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# Evaluation of 3D Surface Roughness Parameters of EDM Components Using Vision System

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**Abstract**

Surface roughness evaluation is very important for many fundamental problems such as friction, contact deformation, tightness of contact joints positional accuracy etc. Many techniques have been developed for measuring surface finish ranging from the simple touch comparator to sophisticated optical techniques. In recent years, the advent of high-speed general-purpose digital computers and vision systems has made image analysis easier and more flexible. Unlike the stylus instruments, computer vision systems have the advantages of being non-contact and are capable of measuring an area from the surface rather than a single line. A vision system is considered relatively cheap, fast and suitable for automation.

Work pieces are prepared with varied roughness using manufacturing process of EDM and subjected to different machining parameters such as variable current and voltage. The proposed method used vision system. Vision system consists of a CCD camera, frame grabber, advanced image processing card and a high end computer. The surface images are grabbed using CCD camera and then transferred to the computer memory through frame grabber. An image processing algorithm is prepared using MATLAB. The surface roughness parameter values (3D) obtained by Vision system are then compared with those obtained by Optical method. Strong correlation is obtained between the vision roughness and optical roughness parameters. Hence the proposed method can be used in the assessment of 3D surface finish. The complete analysis of results is presented in this work.


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*Keywords:* Vision System; Non-contact Measurement; 3D Surface Roughness; Frame Grabber.

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## 1. Introduction

Surface roughness measurement is an important requirement in many engineering applications. Surface finish is specified as the component requirement for many produced parts and manufacturing operations in order to satisfy their desired functionality and aesthetics, Whitehouse (2003). In manufacturing, the surface finish is adopted as finger print of the machining process, Fadare and Oni (2009), H. Y. Kim et al. (2002). In many engineering applications maintaining some amount of roughness is very important concern to have adequate contact between mating components, hence surface roughness controls are mandatory to define the process and validate the quality of the machined parts Bharat Bhushan (2001).

In recent years, the advent of high-speed general purpose digital computer and vision systems have made image analysis easier and more flexible D. A. Fadare and A. O. Oni (2009). Computer vision technology has maintained tremendous vitality in many fields Gadelmawla, (2004). Several investigations have been performed to inspect surface roughness based on computer vision technology Ossama B. Abouelatta (2010). A vision system has been introduced to capture images for surfaces to be characterised and software has been developed to analyse the captured images Ramaswamy, (2001).

Machine vision is the technology to replace or complement manual inspections and measurements with digital cameras and image processing Dhanashekar and Ramamoorthy, (2006). The technology is used in a variety of different industries to automate the production, increase production speed and yield, and to improve product quality Chin Y. Poon and Bharat Bhushan, (1995). The application of machine vision system offers better solution in on-line and real-time monitoring surface roughness Yann Quinsat and Christophe Tournier, (2012). Machine vision involves the use of charge coupled device (CCD) camera, frame grabber, computer system and image processing software to acquire, analyses, monitor, and assess surface roughness parameters Rajaram Narayanan et al. (2007).

Machine vision systems play an important role in the monitoring and control of automated machining systems Kiran.M.B et al. (1998). It has generated a great deal of interest in the manufacturing industry. Using machine vision, it is possible to characterize, evaluate, and analyse the area of the surfaces of machined components Kumar et al. (2005). Machine vision in operation can be described by a four-step flow: Image capturing, Analysing the image to obtain a result, Communicate the result to the system in control of the process and Take action depending on the vision system's result Rajaram Narayanan et al. (2007).

3D surface roughness (or 3D Amplitude) parameters gives information about the statistical average properties Kiran.M.B et al. (2012). 3D surface roughness parameters such as $S_a$, $S_q$, $S_{sk}$, $S_{ku}$, $S_z$, $S_p$ and $S_v$ are used to define the surface roughness in this work.

The amplitude parameters as defined by M. B. Kiran et al.(2012) is as below,
The Roughness Average, Sa, is defined as:

$$Sa = \frac{1}{MN}\sum_{K=0}^{M-1}\sum_{l=0}^{N-1} [z(x_k, y_l)] \quad (1)$$

The Root Mean Square, (RMS) parameter Sq, is defined as:

$$Sq = \sqrt{\frac{1}{MN}\sum_{K=0}^{M-1}\sum_{l=0}^{N-1}[z(x_k, y_l)]^2} \quad (2)$$

The Surface skewness, Ssk , describes the asymmetry of the height distribution histogram, and is defined as:

$$\mathrm{Ssk} = \frac{1}{MNSq^3}\sum_{k=0}^{M-1}\sum_{l=0}^{N-1}[z(x_k , y_l)]^3 \quad (3)$$

The Surface Kurtosis, Sku, describes the "peakedness" of the surface topography, and is defined as:

$$\mathrm{Sku} = \frac{1}{MNSq^4}\sum_{k=0}^{M-1}\sum_{l=0}^{N-1}z(x_k, y_l)^4 \quad (4)$$

The Peak-Peak Height, are defined as the height difference between the highest and lowest pixel in image.

$$Sz = Z_{max} - Z_{min} \quad (5)$$

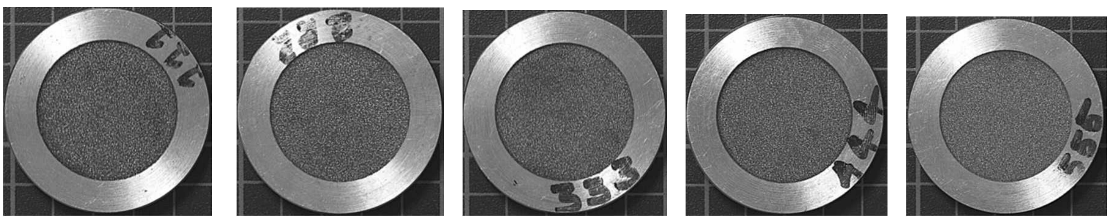
Maximum Valley Depth Sv: is defined as the largest valley depth value.
Maximum Peak Height Sp: is defined as the largest height value.

## 2. Methodology

- *Specimen preparation*, Specimens are prepared by Electric Discharge Machining process.
- *Measurement of 3D Surface Roughness Parameters by Optical method,* 3D Surface Roughness Parameters for the above specimens, are measured by using Optical method, because, optical method is considered standard worldwide.
- *Setting up of Vision system*, Vision system contains CCD camera, Frame grabber, advanced image processing cards and a computer.
- *Software development,* Algorithm for calculating 3D Surface roughness parameters for the specimens is prepared by using Matlab.
- *Experimentation*, During experiment, a test specimen is illuminated, the image is captured using a CCD camera then stored in the computer and use it for subsequent processing. The procedure is repeated for all the specimens.
- *Results and Analysis*, Results obtained during the experiment are analysed and concluded

## 3. Specimen Preparation

Specimens prepared using EDM operation by changing current parameters such as $T_{on}$ -Pulse On in µsec, IP-Peak current in amps as shown in figure 1. Base current IB is kept constant at 2 amps. Pulse off $T_{off}$ is also kept constant at 9µsec. EDM oil is used while performing EDM operation on specimens. Table 1 shows current variation in pulse on.



EDM1 EDM2 EDM3 EDM4 EDM5

Fig.1. Captured images of EDM (varying current) specimens using vision system

**Setting up of Vision System**

The vision system (Figure.2) consists of a CCD (Charge Coupled Device) Camera *SVS-Vistek* for grabbing the image of a machined surface, illuminated by normal lighting. A higher end computer (*HP Z220 workstation*) used for storing and processing of surface image. The workstation also consists of a special purpose, advanced image processing hardware *Matrox Solios Frame Grabber Card* and *Matrox image library* software for quick processing of surface images.

Table 1: Varying EDM parameters for specimen preparation (Aluminium)

| Specimen no | $T_{ON}$(μsec) | I.P(amp) |
|---|---|---|
| 1 | 80 | 8 |
| 2 | 70 | 7 |
| 3 | 60 | 6 |
| 4 | 50 | 5 |
| 5 | 40 | 4 |

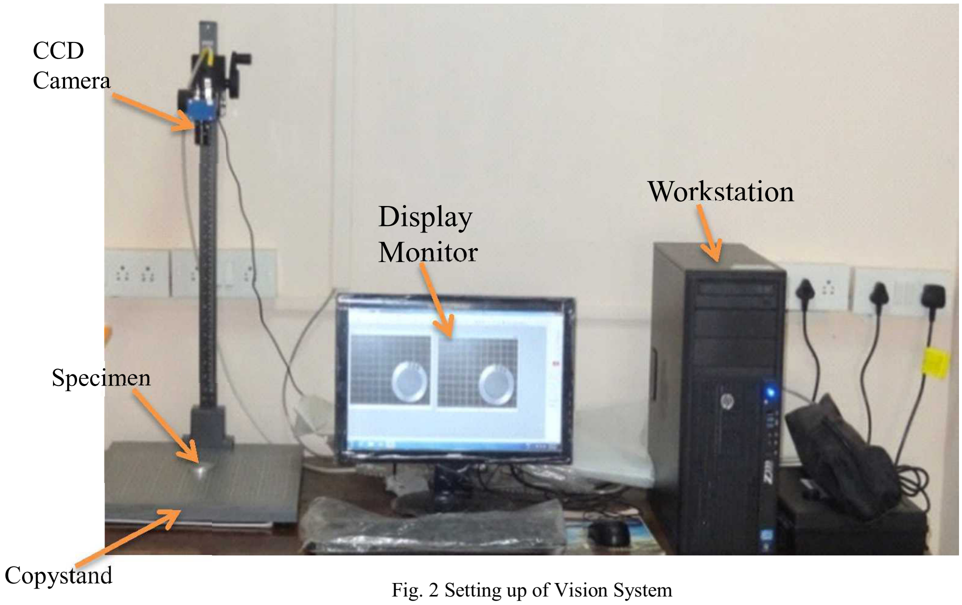



Fig. 2 Setting up of Vision System

## 4. Software development

MATLAB is the tool used for developing algorithm for computing 3D surface roughness parameters. Image processing tool in MATLAB is used to convert captured image of a machined surface to digital image. This digital image contains brightness values at each pixel in a matrix form. MATLAB takes image as input and calculates 3D surface roughness parameters using the developed algorithm. Figure 3 shows the flow chart for developed algorithm for 3D surface roughness parameter measurement.

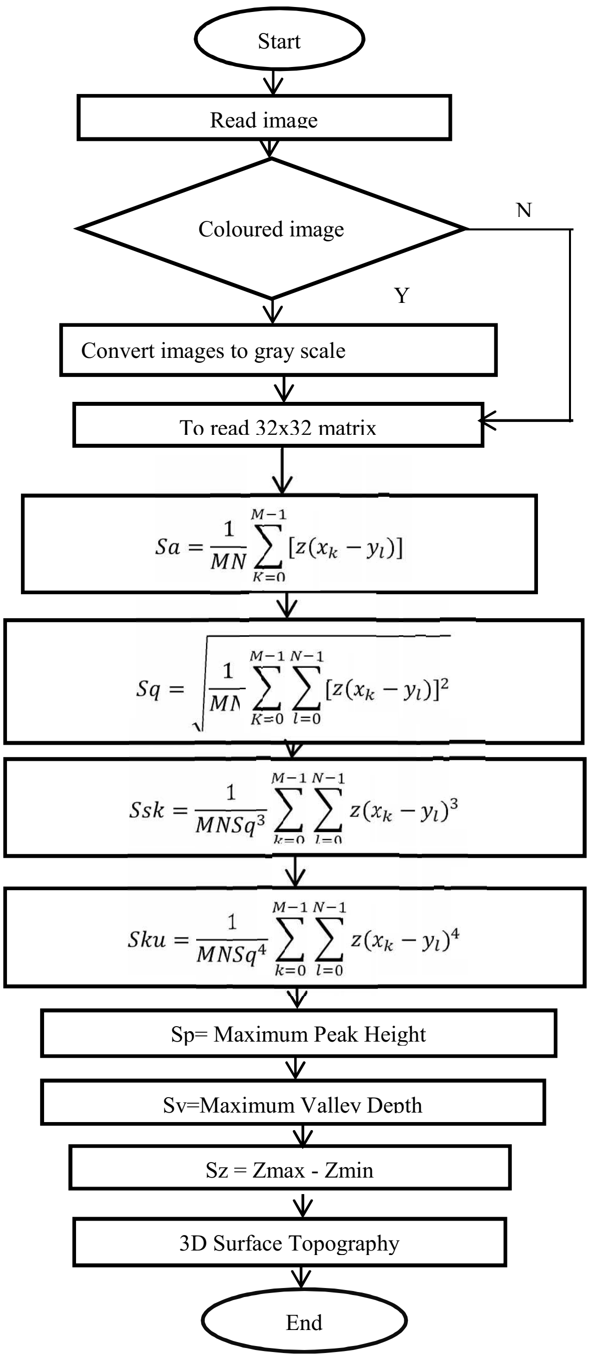



Fig. 3. Flow chart for developed algorithm for 3D surface roughness parameter measurement

## 5. Experimentation

The test specimens are placed below the CCD camera on a table which is provided with linear scale. The CCD camera captures the image of test surface and sends the image data to the computer. Image processing software, designed and developed, has been installed in a Computer. The software calculates the 3D surface roughness parameters. 3D surface roughness parameters obtained by Vision method is then compared with those obtained by Optical method.

### *5.1 3D Surface Roughness Parameters Measurement by Optical Method*

The Optical method used for measuring 3D surface roughness parameters in this work is Confocal Microscope (Olympus LEXT OLS4000).The Olympus LEXT OLS4000 is a confocal microscope capable of taking high resolution 3D images as shown in figure 3. Confocal scanning microscopy is a technique for obtaining high-resolution optical images with depth selectivity. The key feature of confocal microscopy is its ability to acquire in-focus images from selected depths, a process known as optical sectioning. Images are acquired point-by-point and reconstructed with a computer, allowing three-dimensional reconstruction of topological complex objects. The focused area on the surface of test specimen is 2.5mm x 2.5mm. Pitch used is 2.750µ.Objective Lens used is of 20x.

## 6. Results and Analysis

The captured images, surface roughness and corresponding 3D surface topography obtained by optical confocal microscope method for EDM is shown in figure 4, figure 5 and in Table 2. Similarly the vision based measured roughness values are tabulated in table 3 and figure 7 shows the comparison of vision approach versus confocal microscope method.

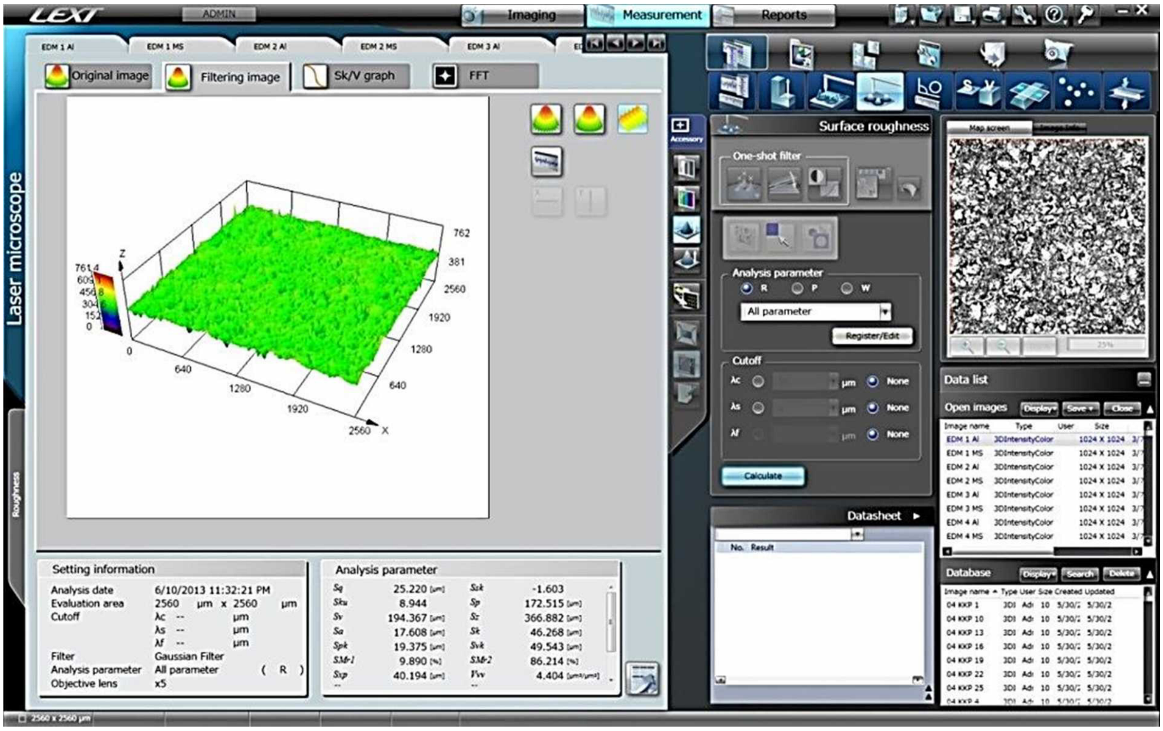
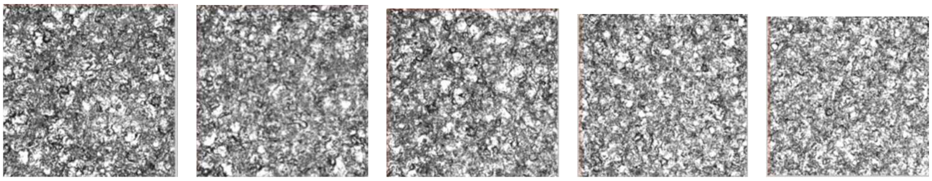
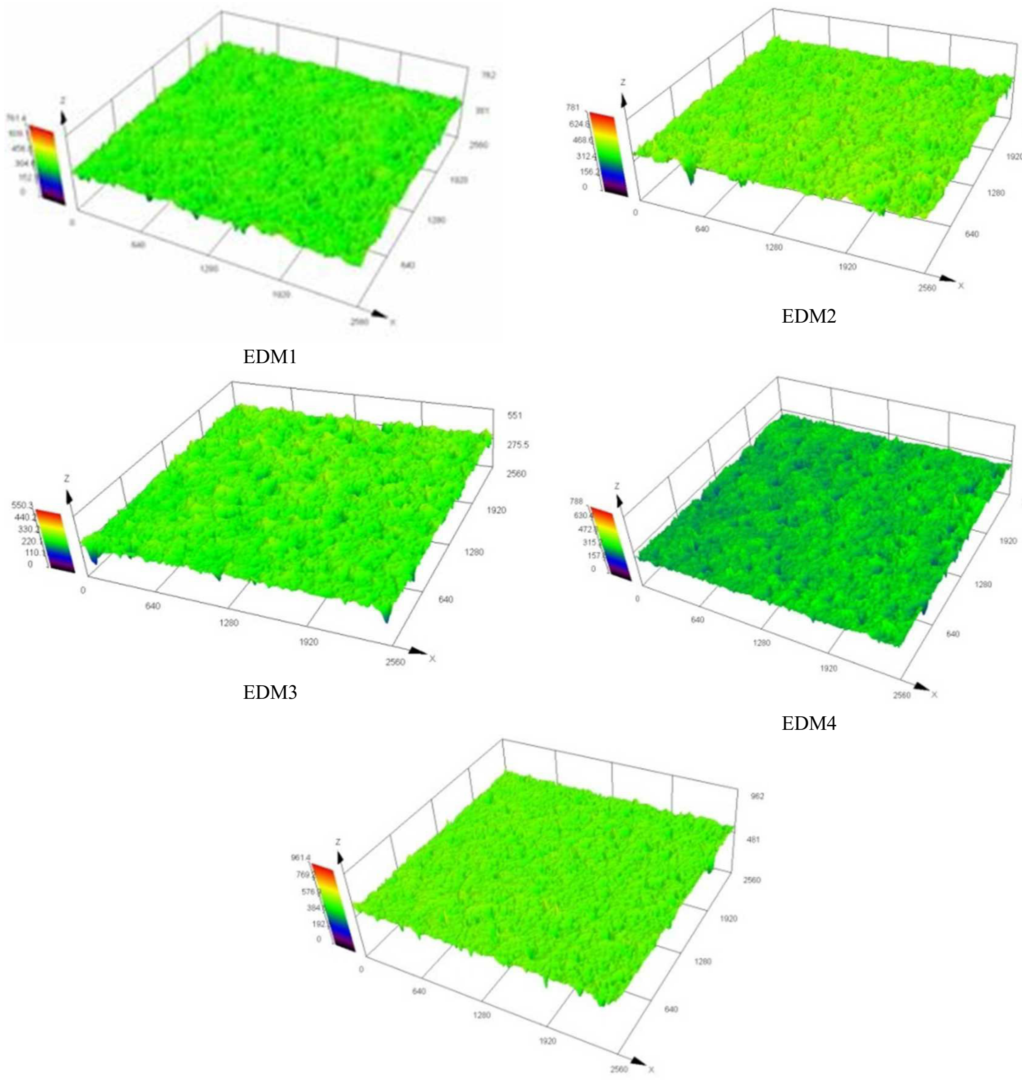



Fig. 4. The captured image, corresponding 3D topography obtained by Optical method for EDM1



EDM1 EDM2 EDM3 EDM4 EDM5

Fig. 5. Captured images using confocal laser microscope of EDM specimens by varying current



EDM1 EDM2 EDM3 EDM4 EDM5

Fig. 6. 3D surface topography of EDM1, EDM2, EDM3, EDM4 and EDM5 specimens by varying current.

Table 2. 3D Surface Roughness Values obtained by Optical Method for EDM specimens

| Specimen No | Sa (µm) | Sq (µm) | Ssk | Sku | Sz (µm) | Sv (µm) | Sp (µm) |
|---|---|---|---|---|---|---|---|
| EDM 1 | 17.608 | 25.220 | -1.603 | 8.944 | 366.882 | 194.367 | 172.515 |
| EDM 2 | 17.988 | 22.670 | -1.311 | 7.244 | 255.335 | 162.482 | 92.853 |
| EDM 3 | 17.232 | 24.577 | -1.713 | 9.463 | 396.832 | 223.602 | 173.230 |
| EDM 4 | 16.280 | 24.942 | -2.454 | 13.420 | 441.480 | 283.735 | 157.746 |
| EDM 5 | 26.891 | 35.560 | -0.354 | 4.359 | 408.607 | 218.214 | 190.393 |

Table 3. 3D surface roughness values obtained by vision approach.

| | Sa (µm) | Sq (µm) | Ssk | Sku | Sz (µm) | Sp (µm) | Sv (µm) |
|---|---|---|---|---|---|---|---|
| EDM 1 | 18.289 | 26.332 | -1.598 | 9.246 | 359.625 | 196.009 | 170.790 |
| EDM 2 | 19.018 | 23.747 | -1.422 | 6.998 | 257.545 | 162.908 | 93.675 |
| EDM 3 | 15.971 | 22.898 | -1.978 | 9.191 | 401.176 | 220.876 | 177.445 |
| EDM 4 | 15.787 | 26.235 | -1.678 | 15.757 | 443.789 | 280.545 | 160.676 |
| EDM 5 | 25.656 | 35.987 | -0.042 | 4.908 | 404.766 | 223.675 | 298.091 |

Table 4: 3D surface roughness parameter comparison for EDM1 specimen

| | Sa (µm) | Sq (µm) | Ssk | Sku | Sz (µm) | Sp (µm) | Sv (µm) |
|---|---|---|---|---|---|---|---|
| Optical Method | 17.608 | 25.220 | -1.603 | 8.944 | 366.882 | 172.515 | 194.367 |
| Vision Method | 17.964 | 25.956 | -1.585 | 8.788 | 365.756 | 173.756 | 192.956 |
| % of Error | 1.98 | 2.83 | 1.12 | 1.74 | 2.70 | 0.71 | 0.72 |

The Table 4 for EDM1 specimen shows that the 3D roughness values obtained from optical method are in close agreement. However it is observed that there may be a slight measurement error of 1.68%. The error in measurement can be attributed to resolution of the camera. It is also found from the experiment that, as the roughness of the specimen increases, the measurement accuracy improves.

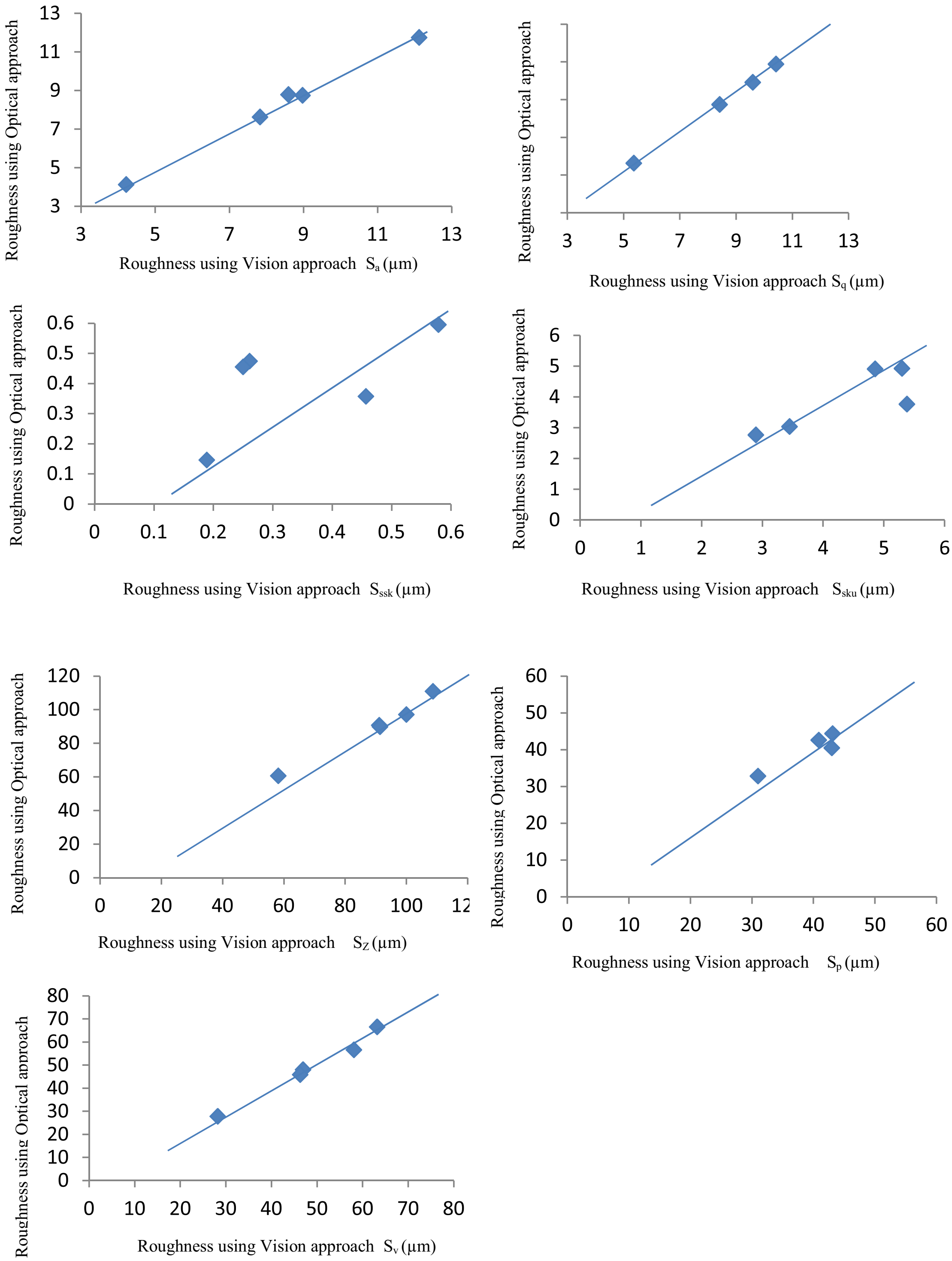



Fig. 7. Graphs comparing roughness values by Vision approach and Optical approach for 3D surface roughness parameters.

## Conclusion

The proposed method is a novel, non-contact method for 3D surface roughness parameter by Vision approach. The system captures the images of test surface and calculates 3D surface roughness parameters from the algorithms developed by using MATLAB. These values obtained by Vision method are compared with those obtained by Optical method. The 3D surface roughness parameters values obtained by Vision method are in close aggrement with those obtained by Optical method. It is also found from the experiment that, as the roughness of the specimen increases, the measurement accuracy improves.

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