



# Fabrication of Stainless Steel Matrix Composites Containing up to 15% Boron Carbide

<sup>1</sup>Medha. R. Elayidom, <sup>2</sup>Abhishek A.S, <sup>3</sup>Akhil Mohan, <sup>4</sup>Abhijith Vijayakumar, <sup>5</sup>R. Rajesh, <sup>6</sup>N. Balakrishnan, <sup>7</sup>D. Thirumalaikumarasamy

<sup>1,2,3</sup> Department of Mechanical Engineering, Noorul Islam University, Kumaracoil-629180

<sup>7</sup> Department of Manufacturing Engineering, Annamalai University, Chidambaram-608002

Email:rajesh1576@yahoo.co.in

[Received:15<sup>th</sup> Feb.2017; Revised: 22<sup>nd</sup> Feb.2017; Accepted: 28<sup>th</sup> Feb.2017 ]

**Abstract-**The use of Stainless steel plays in electronic, automotive, medical, dairy and aerospace industries has been increased in recent years because of its inherent corrosion resistance. However, the severe oxidation loss of stainless steel when utilized at the temperature higher than 1000 °C restricts its further applications. Thus research on the fabrication of stainless steel composite is thought of an essential and effective work. Boron Carbide with very good hardness, high melting point and excellent properties is reinforced with stainless steel to overcome the above said problem. In the present work, Boron Carbide is reinforced with 304 stainless steel substrate to improve its high temperature oxidation resistance. The composites (15 samples) were prepared by means of Powder metallurgy route. Boron Carbide reinforced stainless steel metal matrix composites are potential materials for automobile and dairy industries.

## I. INTRODUCTION

Conventional research in metal matrix composite focused on reinforcing light metals such as Aluminium and Titanium with carbon fibers to improve the strength and wear resistance<sup>1</sup>. Polyacrylonitrile (PAN) based carbon fibers improve mechanical properties<sup>2, 3</sup> while Pitch base fibers improve thermal properties<sup>4</sup>. Stainless steel based alloys mostly used in metal matrix composites are because of its low cost and excellent properties. Also Boron carbide and Titanium carbide are used as a reinforcing material because of its low density, good melting point and high resistant to oxidation<sup>5-8</sup>. The less density of B<sub>4</sub>C is an added advantage to reduce the total weight of the material. In this work, new composites have been developed which include stainless Steel 304 matrices with Boron Carbide as the reinforcing phase, fabricated through powder metallurgy process.

Rosso<sup>9</sup> discussed various methods to fabricate ceramics and MMCs and their related properties along with the applications and future prospects of such materials. He prepared the cylindrical samples of the powders compacted with a pressure of 200–300 MPa. Few samples were pre-sintered and machined afterwards,

while the others underwent direct mechanical operations and then sintered to examine the effect of sintering on the machining of powders. The powders were sintered for 1 hour at a temperature of 1600 °C in the air. The PM technique, compared to other fabrication techniques, is a promising and versatile method for the fabrication of a composite. It ensures better mechanical and structural properties of the composites along with high homogeneity.

Jha et al.<sup>10</sup> revealed the effect of sintering temperature, time, and composition of the constituents on the microstructure, hardness, and density of Fe–ZrO<sub>2</sub> MMC during the synthesis and characterization. The formation of Zr<sub>6</sub>Fe<sub>3</sub>O phase had been noticed in X-ray diffraction (XRD) analysis as a result of partial reaction between Fe and ZrO<sub>2</sub> and this phase increases with ZrO<sub>2</sub> content. The microstructure witnessed the dispersion of Fe, ZrO<sub>2</sub>, and a small amount of Zr<sub>6</sub>Fe<sub>3</sub>O along with some minor impurities in the form of carbon. The density decreases with a percentage increase of ZrO<sub>2</sub>. The hardness of the samples also vary with sintering temperature as explored by them.

Akhtar et.al<sup>11</sup> developed the TiC-465 stainless steel/465 stainless steel composites with 50, 60, 70 wt.% TiC and the hardness and TRS are 85.2, 87, 88.2 HRA and 1332, 1103, 782 MPa, respectively. It has been found that the TiB<sub>2</sub>-TiC (95 wt.%) reinforced steel matrix composites produced by spark plasma sintering. The maximum hardness of the composite is 83.8 HRA. Therefore, it is mandatory to select the correct matrix with proper strength under a particular condition to get good comprehensive properties of composite materials.

Despite its less price and better properties, none of the authors attempted to reinforce stainless steel with Boron carbide. Therefore it was decided to fabricate stainless steel composite reinforced with B<sub>4</sub>C to improve its properties to withstand high temperatures in automobile applications.

## II. MATERIALS AND METHODS

### MATERIAL FABRICATION

The methodology of the paper is as shown in figure 1.

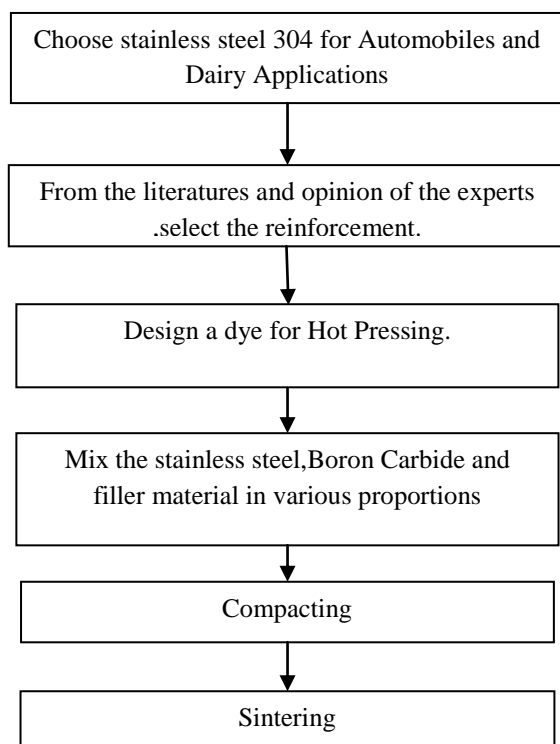


Fig.1 Methodology

A total of 30 stainless steel ingots with varying proportions of stainless steel 304 and Boron Carbide were fabricated by using powder metallurgy process. The steps involved in powder metallurgy are shown in fig. 2

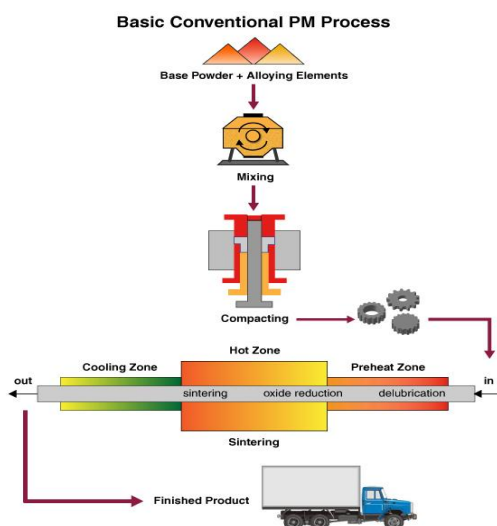


Fig 2 Powder metallurgy process

### RAW MATERIALS

The Raw material used to make MMC in this study are Stainless steel 304 and Boron CarbideStainless Steel

304SAE 304 stainless steel, also known as A2 stainless steel or 18/8 stainless steel. European norm 1.4301, is the most common stainless steel. 304 stainless steel has excellent resistance to a wide range of atmospheric conditions and many corrosive media. 304 stainless steel is used for a variety of household and industrial applications such as screws, machinery parts, car headers, and food-handling equipments. 304 stainless steel is also used in the architectural field for exterior accents such as water and fire features. Table 1 shows chemical composition of stainless steel 304.

Table 1 Chemical Composition of Stainless Steel 304

Composition	Percentage
Ni	9.25
Cr	19.00
Fe	68.595
Si	1.00
Mn	2.00
C	0.080
P	0.045
S	0.030

Boron Carbide : Boron carbide, which has a high melting point, outstanding hardness, good mechanical properties, low specific weight, great resistance to chemical agents and high neutron absorption cross-section is currently used in high-technology industries such as fast-breeders, light weight armors and high-temperature thermoelectric conversion. Boron Carbide is one of the hardest materials known, ranking third behind diamond and cubic boron nitride. It is the hardest material produced in tonnage quantities.

## III. RESULTS AND DISCUSSION

### Fabrication of Composites

Powder technology was used to prepare the B<sub>4</sub>C-steel composite. It was done in two major steps.

Mixing: Blending of powders is necessary to provide a uniform distribution of powder size and for mixing powders of two or more constituents. Blending is usually done by mechanical milling. It requires the breakage of agglomerates and the reduction of sizes of the individual crystals. The compositions of B<sub>4</sub>C and Stainless steel are shown in Table 2. The mixture was rotated at standard RPM 20 and the time required for mixing is 45 minute.

Table 2 volume percentage composition of Boron Carbide with stainless steel.

Sam ples	Iron	B <sub>4</sub> C	Ni	Cr	Mg	Si	S
1	52.40	1.10	6.00	14.25	1.5	.75	.02
2	52.29	2.0	6.00	14.25	1.5	.75	.02
3	52.185	3.15	6.00	14.25	1.5	.75	.02
4	52.08	4.2	6.00	14.25	1.5	.75	.02
5	51.975	5.25	6.00	14.25	1.5	.75	.02
6	51.87	6.3	6.00	14.25	1.5	.75	.02
7	51.765	7.35	6.00	14.25	1.5	.75	.02
8	51.66	8.4	6.00	14.25	1.5	.75	.02

9	51.55	9.45	6.00	14.25	1.5	.75	.02
10	51.45	10.5	6.00	14.25	1.5	.75	.02
11	51.35	11.5	6.00	14.25	1.5	.75	.02
12	51.24	12.6	6.00	14.25	1.5	.75	.02
13	51.135	13.65	6.00	14.25	1.5	.75	.02
14	51.03	14.7	6.00	14.25	1.5	.75	.02
15	50.925	15.7	6.00	14.25	1.5	.75	.02

Compaction: Mixed powders were poured into graphite die-plunger assemblies and subjected to a uniaxial pressing force in order to create green compacts having about 35% theoretical density. The dies had an inside diameter of 50.8 mm (2 in), an outside diameter of 88.9 mm (3.5 in), and a thickness of 50.8 mm (2 in). Graphite plungers having a diameter of 50.8 mm (2 in) and a thickness of 25.4 mm (1 in) were used to secure the bottom and the top of the die assembly. Graphite foil was used to encompass the powder in order to protect the die assembly and aid in the removal of the sintered compact. Foil was placed around the inside diameter of the die as well as above and below the powder. A small ring of 11 mm (0.4375 in) thick graphite belt was used to surround the graphite die assembly in order to lower the amount of convective heat transfer to the surrounding vacuum chamber. Once the powders were loaded into dies, they were subjected to a uniaxial pressing force of about 69 MPa through the use of a mechanical hydraulic press. It is done by a single acting press. The homogeneous mixture of stainless steel 30 and Boron Carbide were placed on a die and compressed with hot pressing. With the help of a thermocouple, temperatures were monitored and the compacting parameters are shown in Table 3.

Table 3.compacting parameters

Temperature	Pressure	Pressing Time	Vacuum
600°C	69 kPa	30 min.	0.25 bar

Sintering :The die assembly was placed in between the two graphite-capped 6" diameter water-cooled copper electrodes of the apparatus. The bottom electrode was then carefully raised towards the top stationary electrode using a mechanical hydraulic press and a uniaxial pressure of about 15 MPa was applied. This pressing force held the entire die assembly together in compression and provided an initial path for current flow, which also ensured that sufficient inter-particle contact was established. The chamber door to the apparatus was sealed and a vacuum pump was powered. When the vacuum level within the chamber reached a value of about 10<sup>-3</sup> torr, a pulsed DC current of about 2000 A at a constant voltage was applied through the powder compact using a full-wave-rectified power supply in order to heat the powder compact to a temperature of 650 °C to 750 °C. At this temperature, adsorbed gases, moisture, and contaminants were eliminated, which was confirmed by a marginal drop in the vacuum level. The pulsed current was applied until the vacuum level reached a plateau and again attained its initial value, which took about 30 minutes. After pulsing, a direct current was applied through the powder compact resulting in Joule heating. Consolidation was

carried out in a vacuum at maximum temperatures between 1750 °C and 1850 °C for 10 to 20 minutes at an applied pressure of 30 MPa. Heating rates from the final pulsing temperature up to 1000 °C was held constant at a rate of about 15 to 20 °C/min, and was subsequently reduced to 5 to 10 °C/min at temperatures above 1000 °C in order to decrease the chances of density gradients within the fully sintered material. Cooling rates were held constant at about 10 °C/min. A total of 15 samples are sintered.

Finishing :The fully sintered samples were removed from the graphite die using a mechanical press and all graphite foil was stripped using a razorblade.

#### IV.CONCLUSION

The successful production of stainless steel composites with volume percentage upto 15% of Boron carbide was produced.

Good strength steel-bonded boron carbide composite was prepared through powder metallurgy and the samples was sintered at various sintering temperatures.

Although this fabrication method is expected to lead to some difference in the distribution and morphology of carbides compared to castings made in foundry conditions, the phase transformations during heat treatment and the chemistry of various phases are expected to be similar.

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