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Preparation of high-performance, press-ready PM premixes – overcoming processing challenges

Lydia Aguirre[1]* and Vlad Paserin[1]
Rio Tinto Metal Powders, Sorel-Tracy, Quebec, Canada
*Corresponding author: lydia.aguirre@riotinto.com

***Abstract* — The key aspects of preparation of successful high-performance, press-ready premixes include base powder characteristics, additives (lubricants in particular), mixing technology, compacted part attributes and careful consideration of PM press compaction conditions. Mastering each of these along with detailed understanding of client's priorities and expectations in a given application is essential for successful, new premix introduction. This paper describes some of the challenges in identifying and processing suitable premix ingredients contained in today's high-performance PM premixes. An example of data available from new powder rheology characterization tools which are aiding in optimization of new premixes is presented.**

Keywords – High-performance premix, lubricants, powder rheology, mixing technology, compaction conditions

I. Introduction

A general trend in powder metallurgy (PM) industry involves transition from in-house prepared PM premixes in automotive parts production plants to powder producer-delivered premixes. A successful design and production of new premixes requires sophisticated material processing and intimate knowledge of customer application requirements and priorities. This paper outlines the key components required for successful premix preparation and introduction in new parts production: premix base powder and additives, processing, and understanding of customer requirements and preferences.

II. Premix Composition

RTMP premixes use Canadian ilmenite ore–sourced iron feedstock and 100 metric ton atomization batches to ensure high chemical purity and powder consistency. In addition to the base powder, common premix ingredients include alloying elements such as copper and graphite, and a lubricant. The premix properties can be improved by different additives introduction methods. These include admixing, pre-alloying, diffusion bonding and binder treating (Figure 1). The last three options are designed to decrease segregation and therefore premix consistency, while retaining base powder compressibility [1].

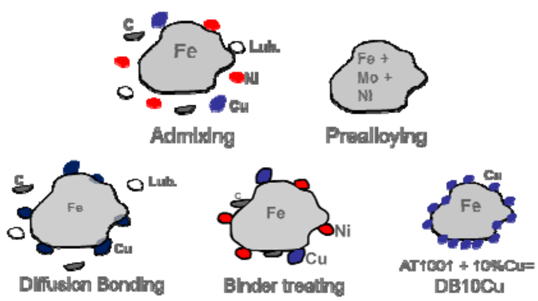

Figure 1. Schematic representation of additives introduction methods

The powder densification during compaction is mainly a function of the intrinsic compressibility of the powder premix, inter-particle sliding forces and the friction between the outer surfaces of the part and the die walls. PM lubricants play a key role in this process.

The PM lubricants used in high-performance premixes are often cohesive powders, causing agglomeration of lubricant particles in handling and processing. This inherent agglomeration ('stickiness") is a consequence of their excellent lubrication capability. Special lubricant pre-treatment steps and mixing technology optimization can be employed to address the cohesive nature of such lubricants. Both commercially-available and in-house developed lubricants [2][3] are being used in preparation of high-performance premixes at RTMP. Active research and development program is in place to identify further improvements in lubricant composition and processing methods, recognizing the trend toward metal stearate–free, pure organic lubricants. The premix preparation methods are highly lubricant-specific (mixing equipment selection, mixing times and component addition sequence).

III. NEW ANALYTICAL TECHNIQUES

New analytical techniques are being employed for rheological assessment of individual premix components as well as the final PM premix itself. Figure 2 shows a powder rheometer from Freeman Technology, model FT4.

The data in the graph in Figure 3 shows two organic lubricants tested in FT4 instrument with very different air permeability characteristics. In this test, airflow is directed through a sample of powder in a small test cylinder, while an increasing amount of compaction pressure is applied from the top (Figure 2). The air pressure drop is recorded as a function of applied normal stress.

Figure 2 FT4 rheometer (Freeeman Technology) and the principle of air permeability measurement.

It can be observed that in the case of lubricant B, the pressure drop remained relatively constant throughout the tested range of applied stress values, demonstrating greater resistance of this sample to "caking" or "stickiness" of particles, compared to Lubricant A.

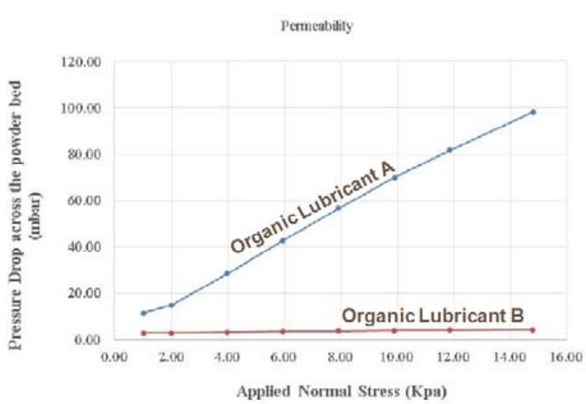

Figure 3. FT4 permeability data showing improved performance of organic lubricant B compared to lubricant A

IV. MIXING TECHNOLOGY

Various mixing technologies are employed in preparation of PM premixes by automotive parts manufacturers and powder producers. While dominant in the industry, tumbling mixers (double cone, V-mixers) often cannot break up organic lubricant agglomerates and other methods of agglomeration avoidance must be employed. Active mixers (e.g. ploughshare) can provide controlled amount of shear which can result in successful dispersion of organic lubricants and their homogeneous distribution in the premix.

Mixing protocol optimization involves the determination of required mixing time to achieve a homogeneous mix, and in the case of active mixers, optimizing the amount of shear applied in the mixing process. Figure 4 shows the evolution of lubricant homogeneity in a large double-cone mixer, along with the amount (weight %) of agglomerates of an organic lubricant (US mesh 50) found in samples removed from the mixer at different stages of the mixing operation.

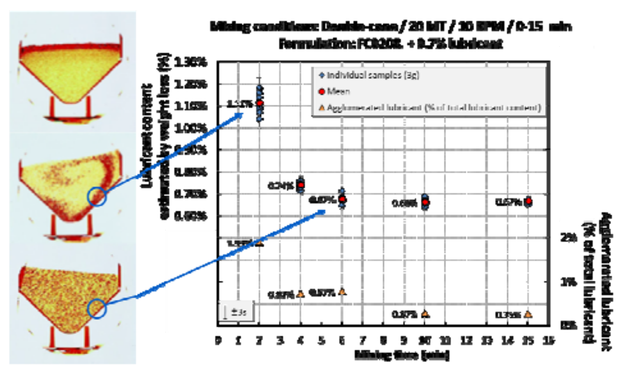

Figure 4 Homogeneity measurement by weight-loss method (organics burn-out), allowing determination of optimum mixing time for the given premix ingredients (FC0208 with 0.7% lubricant)

Relatively short mixing times are required to achieve adequate homogeneity. Avoiding over-blending is important in preserving good flow behaviour of premixes containing pure organic lubricants.

V. APPLICATION REQUIREMENTS

There are many requirements imposed by the part producer (ultimately driven by the automotive application end-use performance demands) that a successful premix must address. Some of these include:

- part ejection force
- maximum achievable density
- part surface quality
- press stroke rate (productivity)
- die temperature control
- density distribution within the part
- weight and dimensional stability
- thin-walled, tall or massive parts production capability
- cost of the premix

In selecting the best premix, part producers often face trade-offs in premix performance. Figure 5 shows an example of two lubricants, one of which (data shown in red) exhibited slight deterioration in part-to-part weight variation but allowed 30% faster stroke rate. This became the dominant decision for material selection, in spite of some degree of staining present on the part after sintering.

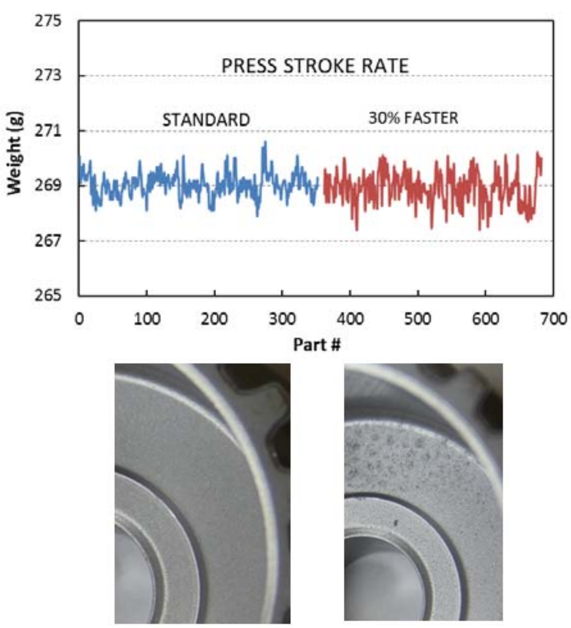

Figure 5 Part-to-part weight variation in two premixes with significantly different achievable stroke rate (top) and surface appearance of the corresponding parts.

VI. CONCLUSION

New instrumentation such as dry powder rheometers like FT4 are useful tools in characterization of the complex behavior and properties of PM premixes. Careful consideration of application requirements and optimization of materials selection, mixing technology and PM press compaction conditions can lead to high rate of success in the introduction of new high-performance PM premixes, enabling automotive part producers to design and manufacture increasingly demanding parts.

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