INVESTIGATING THE RELATIONSHIP BETWEEN MACHINABILITY ADDITIVES AND MACHINING PARAMETERS

Sigurd Berg, Höganäs AB
Owe Mårs, North America Höganäs, Inc.

ABSTRACT

The choice of machinability enhancing additive depends on the machining conditions such as operations used, tool used, material machined and some others. This presentation describes the large variation in tool life when testing additives under different conditions. MnS ans MnX have been tested as additives in PM materials ranging from soft pure Iron to the complex structure of Distaloy AE containing ferrite, perlite, bainite and martensite. The effect of the additives has been compared in drilling and turning applications as well as using different tool materials and coatings.

INTRODUCTION

Powder metallurgy (P/M) is a near-net shape process capable of producing complex parts with little or no need of machining operations. This is a statement which is frequently used for the P/M technology. A customer study reveals that 60% of all P/M components need some machining operation. One explanation for this is the inability to produce geometries as transverse holes, undercuts and treads during the pressing operation. Another explanation is the reported general trend towards design of complex parts that call for machining [1].
Combining this with the knowledge that powder metals are generally considered to have poor machinability in comparison with wrought or cast metal [2], recommendations for the machining operation is therefore important. The advantage of the PM technique is that it provides means of admixing different machinability enhancing additives. There are a large number of additives reported to improve the machinability of PM materials. For example: MoS_2, S, Se, Te, Bi, Pb, MnS, MnX, BN, glasses, plastic impregnation or compounds containing group V11B- elements. These additives must fulfil two main requirements:

1. Same mechanical properties as without additive addition.
2. Improved machinability

Influence of additive on the mechanical properties reveals that nearly all additives decrease the mechanical properties. Additives such as MnS, MnX and BN can be accepted provided the influence on mechanical properties is taken into account.

If decreased mechanical properties can be accepted the effect of sulphur, selenium and tellurium increases, going from sulphur to selenium and tellurium [Ref 3]. Additional effects as round poor shape was found for sulphur, tellurium (due to low boiling point) and MoS_2 (due to dissociation into elemental molybdenum and sulphur).
In this paper the effect from MnS in turning and MnS and MnX in drilling have been investigated.

EXPERIMENTAL

Turning

Turning test for a number of PM materials is performed in an SMT turning lathe. Geometry for working piece: inner diameter 35mm, outer diameter 64mm, height approximately 62mm. Illustrate intermittent turning synchronising hub is used. All turning is performed as a facing operation. Sintering temperature is 1120°C, time 20 min. For material with carbon addition, endothermic atmosphere is used, dissociated ammonia for the other materials.
PVD-coated Hard Metal insert, ISO code CNMG120408-MF is used in the investigation. Depth of cut is fixed to 0.5mm

Drilling

Blind hole drilling test is performed on a wide spectrum of PM qualities. Cylindrical blanks with a diameter of 80 mm and a height of 10 mm are used in the test. HSS drill with a diameter 4 mm, with point angle of 118^{o} under dry condition is selected. Total breakdown of the drill is chosen as criterion, based on the fact that drilling is commonly used as a bulk removal operation.

All tests were carried out using MODIG-NC machining centre. Early in the testing procedure, the heat generated in the workpiece during the drilling cycle was recognised to have an effect on the result and therefore the time between inserts was increased and temperature measurements were carried out on the workpiece.

RESULT AND DISCUSSION

Turning
Classification of P/M materials regarding machinability.

In conventional steel hardness is one of the main properties to define machinability. Low values are normally favourable. Exceptions are very ductile materials where problems arise from the formation of built up edges in the form of poor surface texture, burr formations and short tool life.
If the amount of ferrite present in the microstructure is taken into account PM materials can initially be classified by the macro hardness figure 1. Tool life was evaluated for the investigated mixes as shown in table 1 at a cutting speed of 200 m/min with a feed rate of 0,1 mm/r and criterion 0.3 mm flank wear. Density: 7.0 g/cm^3. Tool: CNMG120408, PVD-TiN coated hard metal.

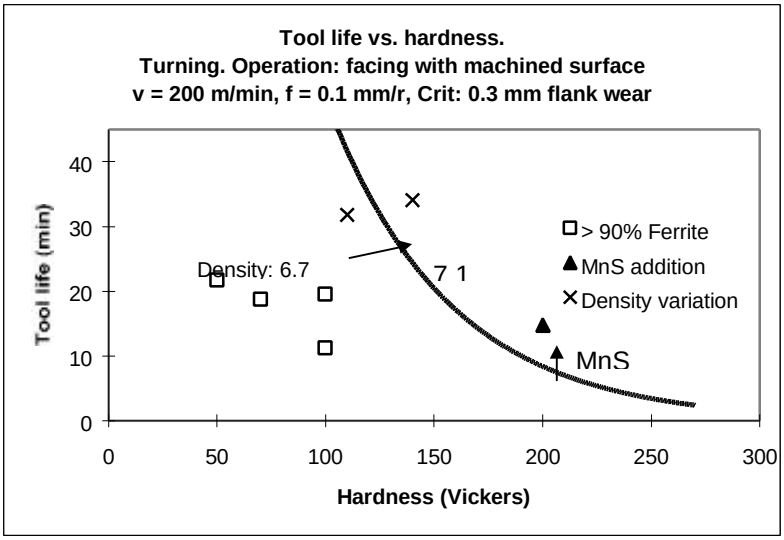


Figure 1. Tool life vs. hardness for PM materials, influence density and additives

The effect of MnS addition (0.5%) is clear. Hard materials strongly benefit from machinability additives. For material with high ferrite amount addition of MnS can move the performance of a material to the "safe" zone in the wear mechanism map.

Effect of Mns addition on tool life

Addition of MnS has been used in PM steels for a long time. The machinability is enhanced in continuous cutting for MnS addition, figure 2a. Feed rate in the evaluation is 0.1 mm/r and cutting is performed in dry condition. Effect from MnS increases at higher cutting speeds. In figure 2b the performance in intermittent cutting is shown.

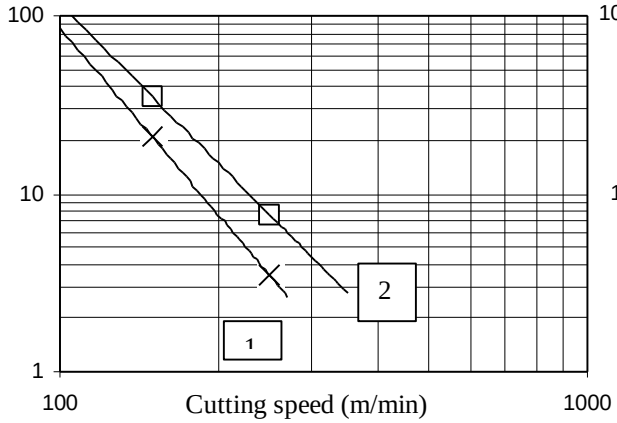


Figure 2a. Continues cutting D. AE 0.5% C, 1.) O% MnS, 2) 0.5% MnS

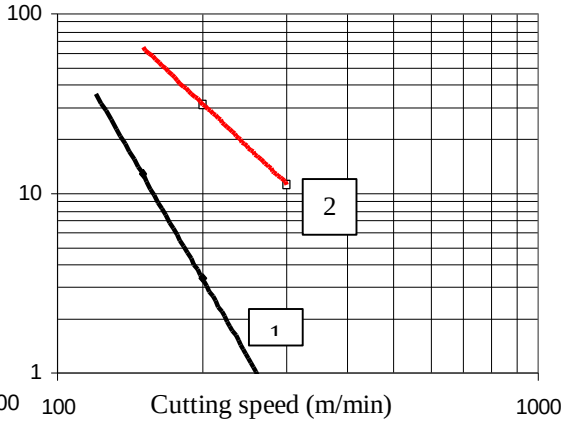


Figure 2b, Intermittent cutting, D.AE 0.5% C 1.) O% MnS, 2) 0.5% MnS

There is a large effect from MnS addition for this type of operation. Explanation for the effect is reduced strain in the shear plane. Measurement of the acting forces (passive, feed and main force)

during a cutting operation reveals decrease in forces with MnS addition [4]. For this type of operation selection of insert is important. Selected insert for intermittent compared to continuous cutting a more ductile core of the insert is to be selected in order to withstand the force variation that occurs during the operation.

Drilling

In the investigation additives as MnS in a content of 0.5% and MnX in a content of 0.3 and 0.5% is used. These levels are commonly used in the PM industry due to the fact that mechanical properties are only to a slight extent effected by the additive.

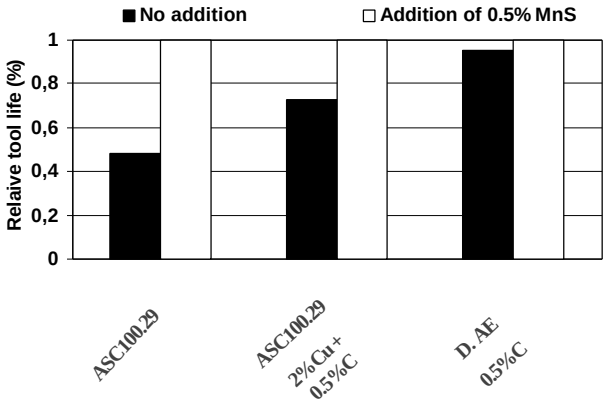


Figure 3a. Effect from 0,5%MnS addition.

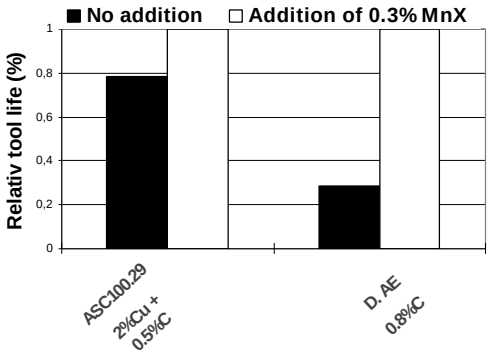


Figure 3b. Effect from 0,3% MnX addition

Addition of MnS to plain iron (ASC100.29) is shown in figure 3a. Value is normalised to mix with addition. Tool life is reduced with 50%. This is due to the fact that smearing occurs during the cutting operation. Addition of MnS improves the friction on the cutting edge and also improves the chip removal. MnS effect for ASC100.29 2% Cu 0.5% C and D.AE 0.5%c is shown in figure 3a.

Effect from MnX addition is shown in figure 3b. It has similar effect as MnS in the iron-copper carbon system. For D.AE 0.8%C the effect is large. Here the selected tool is uncoated HSS drill. Recommended drill for this material is a coated HSS drill. The effect from improved chip removal and lubrication on the cutting edge in this case.

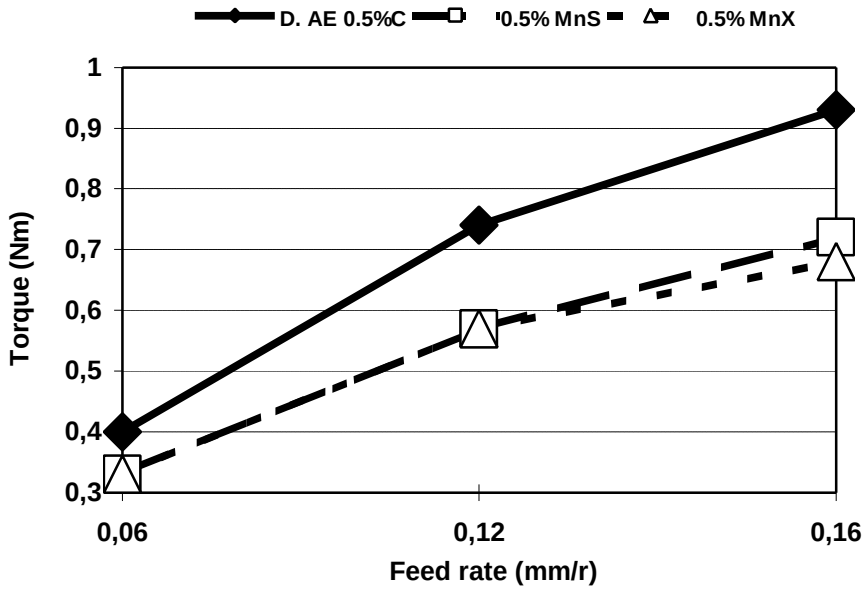


Figure 4 Effect from MnS and MnX on the torque

Improved tool life achieved by addition of MnS and MnX is explained by the reduction in torque and feed force, shown in figure 4 and 5.

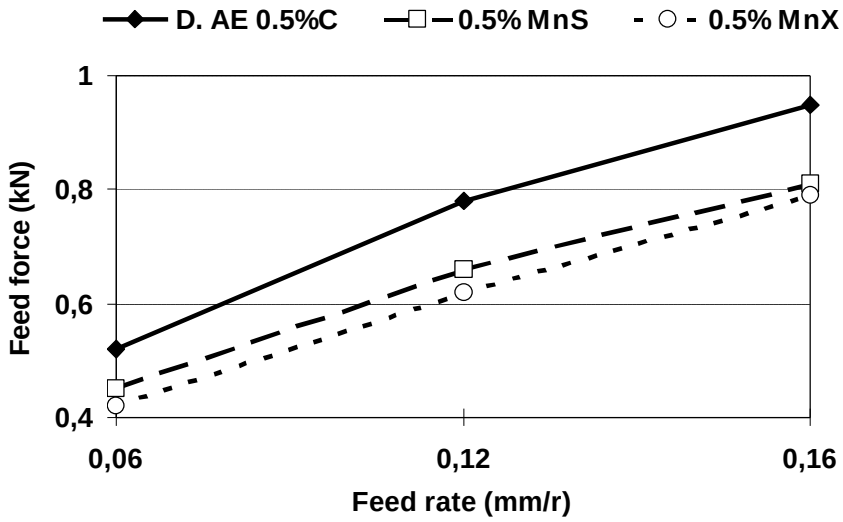


Figure 5, Effect from MnS and MnX on feed force at different feed rates.

The effect of additive increases with increased feed rate both regarding torque and feed force.
To gain the most out of the additive it is therefore of interest to see the performance regarding tool life at different feed rates. In figure 6 relative tool life at different feed rate is shown. Note here that values are normalised at a feed rate of 0.06 for each material. Effect from 0.3% MnX addition at the same feed rate is shown in Figure 3b.

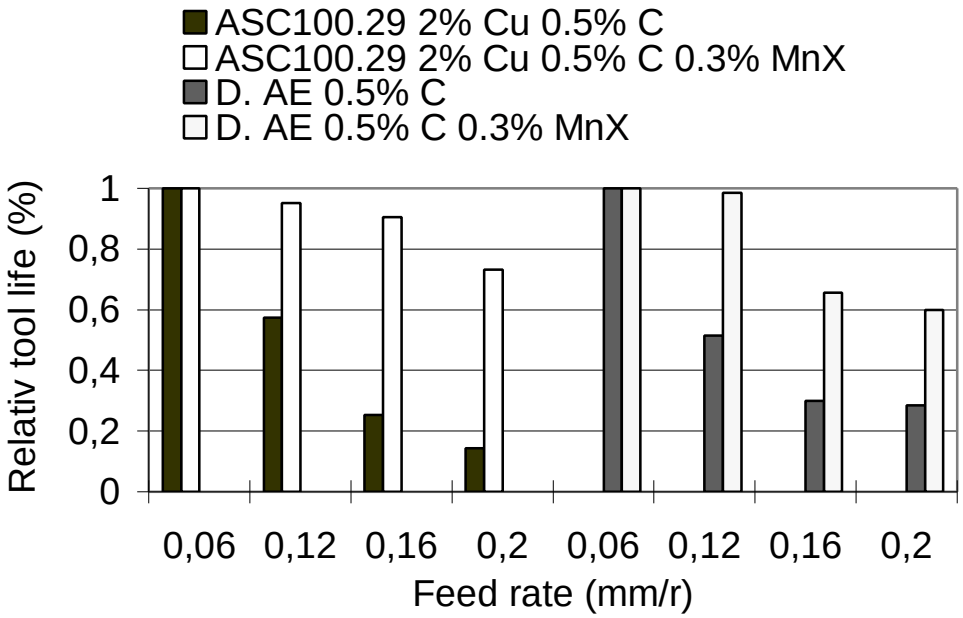


Figure 6. Relative too life at different feed rates for 0.3% MnX addition

At a feed rate of 0.06 mm/r for ASC100.29 2% Cu 0.5% C material the effect from 0.3% MnX addition from figure 3b is ~21%. As the feed rate increases the performance without addition is decreased to a large extent while the performance with 0,3% is maintained, 0.16 mm/r. In figure 6 the performance for D.AE 0.5% C is included. The drop in performance is reached without addition at a feed rate of 0.12 mm/r. By addition of 0,3% MnX the performance is maintained at this feed rate.

For additives like MnX the total gain must therefore include ”optimisation” regarding feed rate.

CONCLUSIONS

Turning

MnS improves the machinability in general.
In intermittent operation the improvements is increased.
Effect of MnS addition increase at higher cutting speeds.

Drilling

Additives MnX and MnS improves the machinablility both regarding cutting speed and feed rate
MnS and MnX decreases the torque and feed force.
Additives facilitates the chip removal.

REFERENCE

1. K.H. Roll, Powder Metallurgy at the Turn of the new century, 1987 Annual Powder Metallurgy Conference Proceedings, Metal Powder Industries Federation.
2. J.S. Agapiou and M.F. DeVries, Machinability of Powder Metallurgy Materials, Int. J. Powder Metal., Powder Technol., Vol 34 (No. 1), 1988
3. U.Engström: Machinability of Sintered Steels, Powder Metallurgy, Vol 26, No 3 1983, p. 137-144.
4. Höganäs Handbook for Sintered Components, Machining guidelines.