Texture Analysis of Electrical Discharge Machined (EDM) surfaces using vision system

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Abstract

Predicting the functionality of an engineering component is possible by the evaluating of roughness of the machined surface. Researchers have been proposing different approaches for the measurement of surface roughness. Highest accuracy in roughness measurement is possible by Contact type measurement. Non-contact type of roughness measurement is fast but do not provide complete information for the complete surface characterization. These techniques fail to measure the roughness of complicated objects. In this scenario, present method becomes very important. Vision system is used for the roughness evaluation. The present method is capable of measuring the surface finish of EDM components and also highest measuring speeds are possible.

Keywords
EDM inspection, Surface finish measurement, texture measurement, non-contact inspection, texture analysis.

1. Introduction
Every machined surface will have a unique texture. Surface texture characterizes a particular machining process. EDM process is no exception. Analyzing surface texture would help in knowing whether a product will succeed and fail, when it is put into service. Critical observation of any machined surface show different types of surface irregularities. Surface irregularity having small wavelength is called roughness. Waviness and form error constitutes irregularities having medium and large wavelength respectively. Conventionally, texture measurement is done using a stylus based instrument. During measurement, a diamond stylus is made to traverse on the surface to be examined. The devise is capable of measuring surface roughness parameters. This method is considered as a standard as it gives accurate readings. The method very useful in sampling inspection of industrial products. That is, the method is a post-process type of inspection. The method is contact type and is not fit for 100% inspection of components.

To meet the modern day customer demand of 100% inspection, require the design and development of novel techniques of surface roughness measurement. As many of the existing techniques are not capable in the measurement of online and in-process inspection of industrial components. As many of these techniques are restricted to laboratory environments, there is a need for the development of a quick, reliable, accurate and robust technique for the surface finish measurement of EDM components.

The objective of this work is to devise a technique for the roughness evaluation of EDM components. Also, the process should be applicable in online measurement of EDM components.

2. Literature Survey
The techniques proposed by various researchers in order to evaluate the surface roughness of engineering components are discussed in the following paragraphs.

Nelson (1969) proposed taper sectioning method. The method consist of cutting the surface at an angle θ followed by examining the surface using a microscope. This is very accurate method. This method can be used for the measurement of peak to valley height. Researchers (Kayser 1943, Way 1969, Shaw 1963) proposed a roughness measurement technique, which used a beam of light is made to illuminate the surface at 45^0. A microscope was used for viewing the surface at 45^0. They concluded that smooth surfaces exhibit a straight image. By measuring the extent of deviation from straightness gives roughness. Researchers (Elmendorf 1958, Halling 1954, Westberg 1967, Vashist 1974) proposed gloss-based roughness measurement. In these techniques, the magnitude of reflectivity could be used as a measure of surface finish. Researchers (Dainty 1975, Asakura 1974, Parry 1975, Leger 1975, Ribbens 1968, Anderson 1969, Nagata 1973) have used laser speckle patterns for the evaluation of surface roughness. They concluded that by observing the diffraction patterns, valuable information about the surface irregularities can be obtained. They could able to measure surface roughness of specimens. The optical methods are non-contact in nature and high measuring speeds are possible. The limitation of these techniques is that they were mainly used in lab environments. Thwaite (1979) proposed a technique for measuring the roughness by using optical Fourier transformation. They observed power spectrum of rough surfaces, through a photographic film, for the evaluation of surface roughness. Sherwood and Cookall (1967) and Radhakrishnan (1977) have studied and found that by measuring the capacitance and inductance, surface roughness can be measured. This is electrical method. Thus, this method is restricted to the evaluation of surface roughness of electrically conducting components.

Moore (1965) measured the time the water takes for leaving the container, as a measure of surface roughness. Researchers (Beckmann 1967, Griffiths 1993, Marx 1990, Nicolau 1937) have studied light scattering from rough surfaces. They concluded that by measuring scatter patterns roughness can be measured. Researchers (Thomas 1982, Whitehouse 1984) did detailed study using diamond-based stylus instruments. The main advantage of the method is that it gives very accurate readings.

With the advent of Image processing and low-cost vision system, many researchers have proposed techniques for analyzing the texture of machined surfaces using vision system (Patel_a 2020, Patel_b 2020, Shivanna 2021). They have analyzed machined surfaces using Vision system and image processing. They have extracted texture features from the images of the machined surfaces. Haralick (1973) defined the texture features. Here Contrast (C1) is defined by equation 1. Correlation (CR1) is defined by equation 2. Cluster prominence (CP1), is defined by equation 3. Dissimilarity (D1), is defined by equation 4.Energy (E1), is defined by equation 5. Entropy (EP1), is defined by equation 6. Homogeneity (H1), is defined by equation 7. Maximum Probability (MP1), is defined by equation 8.Sum entropy (SE), is defined by equation 9.Difference Variance (DV), is defined by equation 10. Difference entropy (DE1), is defined by equation11.Inverse difference moment normalized (ID-M1), is defined by equation 12. and Inverse difference normalized (ID-N1), is defined by equation 13.

$$C1 = \sum_{n=0}^{G-1} n^2 \left\{ \sum_{i=1}^{G} \sum_{j=1}^{G} P(i,j) \right\}, |i-j| = n \qquad -1$$

$$CR1 = \sum_{i=0}^{G-1} \sum_{j=0}^{G-1} \frac{\{i \, X \, j\} \, X \, P(i,j) - \{\mu_x \, X \, \mu_y\}}{\sigma_x \, X \, \sigma_y} \qquad -2$$

$$CP1 = \sum_{i=0}^{G-1} \sum_{j=0}^{G-1} \{i + j - \mu_x - \mu_y\}^4 \, X \, P(i,j) \qquad -3$$

D1 = $\sum_{i=0}^{G-1}\sum_{j=0}^{G-1} P(i,j)|i-j|$ -4

E1= $\sum_{i=0}^{G-1}\sum_{j=0}^{G-1}\{P^2(i,j)\}$ -5

EP1 = $-\sum_{i=0}^{G-1}\sum_{j=0}^{G-1} P(i,j)Xlog(P(i,j))$ -6

H1 = $\sum_{i=0}^{G-1}\sum_{j=0}^{G-1}\frac{P(i,j)}{1+|i-j|}$ -7

MP1 = $max(p_{i,j})$ -8

SE1 = $-\sum_{i=0}^{2G-2} P_{x+y}(i)\, log\left(P_{x+y}(i)\right)$ -9

DV1= $\sum_{i=0}^{G-1}\sum_{j=0}^{G-1}(i-\mu)^2\, P(i,j)$ -10

DE1 = $-\sum_{i=0}^{G-1} P_{x+y}(i)\, log\left(P_{x+y}(i)\right)$ -11

ID-M1 = $\sum_{i=0}^{G-1}\sum_{j=0}^{G-1}\frac{1}{1+(i-j)^2}P(i,j)$ -12

ID-N1 = $\sum_{i=0}^{G-1}\sum_{j=0}^{G-1}\frac{P_{i,j}}{(1+\frac{|i-j|}{N})^2}$ -13

3. Methodology

The steps involved in current research are highlighted in below paragraphs. Specimens are made by EDM process. EDM specimens are made by selecting different process parameters as shown in Table 1. Current, Voltage, Pulse-on-time: (T_{on}) and Pulse-off-time: (T_{off}) are the EDM process parameters. The surface roughness, of all the specimens, are measured using a perthometer. During the measurement, the diamond stylus is made to move on the surface and the 2D and 3D roughness parameters are measured. The measurements are used for the validating the results of the proposed method.

The experimental setup used in the research work is shown in Figure 1. In the experiment, a vision system is used. A CCD camera for capturing the image of the EDM specimens. The analog image is digitized with the help of a frame grabber. Server is used for storing the digital images. The server consists of an advanced image processing board. This board is used for performing the digital image processing operations quickly. Image processing software, MATLAB as well as MATROX image processing libraries are used for performing image processing operations. A software is developed using the libraries, for computing the surface roughness of EDM specimens.

Table 1. EDM process parameters

Component no.	T_{on} (μ seconds)	I.P. (amps)
A	81	9
B	71	8
C	61	7
D	51	6
E	41	5

3.1 Experimentation

The EDM component, whose roughness is to be measured, is mounted on the mount stage of the vision system. The component is illuminated by using the normal lighting. The CCD camera is used for acquiring the image of the component. The digital image of the component is stored in the server. The above procedure is repeated by taking components one at a time. Likewise, the surface images of all the EDM components are stored in the server. The digital image has a resolution of 512x480 pixels. In-house software written in C++ is used for measuring the image roughness of the component.

4.Results and Discussions

A sample digital image of EDM component is shown in Table 2. A digital image consists of brightness intensity values at each pixel. In a grayscale image the image intensity varies from 0-255. Quality of the input image is assessed by constructing a histogram. There can be different types of noise in the input image. One of the reasons for the presence of noise in the input image can be due to the variation in brightness, during illumination. Quality of the image of the captured image is improved by histogram equalization. Figure 2 shows the processed image of an EDM component. The processing is done by using a sobel filter. Co-occurrence matrix (Table 3) is computed using the processed image. Haralick (1973) defined texture features which can be computed from a digital image using the co-occurrence matrix. The texture features are capable of capturing texture aspects of a digital image (Table 4).

Table 2. EDM sample digital image.

Row/Col	1.	2	3	4	5	6	7
1	202	136	236	225	189	188	97
2	180	125	286	186	177	180	66
3	165	158	249	191	158	139	79
4	136	177	209	139	169	107	56
5	135	216	168	148	187	196	95
6	120	258	180	159	229	130	90
7	145	206	217	146	240	142	60

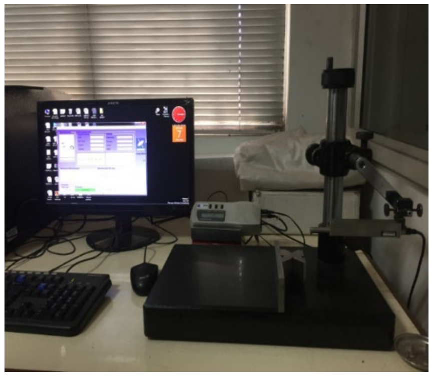

Figure 1. Experimental setup

Figure 2. EDM Specimen image

Table 3. EDM co-occurrence matrix.

9	11	1	0	0	0	0
11	13	3	0	7	0	0
0	12	3	0	0	6	0
6	15	4	0	0	0	7
11	23	2	0	6	7	0
9	26	3	0	0	0	0
10	18	3	0	0	0	0

Table 4. EDM sample texture values

Feature No.	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
1	0.84	0.83	0.88	0.84	0.82	0.80	0.86	0.87	0.88	0.86
2	0.24	0.45	0.37	0.26	0.25	0.45	0.46	0.26	0.48	0.25
3	0.86	0.85	0.87	0.86	0.88	1.78	0.88	0.87	0.86	0.86
4	1.60	1.87	1.84	1.55	1.56	2.07	1.76	1.44	1.95	1.34
5	0.67	0.58	0.68	0.67	0.69	0.68	0.57	0.58	0.67	0.55
6	8.45	8.35	7.33	8.58	7.97	8.29	8.39	9.53	8.14	8.16
7	5.94	4.13	3.95	4.05	3.95	4.26	4.14	4.26	4.14	3.83
8	1.47	2.53	1.54	1.36	1.35	1.64	1.47	1.23	1.69	2.19
9	0.64	1.72	0.68	0.58	0.57	0.74	0.77	3.62	0.78	2.55
10	0.16	2.34	1.19	0.89	0.87	2.27	0.57	4.26	1.06	0.03
11	4.66	6.42	9.02	6.26	7.06	10.80	5.56	3.16	7.96	2.76
12	1.04	0.96	0.96	1.02	1.03	0.97	0.96	1.85	0.96	1.03

Experimental results demonstrated excellent correlation between contrast and Ra between 2 µm to 4.5 µm. When the roughness value for the same specimen was measured ten times, there was a consistency of the order of ±2%.

5. Conclusion

The present method is a non-contact approach for measuring roughness of EDM components. The method used a vision system for evaluating surface roughness of EDM components. The digital images are used for computing the texture features through GLCM. Experimental results demonstrated excellent correlation between contrast and R_a in between 2 µm to 4.5 µm. Roughness of molds and dies are measured by this method.

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Biography
Dr. M. B. Kiran has been working at Pandit Deendayal Energy University in the Department of Mechanical Engineering as Associate Professor. He has been guiding number of Research scholars pursuing MTech. and Ph.D. He has published many research papers in International Journals and Conferences.