The new benefits of binder lubricants

Joseph Capus looks in on a session on binders taking place at the PowderMet 2011 conference in San Francisco and reports on what's new in the field of binder lubricants in PM processing.

Much of the progress in PM applications during the past few decades has been influenced not only by the developments in metal powders and the processes employed to turn them into useable components, but also by the development of new binder-lubricants. Incorporating small quantities of special organic substances, such as resins, into PM mixes with iron powder, other metallic ingredients, graphite and lubricant, was found to enable dusting to be reduced by "glueing" or bonding the finer particles like graphite to the larger iron particles. Powder metallurgists brushed up on their organic chemistry with the result that a variety of proprietary binder materials and processes were developed by the major powder suppliers in Europe, North America and Japan. As these developments have progressed, multiple benefits have been revealed. Binder treatments have evolved from merely improving dusting and segregation characteristics of powder mixes to improving pressing and ejection of parts, green strength, green density, as well as uniformity of sintered parts, etc. Some of these aspects were covered in a session on binders at the PowderMet 2011 conference in San Francisco.

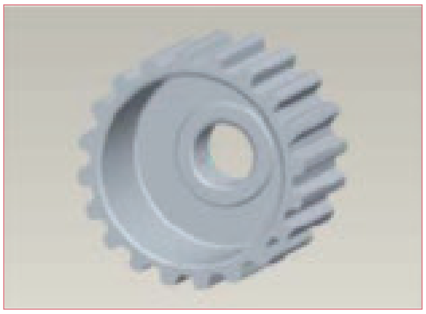

Figure 1: PM water pump pulley component used in production trials. (After Warzel et al.)

Table 1: A.D. and Flow Rate of Trial Mixes Used in Lubricant/Binder Comparison. (After Warzel et al.)

Lubricant	A.D. (g/cm³)	Flow Rate (sec/50 gm)
Amide Wax	2.90	31.3
Amide Wax/Std Starmix®*	3.09	25.0
Starmix® BOOST	3.24	24.4
X-Starmix®	2.95	28.8

*Starmix is a registered trademark of Höganäs AB.

Since the introduction of resin-bonded pre-mixes nearly thirty years ago, initially to alleviate dusting and segregation of fine particles, a variety of additional improvements have been made, resulting in significant performance enhancement. As Roland Warzel and co-authors from North American Höganäs and its Swedish parent company, pointed out, competition from other manufacturing options requires continuing efforts to improve efficiency in PM fabrication, such as in dimensional precision, etc., where binder treatment now plays an important role. In their presentation [1] they reviewed test results in which three different binder formulations were compared with a conventional pre- mix with plain Acrawax as lubricant in the production of water pump pulleys. In the manufacturing trials, conducted at Merisinter, Italy, each of the four mixes were composed of ASC 100.29 atomized iron powder plus 1% copper (as a 10% Cu diffusion alloy) and 0.4% graphite. The lubricant in the conventional mix was 0.75% amide wax, while the three bonded mixes had 0.75% of proprietary resin-binder/lubricant formulations: standard Starmix®, Starmix® BOOST, and a new experimental binder-lubricant called X-Starmix®. Apparent density and flow rate of the mixes were checked before compacting in a Dorst 160 ton hydraulic press. The press was instrumented to measure and record the ejection forces. The water pump pulleys were manufactured using standard procedures, compacting to a density of 6.70 g/cm³ at a rate of 8.7/min (about 520/hr). Each test mix ran for 250 parts, with three samples being taken every 25 parts. Samples were sintered in a production mesh-belt furnace at 1120°C for 20 minutes in Endogas atmosphere with a carbon potential of 0.6%.

Results showed that the choice of lubricant/binder had a significant influence on the A.D. and flow rate (Table 1), with all the bonded mixes having superior flow and A.D. compared with the conventional lubricant premix. The best results were found with Starmix BOOST. The precision of the compacted parts correlated well with the flow-rate data (Figure 2). The ejection force was less strongly affected by the lubricant/binder choice, with the two amide wax and amide wax/

Table 2: Properties of ANCORBOND Mixes.											
	Apparent Density	Flow	Green Density	Green Strength	Green Expansion	Strip	Slide	Sintered Density	DC	TRS	Apparent Hardness
Material	(g/cm3)	(secs)	(g/cm3)	(MPa)	(%)	(MPa)	(MPa)	(g/cm3)	(%)	(MPa)	(HRA)
Premix	3.06	35.8	7.21	15.4	0.15	34.2	18.9	7.23	0.06	961	44
ANCORBOND	3.21	27.6	7.20	20.0	0.15	28.8	15.1	7.16	0.06	961	44
ANCORMAX200	3.33	25.5	7.34	26.3	0.11	29.2	17.7	7.35	0.08	1023	46
ANCORMAX450	3.28	26.2	7.47	33.9	0.22	22.8	22.8	7.49	0.11	1100	41

Note: Ancormax450 mix has 0.40 w/o graphite to lower PFDTRS

binder mixes showing higher values than Starmix BOOST and X-Starmix. The part temperature on ejection followed a similar correlation, with the X-Starmix results running an average 10°C lower than the amide-wax-based mixes. Dimensional measurements of the pulleys after sintering confirmed the influence of lubricant type on the precision of the parts. Both the tooth height and run-out measurements (Figure 3) showed a direct correlation with the A.D. and flow data for the powder mixes. Run-out was significantly reduced for the bonded mixes, with the best performance obtained with the Starmix BOOST.

Green strength improvements

A similar comparison of different binder systems was presented by Chris Schade and colleagues of Hoeganaes Corp[2]. They drew similar conclusions and noted that the initially perceived benefits of reduced segregation and dusting, together with improved die fill, were expanded into higher green strength and other advantages. The authors made a comparison of alternative approaches to the suppression of dusting and segregation using a mix composition based on FN-0205 (iron + 2% nickel + 0.6% graphite). In a laboratory study of compaction and sintering they compared the performance of various binder/lubricant combinations: oils, epoxies, and polymers, as well as Hoeganaes own proprietary binder/lubricant systems. While they found that the use of oil, epoxy or polymer additives were generally quite effective in reducing dusting, other factors such as lubricity were rather variable. The proprietary ANCORBOND® binder material "was designed primarily

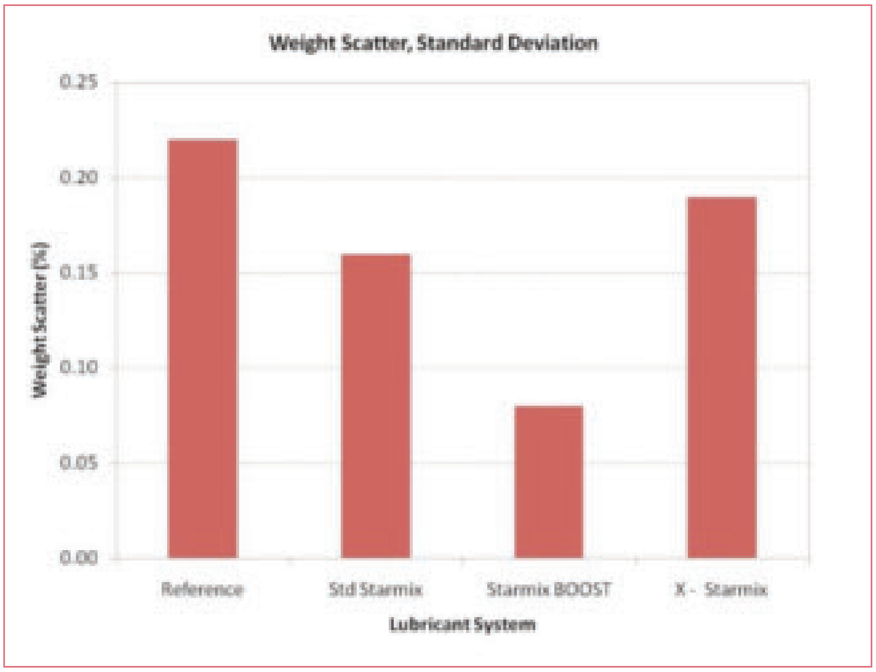

Figure 2: Weight scatter (measured as one standard deviation) of compacted parts. (After Warzel et al.)

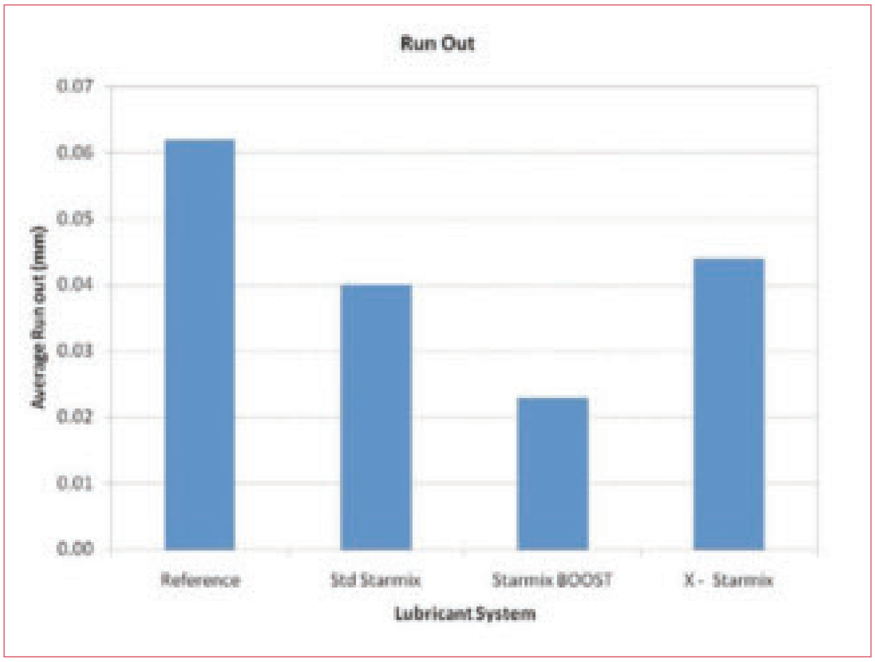

Figure 3: Average run-out measurements for sintered pulleys. (After Warzel et al.)

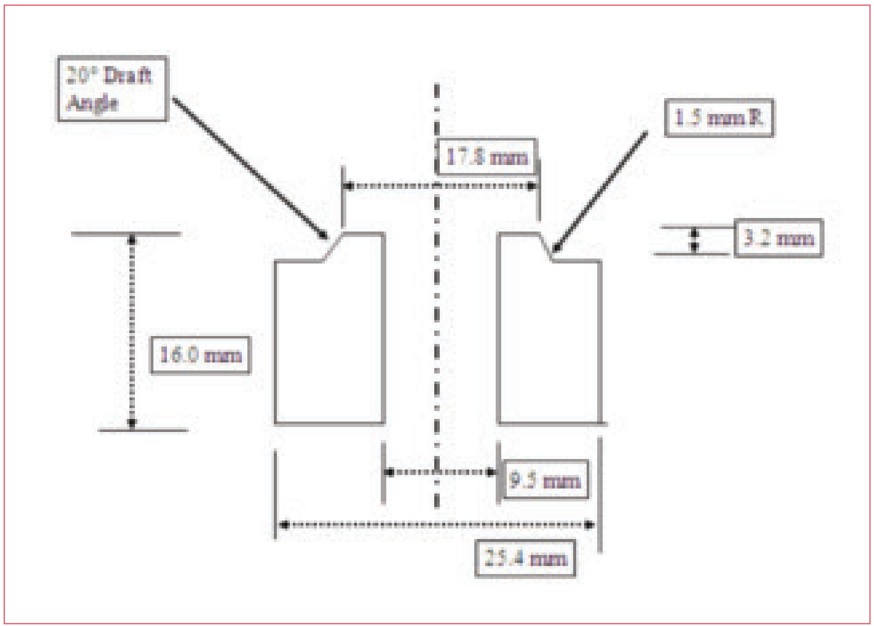

Figure 4: Cross-section diagram of cylindrical part evaluated in die-wear tests. (After Hanejko et al.)

to [enhance] flow and die fill while simultaneously giving reduced dusting and reduced part to part variability". Initially, the binder was used in addition to the pre-mix lubricant. This resulted in a limitation of the achievable pressed density due to the lower pore-free density. The trend to higher performance PM parts required higher densities and led to the development of second-generation ANCORBOND with a lower combined lubricant and binder content. This was accomplished by using "a polymeric binder that had both binding and lubricating characteristics". The second generation ANCORBOND enabled up to 0.1 g/cm³ increased pressed density compared with conventional pre-mixes, while maintaining the benefit of increased press rates (of up to 25%), with enhanced powder flow plus increased material consistency. Details of the comparison of the second generation ANCORBOND mix with an Acrawax mix are given in Table 2. Further developments designed to achieve even higher densities, such as the heated die system ANCORMAX™200 and warm compaction (e,g, ANCORDENSE™450) led to additional increases in sintered density and strength (Table 2), as well as improvements in green strength and ejection characteristics.

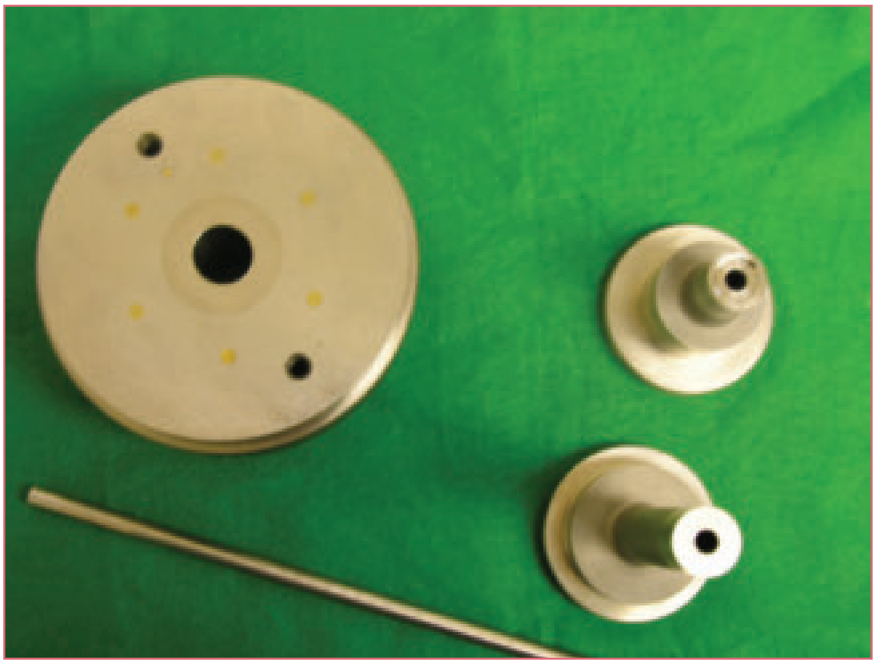

Figure 5: Die set used in die-wear tests. (After Hanejko et al.)

Reduced die-wear

Further developments in binders have resulted in additional, possibly unexpected, benefits. Francis Hanejko and colleagues from Hoeganaes reported in another presentation on the reduced die-wear achieved in the compaction of iron-ferrophosphorus pre-mixes by the use of a new enhanced binder material. [3]

Sintered Fe-FeP PM compositions (MPIF Std FY-4500) find applications in DC magnetic components such as speed sensors, DC solenoids, DC flux-return parts, etc., where high DC permeability and low coercive force are required. FY-4500 materials can be produced by pre-mixing high-purity iron powder with fine Fe_2P or Fe_3P powders. Unfortunately, these intermetallic materials have very high hardness in the region of HV 1000-1050 compared with the particle hardness of iron powder (about HV 100). As a consequence, pre-mixes containing these hard particles can be very abrasive to the compaction tooling, causing accentuated die wear. Hanejko et al. quoted reports that many PM fabricators using FY-4500 pre-mixes had to re-face compaction tooling after only 20,000 pieces.

In previously reported tests [4], it was found that the abrasive effects of Fe_3P particles could be minimised by an experimental chemical binding system. Laboratory compaction tests showed a reduction in strip-and-slide ejection pressure compared with the binder system currently in commercial use. Additional data showed that the mechanical and magnetic properties were equivalent to those found with the existing material. In the San Francisco presentation, results were shown for die wear characteristics found with the new advanced binder system compared with the currently-used binder in simulated production. Two 4500 kg FY-4500 test mixes were prepared: the standard binder-treated FY-4500 in commercial production, and an FY-4500 pre-mix made with the advanced binder system. The cylindrical part (Figure 4) was compacted to 6.95-7.05 g/cm³ in a Dorst TPA 140 mechanical press, at a rate of 700 pieces/hour. Two identical tool-steel die-sets (Fig.5) were used and the parts were compacted at room temperature, running continuously for 8 hours each day until about 25,000 parts were made. Samples were collected every 200 parts. After compaction, samples were sintered at 1120°C for 20 minutes in 90/10 nitrogen/hydrogen. Samples were checked for green and sintered I.D. and O.D., top step change, and overall surface appearance. Test results showed no difference in the mixes regarding A.D., flow rate, compressibility or green strength. Also, magnetic testing of sintered toroids showed no deleterious effect of the advanced binder system, while other sintered properties were similar.

Surface temperature measurements during the compaction trial showed that the parts made with the enhanced binder had a maximum temperature of 60°C at ejection, compared with 68°C for the regular mix. The advanced binder mix ran for 25,000 parts with no tool-binding or excessive noise during compaction or ejection. The commercial binder mix ran into tool-binding after about 23,000 pieces and the trial was stopped. More detailed examination of the compaction performance revealed numerous advantages for the new enhanced binder, "Most significant [of these] were reduced wear of the core rod (~75% reduction) and top punch, [which] manifested itself through reduced flashing of the parts over the production run and elimination of die incidents when the advanced material was compared to the conventional product." Enhanced lubrication of the new binder system was evidenced by the lower part ejection temperature. Surface finish was also improved by the new binder (Fig.6) due to reduced scoring.

The authors concluded that the bottom line was longer tool life projected for the new binder system because of reduced die-wear. "Longer tool life translates into reduced production cost through reduced die maintenance and greater 'up-time' during production".

References

[1] R. T. Warzel, S. Luk, M. Larsson, and P. Knutsson, "The Capability of a Bonded Mix to Improve the Precision of a Powder Metal (PM) Component", presented at PowderMet 2011 in San Francisco.

[2] C. Schade, M. Marucci, and F. Hanejko, "Improved Powder Performance Through Binder Treatment of Premixes", presented at PowderMet 2011 in San Francisco.

[3] F. Hanejko, W. Tambussi, and J. Baumgartner, "Evaluation of Die Wear Characteristics of FY-4500 Materials Utilizing a New Binder System", presented at PowderMet 2011 in San Francisco.

[4] F. Hanejko and W. Tambussi, "Use of Binder-treated Ferrous PM Pre-mixes for improved PM Part Production and Part Density", presented at PM 2010 World Congress, Florence, Italy.