Autodesk Inventor Engineer s Handbook

هندبوک مهندسی نرم افزار Autodesk Inventor

انجمن اینونتور ایران

www.irinventor.com

Email: irinventor@chmail.ir irinventor@hotmail.com

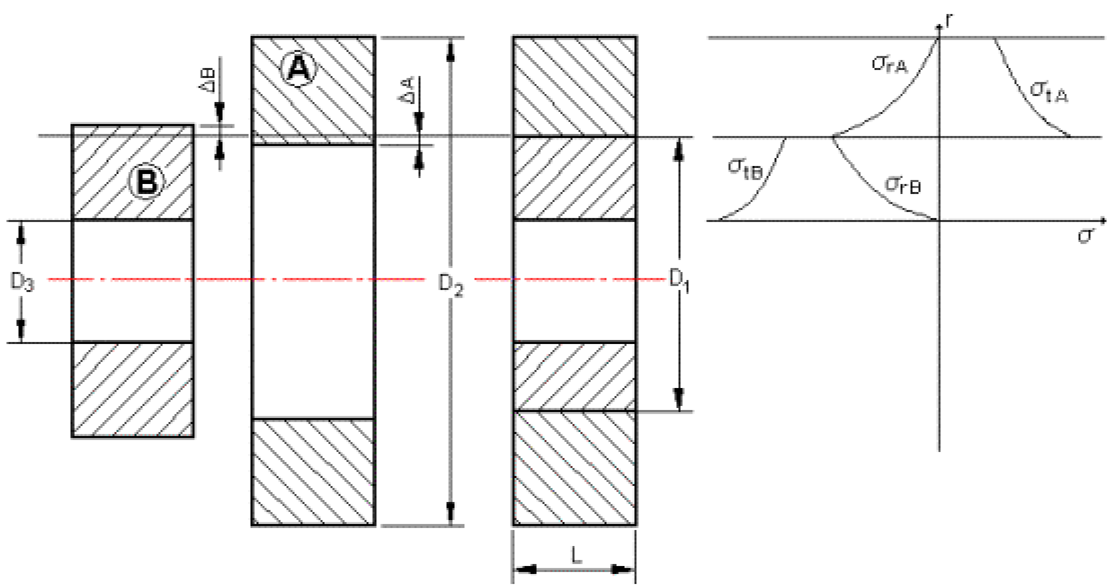
Tel: 09352191813 & 021-46088862

Joints / Fixed Joints

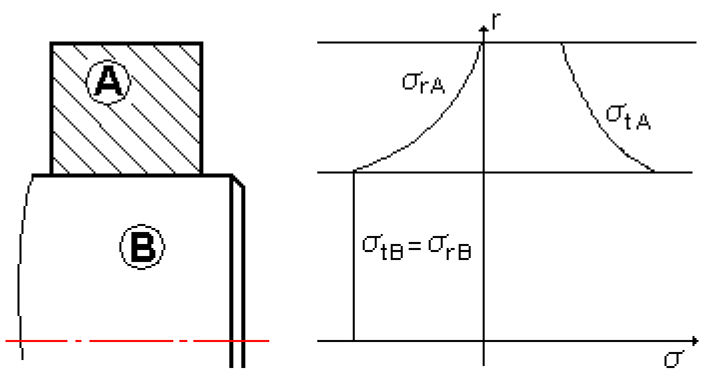
Press Fit Handbook

Calculation formulas

Hollow Shaft



Solid Shaft



$$Q_A = \frac{D_2}{D_1}$$

$$Q_B = \frac{D_1}{D_3}$$

$$C_{1A} = \frac{1}{E_A} \cdot \left(\frac{Q_A^2 + 1}{Q_A^2 - 1} + \mu_A \right)$$

$$C_{1B} = \frac{1}{E_B} \cdot \left(\frac{Q_B^2 + 1}{Q_B^2 - 1} - \mu_B \right)$$

$C_1 = C_{1A} + C_{1B}$

$\Delta = p_T D_1 C_1 + H$

Minimum practicable interference

Minimum practicable interference is calculated from condition of required transmitted load. Smaller interference would not transfer required load.

$$p'_{T\,min} = \frac{k \cdot F_p}{\pi \cdot D_1 \cdot L \cdot \upsilon}$$ or $$p'_{T\,min} = \frac{2 \cdot k \cdot M_p}{\pi \cdot D_1^2 \cdot L \cdot \upsilon}$$

$$\Delta'_{min} = p'_{T\,min} \cdot D_1 \cdot C_1 + H = \frac{k \cdot F_p}{\pi \cdot L \cdot \upsilon} C_1 + H = \frac{2 \cdot k \cdot M_p}{\pi \cdot D_1 \cdot L \cdot \upsilon} \cdot C_1 + H$$

Maximum practicable interference

Maximum practicable interference is calculated from condition of material strength limit. Larger interference would cause hub or shaft material to be damaged.

Hub Shaft

$$p'_{A\,max} = \frac{Q_A^2 - 1}{\sqrt{3 Q_A^4 + 1}} \cdot \sigma_A$$ $$p'_{B\,max} = \frac{1 - \frac{1}{Q_B^2}}{2} \cdot \sigma_B$$

Hollow shaft

The following inequalities must be true:

$\Delta'_{max} \leq p'_{Amax} D_1 C_1 + H$

$\Delta'_{max} \leq p'_{Bmax} D_1 C_1 + H$

Solid shaft

The following inequalities must be true:

$\Delta'_{max} \leq p'_{Amax} D_1 C_1 + H$

$\Delta'_{max} \leq \sigma_B D_1 C_1 + H$

The minimum interference from both inequalities is selected as the maximum interference.

The maximum and minimum interference

The calculation designs a fit according to the corresponding standards, such as ISO, ANSI, JIS, and others. The standard fit cannot exceed limits for maximum and minimum interference. The maximum and minimum interference intended for another calculation part is determined from the selected fit. If the corresponding fit cannot be selected, the deviations are numerically expressed and calculated by dividing the tolerance field into two halves.

Enlarging of outer diameter of external part

$$\varphi_A = \frac{2 \cdot D_2 \cdot p_T}{E_A \cdot \left(Q_A^{\,2} - 1\right)} = \frac{2 \cdot Q_A}{E_A \cdot C_1 \left(Q_A^{\,2} - 1\right)} \cdot (\Delta - H)$$

$\Delta'_{max} \leq p'_{Amax} D_1 C_1 + H$

$\Delta'_{max} \leq \sigma_B D_1 C_1 + H$

The minimum interference from both inequalities is selected as the maximum interference.

Δ_{max} is substituted for Δ when the maximum reduction of D_2 diameter is to be calculated

Δ_{min} is substituted for Δ when the maximum reduction of D_2 diameter is to be calculated

Reducing the inner diameter of internal part

$$\varphi_B = \frac{2 \cdot D_3 \cdot p_T}{E_B \left(1 - \frac{1}{Q_B^{\,2}}\right)} = \frac{2 \cdot Q_B}{E_B \cdot C_1 \left(Q_B^{\,2} - 1\right)} \cdot (\Delta - H)$$

Δ_{max} is substituted for Δ when the maximum reduction of D_3 diameter is to be calculated

Δ_{min} is substituted for Δ when the maximum reduction of D_2 diameter is to be calculated

Calculating pressing force

$$F_{max} = p_{T\,max} \cdot \pi \cdot D_1 \cdot L \cdot \upsilon_1 = (\Delta_{max} - H) \cdot \frac{\pi \cdot L \cdot \upsilon_1}{C_1}$$

$$F_{min} = p_{T\,min} \cdot \pi \cdot D_1 \cdot L \cdot \upsilon_1 = (\Delta_{min} - H) \cdot \frac{\pi \cdot L \cdot \upsilon_1}{C_1}$$

Calculating heating temperature of outer part

$$t_A = t + \frac{\Delta_{max} + V - \alpha_B \cdot D_1 (t_B - t)}{\alpha_A \cdot D_1}$$

Calculating heating temperature of internal part

$$t_B = t + \frac{\Delta_{max} + V - \alpha_A \cdot D_1 (t_A - t)}{\alpha_B \cdot D_1}$$

Torque

$M_p = Fp\ D_1/2$

Meaning of used variables:

M_p Torque
E_A Modulus of elasticity
E_B Modulus of elasticity
μA Poisson's Ratio
μB Poisson's Ratio
D_1 Outer diameter of external part (hub)
D_2 Pressure fit diameter (nominal diameter of calculated fit)
D_3 Inner diameter of internal part (shaft)
L Connection length
F_{pmax} Max. pressing force
F_{pmin} Min. pressing force
k Safety factor
ν Clamping factor
ν_1 Clamping factor during pressing
σ_A Thermal expansion of outer part (hub)
σ_B Thermal expansion of internal part (shaft)

H Surface smoothness
V Assembly clearance
P_{max} Max. contact pressure
P_{min} Min. contact pressure
p'_{Tmin} Minimum practicable contact pressure
p_{Tmin} Minimum practicable contact pressure
p_{Tmax} Maximum contact pressure
p'_{Amax} Allowable pressure on the hole of external part
p'_{Bmax} Allowable pressure on the hole of internal part
Δ Interference
Δ'_{min} Minimum practicable interference
Δ'_{max} Maximum practicable interference
Δ_{min} Minimum interference
Δ_{max} Maximum interference
α_A Factor of thermal expansion of external part material
α_B Factor of thermal expansion of internal part material
t Basic temperature

Clamping factor

Proportionally effects size of the clamping force and the clamping torque and it is a constant for each specific pressure connection. It depends on the sliding friction factor, such as, shape deviation, material heterogeneity, method of creating the pressure connection, and others.

The clamping factor is affected when it is greater:

- At nonlubricated pressure connections.
- In the longitudinal direction than in the circumferential.
- For loosening than for sliding.
- For a pressure connection made by shrinkage than for pressure connection made by expansion and pressing.

Surface quality

effects the size of surface smoothness at contact surfaces and the size of efficient interference. Surface smoothness is not applied to perfectly smooth surfaces. For those surfaces, the efficient interference equals the minimum interference and the maximum loading capacity.

Review of surface quality achieved by specific machining methods.

Roughness Average, Ra - micrometers [µm] (microinches [µin])

	50	25	12.5	6.3	3.2	1.6	0.8	0.4	0.2	0.1	0.05	0.025	0.0125
	(2000)	(1000)	(500)	(250)	(125)	(63)	(32)	(16)	(8)	(4)	(2)	(1)	(0.5)
Flame cutting	-	+	-										
Snagging	-	+	+	-									
Sawing	-	+	+	+	+	-							
Planning, shaping		-	+	+	+	-	-						
Drilling			-	+	+	-							
Chemical milling			-	+	+	-							
Electric discharge			-	+/-	+	-							
Milling		-	-	+	+	+	-	-					
Broaching				-	+	+	-						
Reaming				-	+	+	-						
Electron beam				+	+	+	-	-					
Laser				+	+	+	-	-					
Electro - chemical			-	-	+	+	+	+	-	-			
Boring, turning		-	-	+	+	+	+	-	-	-	-		
Barrel finishing					-	-	+	+	-	-			
Electrolytic grinding							-/+	+	-				
Roller burnishing							-	+	-				
Grinding				-	-	+	+	+	+	-	-		
Honing						-	+	+	+	-	-		
Electro - polish						-	+	+	+	-	-	-	

Polishing							-	+	+	-	-	-
Lapping							-	+	+	-	-	-
Superfinishing							-	-	+	+	+	-
Sand casting	-	+	-									
Hot rolling	-	+	-									
Forging		-	+	+	-							
Permanent mold casting				-	+	-						
Investment casting				-	+	-	-					
Extruding			-	-	+	+	-					
Cold rolling, drawing				-	-	+	+	-				
Die casting					-	+	-					

Key:

+: Average application

- : Less frequent application

The ranges shown are typical of the processes listed.

Higher or lower values may be obtained under special conditions.

Surface Smoothness

Reduces the efficient interference. Since you rarely determine the real surface smoothness value, use its maximum value in the calculation, so that surface smoothness of both contact surfaces reduces the height of unevenness to half. Surface smoothness greatly depends on the surface shape, which is determined by the machining method. It is small for ground surfaces. Surface smoothness values in calculations are entered in [mm] or [in]. The recommended surface smoothness is calculated using the formula:

$$H = R_{zA} + R_{zB} \cong 4\,(R_{aA} + R_{aB})$$

where:

R_{zA} unevenness height of hole surface of external part

R_{zB} unevenness height of shaft surface of internal part

R_{aA} surface texture (mean arithmetic deviation) of external part hole

R_{aB} surface texture (mean arithmetic deviation) of internal part shaft

Assembly clearance

Specifies the assembly clearance, which is an important dimension for the shaft cooling temperature calculation and hub warming. In this formula, the D_1 value is always used in millimeters. With the ANSI calculation, the value is applied in inches.

$$V = 0.01\sqrt{D_1}$$

where:

D_1 diameter of press fit [mm]

Material table

Material name	*Modulus of elasticity [MPa]*	*Allowable stress [MPa]*	*Poisson's ratio [-]*	*Thermal contraction [1/°C]*	*Thermal expansion [1/°C]*
Steel	2 100 000	310	0.3	0.000 011	-0.000 008 5
Malleable cast iron	95 000	55	0.3	0.000 010	-0.000 008
Copper	125 000	40	0.3	0.000 016	-0.000 001 4
Brass	80 000	40	0.3	0.000 018	-0.000 001 6
Bronze	110 000	40	0.3	0.000 016	-0.000 001 4
Aluminum alloy	70 000	30	0.3	0.000 023	-0.000 001 8
Magnesium alloy	41 000	30	0.3	0.000 026	-0.000 002 1
Cast iron	90 000	40	0.25	0.000 010	-0.000 008

Other Materials for CSN

Material name	*Modulus of elasticity [MPa]*	*Allowable stress [MPa]*	*Poisson's ratio [-]*	*Thermal contraction [1/°C]*	*Thermal expansion [1/°C]*
11 600	2 100 000	300	0.3	0.000 011	-0.000 008 5
11 700	2 100 000	300	0.3	0.000 010	-0.000 008 5

ANSI

Material name	*Modulus of elasticity [psi]*	*Allowable stress [psi]*	*Poisson's ratio [-]*	*Thermal contraction [1/°F]*	*Thermal expansion [1/°F]*
Steel	3.00 E $^{+07}$	65 000	0.3	0.000 007	-0.000 007
Malleable cast iron	1.59 E $^{+07}$	20 000	0.33	0.000 010 4	-0.000 010 4
Copper	1.49 E $^{+07}$	25 000	0.14	0.000 011 8	-0.000 011 8
Brass	1.03 E $^{+07}$	15 000	0.33	0.000 013	-0.000 013
Bronze	6.30 E $^{+06}$	18 000	0.28	0.000 014	-0.000 014
Aluminum alloy	2.76 E $^{+07}$	35 000	0.3	0.000 009 6	-0.000 006
Magnesium alloy	1.50 E $^{+07}$	20 000	0.25	0.000 006	-0.000 006
Cast iron	2.36 E $^{+07}$	55 000	0.3	0.000 007 5	-0.000 007 5

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& irinventor@hotmail.com

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