Department	Mechanical Engineering		Program	M. Tech (ITMM)		
Subject Name	Friction, Wear & Lubrication		Subject Code	ITM-101		
Semester	1st	Credits	4	Teacher Incharge/Mentor		Prof. (Dr.) M. F. Wani
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UNIT I

LECTURE 1: INTRODUCTION TO TRIBOLOGY

INTRODUCTION

Tribology is derived from the Greek word "*TRIBOS*" which means "*rubbing*". Thus tribology may be defined as the science and technology of interacting surfaces in relative motion. Tribology encompasses the separate aspects of friction, wear and lubrication, which used to be treated separately. As these three aspects are inter related, it is more meaningful to treat them together as far as possible. Tribology has been coined in 1966 in UK by *Peter Jost* and is now widely accepted.

WHY TRIBOLOGY?

The material resources we have are not going to last forever, also dwindling petroleum resources and high cost of petroleum products have altered us to the need to save energy. Thus conservation of materials and energy has today assumed great significance. As friction losses contribute to loss of energy and also contributed to material losses. The importance of tribology and its study is about conservation of energy resources. Tribology can be utilized in developing better and more reliable design of tribo components or in improving performance with a given design. A survey conducted by ASME indicates that research and development (spread in 5 years) in tribology applied to meet situations can effect a saving of the order of 20 billion dollars in terms of energy and material saving and reliability. The scope of energy and material saving in India is very large and is hardly explored. In view of the constraints a developing economy like ours faces, there is now growing evidence of active interest in conservation. Several seminars in India are being conducted by organizations like PCRA (Petroleum conservation research association), NPC (National productivity council) and other organizations. Most of the efforts so far relate to the efficient burning of fuels rather than friction reduction. The other important area of wear reduction through surface treatments and other techniques resulting in material saving is a neglected area in the country.

TRIBOLOGY - AN INTERDISCIPLINARY SCIENCE

Surface interaction occurs in small areas wherever there is relative motion between surfaces. Hence surface science becomes important. Also there are elastic and plastic deformations which can change with time and an understanding of material science is again important. Environment (lubricant additives, gases etc.) can interact with surfaces and can significantly influence friction and wear. So the nature of chemical and physical interactions are to be taken into account. The engine design plays an important role as this decides the nature and intensity of stresses in the components. Thus it can be seen that the study of tribology involves various disciplines and this should be constantly kept in mind.

TRIBOLOGICAL SURFACE OR ENGINEERING SURFACE

Engineering surface is complex. The Surface is covered with 100-200 A^0 thick oxide layer above which there can be adsorbed contaminant layer. Below the surface there is usually a work hardened layer. Below the work hardened layer modified grain structure can continue to some depth beyond which bulk structure is evident. Besides this the surfaces can have defect, inclusions and even the compositions can be different from the bulk.

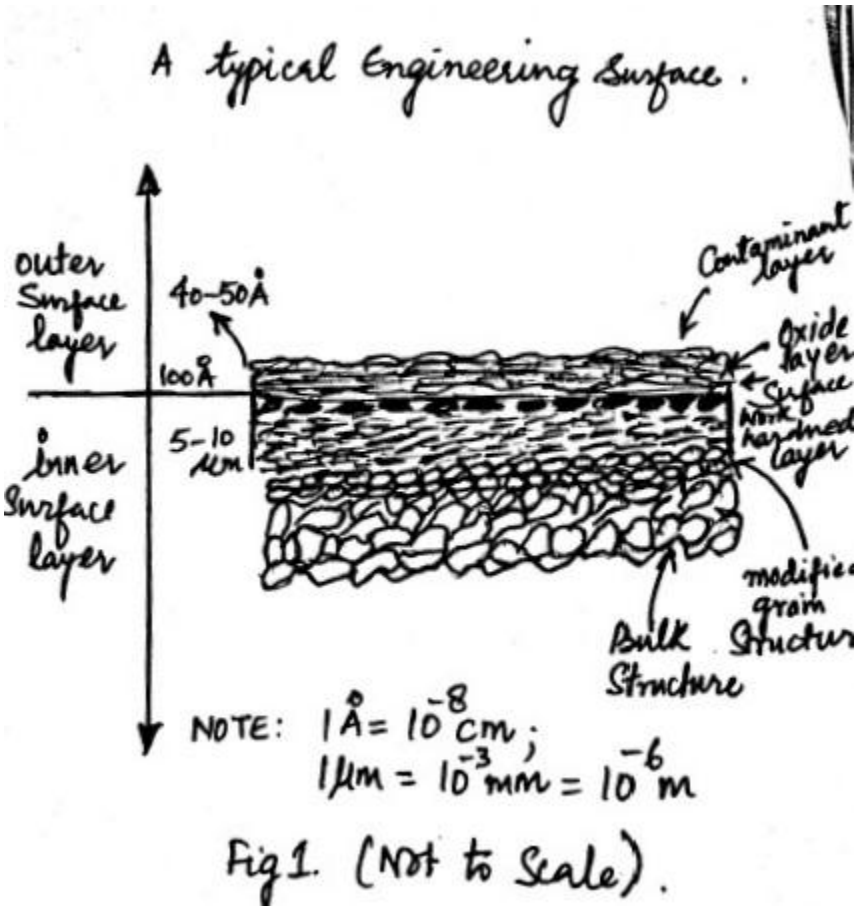

Figure - 1

Powerful tools are available to study surfaces, some of which are given below. These tools are commonly used now for surface/tribological studies.

S. No.	Name of Tool	Remarks
1.	Scanning Electron Microscopy (SEM)	To study surface morphology. Normal resolution upto 60 A^0. Magnification upto 100000. (Available in CRFC, NIT Srinagar)
2.	Energy Dispersive Spectroscopy(EDX)	For elemental analysis of surfaces and wear particles. (Available in CRFC, NIT Sgr.)
2.	X-Ray Diffraction (XRD)	Composition studies of wear particles. Suitable to study surface composition with glancing angle technique.
3.	Electron Microscopy	Morphological studies by studying surface replica. High resolution of 5-10 A^0 is possible.
4.	Electron Probe Micro Analysis (EPMA)	Analysis of surface elements through Characteristic X-Rays. Normally used as attachment with SEM.
5.	Electron Spectroscopy for chemical analysis (ESCA)	Analysis of surface elements as well as state of loading. For example different types of oxides on the surface can be distinguished.
6.	Raman Spectroscopy	Used to identify and analyze elements present on a surface. (Available in CRFC, NIT Sgr.)
7.	3D surface Profilometer	Used to analyze the surface for texture, roughness and

		waviness etc. (Available in Tribology Lab. NIT Sgr.)
8.	Optical Microscope	For micro-structural analysis of surfaces upto a magnification of 1000. (Available in Tribology Lab. NIT Sgr.)

Surface analytical tools are increasingly helping us to understand basic as well as applied tribology. Some examples that can be cited include study of reaction plane formed with EP additives, role of oxides in wear reduction, basic studies on adhesion in presence of monolayer coverage of foreign atoms, and segregation of alloying elements at the surface.

The purpose of the above coverage is to appreciate the role of surface in tribology. It is indeed a very limited coverage of a major area.

TUTORIAL:

Q. No. 1 What do you understand by Tribology and its influence on:

a) Material Conservation

b) Environment preservation

C) Energy conservation

Q. No. 1 What are the various characteristics of a Tribological Surface?

LECTURE 2: SURFACE MEASUREMENT

SURFACE ROUGHNESS

In figure-1 the surface is shown flat for convenience. In fact the surface is flat and has roughness at microscopic levels. The instrument usually used to study shape is profile analyser in which a fine diamond stylus follows the surface height variations which are magnified. Surface profiles have three major components as shown in figure 2.

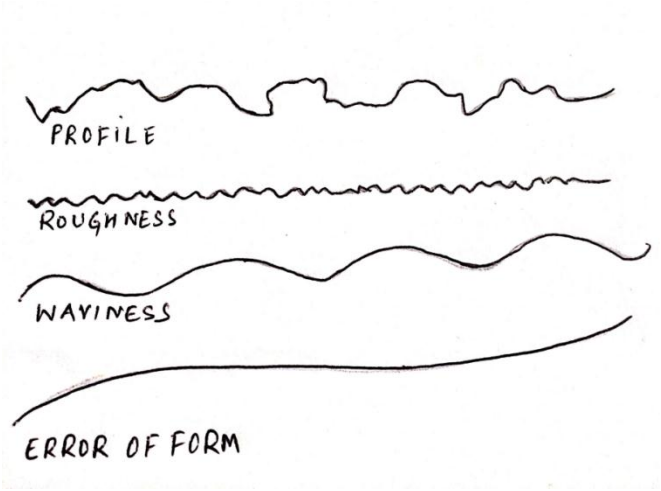

Figure – 2

1. **Roughness:** Closely spaced irregularities which create the predominant surface pattern. Roughness includes those surface features which are intrinsic in the production process.
2. **Waviness:** Surface irregularities of greater spacing than roughness. They are often results of heat treatment, warping etc.
3. **Error of form:** Gross deviation from normal shape. They are normally not considered the part of surface texture.

ROUGHNESS WIDTH CUT-OFF

The greatest width of surface roughness that should be included in measurement is called the roughness width cut-off. Thus roughness measurement will be affected by the selected cut-off. The International standard width cut-off is 0.8 mm, 0.25 mm and 0.08 mm. Normally 0.8 mm cut-off is employed. The cut-off is accomplished by electronic filters.

CHARACTERIZATION OF ROUGHNESS

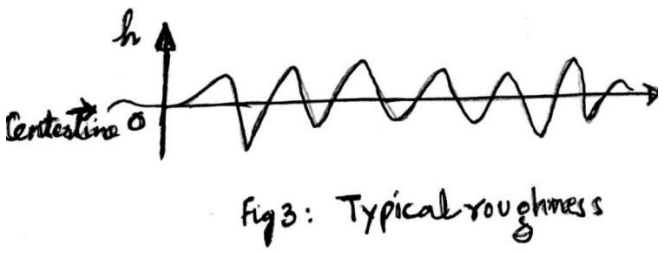

Figure-3

Roughness is an important area of investigation today. The common parameters used and their definitions are given below:

$$R_a = \frac{1}{l}\int_0^l h\, dx \qquad \text{where h = f(x)}$$

$$R_q = \sqrt{\frac{1}{l}\int_0^l h^2 dx}$$

R_a and R_q were earlier called the center line average and Rms value respectively. Another parameter commonly used is the average elevation of the five highest peaks above the five lowest valleys and is called R_z or 10 point average.

The centre line around which measurement of height is done is defined as the line having the form of the normal profile and parallel to the general direction of the profile throughout the sample length, such that the sum of areas contained between it and those parts of the profile which lie on each side of it are equal.

In view of the current auto-correlation and cross-correlation functions, asperity shapes etc. are gaining importance though not yet widely used in roughness specifications.

ISO (International Standards Organization) has defined roughness grades which are reproduced below:

Table 1

Rocommended R_a value (µm)	**Roughness Grade Number**
0.025	N 1
0.05	N 2
0.1	N 3
0.2	N 4
0.4	N 5
0.8	N 6
1.6	N 7
3.2	N 8
6.3	N 9
12.5	N 10
25	N 11

ROUGHNESS HEIGHT DISTRIBUTION

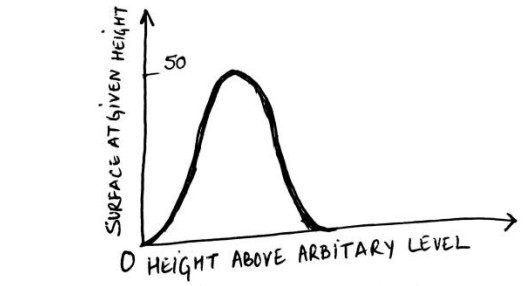

Fig: A typical Height Distribution for a Wear gaussian Surface

Figure- 4

Many engineering surfaces have height distributions that are nearly Gaussian. This is of information in studying surface contact. In some cases (depending on the nature of metal removal process) the height distributions may not be Gaussian. For example in grinding and turning the distribution is in Gaussian while a bead blasted surface shows nearly Gaussian distribution.

TUTORIAL

Q. No. 1: What is surface Roughness? How it is measured?

Q. No. 2 What do you understand by Ra, Rq and Rms?

Text Books :

1. Czichos, H., "A system approach to science and Technology of Friction, Lubrication and Wear" Volume I, Tribology series, Elsevier Publications, 1978.

2. Ludema, K.C., "Friction, wera , Lubrication", CRC Press, NY., 1996.

Reference Books:

1. Peterson M.B.,Winner W.O, "Wear control Handbook" sponsored by The Research Committee on Lubrication, 1980.