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MILITARY TECHNICAL COLLEGE

CAIRO - EGYPT

LIQUID PHASE SINTERING USING SUPER ALLOYS

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ABSTRACT

The outhors are working on a project sponsored by the supreme council of Universities to deal with the subject of duplex powder preform forgings. As a part of its relevant program,the effect on hardness and tensile strength of liquid phase sintering was investigated. For such a study,specimens in circular and rectangular cross sections were produced from EMP 4607 steel powders with the additions of some different brazing alloy powders with an amount of 3.5%. Similar specimens were also prepared from EMP 4607 steel powder only. Brinell hardness values were measured for cylindrical specimens. Tensile tests were performed by making use of the specimens with rectangular cross sections.The effect on mechanical properties of both sintering time and liquid phase sintering was observed.The results obtained at this stage were discussed with the aid of micro-structures examination.

INTRODUCTION

The formation of a liquid phase plays a major role in the sintering of a number of well known systems in powder metallurgy. Sintering in the presence of a liquid phase has been used for about 30 years in the field of hardmetals,cemented carbides,heavy alloys(e.g. W-Cu-Ni systems),porous bearing bronzes and silicon nitride. Studies of these material related to fundamental aspects of liquid phase sintering (mainly for binary and ternary systems) have been reviewed elsewhere(1-7). To date,about 70% by weight and 90 % by value of sintered metallic products are manufactured in the presence of a liquid phase during sintering (5). The nickel base

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superalloy powders appear suitable for liquid phase sintering because of their rather wide solidification interval (100 C) ,from the very few studies devoted to the liquid phase sintering of superalloys (8-10).The present paper is concerned with the application of the liquid phase sintering technique to EMP 4607 alloy steel powder with the addition of 3.5% different brazing alloy powders such as SF40,SF1,684DR and NBZ30. The aim of the present work is to determine the optimal sintering time at 1150 C as far as the ultimate tensile strength and hardness are concerned and to select one of the used additive as a suitable brazing superalloy powder for liquid phase sintering in comparison with the conventional solid phase sintering of 4607 steel powder compact.

EXPERIMENTATION

Some preforms were produced from different powders to have circular and rectangular cross sections being respectively compacted at a pressure of 980 MPa and 478 MPa. Sintering of those preforms was performed in a hydrogen atmosphere under a sintering temperature of 1150 C. Sintering times of 10 ,25 ,60 and 90 minutes were invoked.

EMP 4600 alloy steel powder with 0.75% graphite addition was used as a base metal. This powder is designated in the present work as 4607 steel. To investigate the effect of liquid phase sintering,some of the preforms were produced from 4607 steel powder with the addition of some different brazing alloy powders such as SF40 ,SF1 ,684DR ,NBZ30 and copper with an amount of 3.5 wt.%. Preforms made of NC 100.24 iron powder only were also prepared. The chemical composition of each material used is listed in the following table.1.

Table 1 Details of Used Powders

Type of Powder	Composition %									Melting Range C
	Fe	Cu	Cr	Si	B	C	W	Ni	Mo/ Co	
EMP 4600	Bal.	--	--	--	--	0.75	--	1.8	0.48	-----
Copper	--	99.9	--	--	--	--	--	--	--	1083
SF40	3.5	--	11	3.5	2.2	0.5	--	Bal.	--	970-1160
684DR	1.5	--	7.5	4.0	1.5	0.3	--	Bal.	--	970-1160
NBZ30	--	--	19	10	--	0.15	--	Bal.	--	1080-1135
SF1	--	--	19	8	0.8	0.4	4	17	Bal. Co.	1010-1050

6

Brinell hardness at different locations on the outer surface of the cylindrical samples was measured. Such tests were carried out with a ball of 2.5 mm in diameter and a load of 187.5 Kg. The average value of five readings was analysed. Tensile tests were carried on a Hounsfield tensometer type "W". Specimens were machined according to specifications in the instruction manual of Tensometer type "W" to suit chuck No.12,from the middle part of the preforms with rectangular cross section as shown in Fig.1.

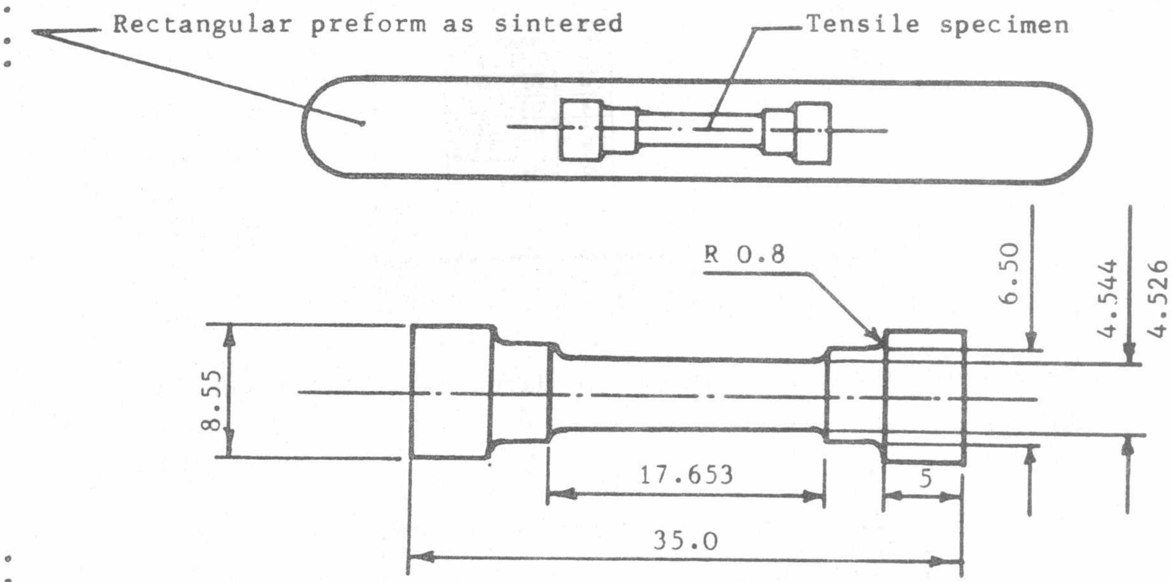


Fig.1 Position and Dimensions of Hounsfield Tensile Test Specimen.

RESULTS AND DISCUSSION

The hardness test average readings and the ultimate tensile strength are plotted on Figs.2&3 respectively against sintering time. The results reveal that there are three trends. The first trend is reflected by an increase in both hardness and ultimate tensile strength values with a corresponding increase in sintering time, reaching a maximum value at 60 minutes sintering time followed by a slight decrease in hardness and ultimate tensile strength should sintering time be expanded to 90 minutes. Such a trend was observed in the case of SF1 ,NBZ30 brazing alloys and copper additives. A set of specimens containing SF1 is chosen to represent this behaviour . Fig.4 presents a detailed metallographic study carried out on those representative specimens. From an analysis of those micro-structures, this first trend can be explained as follows. In the case of the 4607 alloy steel with SF1 brazing alloy addition, neither the 10 minutes nor the 25 minutes sintering times was sufficient to complete the sintering process since the

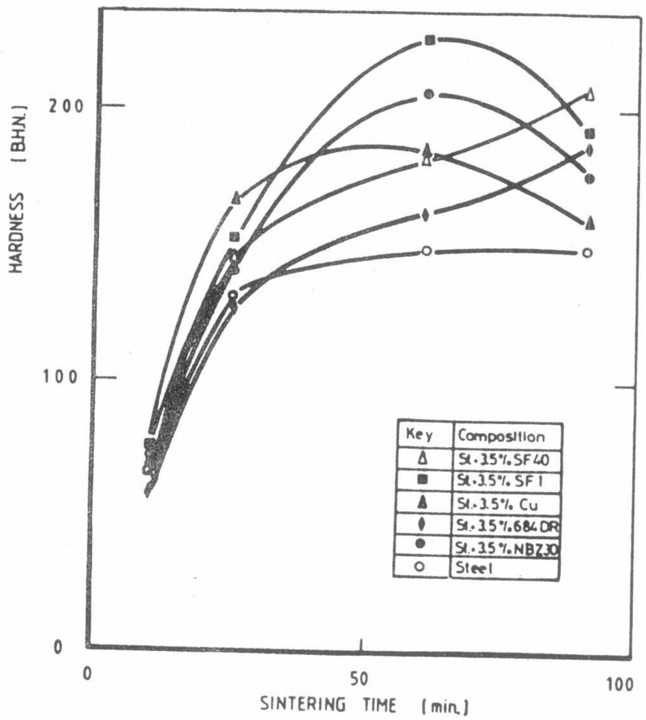


Fig.2 Effect of Sintering Time on the Hardness of Different Alloys as Sintered.

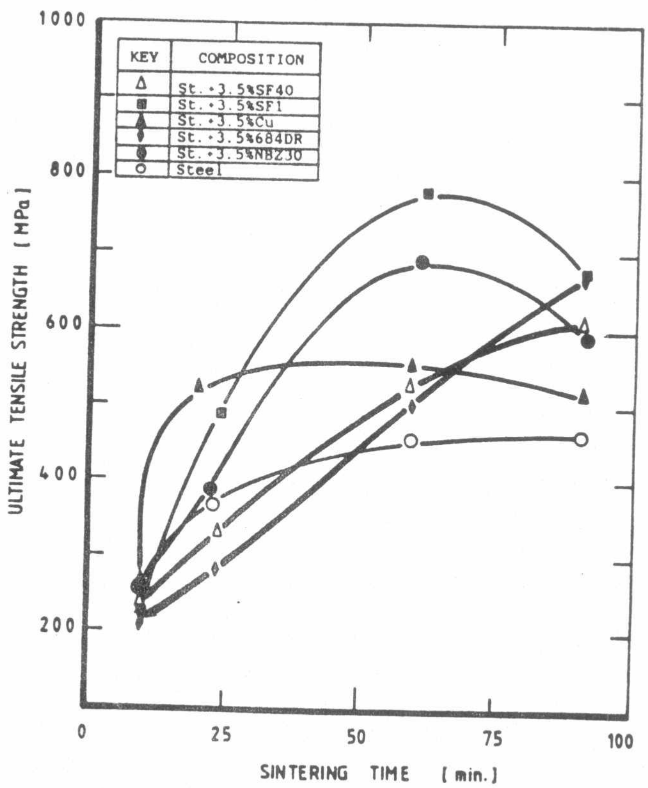
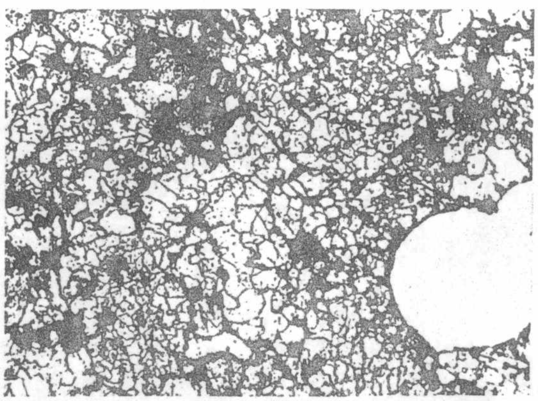


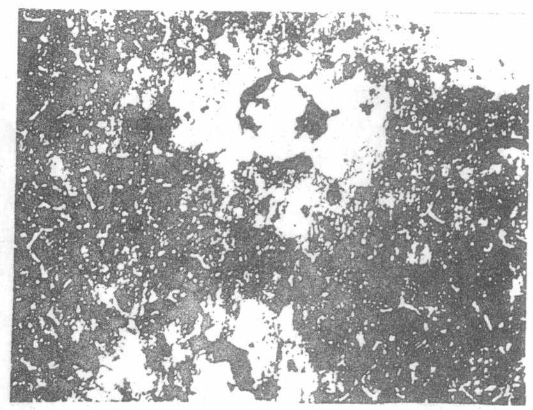
Fig.3 Effect of Sintering Time on the Ultimate Tensile Strength of Different Alloys as Sintered.

grain shape in general is that of the original powders and the white spots of brazing alloy powder remained unchanged as shown in Fig.4-(a) and 4-(b) After been sintered for 60 minutes the brazing alloy powder began to diff-use in the matrix leaving a cavity in its vicinity as shown in Fig.4-(c). At 90 minutes sintering time, the brazing alloy diffusion process was completed leaving cavities in the matrix and thus causing a decrease in both hardness and ultimate tensile strength values as a result of an increase in porosity. This can be observed in the micro-structure of Fig.4-(d) in which white spots disappeared.



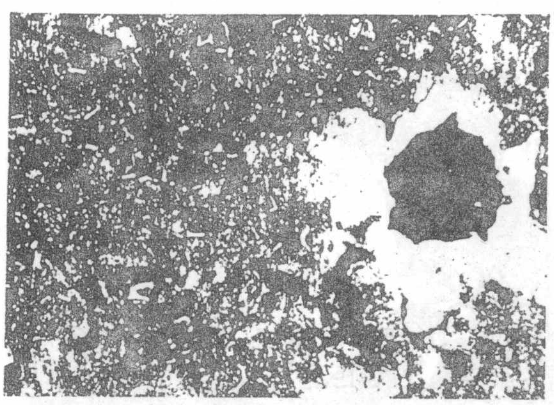
X 500

(A) 10 minutes



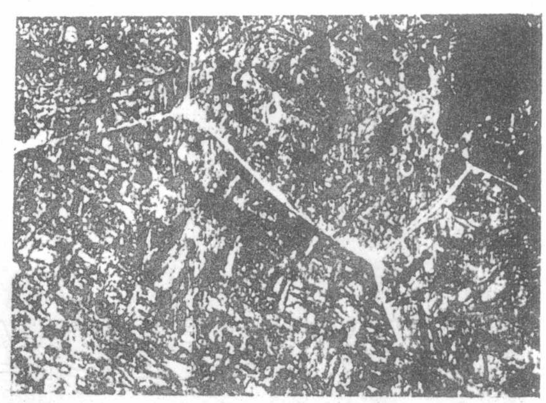
X 500

(B) 25 minutes



X 500

(C) 60 minutes

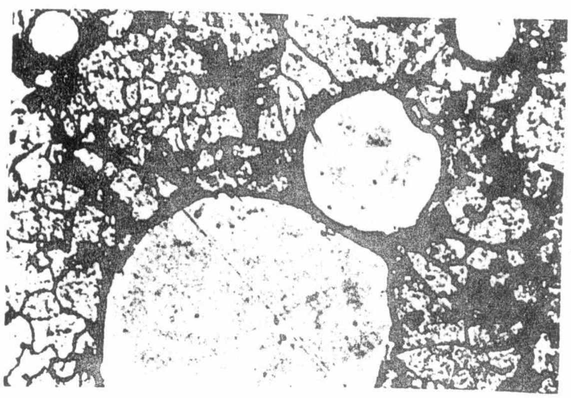


X 500

(D) 90 minutes

Fig.4 Effect of Sintering Time on the Micro-structure of 4607 Steel+ 3.5% SF1.

The second trend is observed as a continuous increase in both hardness and ultimate tensile strength within the investigated range of sintering times. That was the case of adding brazing alloys of SF40 and 684 DR to 4607 steel powder. To explain such a behaviour, a set of specimens of 4607 steel powder with the addition of 684 DR is chosen for a detailed metallographic examination as exhibited in Fig.5. Sintering process was not completed up to 25 minutes sintering time as shown in Figs.5-(a) and 5-(b). White spots represent the original brazing alloy powders in the matrix. At 60 minutes sintering time, the brazing alloy powders did not diffuse into the matrix, whilst traces of uncombined graphite can be observed in the micro-structure of Fig.5-(c) .

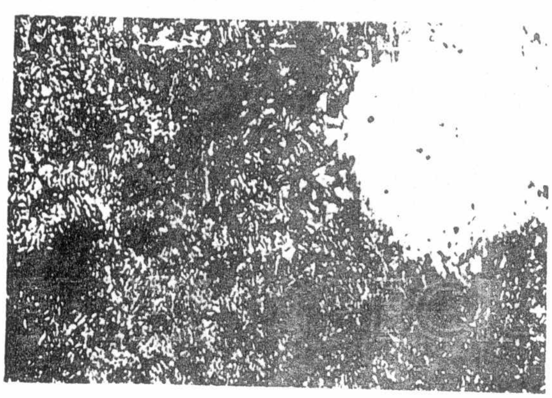


X 500

(A) 10 minutes

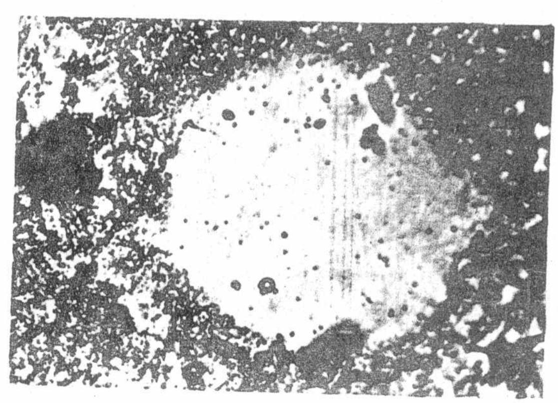
X 500

(B) 25 minutes



X 500

(C) 60 minutes

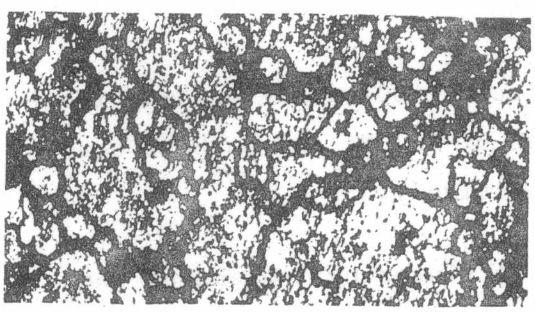


X 500

(D) 90 minutes

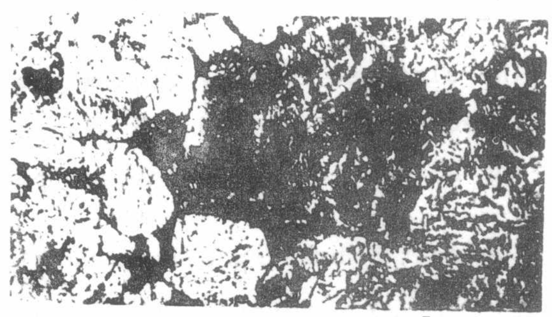
Fig.5 Effect of Sintering Time on the Micro-structure of 4607 Steel + 3.5% 684 DR.

The third trend occurred in the case of 4607 steel powder and can be described as an increase in both hardness and ultimate tensile strength values reaching a maximum value at 60 minutes sintering time. Beyond that limit, no effect on both hardness and ultimate tensile strength could be observed. Micro-structures taken from 4607 steel specimens are shown in Fig.6 This trend can be explained as follows. Up to 25 minutes sintering time was not sufficient to complete the sintering process. This fact is obvious in Figs.5(a) and 5-(b) as can be seen by the variation of grain size from small to large in a randum manner, the grain shape is that of the original powder and the pores are non-uniform in size and quite angular in shape. After been sintered for 60 minutes,the micro-structures of Fig.-5(c) shows a complete absence of the original particle boundaries and grain growth had extended to beyond the size of the original particles.The pores have become very spheroidal and often isolated within grains.However free graphite traces were seen in the matrix. Micro-structure of the specimen sintered at 90 minutes presented in Fig.6-(d) reveals that two counter balancing processes may take place to cause the constancy of both hardness and ultimate tensile strength values. A grain growth process is counter-balanced by a diffusion process of the remaining free graphite in the matrix.



X 500

(A) 10 minutes

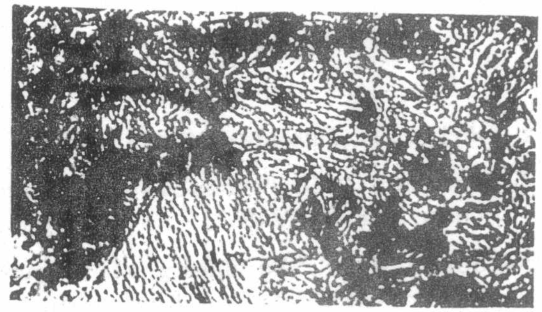


X 500

(B) 25 minutes

X 500

(C) 60 minutes



X 500

(D) 90 minutes

Fig.6 Effect of Sintering Time on the Micro-structure of 4607 Steel Only.

The economical justification of using the costly brazing alloys for liquid phase sintering instead of the relatively cheaper and conventionally used copper is obvious from the following table.

Compared Factors / Material	Increase % in material cost	Increase % in U.T.S
4607* Steel+ 0% add.	0	0
4607 Steel+ 3.5% Cu	13	22
4607 Steel+ 3.5% Ni-base	25	50
4607 Steel+ 3.5% Co-base	50	80

* The price and U.T.S of the 4607 steel powder was taken as the basis for comparison.These are 2.5 £ /Kg.(11) and 450 MPa respectively.

CONCLUSIONS

1- Sintering time in the range of 60 to 90 minutes according to the liquid phase additives to the 4607 steel powder is sufficient to complete the diffusion process during sintering at 1150 C.

2- The ultimate tensile strength of the sintered 4607 steel product incr-eased by 20%,50% and 80% when adding 3.5% of Cu, Ni and Co base braz-ing alloys to the 4607 steel powder respectively.

3- The costly brasing alloys for liquid phase sintering instead of the relatively cheaper and conventionally used copper is economically justified.

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