International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 02 | Feb 2020 www.irjet.net p-ISSN: 2395-0072

Synthesis and Characterization of Aluminum Oxide (Al2O3) Nanoparticles by Combustion Method

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Abstract:- Al2O3 nanoparticles has been successfully synthesized using simple combustion method from AlCl3. The characterization of obtained nanoparticles was carried by Scanning electron microscope (SEM) for the grain size measurement and the quantitative study of the nanoparticle was done using EDAX spectroscopy. The average size of nanoparticles was 10 nm. SEM image showed the distribution pattern of nanoparticles. The usage of Nano fluid increase the cooling process in machining. The surface roughness of the material was then studied by mixing of nanoparticle and base fluid water and this mixture then applied on machining operation. The results showed that the temperature is reduced with help of Nano fluid it act as a coolant and it helps to increase the surface roughness.

Keywords: Al2O3, Combustion method, MQL System, Taguchi method

1. Introduction

Recently the use of nanotechnology has gained a significant attention. To increase the heat treatment, process many researchers has been introduced a Nano size material that is commonly known as Nano fluid. A Nano fluid is a mixture of nanoparticles and a base fluid, the uses of Nano fluid are in electronic components, nuclear reactor, building cooling system, vehicles and etc. [1]. Different types of metal and metal oxide component have been synthesized and use in different application. Aluminum oxide (Al2O3) is one of the most useful oxide ceramics it is used in various fields of engineering like heat-resistance materials, coatings, cutting materials, abrasive grains [2]. Aluminum oxide is hard, highly resistant to chemicals, and has a excellent wear resistant [3]. Different types of conventional method are being used to synthesize the aluminum oxide. Methods like sol-gel, co-precipitation, vapor phase reaction, mechanical milling. In mechanical milling for synthesis of Al2O3 requires a extensive mechanical milling and easily introduced impurities, vapor phase reaction demands high temperature above 1200 , the precipitation method is time consuming (long washing times and aging time) [4]. All above method are relatively expensive, require specialized equipment and time consuming. So, there is a need to have a relatively inexpensive synthesis technique that requires less time.

In this research nanoparticles of Al2O3 were synthesized by a very simple, very easier and cheap method, that is a simple combustion method. This method has a several advantage as low cost, easy to control, less time required, and simple in processing. Nanoparticles obtained from this synthesis process was applied on Turing process on CNC machine to check the surface roughness of the material. As the results seen it is observed that the surface roughness of the material is increased with the use of Nano fluid.

2. Synthesis of Al2O3

The very first stage was the synthesis of Al2O3 nanoparticles. The Al2O3 nanoparticles was synthesized by using combustion method, to synthesis the Al2O3 the AlCl3 was the initial material, AlCl3 with 95%-98% purity, another material was Urea Emparta and the last material was Distilled water this all the material was purchased from The Upper India Scientific Co., Nagpur, then the synthesis process start. The starting solution was prepared by adding 10 gm of AlCl3 was mixed in a 10 ml of distilled water and in another hand 30 gm of Urea was mixed with 20 ml of distilled water and then this both the two solution was mixed and stirred for some time, and then this solution was transferred to ceramic beaker. The whole mixing process was carried out at a room temperature. Then the whole solution was transfer to muffle furnace for 2 – 3 hrs. at 300 for the drying, then for heating the solution was kept at 600 for 4 to 5 hrs. At muffle furnace. After that we collect the white colored powder and wash this powder with the distilled water and again kept in muffle furnace for drying at 120 for 1 to 2 hrs., and then we got our final desired product in ceramic beaker and we predicted as the Al2O3 nanoparticles. This whole process takes 8 to 9 hrs., the muffle furnace used in this work is shown in the Fig.1.

Figure 1: Experimental arrangement.

3. Characterization of Al2O3

The result product was then characterized for their properties. The SEM (Scanning Electron Microscope) and the EDAX was carried out, the SEM image gives us a distribution pattern and the size of the product and in EDAX shows the Al and O as the major components of the nanoparticles. Fig. 2 shows the SEM of Al2O3 this image shows that the calcined image of powder, figure shows that the alluminium is separated and the oxide is formed.

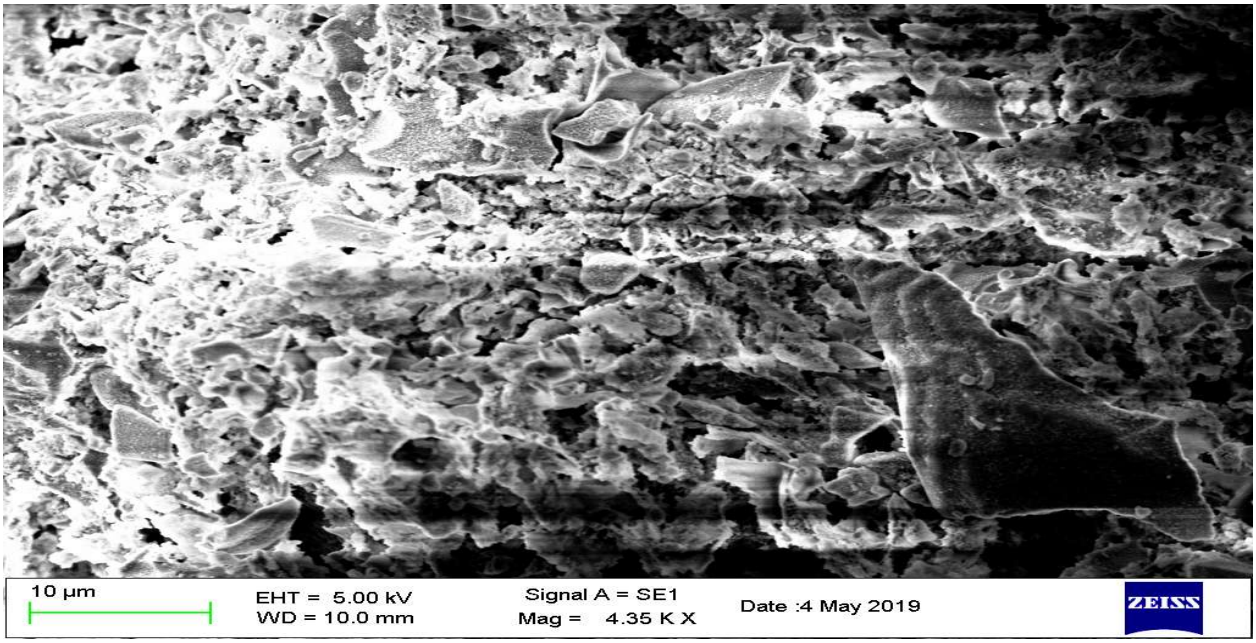

Figure 2: SEM image of calcined powder

The average size of nanoparticle was obtained 10 µm from the SEM image, SEM image gives the morphology of Al2O3 nanoparticle. SEM image gives the distribution pattern of the nanoparticle and the size of the nanoparticle, the width of the nanoparticle is to be 10 mm. The distribution pattern of nanoparticle is shown in fig. 4.

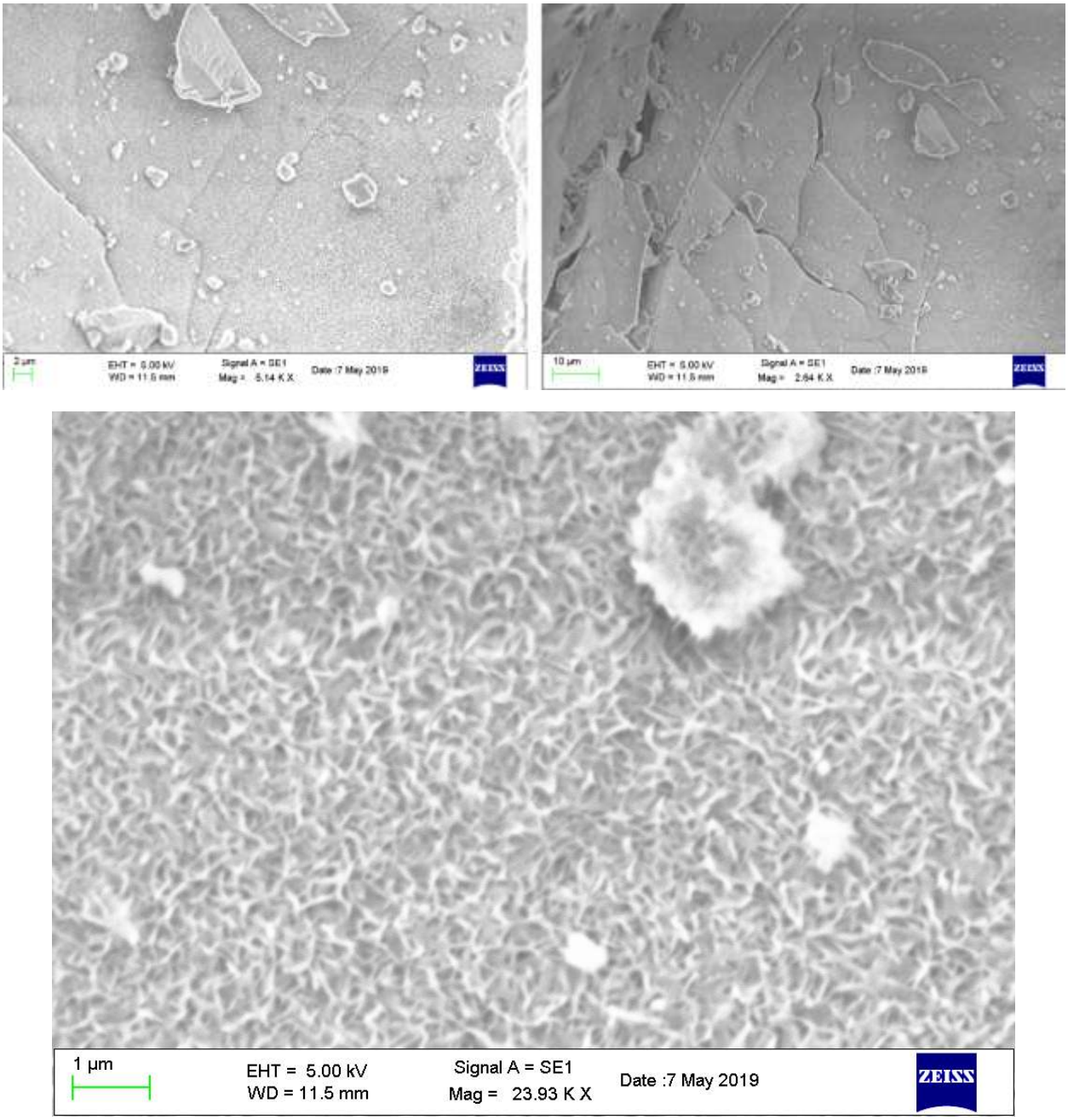

Figure 3: SEM image of Al2O3 Nanoparticle

Fig. 4 shows the EDAX spectroscopy, the quantitative study of the nanoparticle was done using EDAX spectroscopy measurement and is shows as Al and O as the major components as shown in fig.

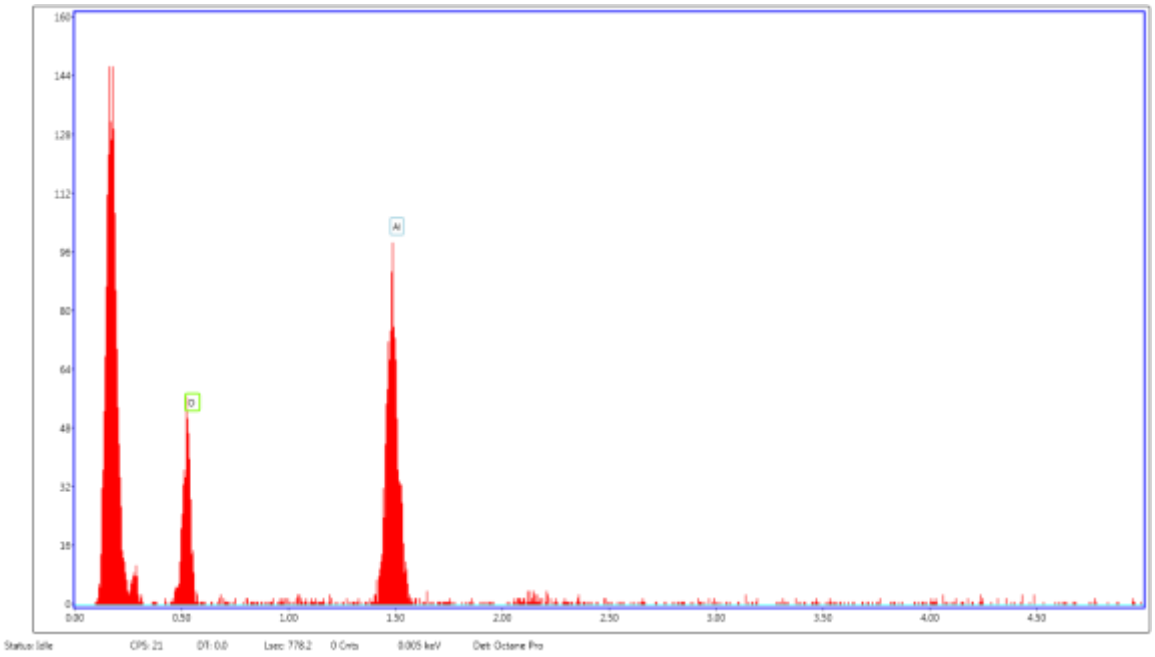

Figure 4: EDAX of Al2O3 Nanoparticle

4. Experiment Method

Al2O3 nanoparticle were then applied as a Nano fluid on the turning operation of EN8 carbon steel with a carbide insert as a tool. The Mechanical properties and Hardness of the EN8 carbon steel is given on the table no.1

Heat Treatment	Tensile Strength Rm	Yield Strength Rm	Rp 0.2	A min on **5.65√So**	Impact		Hardness
					Izod Ft.lb	KCV J	
	MPa	MPa	MPa				HB
N	550	280	–	16	15	16	152/207
	510	245	–	17	–	–	146/197
Q	625/775	385	355	16	25	28	179/229
R	700/850	465	450	16	25	28	201/255

Table 1 : EN8 Medium Carbon Steel Mechanical Properties and Hardness

The nanoparticle was mixed with a water as base fluid with the ratio of 1:10 this mixture was sprayed in the turning operation where the operation is performed with the help of MQL (Minimum Quantity Lubrication) technique. In MQL system very lesser amount of coolant / Nano coolant is mixed with air, and it is sprayed in the cutting area with very high pressure with the help of nozzle. MQL technique can minimize the manufacturing cost as well as environmental hazards also. Al2O3 act as an coolant, it helps to reduce the temperature rises during the machining Fig.5 shows the MQL setup.

Figure 5: MQL Setup

In addition, we select the Taguchi orthogonal array for conducting the experiments as the main parameters Cutting speed, Feed rate, and Depth of cut. Taguchi method is an statistical method, or sometimes called as a robust design methods, developed by Genichi Taguchi to improve the quality of manufactured goods. Taguchi efforts especially in the development of design for studying variation success in the achieving the desired result involves a careful selection of process parameters. Table 1 shows the parameters and their levels of parameters, using this levels we perform the turning operation on CNC machine.

Parameters	**Units**	**Notations**	**Levels of parameters**		
			Level 1	Level 2	Level 3
Cutting speed	RPM	V	1990	2300	2600
Feed rate	mm/rev	F	0.07	0.14	0.21
Depth of cut	mm	D	0.1	0.15	0.2

Table 2 : Selected factors and their Levels

The most suitable orthogonal array for experimentation is L9 array as shown in the Table 2, therefore a total nine experiments are to be carried out for the better result of surface roughness of the material. For the machining operation we apply the three condition first condition is Dry turning, second condition is the Fluid cutting and the third condition is MQL cutting with Al2O3 nanoparticle and water as a base fluid.

Experiment No.	**Control Factors**		
	Speed(m/min)	**Feed rate (mm/rev)**	**Depth of cut(mm)**
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	3
5	2	2	1
6	2	3	2

7	3	1	2
8	3	2	3
9	3	3	1

Table 3: L9 Orthogonal Array

5. Results

For the better result of the turning operation we conducted total 27 operation for different condition. 9 experiment conducted for Dry turning, then again 9 experiment conducted for fluid cutting and 9 experiment on MQL cutting Table 3 shows the result and analysis made by 27 operation

DRY CUTTING				
Exp no:	**Speed (V) RPM**	**Feed rate (F) mm/rev**	**Depth of cut (D) mm**	**Surface Roughness µm**
1	1990	0.07	0.1	2.69
2	1990	0.14	0.15	0.968
3	1990	0.21	0.2	1.002
4	2300	0.07	0.2	0.845
5	2300	0.14	0.1	0.992
6	2300	0.21	0.15	0.99
7	2600	0.07	0.15	1.303
8	2600	0.14	0.2	1.021
9	2600	0.21	0.1	1

FLUID CUTTING				
Exp no:	**Speed (V) RPM**	**Feed rate (F) mm/rev**	**Depth of cut (D) mm**	**Surface Roughness µm**
10	1990	0.07	0.1	2.523
11	1990	0.14	0.15	1.5
12	1990	0.21	0.2	1.075
13	2300	0.07	0.2	1.021
14	2300	0.14	0.1	1.234
15	2300	0.21	0.15	0.925
16	2600	0.07	0.15	1.373
17	2600	0.14	0.2	0.883
18	2600	0.21	0.1	0.821

MQL CUTTING				
Exp no:	**Speed (V) RPM**	**Feed rate (F) mm/rev**	**Depth of cut (D) mm**	**Surface Roughness µm**
19	1990	0.07	0.1	2.331
20	1990	0.14	0.15	0.989
21	1990	0.21	0.2	0.93
22	2300	0.07	0.2	0.648
23	2300	0.14	0.1	0.892
24	2300	0.21	0.15	0.901
25	2600	0.07	0.15	0.877
26	2600	0.14	0.2	0.774
27	2600	0.21	0.1	0.652

Table 3: Result and Analysis

From the above three condition we obtained the minimum surface roughness is 0.648 by using the MQL system in experiment no.22

6. Conclusion

Al2O3 nanoparticle have been successfully synthesized using a combustion method and the average particle size was found to be 10 µm. the formation of Al2O3 nanoparticles was confirmed from SEM (Scanning Electron Microscope), and EDAX analysis. Nano fluid, the mixture of Al2O3 nanoparticle and water as a base fluid has been applied to reduce the temperature generated during turning operation and it helps to reduce the temperature, act as coolant and gives the better surface roughness of the material.

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