Press capacity improvements utilizing Starmix™ powder

Daniel Edman, Hilmar Vidarsson, Björn Johansson
Höganäs AB, Sweden

ABSTRACT

The geometrical complexity of many new PM applications in combination with higher capacity of presses for powder compaction requires metal powder mixes with even and faster die filling characteristics. This demand has led to development of the Starmix™ concept. In Starmix™ additives such as alloying elements, lubricants and machinability enhancing compounds are bonded to avoid segregation, dusting and to improve powder properties. Development work has made it possible to improve the powder flow more than 25%.

This paper presents the gain in productivity due to enhanced flow rate behaviour of Starmix™ in full-scale production tests.

INTRODUCTION

Using a bonding concept on press-ready mixes (premixes) of iron-based powders can give numerous advantages that can be utilized in production of P/M components. Besides the benefit of reduced dusting in the workshop environment and even distribution of graphite, bonding can have a profound impact on the flowability of these mixes, and in turn on parameters that directly or indirectly are dependent on flowability.

These effects are primarily accomplished through the influence that the bonding process has on fine additives, such as lubricants, graphite etc. In unbonded mixes, the relatively small particle size of these materials can cause formation of relatively stable structures in the powder, increasing the risk of bridging in powder handling systems. Related to this are other unwanted phenomena including rat-hole formation in hoppers and poor air permeability in the powder. While bridging and rat-hole formation can cause erratic flow patterns from the hopper down to the filling shoe, the die filling itself can also be subject to severe disturbance. Especially where the cavity includes narrow and/or deep spacing, unbonded premixes often require elaborated filling shoe movements to facilitate even and complete filling. Poor air

permeability will furthermore make it more difficult to remove air pockets that may be formed within the cavity. These factors will slow down the filling cycle and result in an overall productivity loss. It has been shown in a former study using a die filling simulator [1] that bonding of fine additives using the Starmix™-bonding technology will improve the conditions for powder flow and filling.

Other effects that are dependent on the characteristics and stability of the flow patterns include the stability of the apparent density (AD). This can be experienced both in terms of powder density distribution within a die cavity, which in turn influences the green density distribution after compaction, and in terms of overall powder density in the cavity during part-to-part production, which in turn influences weight scatter of green parts. Especially in the latter case, robustness to ensure stable AD-levels will help bring production of parts to within specification and thus bring down quality costs. In previous studies [2,3], this was demonstrated in production trials by comparing a non-bonded premix with a bonded powder mix. Improved weight scatter, especially at increased production rates, were found for the bonded mixes, as well as closer dimensional control.

In the present study the effect of improved physical properties, as Hall flow and apparent density, of Starmix™ on productivity, dimensional and weight tolerances are shown. Comparisons, regarding physical properties, bonding efficiency and mechanical properties, between Starmix™ and corresponding Premix are presented as well as productivity trials at PM part producers.

EXPERIMENTAL PROCEDURE

Material

Composition of the mixes used in this study is presented below. All mixes were produced both as non-bonded Premix and as bonded Starmix™. The Premixes contained 0.8% Amide wax and the Starmix™ powder mixes had an organic content of 0.8%.

1. AHC100.29 + 0.5% C-UF4
2. ASC100.29 + 2% Cu (100 mesh) + 0.6% C-UF4
3. Astaloy Mo + 0.5% P (as Fe_3P) + 0.3% MnS
4. ASC100.29 + 1.6% Cu (100 mesh) + 0.5% MnS + 0.9% C-1651
5. AHC100.29 + 1% C-1651 + 0.5% MnS
6. AHC100.29 + 2% Cu (200 mesh) + 0.9% C-1651
7. ABC100.30 + 2% Ni + 0.75% C-1651
8. Astaloy 85 Mo + 5% MH80.23 + 10% Ni + 0.5% C-1651
9. Astaloy CrM + 0.7% C-1651
10. Astaloy B + 2% Cu (Fine copper) + 0.15% Mo + 0.65% MnS + 1% C-1651
11. Distaloy AF + 0.5% C-UF4 + 0.5% MnS

Testing

Powder properties, Hall flow and Apparent Density (AD), were measured according to ISO 4490-1978 and ISO 3923-1979. Mechanical properties and compressibility were analyzed according to ISO 2740-1986 and ISO 3927. Evaluated test bars for mechanical properties were compacted at 600MPa and sintered at 1120°C in a laboratory belt furnace for 30minutes in 90% N_2/10% H_2. A cooling rate of 0.8°C/s was applied.

Bonding

To measure the amount of bonded graphite and lubricant in the powder mix a Roller Air Analyzer from Aminco, figure 1, was used. The instrument works as an air classifier, where the parameters were set to blow of graphite having a particle size of 4μm. Sample weight used was 50g. Before and after operation the carbon content was analysed in order to calculate the amount of bonded graphite and lubricant as follows:

C_2/C_1*100 = % bonded graphite and lubricant

C_1 = analysed carbon in mix before the blowing test

C_2 = analysed carbon in mix after the blowing test.

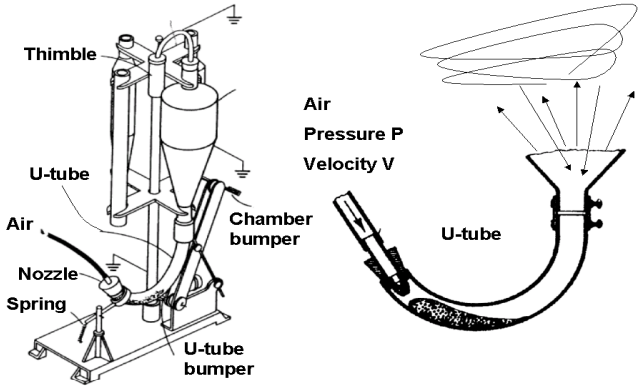


Figure 1. Roller Air Analyzer.

Dusting
The dusting was measured with a Dust track Aerosol Monitor. Air is extracted into the equipment at a flow of 1.7dm^3/min and analyzed for particles less than 10μm in diameter. Sample amount was 5g dispersed through a flow cone into a sample container.

Production trials
In total three trials have been performed.

Mix 1.
The first trial was made in-house in a Dorst (TPA45) mechanical production press. 300 ring-shaped parts were compacted at 16 parts/minute. 16 strokes/minute is close to the maximum possible productivity for the Premix for this part and settings. The dimensions were, outer diameter 35mm, inner diameter 25mm and height 15mm. The weight scatter during compaction was determined.

Mix 2 [3].
The second trial was performed at Pennsylvania Powdered Metal. A small gear, green density range 7.00 – 7.05g/cm^3, was compacted in a mechanical press at rates at 16 – 26 strokes/minute. 500 components were pressed at each compacting rate. The 28 teeth gear has an outer diameter of 43mm and an inner diameter of 23mm. The height was set to 12mm. The gear was evaluated regarding weight and dimensional scatter. The compacted gear is presented in figure 2.



Figure 2. Gear for evaluation

Mix 3 [2].
The third trial was made at a European PM parts producer. The component was ring-shaped with an approximate outer diameter of 75mm, inner diameter of 55mm and a height of 11mm. The target green density was 7.1g/cm^3 and the weight of the component approximately 160g. Performance of Premix and Starmix™ at compaction rates of 14 – 22 strokes/minute in a mechanical press was evaluated regarding weight and dimensions. Each time 1000 parts were compacted.

RESULTS AND DISCUSSION

Powder properties

In table 1 below, Hall flow and apparent density of the mixes are presented. Apparent density level is ~0.2g/cm^3 higher for Starmix™ than corresponding Premix. The flow is much faster for Starmix™. The gain in flow is shown in figure 3.

Table 1. AD and Hall Flow Mixes 1 – 11

Mix	AD g/cm^3		Hall Flow s/50 g	
	Premix	Starmix™	Premix	Starmix™
1	3.08	3.21	32	24
2	3.01	3.25	32	24
3	3.16	3.16	28	23
4	2.94	3.14	32	25
5	3.03	3.24	34	24
6	2.98	3.21	34	25
7	3.12	3.35	32	25
8	3.12	3.36	34	24
9	2.85	3.00	38	29
10	2.99	3.18	34	25
11	3.06	3.23	28	23

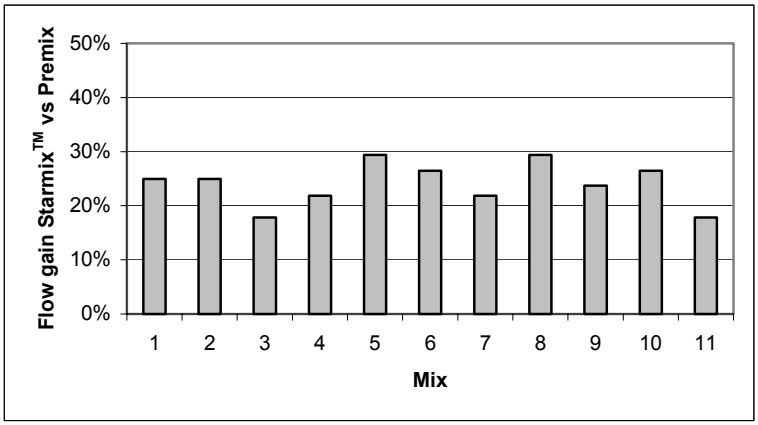


Figure 3. Improvement of Hall flow rate, Starmix™ vs. Premix.

Hall flow rate is in most cases more than 25% faster for Starmix™ compared with corresponding Premix. The gain in flow rate is dependent on the powder composition, however a Starmix™ will always give a faster flow rate compared to corresponding Premix independent on powder composition. The faster flow together with an even filling makes increased productivity possible [2,3]. The productivity gain due to faster filling will also be shown later in this paper.

Bonding
In table 2 the bonding of graphite for the two first mixes, Premix/Starmix™ is shown. The bonding was measured in a roller air analyzer.

Table 2. Bonding of graphite for the investigated mixes 1-2, Premix/Starmix™.

Powder Mix		Before roller test (% graphite)	After roller test (% graphite)	Bonded graphite (%)
1	Premix	0.50	0.28	55
	Starmix™	0.49	0.47	97
2	Premix	0.63	0.28	45
	Starmix™	0.61	0.60	98

Graphite is nearly fully bonded in Starmix™. The apparent bonding for Premix is in the range 45 – 55%. The high bonding degree of carbon serves for higher consistency in tolerances.

Dusting
Dusting of mix 2 was measured in a Dust Track Aerosol Monitor and shown in figure 4. Dusting from a Starmix™ is reduced by ~90% compared to a Premix with the same composition. Less dusting for the Starmix™, due to the high bonding degree of graphite, improves working environment around presses.

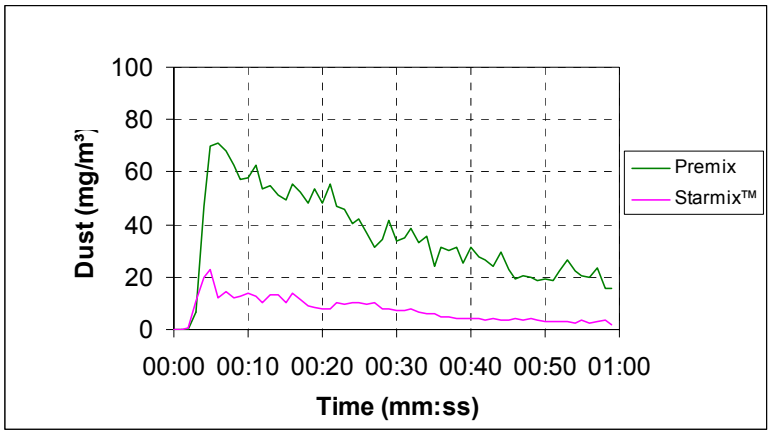


Figure 4. Dusting mix 2, Premix/Starmix™.

Mechanical properties.

Mechanical properties for the two first mixes are presented in table 3.

Table 3. Mechanical Properties.

Mix No.	Type	Green Density g/cm^3	Sintered Density g/cm^3	DC* %	UTS MPa	YS MPa	HV10	Elong. %	Carbon %
1.	Premix	7.07	7.06	0.03	318	213	96	5.1	0.42
	Starmix™	7.06	7.04	0.05	324	216	95	5.5	0.43
2.	Premix	7.07	7.00	0.21	507	358	144	3.2	0.63
	Starmix™	7.06	6.98	0.26	493	351	146	2.9	0.61

* green to sintered.

Mechanical properties are equal for Starmix™ compared to Premix at compaction pressure 600 MPa.

Production evaluation

Mix 1.
Ring-shaped parts of Starmix™ and Premix were compacted in a mechanical press at 16 strokes/min. In figure 5a and 5b the weight variation for the both mixes is shown. The weight scatter is smaller for Starmix™ compared to the corresponding Premix. The results, measured on 300 parts, indicate that the bonding serves for more consistent and more even filling of the die, which reduces the scatter.

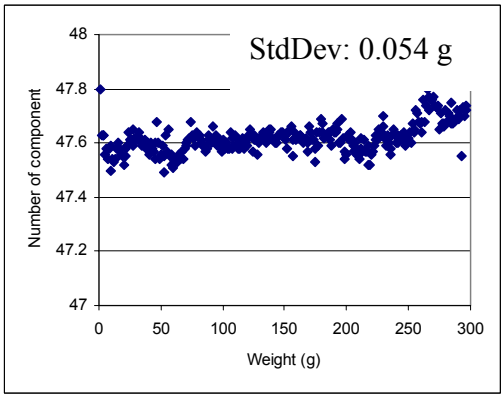


Figure 5a. Weight scatter. Premix. 16 strokes/minute

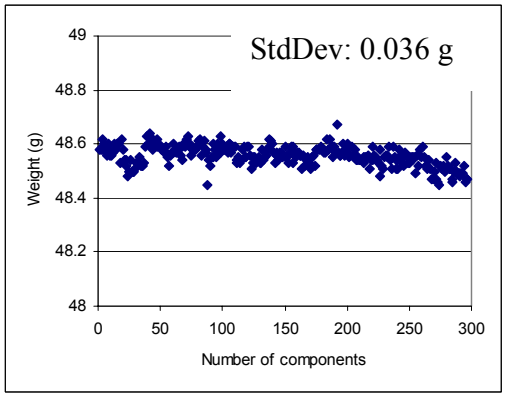


Figure 5b. Weight scatter. Starmix™. 16 strokes/minute

Mix 2.

In figure 6a and 6b the weight scatter for Premix and Starmix™ respectively is presented during compaction of a 28 teeth gear at 24 strokes/ minute. At this high compaction rate the filling of Premix is poor, which increase the scatter, while the good fillability of Starmix™ serves for limited scatter.

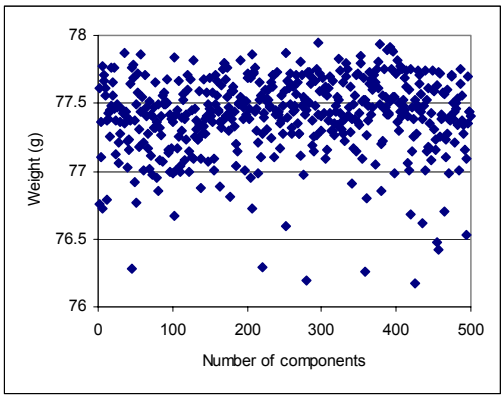


Figure 6a. Weight scatter. Premix. 24 strokes/minute

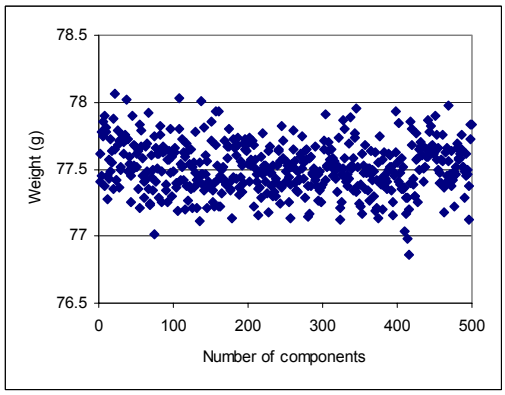


Figure 6b. Weight scatter. Starmix™. 24 strokes/minute

The weight scatter, presented as standard deviation, for Premix and Starmix™ at different compaction rates are further presented in figure 7.

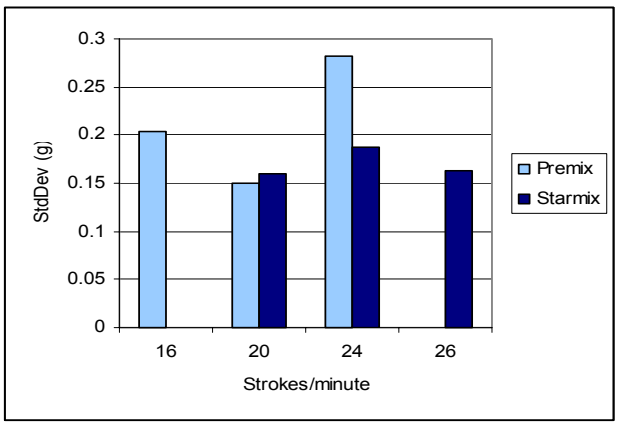


Figure 7. Weight scatter, mix 2, Premix/Starmix™

As indicated above the weight scatter of Premix increases at 24 strokes/minute. This is the maximal productivity limit for Premix. The weight scatter for Starmix™ is stable in the range 20 – 26 strokes/minute. Further increase in productivity was not possible due to press limitations.

The good and even fillability of Starmix™ also influences the dimensional scatter. In figure 8a and 8b the green height and diameter variation, presented as standard deviation, are shown. The height was measured at four different positions and the diameter in two. The dimensional variation for Premix increases with raised productivity, while the variation for Starmix™ is stable up to 26 strokes/minute. This indicates that it is possible to raise the production rate for this component to at least 26 strokes/minute with maintained tolerances, using Starmix™.

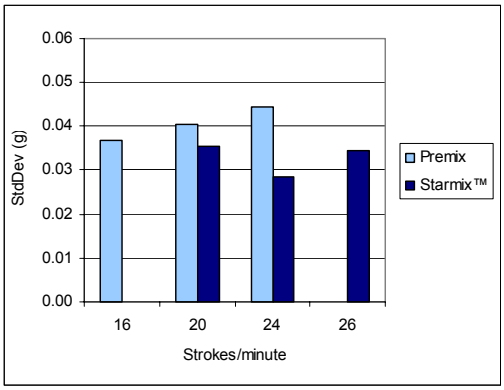


Figure 8a. Green height variation.

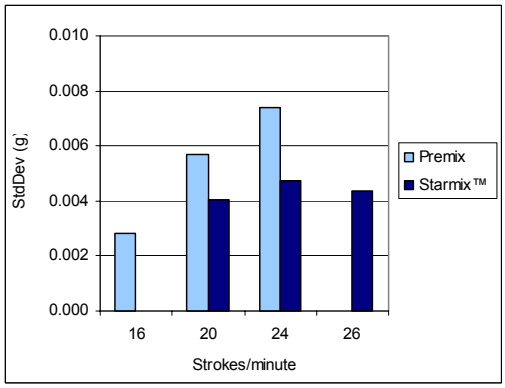


Figure 8b. Green diameter variation.

Mix 3.
The final production trial was performed at the European parts manufacturer. The weight scatter for Premix and Starmix™ at different compaction rates is presented in figure 9. At 16 strokes/ minute Premix fills incompletely, while Starmix™ performs well up to the speed limitation of the press. This final trial confirms that the improved fillability of Starmix™ compared to Premix results in narrow scatter even at high production rates.

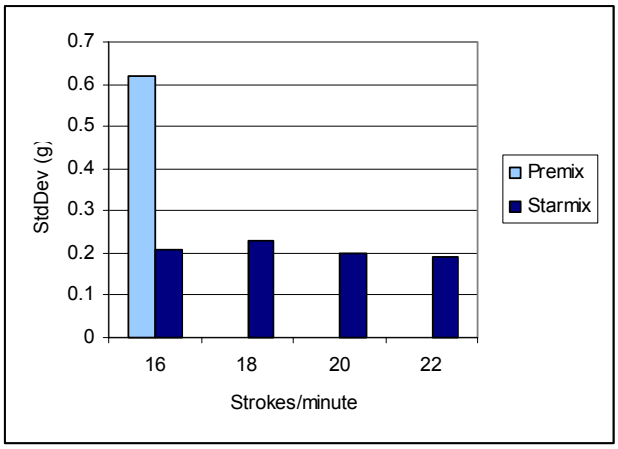


Figure 9. Weight scatter, mix 3, Premix/Starmix™

SUMMARY

Improved fillability of a powder mix gives advantages in weight scatter, dimensional control and productivity. Starmix™ is optimized to achieve an optimized filling behavior, stable apparent density and maximal bonding efficiency. In the present study it is shown that the performance of Starmix™ allows an increased productivity at maintained or even improved tolerances compared with corresponding Premix. The improved Hall Flow values indicate a faster flow behavior for the Starmix™ independent of powder composition. The gain in Hall flow values are dependent on the powder composition, but will in most cases be more than 25% compared with the non-bonded Premix.

Bonding of graphite is close to 100% and results in improved working environment in the workshops and serves for close dimensional control of produced parts.

Mechanical properties are in the same range for Starmix™ compared to Premix.

Independent of powder composition the use of Starmix™ enables increased productivity at close tolerances. This in turn may lead to decreased production- and quality costs.

CONCLUSIONS

- A bonding of graphite close to 100% is achieved by the Starmix™ concept. This serves for improved working environment around presses.
- Mechanical properties for Starmix™ are equivalent with corresponding Premix.
- Hall flow is faster for Starmix™ than corresponding Premix, independent of powder composition. In most cases Starmix™ flow values are more than 25% faster than Premix.
- Improved powder properties, e.g. fillability, AD and flow, of Starmix™ enables higher productivity at equivalent or even improved tolerances than corresponding Premix.

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