Powder Mixes with new lubricants for Part Precision and improve productivity

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Abstract - Powder metallurgy is a cost-efficient process route for the production of net shape or near net shape Components. In many situations, secondary operations for instance, sizing or machining operations are required to meet the tolerance class of the application. Better tolerances of as sintered Components will increase the competitiveness of PM technology by reducing the need for secondary operations. In this presentation, the benefits of advancements in material & mixing methods for dimensional control are discussed. In search of new applications for PM components, the industry has a need for ever higher performing lubricants in metal powder mixes. Over the years, several different paths have been taken to improve performance of mixes. Examples are bonded mixes, mixes for warm compaction and more recently mixes for use with heated tooling. Besides good lubrication during compaction there are several requirements on high performance mixes, such as stable powder behavior in terms of filling the tool, stability to variations in temperature and humidity and environmental friendly. Some newly developed lubricants exhibit improved properties in key areas such as climate robustness, lubrication and the possibility to boost compaction performance by using heated tooling during compaction. Moreover these new lubricants are Zn-free, thus minimizing environmental impact and the need for sintering furnace maintenance. Extensive testing has proven that lubrication is superior to amide wax, lubricant properties are not sensitive to humid climate conditions and that green density can be increased compared to conventional mixes.

Key words: Stain Free Lubricants, Good Lubricity, better production control.

INTRODUCTION

The aim of a lubricant during the P/M compaction process is to reduce internal friction (between Particles) and to reduce external friction (between compact and die wall). Zinc stearate and different amide waxes are the most commonly used lubricants. From the beginning stearic acid was used as a lubricant but the problem with stearic acid is that it gives bad powder properties and that it is easy to form agglomerates both in powder mixes and during storage of the lubricant. Many component manufacturers have problems when using zinc stearate due to stains on sintered components and for environmental reasons. In this paper is a newly developed premix system presented and compared to a Premix with amide wax. This new premix contains a lubricant that does not contain zinc and lubricate very well.

Experimental:

All properties were measured on mixes made in 1000kg scale with a composition of ASC100.29 + 0,5% C-UF4 + 0,8% lubricant. A premix containing amide wax as lubricant was compared to the new Premix system containing the newly developed lubricant, Intralube®E. In addition were several premix with different compositions also tested with warm die compaction (WDC). These mixes can be seen in Table 1.

Table 1. Composition of the mixes

ASC100.29 + 0,5% C-UF4 + 0,6% Lubricant
ASC100.29 + 2% Cu + 0,3% C-UF4 + 0,5% Lubricant
Astaloy85Mo + 0,3% C-UF4 + 0,5% Lubricant
AstaloyCrM + 0,3% C-UF4 + 0,65% Lubricant
AstaloyCrL + 0,3% C-UF4 + 0,6% Lubricant

Flow and apparent density (AD) were measured according to ISO 4490 and ISO 3923 respectively. Green density (GD) was measured according to ISO 3927 on cylindrical specimens with diameter 25 mm and a weight of 50 g. Green strength was measured according to ISO 3995.

The powder properties were also measured in a fillability equipment. The equipment has eight cavities with varying widths between 1 mm and 20 mm and has a fixed length and depth of 30 mm, see Figure 1 and 2. The cavities were filled in sequence at different fill shoe velocities and the powder from each cavity was subsequently collected and weighed. Based on the weight of the powder and volume of the cavity Filling index was calculated according to equation and was plotted versus the filling velocity. Higher filling index indicates a stronger influence on fill density from the width of the cavity.

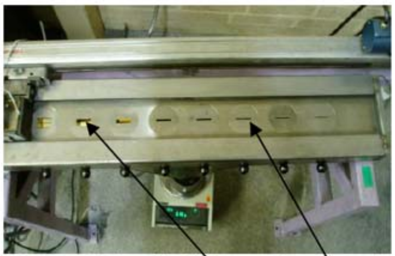


Figure 1. The die filling equipment, above

$$\text{Filling Index} = \frac{AD_{13mm} - AD_{2mm}}{AD_{13mm}} \times 100$$

Figure 2. The die filling equipment

Filling Equation

The ejection properties were measured according Höganäs AB internal method. The static peak ejection force is the max force where the component starts to move. The ejection energy is calculated based on the ejection force and displacement during ejection of the component. The calculation of the ejection energy can be seen in Figure 3. Both the peak static ejection force and the ejection energy are divided by the surface area in contact with the tool die during the ejection. The static peak ejection force and the ejection energy can be seen in Figure 4. The ejection properties were measured when compacting a ring with the dimension OD/ID 55/45 mm and the height was 15 mm.

$$EjE = \sum_{i=0}^{n} \frac{F_{i+1} + F_i}{2} \cdot (L_i - L_{i+1})$$

F = Ejection force
L = Position of the die
n = Number of sampling points
EjE = Ejection energy

Figure 3. The calculation of the ejection energy

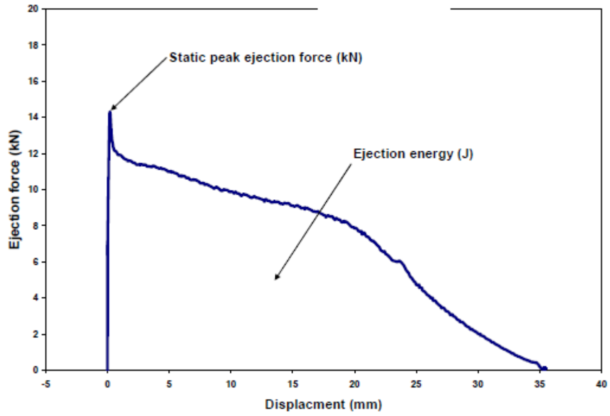


Figure 4 The force (kN) measured during the ejection of a component

Verification in production-like conditions was also made. For this purpose a Dorst TP45A 45ton mechanical press was used. A ring with the dimension OD/ID 35/25 mm and height 30 mm (1,2inch) was compacted 11 parts/min at 600MPa and to a density of 7,1g/cm³. When investigating the ability to form stains after sintering, cylindrical parts with diameter of Ø80 mm and height of 20 mm were compacted to 7,1g/cm³ and sintered in 1120°C for 15min in 90/10 N2/H2 atmosphere.

Results:

Powder properties

The powder properties were measured on mixes made in large scale, 1000kg. The apparent density (AD) of the new Premix was in the same level as the Premix with amide wax. Flow was slightly better with the new system compared to the Premix with amide wax, as can be seen in Figure 5 and 6.

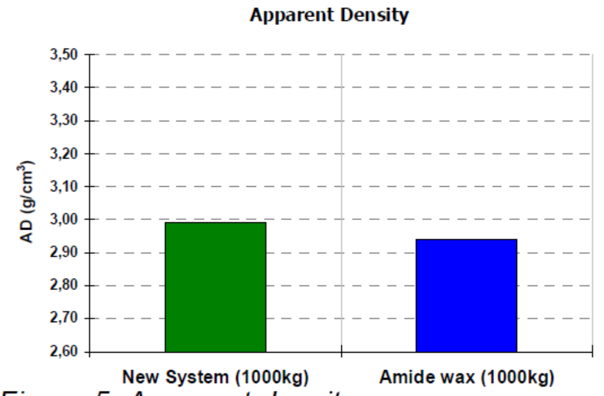


Figure 5. Apparent density

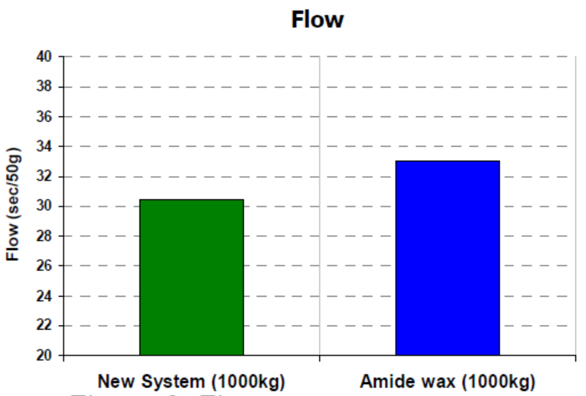


Figure 6. Flow

The powder properties were also measured in the in the fillability equipment. The new Premix was slightly better than the mix with amide wax as can be seen in Figure 7.

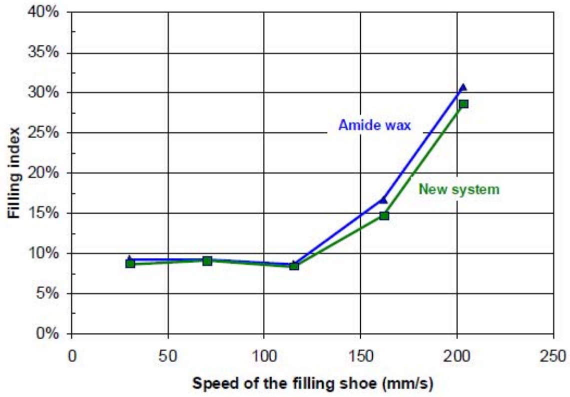


Figure 7. Fillability of the mixes

Ejection properties

The new Premix had god ejection properties. When compacting at ambient temperature the ejection energy was 15-20% better than corresponding Premix with amide wax, as can be seen in Figure 8. In the same figure is also shown that the lubrication gets even better when heating the tool. When having the tool die at 60-80°C (142-176°F), the most advantageous lubrication can be obtained with this new system. The peak ejection force was slightly better than the Premix with amide wax when compact at room temperature and much better when comparing to elevated temperature of the tool die as can be seen in Figure 9.

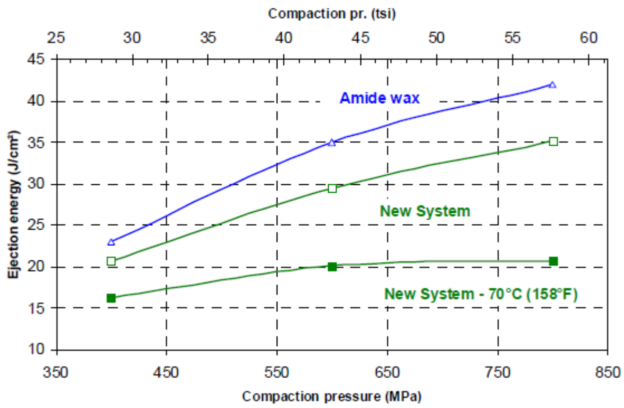


Figure 8. Ejection energy

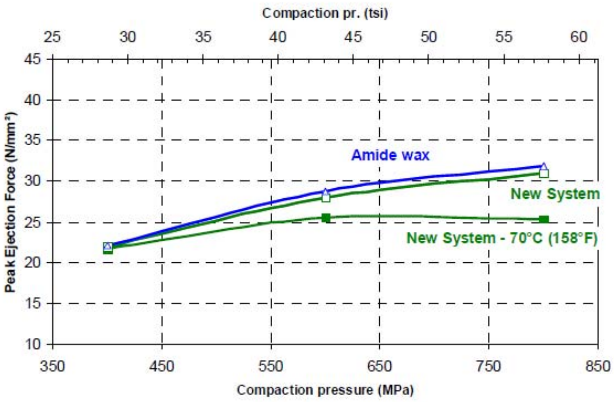


Figure 9. Peak ejection force

Density

The compressibility was as good as for the amide wax mix as can be seen in Figure 10. However, very high density could be obtained if compacted at elevated temperature (70°C, 158°F). Further the compaction pressure could be reduced with nearly 150 MPa when aiming for the same density which can be seen in Figure 11. For the density 7.20g/cm³, 760MPa was needed for the Premix containing 0.8% amide wax, while only 620 MPa was needed if using the new Premix with less lubricant content (0.6%) and compacted at elevated temperature of the die (70°).

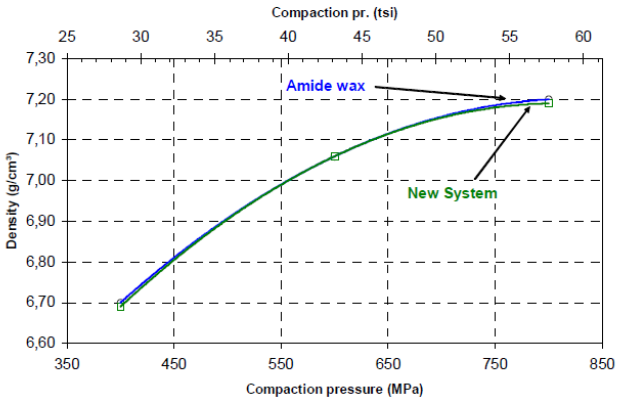


Figure 10. Compressibility

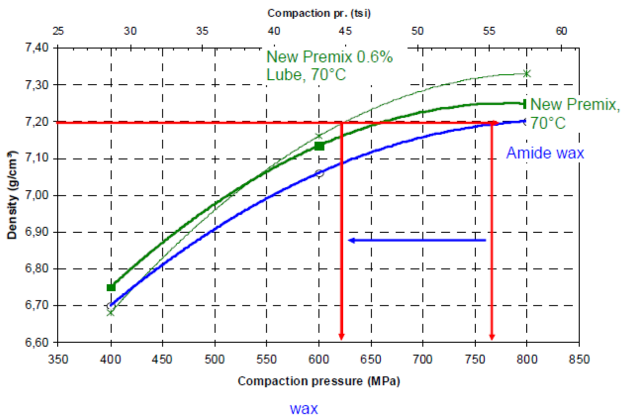


Figure 11. Density

High densities could also be obtained when using the new Premix system in combination with different iron powders such as Astaloy CrM; Astaloy CrL and Astaloy 85Mo, as can be seen in Figure 12. The lubricant content was calculated to fit the iron powder giving good ejection properties in combination with the new lubricant.

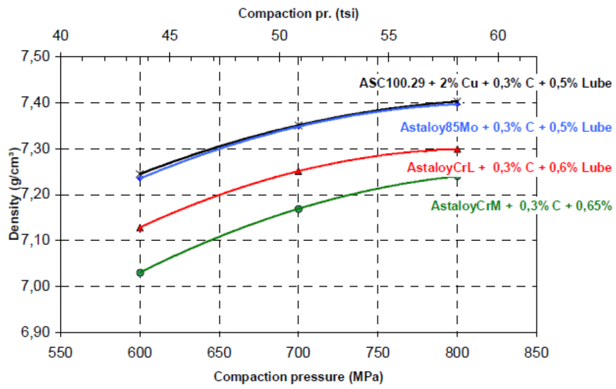


Figure 12. Densities with new system in combination with different iron powders.

Production like conditions

To verify the properties in production like conditions, around 1000 parts of the mixes were compacted in a Dorst press. The temperature of the tool die and of the components was measured. As can be seen in Figure 13 the temperature differences of the tool die and parts after ejection were 10°C lower with the new system compared to the Premix with amide wax. The parts from the new system also had better surface appearance than amide wax as can be seen in Figure 14.

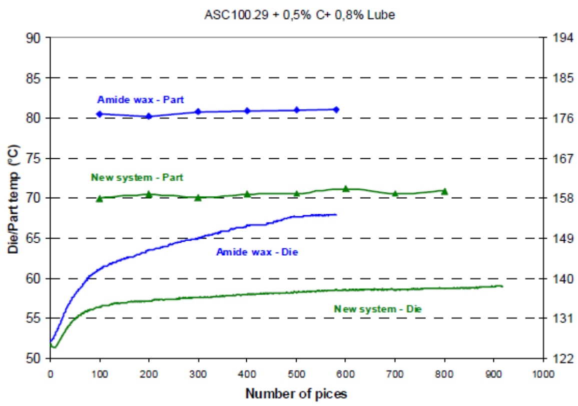


Figure 13. Temperature measurements

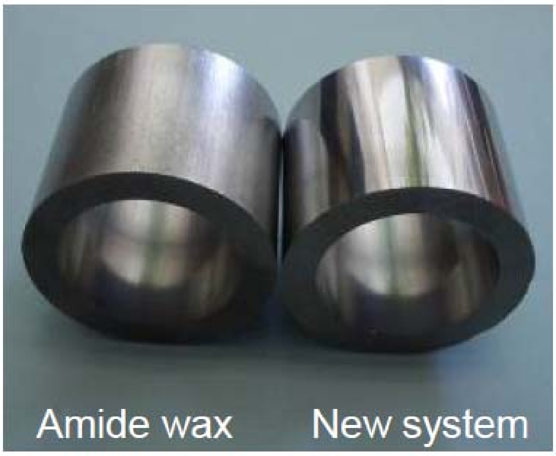


Figure 14. Components after compaction

Both new zinc-free premix system and a Premix with amide wax gives clean burn off and stain free components after sintering, as can be seen in Figure 15 and 16.

Figure 15. A sintered part of the new premix system.

Figure 16. Premix with Amide wax

Green strength

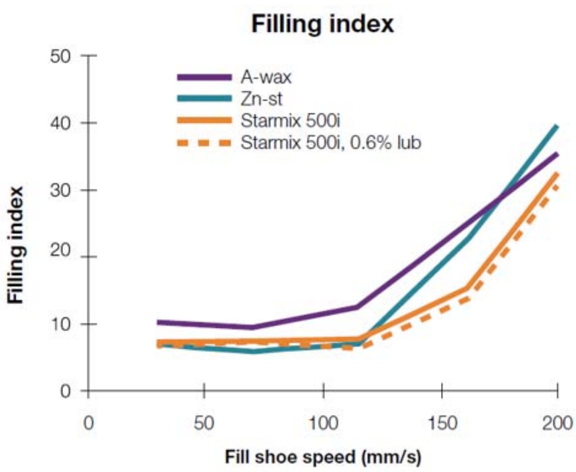
The green strength of the new system was high, 18 N/mm² compacted at 600 MPa whereas a Premix with amide wax gave a green strength of 14 N/mm².

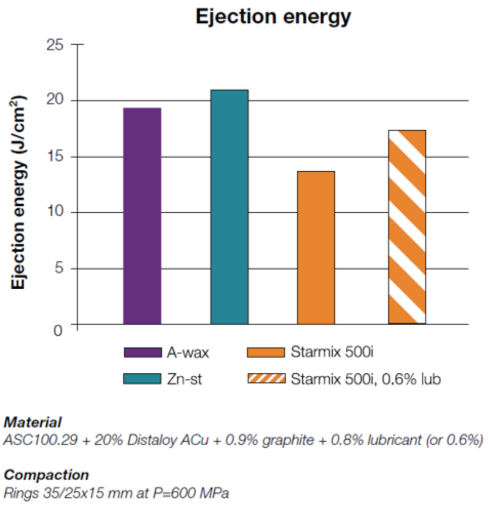
Better Dimension Precision can be obtained by using bonded Starmix® 500i mixes, which is combination of process and newly developed lubricant.

Main product benefits:

- Excellent lubrication
- Good flow and filling
- High green strength
- Zinc free with low staining tendency
- Good DC stability

Starmix 500i is a bonded mix with excellent lubrication. It works well for tall parts and complicated shapes Requiring additional lubrication and by applying warm die compaction, its properties can be further improved.
Good filling characteristics, another feature of the Starmix 500i, enables higher compaction rates as well as improved part precision. As the Starmix 500i is free from zinc the staining tendency is low. Moreover, as there will be no zinc residues in the furnace, the need for furnace maintenance is reduced.





Conclusion:
The new Premix system that has been developed provides many benefits. It is environmentally friendly and delivers stain free components after sintering since it contains no zinc. The system offers good powder properties and high green strength. It also gives excellent lubrication and is recommended to be used with warm die compaction (60-80°C). Another advantage is that compaction pressure can be reduced compared to a Premix with amide wax. The new system is also well suited for and robust when in warm and humid climates. The lubricant in this newly developed Premix is called Intralube E. Starmix 500i gives better dimensional consistency and good lubrication in compaction. It also gives better weight scatter and uniformity in production.

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