Design of High Efficiency Lubricants for Challenging PM Applications
St-Laurent, Sylvain; Paris, Vincent; Thomas, Yannig

Euro PM2011 Conference Proceedings, 2011-10-12

Design of High Efficiency Lubricants for Challenging PM Applications

Sylvain St-Laurent[1], Vincent Paris[1] and Yannig Thomas[2],

[1]Rio Tinto Metal Powders, 1655 Marie-Victorin Rd, Sorel-Tracy, Quebec, Canada, J3R 4R4
[2] NRC-IMI, 75 de Mortagne Blvd, Boucherville, J4B 6Y4, Québec, Canada

ABSTRACT

As powder metallurgy usage broadens, the pressure is on to deliver challenging parts with higher densities or more complex shapes. This, in turns, requires more sophisticated powder mixes and high performance lubricants. In the case of high-density parts, the lubricant content must be decreased in order to ease compaction and reach higher densities. This requirement calls for lubricants that can provide the same level of lubrication at much lower concentrations than the traditional lubricants. With more complex parts, including tall or multi-level parts, the sliding distance before parts are released from the die might increase, calling for a lubricant that offers superior lubrication. This paper exposes the development work that has been conducted on new lubricant formulations. It focuses mainly on the compaction and ejection performance of various lubricating systems designed around a high potential lubricant as evaluated with an instrumented industrial press at high shear rates. The results were compared to commonly used lubricants in the PM industry.

INTRODUCTION

The growth of the PM market is linked to a large extent to the production of more and more complex parts with improved sintered properties and higher densities in a cost competitive way. As an example, it is reported that the density of synchroniser hubs has increased from 6.9 g/cm³ in 2000 to 7.1 g/cm³ in 2010 [1]. However, compaction of parts with complex geometry, high aspect ratio and surface area in contact with the die or higher densities is more challenging and requires high performance powder mixes. On the other hand, parts manufacturers also require better surface finishes together with a reduced dependency on metal stearates or zinc-based lubricants. Many factors affect the compaction behaviour of pre-mixes but lubricant is by far one of the most critical one. This explains why so much effort is devoted to the development of new lubricants with improved lubricating properties as compared to conventional ones (EBS waxes, Zn stearate and Kenolube).

The role of lubricants in powder metallurgy is complex. The lubricant must reduce the internal friction between the particles and at the die wall during compaction so that most of the energy is available to press the part rather than lost as thermal energy. It also plays a significant role during the ejection cycle, where performing lubricants will ease ejection therefore contributing to smoother surface finishes. The lubrication at the die wall is directly proportional to the amount of lubricant admixed in the powder. It is therefore not difficult to achieve better ejection characteristics by simply increasing the lubricant content. However, due to their very low specific gravity, the internal lubricant has also a strong effect on the maximum density that can be reached during compaction, which corresponds practically to about 98% of the theoretical pore free density of the mix. On the other hand, lubricant burn-off in the pre-heat zone of the sintering furnace is also affected by the density reached and the quantity of lubricant in the part. Sintered properties can also be negatively affected by high levels of lubricant. For these reasons, it is therefore critical to limit as much as possible the quantity of lubricant that is added to powder mixes. What is lost in quantity must therefore be compensated by a much higher efficiency, in order to maintain the compaction and ejection properties. It is not uncommon to add as little as 0.3 to 0.4% by weight of lubricant when densities in the vicinity of 7.35 g/cm^3 are targeted.

The properties of some experimental lubricants, characterised by lower softening point than EBS wax or Zn stearate, were described in several papers presented in the last decade [2, 3]. It has been shown that significant density gains can be achieved with such lubricants when low compacting temperatures – about 60 to 70°C – are used. These lubricants also provided

Sintered properties were also evaluated. Standard TRS specimens were pressed at 7.2 g/cm³ and 80°C and sintered at 1140°C for 25 minutes in a 90% N_2 -10% H_2 atmosphere.

RESULTS AND DISCUSSION

1. Compaction and Ejection Performance

The excellent densification and lubrication behaviour of lube HD-C when pressed at temperature of 70°C or above and at relatively low compacting rate was already presented by St-Laurent et al. [4]. Table 2 shows the results obtained on the PTC (WC-Co die, 60°C and 830 MPa) for two references and mix HD-2/0.55. Mix HD-2 gave slightly higher green density than the two reference mixes. The lubrication was comparable to that of Kenolube and significantly better than that of mix with EBS wax even if the level of lubricant in mix HD-2 was 0.15% lower.

As mentioned in the introduction, the aim of this work was the validation of the compaction

Mix Name	G. Density, g/cm³	Slide Coef.	Stripping P., MPa	Sliding P., MPa
Ref-K	7.29	0.75	24.5	12.5
Ref-W	7.29	0.66	40.2	19.8
HD-2/0.55	7.33	0.80	19.2	14.4

Table 2. Results of tests carried out with the PTC in a WC-Co Die at 830 MPa and 80°C.

and lubrication performance of Lube HD-C at higher compacting rate typical of the PM industry. The following paragraphs discuss the results obtained with a mechanical press.

Compaction tests with Vancron 40 Die

Figure 1 shows the compressibility curves of mixes pressed at different temperatures in a Vancron 40 die. At room temperature, mix Ref-K gave the best compressibility, about 0.05 g/cm³ higher than that of mix HD-2/0.55. However, this behaviour was inverted when the die was moderately heated to 60°C. Mixes containing lubricant HD-C gave slightly higher green densities than Ref-K at all pressures used.
The density gain obtained with HD-2/0.55 and HD-3/0.55 when the die temperature was increased from room temperature to 60°C was quite significant, varying between 0.12 to 0.20 g/cm³. In comparison, the gain in density was only half that improvement for Kenolube.

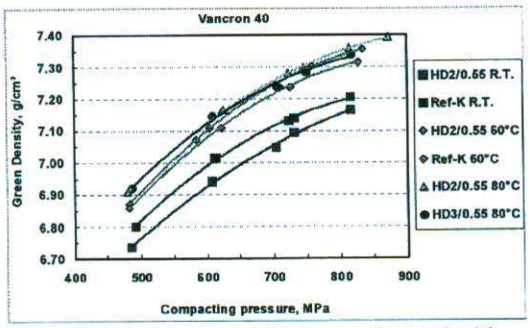

Figure 1. Compressibility curves obtained with a Vancron 40 die.

The maximum ejection pressure as a function of density and temperature is shown in Figure 2. At room temperature, mixes Ref-K and HD-2/0.55 gave very similar ejection values. Also, ejection pressure tends to level off at high compacting pressure for both mixes. Mix Ref-K gave slightly lower ejection values when pressed at 60°C, especially at high compacting pressures. However, a much significant drop in ejection pressure was obtained with mix HD2/0.55. Even lower ejection values were obtained at 80°C. Mix HD-3/0.55, a composite lubricant (HD-C + WP) gave also very good ejection performance at 80°C. Results in Figures 1 and 2 clearly indicate the benefit of a moderate heating of the die on the lubrication performance of lube HD-C.

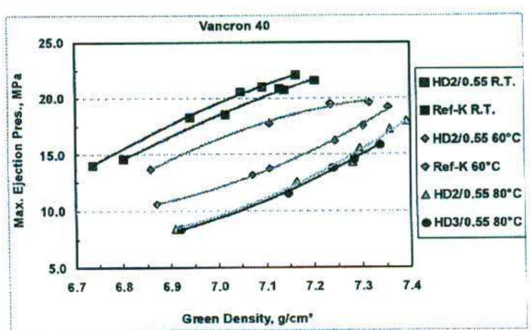

Figure 2. Ejection obtained with a Vancron 40 die.

that of a mix with 0.55% lubricant HD-C. It also offers a better performance compared to the performance of Ref-K (with 0.7% Kenolube) for densities at or below 7.2 g/cm^3. Similar to the behaviour of mix HD-2/0.55, the ejection pressure and ejection energy are more important when the compacting pressure reaches above 700 MPa. However, this lubricant system is a cost effective solution to Kenolube when green densities of 6.8 to 7.2 g/cm^3 are targeted, without the use of Zn stearate and its associated drawbacks.

In order to fully validate the ejection performance of these new lubricants, tests are planned with higher parts and faster compaction rates on the industrial press. These tests were not yet completed and results will be presented in an upcoming publication.

2. *Flowability and Burn-off Characteristics of Lubricants*

In addition to the lubricating behaviour, several other properties must be considered when designing a lubricant system for PM. One of them is the Flowability. Lubricants must promote or maintain good flow properties in order to ensure stable die filling. This in turns helps in reducing the part-to-part weight variation and maintains the density consistent during compaction. The apparent density and flow rate of mixes investigated in this study are reported in Table 3. Mixes with lubricant HD-C gave very good flow rates of about 28 s/50g or below and apparent densities of about 3.20 g/cm^3. Mix HD-3/0.55 containing both lubricants HD-C and WP gave even better flow rates at 24.2 s/50g and apparent density in excess of 3.30 g/cm^3. It has been demonstrated by St-Laurent *et al.* [4] that the excellent flow rates achieved with mixes containing both lubricants HD-C and WP resulted in very good part-to-part consistency during compaction. In all cases, flow rates were better than those obtained with EBS wax. Mix Ref-K also gave a very good flow of ~ 25 s/50g. However, the flow rate of that lubricant is known to be affected by several factors, such as the blending time, blend size as well as the temperature and humidity during blending and compaction [6].

	Ref-K	Ref-E	HD-2/0.55	HD-2/0.45	HD-2/0.35	HD-3/0.55
A.D., g/cm^3	*3.21*	*3.18*	*3.16*	*3.22*	*3.24*	*3.32*
Hall Flow, s/50g	*25.1*	*32.8*	*28.2*	*26.7*	*25.5*	*24.2*

Table 3. Apparent Density and flow rate of Mixes evaluated in that study.

Lubricants must also have very good burn-off characteristics. The ideal lubricant must burn-off entirely and easily and not cause harmful effects on the environment and the sintering furnaces. The burn-off behaviour of lubricants was verified using the TGA. The TGA curves are given in Figure 5. EBS wax (Acrawax C atomised), lube WP used for warm compaction and the new lubricant HD-C totally decompose without residues upon heating. The decomposition of lube HD-C also starts and ends at lower temperatures than the other lubricants. On the other hand, Kenolube and zinc stearate were not completely decomposed in the experiment. This result was expected due to the presence of zinc. As a matter of fact, approximately 90% and 84%, respectively of these lubricants were decomposed, leaving a significant amount of residues. This usually results in stains on the sintered parts.

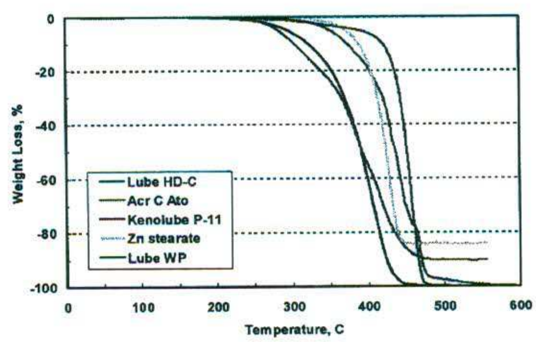

Figure 5. TGA curves obtained for different lubricants.

Table 4 gives the sintered properties of mixes as evaluated at 7.2 g/cm^3. These tests were done in order to confirm that new lubricant had no negative effect on sintered properties. All mixes gave very similar sintered strength and hardness. Dimensional change from green size varied from ~+0.03 to +0.08%. It can be observed that mixes HD-2/0.45 and HD-2/0.35 gave increased densities and sintered strength, likely due to the lower amount of lubricant used.