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Induction Sintering of %3 Cu Contented Iron Based Powder Metal Parts

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Abstract

In this study; iron powder metals were sintered with induction heating process. Sintering process has been achieved with an induction generator that has 12 kW power supply and 30 kHz frequency. ASC10029 grade iron powder was mixed with copper with a ratio of %3 and zinc stearat with a ratio of %0.8 of iron mass by weight. Several duration in the range of 1, 2 and 3 minutes was studied during induction sintering. Transverse rupture strength, hardness and microstructural investigations were done. Obtained mechanical properties and microstructures were compared with traditionally sintered samples. At the end of the induction sintering process for a period of 3 minutes, the maximum stress values that were obtained from traditionally oven-sintered samples for a period of 30 minutes are reached.

Keywords: Induction, Sintering, Iron based powder, Induction sintering, Copper Powder

1. Introduction

The sintering is a modification process which causes significantly an increase in resistance and recovery of the properties by supplying to interlink bits(German, R.M., 1984)(German, R.M., 2007).

The sintering process is generally performed in the sintering furnaces. The sintering furnace controls the heat and the time during the sintering loop. Additionally, it maintains the atmosphere and controls the heat treatment which provides the disposal of the lubricant and bindings. The sintering process is done in batch furnaces and continuous furnaces(German, R.M., 1984)(German, R.M., 2007).

The sintering process of an iron-based powder metal sample in a traditional furnace is performed at 1120°C in 30 minutes. The reason of performing the induction sintering is decreasing 30 minute-sintering duration to a shorter period.

Based on the literature sintering by induction was patented in 1988 in the USA under the name of "Induction sintering process and apparatus"(United States Patent, 1988). The most significant studies done on sintering by induction after that date have been done under the name of high frequency induction heat sintering which are called HFIHS. Parallel to our study, M. Nakamura et al. (Nakamura, M., 2003) took out the patent of rapid sintering of iron and steel by induction heat under hydrogen and nitrogen gases in 2003.

1.1 HFIHS (High Frequency Induction Heat Sintering)

HFIHS method is a method of rapid sintering like SPS (Spark Plasma Sintering) method. As compared to SPS, HFIHS is a new method of sintering (Kim, H.C., Kim, D.K., Woo, K.D., Ko, I.Y., Shon, I.J. 2007). This method is generally applied to ceramics, composites and bio materials. For example; are used in materials such as WC-Co (Kim, H.C., Oh, D.Y., Shon, I.J., 2004), uranium oxide (UO)(Yang, J.H., Kim, Y.W. , Kim, J.H., Kim, D.J. , Kang, K.W., Rhee, Y.W., Kim, K.S., Song, K.W., 2008) , composite like WC-Ni, Fe, Co(Shon, I.J., Jeong, I.K., Ko, I.Y., Doh, J.M., Woo, K.D., 2007)(Kim, H.C., Shon, I. J., Munir, Z. A., 2006), WC-Mo_2C (Kim, H.C., Park, H.K., Jeong, I.K., Ko, I.Y., Shon, I.J., 2007), WC-TiC (Kim, H.C. , Kim, D.K. , Woo, K.D., Ko, I.Y., Shon I.J., 2007), WC-8%Co(Kim, H.C., Jeong, I.K., Shon, I.J., Ko, I.Y. , Doh, J.M., 2006), 8YSZ-Fe_2O_3(Shon, I.J., Jeong, I. K., Park, J.H., Kim, B.R., Lee, K.T., 2007), TiB_2-WB_2 (Shibuya, M., Ohanagi M., 2007), $NbSi_2$-Si_3N_4 (Park, H.K., Shon, I.J., Yoon, J.K., Doh, J.M., Ko, I.Y.,

Munir Z.A., 2008), bio ceramics like Hydroxyapatite (Hap) (Khalil, K.A., Kim, S.W., Darmaraj, N., Kim, K.W., Kim, H.Y., 2007) and Al_2O_3-(ZrO_2+3%Y_2O_3) (Khalil, K.A., Kim, S.W., 2007). When the powders which are generally placed between Al_2O_3 double axis blocks in the plate are pressed as double axis, they are sintered by high frequency induction coil.

Cavdar et al. studied iron and iron based powder metals for sintering samples with medium frequency induction sintering (Cavdar, U., Atik, E., 2008)(Cavdar, U., Atik, E., 2008)(Cavdar, U., Atik, E., 2008).

In our study, which differs from the previous studies, medium frequency was used. Moreover, the sintering process was done after the powder metal pieces are pressed, not during the pressing process.

2. Materials and Method

The samples used in tests were produced by weight of ratio as %3 copper and iron powder. Zinc stearate as the ratio %0.8 by weight was used as the lubricant. Zinc stearate powder vanishes during the sintering process, zinc stearate functions only as a lubricant during the pressing.

The iron powder used in the tests was called ASC10029 which was produced by Hougenas (The characteristics are shown in Table 1). All of these three were mixed in 25 cycle / min. for 20 minutes to have a homogeneous mixture. The samples were sized 10x10x55 mm and they weighed 37 gr. The powder metal samples were produced by pressing in 600MPa pressure with one axis press.

A group of pressed metal powder samples were sintered in a traditional sintering furnace, some parts of these were sintered in argon gas environment, another part in atmosphere environment. The other group was sintered by a 2 kW 30 kHz induction generator in the atmosphere environment. The sintering temperature was 1120°C during the traditional sintering process. The sintering process performed in conventional furnaces was finished in 30 minutes. Two different kinds of induction sintering processes were applied to the same sort of samples. The first sintering process lasted for 1, 2 and 3 minutes in induction sintering. Second sintering process was started with pre-sintering in a traditional sintering furnace at 500°C for 10 minutes and then samples were sintered at 1, 2 and 3 minutes with an induction sintering generator. The heat of the sample was set as 1120°C by an infrared pyrometer during the induction sintering process.

The induction appliance and the sintering progress made by it which is shown in Figure 1.

Transverse rupture strength (TRS) tests were performed in Autograph Shimadzu AG-IS 100 kN, a universal test appliance used for comparing the sintered samples via traditional sintering process and sintered samples via induction sintering.

3. Results and Discussion

The results of transverse rupture strength experiments presented the average of at least 3 samples. The results are shown in Table 2. The break stretching of the samples sintered by induction for 3 minutes were nearly the same as of the samples sintered for 30 minutes by traditional sintering ovens.

The SEM pictures of the samples were taken from the broken surfaces which were formed as the result of transverse rupture strength tests. SEM pictures are only the pictures of the samples which were sintered in 1, 2 and 3 minutes by induction sintering.

In the SEM pictures, it is shown that the samples which were sintered for 3 minutes are sintered better than the ones that were sintered for 1 and 2 minutes. In the pictures of the broken surfaces of the samples, it is seen that the sintered powder forms neck shapes. These shapes are the proof of sintering. The breaking took place at these points.

4. Conclusion

Induction sintering is completed in a shorter period compared to conventional sintering. Maximum stress and break strain values accomplished in 3 minutes via induction sintering are accomplished in 30 minutes via conventional sintering.

Induction sintering is illustrated in SEM views. The best sintering process occurs in 3 minutes which is seen from broken surface views.

If pre-heating and atmosphere controls are made in sintering when high mechanic features can be obtained. In addition to this sample surfaces can have been high quality.

Energy consumption is lower in induction sintering.

Bobbin designing and using which is suitable to component shape and dimensions is important in induction sintering.

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Tables and Figures:

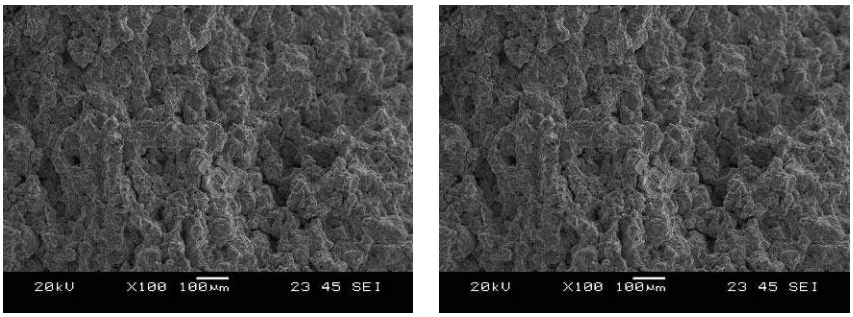
Table 1. The Characteristics of Metal Powder [3]

		SPECIFICATION		**RESULT %**
		MİN.	**MAX.**	
GRANULOMETRY				
B.S.S. MESH	MICRONS			
85	180		0.0	0.0
100	150		0.5	0.3
150	106			12.5
200	74			19.1
300	53			19.8
350	45			11.6
-350	45	30.0	40.0	36.7
PHYSICAL PROPERTIES				
Apparent Densty	g/cc	2.55	2.75	2.69
Flow	Secs		30	26
CHEMICAL ANALYSIS				
Copper	%	99.00		99.74
Oxygen	%		0.15	0.08

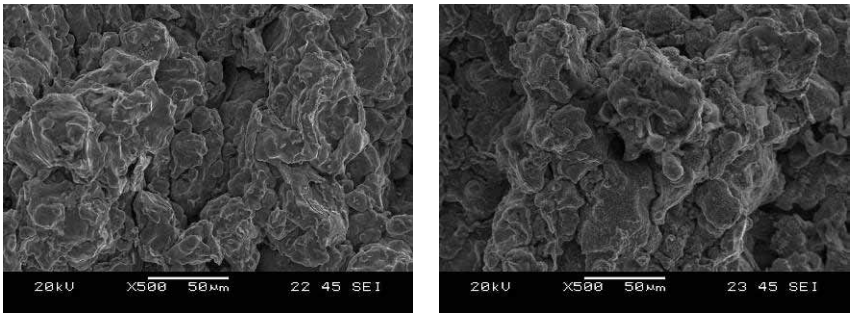
Table 2. 3 point bending results

	Max. Stress (N/mm^2)	**Break Strain (%)**
By classical sintering in 1120°C, 30 minutes sintered samples		
Atmospheric environment	285,6	2,8
Argon environment	375,2	3,1
Induction Sintering, 1120°C		
1 min. Sintering (Atmospheric environment)	93,6	1,2
2 min. Sintering (Atmospheric environment)	236,6	3,3
3 min. Sintering (Atmospheric environment)	318,2	3,1
Presintering 500°C, 10 minutes + Induction Sintering, 1120°C		
1 min. Sintering (Atmospheric environment)	310,6	2,6
2 min. Sintering (Atmospheric environment)	335,2	4,6
3 min. Sintering (Atmospheric environment)	348,3	4,1

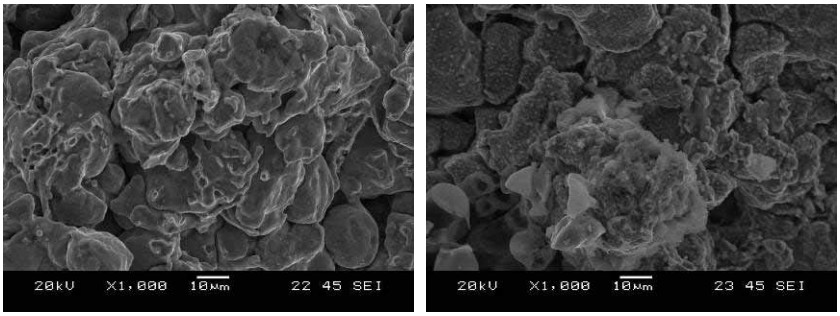
Figure 1. Induction Machine and Sintering Process (Celal Bayar University, research laboratory, Muradiye Campus Manisa, Turkey)



(a) (b)

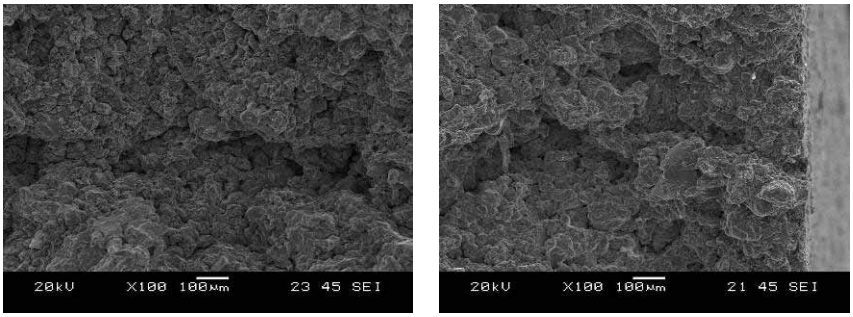


(c) (d)

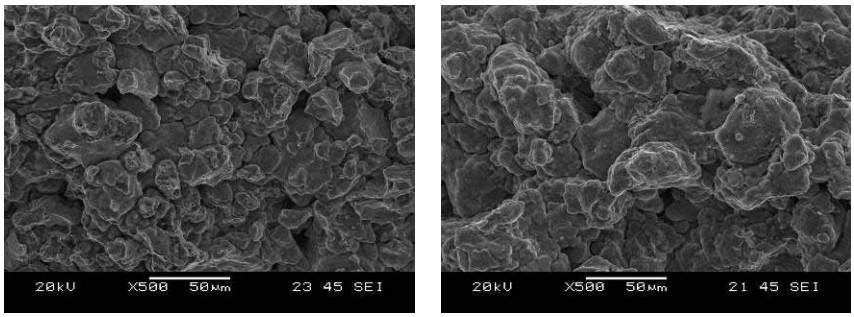


(e) (f)

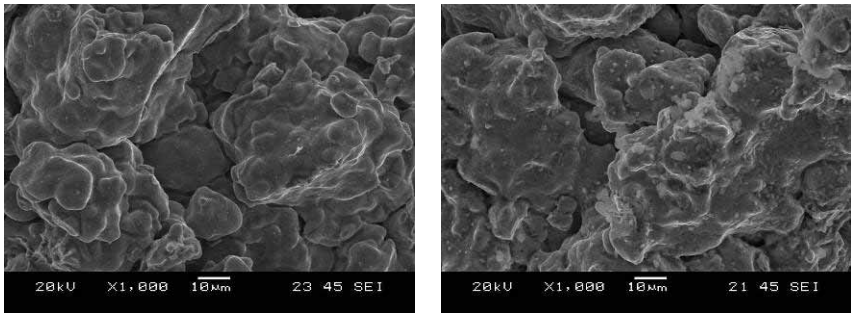
Figure 2. The structure of the samples of 1 minutes sintered by induction in 1120°C.
a) 100x picture of inside part of broken surface, b) 100x picture of outside part of broken surface,
c) 500x picture of inside part of broken surface, d) 500x picture of outside part of broken surface,
e) 1000x picture of inside part of broken surface, and f) 1000x picture of outside part of broken surface
are different places of SEM pictures of 1 minutes induction sintering sample.



(a) (b)



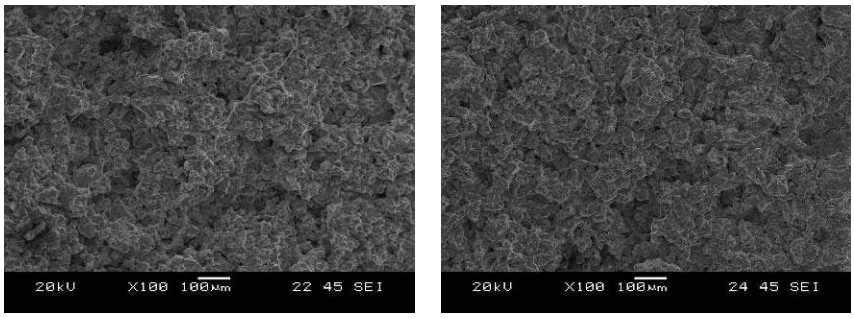
(c) (d)



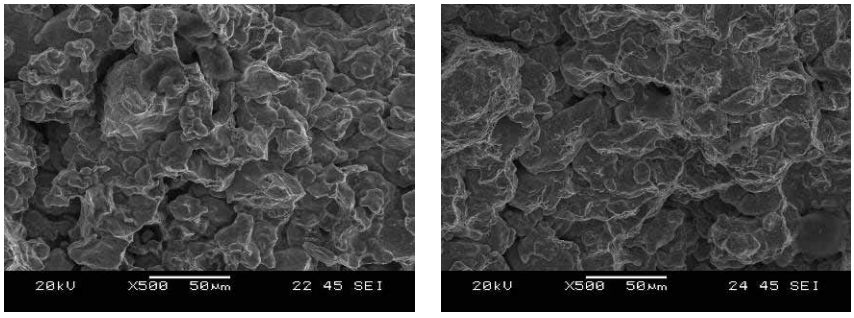
(e) (f)

Figure 3. The structure of the samples of 2 minutes sintered by induction in 1120°C

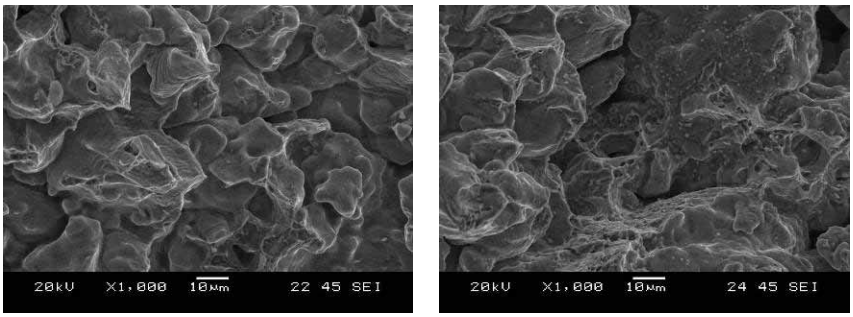
a) 100x picture of inside part of broken surface, b) 100x picture of outside part of broken surface, c) 500x picture of inside part of broken surface, d) 500x picture of outside part of broken surface, e) 1000x picture of inside part of broken surface, and f) 1000x picture of outside part of broken surface are different places of SEM pictures of 2 minutes induction sintering sample.



(a) (b)



(c) (d)



(e) (f)

Figure 4. The structure of the samples of 3 minutes sintered by induction in 1120°C

a) 100x picture of inside part of broken surface, b) 100x picture of outside part of broken surface, c) 500x picture of inside part of broken surface, d) 500x picture of outside part of broken surface, e) 1000x picture of inside part of broken surface, and f) 1000x picture of outside part of broken surface are different places of SEM pictures of 3 minutes induction sintering sample.