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EXPERIMENTAL INVESTIGATION TO EVALUATE THE DIAMETERAL COMPRESSIVE STRENGTH OF GREEN SPECIMEN

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Abstract: Ceramic matrix composites (CMC's) are likely candidates for many industrial applications due to their superior properties. The different processing methods involved in the fabrication of these CMC's are a centre for attraction to researchers and industrial society. The objective of this study was to use taguchi method for the optimization of mixing parameters to obtain a better green specimen. Experimental results show that in order to improve the diameteral compressive strength the optimal combination of mixing parameters were: CNT – 5 wt%, stirring time- 60 min, pressure- 250 MPa.

Keywords: Diameteral compressive strength, MWCNT's, alumina, powder processing, SEM

1. INTRODUCTION

Ceramics are the combined form of metallic and non metallic atoms [1] and also these are the first man made material [2] having high hardness and strength, chemical inertness, low thermal conductivity and good oxidation and corrosion resistance properties [3] As the technological advancement is there these material are not capable to mutate their various properties as per the requirement of different engineering applications due to its inherent brittle nature, poor electrical conductivity and dubious mechanical properties. Composites are generally composed of two or more materials in which one is known as matrix and other filler material or reinforced material [4]. CMC's refers to the materials having good resistant properties to thermal shock, wear resistant properties, high temperature creep behavior and good fracture toughness. The use of filler material or reinforced material counteracts the crack propagation growth due to redistribution of stresses in the adjacent areas to crack tip [1].

Ceramic matrix composites can be fabricated by various methods depends on the requirement and application of materials as reported by various researches. There are three basic methods used for the fabrication of ceramic matrix composites which includes-Gas phase reactions (reaction bonding, chemical vapour deposition (CVD), chemical vapour infiltration (CVI) etc.), Liquid phase reaction (sol-gel, polymer infiltration pyrolysis (PIP) etc.), Solid phase fabrication (sintering of powders and melt casting)[5, 6]. Ekka [7] in his experimental research analyzed the effect of different percentage of binders and plasticizers on diameteral compressive strength and found that with the increase in the percentage of plasticizer the diameteral compressive strength decreases. Jonsen et al. [8] studied the green body behavior of metal powder pressed with high velocity. Amoros et al. [9] did the comparative study of different tests such as diameteral compression test, three point and four point bending test in order to evaluate the strength of green sample.

In this experimental work an effort has been made to optimize the mixing parameters in order to improve the diameteral compressive strength of the green specimen.

2. EXPERIMENTAL PROCEDURE

2.1. Material

The starting material were used - Al_2O_3 powder (CTC 20, Almatis ACC India Ltd., 99.8% pure, density- 3.92 gm/cc) and multiwall carbon nanotube (MWCNT) (> 98% purity, outer diameter- 20nm, density- 2.1 gm/cc, length - Av 20 ìm as described by the supplier).

2.2. Powder Processing

MWCNT were dispersed in isopropyl alcohol with the help of mechanical stirrer at high speed for 1 hour. After successful dispersion MWCNT (with varying 1-5wt %) was mixed with the slurry of alumina prepared by using deionised water with the help of mechanical stirrer for different time. After properly mixed then the desired powder was filtered out with help of filter paper. Then a 0.1 wt% of Polyvinyl alchol (PVA) binder was mixed into the mixture of Al_2O_3- MWCNT.

2.3. Compaction

Compaction of the powder was done on the compression testing machine (fig. 1) with the help of steel die at different pressure as described in the table 1. The sample was of circular cross-

Figure 1: Compression testing machine

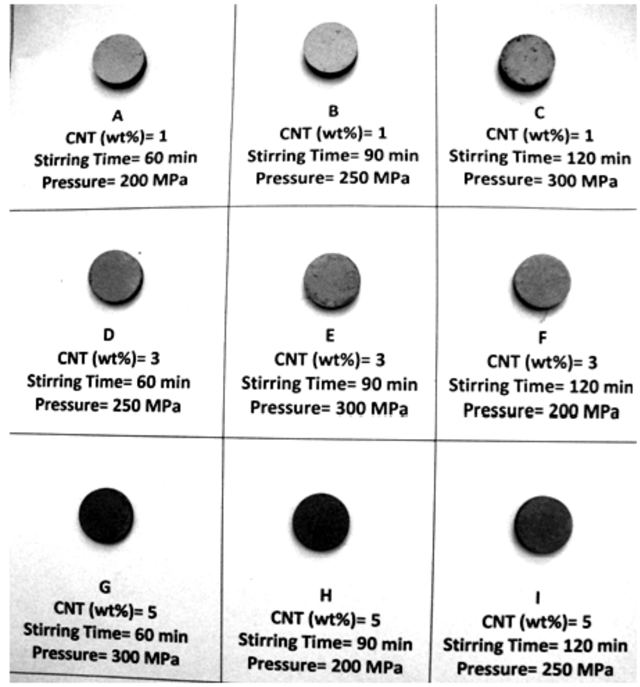

Figure 2: Specimen prepared with varying parameters

section with a diameter of 16 mm and thickness 3 mm as shown in fig 2. For the comparison of properties sample of as received Al_2O_3 was also prepared.

2.4. Design of Experiment

In order to optimize the process parameters for mixing L9 orthogonal array based on Taguchi techniques has been used in this experimentation. The factors with their corresponding levels are shown in table 1 in order to get better green specimen for sintering purpose. The output variable corresponding to these factors will be diameteral compressive strength.

Table 1
Factors and their Levels

S. No.	*Level 1*	*Level 2*	*Level 3*
CNT (wt%)	1	3	5
Stirring Time (min)	60	90	120
Pressure (MPa)	200	250	300

2.5. Properties Evaluation

Scanning electron microscope was used for microstructural evaluation of as received Al_2O_3, MWCNT powder. Diameteral compression test for green specimen were also performed with the help of tablet hardness tester. The diameteral compression strength was then calculated by the following formula:

$$Diametral\ Compression\ Strength = 2.\frac{F}{(\pi.d.t)}$$

F = force in newton

d = diameter of pellet in mm

t = thickness of pellet in mm

3. RESULTS AND DISCUSSIONS

3.1. Microstructural Examination

SEM micrograph of as received alumina and MWCNT is as shown in Fig. 3 and 4.

3.2. Diameteral compression test

For the fabrication of green specimen the purposed parameters with Taguchi approach were used and evaluated for the results of diameteral compressive strength (D.C.S.) test as shown in table 2.

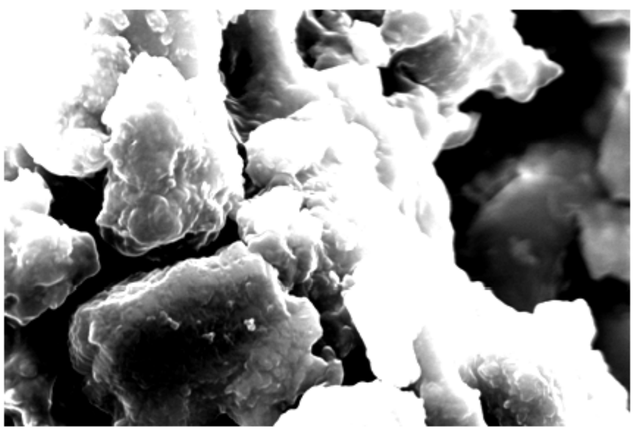

Figure 3: SEM micrograph of as- received alumina

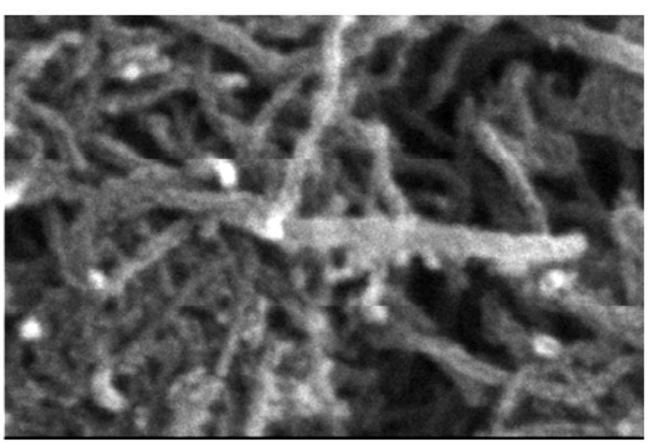

Figure 4: SEM image of MWCNT

The primary objective for the experimentation was to optimize the process parameters for better green specimen. From the analysis of figure 5 it has been concluded that in order to obtain a green specimen with good diameteral compressive strength properties the optimal parameter combination were- CNT – 5 wt% , stirring time- 60 min, pressure- 250 MPa. The analysis of variance results for S/N ratio are shown in table 3 and this table indicates that the CNT (wt%), stirring time (min) and pressure (MPa) are significant at 95% confidence level. This table indicates that the most important parameter is the stirring time followed by pressure and the least significant parameters is CNT (wt %).

Table 2
Experimental Order and Results as per L9 Orthogonal Array

S. No.	*A*	*B*	*C*	*D.C.S (MPa)*	*S/N ratio*
A	1	60	200	1.09	0.74853
B	1	90	250	1.28	2.14420
C	1	120	300	0.76	-2.38373
D	3	60	250	1.28	2.14420
E	3	90	300	0.39	-8.17871
F	3	120	200	0.84	-1.51441
G	5	60	300	1.31	2.34543
H	5	90	200	1.05	0.42379
I	5	120	250	1.01	0.08643

Table 3
Analysis of Variance for S/N Ratio

Source	*DF*	*Seq SS*	*Adj SS*	*Adj MS*	*F*	*P*	*% contri-bution*
CNT (wt %)	2	0.277	0.277	0.138	0.12	0.894	9.449
Stirring Time (min)	2	1.68	1.68	0.844	0.72	0.581	56.599
Pressure (MPa)	2	1.012	1.012	0.506	0.43	0.698	33.834
Residual Error	2	2.341	2.341	1.17			0.12
Total	8	5.317					

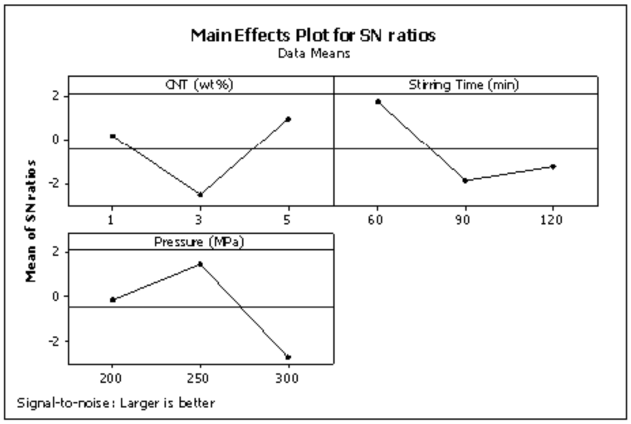

Figure 5: Mean S/N ratio for diameteral compressive strength

3. CONCLUSIONS

From the above analysis the most promisisng factor to obtain a green speciemen of better properties would be as follows;

(1) The optimum weight percentage of CNT in the alumina matrix would be 5 wt%.

(2) The most important parameter in order to improve the diameteral compressive strength was stirring time that is 60 min and least siginificant factor was CNT (wt %).

(3) The optimized stirring time and pressure was 60 min and 250 MPa respectively.

(4) Green specimen can sintered with the help of microwave sintering as it considered being most efficient and almost 100% conversion of electromagnetic waves into heat energy is there and also volumetric heating of specimen take place. The purposed heating cycle for compact consists of different steps: heating of pellets at 100^0C/min, soaking time 15 min, cooling of pellet at 20^0 C/min. The sintering temperature for specimen should be in a range of 1400^0 - 1600^0C under controlled atmosphere.

Further the machining of as fabricated specimen by different modern machining methods can be employed. Out of these machining processes the most suitable modern machining method is electric discharge machining (EDM). The number of input variables of EDM can be varied in order to find out the optimized combination of input variables which can enhance material removal rate and surface finish properties.

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