High Performance Iron Powder Mixes for High Density PM Applications

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Abstract

The achievement of high density at reasonable cost is one of the major challenges of the P/M industry. One of the key factors contributing to the compressibility of a mix is the lubricant. New experimental lubricants enabling higher green density by conventional compaction or temperature-controlled die compaction were identified. The compaction and ejection characteristics of these new lubricants as measured with a fully instrumented lab press are presented and compared to that of conventional lubricants.

Keywords: **Compressibility, Lubricants, High-density, Iron powder mixes**

1. Introduction

A lot of efforts were done during the last decades to improve densification by single compaction. Warm pressing (WP) and die wall lubrication pressing (DWL) were specifically developed for that reason, densities in the range of 7.25 to 7.50 g/cm³ being reported [1]. In comparison, densities achieved by cold compaction of mixes with conventional lubricants are normally limited to 7.2 g/cm³. Nevertheless, even if WP and DWL have great potential, their usage in the PM industry is quite limited likely because of the greater difficulty to control them in a production environment.
Efforts were spent more recently to develop more performing lubricants for cold compaction or temperature-controlled die compaction, which is the process of pressing non-heated powder in a heated die. This paper describes the behavior of new lubricant systems, LubeA and LubeC, specifically designed for these two pressing methods as determined with a fully instrumented and powerful compaction device.

2. Experimental and Results

FN0205 mixes were prepared with ATOMET 1001 and various lubricants. The compaction characteristics of mixes were determined with an instrumented single action compacting press known as the Powder Testing Center (PTC) [2]. This lab press allows continuous recording of the moving punch displacement and pressures to the moving and stationary punches all along the compaction and ejection processes. Pressures at the moving and stationary punches are used to estimate the slide coefficient, a measure of the friction at die walls, and the net pressure (Pnet), the true compacting pressure seen by the compact. The relation between density and Pnet gives the true compressibility of a material. Better description of the analytical method is given in ref 3. Slug specimens 10 mm tall were pressed in a 9.525 mm diameter HSS tool at 60°C and a rate of 1 mm/sec.
Table 1 summarizes the characteristics of mixes pressed at 830 MPa. All mixes contained 0.6% lubricant except the one with wax that contained 0.75%. LubeA and C gave higher green density than the two other lubricants, 7.35 g/cm³ for LubeA versus 7.21 g/cm³ for Wax. The higher density of LubeA and C cannot be directly related to a higher Pnet as sometimes observed [3]. Indeed, very similar slide coefficients, and thus, Pnet were obtained at 830 MPa for all the mixes. Figure 1 gives the true compressibility curves for all systems. For Wax and Kenolube, density leveled off when pressure was important, which is typical. However, for LubeA and C, density continued increasing more significantly as pressure increased at high pressure. This is explained by the fact that these lubricants move easily to the die walls when sufficient pressure is applied.
Figure 2 shows the slide coefficient as a function of density. It is seen for Wax and Kenolube that the slide coefficient was particularly low at density of ~ 6.0 g/cm³ but increased with the In-Die density. On the contrary, slide coefficient for LubeA and C was already very high at low density and remained almost unchanged during the compaction process. This confirms the better lubricating properties of these lubricants, which ensures a better transfer of pressure throughout the part.

Table 1. Compaction and ejection characteristics of various lubricants (FN0205 mixes pressed at 830 MPa).

Lube system	*G.Dens. g/cm³*	*Slide Coef*	*P_{NET} MPa*	*Stripping MPa*	*Sliding MPa*
0.75 Wax	7.21	0.73	700	30.7	19.2
0.6 Keno	7.26	0.75	712	28.2	12.5
0.6 LubeA	7.35	0.76	718	34.9	19.4
0.6 LubeC	7.31	0.81	739	27.0	12.4

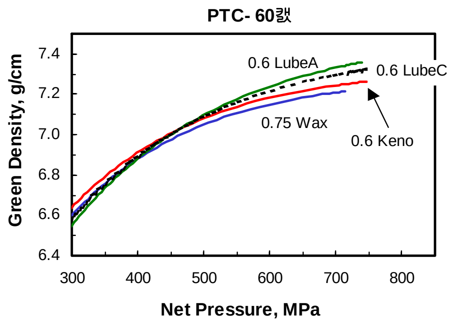

Fig. 1. True Compressibility curves for FN0205 mixes.

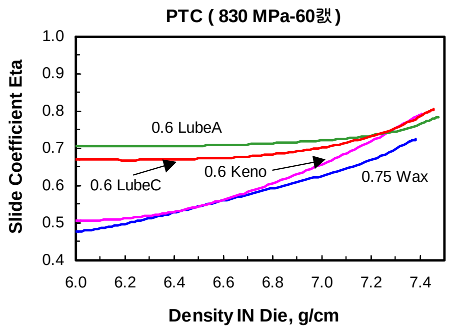

Fig. 2. Slide coefficient as a function of density In-Die (FN0205 mixes).

It is also seen in Table 1 that the ejection performance of 0.6% LubeA was similar to that of 0.75% Wax but not as good as 0.6% Kenolube. Based on that, it is believed that the ejection performance of LubeA should be sufficient for low aspect ratio parts (short length) but would be probably not good enough for parts with higher aspect ratio. LubeC showed much better ejection performance than Lube A, the stripping and sliding shear stress being similar to that of Kenolube. The sliding shear stress of 0.6% LubeC was 35% lower than that of 0.75% Wax.

Figures 3 shows the effect of level of LubeC on green density and sliding shear stress for specimens pressed at 830 MPa and 60°C. In Fig. 3a, reducing the level of LubeC led to an increase in green density, up to 7.35 g/cm³ at 0.5%. On the other hand, it is also seen that increasing the lubricant content up to 0.7% had almost no detrimental effect on green density. This is explained by the fact that lubricant is expelled out of the part at high compacting pressure.

Reducing the level of LubeC from 0.6 to 0.5% led to a slight increase in the ejection in Fig 3b. Nevertheless, it remained significantly lower that the sliding stress achieved with 0.75% Wax and 0.6% LubeA at 830 MPa. The ejection performance of 0.5% LubeC at 830 MPa is even comparable to that of 0.75% Wax pressed at 620 MPa, clearly showing the very good lubricating properties of that new lubricant system. Based on that, we could expect a very good performance on production press, even for high aspect ratio parts.

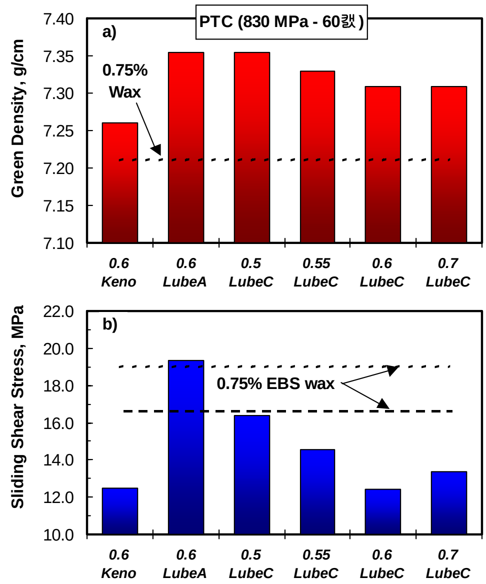

Fig. 3. Compressibility (a) and ejection (b) of FN0205 mixes with various levels of lube C in the PTC.

3. Summary

New experimental systems showed very good compaction and ejection behavior, with gain in density of 0.10 to 0.14 g/cm³ versus EBS wax. Next steps are validation of these lubricants on a production scale.

4. References

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