IMPROVEMENTS IN BONDING OF PRESS-READY LOW-ALLOY STEEL POWDER MIXES

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ABSTRACT

In order to expand the applications for sintered structural components there is a continuous demand for development of new powders and processes which result in improved mechanical properties and precision of tolerances at reduced processing costs.

A wide range of different alloying elements and ways to add these are used in PM. As the way of adding the alloying elements influences both the mechanical properties and the dimensional scatter of the components after sintering it is important that press ready powder mixes are made in such a manner that the required mechanical properties are achieved without losing the dimensional precision. One way to secure this is to bond the constituents to the iron or steel powder. By efficient bonding, powder mixes less prone to segregation and dusting and with improved filling of the press tools can be prepared

In this paper, low alloy steel powder mixes prepared with this new bonding concept are compared with conventional premix, both regarding tool filling behaviour and scatter of dimensional tolerances after pressing and sintering. The results are obtained in mass production trials.

1. INTRODUCTION

Earlier investigations have shown some of the benefits when using bonded powder mixes [1], [2], [3], e.g. dusting, flowability, fillability, density distribution, and consistency of dimensional and mechanical properties. The objective of this paper is to illustrate these incentives under production conditions, using newly developed bonded mixes, i.e. comparing a premix with the new generation STARMIX™ with improved bonding and filling. In order to highlight these advantages, Höganäs AB has performed tests in collaboration with the competence centre APM, in Nässjö, Sweden.

2. EXPERIMENTAL

Three Fe+Cu+C mixes with same nominal chemical composition were produced. Target compositions are listed below.

1. PREMIX ASC100.29 + 2%Cu (Distaloy ACu) + 0.8%C-UF4 + 0.8%Amide wax
2. STARMIX™ ASC100.29 + 2%Cu (Distaloy ACu) + 0.8%C-UF4 + 0.8%Amide wax
3. STARMIX™ ASC100.29 + 2%Cu (fine) + 0.8%C-UF4 + 0.8%Amide wax

The component concerned is illustrated in figure 1 below, and is aimed for a heavy truck water pump. Typical dimensions of the component is: ID=15mm, $OD_{tooth\text{-}tooth}$=28.1mm, $height_{tooth\text{-}tooth}$=24.8mm. Target green density is 6.80 g/cc. OD1 is parallel to the filling shoe movement, OD2 is perpendicular to it.



Figure 1 Component to be evaluated, OD1=parallell to fill shoe movement.

The mixes were compacted in a Dorst TPA 45 mechanical press at a production rate of 14 strokes/minute. As Auger screw feeders are normally used in PM production, and make the trials more demanding for the powder, the material was fed to the hopper using a 3 meter screw feeder, see figure 2.

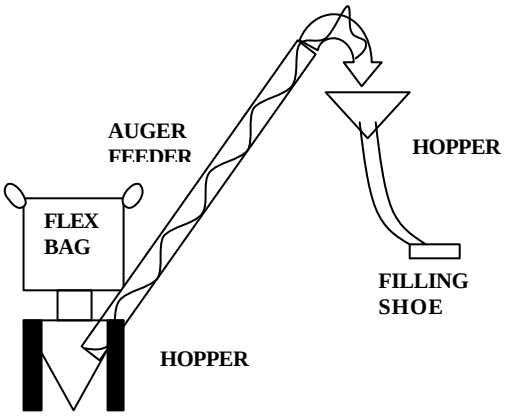


Figure 2 Schematic outline of the powder supply arrangement.

For each mix, a 1000-component compaction run was performed. Every 50 components, 5 samples were taken for further evaluation. Green weight, green outer diameter (OD) and green height was measured. Two perpendicular ODs were measured enabling an ovality calculation. Ovalities for the components were calculated from equation [eq.1] below. Ovalities close to zero are normally obtained, however both positive and negative ovalities are possible.

$$Ovality = \left(1 - \frac{OD1}{OD2}\right) \times 100 \quad [\%] \qquad [eq.1]$$

Additional 5 parts were taken every 25 parts to measure green weight only, to increase the statistical basis. The sampled components were subsequently sintered in 90/10 N_2/H_2 for 25 minutes, whereupon corresponding measurements of sintered properties were made.

Laboratory trials were made in order to evaluate the fillability for the three mixes. Filling index for the mixes was calculated using a die-filling simulator, thoroughly described in a previous paper [3]. Filling index is defined as the ratio of the filling density of a 2-mm and a 13-mm cavity, see [eq.2].

$$Filling\ \ Index = \frac{AD_{13mm} - AD_{2mm}}{AD_{2mm}} \times 100 \quad [\%] \qquad [eq.2]$$

3. RESULTS AND DISCUSSION

Chemical analysis and powder properties were evaluated for the three mixes. The results are found in table 1 below. It can be seen that the three mixes are equivalent in chemical composition.

Property	Premix (Distaloy ACu)	Starmix (Distaloy ACu)	Starmix (Cu fine)
Cu [%]	2.04	2.05	2.05
C [%]	0.74	0.78	0.72
Amide Wax [%]	0.79	0.80	0.83
Flow Hall [s/50g]	33.1	25.4	22.9
Apparent density [g/cm^3]	3.11	3.06	3.16
GD @ 600 MPa [g/cm^3]	7.07	7.07	7.08

Table 1 Analysed properties for the three mixes.

Figure 3 below shows an example of the weight distribution for a 1000-component series. From these data obtained for mix 3, the standard deviation was calculated to 0.08 g, which subsequently was compared with the corresponding results for mix 1 and 2, see figure 4. The data for mix 3 is very stable and the weight varies in the range of 57.04-57.49 g. The comparison shows that the weight scatter for the STARMIX mixes are significantly lower than for premix, as seen in figure 4.

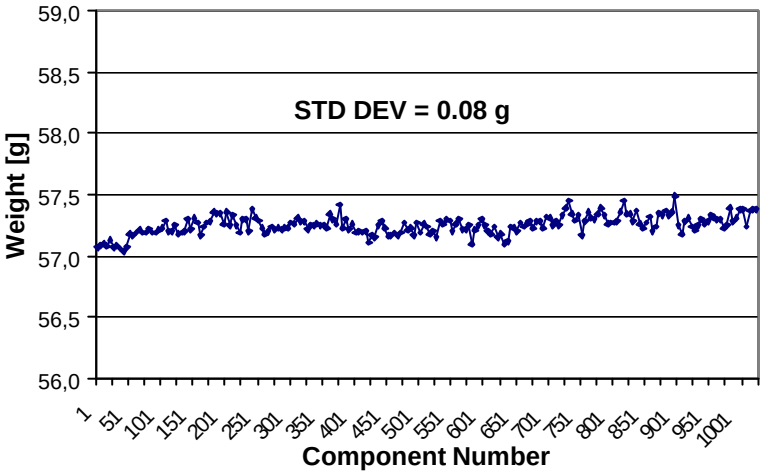


Figure 3 Component weight versus component number for Mix 3.

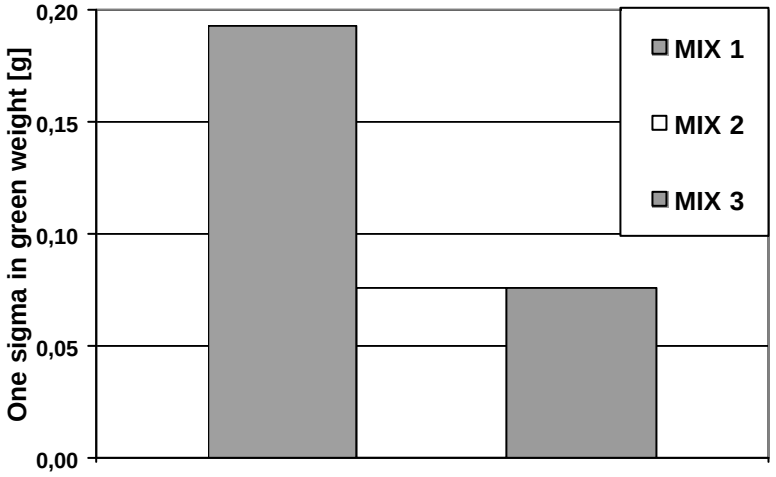


Figure 4 One sigma in green weight versus material.

The dimensions were measured on a total of 100 components per mix. In figure 5, STARMIX powders, i.e. mix 2 and mix 3, show significantly lower scatter than the premix in all green dimensions, both regarding diameter (OD) and height. After sintering, the differences between STARMIX and premix ODs decrease but their relative order still remain with more stable dimensions for the STARMIXes, see figure 6. The scatter in height has increased, whereas the scatter in OD remains on the same level as for the green condition.

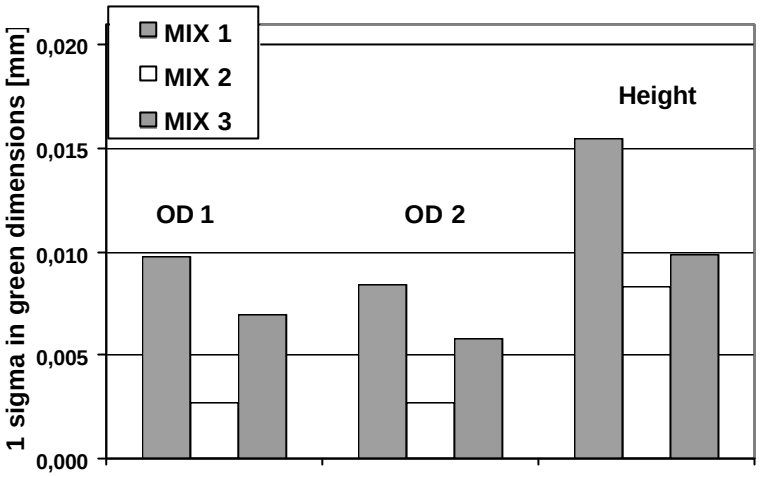


Figure 5 One sigma in green component dimensions versus material.

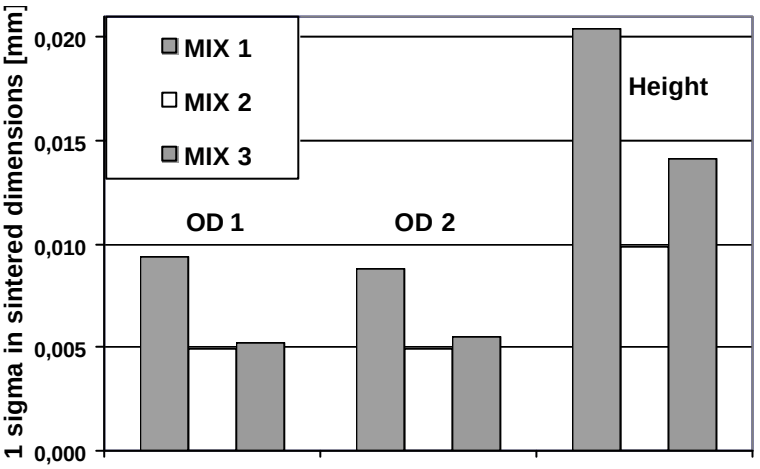


Figure 6 One sigma in sintered component dimensions versus material.

The STARMIX powders also show better green ovality consistency as compared to premix, see figure 7 below. The difference between STARMIX and premix remains after sintering but is smaller, an effect also seen when comparing the green and sintered ODs in figure 5 and 6.

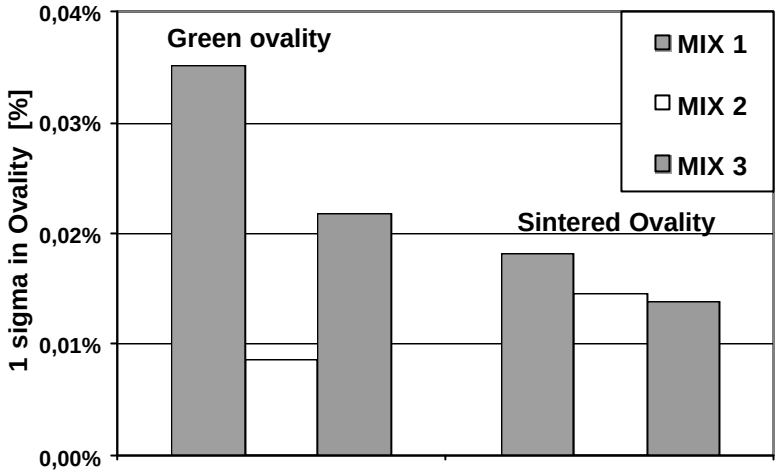


Figure 7 One sigma in green and sintered ovality.

Figure 8 also demonstrates an advantage with STARMIX - dimensional change consistency. The more consistent the DC, the larger the possibility to enhance final component tolerances by altering external factors such as tooling or composition.

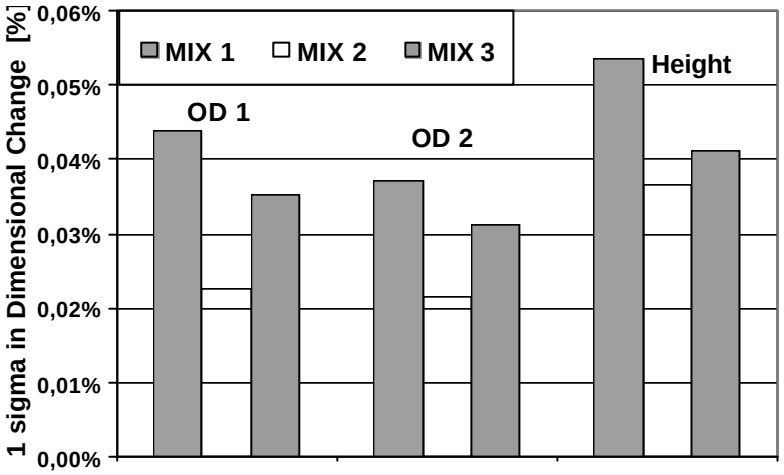


Figure 8 One sigma in dimensional change, green - sintered.

Some of the differences in the green and sintered dimensions and the weight scatter can be understood from the results of the investigation of the fillability, see figure 9 below.

The fillability was evaluated in the die-filling simulator in a laboratory environment [3]. The lower the filling index, the more consistent filling densities in the 2-mm and 13-mm cavities, meaning that the filling density in different parts of a complex die with thin and wide sections will be more consistent. At a certain fill shoe speed, the fill density of the thin cavity starts to deteriorate due to incomplete filling. Then, the filling index increases rapidly, as for the premix above 115 mm/s in figure 9 below. Thus, the STARMIX powders fill more consistently than a premix, and continue to do so even at higher fill shoe speeds.

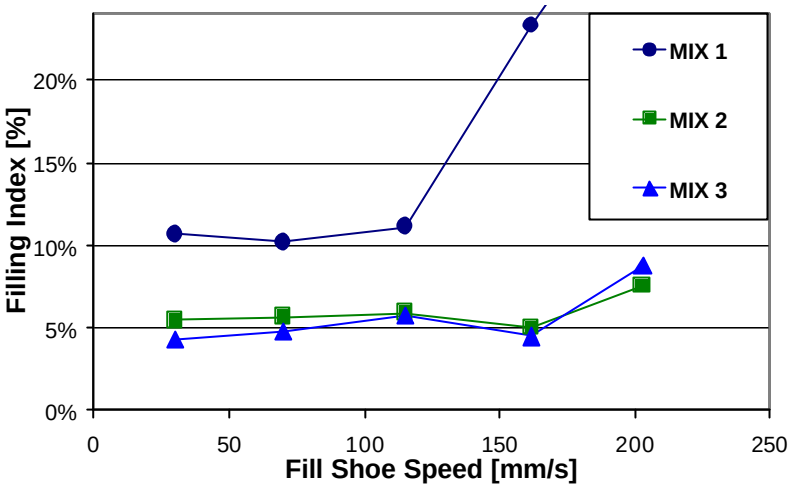


Figure 9 Fillability of the investigated mixes.

The good fillability and filling consistency of the STARMIX may answer the question why its' dimensional scatter is lower in all dimensions, green and sintered. The lower weight scatter for STARMIX™ may also be explained by the enhanced fillability and the fast filling performance observed.

4. CONCLUSIONS

- Bonded STARMIX™ powders give lower scatter in green dimension than the corresponding non-bonded mix.
- STARMIX™ has less scatter in dimensional change than the premix equivalent, thus to a larger extent enabling final component tolerances to be enhanced by altering external factors as tooling or composition
- Compared with a premix, final component tolerances are significantly enhanced when using STARMIX™.
- The fillability of STARMIX™ powders is superior to the corresponding premix. This difference is accentuated further at faster filling rates.

5. REFERENCES

1. M. LARSSON: *Different Means to Improve Consistency of Material Properties and Tolerances of Low-Alloyed PM Steels*, Proceedings of Euro PM2000, Munich, 2000.

2. Dr. H. VIDARSSON, J ARVIDSSON: *Die Filling Capability of Powder Mixes*, Proceedings of PM2000, Kyoto, 2000.

3. M. LARSSON, Dr. H. VIDARSSON: *Efficient Bonding For Dimensional Stability*, Proceedings of PM2TEC 2000, New York, 2000.