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STARMIX® 500i FOR EXCELLENT LUBRICATION AND GOOD FILLING

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Abstract - A successful P/M part production process starts with a suitable powder mix with good properties such as good flow and AD, good lubrication, easy to handle, high productivity and precision. Efficiency and reliability of P/M process as any other powder processing is depending upon behaviour of the powder composition during handling and processing. Starmix 500i is a bonded mix with excellent lubrication. It offers good powder properties and bonding. It works well for parts with complicated shapes requiring additional lubrication and by applying warm die compaction, its properties can be further improved. Good filling characteristics, of the Starmix 500i, enables higher compaction rates as well as improved productivity and tolerances simultaneously. 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. A benchmark where Starmix 500i is compared to other mixes are presented in this paper.

Key words: Powder metallurgy, Warm die compaction, powder properties, high productivity

INTRODUCTION

Bonded mixes, called Starmix, have been part of Höganäs product portfolio since 1980s. Among other things bonded mixes have been developed to focus on improving the dimensional consistency and filling characteristics by reducing the segregation of the various powder mix constituents. Properties of the final component is affected through a number of different mechanisms. For example, the lubrication and binder system which influence the compaction and ejection of the parts. Powder properties are also controlled by the type of mix, which will have a strong influence on the filling, which in turn influences both productivity and the precision of the pressed parts [1]. Dusting during handling of powder is also an important factor both in environmental aspects and also to prevent the loss of fine additives. Starmix is a product type where the fine additives such as graphite is bonded to the iron particles to avoid dusting and segregation and improve the powder properties. Today, a range of Starmix are offered for different application areas. Starmix 500i is the latest product in the line that offers good lubrication, high bonding ratio, high productivity and precision. In addition, the Starmix 500i is free from zinc, which reduces the furnace maintenance due to absence of zinc residual. The use of zinc also has started to be limited due to regional environmental legislation. In this article, the Starmix 500i has been compared to other types of mixes to show the benefits.

MATERIALS AND METHODS

In this experiment set-up, a comparison of five mixes, including three bonded mixes, were performed. The mix composition was chosen to be based on an atomized powder ASC100.29 mixed with 20 % Distaloy ACu. For evaluation of green properties rings of dimension 35/25X15 were pressed at 600 MPa. Powder properties such as flow, apparent density and filling ability as well as compaction properties and green density and strength were evaluated. The mix composition for all samples are presented in table 1. All material presented in table 1 contain 0.8% lubricant beside the last one which contain only 0.6%. Starmix 500i has good lubrication properties which allows lower content of lubricant. That is why also this mix has been added.

Table 1: Experimental set-up

RESULTS AND DISCUSSION

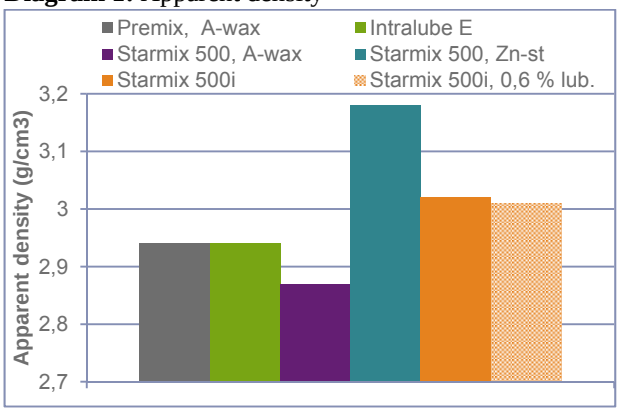
Result from bonding ratio is presented in table 2. Bonding ratio is an indication of how much of the graphite that is bonded to the iron particles. For this measurement an air jet sieve was used. The remaining free graphite is measured after treatment of the mix in the air jet sieve.

Table 2: Bonding ration for all mixes

Mix type	Bonding of graphite (%)
Premix, A-wax	65
Intralube E	59
Starmix 500, A-wax	71
Starmix 500, Zn-st	65
Starmix 500i, Lube E	83

The bonding for Starmix 500i is 83% compared to 59% and 65% for the un-bonded mixes that means less dusting, lower segregation and improved robustness of the product.. The Starmix 500i shows even higher bonding than the Starmix 500 mixes presented here.

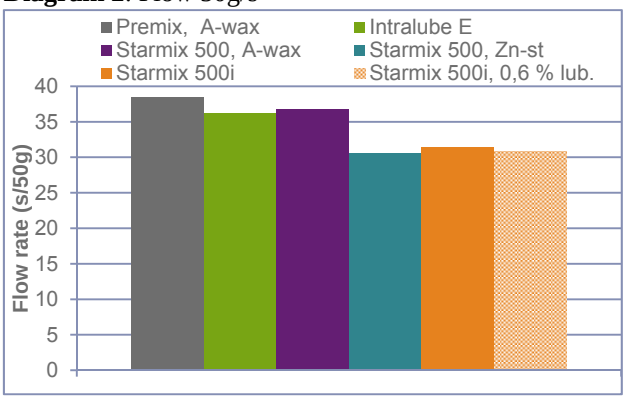
Diagram 1: Apparent density



Apparent density (AD) for all mixes is presented in diagram 1 where the mix with zinc stearate has the highest AD as expected. Starmix 500i shows higher AD compared to the other mixes even with lower amount of lubricant. AD is much affected by the lubricant type.

Mix type	Lubricant (%)	Graphite (%)
Premix, A-wax	0.79	0.89
Intralube E	0.89	0.86
Starmix 500, A-wax	0.81	0.85
Starmix 500, Zn-st	0.82	0.89
Starmix 500i, Lube E	0.81	0.90
Starmix 500 Lube E	0,61	0,90

Diagram 2: Flow 50g/s



The flow rate is presented in diagram 2. Starmix 500i shows faster flow which allows for a faster filling rate. The flow rates was measured in a Hall flow meter.
The reliable flow and filling of the Starmix powder ensure an even and faster filling of the die cavities. The die filling rate is tested by utilizing a die filling simulator (picture 1) [2]. This test involves running a fill shoe containing powder across a series of cavities with different width at varying speed. The powder mass of each cavity is then weighed in order to quantify the filling quality. The cavity width is between 1 to 20 mm. A filling index is defined in order to simplify interpretation of the results.

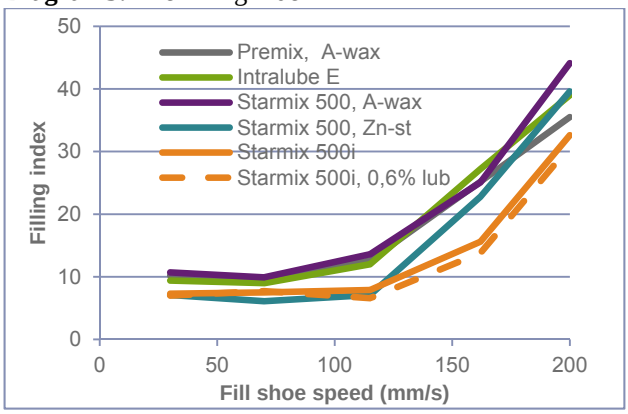
Picture 1: Filling Simulator



Filling index is calculated according to equation 1 and is plotted versus the filling speed.

$$\frac{AD_{13mm} - AD_{2mm}}{AD_{13mm}} \times 100 = \text{Filling index (\%)} \quad (1)$$

Diagram3: The filling index



Starmix 500i show even filling at higher fill shoe speeds compared to other mixes which is a good indication for higher productivity and better precision (see diagram 3). The ejection energy is directly connected to the die-wall friction and the sliding distance of the part inside the die. The ejection energy shows how much energy is needed per cm^2 for the part to eject the die after compaction.

Diagram 4: Ejection energy

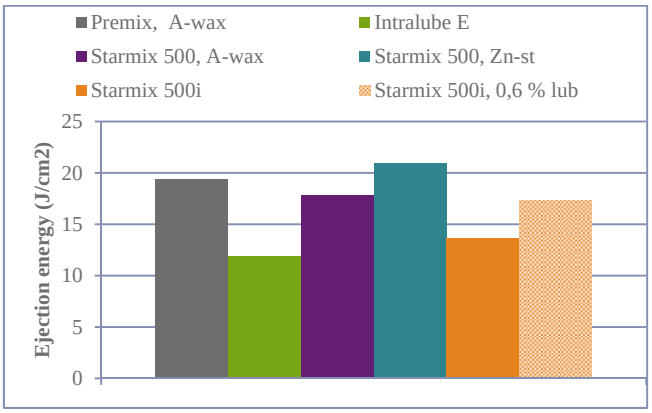
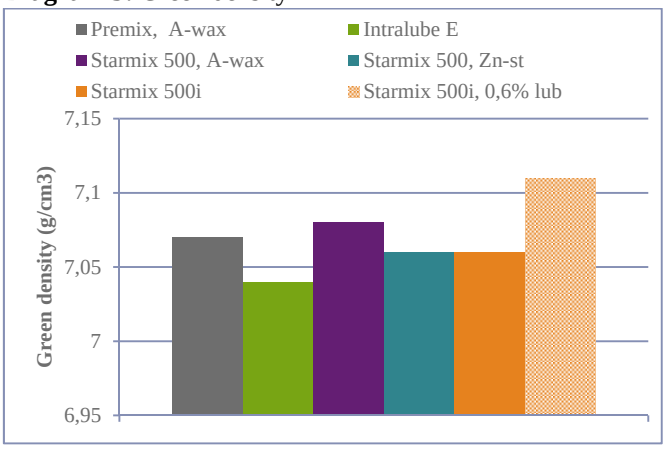


Diagram 4 shows that the ejection energy for Starmix 500i is lower compared to premixes with amide wax and zinc stearate even at lower lubricant content. The lowest ejection energy is detected for Inralube E.

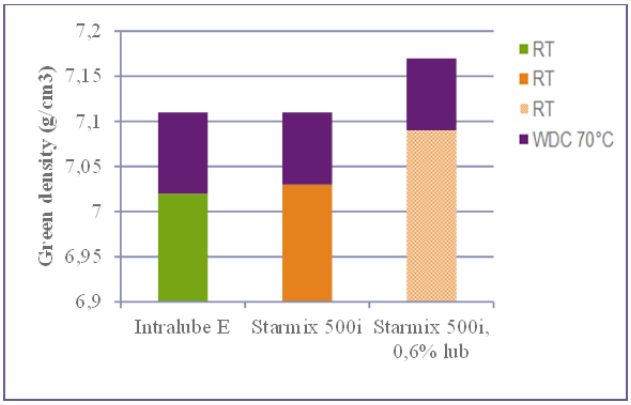
Diagram 5: Green density



The green density is affected by using lower amount of lubricant. By using 0.6% instead of 0, 8% lubricant the green density can be improved which is possible using Starmix 500i. The same effect can also be achieved with Intralube E. The level of green density for all mixes is lower than expected. Other studies shows higher level than is presented here. However the mutual differences seem relevant.

In Diagarm 6 the green density at elevated die temperature for three of the mixes are presented. By heating the die to 70°C the green density can increased by 0.08 g/cm^3. A combination of use of lower lubricant amount which is possible with Starmix 500i and warm die compaction results in density of over 7.15 g/cm^3. Warm die compaction is not possible with mixes containing amide-wax and zinc sterate as these will soften and melt.

Diagram 6: Green density at ambient temperature and warm die compaction





Picture 1: a) Premix with amide wax b) Starmix 500i



c) Premix with zinc stearate

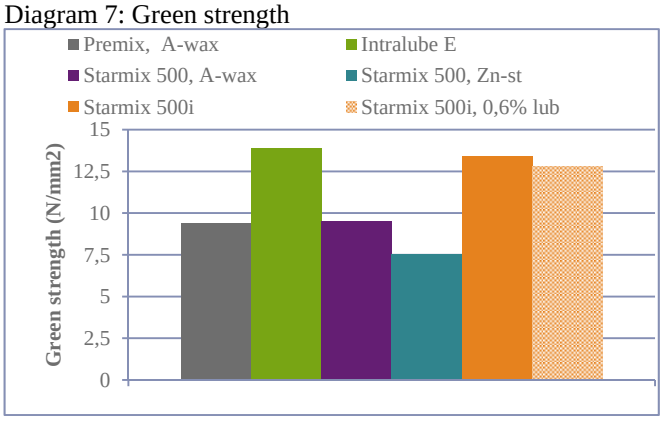
As shown in the pictures above the pressed part with Starmix 500i has no stains while the Premix with amide wax and zinc stearate both have stains.

CONCLUSIONS

Starmix 500i is a bonded mix with excellent lubrication which allows use of lower amount lubricant. That can be used in combination with warm die compaction for even higher densities. Density over 7.15 g/cm was achieved in our tests.

The green strength also gets better with Starmix 500i. In diagram 7 results from green strength tests are presented. It is shown that Starmix 500i has good green strength.

Diagram 7: Green strength



Lower stain tendency is another of the benefits with the Starmix 500i. Below some examples are shown. Picture 1a shows a pressed and sintered part with Premix containing amide wax and picture 1b shows one with Starmix 500i. The picture 1c shows a press body containing zinc stearate.

The bonding ratio of Starmix 500i is high which reduces the risk for dusting during handling of powder and thus prevent loss of the fine additives. Starmix 500i has good flow and high apparent density. The filling index of Starmix 500i was best in these tests which means it can be run with fast flow and uniform filling also at high fill shoe rates. This results in higher productivity and better precision.

Starmix 500i has less staining tendency compared to mixes containing zinc stearate and other metal soaps.

Being zinc-free, the need of furnace maintenance is reduced due to absence of zinc residuals. It can be concluded that Starmix 500i:

- Enables excellent lubrication:
  - higher densities with smaller additions of lubricant or
  - high parts and complicated shapes at higher additions
- Has good flow and filling characteristics
- Is a mix type for high green strength

- Offer an optimal price/performance ratio for more demanding applications.
- Has low staining tendency - no need for part cleaning operation
- Is zinc-free with clean burn off, for reduced furnace maintenance

REFERENCES

[1] Mats Larsson, "*Reducing Dimensional Variation of PM Components throughout the Process Chain*", *World PM2016 in Hamburg on October 11, 2016.*

[2] Fredrik. Vinnerborg, Naghi. Solimanjad, *"Starmix™ – a tool for operational excellence", PM Auto' 2008 Conf., Iran, Isfahan, April 06-08, 2008*