Lecture 09

DIMENSIONING AND TOLERANCES

Mechanical Engineering Graphics
MECH 211
Dimensioning rules

- Each feature of an object is dimensioned once and only once.
- Dimensions should be selected to suit the function of the object.
- Dimensions should be placed in the most descriptive view of the feature being dimensioned.
- Dimensions should specify only the size of a feature. The manufacturing method should only be specified if it is a mandatory design requirement.
- Angles shown on drawings as right angles are assumed to be 90 degrees unless otherwise specified, and they need not be dimensioned.
Dimensioning rules – Cont’d

- Dimensions should be located outside the boundaries of the object whenever possible.
- Dimension lines should be aligned and grouped where possible to promote clarity and uniform appearance.
- Crossed dimension lines should be avoided whenever possible. When dimension lines must cross, they should be unbroken.
- The space between the first dimension line and the object should be at least 3/8 inch (10mm). The space between dimension lines should be at least ¼ inch (6mm).
- There should be a visible gap between the object and the origin of an extension line.
Extension lines should extend 1/8 inch (3mm) beyond the last dimension line.

Extension lines should be broken if they cross or are close to arrowheads.

Leader lines used to dimension circles or arcs should be radial.

Dimensions should be oriented to be read from the bottom of the drawing.

Diameters are dimensioned with a numerical value preceded by the diameter symbol.
Dimensioning rules – Cont’d

- Concentric circles should be dimensioned in a longitudinal view whenever possible.
- Radii are dimensioned with a numerical value preceded by the radius symbol.
- When a dimension is given to the center of an arc or radius, a small cross is shown at the center.
- The depth of a blind hole may be specified in a note. The depth is measured from the surface of the object to the deepest point where the hole still measures a full diameter in width.
- Counterbored, spotfaced, or countersunk holes should be specified in a note.
Dimension figures - Direction

Aligned and unidirectional dimensioning

- **Aligned Dimensions** have text placed parallel to the dimension line, with vertical dimensions read from the right of the drawing.

- **Unidirectional Dimensions** are read from bottom of page

![Diagram](image-url)
Dimension outside the view

(A) Avoid

(B) Good Practice
Extension line practice

- Use any of the four methods, as long as they are legible
- While grouping, stagger dimensions
- Do not break dimension lines for object lines, but for arrow heads

![Diagram](image.png)
Center line practice

Centerline used as an extension line
Radial and diametric dimensions

- More than half a circle: diameter
- Leaders to point towards centre of the circle or arc (Radial)
- Less than half a circle or arc: radius
Dimensioning arcs

- Arc in dimensioned in a view where true shape is seen
- If space is available leader and the value is located inside the arc. If not numeral alone or including leader is moved out
- Cross is indicated with or without dimensions for centre of all arcs except small and unimportant radii
- For long radius, false center with jogged leader can be used
Dimensioning chained features

- smaller dimension should be placed closer to the object to avoid unnecessary crossing

Staggering dimension text

Aligning dimension lines
Detailed explanations

- Extension lines and line indicators are used to detail manufacturing requirements
Not to scale dimensioning

• All features in drawings are scaled accordingly
• Not-scaled features could be also represented but also indicated with an underline
Reference for the extension line

- Dimensioning is always performed between crisp surfaces
- Sometimes, such surfaces are not available and the dimensioning is given to facilitate the manufacturing process, extension lines with reference marks are used
General dimensioning

- Holes should be dimensioned in the view that they are best seen

4 x Ø .375
General dimensioning – Cont’d

- Features should be dimensioned in the views that are best seen
General dimensioning – Cont’d

• Do not draw a view/section for a feature that could be indicated by a symbol
Counterbore  Countersink  Spotface

Section view is needless as symbols in the topview means this
General dimensioning – Cont’d

- Dimension keyseats from the bottom of the keyseat to opposite end of the shaft
- For key seat, from top of keyway to bottom of hole

Keyseats and keyway
General dimensioning – Cont’d

- By giving centre to centre distances and radii of ends
- One radius dimension is only needed, but number of places need to be mentioned
Chamfers

General dimensioning – Cont’d
General dimensioning – Cont’d

- Dimensioned in the longitudinal view

Concentric circles
General dimensioning – Cont’d

- Dimensioned with local notes
- Or by showing the dimensions of both the depth of undercut and the distance

Grooves
Threads are dimensioned with local notes

- Internal or tapped threads on the circular view
- External threads on the longitudinal view
Size Vs. Location

- Both size and location dimensions have to be provided to avoid any confusion
Size Vs. Location

- Both size and location dimensions have to be provided to avoid any confusion
Reminder

• Each feature of an object is dimensioned once and only once

• The location and/or size dimensions for a feature should be placed in the view in which that feature is most clearly seen i.e. where its shape description is most complete

• Any dimension specified should correspond to a range of dimensions in the final product, i.e. each dimension should include an appropriate tolerance
Reminder

• Dimensions lines should never coincide with object lines or other extension lines
• Dimension lines should be unbroken except for the number between the arrowheads
• There should be a visible gap between the object and the origin of an extension line
• Crossing of dimension lines should be avoided wherever possible
Reminder

- Dimensions should reference object lines rather than hidden lines.
- Dimensions should be placed in spaces as close as possible to their point of application.
- When dimensions are "nested", the smaller dimension should be placed closer to the object to avoid unnecessary crossing.
- Dimensions should be located outside the boundaries of the object wherever possible.
Superfluous dimensions
What is Important?

• Understanding of tolerances
• Selection and calculations
• Prescription of tolerances

• **Tolerance of a size**: the difference between the maximum and the minimum allowed size of the specific dimension
Nomenclature

- **Nominal Size** – The general size (used for general identification of part)
- **Basic Size** – Theoretical size (size from which limits are worked out)
- **Actual Size** – Measured size of the actual part
- **Limits** – the max and min sizes shown by tolerances
- **Allowance** – for mating parts – min clearance or max interference
- **Tolerance** - total allowable variance
Nomenclature

- **Maximum material condition (MMC)** – where part contains maximum amount of material
- **Least material condition (LMC)** – where part contains minimum amount of material
- **Clearance fit** – condition of fit that enables space between mating parts
- **Interference fit** – condition of fit that enables no space between mating parts
- **Transition fit** – clearance or interference fit
Tolerance representation

• Direct limits
  (limit dimensioning)

• Tolerance value
  (plus or minus dim)

• Unilateral Tolerances
  (only in one direction from basic size)

• Specific note
  (The * dimensions φ2±0.001)

• General note
  (All diameters φ2±0.001)
Clearance and interference fits

Allowance always equals smallest hole minus largest shaft
Transition fit

MAX Clearance

MAX Interference

ALLOWANCE

Tolerance

CLEARANCE FIT + .001

INTERFERENCE FIT - .002
How to determine fits?

- Evaluate the allowance and the interference
Functional dimensioning

• Functional dimensioning begins with tolerancing the most important features

• The functionality of the assembly has to be very clearly established by the designer

• The assembly procedure as well as the manufacturing processes involved in producing the part must be also clear to the designer

• Tolerances should be as “coarse” as possible and still permit satisfactory use of part – Why?
Tolerance Stack-up

- Tolerances taken in the same direction from one point of reference are additive – tolerances stack-up or accumulation of tolerance
- Tolerance stack-up can be eliminated by careful selection and placement of dimensions
- If Z not given, it will be governed by both X and Y (.01 instead of intended tolerance of .005)
Tolerance Stack-up

Dimensioning with respect to the base base would help
Tolerancing in ISO

International tolerance (IT) Grades

HOLE 40 H8
Fundamental deviation
Basic size
Tolerance grade
IT grade

SHAFT 40 f7
Fundamental deviation
Basic size
Tolerance grade
IT grade

FIT 40 H8/f7
Hole tolerance
Shaft tolerance

FOR MEASURING TOOLS
FOR MATERIAL

IT GRADES
01 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

FOR FITS
FOR LARGE MANUFACTURING TOLERANCES

International tolerance (IT) Grades
Minimum hole size is the basic size.
Limit form vs. note form tolerancing

Hole Tolerance = .025

Shaft Tolerance = .016

Loosest fit = 40.025 - 39.975 = .050

Tightest fit = 40.000 - 39.991 = .009
Metric Tolerances - Standard representation

- If limits are shown up and down, largest limit up
- If shown side by side, smallest limit first
- For angular dimensions, it can be in general note or it can be mentioned similar to that of linear dimensions
Basic hole and shaft system - Imperial size

- **Hole Basis fit**: the basic size is the minimum dia of the hole and fit is calculated based on this.

- **Shaft Basis fit**: the basic size is the maximum dia of the shaft and the fit is calculated based on this.
Example – Run Fit

0.500 is the lower limit hole
0.496 is the upper limit shaft
0.004 is the ALLOWANCE

0.496 is the upper limit shaft
0.003 is the shaft tolerance
0.493 is the LOWER LIMIT SHAFT

0.500 is the lower limit hole
0.003 is the hole tolerance
0.503 is the UPPER LIMIT HOLE

0.500 is the smallest hole
0.496 is the largest shaft
0.004 is the tightest fit

0.503 is the largest hole
0.493 is the smallest shaft
0.10 is the loosest fit
Geometric tolerancing

- Used to limit the abatement in the geometric or positional variation of features

Total flatness tolerance, .05 inch. This entire tolerance zone may move up and down within the size tolerance zone.

Total height tolerance .2 inches

Flatness tolerance indication in drawing

Actual Surface of Table

30+/-1
Example of feature control frames

Geometric tolerance symbol (Parallelism)

Geometric tolerance value

Reference Datum

Size dimension

Geometric tolerance symbol (Roundness)

Geometric tolerance value
Dimensioning and tolerancing symbols

<table>
<thead>
<tr>
<th>General Tolerance Symbols</th>
<th>Tolerance Symbols of Form, Orientation, and Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Condition</td>
<td>Symbol</td>
</tr>
<tr>
<td>(M)</td>
<td>Flatness</td>
</tr>
<tr>
<td>(L)</td>
<td>Straightness</td>
</tr>
<tr>
<td>(R)</td>
<td>Roundness</td>
</tr>
<tr>
<td>(S)</td>
<td>Cylindricity</td>
</tr>
<tr>
<td>Regardless of Feature Size</td>
<td>Profile of a Line</td>
</tr>
<tr>
<td>Primary Datum</td>
<td>Profile of a Surface</td>
</tr>
<tr>
<td>Secondary Datum</td>
<td>Angularity</td>
</tr>
<tr>
<td>Tertiary Datum</td>
<td>Perpendicularity</td>
</tr>
<tr>
<td></td>
<td>Parallelism</td>
</tr>
<tr>
<td></td>
<td>Position</td>
</tr>
<tr>
<td></td>
<td>Concentricity</td>
</tr>
<tr>
<td></td>
<td>Symmetry</td>
</tr>
<tr>
<td></td>
<td>Circular Runout</td>
</tr>
<tr>
<td></td>
<td>Total Runout</td>
</tr>
</tbody>
</table>

Feature Control Symbols:

- Geometric Characteristic Symbol
- Zone Descriptor
- Feature Tolerance
- Modifier
- Primary Datum Reference
- Secondary Datum Reference
- Tertiary Datum Reference

- Arc Length
- Basic Dimension
- Conical Taper
- Counterbore or Spotface
- Countersink
- Deep or Depth
- Diameter
- Dimension Not to Scale
- Number of Times/Places
- Radius
- Reference Dimension
- Spherical Diameter
- Spherical Radius
- Slope
- Square
Straightness of the axis

- **VMC Modified**
  - Points: 
  - \( \phi 0.50 \) mm
  - \( \phi 0.002 \) in max

- **Drawing**
  - True Axis of Shaft, 3-Dimensional Twist

- **Effect**
  - Scale enlarged

- **Inspection Methods**
  - Use block inspection to locate true axis

- **True Axis of Shaft, 3-Dimensional Twist**
  - \( \phi 0.002 \) in max
  - Plus any basic tolerance
Roundness

Perfect Circle, Cannot Exceed MMC Size

Actual Part Profile

Precision Slide

Part

Precision Spindle

Drawing

Tolerance Zone

Inspection Method (check only one slice at a time)

Ø .500

| Ø .002 |
Cylindricity
Drawing with GT - Example
Machine elements

Fasteners, gears, bearings, welding

MECHANICAL ENGINEERING

DRAWING

MECH 211
Content of the lecture

• Machine elements and standards
• Non-permanent fasteners – bolts and screws
  • Features, representation, assembly representation and note
• Other non-permanent fasteners
• Permanent fasteners – rivets, joining through soldering, brazing and welding
• Springs
• Assembly drawings
• Machine elements: gears, cams, bearings, etc.
• Examples of mechanisms and representations
Fasteners

• Use to join two or more components

• Two major categories:
  • Non-permanent fastening methods
  • Permanent fastening methods

• The Boeing 747 has 2.5 million fasteners!
Non-permanent fasteners

- Bolts and nuts, machine screws, studs, pins, rings, keys, etc.
- An assembly could be disassembled without destroying the fastener or a part of the assembly
Bolts, nuts and machine screws

- Used to assemble machine parts through the friction obtained in a helical groove made on two conjugated parts
- The threads are cut or rolled in a blank of material (metal) while the conjugate part moves axially on the thread when turned
- Bolts and nuts must have the same geometric features in order to be mated.
Screw and thread terminology

- **Screw Thread** - A ridge of uniform section in the form of a helix on the external or internal surface of a cylinder.

- **Major Diameter** - The largest diameter of a screw thread.

- **Minor Diameter** - The smallest diameter of a screw thread.
Screw and thread terminology

- **Axis** – the longitudinal center line of the original work (blank) or hole

- **Chamfer** – the angular relief at the beginning or end of the thread to allow easier engagement with the mating part

- **Crest** – the peak of the top of a thread

- **Depth** – the distance between the crest and the root
Screw and thread terminology

- **Die** – the tool used to perform external threads

- **External thread** – the screw thread on the outside of a cylindrical surface

- **Internal thread** – the screw thread on the inside of a cylindrical surface

- **Lead** – the distance that a screw will travel along the axis when turned by 360°
Screw and thread terminology

- **Pitch** – the distance between corresponding points on adjacent thread forms, measured parallel to the axis expressed in 1 divided by the number of pitch in one inch

- **Pitch diameter** – the diameter of an imaginary cylinder that is located equidistant between the major and the minor diameter
Screw and thread terminology

- **Root** – the bottom of the screw thread cut in a cylinder
- **Tap** – the tool used to thread holes
- **Thread angle** – the angle between the surfaces of two adjacent threads
- **Thread series** – the number of threads per inch for a given diameter
Thread specifications – imperial system

- ANSI Y14.6 - 1998
- Thread form
- Thread series
- Major diameter
- Class of fit
- Threads per inch
• Shows some common thread forms

• Inch & Metric have same proportion

• Sharp V was original american national thread

• American national now has flattened root and crest to increase strength

• **Unified thread** is agreed as standard in US, Canada and Britain, the crest may be flat or rounded but the root is rounded. Otherwise similar to American national
Form

- **ISO Metric** is the most common of all the depth is smaller than that of unified national thread.

- **Knuckle thread** is rolled or cast (used in light bulbs and sockets).

- **Square and Acme** threads are used for transmitting power.

- **Buttress thread** takes pressure on one side (⊥ to the axis).
Motion and measurement screws

Controls and positioning applications
Measuring thread pitch

- **Pitch** is the distance parallel to axis between corresponding points in adjacent thread.

- **Pitch** is measured in millimeters for metric thread and indicated along with the major dia (eg. M10 X 1.5).

- For inch threads, it is mentioned as threads per inch.

- **Thread Pitch** is measured with scale or a thread pitch gage.
Series

- **Series** depends on the pitch and the major dia of the thread

  - **Coarse series** – used for quick assembly and disassembly of cast iron, soft metals and plastics *(UNC)* – Less TPI

  - **Fine series** – used when a great deal of force is necessary for assembly *(UNF)* - More TPI

  - **Extra fine series** – used when the length of engagement is short and the application calls for high degrees of stress *(UNEF)* – Lot of TPI
Series

- If it is not stated in the drawing, it is always assumed to be right hand thread
- A bolt threaded into a tapered hole should be turned clockwise
- Some special cases (where the torque may loosen the fastener) may require Left hand threads
- If Left hand threads are necessary it is indicated in the drawing by the letters LH after the thread designation
Single and multiple thread forms

- If it is not stated in the drawing, it is always assumed to be single thread.
- Single thread has a single ridge in the form of helix and lead = pitch.
- Multiple threads have 2 or more ridges running side by side.
- The slope line is the hypotenuse of the right triangle whose short side = \(0.5P\) for single thread and \(p\) for double and \(1.5\) \(P\) for triple threads.
- Multiple threads are required when small rotation must gives faster movement at low required power (Eg. Toothpaste caps ).
Thread Symbols

- Can use, simple, schematic or detailed as needed. Simplified is common.
- Detailed is more pleasing, so for major dias >1” detailed is preferred.
Thread Symbols

Simplified Symbols:
- M20 x 2.5
- .75-10 UNC-2B

Schematic Symbols:
- (a) (b) (c) (d) (e) (f) (g) (h) (j) (k) (m) (n) (o) (p) (r) (s)
Class of fit

- **Class 1 A and B** – a loose fit where quick assembly is required and play between parts is acceptable

- **Class 2 A and B** – a high quality general purpose commercial class of fit for bolts, nuts and screws used in mass production

- **Class 3 A and B** – a very high quality threaded fasteners with a close fit used for precision assembly subjected to vibrations

- **A** is for external threads and **B** is for internal threads
Thread notes

- Major diameter
- Threads per inch
- Form
- Series
- Class of fit
- Internal

- External
- Left hand

- .5-13UNC-3B
- .250-20UNC-2A-LH

**Legend**

- **UNC** Means Unified National Coarse
- **UNF** Means Unified National Fine
- **UNEF** Means Unified Extra Fine Series
- **UN** Means Uniform Pitch Series
- **UNM** Means Unified Miniature Series
- **NC** Means National Coarse Series
- **NF** Means National Fine Series
- **UNR** Means Unified National Round
How to represent a thread

- Tap drill depth
- Thread depth (to last perfect thread)
- Drill depth
- Tap drill size
- .147 DIA X 1.00 DEEP
- .190-24UNC-2B X .75 DEEP
- Thread depth
ISO representation of threads

- Thread form symbol – **M**
- Nominal size – **in mm**
- Pitch size – **in mm**
- General purpose tolerance – a **tolerance class that includes a tolerance position and a tolerance grade for both pitch diameter and minor diameter**
Basic metric thread note

Metric
Diameter (mm)
Pitch (mm)

M24 X 2

Internal

External
Complete threading - metric system

- The number of the tolerance grades reflects the size of the tolerance.
- For example, grade 4 < grade 6 < grade 8 tolerances.
- In addition to the tolerance grade, a positional tolerance is required.
- For external threads:
  - Tolerance position e (large allowance)
  - Tolerance position g (small allowance)
  - Tolerance position h (no allowance)
- For internal threads:
  - Tolerance position G (small allowance)
  - Tolerance position H (no allowance)
# TPI for various UN forms

<table>
<thead>
<tr>
<th>Sizes</th>
<th>ANSI</th>
<th>Basic Major Diameter</th>
<th>Coarse UNC</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>0.0000</td>
<td>0.0730</td>
<td>64</td>
</tr>
<tr>
<td>2</td>
<td>0.0800</td>
<td>0.0360</td>
<td>56</td>
</tr>
<tr>
<td>1</td>
<td>0.1120</td>
<td>0.0300</td>
<td>48</td>
</tr>
<tr>
<td>3</td>
<td>0.1600</td>
<td>0.0300</td>
<td>36</td>
</tr>
<tr>
<td>4</td>
<td>0.1900</td>
<td>0.0300</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>0.2400</td>
<td>0.0300</td>
<td>24</td>
</tr>
<tr>
<td>6</td>
<td>0.2900</td>
<td>0.0300</td>
<td>20</td>
</tr>
<tr>
<td>8</td>
<td>0.3800</td>
<td>0.0300</td>
<td>16</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Threads per inch</th>
<th>ANSI</th>
<th>Basic Major Diameter</th>
<th>Extra Fine UNC</th>
<th>UNF</th>
<th>UNEF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2</td>
<td>0.5000</td>
<td>0.5000</td>
<td>0.4000</td>
<td>0.3000</td>
<td>0.2000</td>
</tr>
<tr>
<td>1/4</td>
<td>0.6250</td>
<td>0.6250</td>
<td>0.5000</td>
<td>0.4000</td>
<td>0.3000</td>
</tr>
<tr>
<td>1/8</td>
<td>0.7500</td>
<td>0.7500</td>
<td>0.6250</td>
<td>0.5000</td>
<td>0.4000</td>
</tr>
<tr>
<td>1/16</td>
<td>0.9375</td>
<td>0.9375</td>
<td>0.8750</td>
<td>0.7500</td>
<td>0.6250</td>
</tr>
<tr>
<td>1/32</td>
<td>1.1250</td>
<td>1.1250</td>
<td>1.0937</td>
<td>0.9375</td>
<td>0.8750</td>
</tr>
<tr>
<td>1/64</td>
<td>1.4062</td>
<td>1.4062</td>
<td>1.3125</td>
<td>1.1250</td>
<td>1.0937</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sizes</th>
<th>ANSI</th>
<th>Basic Major Diameter</th>
<th>Coarse UNC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/8</td>
<td>1.1250</td>
<td>1.1250</td>
<td>1.0937</td>
</tr>
<tr>
<td>1/16</td>
<td>1.4062</td>
<td>1.4062</td>
<td>1.3125</td>
</tr>
<tr>
<td>1/32</td>
<td>1.8750</td>
<td>1.8750</td>
<td>1.7500</td>
</tr>
<tr>
<td>1/64</td>
<td>2.5000</td>
<td>2.5000</td>
<td>2.3750</td>
</tr>
<tr>
<td>1/128</td>
<td>3.7500</td>
<td>3.7500</td>
<td>3.5000</td>
</tr>
<tr>
<td>1/256</td>
<td>5.0000</td>
<td>5.0000</td>
<td>4.6875</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Threads per inch</th>
<th>ANSI</th>
<th>Basic Major Diameter</th>
<th>Extra Fine UNC</th>
<th>UNF</th>
<th>UNEF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.0000</td>
<td>2.0000</td>
<td>1.6000</td>
<td>1.2500</td>
<td>1.0000</td>
</tr>
<tr>
<td>2</td>
<td>2.5000</td>
<td>2.5000</td>
<td>2.0000</td>
<td>1.5000</td>
<td>1.2500</td>
</tr>
<tr>
<td>3</td>
<td>3.5000</td>
<td>3.5000</td>
<td>2.8125</td>
<td>2.0000</td>
<td>1.6000</td>
</tr>
<tr>
<td>4</td>
<td>4.5000</td>
<td>4.5000</td>
<td>3.5000</td>
<td>3.0000</td>
<td>2.5000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sizes</th>
<th>ANSI</th>
<th>Basic Major Diameter</th>
<th>Coarse UNC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/8</td>
<td>1.1250</td>
<td>1.1250</td>
<td>1.0937</td>
</tr>
<tr>
<td>1/16</td>
<td>1.4062</td>
<td>1.4062</td>
<td>1.3125</td>
</tr>
<tr>
<td>1/32</td>
<td>1.8750</td>
<td>1.8750</td>
<td>1.7500</td>
</tr>
<tr>
<td>1/64</td>
<td>2.5000</td>
<td>2.5000</td>
<td>2.3750</td>
</tr>
<tr>
<td>1/128</td>
<td>3.7500</td>
<td>3.7500</td>
<td>3.5000</td>
</tr>
<tr>
<td>1/256</td>
<td>5.0000</td>
<td>5.0000</td>
<td>4.6875</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Threads per inch</th>
<th>ANSI</th>
<th>Basic Major Diameter</th>
<th>Extra Fine UNC</th>
<th>UNF</th>
<th>UNEF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.0000</td>
<td>2.0000</td>
<td>1.6000</td>
<td>1.2500</td>
<td>1.0000</td>
</tr>
<tr>
<td>2</td>
<td>2.5000</td>
<td>2.5000</td>
<td>2.0000</td>
<td>1.5000</td>
<td>1.2500</td>
</tr>
<tr>
<td>3</td>
<td>3.5000</td>
<td>3.5000</td>
<td>2.8125</td>
<td>2.0000</td>
<td>1.6000</td>
</tr>
<tr>
<td>4</td>
<td>4.5000</td>
<td>4.5000</td>
<td>3.5000</td>
<td>3.0000</td>
<td>2.5000</td>
</tr>
</tbody>
</table>
Bolts, nuts and screws

A. Bolt
B. Stud
C. Cap Screw
D. Machine Screw
E. Set Screw
Bolts, nuts and screws

- Large variety of bolts (dimensional, head shape, etc.)
- Material, quality, finishing
- Grade

(a) BOLT  (b) CAP SCREW  (c) STUD

Washer face

Semifinished and finished

Unfinished

GRADE 2  GRADE 5  GRADE 8
Bolts, nuts and screws

- Unfinished bolts are not machined anywhere except for the thread portion.

- Finished bolts have machined face for washer holding or flush location on parts.
Fastener locking

(a) Regular Unfinished Jam Nut (AMER STD)
(b) Regular Semi-Finished Jam Nut (AMER STD)
(c) (d) (e) (f)
(g) (h) (j) (k) (m) (n)

FINISHED SLOTTED NUT (AMER STD)
FINISHED CASTLE NUT (AMER STD)
ESNA STOP NUT
Fastener locking

(a) Castellated nut
(b) Cotter pin locking

(a) Slots.
(b) Cotter pin locking.

Jam nut
Durlock nut
Standard Cap Screws

- 5 different capscrews shown. Socket head can have different shapes of head and sockets
- Sued in machines to pass through clearance hole to screw into another and improve appearance
- Socket screws are used while in crowded condition
Standard Cap Screws

- Similar to cap screws but smaller in size.
- General diameters between .06 to .75 inches
- Hex head (not shown here) may be slotted if desired
- Other heads are available as either slotted or recessed
- Generally used for screwing into thin materials
Part representation
Part representation

Countersink head
machine screw

Dia"-XXUNY-2A
Assembly representation
Assembly representation
Assembly representation
Assembly representation
Assembly representation
Assembly representation
Other nonpermanent fasteners

- Clips, rings, pins, etc.
Other non-permanent fasteners

- Clips, rings, pins, etc.

COTTER PINS
STANDARD EXTENDED PRONG STYLE
WITH SQUARE CUT ENDS

STANDARDS: FROM 1/32 X 1/4 -- TO -- 3/4 X 5 MANY SIZES IN STOCK
MATERIALS: STEEL-BRASS-STAINLESS-PLATED STEEL-MONEL & OTHERS
OTHER ITEMS: PRICE & DELIVERY ON REQUEST CALL US FOR SPECIALS

NOT ALL STYLES ARE AVAILABLE IN ALL MATERIALS

DOWEL PINS
PRECISION GROUND
WE CAN QUOTE ON SPECIALS, TO YOUR SPECS. CALL US!

SPRING PINS
EASILY INSTALLED ECONOMICAL
SELF-LOCKING LONG WEARING

GROOVED PINS*
Positive holding action with six
standard solid pin types and
many specials.
Sizes: 1/16" through 1/2" diameter
1/4" through 4 1/2" long.

TAPER PINS*
TAPER IS 1/4" PER FOOT
CHECK WITH US FOR PRICES & AVAILABLE

ESCUTCHEON PINS*
( DRIVE PINS )
ALL SIZES, BRASS & STEEL
MINIMUM ORDER QUANTITIES REQUIRED, CHECK WITH US.

CLEVIS PINS*
ALL TYPES & ALL MATERIALS
COMMERCIAL & AIRCRAFT
STANDARD & SPECIAL
Clevis pin holes are drilled in all pins.

SPECIAL PINS*
QUOTED TO YOUR SPECIFICATIONS & PRINTS.

*These items are supplied from our source factories. They will probably require more lead time than the items supplied from our stock. We will always inform you what the delivery time is, before you place your order, CALL US!
Permanent fasteners

- Once assembled, the parts of the assembly (including the fastener) would be destroyed to disassemble the assembly.

- Rivets, soldering, brazing, welding
# Rivets

- Used to permanently fasten mechanical components

<table>
<thead>
<tr>
<th>rivet size</th>
<th>diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/32&quot;</td>
<td>2.4</td>
</tr>
<tr>
<td>1/8&quot;</td>
<td>3.2</td>
</tr>
<tr>
<td>5/32&quot;</td>
<td>4.0</td>
</tr>
<tr>
<td>3/16&quot;</td>
<td>4.8</td>
</tr>
</tbody>
</table>

- Countersunk rivets for jobs which require a flush surface: drill makes hole and countersinks in one operation.
- Large flange rivets for fastening soft or brittle materials: greater load-bearing surface is needed.
Riveting process

Before Bucking
- rivet gun
- unworked rivet
- plate #1
- plate #2
- bucking bar

After Bucking
- shop head deforms
- "clamps" the two pieces of metal together

3-D View of a Bucked Rivet
- machining head
- shop head
Fastening with rivets

The headless end of the rivet is plastically deformed such that keeps together two components
Fastening with rivets
Fastening with rivets
Fastening with rivets
Fastening with rivets
Fastening with rivets
Fastening with rivets
Common riveted joints

(a) SINGLE RIVETED LAP JOINT
(b) DOUBLE RIVETED LAP JOINT
(c) SINGLE RIVETED BUTT JOINT
(d) DOUBLE RIVETED BUTT JOINT
Self piercing rivets

Blind rivets

(a)

(b)
Soldering, brazing, welding

- Joining of two part using a third component – *filler* that joins the parts when in liquid state

- Soldering and brazing – low temperature binding materials – Sn-Pb, Cu-Ag alloys

- Limited capability to face thermo-mechanical loading
Welding

- Very well regulated activity
- It requires license to practice
- Welders bear significant responsibility
- The activity is based on rigorous rules and regulations
- Designer prescribe welding based on mechanics of materials calculations
- Symbols indicate the type of welding
Basic welding symbol

- **T**: Specification, process, or other reference.
- **S (E)**: Basic weld symbol or detail reference.
- **F/A**: Field weld symbol.
- **R**: Weld-all-around symbol.
- **L-P**: Reference line.
- **(N)**: Number of spot or projection welds.
- **Both sides**: Indicates that the weld is applied to both sides of the joint.
- **Other side**: Indicates that the weld is applied to the other side of the joint.
- **Arrow side**: Specific direction for the weld.
- **Length of weld**: Length of the weld.
- **Pitch (center-to-center spacing) of welds**: Spacing between welds.
- **Groove angle; included angle of countersink for plug welds**: Angle of the groove.
- **Finish symbol**: Symbol for the finish of the weld.
- **Contour symbol**: Symbol for the contour of the weld.
- **Effective throat**: Depth of preparation, size, or strength for certain welds.
- **Root opening; depth of filling for plug and slot welds**: Depth measurement for plug and slot welds.
- **Elements in this area remain as shown when tail and arrow are reversed**: Indicates that the orientation of the symbol can be reversed without changing the interpretation of the weld.
### Basic Welding Symbols

<table>
<thead>
<tr>
<th>Location Significance</th>
<th>Fillet</th>
<th>Plug or Slot</th>
<th>Spot or Projection</th>
<th>Stud</th>
<th>Seam</th>
<th>Back or Backing</th>
<th>Surfacing</th>
<th>Edge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrow Side</td>
<td><img src="image" alt="Fillet Arrow Side" /></td>
<td><img src="image" alt="Plug or Slot Arrow Side" /></td>
<td><img src="image" alt="Spot or Projection Arrow Side" /></td>
<td><img src="image" alt="Stud Arrow Side" /></td>
<td><img src="image" alt="Seam Arrow Side" /></td>
<td><img src="image" alt="Back or Backing Arrow Side" /></td>
<td><img src="image" alt="Surfacing Arrow Side" /></td>
<td><img src="image" alt="Edge Arrow Side" /></td>
</tr>
<tr>
<td>Other Side</td>
<td><img src="image" alt="Fillet Other Side" /></td>
<td><img src="image" alt="Plug or Slot Other Side" /></td>
<td><img src="image" alt="Spot or Projection Other Side" /></td>
<td><img src="image" alt="Stud Other Side" /></td>
<td><img src="image" alt="Seam Other Side" /></td>
<td><img src="image" alt="Back or Backing Other Side" /></td>
<td><img src="image" alt="Surfacing Other Side" /></td>
<td><img src="image" alt="Edge Other Side" /></td>
</tr>
<tr>
<td>Both Sides</td>
<td><img src="image" alt="Fillet Both Sides" /></td>
<td><img src="image" alt="Plug or Slot Both Sides" /></td>
<td><img src="image" alt="Spot or Projection Both Sides" /></td>
<td><img src="image" alt="Stud Both Sides" /></td>
<td><img src="image" alt="Seam Both Sides" /></td>
<td><img src="image" alt="Back or Backing Both Sides" /></td>
<td><img src="image" alt="Surfacing Both Sides" /></td>
<td><img src="image" alt="Edge Both Sides" /></td>
</tr>
<tr>
<td>No Arrow Side or Other Side Significance</td>
<td><img src="image" alt="Fillet No Arrow Side or Other Side Significance" /></td>
<td><img src="image" alt="Plug or Slot No Arrow Side or Other Side Significance" /></td>
<td><img src="image" alt="Spot or Projection No Arrow Side or Other Side Significance" /></td>
<td><img src="image" alt="Stud No Arrow Side or Other Side Significance" /></td>
<td><img src="image" alt="Seam No Arrow Side or Other Side Significance" /></td>
<td><img src="image" alt="Back or Backing No Arrow Side or Other Side Significance" /></td>
<td><img src="image" alt="Surfacing No Arrow Side or Other Side Significance" /></td>
<td><img src="image" alt="Edge No Arrow Side or Other Side Significance" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location Significance</th>
<th>Groove</th>
<th>Scarf for Brazed Joint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrow Side</td>
<td><img src="image" alt="Square Groove Arrow Side" /></td>
<td><img src="image" alt="Flare-Bevel Scarf for Brazed Joint Arrow Side" /></td>
</tr>
<tr>
<td>Other Side</td>
<td><img src="image" alt="Square Groove Other Side" /></td>
<td><img src="image" alt="Flare-Bevel Scarf for Brazed Joint Other Side" /></td>
</tr>
<tr>
<td>Both Sides</td>
<td><img src="image" alt="Square Groove Both Sides" /></td>
<td><img src="image" alt="Flare-Bevel Scarf for Brazed Joint Both Sides" /></td>
</tr>
</tbody>
</table>
Basic welding symbols

<table>
<thead>
<tr>
<th>Weld-All-Around</th>
<th>Field Weld</th>
<th>Melt-Thru</th>
<th>Consumable Insert</th>
</tr>
</thead>
<tbody>
<tr>
<td>📌</td>
<td>🔄</td>
<td>📌</td>
<td>(Square)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Backing/Spacer (Rectangular)</th>
<th>Contour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Backing</td>
<td>Flush or Flat</td>
</tr>
<tr>
<td>Spacer</td>
<td>Convex</td>
</tr>
<tr>
<td></td>
<td>Concave</td>
</tr>
</tbody>
</table>

**Basic Joints**

Identification of Arrow Side and Other Side Joint

<table>
<thead>
<tr>
<th>Butt Joint</th>
<th>Corner Joint</th>
</tr>
</thead>
<tbody>
<tr>
<td>📌 Arrow of Welding Symbol</td>
<td>📌 Arrow of Welding Symbol</td>
</tr>
<tr>
<td>📌 Arrow Side of Joint</td>
<td>📌 Arrow Side of Joint</td>
</tr>
<tr>
<td>📌 Other Side of Joint</td>
<td>📌 Other Side of Joint</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>T-Joint</th>
<th>Lap Joint</th>
</tr>
</thead>
<tbody>
<tr>
<td>📌 Arrow of Welding Symbol</td>
<td>📌 Arrow of Welding Symbol</td>
</tr>
<tr>
<td>📌 Arrow Side of Joint</td>
<td>📌 Arrow Side of Joint</td>
</tr>
<tr>
<td>📌 Other Side of Joint</td>
<td>📌 Other Side Member of Joint</td>
</tr>
</tbody>
</table>

Arrow of Welding Symbol
# Basic welding symbols

<table>
<thead>
<tr>
<th>Double-Fillet Welding Symbol</th>
<th>Chain Intermittent Fillet Welding Symbol</th>
<th>Staggered Intermittent Fillet Welding Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fillet Weld Size</td>
<td>Pitch (Distance Between Centers)</td>
<td>Pitch (Distance Between Centers)</td>
</tr>
<tr>
<td></td>
<td>of Segments</td>
<td>of Segments</td>
</tr>
<tr>
<td></td>
<td>1/4</td>
<td>5/16</td>
</tr>
<tr>
<td>3/16</td>
<td>2-5</td>
<td>1/2</td>
</tr>
<tr>
<td></td>
<td>Length</td>
<td>3-5</td>
</tr>
<tr>
<td></td>
<td>(Length of Leg)</td>
<td>(Length of Leg)</td>
</tr>
<tr>
<td>Omission of Length Indicates that Weld Extends Between Abrupt Changes in Direction or as Dimensioned</td>
<td>Fillet Weld Size (Length of Leg)</td>
<td>Fillet Weld Size (Length of Leg)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plug Welding Symbol</td>
<td>Back Welding Symbol</td>
<td>Backing Welding Symbol</td>
</tr>
<tr>
<td></td>
<td>Included Angle of Counter Shank</td>
<td>Back Weld</td>
</tr>
<tr>
<td></td>
<td>Pitch (Distance Between Centers)</td>
<td>OR</td>
</tr>
<tr>
<td>Plug Weld Size (Diameter of Hole at Root)</td>
<td>30°</td>
<td>1st Operation</td>
</tr>
<tr>
<td></td>
<td>Depth of Filling (Omission Indicates Filling is Complete)</td>
<td>2nd Operation</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>3/4</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1/2</td>
<td>3-5</td>
</tr>
<tr>
<td></td>
<td>1/2</td>
<td>(Length of Leg)</td>
</tr>
<tr>
<td></td>
<td>3-5</td>
<td>(Length of Leg)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spot Welding Symbol</td>
<td>Stud Welding Symbol</td>
<td>Seam Welding Symbol</td>
</tr>
<tr>
<td></td>
<td>Spot Weld Size</td>
<td>Increment Length</td>
</tr>
<tr>
<td></td>
<td>Number of Welds</td>
<td>Pitch</td>
</tr>
<tr>
<td></td>
<td>0.025</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RSW</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Process</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Square-Groove Welding Symbol</td>
<td>V-Groove Welding Symbol</td>
<td>Double-Bevel-Groove Welding Symbol</td>
</tr>
<tr>
<td></td>
<td>Groove Weld Size</td>
<td>Groove Weld Size</td>
</tr>
<tr>
<td></td>
<td>3/16</td>
<td>1/4</td>
</tr>
<tr>
<td></td>
<td>1/8</td>
<td>1/8</td>
</tr>
<tr>
<td></td>
<td>Root Opening</td>
<td>60°</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Groove Weld Size</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Groove Weld Size</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Root Opening</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Arrow Points Toward Member to be Beveled</td>
</tr>
</tbody>
</table>
• Designed to store energy when deflected and return the same amount of energy when released

• Basically divided as **Helical** and **Flat** springs

• Helical springs are sub divided as
  – Compression Springs
  – Extension Springs
  – Torsion Springs
Helical Springs

Compression, Extension & Torsion

(a) Detailed Round-Wire Spring
(b) Detailed Square-Wire Spring
(c) Small Spring in Section
(d) Use of Phantom Lines
(e) Schematic Compression Spring
(f) Schematic Tension Spring

FL = Free length
t = Dia of wire
D = Controlling dia inside or outside
L₁ = Comp length (Min)
L₂ = Comp length (Max)
No. of coils
Plain End
Squared End
Plain End Ground
Squared and Ground

(a) (b) (c) (d)

MATERIAL: 2.00 OIL TEMPERED SPRING STEEL WIRE
14.5 COILS RIGHT HAND
MACHINE LOOP AND HOOK IN LINE
SPRING MUST EXTEND TO 110 WITHOUT SET
FINISH: BLACK JAPAN

MATERIAL: .059 MUSIC WIRE
6.75 COILS RIGHT HAND NO INITIAL TENSION
TORQUE: 2.50 INCH LB AT 155° DEFLECTION SPRING MUST
DEFLECT 180° WITHOUT PERMANENT SET AND
MUST OPERATE FREELY ON .75 DIAMETER SHAFT
FINISH: CADMIUM OR ZINC PLATE
Spring representation

Working drawing of a compression spring
Machine elements
Machine elements

• Used to transmit power or support elements that transmit power
• Gears, belts/pulleys, chain/sprockets, cams/followers
• Shafts, bearings
• Springs, ratchets, clutches, brakes
Gears

Gear and pinion mechanisms – power transmission
Between two close-positioned shafts
The profile of the tooth is a portion of an involute (the curve generated by a line that rolls without sliding on a circle).

Gears

- The profile of the tooth is a portion of an involute (the curve generated by a line that rolls without sliding on a circle)
Gears

- Meshing require the same geometry of the teeth.
- The rule of meshing – the transmission ratio $i$. 
Gears
• Pressure angle is the direction of the transmitted force versus the normal to the center line

Gears

Pressure Angle
14.5°

Pressure Angle
20°

Pressure Angle
25°
Gears nomenclature
Gears representation

A table containing cutting data must accompany the representation.

This gear is not sectioned unless something inside should be shown.
Gears representation

A table containing cutting data must accompany the representation
Gears representation
Gears

- Rack representation (the cutting data is included)
- Transmission of linear motion to circular or vice versa

<table>
<thead>
<tr>
<th>CUTTING DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>NUMBER OF TEETH</td>
</tr>
<tr>
<td>DIAMETRAL PITCH</td>
</tr>
<tr>
<td>LINEAR PITCH</td>
</tr>
<tr>
<td>PRESSURE ANGLE</td>
</tr>
<tr>
<td>ACTUAL TOOTH THICK. AT PITCH LINE</td>
</tr>
<tr>
<td>PITCH TOL</td>
</tr>
<tr>
<td>INDEX TOL</td>
</tr>
</tbody>
</table>

ALL TOOTH ELEMENT SPECIFICATIONS ARE FROM THE SPECIFIED DATUM.
Worm and Gear representation

Transmission of motion between out of plane, perpendicular axes
Bevel gear assembly

- Bevel Gear representation
- Transmission of motion between in plane, perpendicular axes

<table>
<thead>
<tr>
<th>CUTTING DATA</th>
<th>GEAR</th>
<th>PINION</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO. OF TEETH</td>
<td>30</td>
<td>15</td>
</tr>
<tr>
<td>DIA. PITCH</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>TOOTH FORM</td>
<td>20° STD INVOLUTE</td>
<td></td>
</tr>
<tr>
<td>ADDENDUM</td>
<td>2183</td>
<td>4484</td>
</tr>
<tr>
<td>ROOT ANGLE</td>
<td>31° 47'</td>
<td>23° 41'</td>
</tr>
<tr>
<td>WHOLE DEPTH</td>
<td>7313</td>
<td></td>
</tr>
<tr>
<td>CHORDAL ADD.</td>
<td>.2204</td>
<td>.4652</td>
</tr>
<tr>
<td>CHORD. THICK.</td>
<td>.4303</td>
<td>.6073</td>
</tr>
</tbody>
</table>
Gears
Cams and followers
Clutches

Reduce the high stress when power is coupled to an idle shaft.
Ball and roller bearings
Ball and roller bearings
Example of mechanisms

- Push Rod Valve Gear
- Overhead Camshaft
- Revolving cam opens valve
- Cam
- Camshaft sprocket
- Bucket tappet
- Valve spring
- Inlet valve
- Exhaust valve
- Tappet clearance
- Rocker shaft
- Lock nut for adjusting valve clearance
- Spring
- Camshaft sprocket
- Push rod
- Tensioner
- Sprocket
- Crankshaft sprocket
- Camshaft rotating at half of engine speed (twice as many teeth as the sprocket)
Example of mechanisms
Example of mechanisms

Bosch Electronic Petrol Injection
Example of mechanisms

- Spark plug
- Inlet valve closed
- Exhaust valve closed
- Petrol-air mixture burns in combustion chamber
- Piston is forced down by expanding gases
- Connecting rod
- Crankshaft
Example of mechanisms
Machine elements
Machine elements

- Used to transmit power or support elements that transmit power
- Gears, belts/pulleys, chain/sprockets, cams/followers
- Shafts, bearings
- Springs, ratchets, clutches, brakes
Gears

Gear and pinion mechanisms – power transmission
Between two close-positioned shafts
Gears

- The profile of the tooth is a portion of an involute (the curve generated by a line that rolls without sliding on a circle)
Gears

- Meshing require the same geometry of the teeth
- The rule of meshing – the transmission ratio $i$
Gears

- Pressure angle is the direction of the transmitted force versus the normal to the center line.
Gears nomenclature
A table containing cutting data must accompany the representation.

This gear is not sectioned unless something inside should be shown.
Gears representation
Gears

- Rack representation (the cutting data is included)

<table>
<thead>
<tr>
<th>CUTTING DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>NUMBER OF TEETH</td>
</tr>
<tr>
<td>DIAMETRAL PITCH</td>
</tr>
<tr>
<td>LINEAR PITCH</td>
</tr>
<tr>
<td>PRESSURE ANGLE</td>
</tr>
<tr>
<td>ACTUAL TOOTH THICK. AT PITCH</td>
</tr>
<tr>
<td>LINE TOL</td>
</tr>
<tr>
<td>INDEX TOL</td>
</tr>
</tbody>
</table>

ALL TOOTH ELEMENT SPECIFICATIONS ARE FROM THE SPECIFIED DATUM.
Worm and gear
Bevel gear assembly

<table>
<thead>
<tr>
<th>CUTTING DATA</th>
<th>GEAR</th>
<th>PINION</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO. OF TEETH</td>
<td>30</td>
<td>15</td>
</tr>
<tr>
<td>DIA. PITCH</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>TOOTH FORM</td>
<td>30° STD INVOLUTE</td>
<td></td>
</tr>
<tr>
<td>ADDENDUM</td>
<td>.2183</td>
<td>.4484</td>
</tr>
<tr>
<td>ROOT ANGLE</td>
<td>31°47'</td>
<td>23°41'</td>
</tr>
<tr>
<td>WHOLE DEPTH</td>
<td>73.13</td>
<td></td>
</tr>
<tr>
<td>CHORDAL ADD.</td>
<td>.2204</td>
<td>.4652</td>
</tr>
<tr>
<td>CHORD. THICK.</td>
<td>.4303</td>
<td>.6073</td>
</tr>
</tbody>
</table>

Dimensions:
- Gear diameter: 7.250
- Pinion diameter: 2.451

Other dimensions provided in the diagram.
Gears
Cams and followers

Displacement
follower
Hub
Cam Shaft
Cam Rotation
Cam Profile
Cam

In-Line
Offset
Progress
Cams

Roller-type followers stud and bore
Clutches

Reduce the high stress when power is coupled to an idle shaft
Bearings

Radial ball bearing

Thrust ball bearing
Ball and roller bearings

Deep groove ball bearing
Angular contact ball bearing
Cylindrical roller bearing
Needle roller bearing

Tapered roller bearing
Spherical roller bearing
Thrust ball bearing
Thrust roller bearing
Ball and roller bearings
Working drawings

• One working drawing is made for each non-standard component
• All the necessary information to carry out manufacturing must be contained within the drawing
• Recommendation: use a reference (textbook) when draw a working drawing
• Assembly working drawing contain the necessary information to perform the assembly of the system
Working drawings

1. PIN DOWEL

2. SLINGER

3. BRACKET

BILL OF MATERIALS

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QUAN</th>
<th>DRAWING NO. OR PART NAME</th>
<th>DESCRIPTION</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>NUMBER REQUIRED</th>
<th>MATERIAL</th>
<th>FINISH</th>
<th>RICHARD D. IRWIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES</td>
<td>WEIGHT:</td>
<td>NAME</td>
<td>DATE</td>
</tr>
<tr>
<td>TOLERANCES ARE: FRACTIONS ==</td>
<td>DRAWN BY:</td>
<td>Kevin</td>
<td></td>
</tr>
<tr>
<td>XXX DECIMALS ±</td>
<td>CHECKED BY:</td>
<td>Bryan</td>
<td></td>
</tr>
<tr>
<td>XXX DECIMALS ±</td>
<td>APPROVED BY:</td>
<td>Carolyn</td>
<td></td>
</tr>
<tr>
<td>ANGLES: ±</td>
<td>SCALE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>XXX METRIC ±</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>XXX METRIC ±</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
BRUSH ASSEMBLY (2X)
2.354.802.01 (4)

SOLDER LUG (2X)
3.413.820.01 (3)

BRUSH ENDSHIELD
3.137.964.01 (1)

BEARING, SPHERICAL
3.145.820.02 (4)

NOTES:
1. BRUSH ASSEMBLIES (2.354) AND SOLDER LUGS (3.413) TO BE FULLY SEATED.
2. SOLDER LUG (3.413) TO WITHSTAND 30N MINIMUM PUSH-OUT FORCE AFTER ASSEMBLY.
Working drawings
Working drawings
Example of mechanisms
Example of mechanisms

FRONT SECTION OF A 4-CYLINDER INTERNAL COMBUSTION ENGINE

- High tension lead from distributor to spark plug
- Rocker shaft
- Valve spring
- Spark plug cover
- Exhaust Manifold
- Combustion chamber
- Dipstick
- Starter motor
- Flywheel
- Carburettor
- Inlet Manifold
- Distributor
- Push-rod
- Tappets
- Camshaft
- Oil pump housing
- Oil filter
- Oil suction filter
Example of mechanisms

Bosch Electronic Petrol Injection
Example of mechanisms
Example of mechanisms