MILITARY TECHNICAL COLLEGE

CAIRO - EGYPT

HEAT TREATMENT OF LIQUID PHASE SINTRED DUPLEX POWDER PREFORMS

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ABSTRACT

The purpose of the present work is to investigate the effect of heat treatment on duplex powder preforms with liquid phase sintering. For such a study, 4607 alloy steel powder with the separate addition of some different brazing alloy powders were prepared as well as NC 100.24 iron powder. Some cylindrical duplex preform samples were produced by suitable compaction and sintering for different times. NC 100.24 iron powder was invaribly located in the core,whilst the sheath material was one of the alloy steel prepared with and without the additives. The specimens were then properly heat treated to record its effect on hardness values. Crushing tests and micro-hardness tests were performed across the material transition zone. The results were discussed in terms of micro-structures examination.

INTRODUCTION

Recently the production of duplex materials by powder metallurgy technique is goining more interest due to the wide fields of their applications in industry such as gear production,porous bushings etc. Many researches (1-12) in the last decades are directed to obtain adequate mechanical properties to meet specific practical requirements.

The application of liquid phase sintering provided by addition of superalloys as brazing materials during the production of duplex powder materials is not fully investigated(13,14). This new trend in using such brazing alloys is developed to substitute for the traditional copper additions to provide liquid phase during the sintering process. In the same time such superalloys will probably result in better mechanical and bonding properties

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due to their inherent high properties. Moreover, there are not sufficient published data about the heat treatment of such duplex powder materials. This may be due to the difficulties encountered in carrying out heat treatment of porous materials despite of its well known contribution to the modefication of mechanical properties.

Therefore, the aim of this work is to investigate the effect of additions of cobalt and nickel based brazing alloys to form liquid phase during the sintering process and to study the sheath/core interface properties before and after heat treatment, since improving the bonding strength at the sheath/core interface has a significant role during servicing duplex machine parts.

EXPERIMENTATION

Some cylindrical duplex preform samples were produced by the compaction of different powders at a pressure of 980 MPa. A core to sheath area ratio of 0.37 were adopted. Iron powder of NC 100.24 was invariably located as a sheath, whilst the core material was one of purposely prepared 4607 steel powder alone as a base metal and also mixed with some different brazing alloy powders with an amount of 3.5 wt.%. Powders of 4607 steel was prepared from EMP 4600 alloy steel with 0.75 wt.% graphite additions. Powders of SF40, SF1, 684 DR, NBZ30 and copper were chosen as brazing alloys to accomodate liquid phase sintering of different systems. The chemical composition of each material used is given in table 1. The combinations of the materials both in the sheath and in the core of each used duplex preform with the corresponding code is shown in table 2.

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
NC.100.24 Iron	Bal.	--	--	0.3	--	0.1	--	--	--	------

Table 2 Codes and materials of used duplex preforms.

DUPLEX MATERIAL SHEATH / CORE	CODE
NC 100.24 iron / EMP 4607 steel	A-1
NC 100.24 iron / 4607+ 3.5% SF40	A-2
NC 100.24 iron / 4607+ 3.5% SF1	A-3
NC 100.24 iron / 4607+ 3.5% 684DR	A-4
NC 100.24 iron / 4607+ 3.5% NBZ30	A-5
NC 100.24 iron / 4607+ 3.5% Cu.	A-6

Such preforms were sintered at a temperature of 1150 C in a dry hydrogen atmosphere. Sintering times invoked were 10,25,60 and 90 minutes.Similar single material samples were produced by making use of the above technique.Each one of those specimens was prepared from one of the materials combinations listed in table 2.

Six Brinell hardness measurements were performed and an average value for each single material was recorded and plotted against sintering time as shown in fig.(1). Such results were compared with the hardness values obtained from the cores of the corresponding duplex samples having the same materials combination in the core. At this stage,all the specimens were heat treated as follows. The preforms were heated in a hydrogen atmosphere for 20 minutes at 900 C and then quenched in a water both(15).

Brinell hardness were then after heat treatment similarly measured again to be plotted against sintering time on fig.(2).Duplex samples were cut into two cylindrical parts for the following examination. Micro-hardness values were traced across the duplex specimens to have an indication about the nature of the bonding zone at the interface, Fig.(5) exhibits an example. Crushing tests were also performed to evaluate the shear strength of the interface material in duplex samples. Fig.(3)shows such shear strengths presented against sintering time for the different duplex specimens. The results so obtained are discussed with the aid of some micro-structures examination of the core and sheath materials.

DISCUSSION

Fig.(1) reveals that there are three trends of the hardness values in relation to the sintering time in the case of the as-sintered preforms. The first trend is recognised by an increase of the values reaching a maximum at 60 minutes sintering time followed by a slight decrease in hardness. That was observed in the case of SF1, NBZ 30 and copper brazing material as shown in table 2 under code number A-3,A-5 and A-6 respectively. The second trend is the continuous increase in hardness within the investigated range of sintering time.Duplex material ,code number A-2 and A-4 which included SF40 and 684 DR brazing alloys respectively present such a case. In the case of EMP 4607 steel with no additions of brazing alloy, code number A-1,the trend can be described as an increase of hardness values reaching a maximum value at a sintering time of 60 minutes and remaining unchanged beyond that time. Such findings are justified and discussed in details in the first paper presented in this proceeding by the same authors(14).A detailed metallographic study was carried out on specimens

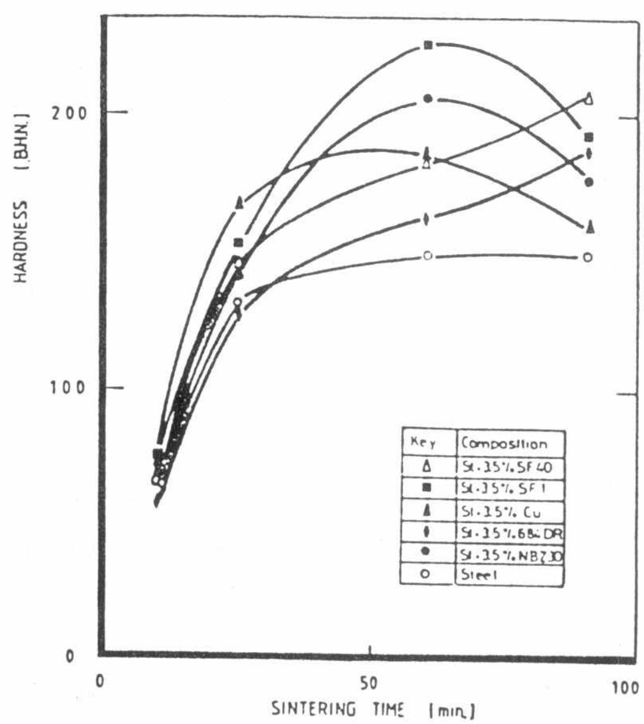


Fig.1 Effect of Sintering Time on the Hardness of Different Alloys as Sintered.

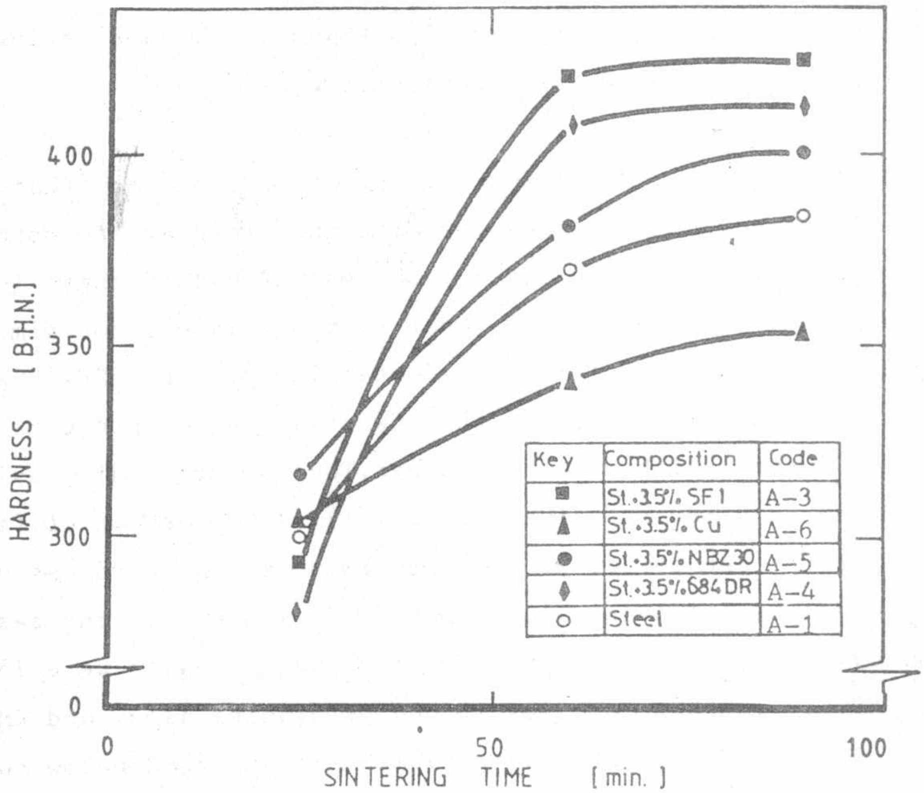


Fig.2 Effect of Sintering Time on the Hardness of Different Alloys, After Heat-Treated.

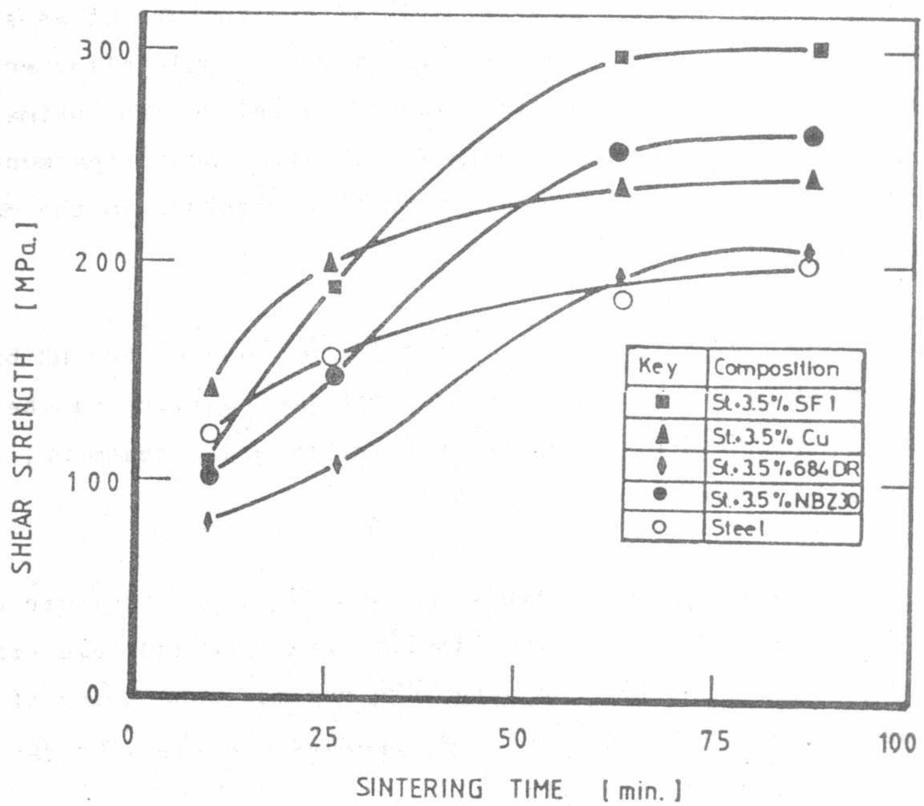


Fig.3 Effect of Sintering Time on the Shear Strength of Different Alloys After

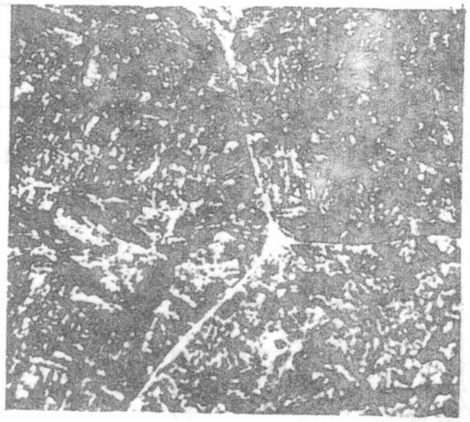
containing SF1 and 684 DR as brazing alloys and of EMP 4607 alloy steel to represent respectively the above described trends.

In the case of heat treated specimens, figs.(2) and (3) show that all the alloys used followed the same and similar trends relevant to both hardness and shear strength values. Thus it may be concluded that there is a direct relation between such hardness and shear strength values. For similarity it can be observed that the preforms, A-3 containing 3.5 wt.% SF1 brazing alloy attained the highest values whilst the lowest values of preforms A-6 containing EMP 4607 steel with 3.5 wt.% copper. The following discussion is based on the measured hardness values of fig.(1). A comparison of fig.(1) and fig.(2) illustrates the effect of heat treatment on the hardness values of each alloy used. The hardness values increased with 90% in the case of SF1 brazing alloy. For 60 minutes sintering time, the increases were 150% and 140% respectively in the two cases of 684 DR brazing alloy and EMP 4607 alloy steel. Such an effect of heat treatment is analysed below to be justified with the aid of micr-structure examinations. The microstructures of these alloys before and after heat treatment are illustrated in fig.4 for the preforms sintered for 90 minutes. Figs.(4a) and (4b) represent EMP 4607 steel alloy with the addition of 3.5 wt.% SF1. The structure of as sintered alloy, fig.(4a), exhibits a complete net-work of rich cobalt alloy enclosing grains of austenite. The structure is composed largely of an intimate mixture of Cr_7C_3 spins and solid solution. However, after heat treatment, fig.(4b the structures becomes finer and consists of fine carbides in the matrix of lower bainite (Troosto-martensite).

Figs.(4c) and (4d) show the microstructures in the case of 684 DR brazing alloy. Well -formed laminated pearlite and sorbitic pearlite can be easily identified in as -sintered preforms, fig.(4c). After heat treatment, the structure is mainly lower bainite, fig.(4d).

For EMP 4607 alloy steel, shown in figs.(4e) and (4f), the structure of the as sintered alloy fig.(4e) shows fine lamellar pearlite and some troostite. Due to heat treatment, fig.(4f), the structure becomes consisting of lower bainite and needles of carbides which are separated on the cleavage planes of the original iron solid solution.

Fig.(5) illustrates the micro-hardness values across the transition zone



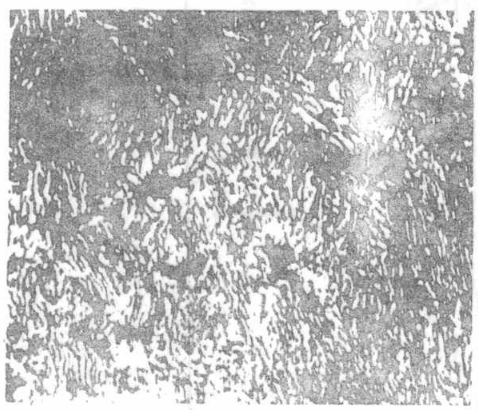
X 500

(a) As Sintered

EMP 4607
+
3.5% SF1

X 500

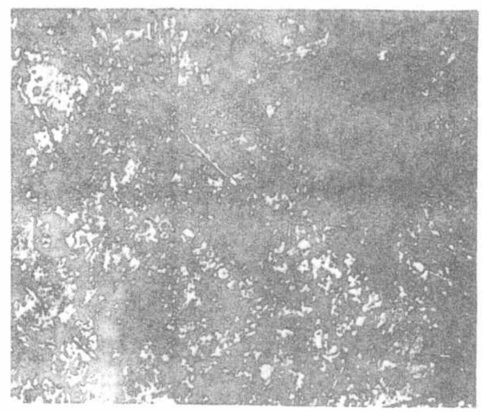
(b) As Hardened



X 500

(c) As Sintered

EMP 4607
+
3.5% 684 DR



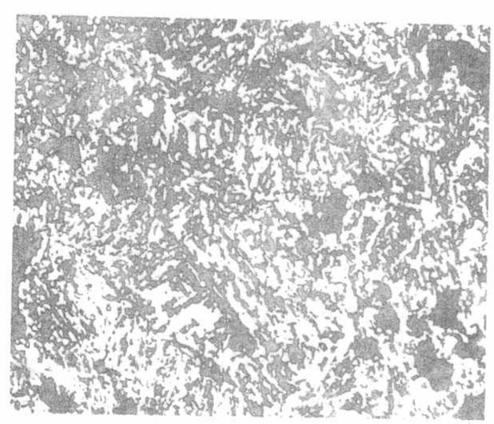
X 500

(d) As Hardened

X 500

(e) As Sintered

EMP 4607
only



X 500

(f) As Hardened

Fig.4 Effect of Heat Treatment on the Microstructure of Sintered EMP 4607 Steel With and Without Liquid Phase Additives,(all samples were sintered for 90 min. at 1150 °C,water hardened from 900 °C).

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between the core made from EMP 4607 steel with 3.5 wt.% SF1 and 684 DR brazing alloys and the outer layer made from NC 100.24 iron for specimen sintered for 90 minutes and heat treated. The figure shows that there is a diffusion zone divided on both sides of about 4mm and 7 mm respectively in the cases of SF1 and 684 DR.

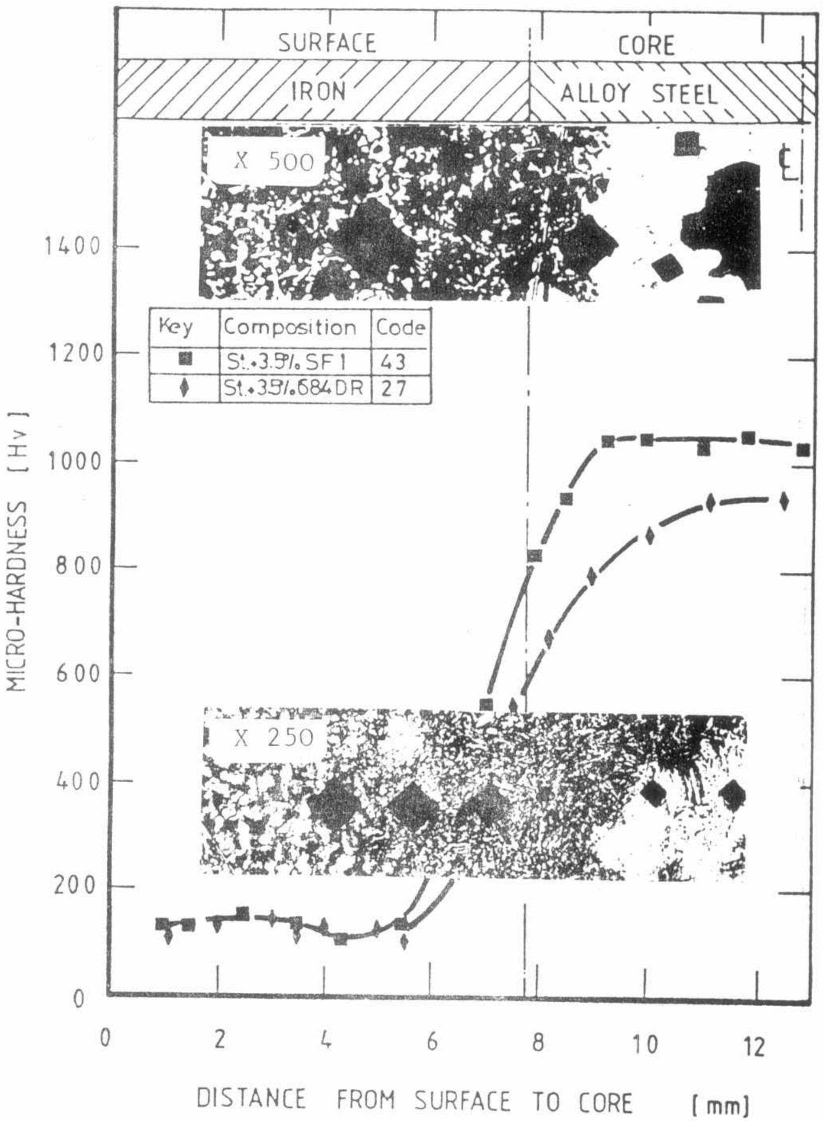

Fig.5 Distribution of Micro-Hardness Through the Interface Bond of Two Duplex Preforms Made From (4607+3.5% SF1/Iron) and (4607+3.5% 684 DR /Iron) After Heat Treated.

The figure also shows that the micro-hardness readings are much higher than the corresponding Brinell hardness values shown in fig.(1). This is explained by the elimination of porosity effect in the case of miro-hardness measurements.

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CONCLUSIONS

1- The basic process of liquid phase sintering is sufficiently flexible to be extended to a wide range of using brazing alloys.

2- As far as the interface bonding strength of sintered duplex material, (iron coverd steel), is concerned, the addition of 3.5% cobalt base brazing alloy as a liquid phase to the steel part is justified.

3- The highest values of both hardness and shear strength were attained in the case of adding 3.5% cobalt base brazing alloy to the steel part of the duplex product (iron/steel).

4- The effect of adding nickel base brazing alloy to the steel part of duplex materials on the diffusion zone in both sides, iron/steel, was more pronounced than that of adding cobalt base .

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