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Surface modification of EDM process using Carbon Nano tubes, A Review

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Abstract:- Better surface finish demand is increasing from recent years for machining of tough and super alloys. Traditionally EDM Dielectric is mixed with either aluminum (Al), chromium (Cr), copper (Cu), and silicon carbide (SiC) powder to obtain high surface finish value. In new technology researchers mix Carbon nano tube (CNT) with dielectric fluid in EDM process because of high thermal conductivity of CNTs. The analysis of surface characteristics like surface roughness, micro cracks of work pieces are carried out and an excellent machined nano surface finish is attained.

Keywords:- CNT, EDM, MWNT,PHEDM, SWNT, SR,

I. INTRODUCTION

Electrical-discharge machining is generally employed for machining of hard and tough materials; so-called difficult-to-machined materials.EDM is used for production of complicated shapes and dies with high accuracy[1-3]. The work piece and the electrode do not directly contact with each other, thus eliminating the force-induced chatter or vibration problems and allowing small or thin components to be machined without causing distortion [4-5]. The spark between the tool and work piece produces a very high temperature on the work piece surface, and removes the material by melting and vaporization. A small amount of molten layer is expelled from the surface, while the residual melted layer that is not flushed out by the dielectric fluid is later solidified on the work piece surface as recast layer. The electrical-discharge often will induce machining defects such as craters, micro cracks, micro voids and pockmarks on the surface layer leading to low surface finish value [6-7]. Although an excellent machined finish can be obtained by setting the EDM parameters at a low pulsed current and a small pulse on-time to improve strength but this approach is more time consuming. In general, the conventional machining processes such as grinding, polishing, and lapping are adopted to remove the surface damage layer induced by EDM process. These operations will cause excessive tool wear and expensive.

II. CARBON NANO TUBES

Carbon nanotubes are one of the most commonly mentioned building blocks of nanotechnology. With one hundred times the tensile strength of steel, thermal conductivity better than all but the purest diamond, and electrical conductivity similar to copper, but with the ability to carry much higher currents, they seem to be a wonder material. Carbon nano tubes were discovered in 1991 by Sumio Iijima of NEC and are effectively long, thin cylinders of graphite, which in turn is made up of layers of carbon atoms arranged in a hexagonal lattice, like chicken wire as shown in figure 1. Though the chicken wire structure itself is very strong, the layers themselves are not chemically bonded to each other but held together by weak forces called Vander Waals. It is the sliding across each other of these layers that gives graphite its lubricating qualities and makes the mark on a piece of paper as you draw your pencil over it. Now imagine taking one of these sheets of chicken wire and rolling it up into a cylinder and joining the loose wire ends. The result is a tube that was once described by Richard Smalley

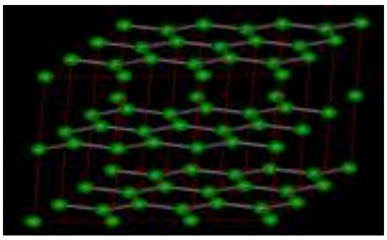

Fig. 1: Layer structure of graphite. Source: gallery of crystal structures,

III. TYPES OF NANO TUBES

Carbon nanotubes are generally of two types, single-walled varieties (SWNTs), which have a single cylindrical wall as in Figure 2, and multi-walled varieties (MWNTs), which have cylinders within cylinders as in figure 5. The lengths of both types vary greatly, depending on the way they are made, and are generally microscopic rather than nanoscopic, i.e. greater than 100 nanometers (a nanometer is a millionth of a millimeter). The aspect ratio (length divided by diameter) is typically greater than 100 and can be up to 10,000, but recently even this was made to look small. In May last year SWNT strands were made in which the SWNTs were claimed to be as long as 20 cm. Even more recently, the same group has made strands of SWNTs as long as 160 cm, but the precise make-up of these strands has not yet been made clear.

A. Single-Walled Carbon Nanotubes (Swnts)

SWNTs are best nano tubes but major drawback of these is that difficult to make as compared to Multi wall nano tubes. These have amazing properties. these are basically tubes of graphite and are normally capped at the ends as shown in figure 3, although the caps can be removed. The caps are made by mixing in some pentagons with the hexagons and are the reason that nanotubes are considered close cousins of buckminsterfullerene as shown in figure 4, a roughly spherical molecule made of sixty carbon atoms, that looks like a soccer ball and is named after the architect Buckminster Fuller (the word fullerene is used to refer to the variety of such molecular cages, some with more carbon atoms than buckminsterfullerene, and some with fewer). Discussions of the electrical behavior of carbon nanotubes usually relate to experiments on the single-walled variety. As we have said, they can be conducting, like metal (such nanotubes are often referred to as metallic nanotubes), or semiconducting, which means that the flow of current through them can be stepped up or down by varying an electrical field.

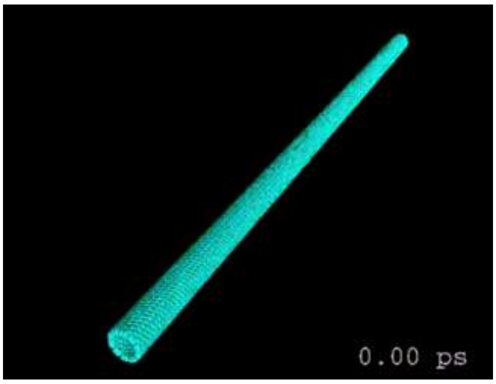

Fig. 2: Single wall nano tube

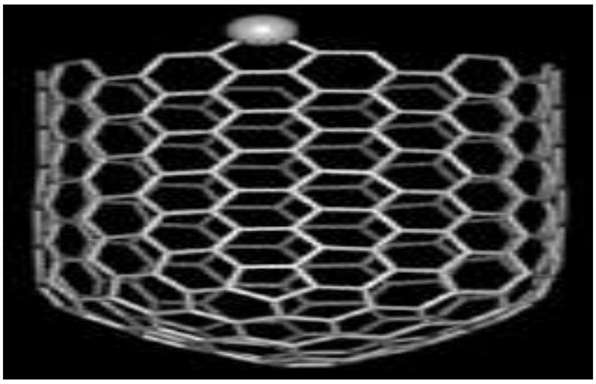

Fig. 3: Simulated structure of a carbon nanotube.

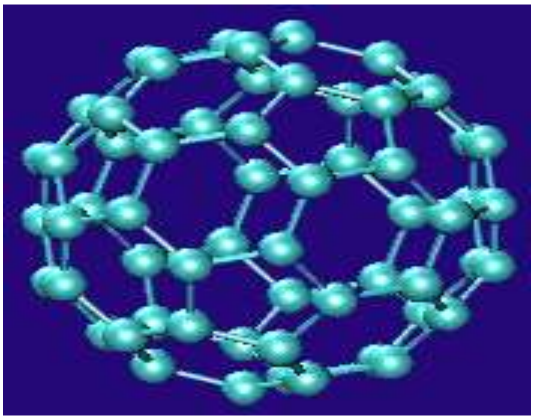

Fig. 4: Buckminsterfullerene.

B. Multi-Walled Carbon Nanotubes (Mwnts)

Multi-walled carbon nanotubes are basically like Russian dolls made out of SWNTs concentric cylindrical graphitic tubes. In these more complex structures, the different SWNTs that form the MWNT may have quite different structures (length and chirality). MWNTs are typically 100 times longer than they are wide and have outer diameters mostly in the tens of nanometers. Although it is easier to produce significant quantities of MWNTs than SWNTs, their structures are less well understood than single-wall nanotubes because of their greater complexity and variety. Multitudes of exotic shapes and arrangements, often with imaginative names such as bamboo-trunks, sea urchins, necklaces or coils, have also been observed under different processing conditions. The variety of forms may be interesting but also has a negative side. MWNTs always have more defects than SWNTs and these diminish their desirable properties.

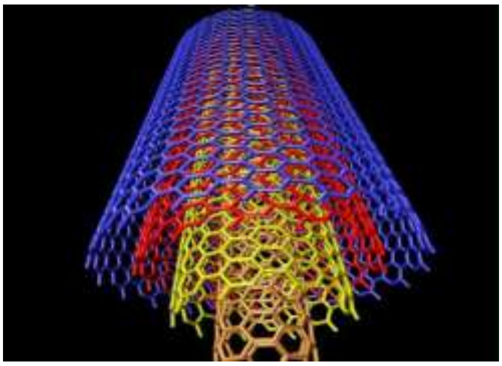

Fig. 5: Representaion of a multi-walled carbon nanotube

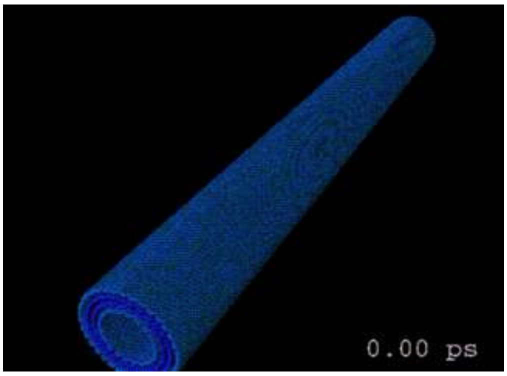

Fig. 6: Multi wall carbon nano tube

IV. NANOTUBE GEOMETRY

There are three unique geometries of carbon nanotubes. The three different geometries are also referred to as flavors. The three flavors are armchair (Fig 7), zig-zag (Fig 8), and chiral (Fig 9) [e.g. zig-zag (n, 0); armchair (n, n); and chiral (n, m)]. These flavors can be classified by how the carbon sheet is wrapped into a tube (see pictures below).

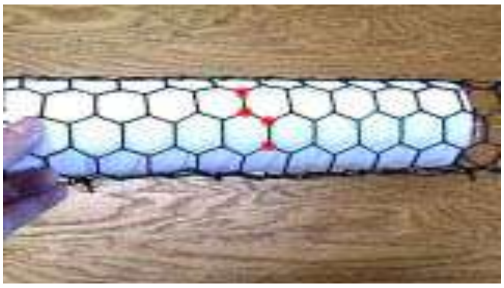

Fig. 7: Armchair arrangement of carbon atoms

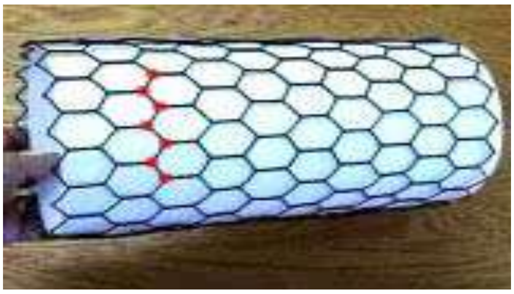

Fig. 8: Zig-zag arrangement of carbon atoms

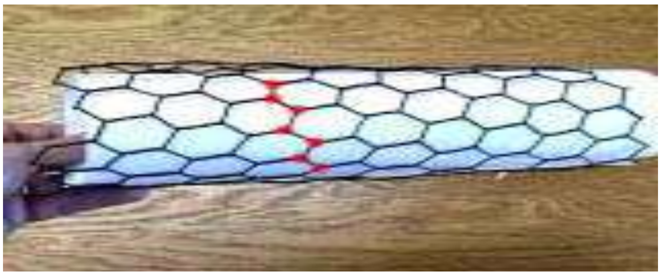

Fig. 9: Chiral arrangement of carbon atoms

V. EDM WITH CARBON NANO TUBES

Researchers had made a lot of efforts on the conventional EDM to produce fine surface finish and to minimize the micro cracks and damage surface on work surface. Nano surface finish has become an important parameter in the semiconductor, optical, electrical and mechanical industries. The materials used in these industries are classified as difficult to machine materials such as ceramics, glasses and silicon wafers. Machining of these materials up to nano accuracy is a great challenge in the manufacturing industry. Finishing of micro components such as micro-moulds, micro-lenses and micro-holes need different processing techniques. Conventional finishing methods used so far become almost impossible or cumbersome. Generally EDM Dielectric is mixed with either aluminum (Al), chromium (Cr), copper (Cu), and silicon carbide (SiC) powder that reduces the insulating strength of the dielectric fluid and increases the spark gap between the tool and work piece, thus disperses the discharging energy to obtain superior surface finish [8-10]. Conductive powders added to dielectric can increase the micro hardness, make the molten layer of material thinner and reduce cracks [11-13]. To obtain near mirror- finish it is important to have the correct combination of Powder and work piece materials. By using graphite, silicon (Si), aluminum (Al), crushed glass, silicon carbide (SiC) and molybdenum sulphide with different grain size, Al powder has been reported to give mirror finish for SKH-51 work pieces, but not on SKH-54 work pieces [14]. Powder properties has great influence on the Surface Quality of SKD-11 work piece using Al, chromium (Cr), Copper (Cu), and SiC powders. The smallest particle (70–80 nm) generates best surface finish and Al powder produces the best surface finish. The suspended powder such as graphite (Gr) and silicon (Si) distributed in the dielectric can cause the effect of lowering the breakdown voltage so that the discharges can occur at a wider inter electrode gap, which facilitates flushing debris and reducing servo hunting so that machining is more stable with improved machining efficiency [16-17]. When the silicon powder is used, the surface roughness can be significantly reduced allowing the generation of mirror-like surfaces. The presence of silicon in the dielectric can eliminate the undesirable discharge conditions [18]. The particle size, the particle concentration, the particle density, the electrical resistivity and the thermal conductivity of powder are important characteristics that significantly affect the machining performance in EDM process [19]. silicon powder showed a positive influence in the reduction of the operating time required to achieve a specific surface quality, and in the decrease of the surface roughness, allowing the generation of mirror-like surfaces [20]. It is necessary to optimize the process parameters of powder mixed electrical discharge machining (PMEDM) like Pulse on time, duty cycle, peak current and concentration of the silicon powder added into the dielectric fluid of EDM to reduce the roughness [21]. While the smallest particles generate the best surface finish of the EDM work, literature also shows that powders of lower density, lower electrical resistivity and excellent thermal conductivity will benefit to improve the machining performance in the EDM process [22]. The graphite, aluminium and alumina nanopowders mixed in dielectric on micro EDM of tool steel (SKH-51) and tungsten carbide (WC). The results show the presence of a conductive or semi-conductive nanopowder lowers the breakdown strength and increases the spark gap during powder-mixed micro-EDM. The surface finish and topography is improved significantly owing to the increased spark gap and uniform discharging. In addition, the lower breakdown strength of dielectric and increased spark gap contribute to higher MRR, lower tool wear, and better surface finish [23-24]. Mixing of boron carbide powder in deionized water dielectrics enhances machining performance in micro-EDM of Ti-6Al-4V alloy [25]. Silicon powder concentrations, peak current and pulse duration play important roles in improving the surface quality in EDM of metal matrix composites, while the supplied voltage is an insignificant variable [26]. The Al particle size and concentration significantly affect machining efficiency during EDM of Inconel 718 [27]. Recently, the nano powder-mixed EDM plays an important role in improving EDM performance. Before 2010's, the improvement of surface finish of EDM specimen was mainly by the use of micro powders (such as Al, Cr, Cu, SiC, Gr). However, owing to their heavy specific gravity these result in non-uniform dispersion in the dielectric. The graphite nano-powder-mixed in the dielectric resulted in 20-30% reduction in surface roughness of WC-Co (Figure 10), lower the breakdown strength and facilitate the ignition process thus improving the material removal rate [28]. The reduction of 35% in machining time was obtained after using nano MoS_2 and nanographite powders suspension in dielectric fluid [29-30].

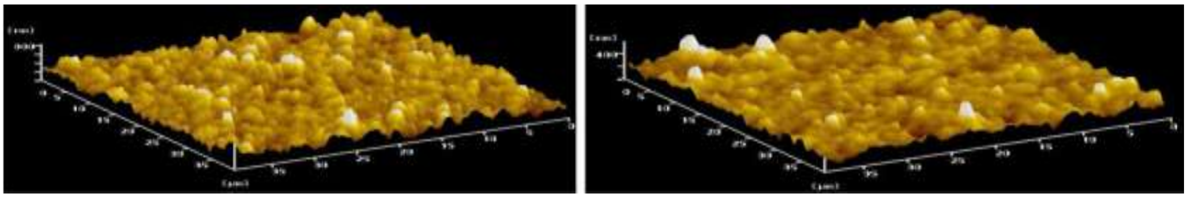

Fig. 10 : (a) die-sinking, without nano-powder (b) die-sinking, with nano-powder

Carbon nanotubes (CNTs) are high aspect-ratio structures with a straight-pin shape and low density, coupled with very good electrical properties and excellent thermal conductivity, making them an ideal candidate for both electrode and powder-mixed EDM (PMEDM). MWCNTs as mini-scale electrodes for EDM can endure distortion providing precise surface [31]. The technique of dielectric mixed with CNTs is a novel approach to attain a very fine finish. The average surface roughness of 0.09 m was achieved within 1.2 h, and the material defects of the recast layer and the micro-cracks were considerably reduced by adding CNT powders to the dielectric at a concentration of 0.4 g/l. The surface finish and the machining time of the work piece have been improved up to 70% and 60%, respectively. Figure 11 SEM micrographs of the machined surface in use of dielectrics of (a) kerosene and (b) kerosene+CNTs. It is clear that EDM process without the added CNTs in dielectric produces more damage such as pinholes, micro-voids and crater on the machined surface, while the surface machined under kerosene mixed with CNT powder was smoother with less micro-cracking [32]. Specimens sparked by MWCNTs have better surface finish, reduction of micro cracks and superior surface morphology as compared with specimens sparked without MWCNTs [33]. The electrical conductivity of hybrid Al_2O_3/CNTs composites has an increasing tendency as the CNTs content is increased. The conductivity of the materials and homogeneous distribution of CNTs in the matrix are important factors for micro-EDM of Al_2O_3/CNTs hybrid composites [34]. The AISI D2 tool steel sparked by SWCNTs has better surface finish and better surface morphology as compared with specimens sparked without SWCNTs. The SWCNTs can absorb the heat from electrical discharged material and minimize the white layer formed in the work piece. A nano finish can be obtained by setting the machining at low pulse energy [35-36]. The surface roughness of the work piece and the machining efficiency of the EDM with powder mixed into the dielectric were improved by 70% and 66% respectively, compared with conventional EDM.CNTs demonstrate better achievement than other powder.[37]

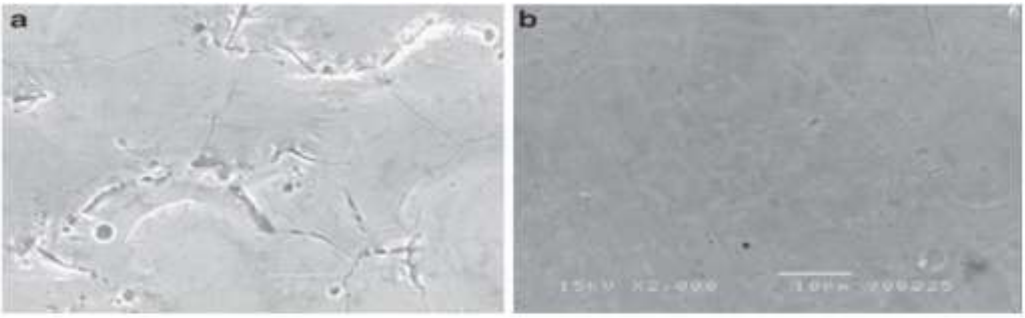

Fig. 11: SEM micrographs of the machined surface in use of dielectrics of (a) kerosene and (b) kerosene+CNTs

Comparsion of roughness obtained by different dielectric is shown in Table 1. By using nano material especially multi wall carbon nano tube in the machining process like grinding, the surface characteristics can be improve from micro to nano level [38].

Table 1: Roughness obtained by different dielectric [38]

Samples	Ra Values *(µm)*
Sample1(with no lubricant)	0·251
Sample2(with water soluble oil)	0·137
Sample3(with SAE20W-40)	0·096
Sample4 (with SAE20W-40 + MWCNT)	0·057

Field emission scanning electron microscope (FESEM) study reveals that the electrical conductivity has a increasing tendency as the CNTs content is increased in aluminum oxide (Al_2O_3) and has a critical point at 5% Al_2O_3 (volume fraction). Further homogeneous distribution of CNTs in the matrix is important factors for micro-EDM of Al_2O_3/CNTs hybrid composites [39].

VI. CONCLUSIONS

From the Literature it is concluded that using carbon nano tube as dielectric in EDM process, surface finish can be enhanced to great level. Further there should be optimization of various EDM process parameters to achieve the better surface characteristics.

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