DIE FILLING CAPABILITY OF POWDER MIXES

Hilmar Vidarsson and Johan Arvidsson

Höganäs AB, S-263 83 Höganäs, Sweden

Abstract - The quality of powder mixes in P/M is frequently studied using standardized techniques, such as Hall Flow, AD etc. These techniques are however limited in predicting the performance during production. For this purpose, a die-filling simulator has been developed. Filling of dies of rectangular shape was characterized to establish the importance of the die width and orientation on the filling density of powder mixes. Furthermore, the effect of bonding of the powder mixes on the die filling was studied, especially in terms of the maximum feed shoe rate possible for complete filling. The results are discussed in terms of impact on filling performance during pressing.
KEYWORDS: POWDER MIX, BONDING, FILLING, FLOW

1. INTRODUCTION

The performance of iron powder mixes during pressing is to a large extent dependent on the powder properties. This includes important parameters directly connected to production costs and quality of produced parts, such as production rate, weight scatter, powder density distribution and dimensional stability. Several characterisation methods are used to ascertain sufficient quality of powder mixes, including Hall Flow and Apparent Density (AD). These methods are however in many cases limited in predicting the performance of the mix in terms of the above mentioned parameters.

In this study, a die-filling simulator has been used to study the filling behaviour of iron powder mixes. Special attention has been paid to the die orientation relative to the direction of movement of the filling shoe. The effect of different lubricants in premixes, and of bonding of iron powder mixes will be presented.

2. EXPERIMENTAL

The die-filling simulator, described in detail a previous publication [1], consists of a series of rectangular dies of different widths (1-20 mm), having a fixed length (30 mm) and height (30 mm). The dies can be oriented in parallel or perpendicular to the travel of the filling shoe. The cavities are filled automatically at different speeds and the powder is subsequently collected on a balance for calculation of filling densities from the weight and measured volumes of the cavities.

An example of the typical filling densities, plotted against die width is shown in Figure 1, shows the commonly observed dependence on die cavity width. In order to facilitate a simple presentation of the behaviour of different mixes at various filling shoe speeds, these are presented as the Filling Index, defined as:

$$Filling_Index = \frac{AD_{13mm} - AD_{2mm}}{AD_{13mm}} \times 100\% \qquad (1)$$

where AD_{2mm} and AD_{13mm} are the filling densities in the 2 and 13 mm wide cavities respectively (see Fig. 1).

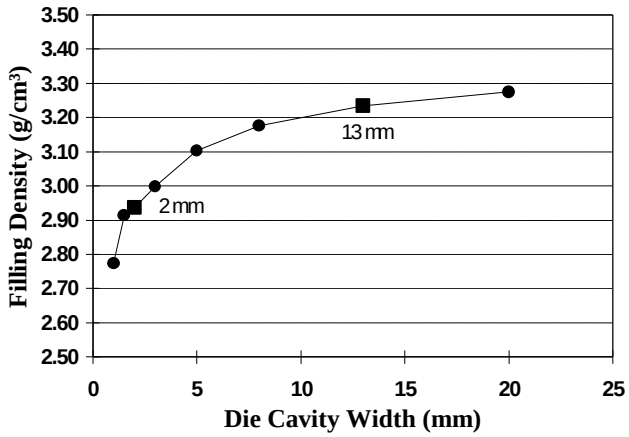


Fig. 1 Filling density as a function of width of cavity oriented in parallel with filling shoe movement. Filling shoe speed: 70 mm/s.

Three premixes were prepared, each using a different lubricant. The composition was as follows:

1. ASC100.29 + 2% Cu + 0,5% CUF-4 + 0,8% Zinc Stearate
2. ASC100.29 + 2% Cu + 0,5% CUF-4 + 0,8% Amide Wax
3. ASC100.29 + 2% Cu + 0,5% CUF-4 + 0,8% Kenolube®

Furthermore, an organically bonded powder mix was prepared:

4. ASC100.29 + 2% Cu + 0,5% CUF-4 + 0,8% Amide Wax

The mixes were primarily characterised using Hall Flow and AD, followed by the investigation in the die-filling simulator.

3. RESULTS AND DISCUSSION

The results from the Hall Flow and AD are shown in Table 1.The premix containing Zinc Stearate has the highest AD and a relatively fast flow rate, as expected. The premix containing amide wax has a much lower AD and a relatively poor flow rate, while the premix containing Kenolube® exhibits relatively fast flow rate and an intermediate AD level. The bonded mix shows values similar to that of the premix containing Kenolube®.

Table 1. Hall Flow and AD for the mixes under study

Mix No.	Mix Type	Lubricant	Hall Flow (s/50g)	AD (g/cm³)
1	Premix	Zinc Stearate	27.0	3.31
2	Premix	Amide Wax	30.4	3.07
3	Premix	Kenolube	26.3	3.18
4	Bonded	Amide Wax	25.5	3.14

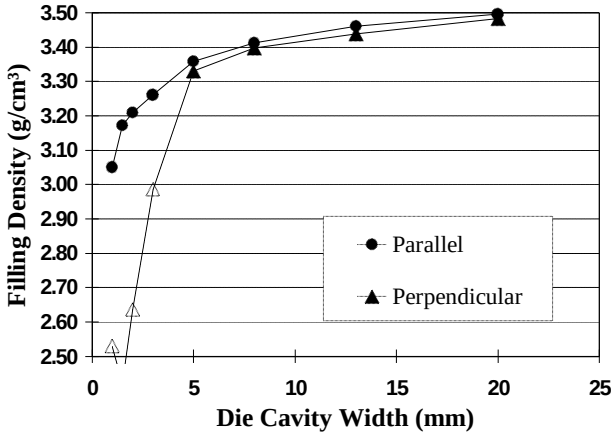


Fig. 2A Mix 1: Premix containing Zinc Stearate.

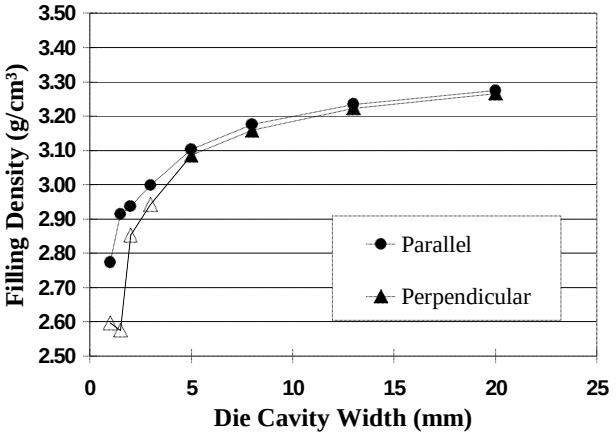


Fig. 2B Mix 2: Premix containing Amide Wax.

Examples from the results from the die simulation are shown in Figures 2A-D. The curves were registered at filling shoe rate of 70 mm/s for cavity orientations both parallel (●) and perpendicular (?) to the direction of the filling shoe movement. Filled symbols denote complete filling, while unfilled symbols denote incomplete filling.

The shapes of the curves resemble the ones reported on in earlier studies using instrumentation of similar design [2,3]. Bocchini [3] suggested the existence of boundary layers close to the die surface as the reason for this characteristic shape. The curves in Figs 2A-D show however several more features. One is that while filling cavities in a direction parallel with the cavity orientation is relatively easy, filling cavities in a direction perpendicular with the cavity orientation is more difficult, especially for narrow cavities. Another feature is that the premixes generally do not perform as well as the bonded mix.

Comparison of the results in Table 1 and Figs. 2A-D show that it is difficult to predict the filling performance from both Hall Flow and AD. Especially the characteristics in the premix containing Zinc Stearate are surprising when taking into consideration the relatively high AD-level observed for this mix.

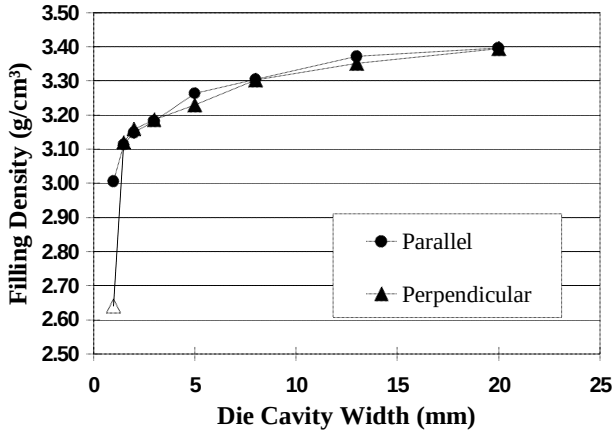


Fig. 2C Mix 1: Premix containing Kenolube®.

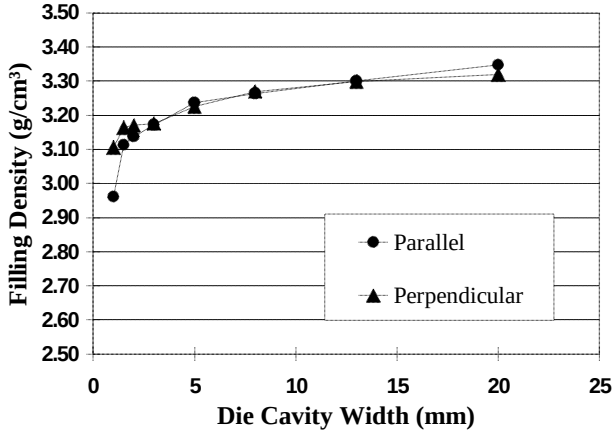


Fig. 2D Mix 4: Bonded mix containing Amide Wax..

This is further illustrated in the plots of the calculated Filling Index in Figures 3A-D. In these figures, the ability of different powder mixes to fill the cavities at different filling shoe speeds is demonstrated for both parallel and perpendicular orientations (symbols have the same meaning as in Fig.2). The premixes show inferior performance in that they cannot maintain their filling performance at increasing speeds as compared with the bonded mix. Especially at perpendicular orientations, the premixes fail at relatively low filling shoe speeds.

Furthermore, where complete filling has been achieved, the Filling Index levels, which reflect the dependence of the filling density on the cavity size (lower Filling Index = more even filling), are found to be dependent on factors such as cavity orientation, type of lubricant and whether the mix is bonded or not. While cavities oriented perpendicular with movement of the filling shoe show only limited dependence on the type of mix, this is found to be more pronounced for cavities oriented in parallel. This implies different mechanisms of powder filling for the two cavity orientations. When filling in parallel, a cavity remains open during most of the time while the filling shoe is moving across, thus allowing air to escape until almost the whole cavity has been filled. Premixes and bonded mixes show differences to form bridging or boundary layers, and thus differ in levels of Filling Index. Filling a cavity in perpendicular can however cause air to become entrapped before the filling is completed, especially when the cavity is narrow and/or when relatively high filling shoe speeds are used. Upward movement of the entrapped air will cause aeration, or partial fluidization of the powder remaining in the filling shoe, thus influencing the packing pattern for the powder entering the cavity during the final stage of filling.

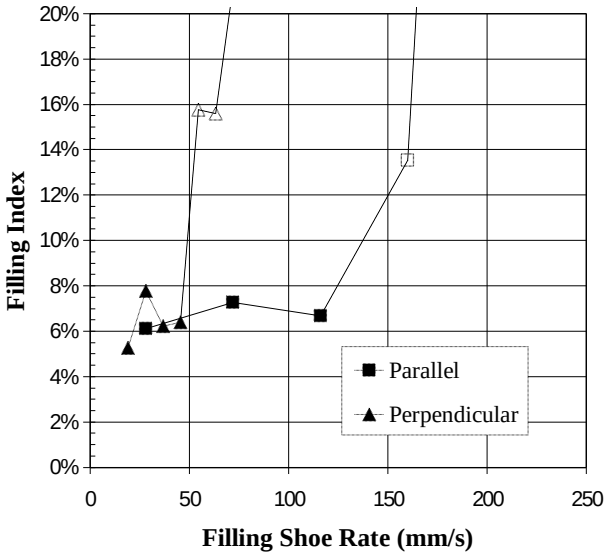


Fig. 3A Mix 1: Premix containing Zinc Stearate

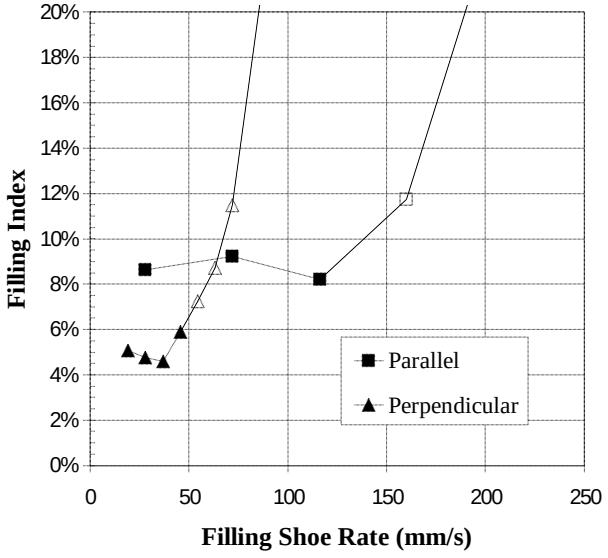


Fig. 3B Mix 2: Premix containing Amide Wax.

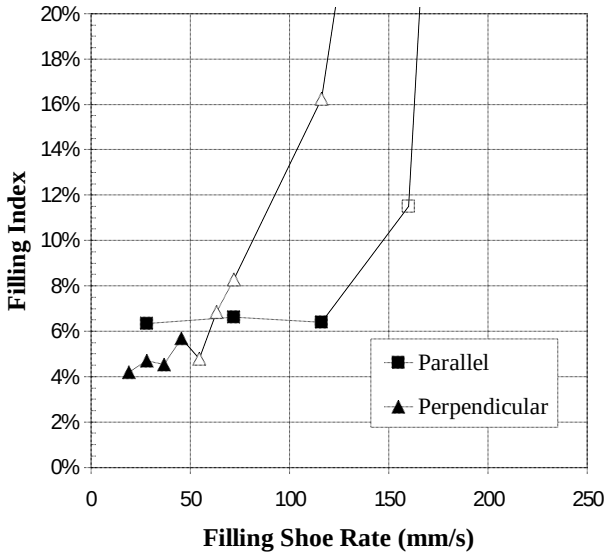


Fig.3C Mix 3: Premix containing Kenolube®.

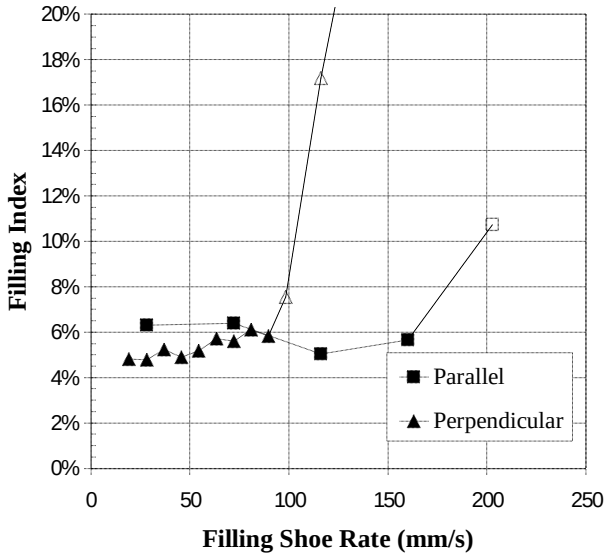


Fig. 3D Mix 4: Bonded mix containing Amide Wax.

Kondoh and Takemoto have visually observed this in their study of filling of complex cavities with powder mixes [4]. Under conditions of perpendicular filling, the mechanism of filling was influenced considerably by removal of entrapped air. In some cases, exceeding critical filling shoe speeds did even result in voids within the powder volume.

It is thus evident that the filling performance of a powder mix is not only dictated by the ability to flow from forces of gravity, but also by bridging tendencies and by the ability to become aerated. The results in this study show that while premixes exhibit some differences in performance, high performance can only be obtained from a bonded powder mix with good flowability.

This can be found to be especially useful when filling complex cavities with large filling heights. Not only is the filling density distribution for bonded mixes less dependent on the spacing within the cavity, but the filling process can be made quicker and less elaborated. This is expected to facilitate better results in terms of spring back and dimensional change, and higher productivity during the pressing operation.

4. CONCLUSIONS

The study of different iron powder mixes in the die-filling simulator has given valuable insight in which parameters influence the performance during filling. The study showed that while premixes that are of different flowability due to the type of lubricant used exhibit some differences in performance, high performance is only observed from a bonded mix of good flowability. This is expected to have a positive impact on parameters during pressing, and result in higher productivity.

5. REFERENCES

[1] M. Larsson and H. Vidarsson: Proceedings of the 2000 International Conference on Powder Metallurgy and Particulate Materials, May 30-June 3, New York.

[2] E. R. Rice and J. Tengzelius, Powder Metallurgy, Vol.29, No.3 (1986) 183.

[3] G. F. Bocchini, Powder Metallurgy, Vol.30, No.4 (1987) 261.

[4] M. Kondoh and S. Takemoto: Advances in Powder Metallurgy and Particulate Materials, 1996. Vol. 2, Washington, DC, USA, 16-21 June 1996.