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Method of Surface Roughness Evaluation using Ruby Laser Beam

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ABSTRACT

Surface roughness is an important parameter when dealing with issues such as friction, lubrication, and wear. Surface finish is a desired criterion which influences on performance of mechanical parts as well as productivity. Good surface finish helps in reducing fatigue load, improving corrosion resistance and creep life. It also affects functional attributes of parts like friction wear, heat transmission and lubrication. Most of the surface roughness readings are taken in terms of arithmetic average of absolute values (R_a). An optical system designed for measurement of surface roughness is the subject of this paper. The system's operation is based on the light scattering from surface irregularities. This system can be used for controlling the rough surfaces of objects under static conditions and while their movement. Measurement of form and surface waviness requires steady-rate displacement of the measuring setup with respect to the object. The principle of the system's operation and components and their working are discussed in this paper. Light scattering is a quick, sensitive, area sampling, and accurate method, and unlike the stylus method, is completely non destructive technique for surface roughness measurement.

Keywords **-Measurement of Surface Roughness, Optical measurement, Surface finish.**

1. INTRODUCTION

Roughness is a universal characteristic of all surfaces, and can take many forms. In machined components, it often consists of minute scratches in random directions that remain after polishing or of grooved structures produced by turning or any other machining process. Scratches or pits are sometimes caused by improper handling. Some materials such as ceramics or Silicon Carbide contain voids, while others including aluminum or beryllium have hard inclusions in their bulk, all these things can appear on the surface [1].

Stylus measurements are widely used for surface roughness, but they lack lateral resolution due to the tip geometry. They may cause surface damage due to high forces exerted on the surface. Optical profilers offer quick measurement of surface features without surface contact, but they are limited in lateral resolution due to the wavelength of light used. Quality and productivity play significant role in today's manufacturing market. From customers' viewpoint quality is very important because the extent of quality of the procured item (or product) influences the degree of satisfaction of the consumers during usage of the procured goods. Therefore, every manufacturing or production unit should concern about the quality of the product. Apart from quality, there exists another criterion, called productivity which is directly related to the profit level and also goodwill of the organization. Every manufacturing industry aims at producing a large number of products within relatively lesser time. But it is felt that reduction in manufacturing time may cause severe quality loss [2].

2. DIFFERENT OPTICAL METHODS USED FOR MEASUREMENT OF SURFACE ROUGHNESS

Many techniques have been developed to measure surface roughness, which vary from the conventional profilometer to the recently developed laser diffraction technique, optical techniques, interferometry profiler. The various optical techniques used for measurement of surface roughness which is listed below:

2.1. Optical Instruments:

A beam of electromagnetic radiation can be reflected off a surface in three different ways: specularly, diffusely, or both. This is illustrated in Fig 1. Depending on the surface roughness, radiation of a certain wavelength may be reflected specularly, while radiation of another wavelength may be reflected diffusely. Thus, the amount of specular and diffuse reflection can be used to determine surface roughness.

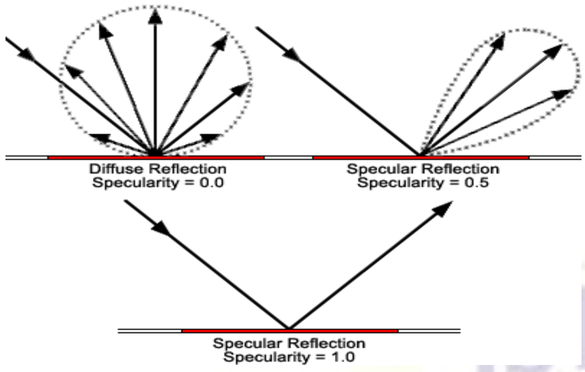

Fig 1. Modes of Reflection: (a) Diffuse Only; (b) Combined Specular and diffuse; (c) Specular only [3]

Advantages of Optical instruments are optical profilometer do not touch the surface and therefore cannot be damaged by surface wear or careless operators, measurement speed is much higher, they can measure surfaces through transparent medium such as glass or plastic film. It can be used on soft materials like lenses, floppy discs. Disadvantages are it requires specimens must be small enough in order to fit into the specimen cell of the microscope, their lateral resolutions are limited by the properties of the optical systems and by the light beams illuminating the surface, it requires high quality optics[3].

2.2. Long path length Optical Profiler:

The interaction of polarized light with a surface can be employed to evaluate surface roughness. In the case of the long-path length optical profiler, a laser beam focuses onto a surface by means of an arrangement of mirrors. Before reaching the specimen, the laser goes through a Wollaston prism that polarizes the beam into two orthogonal components. The beams are then focused onto the surface where they reflect back to the prism. Finally, the reflected beams are directed to a beam splitter, which sends each beam to a different detector. The phase difference of the polarized beams, which is related to the height difference at the surface, results in a voltage difference that can be measured. This instrument used to have a vertical range and resolution of 2 µm to 0.025 nm, respectively. A schematic diagram of the instrument is shown in Fig 2.

The advantages of long path length optical profiles are quick inspection of similar surfaces, nondestructive and rapid surface metrology measurement, large scale scanning rang it gives vertical measurement 4 mm and horizontal is 70 x 70 mm [4].

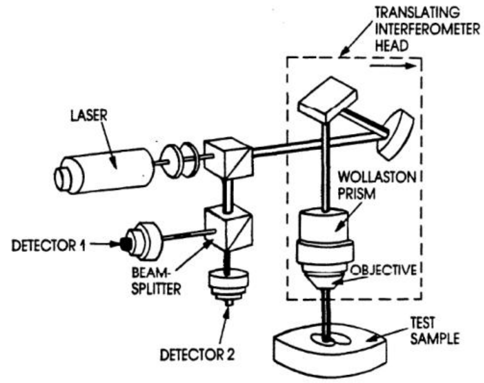

Fig.2.Long path length Optical Profiler [4]

But it has some limitations are affected by air turbulence and temperature variation. The reference mirror requires known flatness value; it is as close to perfect flatness as possible because the optical path differences are due to height variances in the test surface.

2.3. Light scattering technique:

Light scattering technique uses a beam of light of known wave length that is projected onto a surface at an incident angle θ. If the surface is perfectly smooth, the light will be reflected at the same angle as θ, according to the law of reflection. However, if the surface is rough, the reflection will be scattered around the direction of specular reflection shown in fig.3. The diffused light intensity has close to linear relationship with surface roughness. For surfaces with Ra value of 2 µin, 95 percent or more of the incident radiation will be reflected specularly. For surfaces with Ra value of 20 µin, 95 percent or more of the incident radiation will be scattered [5].

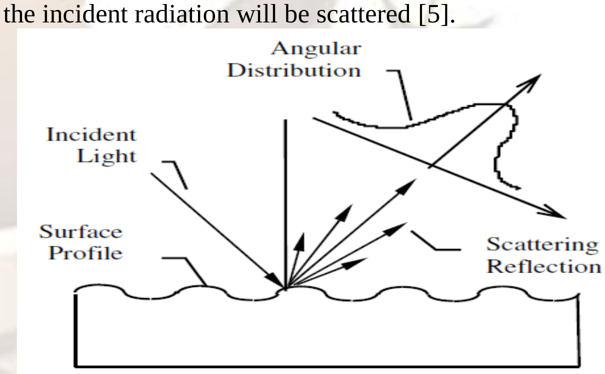

Fig 3. Basic Light Scattering Principle [5]

The advantages of light scattering techniques are it is non destructive testing, it gives rapid response time, if the wavelength is known, it is possible to calculate height differences across a surface, in fractions of a wave. But it has one limitation that isolated or singular scratches or digs are not identified by this technique.

3. PRINCIPLE OF OPTICAL METHOD:

The measurement setup works on the principle that a laser beam reflected from a rough surface becomes scattered. The larger surface micro-regularities the wider angles of light scattered from the object surface. Surface roughness is estimated through measuring the angular distribution of scattered light. In this method the rough surface is considered as a set of micro specular reflectors. Due to such simplification it is possible to show that the angular distribution of scattered light from rough surface corresponds with the angular distribution of irregularity inclination. What is more, the system allows for determination of the slope profile parameters, the variance of angular distribution of scattered light intensity and other characteristic parameters of measured distribution. A diagram explaining the principle of operation of the system is shown in Fig. 4.

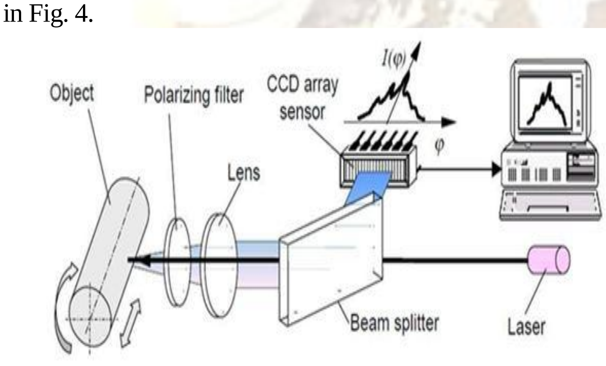

Fig 4. Diagram explaining the principle of operation of the system designed for evaluation of machined surface irregularities [6]

A laser beam running through a beam-splitter, optical lens and a polarizing filter is projected onto the object surface. The light reflected from the object surface runs again through the polarizing filter and optical lens. Then the beam splitter directs the light to a CCD array sensor. This CCD array sensor, owing to a special driver, is linked with a microcomputer. Consequently, the values angular distribution of the light scattered I(φ) are stored in the microcomputer. The program developed on the basis of these values presents a graphical visualization of this distribution and determines respective parameters of surface roughness

The instrument can measure motionless or moving surfaces. Motion of surfaces makes averaging the measuring signals as a function of time. The variance of angular distribution of scattered light intensity, marked by SN, is proportional to the root mean square slope of the profile Δq expressed by the following expression:

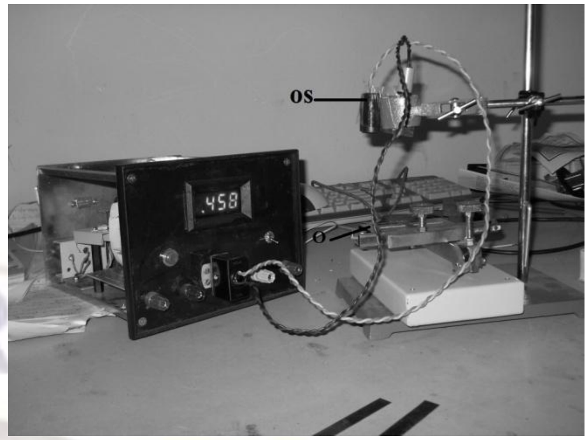

Fig. 5. View of the measurement setup: OS - Optical System; O-Measured Object

$$\Delta q = \sqrt{\frac{1}{l}\int_0^l \left(\frac{d_y}{d_x}\right)^2 d_x} \qquad (1)$$

Where l denotes the elementary segment of surface profile, whereas the dy to dx ratio is a derivative of surface profile [6]. Fig 5 shows actual setup of optical instrument.

4. COMPONENTS:

4.1. Charge-coupled device (CCD):

A charge-coupled device (CCD) is a device for the movement of electrical charge, usually from within the device to an area where the charge can be manipulated, for example conversion into a digital value. This is achieved by "shifting" the signals between stages within the device one at a time. CCDs move charge between capacitive bins in the device, with the shift allowing for the transfer of charge between bins. The CCD is a major technology for digital imaging. In a CCD image sensor, pixels are represented by p-doped Metal Oxide Semiconductor (MOS) capacitors. CCD image sensors are widely used in professional, medical, and scientific applications where high-quality image data is required. In applications where a somewhat lower quality can be tolerated, such as webcams, cheaper active pixel sensors are generally used [7].

4.2. Polarizing filter:

The polarizing filter works on three different stages. The first stage of the polarizer is a linear filter which filters out light that is linearly polarized in a specific direction. The second stage, for technical reasons related to the auto sensors within the camera, then circularly polarizes the light before it enters the camera. Light reflected from a non-metallic surface becomes polarized; light reflected from metal is not polarized, due to the electromagnetic nature of light. A polarizer rotated to pass only light polarized in the direction perpendicular to the reflected light will absorb much of it. This absorption allows glare reflected from, for example, a body of water or a road to be much reduced. Reflections from shiny surfaces of vegetation are also reduced. A polarizer can produce better color saturation and improve the contrast in the image [8].

4.3. Beam Splitter:

A beam splitter is an optical device that splits a beam of light in two. In its most common form, a rectangle, it is made from two triangular glass prisms which are glued together at their base using Canada balsam. The thickness of the resin layer is adjusted such that (for a certain wavelength) half of the light incident through one "port" (i.e., face of the cube) is reflected and the other half is transmitted due to frustrated total internal reflection. Polarizing beam splitters, such as the Wollaston prism, use birefringent materials, splitting light into beams of differing polarization [9].

4.4. Digital Process Module (DPM):

DPM is also called as Digital signal processing (DSP) is concerned with the representation of discrete time, discrete frequency, or other discrete domain signals by a sequence of numbers. With the increasing use of computers the usage of and need for digital signal processing has increased. To use an analog signal on a computer, it must be digitized with an analog-to-digital converter. DSP is usually to measure, filter and/or compress continuous real-world analog signals. It can also used to convert the signal from an analog to a digital form, by sampling and then digitizing it using an analog-to-digital converter (ADC), which turns the analog signal into a stream of numbers [10].

5. EXPERIMENTAL RESULTS:

The system is developed for experimental investigations focused on evaluation of the surface roughness. These investigations were carried out on flat metal surfaces which are made in controlled conditions and measurement methods are used stylus as well as optical scattering method. The result values obtained on optical instrument are closely matching with those on standard one i.e. Stylus instrument.

This confirms the closeness of the reading between the two instruments. This also indicates the reliability of the instrument developed by us since results are closely matching. Further improvement is being carried out in order to improve the performance and accuracy to the maximum extent.

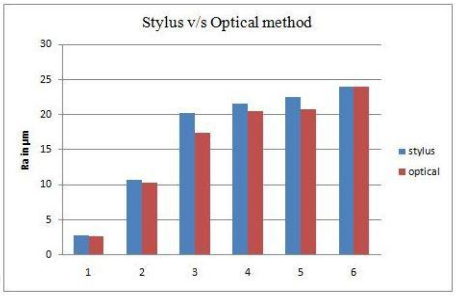

Fig 6.Graph of Stylus Vs Optical method

6. CONCLUSION:

1. Light scattering techniques offer the advantage of high speed measurement without the need to contact the surface being measured..
2. It is a quick, sensitive, area sampling, and accurate method, and unlike the stylus method, is completely non destructive technique for surface roughness measurement.
3. Optical instrument gives reading at different locations this is main advantages over stylus but stylus gives only readings at different cut of lengths.
4. Optical instrument can be used in mass production.

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