Introduction to Engineering

Dimensioning 4: Tolerances

Control of Variability &
Reading Construction and Working Drawings

Goals

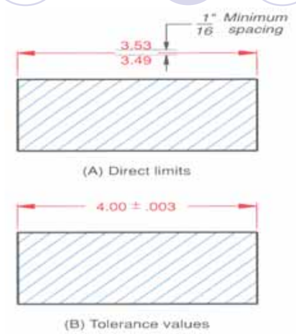
- Understand the description and control of variability through tolerancing.

Tolerance is the total amount a dimension may vary and is the difference between the maximum and minimum limits.

Ways to Express:

1. Direct limits or as tolerance values applied to a dimension
2. Tolerance values
3. A general tolerance note in title block
4. Notes referring to specific conditions

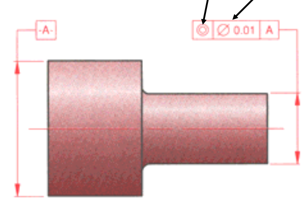
Direct limits and tolerance values



Geometric Tolerance System

Geometric dimensioning and tolerancing (GD&T) is a method of defining parts based on how they function, using standard ANSI symbols.

(Beyond our scope for now.)



Tolerance Specifications in Title Block

General tolerance note specifies the following tolerance for untoleranced dimensions:

INCHES:

One-place decimal ±.1

Two-place decimal ±.02

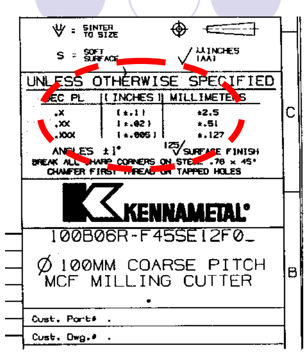
Three-place decimal ±0.005

MILLIMETERS:

One-place decimal ±2.5

Two-place decimal ±0.51

Three-place decimal ±0.127



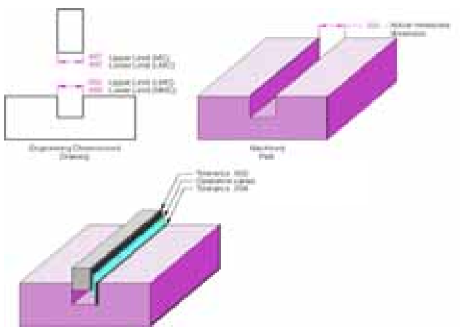
Notes referring to specific conditions

General Tolerances could be in the form of a note similar to the one shown below:

ALL DECIMAL DIMENSIONS TO BE HELD TO ±.002"

Means that a dimension such as .500 would be assigned a tolerance of ±0.002, resulting in a upper limit of .502 and a lower limit of .498

Important Terms



Important Terms – single part

- **Nominal Size** – general size, usually expressed in common fractions (1/2" for the slot)
- **Basic Size** – theoretical size used as starting point (.500" for the slot)
- **Actual Size** – measured size of the finished part (.501" for the slot)

Important Terms – single part

- **Limits** – maximum and minimum sizes shown by tolerances (.502 and .498 – larger value is the upper limit and the smaller value is the lower limit, for the slot)
- **<u>Tolerance</u>** – total allowable variance in dimensions (upper limit – lower limit) – object dimension could be as big as the upper limit or as small as the lower limit or anywhere in between

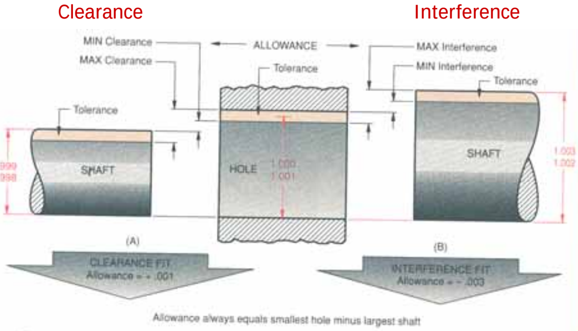
Important Terms – Multiple Parts

- **Fit** – degree of tightness between two parts
  - *Clearance Fit* – tolerance of mating parts always leave a space – *fits easily*
  - *Interference Fit* – tolerance of mating parts always interfere – *will not fit without force*
  - *Transition Fit* – sometimes interfere, sometimes clear – *may or may not fit*

Shaft and Hole – Clearance and Interference Fits

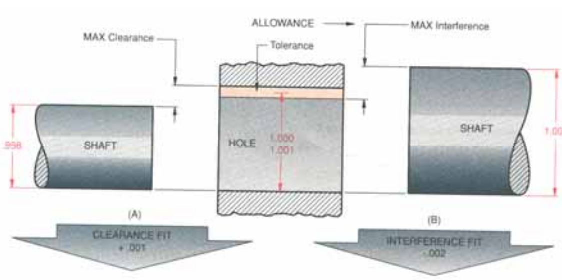
Clearance

Interference

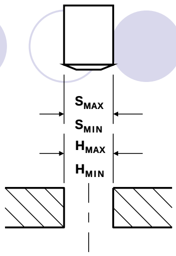


Shaft and Hole Fits – Transition Fit

Transition



Basic Hole System



- Clearance = Hole – Shaft
- $C_{max} = H_{max} – S_{min}$
- $C_{min} = H_{min} – S_{max}$

Both C_{max} >0 and C_{min} >0 – Clearance fit

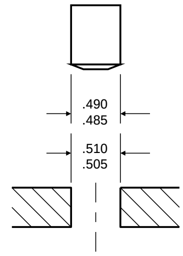
Both C_{max} <0 and C_{min} <0 – Interference fit

C_{max} > 0 and C_{min} < 0 – Transition fit

- System Tolerance = $C_{max} - C_{min}$

Basic Hole System – Example

Calculate Maximum and Minimum Clearance



Clearance = Hole – Shaft

Cmax = Hmax – Smin

Cmax = .510 - .485 = .025

Cmin = .505-.490 = .015

What is Type of Fit? Cmax >0 & Cmin > 0 Clearance

Checking your work

- Tolerance of the system = the sum tolerances of all its parts

$$T_{sys} = T_{hole} + T_{shaft}$$

AND

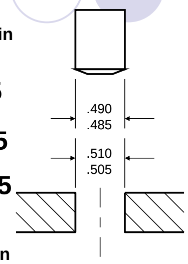
$$T_{sys} = C_{max} - C_{min}$$

- Check:

$$T_{hole} + T_{shaft} = C_{max} - C_{min}$$

For Example

$T_{sys} = T_{hole} + T_{shaft} = C_{max} – C_{min}$



T_{hole} = .510 - .505 = .005

T_{shaft} = .490 - .485 = .005

$C_{max} – C_{min}$ = .025 - .015

$T_{hole} + T_{shaft} = C_{max} – C_{min}$

.005 + .005 =.025 - .015

T_{sys} = .010 = .010

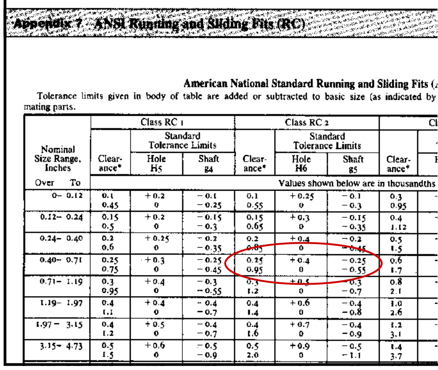
How to Determine Limits

- You can calculate tolerances, given the max and min limits on a dimension.
- How does a design engineer know what limits to use?
  - First, decide what type of fit you want.
  - Then, use a table.

Standard Precision Fits: English Units

- Running and sliding fits (SC)
- Clearance locational fits (LC)
- Transition locational fits (LT)
- Interference locational fits (LN)
- Force and shrink fits (FN)

Example – What are tolerance limits for a Nominal ½” hole with RC**2** fit?



Appendix 7 ANSI Running and Sliding Fits (RC)

American National Standard Running and Sliding Fits (

Tolerance limits given in body of table are added or subtracted to basic size (as indicated by mating parts.

Nominal Size Range, Inches (Over To)	Class RC 1 Clearance*	Class RC 1 Standard Tolerance Limits Hole H5	Class RC 1 Standard Tolerance Limits Shaft g4	Class RC 2 Clearance*	Class RC 2 Standard Tolerance Limits Hole H6	Class RC 2 Standard Tolerance Limits Shaft g5	Cl[illegible] Clearance*
	Values shown below are in thousandths						
0– 0.12	0.1 0.45	+0.2 0	−0.1 −0.25	0.1 0.55	+0.25 0	−0.1 −0.3	0.3 0.95
0.12– 0.24	0.15 0.5	+0.2 0	−0.15 −0.3	0.15 0.65	+0.3 0	−0.15 −0.35	0.4 1.12
0.24– 0.40	0.2 0.6	+0.25 0	−0.2 −0.35	0.2 0.85	+0.4 0	−0.2 −0.45	0.5 1.5
0.40– 0.71	0.25 0.75	+0.3 0	−0.25 −0.45	0.25 0.95	+0.4 0	−0.25 −0.55	0.6 1.7
0.71– 1.19	0.3 0.95	+0.4 0	−0.3 −0.55	0.3 1.2	+0.5 0	−0.3 −0.7	0.8 2.1
1.19– 1.97	0.4 1.1	+0.4 0	−0.4 −0.7	0.4 1.4	+0.6 0	−0.4 −0.8	1.0 2.6
1.97– 3.15	0.4 1.2	+0.5 0	−0.4 −0.7	0.4 1.6	+0.7 0	−0.4 −0.9	1.2 3.1
3.15– 4.73	0.5 1.5	+0.6 0	−0.5 −0.9	0.5 2.0	+0.9 0	−0.5 −1.1	1.4 3.7

Hole Max .5004

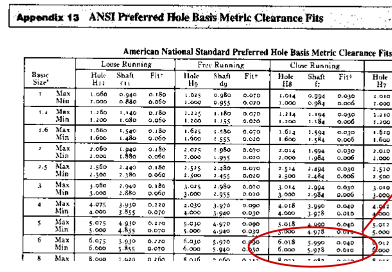
Min .5000

Shaft

Max .49975

Min .49945

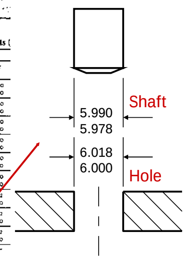
Metric Tolerance Example - Nominal 6 mm Hole and Shaft with Close Running Fit 6 H8/f7



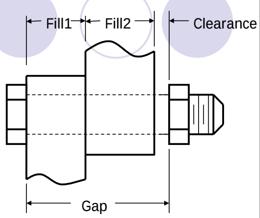
Appendix 13 ANSI Preferred Hole Basis Metric Clearance Fits

American National Standard Preferred Hole Basis Metric Clearance Fits (

Basic Size*		Loose Running Hole H11	Loose Running Shaft c11	Loose Running Fit*	Free Running Hole H9	Free Running Shaft d9	Free Running Fit*	Close Running Hole H8	Close Running Shaft f7	Close Running Fit*	Hole H7
1	Max Min	1.060 1.000	0.940 0.880	0.180 0.060	1.025 1.000	0.980 0.955	0.070 0.020	1.014 1.000	0.994 0.984	0.030 0.006	1.010 1.000
1.2	Max Min	1.260 1.200	1.140 1.080	0.180 0.060	1.225 1.200	1.180 1.155	0.070 0.020	1.214 1.200	1.194 1.184	0.030 0.006	1.210 1.200
1.6	Max Min	1.660 1.600	1.540 1.480	0.180 0.060	1.625 1.600	1.580 1.555	0.070 0.020	1.614 1.600	1.594 1.584	0.030 0.006	1.610 1.600
2	Max Min	2.060 2.000	1.940 1.880	0.180 0.060	2.025 2.000	1.980 1.955	0.070 0.020	2.014 2.000	1.994 1.984	0.030 0.006	2.010 2.000
2.5	Max Min	2.560 2.500	2.440 2.380	0.180 0.060	2.525 2.500	2.480 2.455	0.070 0.020	2.514 2.500	2.494 2.484	0.030 0.006	2.510 2.500
3	Max Min	3.060 3.000	2.940 2.880	0.180 0.060	3.025 3.000	2.980 2.955	0.070 0.020	3.014 3.000	2.994 2.984	0.030 0.006	3.010 3.000
4	Max Min	4.075 4.000	3.930 3.855	0.220 0.070	4.030 4.000	3.970 3.940	0.090 0.030	4.018 4.000	3.990 3.978	0.040 0.010	4.012 4.000
5	Max Min	5.075 5.000	4.930 4.855	0.220 0.070	5.030 5.000	4.970 4.940	0.090 0.030	5.018 5.000	4.990 4.978	0.040 0.010	5.012 5.000
6	Max Min	6.075 6.000	5.930 5.855	0.220 0.070	6.030 6.000	5.970 5.940	0.090 0.030	6.018 6.000	5.990 5.978	0.040 0.010	6.012 6.000
8	Max	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]



Basic System



Clearance = Gap – Fill

Fill = Fill1 + Fill2

- $C_{max} = G_{max} – F_{min}$
- $C_{min} = G_{min} – F_{max}$

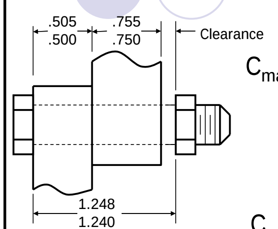
  Both C_{max} >0 and C_{min} >0 – Clearance fit

  Both C_{max} <0 and C_{min} <0 – Interference fit

  C_{max} > 0 and C_{min} < 0 – Transition fit

- System Tolerance = $C_{max} - C_{min}$

Gap and Fill Clearance Example



What is Type of Fit?

Both are negative,

so interference fit.

Clearance = Gap – Fill

$C_{max} = G_{max} – F_{min}$

C_{max} = 1.248 – (.500 + .750)

C_{max} = 1.248 – (1.250)

C_{max} = - 0.002

$C_{min} = G_{min} – F_{max}$

C_{min} = 1.240 – (.505 + .755)

C_{min} = 1.240 – (1.260)

C_{min} = - 0.020