

Synthesis CNTs Particle Based Abrasive Media for Abrasive Flow Machining Process

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Abstract. Abrasive flow machining (AFM) is a modern fine finishing process used for intricate and internal finishing of components or parts. It is based on flowing of viscoelastic abrasive media over the surface to be fine finished. The abrasive media is the important parameter in the AFM process because of its ability to accurately abrade the predefined area along its flow path. In this study, an attempt is made to develop a new abrasive, alumina with Carbon nanotubes (CNTs) in viscoelastic medium. CNTs in house produced through chemical vapour deposition technique and characterized through TEM. Performance evaluation of the new abrasive media is carried out by increasing content of CNTs with fixed extrusion pressure, viscosity of media and media flow rate as process parameters and surface finish improvement and material removal as process responses in AFM setup. Significantly improvement has been observed in material removal and maximum improvement of 100 % has been observed in the surface finish on the inner cylindrical surface of the cast iron work piece.

Keywords: AFM, CNTs, TEM

1. Introduction

Abrasive flow machining (AFM) is used to fine machining by flowing of viscoelastic abrasive media over predetermined surface areas. AFM process has capability of fine finishing of intricate shapes and holes which are not accessible easily [1]. In addition AFM process has many attractive advantages, such as self-sharpening, self-adaptability, controllability and finishing tool requires neither compensation nor dressing. AFM can be classified based on motion or flow of abrasive media as: One way AFM, Two-way AFM and Orbital AFM process [2-7]. In AFM process parameters, extrusion pressure has a major role in material removal and reduction of surface roughness [5-15]. On the other hand, abrasive media acts as deformable grinding tool. It is the key of Abrasive Flow machining. In general, abrasive media flow volume is increased than material removal increases. Theoretically it can be understood that as media flow



volume is increased, more number of abrasive particles comes in contact with work piece and more abrasion takes place. Rhoades [10] has reported that media flow rate is less influential parameter in respect to material removal. Slower slug flow rates are best for uniform material removal and high slug flow rates produce large edge radii. The media flow rate is insignificant with regard to material removal. On the other hand, it has been claimed by Jain and Jain [7] Singh [11] the media flow rate influences both of the material removal and surface roughness. Williams and Raju [5] and Williams et. al. [12] have reported that viscosity of the media is one of the significant parameters of the AFM process. Keeping all other parameters constant, an increase in viscosity improves both material removal and reduction of surface roughness. According to one thumb rule [14] finer abrasives should be used when the initial roughness of the work surface is less. The reason for a decrease in material removal is that with an increase in mesh size (or decrease in grain size in mm) the depth of penetration as well as width of penetration, decreases. There are various abrasive particles like Al_2O_3 , SiC, CBN, diamond powder and so on are available which are being used for abrasive finishing process [6-14]. Al_2O_3 and SiC are most suitable abrasives for many applications but Cubic boron nitride (CBN) and diamond are specifically used for special applications. Abrasive particles to base material ratio can be varying from 2 to 12. The abrasives have limited life. The additives are used to enhance the base carrier to get the desired flowability and rheological characteristic of the media. In the present study, a new type of abrasive media is developed to insure faster finishing and reduction of surface roughness. The new type of abrasive flow media is based on synthesis of iron filled CNTs with Al_2O_3 and its performance evaluation of cast iron workpiece in AFM as CNTs is known very strong mechanical properties. CNTs has been synthesised through chemical vapour deposition technique as it is fast and economical viable process [15-18].

2. Materials and Methods

The newly developed abrasive media, as shown in fig. 1, which having Al_2O_3 (180 mesh size), polymer and hydrocarbon gel (Polymer to gel ratio:1:1) is mixed properly in predetermined proportion to get the viscous elastic media which can machine effectively. Hydrocarbon gels are commonly used lubricants in the media. All additives including CNT particles (0, 5grams and 10 grams) in different percentages are carefully blended in predetermined quantities to obtain consistent formulation with 810 Pas media viscosity. CNTs with filled Fe was synthesized by Chemical Vapour Deposition. In this process, heating the solution of Ferrocene(5gm) and Toluene(25ml) in the oven, maintaining the oven temperature around $800^{\circ}C$ and argon gas(100 sccm) is passed to get inert atmosphere (setup fig. 2). The performance evaluation of the newly developed abrasive media was conducted in Precision Manufacturing Laboratory developed vertical double acting AFM machine setup (table 1), of Delhi Technological University. Cast Iron work piece (fig. 3) were prepared with initial surface roughness and weight were taken. The surface roughness was measured in five different locations using Taylor Hobson. The internal cylindrical surface was finished by AFM process. Each workpiece was machined for a predetermined number of cycles (8 cycles) and extrusion pressure.



Fig. 1:- Abrasive laden Media (carrier+Al₂O₃+CNT) Fig.2. Thermal CVD Setup Fe-filled CNTs.

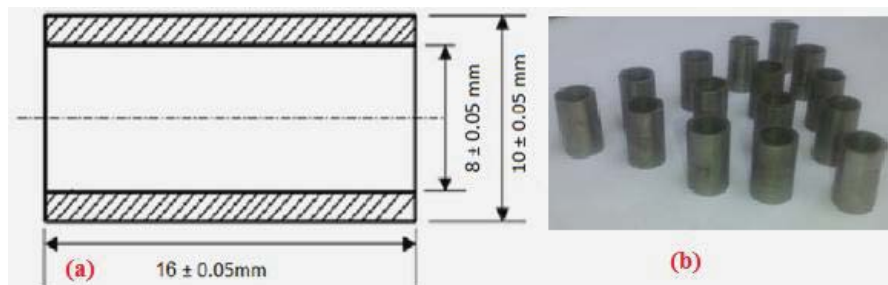


Fig. 3:- Cast Iron work pieces used in trials and its dimensional details.

Table1:- Process parameter of AFM setup.

S. No.	Process Parameter	Range	Unit
1	Extrusion Pressure	5-35	MPa
2	No. of Cycle	1-9	Number
3	Temperature	32± 2	°C
4	Media Flow volume	290	cm ³
5	Capacity	25 + 25	Ton
6	Stroke length	96	mm
7	Hydraulic cylinder Bore diameter-2 No.	130	mm
8	Hydraulic cylinder Stroke	90	mm
9	Working Pressure	210	kg/cm ²
10	Maximum Pressure in the Cylinder	35	MPa
11	Stroke Length of Piston	300	mm

3. Results and discussion

3.1. Characterization of CNTs filled with Iron

Fig. 4 shows the TEM micrographs of Fe filled CNTs at different locations and it shows that the growth of CNTs is uniform and there is very less amount of other carbon impurities such as amorphous carbon, soot or carbon particles.

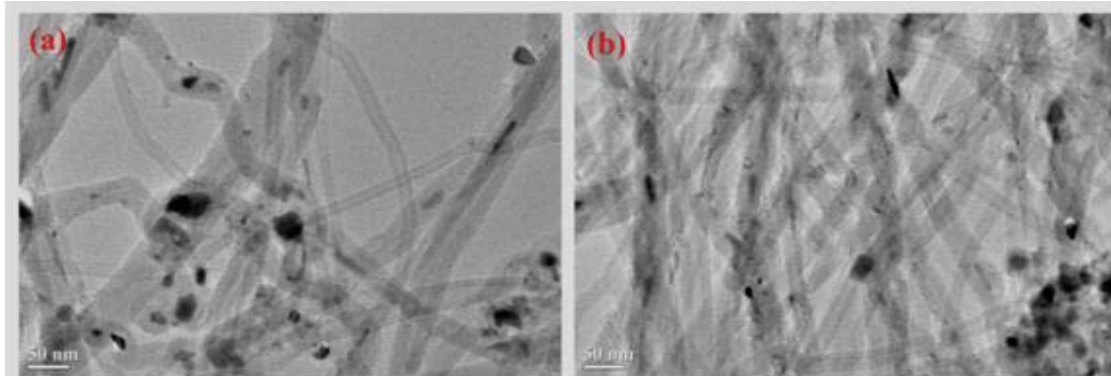


Fig. 4:- TEM images of CNTs at different locations.

3.2. Characterization of developed abrasive Media

The three abrasive media has developed. The first abrasive media has aluminium oxide, polymer and hydrocarbon gel is mixed properly in predetermined proportion to get the viscous elastic media with no content of CNTs particles. The second and third abrasive media added with 5 and 10 grams CNTs with iron filled respectively. Fig. 5 is the SEM micrograph of the media (Al_2O_3 and Carrier only) before addition of CNTs where, (a) is the SEM micrograph at scale bar of $100\ \mu\text{m}$ in which abrasives edges are not clearly visible, (b) is the SEM micrograph at a scale bar of $5\ \mu\text{m}$ in which abrasive edges are visible. This SEM micrograph (Fig. 5 (a)) of the media (Al_2O_3 +carrier+ Fe-filled CNTs) shows the sharp edges of alumina particle are clearly visible which is responsible for machining the work surface.

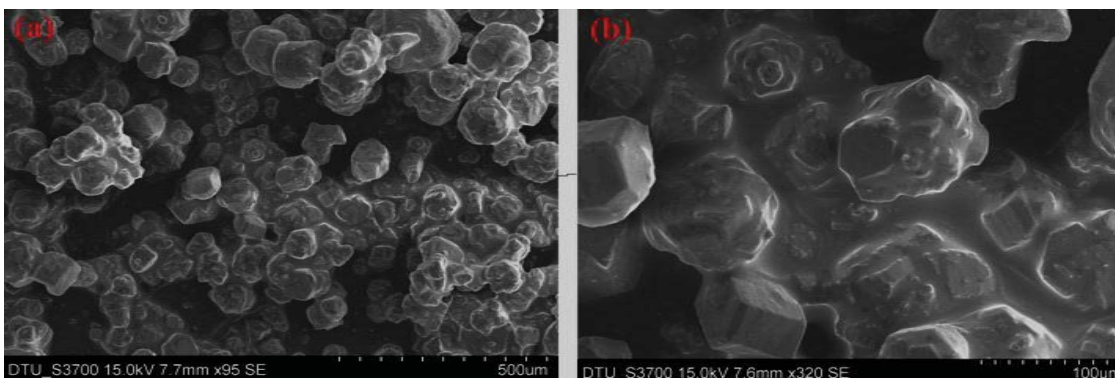


Fig. 5:- SEM image of media (Al_2O_3 +carrier+ Fe-filled CNT).

3.3. Effect of CNTs on material removal

Fig. 6 shows that as the amount of CNT particles increased, the material removal of cast iron workpiece increased when other AFM machining parameters are constant. As we know that CNT particles are harder as compare to the aluminium oxide and CNT has very sharp cutting edges. So when the extrusion pressure is applied, it easily cuts the peak of the surface material and causes more material removal.

3.4. Effect of CNT on surface finish

It can be seen from the fig. 7, that as the amount of CNT increases the % increase in surface finish (Ra) slightly increases but after level 2 (10 grams CNTs), % improvement in Ra sharply increased (100%).

This is due to more number of abrasive particles taking part in machining process and also continues to remove fresh materials from the work surface which lead to increase in MR and surface finish.

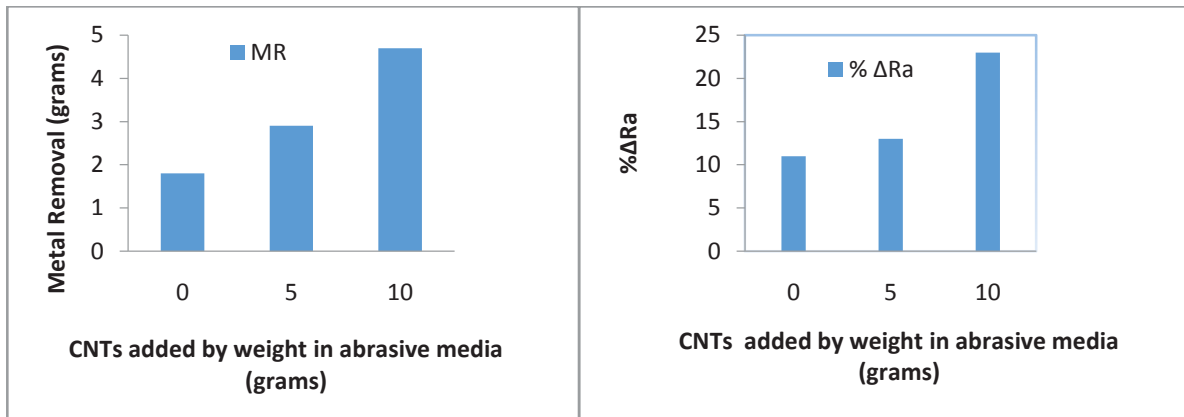


Fig. 6:-Effect of CNT particles on MR.

Fig. 7:- Effect of CNT on Ra.

4. Conclusion

The present study was carried out to develop CNTs based abrasive media for AFM successfully. It has been found and showed that the use of CNTs with abrasive media led to an improvement in the response parameter of percentage improvement in surface finish and material removal. At selected parameters a maximum improvement of 100% has been observed in the Surface finish on the inner cylindrical surface of the cast iron work piece.

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