# CHARACTERIZATION AND DIFFERENT MACHINABILITY BEHAVIORS ON SYNTHESIZED ZIRCONIUM COMPOSITE

**E. Narayanan Nampoothiri[1*], P. Nidhya[2]**
[1]Research Scholar, Anna University, Chennai- 600025.
[2]Research Scholar, Manonmaniam Sundaranar University, Tirunelveli- 627012.
*Corresponding author mail ID: narayanan1325@gmail.com

**Abstract: Now a day's reinforced metal matrix composites plays an important role in any industries. But it is hard to machine using conventional techniques due its excellent properties. The titanium carbide (TiC) particulate reinforced zirconium composite was synthesized through stir casting method and material characterization was studied through Scanning Electron Microscope (SEM) and Energy Dispersive Analysis of X-rays (EDAX). The various material properties were measured like as hardness, density, impact strength and tensile strength. The machinability behaviors were analyzed by ultrasonic machining (USM). During machining processes, the various input parameters are considered with different levels. The response parameters such as material removal rate (MRR) and Surface roughness (Ra) are recorded by varying the input parameters. The significance of parameters has been found by Analysis of variance (ANOVA) for each machining processes. The mathematical models were derived for each machining processes which was used to predict the responses.**

**Keywords: Zirconium composite, Material removal rate, surface Roughness, Titanium carbide, Ultrasonic machining, ANOVA.**

## 1.Introduction

Normally, metal matrix has more advantages with respect to their material properties like as high specific strength, corrosion and wear resistance [1]. Metal Matrix Composites are plays an important role in aerospace Industries due to their exceptional material properties [2]. The cluster of reinforcement of particles have offers high impact to the properties and quality of the material [3]. The wear resistance of the metal matrix was mainly depending up on the nature and quantity of reinforcement content [4]. The material removal mechanisms were studied on zirconium and titanium carbide/nitride based metal matrix [5]. The high strength and hardness was achieved due to the addition of zirconia particles [6]. Stir casting is an effective method used to fabricate composites with hard ceramic particles [7]. The stir casting is one of the liquid metallurgy techniques which is used to improve the bonding strength between reinforcement of particles and base metal [8]. An ultra sonic vibration through transducer and abrasive slurry was used to remove the material from the work piece[9].High hardness material and brittle materials were easily machined by ultra sonic machining process[10].The machinability analysis was carried in ultrasonic drilling of zirconia based ceramics[11].Surface roughness is depends on the input parameters like as grit size and power rating[12].There is no correlation between tool wear rate and slurry concentration in ultrasonic machining of titanium[13]. The ultrasonic machining behaviors and their effect on responses were studied in duplex brass [14].

In this experiment deals with Material synthesis, characterization and ultrasonic machining (USM) on synthesized zirconium metal matrix. The significance of parameters has been found by Analysis of variance (ANOVA) and mathematical models were also derived for each machining processes.

## 2. Manufacturing method

The Zirconium metal matrix was fabricated through stir cast technique. The billet of pre heated Zirconium and hafnium are kept in crucible furnace. The furnace was operated at 1600°C. The stirring speed was 700 rpm maintained for this experiment. After that, Chromium, Silicon Carbide and Titanium particles were added in to the mixture. The molten metal was poured in to cavity and then allowed to solidify. The required specimens (60X40X8mm) were prepared. The various substance properties such as hardness (130BHN), density (8.12 gm/cc), impact strength (12J) and tensile strength (580 Mpa) were found.

**3. Material Characterizations**

Figure 1 shows the SEM image of Zirconium metal matrix which consists of all particles. The chromium, zirconium and hafnium particles were shown in enlarged view. The hard phase of the material structure was observed in this SEM image due to vary in size and nature of the particles. The hardness value of zirconium metal matrix was 630 BHN. This type of material structure is very difficult to machine by conventional machining processes. The stability of the structure was achieved due to addition of various particles like as chromium, zirconium, silicon, hafnium and titanium carbide particles.

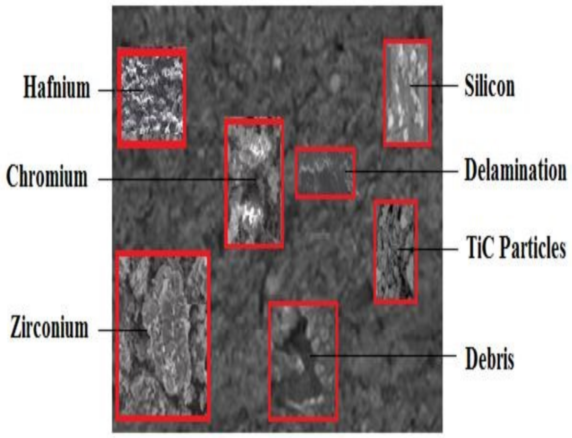


**Figure 1.** SEM image of Zirconium metal matrix

The material compositions were validated through EDAX image shown in Figure 2. The high peak value as zirconium which has the weight percentage as 53.45 and low peak value as carbide which has the weight percentage as 0.51.The material composition of zirconium metal matrix was shown in table 1.

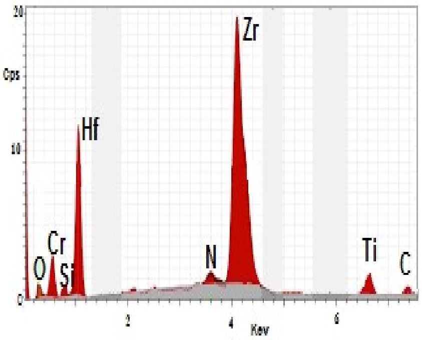


**Figure 2.** EDAX image of Zirconium metal matrix

**Table 1.** Composition of Zirconium metal matrix

| Alloy elements | Wt % |
|---|---|
| Zirconium | 53.45 |
| Hafnium | 30.23 |
| Chromium | 09.43 |
| Nitrogen | 02.17 |
| Oxygen | 01.43 |
| Silicon | 01.11 |
| Titanium | 01.67 |
| Carbide | 00.51 |

**4. Experimental results and discussions**

**4.1. Ultrasonic machining process**

The KEBER type of Ultrasonic machining process was used. During this machining process, power rating (100300W), slurry concentration (15-30%) and grit size (200-400) were considered as the input parameters. The abrasives like as boron carbide and silicon carbides were added in to the slurry. The Material Removal Rate (MRR) and Surface Roughness (SR) were considered as output parameters. Ultra sonic machining experimental observations were shown in Table 2.

**Table 2.** Ultra sonic machining experimental observations

| S.No. | A:Power rating(W) | B: Slurry concentration (%) | C:Grit size | MRR ($mm^3$/min) | SR(μm) |
|---|---|---|---|---|---|
| 1 | 100 | 15 | 200 | 8.23 | 2.54 |
| 2 | 100 | 20 | 300 | 9.11 | 2.64 |
| 3 | 100 | 30 | 400 | 10.76 | 3.73 |
| 4 | 150 | 15 | 300 | 10.94 | 5.66 |
| 5 | 150 | 20 | 400 | 12.65 | 4.91 |

| | | | | | |
|---|---|---|---|---|---|
| 6 | 150 | 30 | 200 | 10.21 | 3.57 |
| 7 | 300 | 15 | 400 | 13.31 | 7.32 |
| 8 | 300 | 20 | 200 | 13.76 | 8.23 |
| 9 | 300 | 30 | 300 | 12.45 | 9.84 |

The Comparison of responses MRR and SR was shown in fig.3.The maximum material removal rate (13.76 $mm^3$/ min) was obtained at power rating as 300w, slurry concentration as 20% and grit size as 200. The minimum surface roughness (2.54µm) was achieved at power rating as 100w, slurry concentration as 15% and grit size as 200.

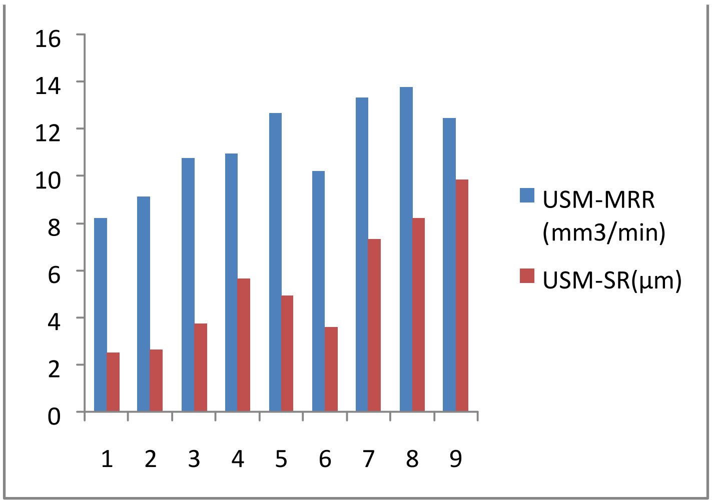


**Figure 3.** Comparison of responses MRR and SR-USM

From Analysis of variance (ANOVA) table 3, power rating provides the most contribution factor (74.80%) on material removal rate. The second most influential factor was grit size (14.66%).

**Table 3.** Analysis of variance for MRR-USM

| Source | DF | Adj. SS | Adj. MS | F-Value | P-Value | Percentage % |
|---|---|---|---|---|---|---|
| A:Power rating | 2 | 21.736 | 10.8680 | 15.01 | 0.042 | 74.80 |
| B: Slurry concentration (%) | 2 | 1.615 | 0.8075 | 1.12 | 0.046 | 05.56 |
| C:Grit size | 2 | 4.259 | 2.1294 | 2.94 | 0.254 | 14.66 |
| Error | 2 | 1.448 | 0.7242 | ---- | ---- | 04.98 |
| Total | 8 | 29.058 | ---- | ---- | ---- | 100 |

The prediction of the response such as MRR was confirmed through developed model which was shown in equation 1. Here, A, B and C are considered as power rating, slurry concentration (%) and grit size respectively.

MRR = 11.269 - 1.902 A -100 - 0.002 A -150 + 1.904 A -300 - 0.442 B -15 + 0.571 B -20 - 0.129 B -30 - 0.536 C-200 - 0.436 C -300 + 0.971 C – 400 ------- Eqn. (1)

From Analysis of variance (ANOVA) table 4, power rating provides the most contribution factor (88.12%) on surface roughness.

**Table 4.** Analysis of variance for SR-USM

| Source | DF | Adj. SS | Adj. MS | F-Value | P-Value | Percentage % |
|---|---|---|---|---|---|---|
| A:Power rating | 2 | 47.2784 | 23.6392 | 13.74 | 0.068 | 88.12 |
| B: Slurry concentration (%) | 2 | 0.5046 | 0.2523 | 0.15 | 0.872 | 00.94 |

| | | | | | | |
|---|---|---|---|---|---|---|
| C:Grit size | 2 | 2.4241 | 1.2120 | 0.70 | 0.587 | 04.52 |
| Error | 2 | 3.4416 | 1.7208 | ---- | ---- | 06.42 |
| Total | 8 | 53.6488 | ---- | ---- | ---- | 100 |

The prediction of the response such as SR was confirmed through developed model which was shown in equation
2. Here, A, B and C are considered as power rating, slurry concentration (%) and grit size respectively.
SR = 5.382 - 2.412 A-100 - 0.669 A -150+ 3.081 A -300 - 0.209 B-15
- 0.122 B -20 + 0.331 B -30 - 0.602 C-200 + 0.664 C-300 - 0.062 C-400 ------- Eqn. (2)

**5. Conclusions**

- The titanium carbide (TiC) particulate reinforced zirconium metal matrix was synthesized through stir casting method and its material characterization was reported.
- The various material properties such as hardness (630BHN), density (8.12 gm/cc), impact strength (12J) and tensile strength (580 Mpa) were found.
- Zirconium metal matrix was machined by various unconventional machining processes.
- In ultrasonic machining process, the maximum material removal rate (13.76 $mm^3$/ min) was obtained at power rating as 300w, slurry concentration as 20% and grit size as 200.
- The minimum surface roughness (2.54µm) was achieved at power rating as 100w, slurry concentration as 15% and grit size as 200 and power rating provides the most contribution factor on material removal rate and surface roughness.

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