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SURFACE ROUGHNESS ANALYSIS OF MACHINED HARD METAL WORK-PIECE

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Abstract

Surface properties play a very important role in functioning of a machine component. The working of machine parts their load taking capacity, life span, wearing properties, bearing failure, fatigue strength etc. have a direct impact of its surface topography which further depends upon the component's manufacturing process and material used. The surface of a solid has complex properties and complex structure. Due to surface interaction the surface properties play a crucial role in contact area with other material which directly affect lubrication, wear and friction in affected area. Moreover the surface properties also affect other applications i.e. thermal, electrical, appearance and painting, coating etc.Whichever method is used for surface preparation the surface of solid always carry some irregularities which deviate it from desired surface specifications. These irregularities may be in the form of shape variation or in the form of variation in interatomic dimensions. On conventional materials it is nearly impossible to produce flat molecularly surface. For the applications which require where very high precision surface both micro and macro topography is very important (Bhushan1999a,b).
Therefor the detailed analysis of machined surface is very important for the estimation of performance of a machined component. In this paper we will explain the important surface properties and how we can analyse the finished surface of a hard material work-piece.

Keywords*:* Roughness, Surface integrity, friction, wear. Ra value, Lay, Waviness etc,

1. INTRODUCTION

The early part failure in machines happens due to the surface irregularities as it'sroot acts as sharp corner leads to failure of parts. Therefore in order to increase the life of machine parts the machine part should possess very good surface finish on all working and non-working surfaces and least induced stress.
Whereas if the requirement is that the part have good bearing properties then such surface should have large number of irregularities, i.e. a large number of valleys and hills. The material wear rate is proportional to the contact surface area and the acting load per unit area. Further different types of requirements requires different types of surfaces. Therefore, in order to use desired type of surface as per specification or need of process requirement, thequantitatively measurement of surface texture becomes essential and suitably devised methods for this purpose may be used.

2. UNDERSTANDING THE SURFACE PROPERTIES AND CAUSES OF SURFACE IRRIGULARTIES

There may be several kinds of causes for departure from a truly smooth surface. The texture or roughness {succession of minute irregularities} on surface is affected by the process of machining employed for production of that part. The complete roughness is because of various types of irregularities. The primary texture is resultant of cutting tool action and in this case the valleys and hills on a component surface appears very close and the surface appears as rough. The secondary texture is due to deficiency in machine tool used in production of that component and here the valleys and hills appears far apart on a surface.

There are many kinds of irregularities generally present in a material other than deviation from the specifications of a component due to physical molecular structure. The solid surface may possesses different regions having particular physical-chemical properties that of the major constituent of that mixture (alloy in case of metals)(Gatos, 1968; Haltner, 1969; Buckley, 1981). Some times this particular zones of bulk material during the forming process gets as work-hardened and get deformed surface layer. The surface properties of such deformed layer bulk material zone are different from the other common material zones. The mechanical behaviour of such deformed layer zones varies with variation in depth and amount of such deformed layers.
In other than noble metals the surfaces of materials are reactive chemically with other matters present in surroundings. Many of them form oxide layer on surface in air and in other environments they may form other type of layers i.e. chlorides, nitrides, sulphides etc. generally these are referred as chemical corrosion film. Sometimes oily or greasy films are also found on surfaces of solids. These films of any types present on the surface of solids changes the wear and frictional characteristics of these solids. Due to which the behaviour of the surface also gets affected.

The main difference between primary and secondary texture is this wavelength difference.
A surface is quite complex and may possess different wavelengths happensdue to cutting action, tool feed , vibrations, imperfections in machine tools, etc.

The irregularities can be further classified from first, second, third and fourth orders based on the cause of the irregularity:
irst Order. The imprecision in machine tools itself is responsible for generation of this type of irregularities e.g. absence of straightness of guide-ways of tool post. These type of irregularities are considered in first order.

Second Order. The presence of vibrations in machine tools causes this type of irregularities e.g. chatter marks and these are considered in second order.

Third Order. Some irregularities are created due to the presence of specific characteristics of machining process even if the machine tools are working perfectly.

Fourth Order. The material used during machining some time rupture due to cutting forces during chip separation. This happens when composition of material is not uniform.

The above mentioned four orders irregularities can be regrouped under two broad groups as detailed below:

First group includes considerable wave-length irregularities of a periodic character which occurs due to mechanical disturbances in the producing set-up.These irregularities are also called as macro-geometrical errors and comprise irregularities of first and second order. These errors occurs mainly because of non-linear feed motion, lack of straightness of guide-ways and misalignment of centers. These errors are also mentioned as secondary texture or waviness.

Second group comprisessmall wavelength irregularities produced by the direct action on material by the cutting part or by some other disruption such as wear, frictionor corrosion. Tool feed rate and tool chatter are the main causes for these errors, it includes irregularities of both third and fourth orders and produces the micro geometrical errors. The errors considered in this group are also referred to asPrimary Texture or Roughness.

2.1 Surface RoughnessTerminology

There are different factors for the different types of departures on the surface. Roughness is in the form of fine irregularities produced by the direct impact of finishing process used. The roughness characteristics in machining operations are produced by the tool as well as faults in machining operations as well.
For complete analyses of surface roughness, a practical approach is needed which can essentially measure and analyze all the components /elements and the results can be used to made combined texture.In practical all this is very tedious and difficult work and all the assessment of practical method needs to be compared with a readily available specified quality requirements in numerical form.
Surface roughness measurement in three dimensional geometry measurement of surface roughness pretenses a problem,the process is converted in to a two dimensional geometry for making it simple by restricting measurement to each individual profile of section plane taken through the surface. Generally direction perpendicular to the major markings or lay on surface is used as direction of measurement.
The surface roughness consider both the shape and size of the irregularities e.g. The height of departure from nominal profile is equal but the in-between irregularities spaces may be closer or wider and may have different forms.

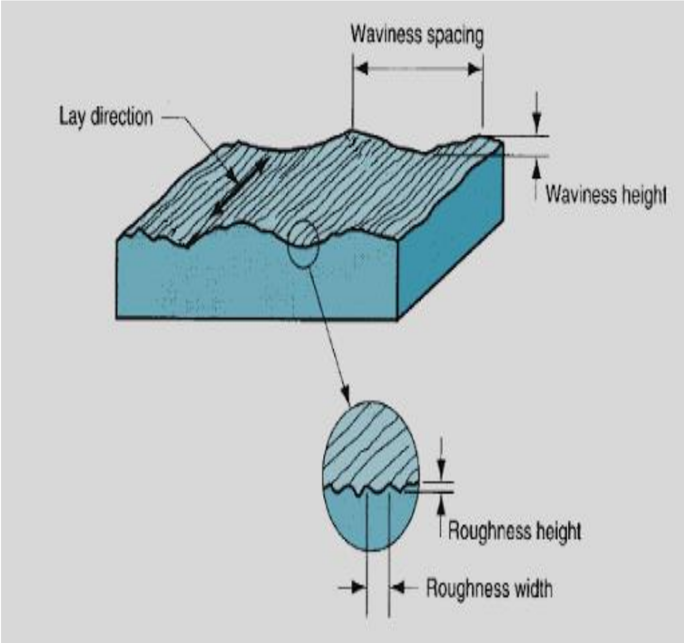

Fig. 1. Surface Roughness Details

In order to study the roughness of surface of solids we have to understand the important technical terms associated with it first.
Geometrical Surface: it is the prescribed surface by design or by the manufacturing process,neglecting the surface roughness and form errors.
Real Surface: It is the surface restraining the body and splitting it from the surrounding surface.

Effective Surface: It is the close demonstration of real surface attainedwith the help of instruments.

Surface Texture: Random or repetitive deviations of actual surface properties from the nominal surface properties which form the surface pattern. Surface texture includes flaws, lay. Waviness and Surface roughness. All these four terms are defined below to have their clear understanding:
Lay:It is the predominant surface patternthe direction, and it is generally depends on the manufacturing process used to form the surface.
Flaws: These are irregularities which take place at one place or at comparatively intermittent or widely varying intervals in a surface i.e. cracks, blemishes, scratches,random etc.
Waviness: It is the periodically appeared uneven surfaces at longer intervals, it is also defined as non-conformity from an ideal surface that appears repetitively at fairly longer intervals than the depth. It is also referred as macro-roughness.

Surface Roughness: It is measurement of surface irregularities. It is also referred as micro-roughness.

Primary Texture (Roughness) : It is created due to the inherent action of the manufacturing process are in the form of irregularities in the surface roughness which includes transverse feed marks and the irregularities within them.

Secondary Texture (Waviness): These irregularities are produced due to factors such as machine or work or machine deflections, chatter, vibrations, heat treatment or deforming strains.

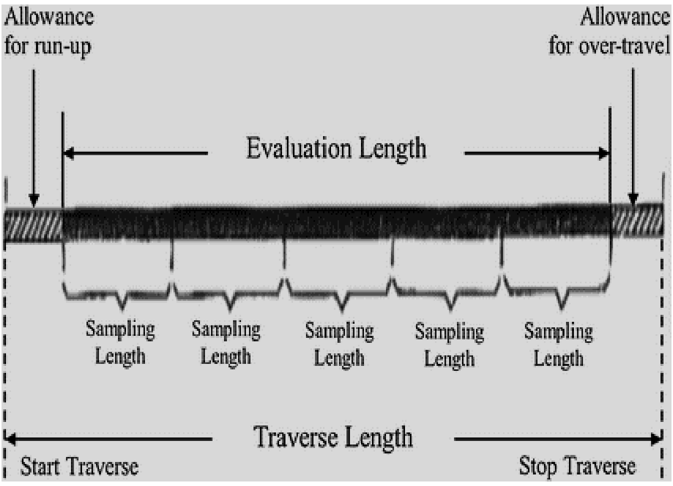

Fig. 2 Traversing Length and Evaluation Length

Centre line: The Roughness is measured about this line.

Traversing length: It is the length necessary for the surface evaluation of the profile. One or more sampling lengths may be included in the traversing length.

Sampling length (l): It is the profile length which is necessarily taken in to account for the irregularities evaluation. It is called as "cut off" length in context of measuring instruments.

Mean line of the profile: The line which separates the effective profile and having the geometrical profile form such the sum of the squares of distances (Y1, Y2-----Yn) between effective points and mean line is a minimum within the sampling length.

Centre line of profile: A line which is generally parallel to the profile general direction and for which the areas above and below this line are equal to the total area encompassed by the profile. The mean line and the centre line are equivalent if the waveform is repetitive
The spacing of irregularities is known as distance between the irregularities which are more prominent within the effective profile sampling length.

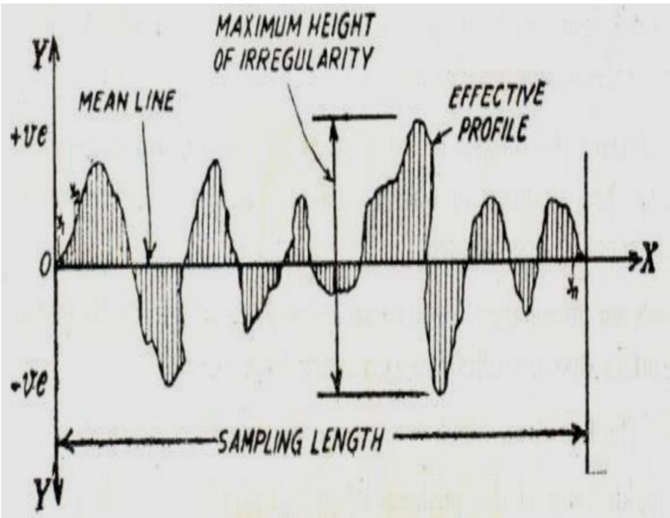

Fig. 3 Sampling Length Details

This information is useful in relative motion for measurement of the wearing-in of surfacesand assessing the thermal and electrical and thermal conductivity between contact's surfaces.The Spacing of irregularities is having importance in steel sheet applications, friction and lubrication fields where height and spacing parameters are used in combination.

The deviation of arithmetical mean from the profile mean line (Ra) is defined as the ordinate average value (y1, y2,....yn) from the mean line.
The sum-up of ordinates is done without considering their algebraic signs i.e.

$$R_a = \frac{1}{n}\int_0^l |y|\,dx$$

$$R_a = \frac{\sum_0^n |y_i|}{n}$$

Where n indicates the no. of divisions over the length l.

Rz(Irregularities Ten point height): It is the average difference with in the sample length between five deepest valleys and five highest peaks measured from parallel a line to mean line and not crossing the profile.

$$R_z = \frac{|R_1 + R_3 + R_5 + R_7 + R_9| + |R_2 + R_4 + R_6 + R_8 + R_{10}|}{5}$$

Rmax (Irregularity Maximum height): It is the distance with in the sampling length between two lines touching the profile at highest points, when both lines are parallel to the mean line.

Terms used to describe surface roughness

Average Valley to Peak height Rz: It is the single valley to peak height which is average of five adjoining sampling lengths.

Rt measurement:Within the assessment length It is the maximum valley to peakheight. This measurement is valuable for guidance for analysing finish for planning of metal cutting operations.

Average Wavelength =2πRa / Mean slope.

Bearing area: It is defined as the segment of surface at a given height below or above the mean line.

Centre line. A line representativeof the geometrical profile form and parallel to the overall direction of the profile through-out the sampling length, such that the amounts of the areas confined between it and those parts of the profile which lie on any side of it are equal.
Depth of surface smoothness.

$$R_p = \frac{1}{L}\int_0^L (h_{max} - h)\,dx$$

Least-squares mean line: A reference line demonstrating the geometrical profile form in the sampling length limits and it is placedsuch that the sum of the squares of the profile's deviations with in the sampling length from the mean line is a minimum.

3.EXPERIMENTAL SURFACE ROUGHNESS ANALYSIS OF A HARD METAL WORK PIECE USING TAYLOR HOBSON TALYSURF

There are different direct instrument to measure surface finish of any surface .The direct surface roughness instrument allow to find a surface finish numerical value of any surface. In this category most of the instruments with stylus probe. In our experimental set up we used Taylor Hobson Talysurf for surface finish measurements. This instrument is famous for its working speed and accuracy in measurements.

3.1 Construction and working of Taylor Hobson Talysurf: -This is a Stylus probe type Instrument and consists of following main parts:-

A. Shoe or Skid
B. Probe or Stylus
C. Amplifying Unit

D. Recording and Analysis unit

In this instrument a diamond stylus of about 0.002 mm tip radius is used as the measuring head. Ashoe or skid is moved on the surface using a motorised driving unit. Further it also have provision of manual traversing of stylus to the neutral position if needed.

There is E-shaped stamping in the instrument, the outer legs of this E-stamping have coils which carries Alternating Current. The stylus carrying arm acts as an armature which is with swivels about the centre of E-stamping. An oscillator is formed by these two coils with two other resistances. Due to air gap between the E-stamping and armature the amplitude of

Original Alternating current flowing in the coils gets modulated. Hence it needs to be demodulated so that the vertical movement of stylus is directly proportional to the current.A permanent record is produced by the pen recorder which gets operated by the demodulated output. The display meter displays the numerical assessment directly.

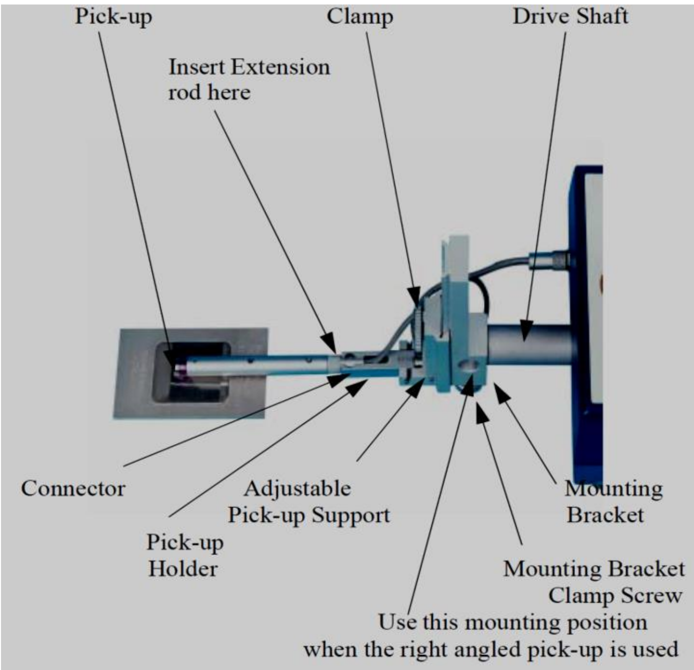

Fig. 4 Construction details of Taylor Hobson Talysurf

3.1 Measurement of Surface Roughness Using Taylor Hobson Talysurf:-

The experimental setup done to measure the roughness of selected samples is shown in figure 5. First of all five hard metal work pieces (Sample 1,2,3,4,5) having size of 10 x 10 x 60 mm of EN-26 were finished using grinding operation. After finishing fivepoints (A,B,C,D,E) were marked on each work-piece to measure the surface roughness. Now as shown in fig. 4 above first of all the Taylor Hobson Talysurf was calibrated using the procedure prescribed by the manufacturer. After calibration the surface roughness was measured on each five points for all five work pieces. The measurements obtained during this experiment are tabulated in the tablegiven below:-.

SAMPLE1 (S1)	**A**	**B**	**C**	**D**	**E**
Ra	0.482	0.491	0.483	0.471	0.473
Rq	0.646	0.630	0.642	0.623	0.612
Rz	3.81	3.71	3.83	3.82	3.83
SAMPLE 2 (S2)	**A**	**B**	**C**	**D**	**E**
Ra	0.496	0.496	0.496	0.496	0.496
Rq	0.636	0.636	0.636	0.636	0.636
Rz	3.47	3.47	3.47	3.47	3.47
SAMPLE3 (S3)	**A**	**B**	**C**	**D**	**E**
Ra	0.509	0.509	0.515	0.515	0.512
Rq	0.671	0.671	0.665	0.665	0.658

Rz	3.57	3.57	3.97	3.97	3.95
SAMPLE 4 (S4)	**A**	**B**	**C**	**D**	**E**
Ra	0.530	0.548	0.547	0.552	0.558
Rq	0.662	0.705	0.719	0.708	0.702
Rz	3.600	3.66	3.63	3.64	3.56
SAMPLE5 (S5)	**A**	**B**	**C**	**D**	**E**
Ra	0.575	0.571	0.578	0.569	0.558
Rq	0.726	0.718	0.712	0.710	0.708
Rz	4.32	4.38	4.26	4.40	4.52
Note : All above values are in µm.					

Table.1 Surface Roughness Measurement Data ofSamples.

Fig.4 Experimental Setup Using Taylor Hobson Talysurf

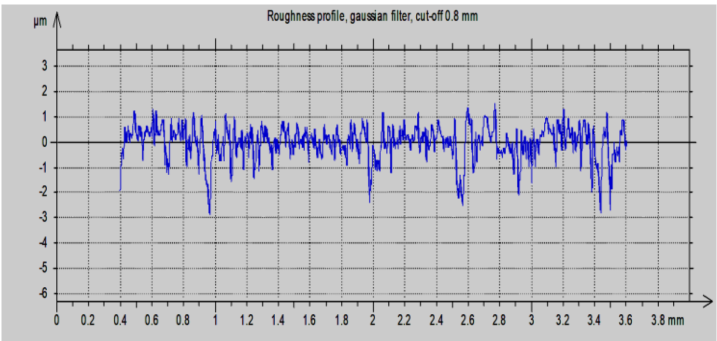

Fig. 5Roughness Profile of Point "A" of Sample1(S1) Generated by theTaylor Hobson Talysurf after measurement of surface roughness.

4. Results and Discussion

i. Surface roughness is very important physical property of a mechanical part, it ensure the proper fitting and to achieve expected life cycle completion without premature failure.
ii. Taylor Hobson Talysurf is a very reliable device to measure the very fine surface roughness.
iii. It can measure the roughness in nano-metres.

iv. The profile generated by this device helps the investigator to understand the roughness in better way.
v. The overall surface variation in sample 1 is 0.02 µm. In sample 2 it is 00 µm. In sample 3 it is 0.006µm. In sample 4 it is 0.028 µm. In sample 5 it is 0.02 µm.
vi. From the table 1 and fig.7 is can be observed that the sample 2 has most perfect surface. It is followed by sample 3 & 1 and at last sample 4.

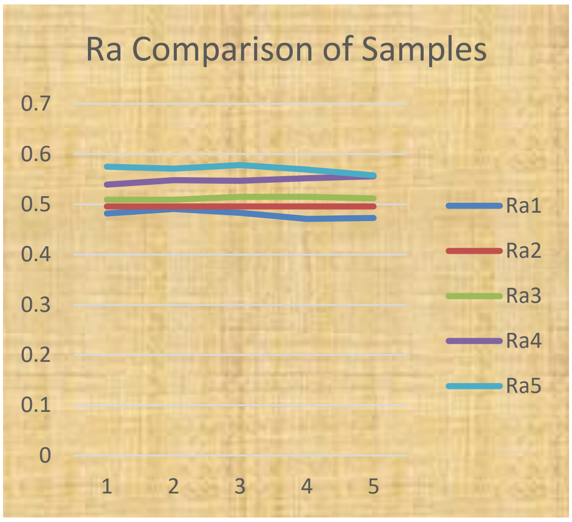

Fig 7 Comparison of Ra of all samples

CONCLUSSION

Surface properties play a very important role in functioning of a machine component. The working of machine parts their load taking capacity, life span, wearing properties, bearing failure, fatigue strength etc. have a direct impact of its surface topography which further depends upon the component's manufacturing process and material used. Moreover the surface properties also affect other applications i.e. thermal, electrical, appearance and painting, coating etc. Whichever method is used for surface preparation the surface of solid always carry some irregularities which deviate it from desired surface specifications. Therefor the detailed analysis of machined surface is very important for the performance of a machined component. There are different types of devices that can be used for surface analysis of a machined component. Taylor Hobson Talysurf is such a high precision measuring device which is widely used for surface analysis of machined components. This device provide us all the detailed reports of surface with a detailed layout of profile of surface which is being investigated. It help us to become sure that the machined component has the desired surface properties. Which will ensure the desired work performance and life span fulfilment by the components.

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