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Experimental Study for Non-Wetting Behavior on EDM Textured Surface of Stainless Steel 316L

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ABSTRACT

Contact angles or wettability of the surface play an important role in field of biomedical. Stainless steel 316L (SS 316L) is being used vastly for generating hydrophobic surfaces for implants. In the present study Electric discharging machining (EDM) machining process is carried out to generate the hydrophobic surface using copper electrode at various EDM parameters as one step process. Hydrophobic surfaces are essential part for a surface having property of non-wetting behavior. An experiment for measuring contact angle of non-wetting surface of stainless steel 316L with sessile drop goniometer method was conducted. Measuring the static contact angle and drop of water on stainless steel 316L with different surface roughness was carried out. Contact angle measurements is assessed for surface hydrophobicity. It was observed that stainless steel 316L was good hydrophobic properties having non-wetting surface with increasing surface roughness of SS 316L at a one step process without any coating. As a result, the contact angle of is increased from 87.1° to 149.5 with increasing of surface roughness of SS 316

KEYWORDS: EDM, hydrophobicity, surface roughness, stainless steel 316L, non-wetting

I. INTRODUCTION

As the word machining process comes there are many machining processes that are available in tool making industry. These processes can be divided into two process conventional and non-conventional machining processes. For example, milling and turning machining process are considered as conventional machining. The electrical discharge machining is considered as non-conventional due to its different method of machining. EDM is used the most widely and successfully applied machining process for different workpiece materials for the advanced industries. EDM is mostly used method due to production of close tolerance shapes, 3D complex shapes. Thermal energy causes the vaporization of material from workpiece and material is removed. As the word machining process comes there are many machining processes that are available in tool making industries.

The concept of hydrophobic surfaces is originally come from Since the 1990's Hydrophobic and self-cleaning leaf surfaces have been studied since the 1990's in great detail, lotus leaf was the most popular and first to be thoroughly examined (Barthlott and Neinhuis, 1997; Bhushan and Jung, 2006; Cheng *et al.*, 2006*)* the inspiration of lotus leaves in nature. Because of the very high-water repellency (superhydrophobicity) and the self-cleaning properties exhibited by the lotus leaf have been referred to as lotus effect, which has been attributed to a combined effect of the hydrophobicity induced by the surface roughness resulted from the hierarchical structures on the leaf. From long lime to generate the hydrophobic surface materials coatings are continuously being used to protect textured surfaces.

Hydrophobic and hydrophilic surfaces:Sometimes water spreads evenly when it hits a surface, sometimes it beads into tiny droplets. Those it spreads across, maximizing contact surface are known as hydrophilic. Those that naturally repel water, causing droplets to form, are known as hydrophobic. These hydrophobic surfaces are known as now-wetting or water repelling surfaces. If the droplet spreads, wetting a large area of the surface, then the contact angle is less than 90 degrees and that surface is considered hydrophilic, or water-loving. But if the droplet forms a sphere that barely touches the surface like drops of water on a hot fry pan the contact angle is more than 90 degrees, and the surface is hydrophobic, or water-fearing. These non-wetting surface features of hydrophobic leaf structures have been used as a biological blueprint in the structuring of a variety of materials, rendering their surfaces highly water-repellent. Superhydrophobic antibacterial surfaces have high potential for wide functionality in biomedical and biological sciences due to their availability, easy fabrication process and versatility (M. Wilson *et.al.*, 2002). The present work is to investigate the non-wetting behavior on EDM machined textured surface on stainless steel by increasing the surface roughness

II. Materials and Methods

A. Experimental set-up and instruments

As to generate non-wetting behavior first of all we have to fabricate the material surface and to increase the surface roughness. The experiments have been conducted on die electric discharge machine (EDM) of J.K. machines available at the department of mechanical engineering at CTAE laboratory. With the help of various factors i.e., discharge current, pulse on time and pulse off time are used. The experimental set up is shown in Figure 1. and the specifications of the EDM in Table 1.

Figure 1. EDM machine set-up

Table 1. Specifications of EDM

Brand	**JK Machines**
Model	ZNC-250
No. of axis	3 axes (X, Y and Z)
X, Y & Z axle range	250, 250 & 200 mm
Maximum capacity of the operating platform	200 mm
Maximum processing speed	200 mm³/min
Maximum power consumption	6 kW
Pulse width (T_{on})	4-999 microseconds
Pulse gap (T_{off})	1-99 unit being 10 microseconds
Adjusting current	0-40 Ampere
Servo tracking voltage (processing voltage)	1-9 volts
Least count	0.005 mm

For performing the machinability of SS 316L machining parameters has been used to carried out all the experiments using cooper electrode for achieving maximum value of surface roughness. Discharge current (I), pulse on time (Ton), pulse off time (Toff) and servo voltage has been taken as parameters. The electrode is used as negative terminal to keep it minimum tool wear which is connected to RC terminal for the generation of pulse. The workpiece works as positive terminal while dielectric is used a medium between the electrode and workpiece through the nozzles to remove the debris and the molten metal during the machining.

To evaluate the machining time of each and every sample was note down by using stopwatch. After that surface roughness was measure for all the machined samples by Mitutoyo SURFTEST SJ-210 roughness tester shown in Figure 2

Figure 2. Surface roughness measurement by SURFTEST SJ-210

B. Materials

To study the experimentation stainless steel 316L material is used as this metal acts as biocompatible to the human body and copper is used as electrode treated antibacterial coating.

The workpiece was made of dimension 50 mm × 13mm × 5 mm as shown in Figure 3 and copper electrode having diameter of 16mm.

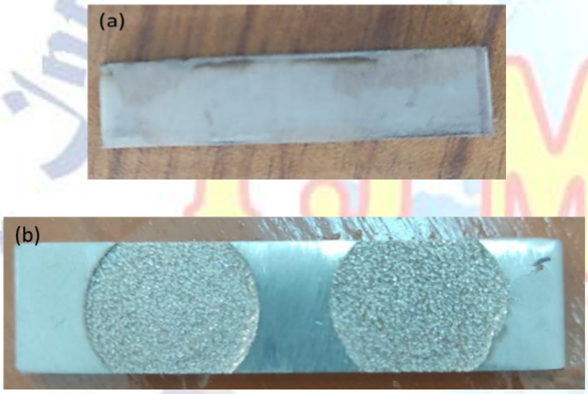

Figure 3. (A) Workpiece SS 316L plate and (B) EDM machined Workpiece

Copper is selected as electrode for producing high value of surface roughness which is most useful for non-wetting of the material surface and also for as antibacterial coating to reduce infections, so for this the copper ions are impregnated with the nano particles to protect the bacterial growth in surrounding culture.

Using copper in the EDM machining the randomly distributed craters and holes are potentially help to generate rough surface which is useful for hydrophobicity as well as protect from bacterial growth.

C. Design of the experimentation

Taguchi's parameter design approach is used to study the effect of non-wetting of EDM textured surface. Taguchi is powerful technique for design a high-quality system. Taguchi design involves using orthogonal arrays to organize the parameters that affects the process and the levels at which they should be varied. Parameters and levels are taken and Table L25 orthogonal array is used. Minitab 18 software has been used for the same.

Various factors influencing wettability of the EDM machined surface including machining parameters, dielectric mediums, surface structures, surface chemistries and workpiece materials are analyzed and discussed. Wettability is observed by the different contact angle on the EDM machined SS 316L by the help of goniometer instrument.

III. RESULTS AND DISCUSSION

A. Non-wetting behavior of SS 316L

According to Young's contact angle which is depends on surface free energy of the material, so it is known as the intrinsic contact angle. In this study, the material stainless steel 316L is used throughout the work. Number of samples were machined on the EDM for the measurement of the Young's contact angle. Flat surfaces without EDM machined surface having an arithmetical mean roughness (Ra) of 0.50 μm was obtained, and a contact angle of 61.4° was measured (Figure 4.14 (a) and (b)). After dielectric EDM texturing on the workpiece the contact angle was increased to 149.5° which indicated high hydrophobicity shown in Figure 4.14 (c) and (d)

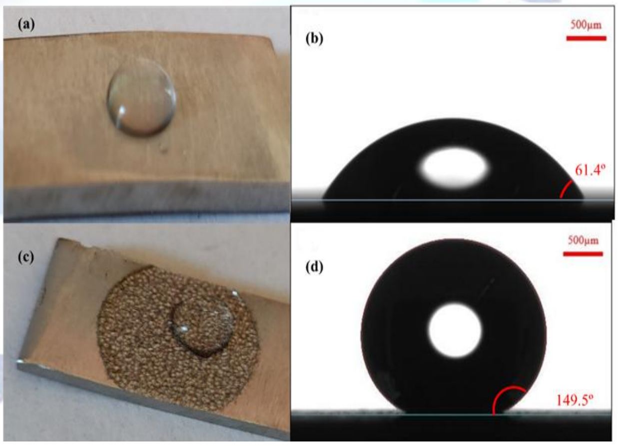

Figure 4.Water droplets on an untreated surface and a EDM textured surface taken by (a, c) regular microscopy and (b, d) goniometer respectively.

For the study of hydrophobic non-wetting surface water impact on surface resistance has been investigated by shooting a slow-motion video of a droplet which is falling onto two different surfaces. One on without EDM machined surface and second on EDM machined surface. droplets of water have been released 5 cm above from the surfaces, and a picture was captured sequentially by using a high-speed camera with a speed of generating 6000 frames per second for each and every experiment, as shown in Figure 4. Water droplet on the without EDM surface the water droplet spread on the surface as it contacts which shows that the wetting behavior of the surface. But, on an EDM machined textured surface, the water drop has been bounced back on the machined surface which desired a completely non-wetting behavior of the surface as in Figure 5.

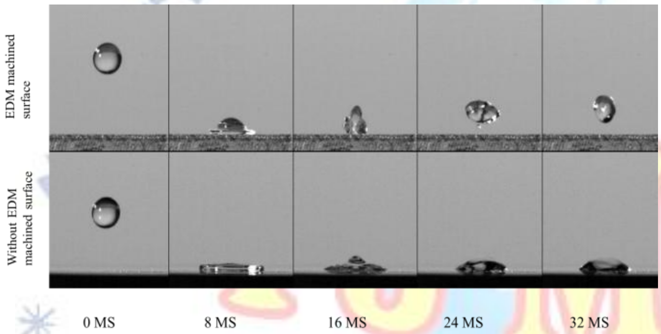

Figure 5.Captured picture from impacting of water droplet sequentially.

B. *Effect of surface roughness*

The wetting behavior of hydrophobic surfaces is depended by both their chemical composition and geometric microstructures., from the experimental results it can be seen that the contact angle on surface of stainless steel 316L is increases gradually from 0.50 µm to 13.6 µm. From the results it is clear that contact angle depends on chemical properties and surface roughness. This result indicates that wettability of stainless steel 316L with different parameters strongly depend on surface roughness. Figure 6. it can be clearly seen that with increase of current surface roughness is increased.

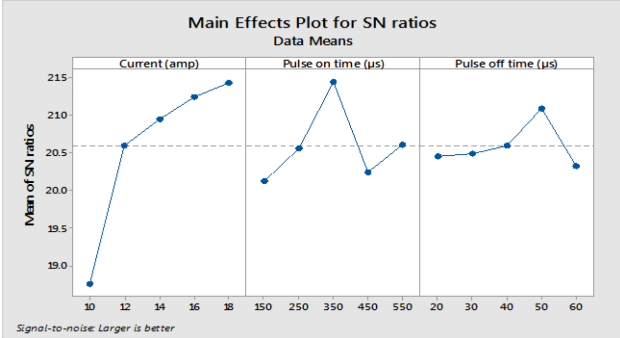

Figure 6. Effect of parameters on surface roughness.

IV. Conclusion

The results from the experimental study shows that the surface textured created by EDM is interdependent with the discharge energy and affects the wettability of the machined surfaces. We can also say that from surface texture parameters i.e., discharge current pulse on time and pulse off time it confirms a strong correlation their curvatures and wetting properties. It also shows that textured surface has also been enhance the surface properties of the materials in the context of applications for hydrophobic non- wetting surfaces and roughness.

Surface roughness shows a continuous increase with the parameters such as, intensity of current, pulse on-time. Which increase the value on contact angle and this is strong factor for non-wetting behavior of the surface.

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