its usefulness in this alloy system will be application dependent. In addition, MA additive in sintered parts did not cause the accelerated rusting found on the surface of samples containing MnS.