ME 216: Engineering Metrology

Fundamentals of Geometric Tolerances

Dr. Suhas S. Joshi, Department of Mechanical Engineering, Indian Institute of Technology, Bombay, Powai, MUMBAI – 400 076 (India)
Phone: 91 22 2576 7527 (O) / 2576 8527 ®; ssjoshi@iitb.ac.in
Tolerance of Size and Geometry

The tolerance on ‘Size’ is also called as ‘Dimensional’ tolerance.

Example – \( \phi 25^{+0.020}_{-0.000} \)

But these tolerances may not be sufficient to manufacture the desired fit perfectly. So we require additional tolerances, called ‘Geometrical’ Tolerances. Example –

Fit is acceptable, assembly possible
Parts in Correct Orientation

Fit is acceptable, assembly Not possible
Parts not in correct Orientation
Tolerance of Size and Geometry

Fit is acceptable, assembly Not possible Parts not in correct **Shape**

Fit is acceptable, assembly Not possible Parts not in correct **Position**
Tolerance of Size and Geometry

Therefore, in addition to selecting FIT, it is also important that we specify additional tolerances so that the desired FIT is achieved. These types of tolerances which help specify the functional requirements more clearly, are called as ‘Geometrical Tolerances’. These are of following three types –

1. Tolerances on **Shape or Form**
2. Tolerances on **Orientation**
3. Tolerances on **Position**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Tolerance Value</th>
<th>Reference datum</th>
</tr>
</thead>
</table>

Geometric Tolerance Representation
## Geometric Tolerances

### A. Characteristics of Form/Shape

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Characteristics</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Straightness</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Flatness</td>
<td>![Flatness Symbol]</td>
</tr>
<tr>
<td>3.</td>
<td>Circularity</td>
<td>![Circularity Symbol]</td>
</tr>
<tr>
<td>4.</td>
<td>Cylindricity</td>
<td>![Cylindricity Symbol]</td>
</tr>
<tr>
<td>5.</td>
<td>Profile of a Line</td>
<td>![Profile of Line Symbol]</td>
</tr>
<tr>
<td>6.</td>
<td>Profile of a Surface</td>
<td>![Profile of Surface Symbol]</td>
</tr>
</tbody>
</table>
## Geometric Tolerances

### B. Characteristics of Orientation

<table>
<thead>
<tr>
<th>S. N.</th>
<th>Characteristics</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Parallelism</td>
<td>///</td>
</tr>
<tr>
<td>2.</td>
<td>Perpendicularly</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Angularity</td>
<td>\</td>
</tr>
</tbody>
</table>

### C. Characteristics of Position

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Characteristics</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Position</td>
<td>○</td>
</tr>
<tr>
<td>2.</td>
<td>Concentricity/Co-axiality</td>
<td>○</td>
</tr>
<tr>
<td>3.</td>
<td>Symmetry</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Run out</td>
<td>▽</td>
</tr>
</tbody>
</table>

| 6    |                                |        |
Geometric Tolerances

Straightness

It is the characteristic of a line where all the elements of a line are co-linear. In general, there could be two lines, within which, all the points on a line lie.
Geometric Tolerances

Concept of Maximum Material Condition

As the feature size reduces below its MMC, the tolerance goes on increasing as can be seen from the adjoining table.

<table>
<thead>
<tr>
<th>Feature Size</th>
<th>Tolerance</th>
<th>Size of zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>25.020</td>
<td>φ 0.01</td>
<td>25.030</td>
</tr>
<tr>
<td>25.010</td>
<td>φ 0.02</td>
<td>25.030</td>
</tr>
<tr>
<td>25.000</td>
<td>φ 0.03</td>
<td>25.030</td>
</tr>
<tr>
<td>24.990</td>
<td>φ 0.04</td>
<td>25.030</td>
</tr>
</tbody>
</table>
Geometric Tolerances

Flatness
It is defined as minimum distance between two planes within which all the points on a surface lie. A surface along which all the points lie along single plane is called as perfectly flat surface.

The maximum material condition is not applicable to Flatness
Geometric Tolerances

**Circularity**

It is defined for a cylindrical or conical surfaces. It defines the distance between the surface and its axis.

Ideally, all points on a surface (at a cross-section), should be equidistant from the axis for the cross-section to be perfectly circular.

The tolerance on circularity is defined by two concentric circles within which a surface can lie. The distance between two the concentric circles is called tolerance.

The maximum material condition is not applicable to circularity.
**Geometric Tolerances**

**Cylindricity**

It is defined for a surface of revolution. It defines the distance between the surface and its axis.

Ideally, all points on a surface (of revolution), should be equidistant from the axis for the cross-section to be perfectly cylindrical.

The tolerance on cylindricity is defined by two concentric cylinders within which a surface can lie. The distance between the two concentric cylinders is called tolerance.

The maximum material condition is not applicable to cylindricity.
Geometric Tolerances

Profile of Line or Surface
It is defined for a line of any shape of surface of any shape. It defines the distance between two lines or surfaces of the same shape as that of the line or surface in question, separated by a distance equal to tolerance.

Profile of a line

Profile of a surface
Geometric Tolerances

Perpendicularity
It is defined for a feature (like surface or line) with reference to another feature called reference. It defines the distance between two lines or surfaces that are parallel to each other and perpendicular to the datum surface and encompass the line or surface in question.

Perpendicularity of a Line with Surface as datum

Maximum size of the part = Maximum size permitted by the dimensional tolerance (25.020) + geometrical tolerance (0.01) = 25.03 mm
Minimum size of the part = Minimum size permitted by the dimensional tolerance (24.98) - Geometrical tolerance (0.01) = 24.97 mm
Geometric Tolerances

Perpendicularity of a Surface with Line as a datum

Given plane

Datum

Tolerance zone: Two parallel planes
Geometric Tolerances

Perpendicularity of a Surface with Surface as a datum

Maximum size of the part = Maximum size permitted by the dimensional tolerance (15.040) + geometrical tolerance (0.01) = 15.05 mm

Minimum size of the part = Minimum size permitted by the dimensional tolerance (14.96) - Geometrical tolerance (0.01) = 14.95 mm
Geometric Tolerances

Parallelism
It is defined for a feature (like surface or line) with reference to another feature called reference. It defines the distance between two lines or surfaces that are parallel to each other and parallel to the datum surface and encompass the line or surface in question.

Parallelism of a Line with Line as datum
Geometric Tolerances

Parallelism of a Line with Line as a datum

Max. distance between holes = Max distance permitted by the dimensional tolerance 
(70.040) + (1/2) Geometrical tolerance (0.005) = 70.045 mm

Min. distance between holes = Min. distance permitted by the dimensional tolerance 
(69.96) – (1/2) Geometrical tolerance (0.005) = 69.955 mm
Geometric Tolerances

Parallelism of a Line with Surface as a datum

\[ φ \leq 0.01 \]

Datum Surface

Datum Surface
Geometric Tolerances

Parallelism of a Surface with Surface as a datum

Given axis

Datum Surface

Tolerance zone
Geometric Tolerances

Angularity
It is defined for a feature (like surface or line) with reference to another feature called reference. It defines the distance between two lines or surfaces that are at an angle to the datum surface and encompass the line or surface in question.

Given axis of hole
Tolerance zone
Geometric Tolerances

Position
It defines the perfect (exact) location of a point, line or a surface in relation to the other datum

Position of a line

Position of a line with surface as a datum

Given axis
Datum plane
**Geometric Tolerances**

**Concentricity**
It defines the position of an axis in relation to the other datum axis. It defines a cylinder which coincides with the datum axis and of diameter given by the geometrical tolerance.
Geometric Tolerances

Run out
It defines the deviation from the desired form and orientation during one full rotation of the part on the datum axis.

Given surface
Tolerance zone bound by two concentric cylinders