IMPROVED PROPERTY AND DIMENSIONAL CONSISTENCY ACHEIVED USING P/M MIXES BONDED BY THE STARMIX™ PROCESS

Thorne Peter*, Milligan David*, Engstrom Ulf*, Hofecker Paul*, O'Keefe Denis*, Edman Daniel, Roger Neyman***, Shawn Miller******

***North American Hoganas, Inc., USA**
****Hoganas AB, Sweden**
*****SMC Powder Metallurgy, USA**
******University of Pittsburgh Johnstown, USA**

Abstract

There are many factors that will help P/M continue to be a cost effective alternative to more traditional metal forming technologies. Among these factors are consistency of properties and dimensions during the manufacturing process. Material handling, mix composition, and manufacturing environment all affect the performance of P/M mixes. This paper will discuss how mixes bonded using the STARMIX™ process can improve the consistency of dimensions and properties by reducing the possibility of segregation of mix constituents. The improvements in component consistency were analyzed during production of typical P/M.

Introduction

Consistency of dimensional properties is an important factor to consider when designing processes for the P/M industry. There are many ways to improve the dimensional consistency. Two popular methods are changing the material handling system to produce mass flow and changing to a mix with bonded constituents. Keeping this in mind, the bonding method plays an important role in consistency of the mix. There is an improvement in consistency using a prealloyed premix instead of an admixed premix since the composition of each particle is consistent instead of a mixture of iron and additives. A draw back to prealloyed powders is that the compressibility will be reduced. STARMIX™ and diffusion-alloyed additives were developed in part to improve this consistency without the as mentioned side effects of prealloying. In this paper a comparison of dimensional properties will be examined versus conventional mixes.

STARMIX™ has been tested and demonstrated to produce a reduction of graphite segregation by organically bonding the graphite to the base iron. It has been demonstrated that bonding can control multiple modes of segregation, such as dusting (the graphite lost to the outside air). Also we can examine, the percent bonding of graphite (amount of graphite that is bonded to the base iron) [1]. One way to measure dusting is to use a dust track aerosol monitor (figure 1). This system runs by having powder flow into a sample container, and removing air the from container at 1.7 dm^3/min. Any powder particles trapped in the airflow are collected, observed, and analyzed over time by a piece of monitoring equipment (figure 2) [1].

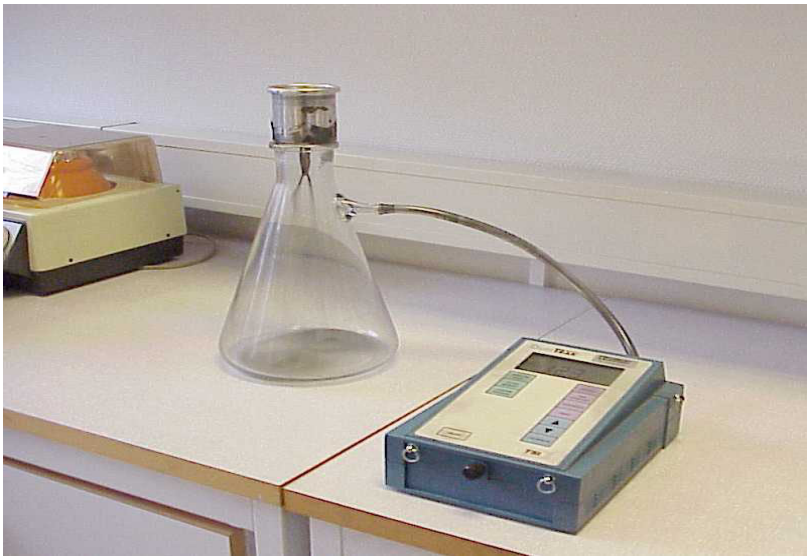


Figure 1. Dust track aerosol monitor.

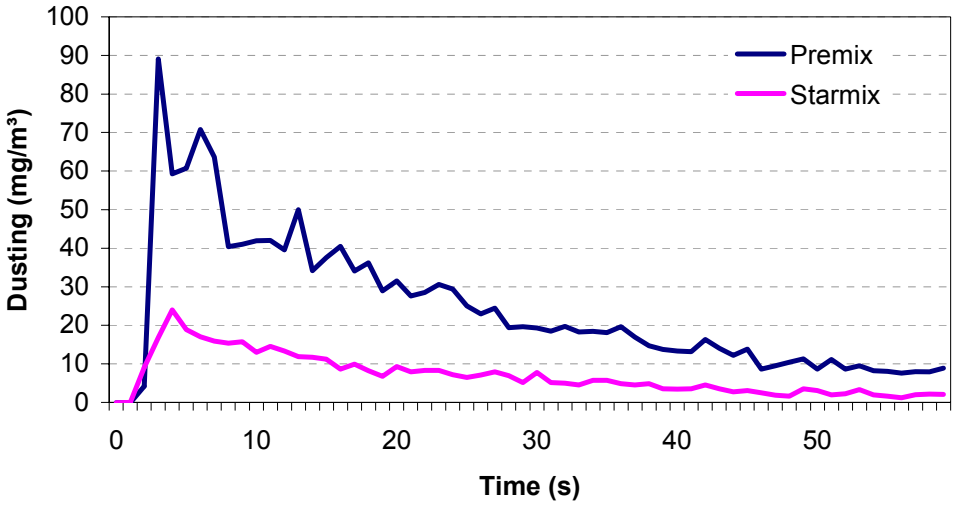


Figure 2. Results test for dusting.

To measure the bonding of graphite an Aminco Roller Air Analyzer (figure 3) can be used. The amount of Graphite is measured before and after the roller air analyzer test process and examined using equation i. The process can be performed by placing graphite containing powder in the U-

tube and blowing air into that tube causing the powder to circulate in the tube. Any graphite that is free in the air will be blown through the opposite end of the tube and not calculated C_2. The results show (figure 4) the bonding to be almost double with the bonded mix, as tested on an FC-0208 mix [1].

Equation i. $$\frac{C_2}{C_1} \times 100 = \text{Bonded graphite (\%)}$$

C_1 = Analyzed graphite before test
C_2 = Analyzed graphite after test

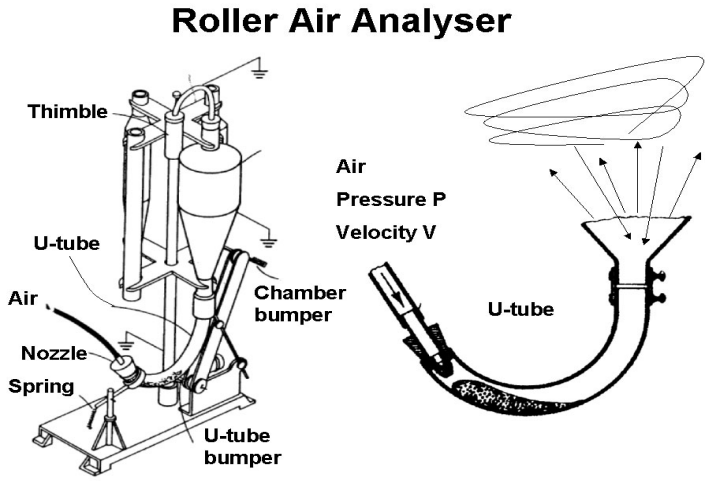


Figure 3. Aminco Roller Air Analyzer.

Table I. Degree of bonding.

Mix type	Degree of bonding
Premix	55%
Starmix™	98%

Previous studies have shown that not only is it important to control dusting from a dimensional control standpoint, but also for the general quality of the working environment. Once the dust settles it gives any equipment or the floors a dirty appearance. Lastly this graphite dust can settle into another mix, which is not scheduled to contain graphite. This is called cross contamination [1].

The STARMIX™ process has also been revealed to improve die-filling rate (speed and ability to fill a die cavity), thus improving the press speed (increased production rates) [1], [2]. The weight stability has also been examined over a large production run, and has shown improvements over a standard premix [3]. The die filling rate is tested by utilizing a die filling simulator (figure 4). This test involves running a fill shoe containing powder across a series of machined out slots at varying speed. The cavities are then emptied and the material weighed to calculate the amount of

powder, which filled each cavity. Some results of this test are shown in figure 5, which show that the bonded material has a better filling index than the premix powder.

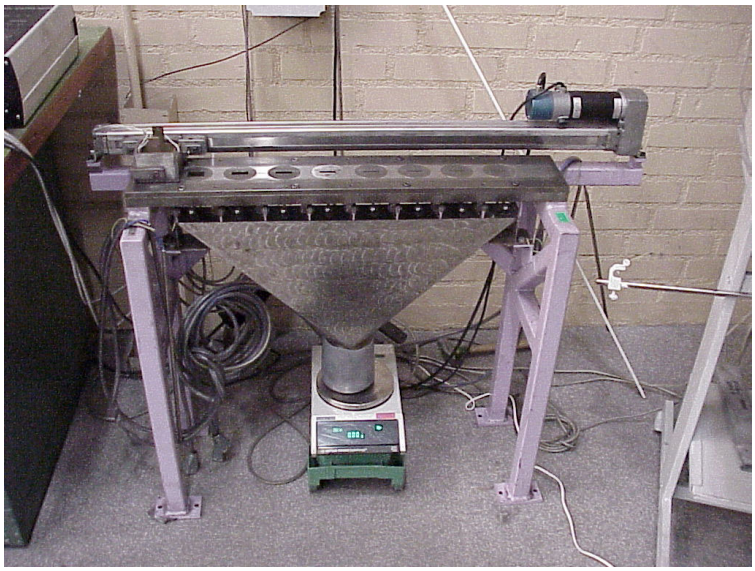


Figure 4. Die filling simulator.

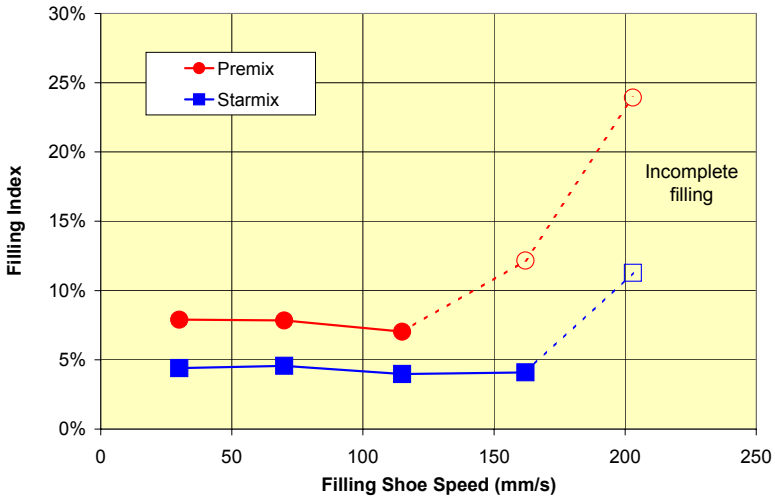


Figure 5. Results of the die fill simulation.

Production rate has also been analyzed using the different types of mixes. A bonded mix and a nonbonded mix were compacted at different speeds and the weight and density were measured. The scatter of the green density variation is shown in figure 6 as a standard deviation. This shows that as the press speed increases the stability of the bond mix remains more stable and that using a bonded mix the stability at 26 strokes/minute is as good as non-bonded at 20 strokes/minute. That's an increase of 30% in press speed.

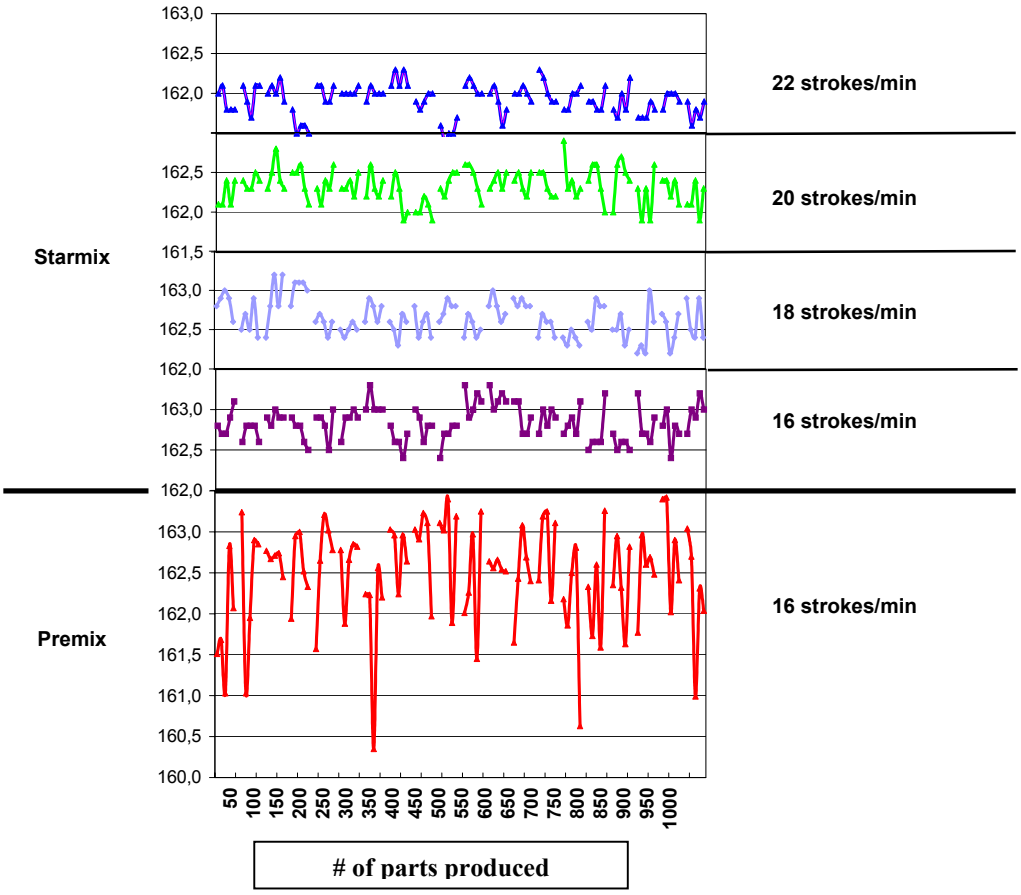


Figure 6. Results of weight vs. press speed.

Increasing production rates is important for reducing costs. STARMIX™ powder is a simple way to increase production and lower prices. Also by improving the filling rate the weight stability is improved, which leads to better density ratios from top to bottom or in thin sections of a part and better weight control part to part. This will lead to less out of spec parts and less sorting, reworking or unusable parts, not to mention less press adjustments, which all lead to a lower cost per part.

Another aspect that needed analysis was how the bonding affects the final properties. In order to do this a mix was examined for mechanical properties both bonded and non-bonded. The mix composition is as follows:

ASC100.29 + 2% Cu (100 mesh) + 0.6% C-UF4 + 0.8% Amide wax.

The result for the mechanical testing (table II) show no significant difference between the bonded and nonbonded mixes [2].

Table II. Comparison of Material Properties.

Type	Green Density g/cm^3	Sintered Density g/cm^3	DC* %	UTS 10^3psi/MPa	YS 10^3psi /MPa	HV10	Elong %	Carbon %
Premix Starmix™	7.07	7.00	0.21	73.5/507	51.9/358	144	3.2	0.63
	7.06	6.98	0.26	71.5/493	50.9/351	146	2.9	0.61

* green to sintered.

Copper segregation can also be a source of variation in the finished product. The modes of segregation are similar to the ones previously mentioned, but there is another mode that occurs during handling. This segregation occurs because of the differences in size and density of additives. The additives such as copper will settle to the bottom of the container leaving the iron particles at the top, which will manifest as variation in chemistry part to part. To reduce the segregation of additives, copper can be bonded to the base material. This is not done by using the same STARMIX™ process, as with the graphite. The copper can be bonded using a diffusion alloying technique developed by Hoganas AB. This process has been tested for the different forms of segregation and has proven to aid in the prevention of segregation by bonding the copper to the base material [4].

Experimental Procedure

This evaluation was performed using a gerotor produced by SMC Powder Metallurgy in Galeton, PA (figure 7). The gerotor has a 76mm (3 inch) outer diameter (OD) and approximately 6.4mm (¼ inch) in thickness. The large OD and thick and thin wall sections of the gerotor make it more difficult to control the consistency of the OD. Gerotors also have strict dimensional requirements.

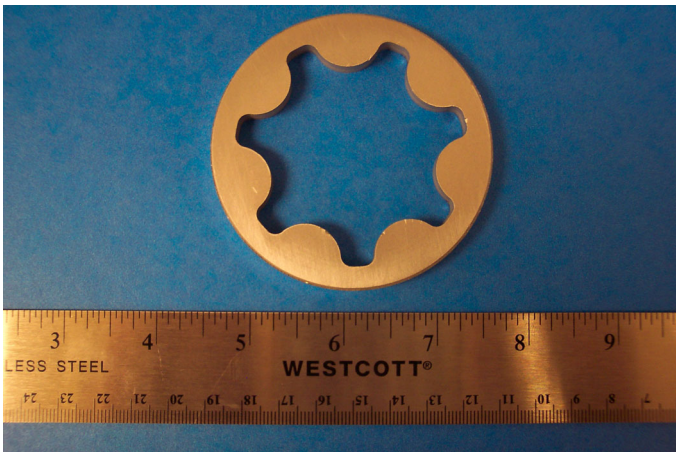


Figure 7. Gerotor courtesy of SMC.

Mixes

Four premixes (table III) were produced using conventional mixing technology. Using identical ingredients, four more mixes were produced using the STARMIX™ process (table IV). All mixes were made according to the MPIF FC-0205 designation with 0.8% lubricant added. The first three regular premixes and the first three STARMIXES™ use the same base iron with

different types of Cu. The fourth mix for regular premix and the STARMIX™ use the same Cu as the third mix, but use a sponge iron for the base iron. The first copper used (Acupowder165) is an admixed Cu. The rest of the coppers (D.Cu, D.ACu) that were added are all diffusion bonded to the base iron.

Table III. Table of Regular Premixes.

#	Base Iron	w/o	Cu	w/o	C	w/o	Lube	w/o
1	ASC100.29	Bal.	165	2.00	1651	0.50	Kenolube	0.80
2	ASC100.29	Bal.	D.ACu	20.0	1651	0.50	Kenolube	0.80
3	ASC100.29	Bal.	D.Cu	20.0	1651	0.50	Kenolube	0.80
4	NC100.24	Bal.	D.Cu	20.0	1651	0.50	Kenolube	0.80

Table IV. Table of STARMIXES™.

#	Base Iron	w/o	Cu	w/o	C	w/o	Lube	w/o
1	ASC100.29	Bal.	165	2.00	1651	0.50	SL Amide Wax	0.80
2	ASC100.29	Bal.	D.ACu	20.0	1651	0.50	SL Amide Wax	0.80
3	ASC100.29	Bal.	D.Cu	20.0	1651	0.50	SL Amide Wax	0.80
4	NC100.24	Bal.	D.Cu	20.0	1651	0.50	SL Amide Wax	0.80

Compaction

3000 gerotors from each mix were compacted to a 6.85 g/cm^3 green density using an 825 st Cincinnati mechanical press at approximately 11-12 strokes per minute. All material was loaded into the press using the existing auger system (figure 8). The powder is emptied into the lower hopper, and then auger fed into the upper hopper. No portions of the feed system were modified or optimized during any of the trials. 150 pieces of each mix from throughout the production run were collected, weighed, and identified.

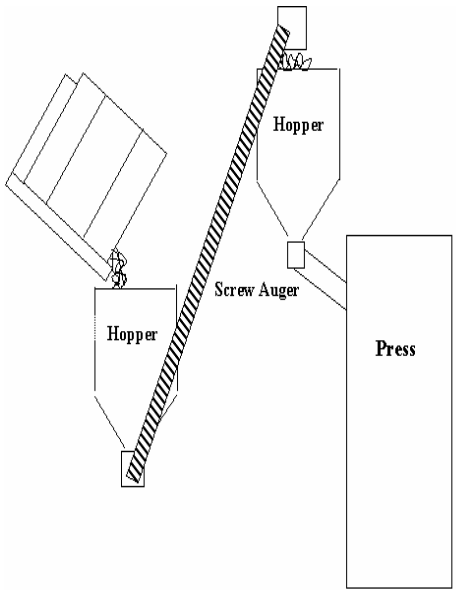


Figure 8. Screw Auger powder feed system for compaction. [5]

Sintering

The identified gerotors were then randomized and mixed with the balance of the gerotors. All gerotors were then sintered continuously on a 24-inch Abbott belt furnace at 1120ºC (2050ºF), in a 90%N_2/10%H_2 atmosphere. The gerotors were double stacked on graphite trays at a belt speed of 3 minutes/foot, 30 minutes at temperature. The 150 marked parts from each mix were then recollected for evaluation. All marked parts were measured for out of roundness (OOR), and outside diameter (OD).

The OOR was measured on all 150 parts from each premix and STARMIX™, and average and standard deviation were calculated. The OOR was calculated using equation ii by measuring the part in two directions (figure 9). One measurement was taken in the filling direction. The other measurement was taken perpendicular to the filling direction.

Equation ii. OOR=Absolute Value (D1-D2)

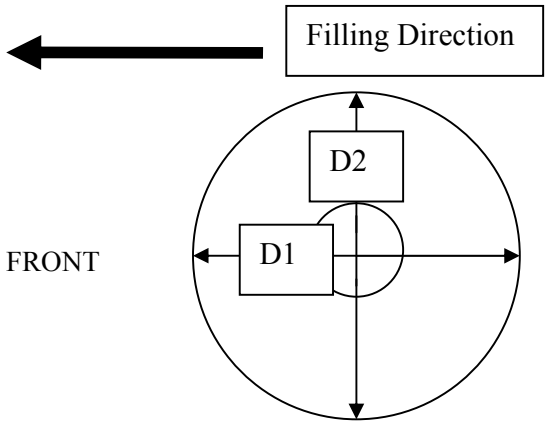


Figure 9. OOR measurement.

Results

The first property that was examined was the OOR. (OOR gives a good representation of the amount of segregation of the additives within the mixes.) Table V compares the OOR for each mix. Figure 10 shows the graph for the average and the standard deviation for all of the OOR values on each mix comparing conventional premixes vs. STARMIXES™. All OOR values are in inches.

Table V. OOR values.

Copper	165		D.ACu		D.Cu		NC	
	STARMIX™	Premix	STARMIX™	Premix	STARMIX™	Premix	STARMIX™	Premix
Average	0.0020	0.0020	0.0009	0.0015	0.0006	0.0007	0.0009	0.0012
Stddev	0.0010	0.0014	0.0006	0.0010	0.0005	0.0007	0.0006	0.0006

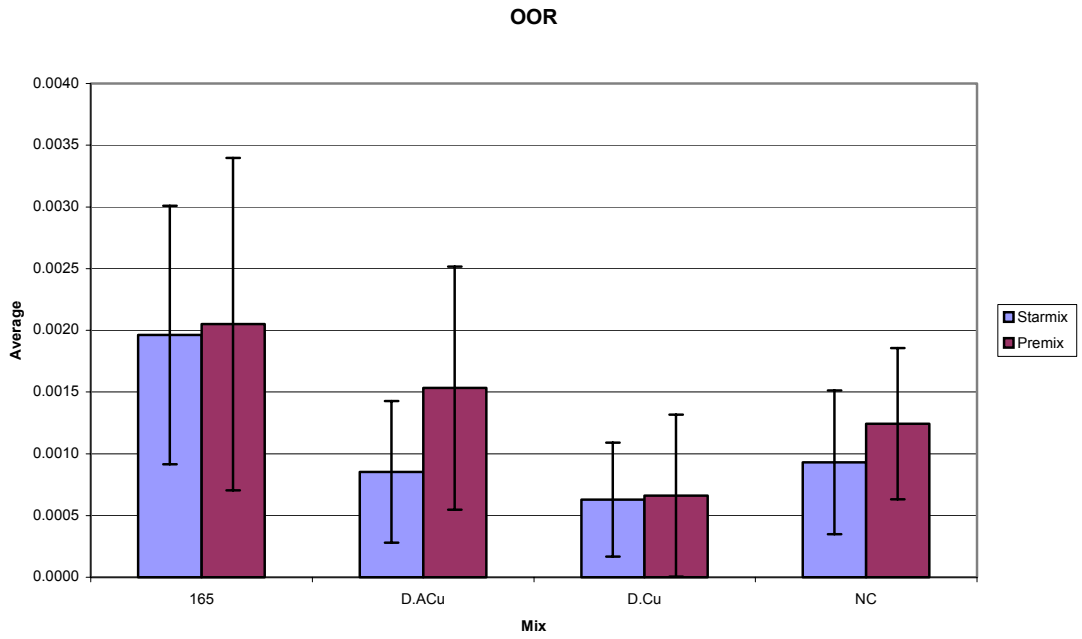


Figure 10. Average and standard deviation of OOR values.

An important factor to note is that not only is there a better average and standard deviation for all of the STARMIXES^{TM}, but the three mixes that are produced with the diffusion-alloyed Cu show the same trend versus the admixed 165 Cu. Therefore it can be determined that not only are STARMIXES^{TM} more stable but diffusion bonded powders are as well.

Lastly from the data collected for OOR an average dimensional change was calculated for each mix. (Table VI) These values were produced using equation iii below. The diameter of the die is 75.9mm (2.9883in).

Equation iii. DC=(OD-ID)/ID*100
DC- Dimensional change (die to sinter)
OD- Outer diameter of finished part.
ID- Die diameter

Table VI. Dimensional change values

Copper	165		D.ACu		D.Cu		NC	
DC (%)	STARMIX^{TM}	Premix	STARMIX^{TM}	Premix	STARMIX^{TM}	Premix	STARMIX^{TM}	Premix
Average	0.48	0.47	0.50	0.47	0.45	0.46	0.39	0.43

From the above DC table a couple of points can be made. The DC for the atomized powders is very similar between the bonded and regular premixes. The sponge on the other hand shows a reduction in DC for the bonded mix.

Conclusions

From the above testing the following conclusions can be drawn:

- The STARMIX™ process demonstrates less variation in carbon content than traditional premixes.
- The STARMIX™ process produces a potential reduction in cost by the ability to increase press speeds, and possible improvements in DC consistency.
- Better DC tolerances can be held using parts produced from STARMIX™.
- Binder-treating premix does not negatively affect the mechanical properties of the finished product.
- Diffusion alloyed copper materials also demonstrate improved performance in a production environment when compared to conventional premixes.
- Combining diffusion alloying and the STARMIX™ technology provide the opportunity to produce parts with better dimensional control as compared to a standard premix.

References

1 M. LARSSON, D. EDMAN: *Improved tolerances by optimized powder mixes*, Proceedings of PM2004, Vienna, Austria, October 2004

2 H.VIDARSSON, S. BERG, D. EDMAN, B. JOHANSSON, P.THORNE: *Close Dimensional Stability at High Production Rates*, Proceedings of PM2TEC 2003, Las Vegas, June 2003

3 H.VIDARSSON, J. LEWENHAGEN, B. JOHANSSON: *Efficient P/M Part Production through Bonded Mixes having unique powder properties*, Proceedings of PM2TEC 2002, Orlando, June 2002

4 M. LARSSON: *Different means to improve consistency of material properties and tolerances of low-allowed pm steels*, Proceedings of Euro PM 2000, Münich

5 T. LUZIER, D. MILLIGAN, P HOFECKER, O MARS: *Improved final component consistency using flexbag handling systems*, Proceedings of PM2TEC 2003, Las Vegas, June 2003