Developing a soft magnetic P/M component used in wireless communication devices with high green strength lubricants

Ray Guo*, Chao-Hsu Cheng**, John Lee***

** QMP Metal Powders, Asia Pacific, Hong Kong*
*** Chung Chou Institute of Technology, Taiwan*
**** Yin King Industrial Company, LTD., Taiwan*

ABSTRACT

A soft iron frame is an essential component of electronic circuits used in wireless communication devices to prevent electromagnetic interference between electronic elements and electromagnetic radiation which is harmful to the human. The structure of the iron frame could be complicated and delicate with walls as thin as 0.8mm depending on the specific designs of electronic circuits. Traditional metal stamping process could not satisfy the dimensional tolerance and flatness because of the part distortion.

A challenge faced with manufacturing the iron frame using the P/M process was the green compact handling due to its fragileness at thin wall sections. The scrap rate of green compacts was as high as 50% with the powder mix using the regular lubricant such zinc stearate or EBS wax. The approach for the P/M frame manufacturing was taken by using the recently developed high green strength lubricants. A high purity iron powder ATOMET 1001HP with addition of 0.45% phosphorous was selected for the development of the frame to meet the requirements of magnetic properties. Several high green strength lubricant systems were evaluated with cold and warm compacting processes, also with or without post-compaction curing. A specific lubricant system was chosen for the frame, which yielded a sufficient green strength for compact handling and minimized the production cost.

INTRODUCTION

Wireless data communications are increasingly used because of the development of new technologies and wide availability of new wireless communication devices. Nowadays, the devices, such as wireless modems, PC cards and USB adapters, are available as the plug-ins or embedded for computers, ranging from desk-tops to palm-tops (Figure 1). As the size of electronic circuits is getting smaller and the device is carried everywhere, the electromagnetic interference between the electronic elements and other devices has become a serious problem, the electromagnetic radiation is also a potential hazard to the human health. Therefore, the electromagnetic radiation has to be taken into consideration when the electronic circuits are designed.

Figure 1. The devices used for wireless telecommunication

Shielding is an effective way to prevent the electromagnetic interference. A metallic shield is used to isolate a circuit to prevent the radiation from escaping. Traditional metallic shield houses are manufactured by stamping electric Si-steel sheets, ending up with several steel shield houses in a PCB, which complicates the assembly line operations and makes them more difficult for automation.

The other design is a metallic frame sealed by the metallic foil, which provides the electromagnetic shielding for each individual radioactive circuit. The frame can not be economically manufactured by stamping due to the part dimensional distortion and poor flatness. To solve the problem of the frame manufacturing, Yin King Industrial Company Ltd. [1] has developed the frames with the powder metallurgy technology. Figure 2 illustrates a P/M frame developed for a specific PCB circuit.

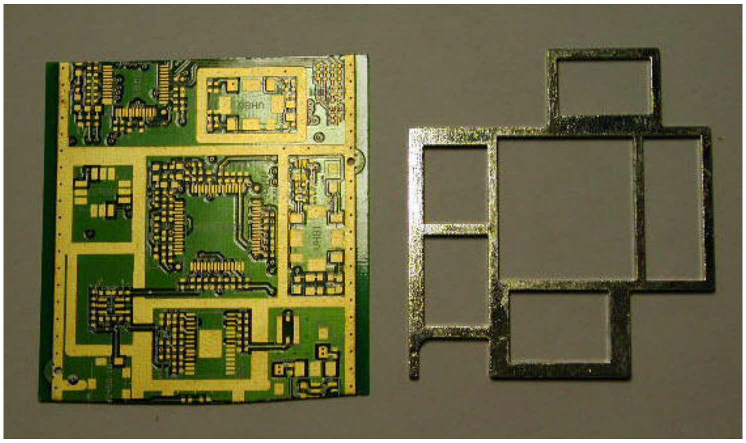
TECHNICAL CHALLENGE

Powder metallurgy manufacturing is very practical for this type of high volume parts. It can produce complex shapes for different designs of PCBs without material wastage. However, there are technical challenges in making the frames. As the devices are getting smaller, the electronic circuits are getting smaller, so are the frames. The frames can be complicated and delicate with walls as thin as 0.8 mm. The part requires a sufficient green strength to withstand breakage during part ejection and green compact handling before entering the sintering furnace. In early development, production trials were carried out with conventional lubricants, such as zinc stearate and EBS wax. The green compact scrape rate was as high as 50%. The technical challenge was to find a way to increase the green strength and minimize the green compact scrape rate.

There are several ways to increase the green compact strength as summarized below [2]:

1. Increase the green density by warm compaction.
2. Reduce/eliminate the lubricant in the mix by using die-wall lubrication.
3. Use the high green strength lubricants which have been developed recently.

Considering the production cost and facility availability, the high green strength lubricants were selected and evaluated for producing the frame part.



3 cm

Figure 2. The soft metal frame for shielding and the PCB configuration

HIGH GREEN STRENGTH LUBRICANTS

Recent developments of new polymeric lubricants with good lubricating characteristics make it possible to achieve high green strength by compaction. Tremblay et al, [3-4] developed new lubricating systems, which could yield sufficient green strength for green machining operations. The BM system (Figure 3) may require an optional curing treatment, depending on the compact density and machining conditions.

However, this lubricating system was developed for large part compaction at a part ejection temperature higher than 50 °C, which is the temperature needed for the lubricant to reach the high green strength effectively. Since the metal frames are thin the friction with die wall would not generate the temperature higher than 50 °C. Therefore, another HGS lubricant system, coded as CR system, was selected for the metal frame production trial.

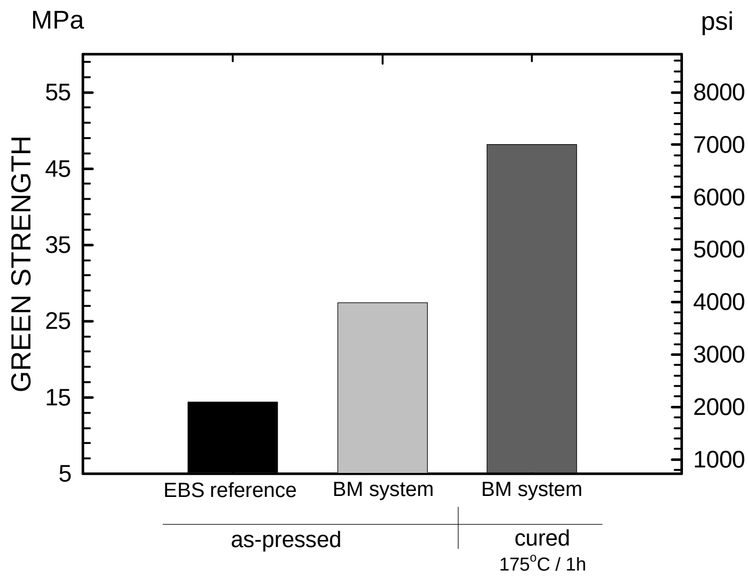


Figure 3. Effect of the BM lubricating system on green strength of specimens of FLC4608 pressed to 7.0 g/cm^3 at 55 °C

CR SYSTEM FOR HIGH GREEN STRENGTH APPLICATIONS

The CR system is specially chosen for parts which are compacted at room temperature and require high green strength to reduce chipping and breakage during green compact handling. The chemical composition and particle size are listed in Table 1 with references to EBS wax and zinc stearate lubricants.

Table 1. Composition and particle size of zinc stearate, EBS and CR system

Lubricant	Chemical Composition	Particle Size (μm)
ZnSt	Stearate Salt	< 45 (95.0%)
EBS Wax	"N,N Ethylene Bisstearamide"	< 45 (100%)
CR System	Polymer	10 *

***** mean particle size

The evaluation of the CR system was first done on a laboratory scale with a FC0205 mix containing 0.75% lubricant. The physical properties, apparent density (AD) and flow rate, of the FC0205 mix are shown in Figure 4. The mix containing the CR lubricant has a lower apparent density and a slower flow rate than the conventional lubricant, EBS wax or ZnSt. The lower AD and slower flow was not a concern for making the frames because of its shallow die fill, also the flow rate could be improved by using the binder treatment technology, FLOMET, if required.

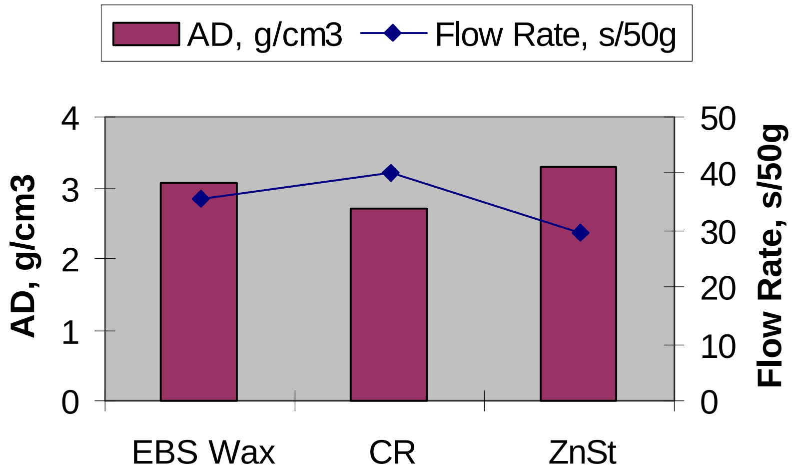


Figure 4. Physical properties of FC0205 mix containing 0.75% lubricant

Mixes were pressed to a density of 6.8 g/cm^3 and the green strength was measured according to the MPIF Test Standards. The compacts were then sintered in a $90N_2$:$10H_2$ atmosphere at 1120 °C for 25 min and tested for transverse rupture strength (Table 2).

Table 2. Compacted and sintered properties of FC0205 mix containing 0.75% lubricant

Lubricant	Compacting Pressure, MPa	Green Strength MPa	TRS MPa
ZnSt	414	8.14	816.4
EBS Wax	407	10.62	854.9
CR System	427	15.66	830.2

There were no significant differences in the compressibility and sintered strength with three types of lubricants, but the green strength of compact with CR system was almost doubled that of zinc stearate and increased by 50% as compared with EBS wax.

MATERIAL FOR MAGNETIC APPLICATIONS

The material selected for the frames is a MPIF standard material, FY4500, for magnetic applications, which is an iron base powder with admixture of ferrophosphorous (0.45% P). It is well known that the magnetic properties are directly related to the part density and the purity of the material. In order to maximize the magnetic properties, the high purity water atomized powder, ATOMET 1001HP, was used as the base iron powder. Table 3 lists the properties of ATOMET 1001HP.

Table 3. Properties of ATOMET 1001HP base powder

Physical and compacting properties

AD g/cm³	Flow s/50g	Particle Size, wt%			Green density at 600MPa, g/cm³
		250-150µm	150-45µm	<45 µm	
2.92	25	14	66	20	7. 15

Chemical Analysis, wt%

C	O	S	Mn	Al	V	Ti	Ni	Cu	Fe
0.004	0.006	0.004	0.04	0.004	0.006	0.001	0.007	0.02	>99

The powder contains exceptionally low levels of impurities and is highly compressible - up to 7.2 g/cm^3 density at 600 MPa by a single cold press. The high purity is ideal for the magnetic applications with the following benefits: high magnetic permeability, high induced magnetization and low coercive force. Table 4 shows the typical magnetic properties of FY4500 (ATOMET 1001HP + 0.45%P), which was sintered at 1120 °C for 60 min in a hydrogen based atmosphere.

Table 4. Typical Magnetic Properties of FY4500 Material

Sintered density g/cm³	Induction at 1190A/m	Remanence Br (T)	Maximum Permeability (max)	Coercive Force (A/m)
7.0	1.11	1.08	3780	1100.64
7.2	1.20	1.18	4130	109.05
7.4	1.29	1.24	4445	107.46

IRON FRAME PRODUCTION AND DISCUSSIONS

Powder mix: ATOMET 1001HP + 0.45% P + 0.5% CR lubricant. The mix containing 0.5% EBS wax was also used as reference (Table 5).

Table 5. Powder mixes used in the production trial

Mix	Iron Base Powder	Phosphorous	Lubricant	AD, g/cm³	Flow, s/50g
A	ATOMET 1001HP	0.45%	0.5% CR	2.85	31.5
B	ATOMET 1001HP	0.45%	0.5% EBS wax	3.10	30

Compaction: Single compaction to a green density of >7.1 g/cm^3 at room temperature on a 60 mt mechanical press with a press speed of 15 spm. Green compacts were handled manually and placed on a sintering plate.

Sinter: A stock of 10 frames on a sintering plate in a continuos mesh belt furnace, sintered at 1120 C for 30 min in a N_2/H_2 atmosphere. An as-sintered frame is shown in Figure 5.

Secondary operations: Surface grinding and tin plating to enhance the surface contact and wettability during PCB soldering.

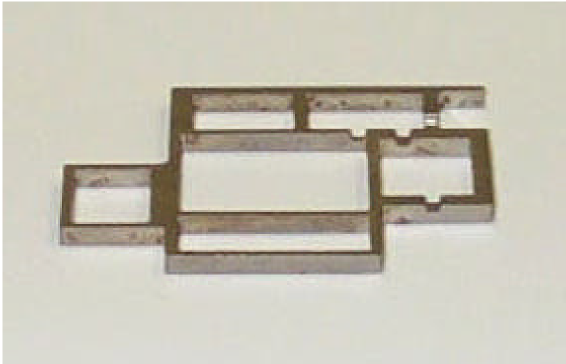


Figure 5. As-sinter frame

Discussions:

The production trial with EBS-containing mix showed that the scrap rate was as high as 50% due to the breakage of green compacts. Using the HGS lubricant, CR system, yielded high green strength for better compact handling. As a result, the scrap rate was significantly reduced to a few percent. The future work is to use automatic green compact handling system replacing manual handling with the objective of completely eliminating green compact breakage.

SUMMARY

A soft magnetic frame was developed using powder metallurgy technology with HGS lubricant – CR system. The CR lubricant significantly increased the green strength of the compacts, effectively reduced the breakage of green compacts and enabled to produce the P/M frames more economically.

REFERENCE

[1]. Taiwan Patent Pending, Application File No.: 16277 (2001).

[2]. F. Chagnon, L. Tremblay, S. St-Laurent and M. Gagne, "Improving Green Strength to Enable Green Machining", SAE Technical Paper No. 1999-01-0337, Oct., 1998, pp. 71-76.

[3]. L. Tremblay, F. Chagnon, Y. Thomas and M. Gagne, "Green Machining of P/M Parts Using Enhanced Green Strength Lubricating Systems", SAE Technical Paper No. 2001-01-0399, March, 2001.

[4]. L. Tremblay, F. Chagnon and Y. Thomas, "Enhancing Green Strength of P/M Materials", *Powder Metall. Particulate Mater*., Part 3, 2001, pp. 129-141, New Orleans.