QUALITY AND PRODUCTIVITY IMPROVEMENT OF BELT PULLEYS BY USING HIGH PERFORMANCE BONDED MIXES

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ABSTRACT

Belt pulleys are commonly produced by the powder metallurgy process. The shape normally features a teeth section where a narrow and deep cavity is to be filled when the parts are pressed. With modern presses the performance of the powder mixes will often limit the productivity of the compaction process. Increased press rate will lead to distortion of shape due to uneven filling of the tool die. By using high a performance bonded mix filling is improved and the shape of the parts, e.g. parallelism and run-out, are improved in combination with increased productivity. In this paper results are presented from manufacturing of belt pulleys in a state-of-the-art hydraulic press. A high performance bonded mix is benchmarked with an elemental mix of the same nominal composition. Improvements in productivity as well as quality of sintered components are presented.

INTRODUCTION

With Starmix™, graphite as well as lubricant and other additives of fine particle size are bonded to the iron powder particles by utilizing an organic binder. By adhering the graphite and other additives control of carbon content is improved. With better carbon control, scatter in dimensions of the sintered parts and mechanical properties can be minimized. The working environment in press shops is also improved by decreasing the dusting of fine particulate additives. Benefits from using bonded mixes have previously been evaluated and reported. For instance, less influence on the fill density by the cavity size is described in [1], and in [2] and [3] decreased scatter in weight is reported.
This paper presents results from trials with the latest generation of bonded mixes, Starmix™ BOOST. Lubrication has been enhanced and powder properties have been further improved to give excellent filling behaviour. The lubricant and binder system is Zn-free and burns off without forming stains in the surfaces of the sintered parts.

The results presented are generated from production of belt pulleys at Metalsinter srl. Belt pulleys are common types of products produced by Powder Metallurgy, nevertheless some belt pulleys have geometries that are challenging from both filling and lubrication points of view with high and thin gear section. For this reason a belt pulley was selected for making a benchmark between Starmix™ BOOST and a premix of the same nominal composition with amide wax as lubricant.

EXPERIMENTAL

Press Technology

The press used in this investigation was a hydraulic CNC press TPA 160/3 HP. The tool set used to compact the water pump pulleys had three lower and two upper punches.

Materials

Two mixes were included in the investigation, see table 1 for designations of the mixes. The two mixes were of the same nominal composition, Fe + 1 % Cu + 0.4% Graphite + 0.75% lubricant. Both mixes were based on high compressible pure iron powder ASC100.29 and copper added as Distaloy ACu.

Table 1: Designations of powder mixes

Mix designation	Type of mix	Lubricant	AD (g/cm^3)	Flow (s/50 g)
A	Premix	Amide wax	3.02	30.3
B	Starmix™ BOOST	BOOST lubricant	3.24	24.4

Both mixes were manufactured in 500 kg scale. Mix B, the latest generation of bonded mix, was developed to give excellent filling performance, also manifested by high AD and fast flow.

Component

The part used in this investigation was a belt pulley; see Figure 1 for a drawing of the belt pulley. A number of key dimensions were measured on the belt pulleys to control the consistency of dimensions and the shape. In Figure 1 to the right the positioning of the measurements and nominal dimensions are indicated.

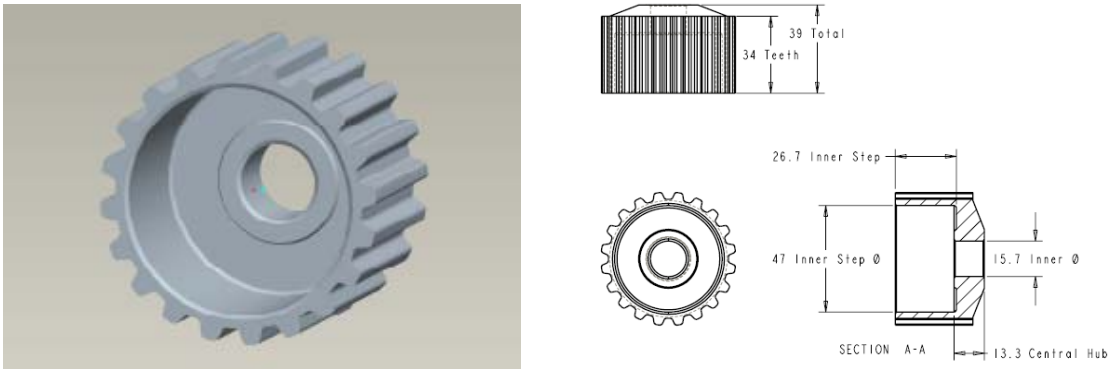


Figure 1: Drawings of the belt pulley

The nominal density of the belt pulley was 6.7 g/cm^3 and the nominal weight was 272.5 g. The outer diameter was 59 mm and the height of teeth section was 33.8 mm.

Compaction

The filling mode was gravity filling. A counter pressure of 120 kN by the upper punch was used during the ejection. Directly after the ejection temperature of the parts was measured. Press force, ejection force and weight were registered automatically by the control system of the press. Registered weight data were used in a control loop for the fill height. When three consecutive parts were outside +/- 0,3% of the nominal weight, fill height was automatically adjusted. Parts outside +/-0,8% of the nominal weight were automatically scrapped. Mix B was pressed both with and without cooling of the tool die. Cooling of the tool die mainly influenced the ejection properties and results from both trials will only be presented for the lubrication, otherwise results from the trial with cooled tool die is presented for Mix B.

Sampling plan

Each test run included a continuous run of 250 parts. Groups of 3 parts were sampled after 22, 47, 72, 97, 122, 147, 172, 197, 222 and 247 parts had been pressed. Altogether 30 parts were sampled from each test run.

Sintering conditions

The parts were sintered in a production furnace at Metalsinter. Sintering temperature was 1120°C for ~20 min in endogas with 0.6% C-pot.

Measurement of scatter and accuracy of dimensions

Heights of the parts were measured as indicated in Figure 1. Heights of the teeth were measured on four positions on each part, turning the part 90° between each measurement.

The difference between the highest and lowest value was calculated as a measure of the parallelism of the parts. Run-out was measured by placing the parts on a lash-free axis, rotating them and registering the maximum difference in radius by an indicator. Run-out includes both roundness as well as the centering of the hole. Dimensions of the parts were measured on the parts in green and in sintered state.

RESULTS

Initially press rate setting with Mix A was 8.7 parts/minute as this was judged to be the maximum speed to have good weight consistency with the Premix. With higher press rate, filling of the tool die was incomplete.

With Mix B a press rate of 10.7 parts/minute was possible. At this rate filling was complete but an increase in weight scatter and run-out of the pressed parts was noted. The press rate was then decreased to 9,1 parts/minute to compare the potential improvement in quality that can be achieved by Mix B without sacrificing productivity.

Weight stability

The weights of the pressed parts are presented in Figures 2 and 3. It can be seen that the weight stability of Mix B was superior to that of Mix A. Mix B was better both regarding random scatter and stability in weight. Due to the automatic weight control two adjustments of the fill height were made for Mix A and one adjustment was made for Mix B, this is also indicated in the Figures.

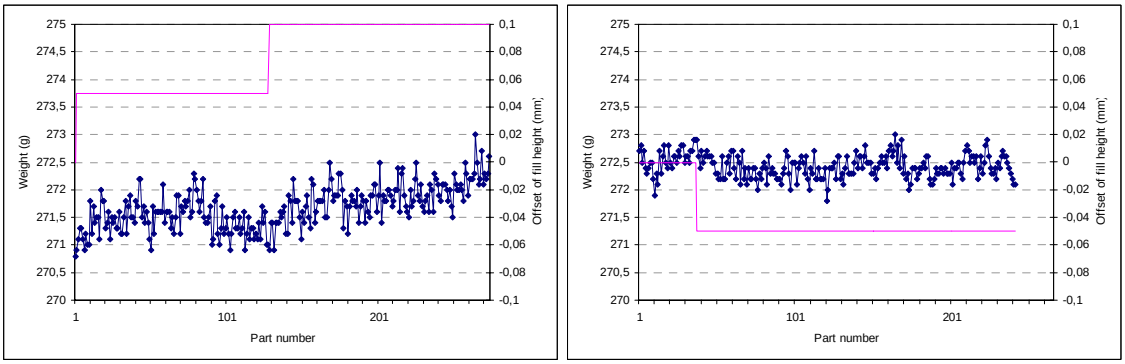


Figure 2 and 3: Weight of pressed parts and fill height adjustments of Mix A and Mix B

The weight scatter expressed as one standard deviation and as moving range is presented in Figure 4. More improvement was found for the standard deviation than in the moving range. The reason for this was that Mix B did not exhibit trends in the weight as Mix A did.

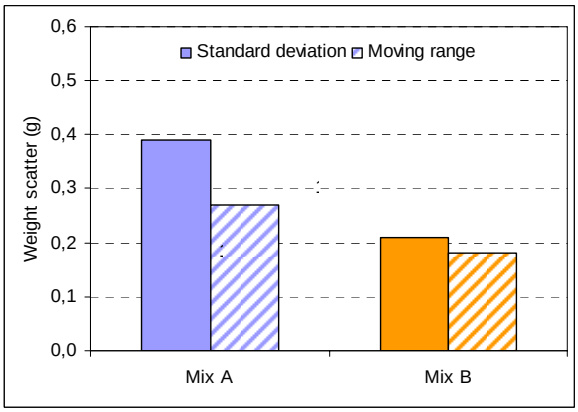


Figure 4: Weight scatter expressed as standard deviation and moving range

Lubrication

The belt pulley used in this investigation was a challenging part regarding lubrication due to the high and relatively thin gear section. In Figure 5 the peak ejection force is presented. With Mix B the peak ejection force was decreased by 24%. When cooling of the tool die was used the ejection energy for Mix B was 13 kN higher. Lower peak ejection force decreases the stress on the green part during ejection. With lower peak ejection force due to improved lubrication the risk of crack formation during ejection of the parts is decreased.

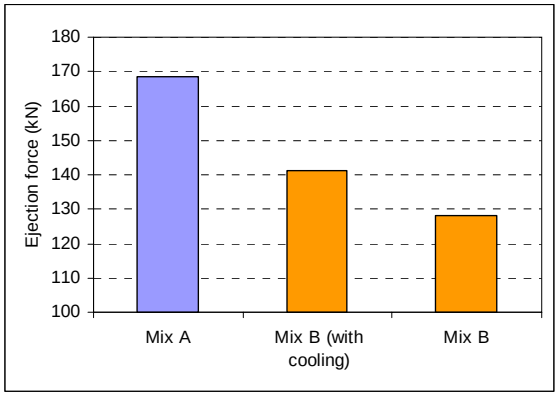


Figure 5: Peak ejection force

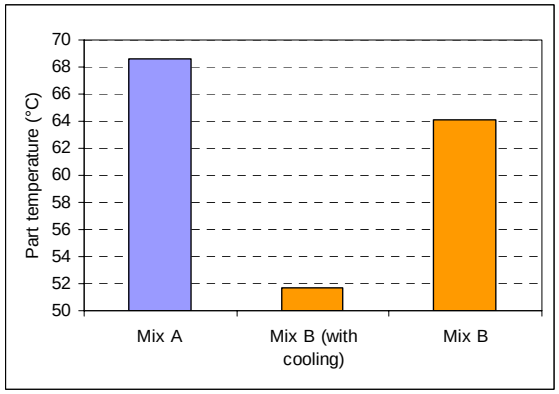


Figure 6: Temp. of the parts after ejection

During the ejection the energy required to eject the parts will to a large extent transform to heat. The temperature of the parts after ejection is thus a good indication of the ejection energy required. Measured temperatures are presented in Figure 6, parts of Mix B were 4°C colder compared to parts of Mix A. With better lubrication risk of scoring of the surface of the parts is decreased. With cooling of the tool die parts of Mix B were 12°C colder after ejection, but as shown in Figure 5 the lubrication was then less efficient.

Scatter in dimensions

Dimensions of the parts were measured on green and sintered parts. Scatter in average tooth height is presented in Figure 7. Each part was measured in four positions, the average of the four values was calculated and the scatter in the average heights was calculated for the sampled parts. For each mix the scatter was more or less the same before and after sintering. The scatter in tooth height of Mix B was significantly smaller compared the Mix A.

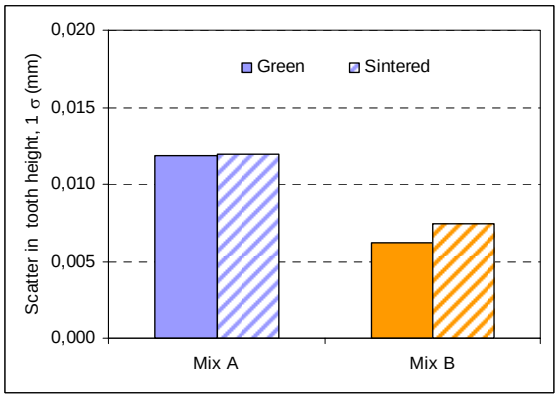


Figure 7: Scatter in average tooth height

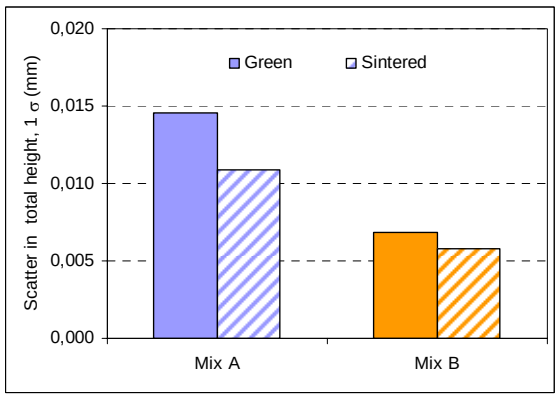


Figure 8: Scatter in total height

In Figure 8 the scatter in total height of the belt pulleys is presented. Also here the scatter in total height of parts made of Mix B was half the scatter of the parts made of Mix A.

The filling of the central hub of the belt pulley was less challenging from the filling point of view, as the section was wide and not so high. Consequently, height stability for Mix A was

better than for other sections and the room for improvement was smaller. Mix B was somewhat better before sintering and somewhat worse after sintering, see Figure 9.

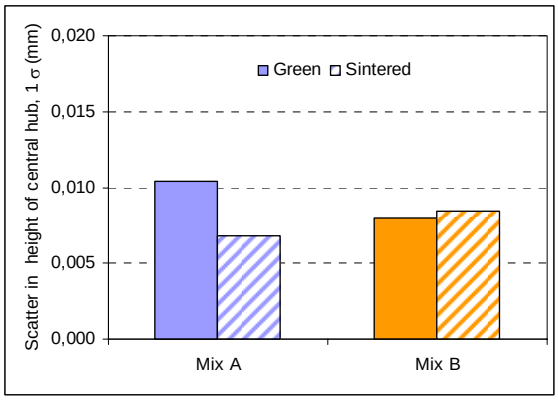


Figure 9: Scatter in height of central hub

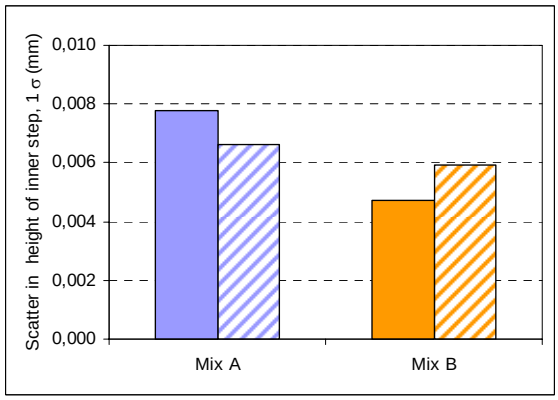


Figure 10: Scatter in height of the inner step

In Figure 10 the scatter in the height of the inner step is presented. Mix B was better than Mix A, the difference was, however, small after sintering.

Accuracy in geometry

Two parameters reflecting the accuracy in the geometry of the parts were considered in the trials; plane parallelism and run-out. The difference in tooth height, i.e. difference between the highest and lowest value measured on sampled parts, is a measure of the plane parallelism of the parts, see figure 11 for results. In green state Mix B exhibited an average difference in teeth height that was half compared to Mix A. After sintering the difference between the mixes was less but Mix B was still 27% better.

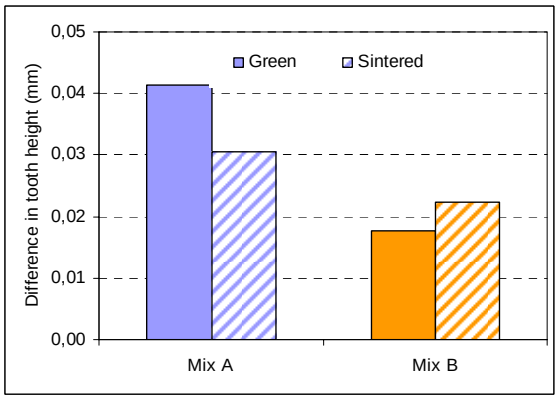


Figure 11: Difference in tooth height

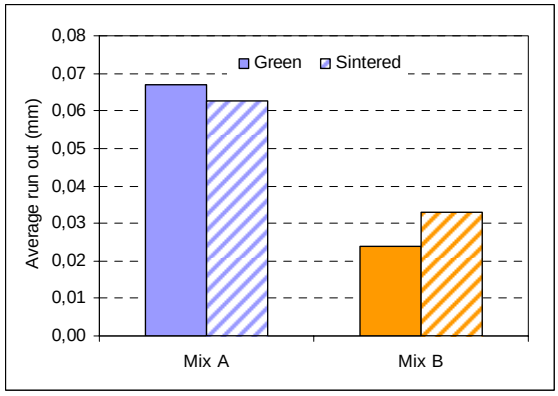


Figure 12: Run-out

Run-out includes both out-of-roundness of the parts as well as centering of the hole. Uneven filling of the tool die may lead to the core rod of the tool die being pushed in a direction where fill density of the powder is lower. In Figure 12 results of run-out are presented. The run-out of parts pressed of Mix B was significantly less compared to parts pressed of Mix A, both in green and sintered state.

Process capability

The process capability has been calculated for the green parts based on the specifications for the component and the standard deviations, see Figure 13 where the Cp values for weight and heights are presented. Cp only takes the scatter and not the level into account. This is the most fair comparison since the levels of these parameters are determined by the settings of the press. Run-out is different; the level of average run-out is an important parameter that cannot be as easily adjusted on the press as the weight and heights. For this

reason the Cpk value, which takes both the scatter and level into account, was calculated and presented for run-out. In Figure 13 it can be seen that the capability was 25% - 100% higher when belt pulleys were produced by Mix B instead of Mix A.

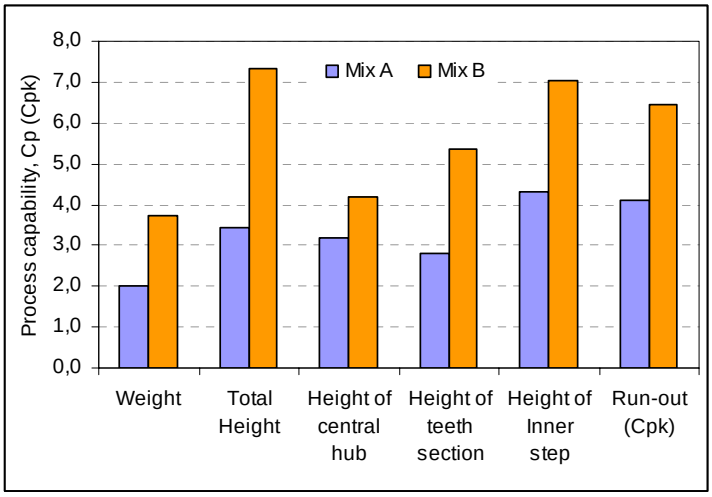


Figure 13: Process capability of green parts

Capabilities with Mix A are sufficient for the specifications of the component today. If tighter specifications are required for a component, the use of Mix B can be a way to produce with high enough process capability to ensure the quality without scrapping components that are out of specification or having to employ inspection of all components.

CONCLUSIONS

Starmix™ BOOST has been benchmarked with a premix with amide wax as lubricant in production of belt pulleys.

- Lubrication was superior manifested by lower peak ejection force and lower temperature of the parts after ejection
- Weight scatter was decreased
- Scatter in height was decreased
- Run-out and plane parallelism was improved

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