A Study on the Sinter Brazing Joint of Powder Metal Components

Pujan Tripathi
Department of Engineering Technology
Missouri Western State University
4525 Downs Drive
St. Joseph, MO 64507, USA

George Yang
Department of Engineering Technology
Missouri Western State University
4525 Downs Drive
St. Joseph, MO 64507, USA
E-mail: yang@missouriwestern.edu

***Abstract*—The research focuses on the development of a new joint method, the sinter brazing of powder metal components. Various kinds of powder metallurgy composition were tested in the sinter brazing joint, mainly to study the operating conditions, strength of the joint. Although each of these processes brings about different results in metal, all of them involve three basic steps: heating, soaking, and cooling. Heat treatment such as heating, soaking, cooling, hardening, tampering has been investigated.**

Keywords-Powder Metallurgy; Sintering; Brazing; Metal Joining

I. INTRODUCTION

Powder metallurgy is a processing method where green parts are compacted using dies and get sintered. Sintering offers equivalent strength as a cast iron and superior design flexibility and produces Near-Net-Shaped (NNS) parts at lower costs and it reduces the need for the machining process. Now, sinter brazing is an established joining process for Powder Metal components, and it is often used in the production of automotive applications. A successfully brazed joint relies widely on the interaction between brazing alloy, the joining surfaces, and sintering atmosphere conditions. The purpose of testing brazing materials is to test the capabilities of the brazing filler materials in order to produce sinter brazed components, processed through sinter brazing to heat treatment with air quench and to compare different brazing pastes to determine their quality and strength to the powder metal components.

Product designs within the powder metal industries utilize joining techniques to assemble a component from different compacted pieces. This enables PM industries to provide cost-effective complex parts for various applications compared to traditional fabrication practices. Sinter-brazing is one of the methods for joining the parts easily and efficiently. Brazing mechanism can be complex; however, it has the potential to reduce additional processing steps in a manufacturing scenario. The process can be achieved within one step instead of the traditional two steps. It also has economic advantages [1]. The metallic bond formed between parent mental surfaces has an adequate strength to achieve the high-performance standards according to the requirements.

Interconnected porosity generates significant capillary forces that rapidly pull braze away from the connection interface. Moreover, the pore network becomes like a conduit that fills the bulk of the part with filler materials which results in a joint deficiency. Therefore, porosity is a considerable challenge in the sinter-brazing process. Using Copper (Cu) to infiltrate before brazing can be a potential solution to fill the pore network but is an expensive process. Another option is compressing to densities > 7. g/cm3 [4] but has a risk to get reduced strength than expected in the connection interface.

Burgess Norton Mfg. Co. (Geneva Illinois) is making powder metal products since 1903 and operating seven facilities all over the world. 1000101-MPIF FLC:4405 is a widely used filler alloy for infiltration during the sinter-brazing process by Burgess Norton. This alloy limits the loss of material in the pore network and creates a strong bond between the parent metal surfaces. This can be achieved by increasing the liquid temperature to increase the surface tension, thus reducing the flow ability to prevent braze alloy to penetrate further. However, the process is not entirely smooth and influenced by many external parameters. Despite having a high success ratio, it has occasional failure due to excessive infiltration. Significant work has been done to understand this challenge within manufacturing. One of the methods to counter excessive infiltration is to add some iron powder to the braze pre-mix to influence the onset of solidification temperature [5,6].

Brazing has many established best practices [1,6,7]. Performing each step of the sintering cycle within the controlled environment is one critical factor. To have an effective relubrication without shooting, a little oxidizing is required within the preheat zone. Although, some surface contaminants can negatively influence wetting and hinder braze from flowing through a gap. The excessive oxidizing atmosphere can cause inefficiency in reducing the brazing material; a greenish tint on the surface indicates excessive oxidation[1]. Also, furnace temperature should be adjusted for different loads. Furthermore, maintaining consistent temperature is essential to regulate desired brazing metal flow. Slow heating rates can segregate braze from ler melting constituents and alloy with an iron after re-solidification, impeding the remaining brazing metal from flowing into the pore network [2].

For successful brazing, wetting parent material surfacing with liquid braze is one of the key factors. It is important to dissolve the surface oxides by utilizing a flux on brazing and parental material to prevent braze to flow into the pore network within the joint [8]. However, in that process, glassy residues of metal oxides are left behind which can be adherent in nature. Thus, it is recommended to incorporate blind holes or enclosed cavities within the design. Regardless, if not performed in a vacuum chamber, adding flux is essential in the sinter-brazing process.

Traditionally, sinter-brazing was performed with 1000101-MPIF FLC:4405and sintering in a furnace cycle process. But to challenge the capabilities of sinter brazing materials and its components, another test took a place and the research done with the powder 1000111-MPIF FLC-4808 which showed the significant results in the sinter brazing procedure.

II. Materials and Methods

The braze alloys that are used in the study are, Brazing powder 1000101-MPIF FLC:4405 and 1000111-MPIF FLC-4808. These are the two most used powder of Burgess Norton Mfg. Co. (Geneva Illinois). The sinter brazing paste is used SCM-Sinter Braze Grade:C-458 and SCM-Sinter Braze Grade: EXP6778-99.

TABLE I. Description of two testing metal powders

TYPE	**GRADE**	**Description**
Pre-alloyedSteel	FL-4405	Low alloy steel with pre alloyed manganese, molybdenum and nickel content for better hardenability.
Hybrid-alloySteel	FLN2-4405, FLN4-4400, FLN4-4405, FLN6-4405, FLNC-4405,	Low alloy steel with pre alloyed molybdenum and admixed nickel and copper for better compressibility.

For the procedure weight of the powder used 18.5 to 20.00 grams. Selected TSI is 33 to 35. And the pressure used to test the shear strength is 39,197lbs to 43, 761lbs.for the testing density needed was 6.7 to 6.9 g/cm^3. Brazing slugs weighted length of 1.2mm, width 0.5mm and approximate Height of 0.2mm. Brazing material used a sinter brazing paste and in which the weight of the paste used around 0.15 to 0.20grams.

TABLE II. Molybdenum- Nickel-Steel- pre alloyed- As sintered

	Chemistry					Typical properties					
GRADE	C	Mn	Mo	Ni	Cu	Density g/cm^3	Tensile Strength ksi (MPa)	Yield Strength ksi (MPa)	Elongation %	Unnotched Impact Energy ft-lb (J)	Apparent Hardness HRB
FL-4405	0.4-0.7	0.05-0.30	0.75-0.95	-	-	6.70 7.10	52 (360) 66 (460)	42 (290) 52 (360)	1	6 (8) 16 (22)	60 73

TABLE III. MOLYBDENUM-NICKEL STEEL – PRE-ALLOYED –HEAT-TREATED

	Chemistry					Typical properties					
GRADE	C	Mn	Mo	Ni	Cu	Density g/cm^3	Tensile Strength ksi (MPa)	Yield Strength ksi (MPa)	Elongation %	Unnotched Impact Energy ft-lb (J)	Apparent Hardness HRC
FL-4405-HT	0.4-0.7	0.05-0.30	0.75-0.95	-	-	6.70 7.10	110 (760) 160 (1100)	~UTS	<1	5.5 (7) 9 (12)	24 34

Reference: https://www.ssisintered.com/materials/low-alloy-molybdenum-nickel-steels.[10]

III. METHOD

Make slugs of powder Brazing powder 1000101-MPIF FLC:4405 and 1000111-MPIF FLC-4808, the basic requirement for making slugs is to get a density of 6.7 to 6.9g/cm^3. Once the density and slugs are made use sinter brazing paste on both the different products. Once the brazing material is applied the brazed parts are ready for sintering. Sintering is effective when the process reduces the porosity and enhances properties such as strength, electrical conductivity, transparency and thermal conductivity; yet, in other cases, it may be useful to increase its strength but keep its gas absorbency constant as in filters or catalysts. During the firing process, atomic diffusion drives powder surface elimination in different stages, starting from the formation of necks between powders to the final elimination of small pores at the end of the process. In a furnace, test brazed parts are heated for 16 hours cycle and at 1600c temperature. Once the sintering is done slugs were being tested for the shear strength. Once the product is sintered then there are two possibilities for the heat treatment, there might be a chance that the product might get melt, or its bond gets stronger. But there are high chances that the product gets melted. After the sintering the heat treatment took place, Heat treatment is any one of several controlled heating and cooling operations used to bring about the desired change in the physical properties of a metal. Its purpose is to improve the structural and physical properties for some particular use or for future work of the metal. There are five basic heat-treating processes: hardening, case hardening, annealing, normalizing, and tempering. Although each of these processes brings about different results in metal, all of them involve three basic steps: heating, soaking, and cooling. Heat treatment steps are as followed, heating, soaking, cooling, hardening, tampering. Following the heat treatment process was Air quenching carburizing process. Specification of this process, A Cycle – Air Cooled, Endo Gas Carburizing, Deep Freeze Tempering – 150 ℃ – 230 ℃

1st Zone - 1600
2nd Zone – 1600
3rd Zone – 1600
4th Zone – 1550
5th Zone – 1550

Figure 1. Temperature Range of Sintering

The following figure illustrates the method to use the Universal Tester machine to separate the two brazed components, to calculate shear strength.

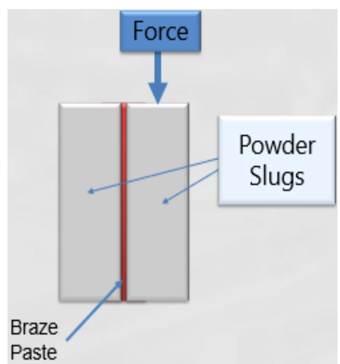

Figure 2. Tensile Testing Illustration

This device is measuring the rupture strength. Shear strength is calculated by the following procedure:

- Drill a 0.25" (6.4mm) diameter hole by 0.125" (3.2mm) deep through the center of braze
- Place a 0.25" Dowel pin in the hole and push down with tensile tester until part splits
- Record reading = Breaking Load

IV. RESULTS AND CONCLUSION

The research took place at Burgess Norton Mfg. [9]. Co. The test showed that the brazing paste SCM-Sinter

Braze Grade: EXP6778-99 showed a significant increase in strength in comparison to the SCM-Sinter Braze Grade:C-458 paste. The EXP6778-99 paste was also not affected by the Heat Treat operation (typically weakens). This was a significant finding because no other sinter brazing process are currently Heat-Treating parts after they have been brazed due to the weakening of the bond.

TABLE IV. SHEAR STRENGTH OF DIFFERENT JOINTS

Shear Strength (psi) Summary		
Powder	**714080-99 RoHS Compliant**	**EXP6778-99**
1000101	2643.4	5018.3
1000101HT	2405.6	6230.5
1000111	3998.5	7118.6

Reference: Burgess Norton Mfg. Co. [9]

REFERENCES

[1] Gabrielov, C. Wilson, and J. Hamill, "Sinter-Brazing Automotive Powertrain Components," International Journal of Powder Metallurgy, Vol. 37, 7, 2001, pp 46-48.

[2] M. Frank, "Advanced Sinter brazed P/M Subassemblies in Torque Transfer Systems: Reduction Hubs and Carriers," SAE, 2002.

[3] M. Onoda, R. Kameda, and T. Koiso, "Application of Sinter-Brazing," Metal Powder Report, November 1983, pp 632 – 634.

[4] P. Beiss, "Finishing processes in powder metallurgy," Powder Metallurgy, 1989, 32, 4, pp 277-284.

[5] M. Stromgren and O. Andersson, "Brazing of P/M Parts by Sintering," Technical Report - PM 89-6.

[6] W. Knopp, Brazing Alloy Composition, United States Patent 3,717,442 Feb. 20, 1973.

[7] R. Peaslee, "How to Identify Brazing Failures," Advanced Materials & Processes, December 2003, p 35.

[8] AWS Committee, Brazing Manual, 1963, American Welding Society, New York, NY.

[9] Burgess Norton Mfg. Co. https://www.ssisintered.com/materials/low-alloy-molybdenum-nickel-steels.