🌐 *United International Journal of Engineering and Sciences* 🌐
(UIJES – A Peer-Reviewed Journal); ISSN:2582-5887 | Impact Factor:8.075(SJIF)
📘 *Volume 5 | Special Issue 1 | 2025 Edition*
National Level Conference on "Advanced Trends in Engineering Science & Technology" – Organized by RKCE

Experimental Investigation on Mechanical and Slurry Erosion Behavior of Al - 5083 with Tio2/CNT/Al2o3 Nano Particulates Composite Fabricated by PM Technique

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Abstract* –Corrosion-Erosion is seviour problem in the ships, boats and submarines, pipelines which are working under water. To overcome this problem is by adding Nano particulates like TiO2, CNT and Al2O3 having size of 20 to 40 µm to the MMCs like Al-5083 , making the powder using Mechanical Alloying process and fabrication of specimens based on the PM Technique. The properties of different particulates has selected has 1%, 1.5% and 2%.Micro Vickers hardness testing machine is used to find the hardness of fabricated specimens and hardness test is conducted on standard specimen(ASTM E 384).And maximum hardness occurred in specimen is 57.9HV0.1 in TiO2 1% Composition and minimum hardness value is 15.3HV0.1 in CNT 2% Composition. Development of Special Specimen holder and it consists of different variables ,gap between specimen and wall, angle of the specimen and immersion medium and Slurry Erosion tests are conducted by using L27 Taguchi Orthogonal array and pot slurry erosion test is carried out for 15 minutes for each specimen. Maximum weight that specimen having is 15.7169 in CNT 2% Composition and wt loss % after the pot slurry erosion test is 15.2017 avg wt loss% occurred is 0.5152 in the medium of BASIC. From the experiments and analysis of variance it is observed that TiO2 with 2% composite gives minimum erosion at 90° orientation having maximum gap in a Basic medium. The experimental value of hardness test and erosion test are validated statistically using Origin software and observed that the results are significantly different at 0.05 Confidence level.

***Keywords* – Corrosion-Erosion, MMCs, Nano Particulates,TiO2,CNT,Al2O3, Al-5083 Alloy, Powder Metallurgy, Micro Vickers Hardness Test, Taguchi Orthogonal Array, Pot Slurry Erosion Test, Erosion Minimization**

I. INTRODUCTION

The mechanical process of erosion and Electrochemical process of corrosion are combined to known as Erosion-Corrosion in engineering materials.[1] It occurs in materials when solid particles interact with a corrosive liquid. Erosion occurs when solid particles carried by a stream of liquid or gas hits a target material causing it to deform or fracture. Corrosion on the other hand is the gradual destruction of material when it undergoes a chemical reaction with its environment. The process is most powerful in soft alloys such as, copper, aluminium, lead etc[2].

Process Powder metallurgy is the process of blending fine powdered materials, compacting the same into a desired shape or form inside a mould followed by heating of the compacted powder in a controlled atmosphere, referred to as sintering to facilitate the formation of bonding of the powder particles to form the final part[3].Thus, the powder metallurgy process generally consists of four basic steps, powder manufacture, blending of powders, compacting of powders in a mould or die, and sintering.[4] Compacting is generally performed at room temperature and at high pressure. Sintering is usually done at elevated temperature and at atmospheric pressure. Often, compacting and sintering are combined. Powder Metallurgy route is very suitable for parts that are required to be manufactured from a single or multiple materials with very high strength and melting temperature that pose challenge for the application of casting or deformation processes[5].

II. MATERIALS AND METHODS

TiO_2 is known for its high hardness, wear resistance, and excellent corrosion resistance. It improves the erosion resistance of the alloy when subjected to abrasive conditions, such as sand or sediment impact in underwater environments.TiO_2's incorporation into Al-5083 enhances the alloy's ability to withstand wear and fatigue, making it ideal for marine applications like ships, submarines, and pipelines.CNTs are highly valued for their exceptional mechanical properties, such as high tensile strength, flexibility, and thermal conductivity. When added to Al-5083, CNTs can significantly improve the strength and fracture toughness of the composite.Al_2O_3 is a ceramic material known for its hardness, wear resistance, and thermal stability. It improves the erosion resistance of Al-5083 alloy when exposed to abrasive forces in underwater conditions.

The metal powders are mixed with binding agents as shown in Fig 1,the selected nanoparticulates (like TiO_2, CNT, or Al_2O_3) are added at the appropriate proportions (e.g., 1%, 1.5%, or 2%) to the base metal powder (e.g., Al-5083 alloy).The mixed powder is placed into a mold or die, and a high-pressure press as shown in Fig 2, is used to compact the powder into the desired shape.This step is crucial because the quality of the compacted part influences the final properties of the material, such as its density, strength, and uniformity.Sintering is the heat treatment step where the compacted powder is heated to a temperature below its melting point, typically in a controlled atmosphere with the help of this graph as shown in graph 1 and by using annealing furnace sintering operation is done. According to above graph we have to rise 0 °C to 430 °C within 25 minutes , then maintain this 430 °C temperature for 5 minutes, then rise temperature up to 530°C in 15 minutes and then maintain this 530°C temperature for 30 minutes . The total working time annealing furnace is 75 minutes.This process causes the powder particles to bond together, forming a solid part with improved mechanical properties.

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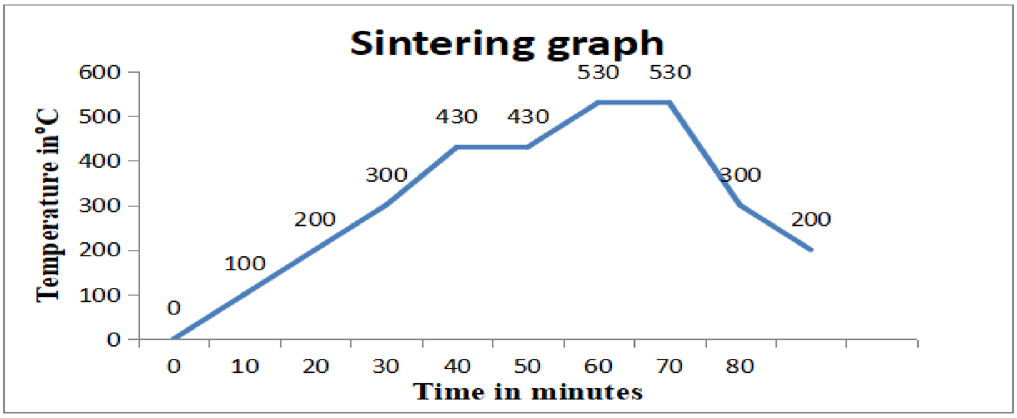
Fig 1 V-type blending machine

Fig 2 Dies selection for compaction



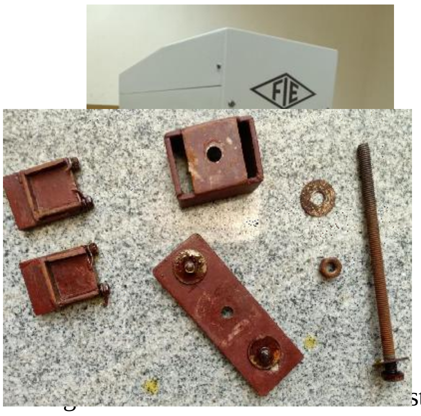
Graph 1 for sintering process

III. EXPRIMENTATION

Initially we divide the experimentation into two categories they are 1.Hardness test. 2.slurry wear test.

3.1 Hardness test

In this test diamond cone is used as indenter . As diamond has sharp edge so the dia of indenter is easy to find due to sharp edge. Angle between the opposite faces of the indenter is 136 degrees ,and use full angle is 120 degrees.All Vickers ranges use a 136 degrees pyramid diamond indenter that forms a square indent.The indenter is pressed into the sample by an accurately controlled test force.The force is maintained for a specific dwell time, normally 10-15 seconds.After the dwell time is complete, the indenter is removed leaving an indent in the sample that appears square shaped on the surface as shown in Fig 4.The size of the indent is determined optically by measuring the two diagonals of the square indent.The Vickers hardness number is a function of the test force divided by the surface area of the indent. The Vickers hardness number is a function of the test force divided by the surface area of the indent. The average of the two diagonals is used in the following formula to calculate of the Vickers hardness.First we conducted a hardness test by Micro Vickers hardness testing machine as shown in Fig 3 on total 54 work pieces these work pieces are divided into three categories of CNTs 1%,1.5%,2% ,AL2O3 1%,1.5%,2% and TiO2 1%,1.5%,2% and vickers micro hardness values shown in Graph 2.



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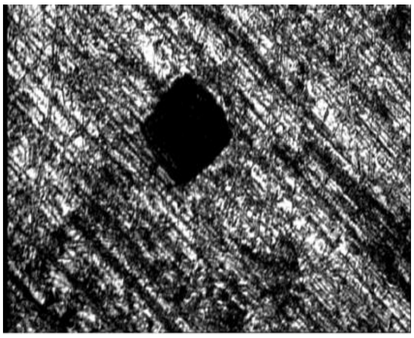
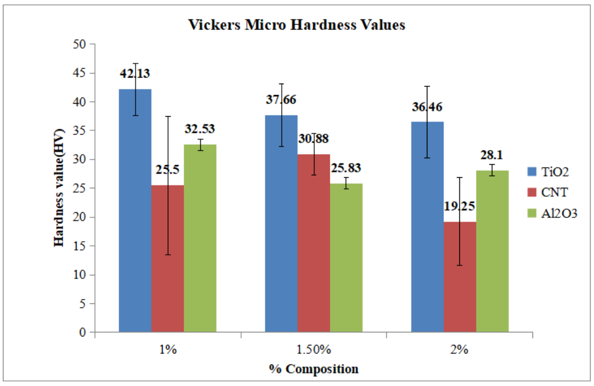


Fig 4 Image after impingement of load



Graph 2 Vickers Mirco Hardness values

3.2 Slurry Erosion Test

For the Fabrication of work piece holder, we took mild steel bars of cross-section 180*50 at the top portion and 35*50*24 blocks on either sides of top portion.A cuboid block is manufactured, and it is placed at center giving some provision about 10mm.To hold the Work piece strips are welded on the two blocks of 35*50*24 as shown in Fig 5. After drilling is taken place for the top portion and the cuboid block for connecting shaft between the prototype and the drilling machine.Drilling and tapping operation is carried out for holding the work piece on the blocks and also provision is made on top plate to adjust distance between cuboid and blocks.After this the prototype is coated with paint for corrosive resistance and assembled as shown in Fig 6.

Fig 5 Parts for workpiece holder

Fig 6 Assembly of workpiece holder

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a) Type of particulate	1) CNT
	2) AL2O3
	3) TiO2
b) Composition(%)	1) 1%
	2)1.5%
	3) 2%
c) Gap	1) Maximum distance
	2) Middle distance
	3) Minimum distance
d) Angle	1) 0°
	2) 45°
	3) 90°
e) Solution	1)Neutral (7 pH)
	2) Acidic(Hcl) (6.5 pH)
	3) Base(Nacl) (8.2 pH)

Table 1 Formation of table for different variables and levels

Formation of table for different variables and levels as shown in Table 1 .In the Taguchi OA design, only the main effects and two-factor interactions are considered, and higher-order interactions are assumed to be non existent. In addition, designers are asked to identify which interactions might be significant before conducting the design. By using Minitab 17 software we can create work sheet with L27 row.

Run	Particulate	Composition %	Gap	Angle	Solution	% Wt loss		
						Trail -1	Trail -2	Avg wt loss%
1	1	1	3	1	1	0.1965	0.4289	0.3127
2	1	1	3	1	2	0.1781	0.2201	0.1991
3	1	1	3	1	3	0.2071	0.1178	0.2345
4	1	2	2	2	1	0.1819	0.2509	0.2164
5	1	2	2	2	2	0.2796	0.1913	0.2354
6	1	2	2	2	3	0.2720	0.0467	0.1593
7	1	3	1	3	1	0.3489	0.1120	0.2304
8	1	3	1	3	2	0.2413	0.1930	0.2564
9	1	3	1	3	3	0.5152	0.1778	0.3465
10	2	1	2	3	1	0.1128	0.2307	0.1717
11	2	1	2	3	2	0.0376	0.1531	0.0953
12	2	1	2	3	3	0.0821	0.1088	0.09545
13	2	2	1	1	1	0.0375	0.2190	0.12825
14	2	2	1	1	2	0.1831	0.1265	0.1548
15	2	2	1	1	3	0.1459	0.1851	0.1655
16	2	3	3	2	1	0.1002	0.1516	0.1259
17	2	3	3	2	2	0.0056	0.1918	0.0987
18	2	3	3	2	3	0.1205	0,1305	0.1120
19	3	1	1	2	1	0.0553	0.2607	0.1580
20	3	1	1	2	2	0.0162	0.2696	0.1429
21	3	1	1	2	3	0.3217	0.2607	0.2939
22	3	2	3	3	1	0.0244	0.1655	0.0949
23	3	2	3	3	2	0.0139	0.1796	0.09675
24	3	2	3	3	3	0.0663	0.2655	0.1659
25	3	3	2	1	1	0.1789	0.3092	0.2440
26	3	3	2	1	2	0.0989	0.1622	0.1305
27	3	3	2	1	3	0.0633	0.0810	0.07215

Table 2 Taguchi orthogonal L27 table

Experiments are done according to this table 2 on the prototype which is connected to drilling machine. We provide certain protection for drilling machine over water sprinkles. The water level in the container is 150 mm. we provide supports to withstand the vibrations and loads during operation .we provide magnetic stirrer as shown in Fig 10 to avoid settlement of sand at the bottom and prototype is rotated about 15 minutes. According to above orthogonal L27 table 54 specimens are tested in 2 trails. 54 specimens are divided into 3 types CNT, AL2O3, TiO2 each divided into 18 specimens. These 18 specimens are tested under different test conditions. Considerations are Gap (maximum distance, middle distance, minimum distance),Angle (0° ,45° ,90°) ,Medium (Distilled water ,Acidic ,Basic) as shown in Fig 7,8 and 9.

Fig 7 Runs at 0° angle

Fig 8 Runs at 45° angle

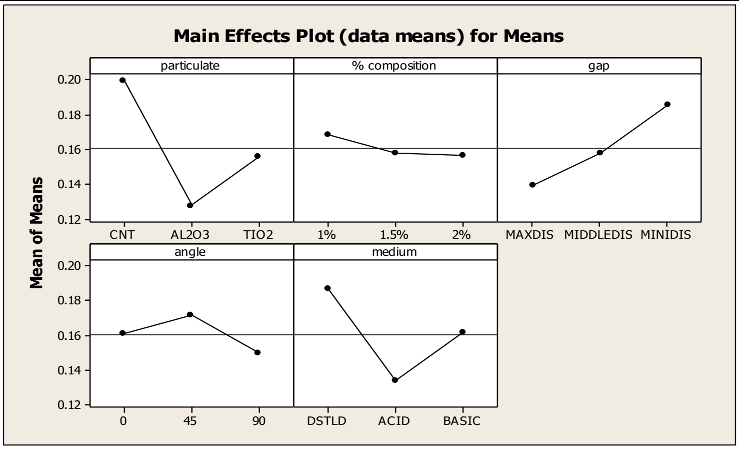
Fig 9 Runs at 90° angle

Fig 10 Pot Slurry Erosion Test with Magnetic Stirrer

IV. RESULTS AND DISCUSSION

4.1 **Main effects plot :**

Use a main effects plot to examine differences between level means for one or more factors. There is a main effect when different levels of a factor affect the response differently. A main effects plot graphs the response mean for each factor level connected by a line

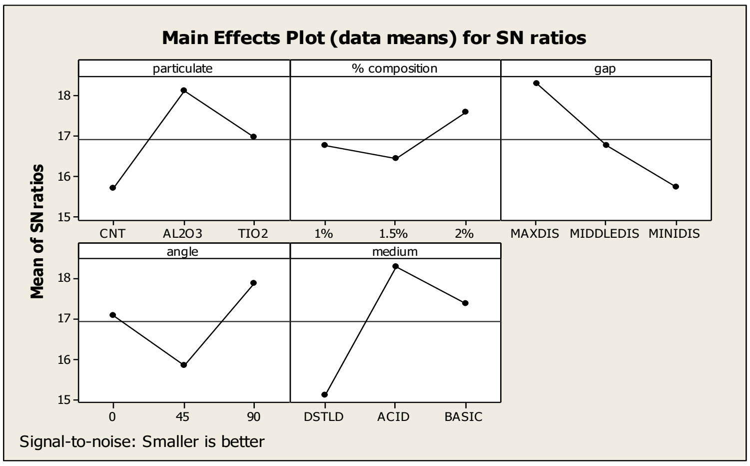


Graph 3 Main effects plot for means\

4.2 Main effect plot for SN ratios

4.2.1 S/N ratios

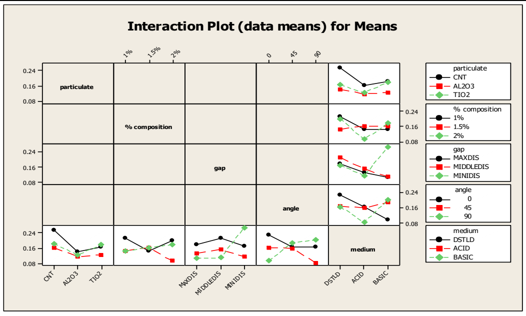
The conclusion of the previous paragraph is that quality can be quantified in terms of the respective product's response to noise factors and signal factors. The ideal product will only respond to the operator's signals and will be unaffected by random noise factors (weather, temperature, humidity, etc.). Therefore, the goal of your quality improvement effort can be stateas attempting to maximize the signal-to-noise (S/N) ratio for the respective product. These S/N ratios can be computed with the Taguchi robust design options in the Experimental Design module. You can compute these S/N ratios for any data with STATISTICA Visual BASIC, and use the resulting values with all designs available in the Experimental Design module.



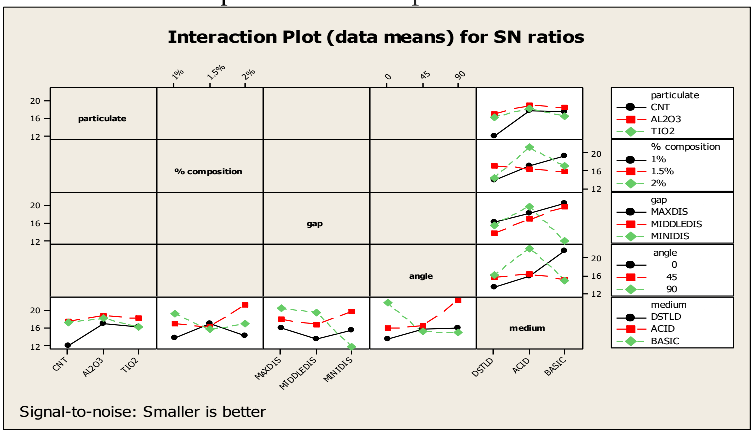
Graph 4 Main effects plot for SN ratios

4.3 Interpret the key results for Interaction Plot :

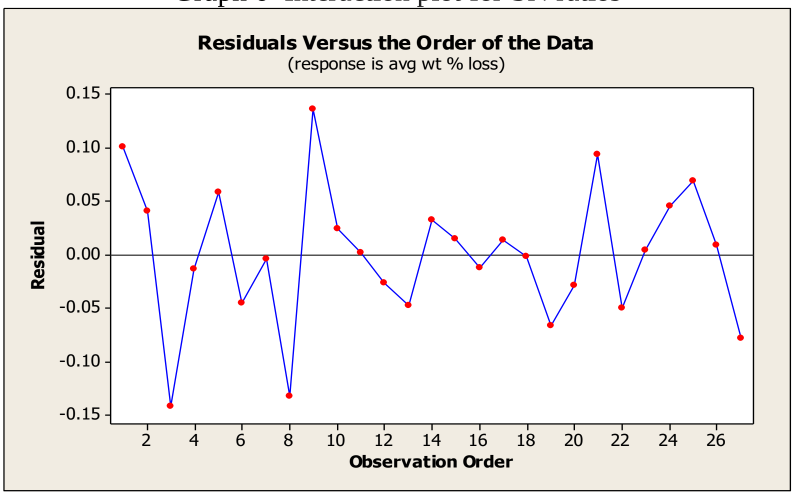
Taguchi designs traditionally focus on main effects, but it is important to test suspected interactions. Use the interaction plots to determine whether the effect of one factor on a response characteristic (S/N ratio, means, slopes, or standard deviations) depends on the level of another factor.



Graph 5 Interaction plot for means



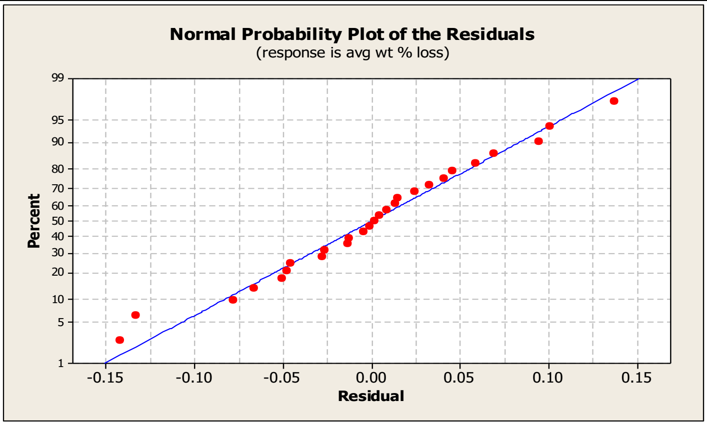
Graph 6 Interaction plot for SN ratios



Graph 7 Residuals Versus the Order of the Data

d) Normal probability plot of the residuals:

The normal probability plot of the residuals should approximately follow a straight line. The following patterns violate the assumption that the residuals are normally distributed. S-curve implies a distribution with long tails. Inverted S-curve implies a distribution with short tails



Graph 8 Normal probability plot of the Residuals

V. CONCLUSION

Corrosion-Erosion is seviour problem in the ships, boats and submarines, pipelines which are working under water. Preventive methods available are protective coatings,paintings and choosing proper design. To overcome the Problem by Combining of Metal matrix composite of Al-5083 with TiO2, CNT and Al2O3 nano particles as particulates with different properties has fabricated using Powder Metallurgy technique.The properties of different particulates has selected as 1%,1.5% and 2% based on literature review..Mechanical Alloying technique(MA) is used for making composite powder.Vickers Micro hardness test is conducted on standard specimen(ASTM E-384) and observed that TiO2 with 1% composite is having higher hardness value compared to other particulates.Pot slurry Erosion test prototype is developed for different variables , gap between specimen and wall, angle of the specimen, different immersion medium.Slurry erosion tests are conducted using L27 Taguchi Orthogonal array.From the experiments and analysis of variance it is observed that TiO2 with 2% composite gives minimum erosion at 90° orientation having maximum gap in a Basic medium.Predicted model for minimization of slurry erosion is developed using regression analysis.The experimental value of hardness test and erosion test are validated statistically using Origin software and observed that the results are significantly different at 0.05 Confidence level.

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