5. DIMENSIONS, TOLERANCES AND SURFACE

5.1 Dimension, Tolerances and Related Attributes
5.2 Surfaces
5.3 Effect of Manufacturing Processes
Introduction

- **Dimensions** – the sizes and geometric features of a component specified on the part drawing.
  - How well the parts of a product fits together.

- **Tolerance** – Allowable variation in dimension.

- **Surface** – affects product performance, esthetic and ‘wear’
5.1 Dimensions, Tolerance and Related Attributes

- Dimension – ‘a numerical value expressed in appropriate units of measure and indicated on a drawing along with lines, symbols and notes to define the size/geometric characteristics of a part’
- Variations in the part size comes from manufacturing processes
- Tolerance – the limit of the allowed variation
Tolerance

- Bilateral Tolerance
- Unilateral Tolerance
- Limit dimension
Other Geometric Attributes

- Angularity
- Circularity
- Concentricity
- Cylindricity
- Flatness
- Parallelism
- Perpendicularity
- Roundness
- Squareness
- Straightness
5.2 Surface

- Nominal Surface - intended surface contour of part
- Actual surface - determined by the manufacturing processes
- Wide variations in surface characteristics
- Important reasons to consider surface
  - Esthetic reason
  - Safety
  - Friction and wear
  - Affects the mechanical integrity of a material
  - Ability to assemble
  - Better contact
Surface Technology

- Relationship between processes and surface characteristics
- Defining the Characteristics of a surface
  - Surface texture
  - Altered layer – result of some processes
  - Oxide film
  - Substrate – grain structure
Surface Texture

- Repetitive deviation from the nominal surface.
- Roughness - the small, finely spaced deviations from the nominal surface.
- Waviness – the deviation of much larger space that come about from deflection, vibration, heat treatment and etc.
- Lay – the predominate pattern of the surface texture.
- Flaws – irregularity such as cracks, scratch, inclusions and etc.
Surface texture features
Possible lays of a surface

*Lay* - predominant direction or pattern of the surface texture

<table>
<thead>
<tr>
<th>Lay symbol</th>
<th>Surface pattern</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>=</td>
<td></td>
<td>Lay is parallel to line representing surface to which symbol is applied.</td>
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<tr>
<td>⊥</td>
<td></td>
<td>Lay is perpendicular to line representing surface to which symbol is applied.</td>
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<tr>
<td>X</td>
<td></td>
<td>Lay is angular in both directions to line representing surface to which symbol is applied.</td>
</tr>
<tr>
<td>M</td>
<td></td>
<td>Lay is multidirectional.</td>
</tr>
<tr>
<td>C</td>
<td></td>
<td>Lay is circular relative to center of surface to which symbol is applied.</td>
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<tr>
<td>R</td>
<td></td>
<td>Lay is approximately radial relative to the center of the surface to which symbol is applied.</td>
</tr>
<tr>
<td>P</td>
<td></td>
<td>Lay is particulate, nondirectional, or protuberant.</td>
</tr>
</tbody>
</table>
Surface Roughness & Finish

- **Surface roughness** - a measurable characteristic based on roughness deviations
- Surface finish – a subjective term
- Arithmetic Average (AA)
  \[
  R_a = \frac{1}{L_m} \int_0^{L_m} |y| \, dx 
  \]
  Approximation \[
  R_a = \frac{1}{n} \sum_{i=1}^{n} |y_i| 
  \]
  - \(R_a\) = arithmetic mean value of roughness
  - \(y\) = the vertical deviation from nominal surface
  - \(L_m\) = the specified distance
- Root-mean-square (RMS) – the square root of the mean of the squared deviation over the measured length
- RMS > AA usually.
Surface Roughness

• A problem with the $R_a$ computation is that waviness may get included.
• A parameter called the *cutoff length* is used.
• Cutoff length is a sampling distance along the surface. A sampling distance shorter than the waviness width eliminates waviness deviations.

![Diagram of surface roughness and its components: actual surface, nominal surface, and vertical deviations.](image)
Surface Roughness

- **Deficiency**
  - Too simplified
  - Waviness is not included

- **Remedy**
  - Use Cutoff length (a sampling distance along the surface)

- **Symbols**
Surface Integrity

- Metallurgical changes in the altered layer beneath the surface can significantly affect a material's mechanical properties.
- *Surface integrity* is the study and control of this subsurface layer and the changes in it that occur during processing:
  - Absorption
  - Alloy depletion
  - Cracks
  - Craters
  - Heat-affected Zone
  - Inclusion
5.3 Effect of Mfg Processes

- Typical tolerance
  - Sand Casting
    - Cast Iron ±1.3mm
    - Steel ±1.5mm
    - Aluminum ±0.5mm
  - Die Casting ±.12mm
  - Plastic Molding
    - Polyethylene ±0.3mm
    - Polystyrene ±.15mm
  - Machining
    - Drilling +0.08, -0.03mm
    - Milling ±0.08mm
    - Turning ±0.05mm
  - Abrasive processes
    - Grinding ±0.008mm
    - Lapping ±0.005mm

- Surface finish, roughness
  - Casting
    - Die Casting Good 1-2µm
    - Investment Good 1.5-3
    - Sand Casting Poor 12-25
  - Metal forming
    - Cold rolling Good 1-3
    - Hot rolling Poor 12-25
  - Machining
    - Boring Good 0.5-6
    - Drilling Medium 1.5-6
    - Milling Good 1-6
    - Turning Good 0.5-6
  - Abrasive Processes
    - Grinding Very Good 0.1-2
    - Lapping Excellent 0.05-0.5
6. FRICTION, WEAR AND LUBRICATION

6.1 Friction
6.2 Wear
6.3 Lubrication
Introduction

- Tribology – the study of friction, wear and lubrication of interacting surfaces in relative motion.
6.1 Friction

- Barreling in compression test
- In forging, rolling, sheet metal forming and machining
- Friction – the resistance to relative motion between two bodies in contact.
- Force to overcome friction
- Static ($\mu_s$) and Kinetic ($\mu$) frictions
6.2 Wear

- Wear Mechanism
  - Adhesion Wear
  - Abrasion
  - Oxidation and other chemical reaction
  - Diffusion
  - Other types of Wear – galling, fretting, erosion etc.
Protection from friction and wear

- Proper material selection
- Surface treatment
- Smoother surface (dry)
- ‘Rough’ surface (lubrication)
- Proper operating condition (speed, temperature and pressure)
6.3 Lubrication

- Fluid Film Lubrication
  - thick-film or hydrodynamic lubrication.
    - Viscosity of a lubricant
    - Results erosion
  - Thin-film lubrication
    - Friction increases

- Mixed-film lubrication

- Boundary Lubrication—presence of boundary layer that carry normal force
  - Extreme pressure lubrication for high T and P

- Solid Lubrication
Lubricants in Manufacturing

- Functions of Metal Working Lubricants
  - Separate surfaces
  - Protect surfaces
  - Remain stable and durable
  - Cools the materials
  - Not Health-hazard
  - Inexpensive

- Mineral oil, Natural oil, synthetic fluids, Compounded lubrication, Aqueous lubrication, and coating and barrier.