



ESCOLA POLITÉCNICA DA UNIVERSIDADE DE SÃO PAULO

Desenhos técnicos de fabricação, tolerâncias e acabamento superficial

2023.1 R3b

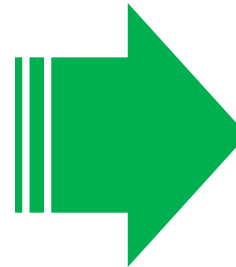
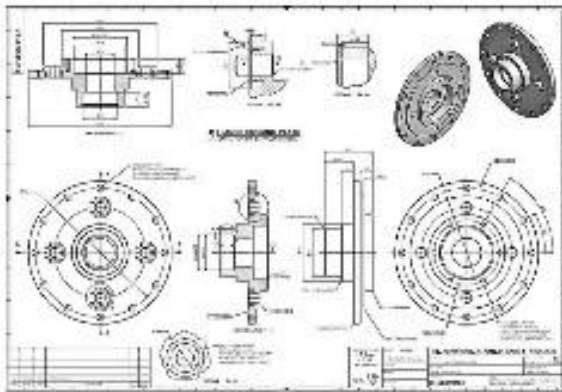


Como uma matéria prima vira uma peça?



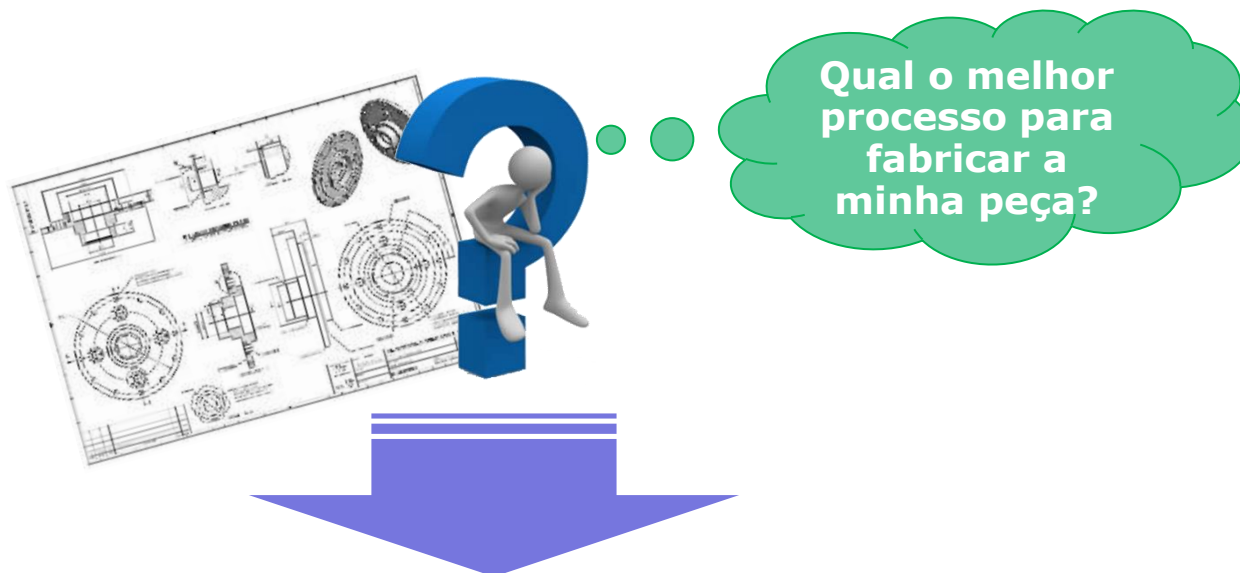


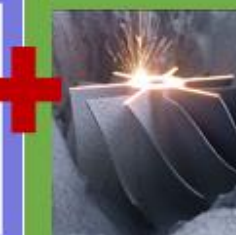
Como um desenho técnico vira uma peça?





Processos de fabricação

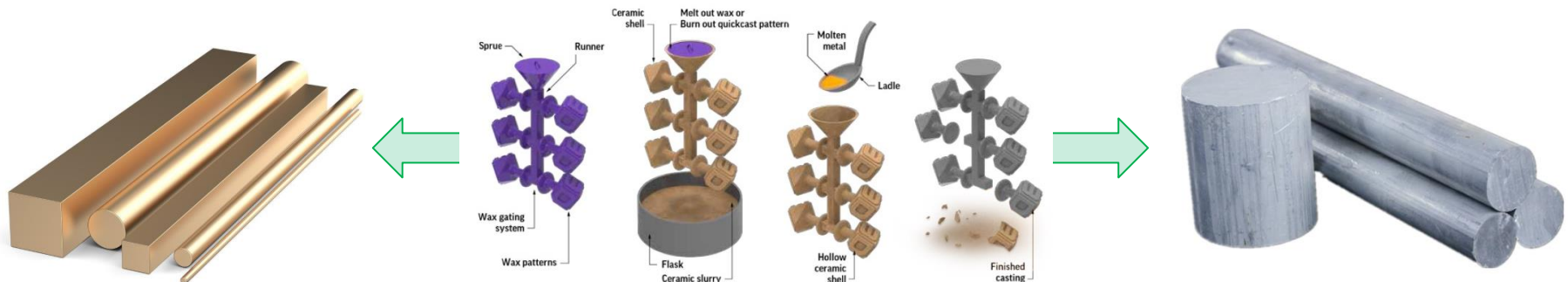
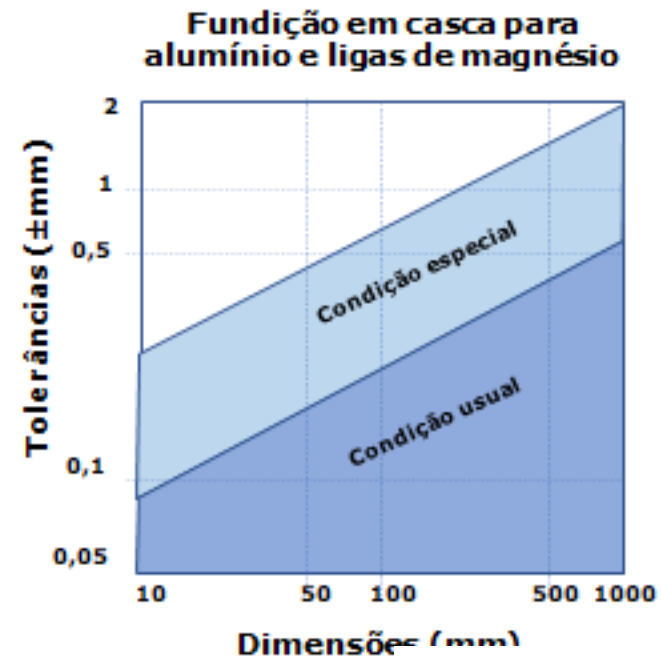
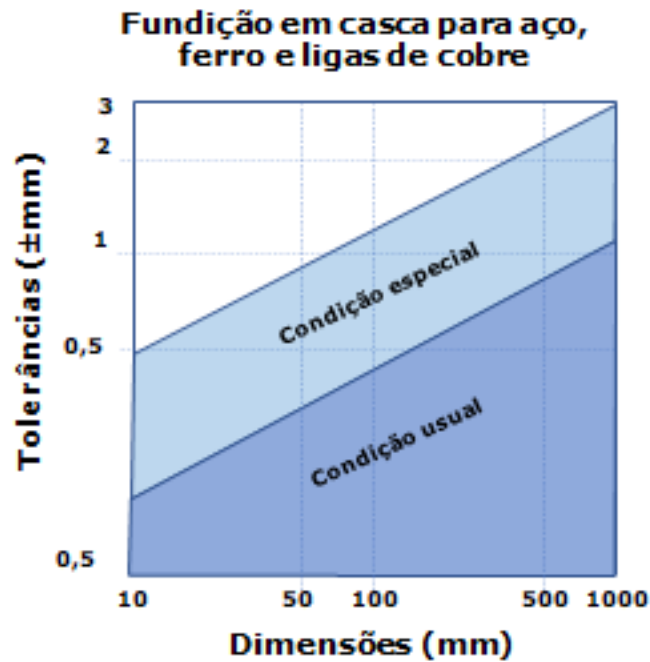


Processos de Fabricação						
1	2	3	4	5	6	7
Formas primárias	Formas conformadas (secundárias)	Usinagem	Uniãoes	revestimentos	alterações de propriedades dos materiais	Manufatura aditiva
						



Relação entre processos de fabricação e tolerâncias

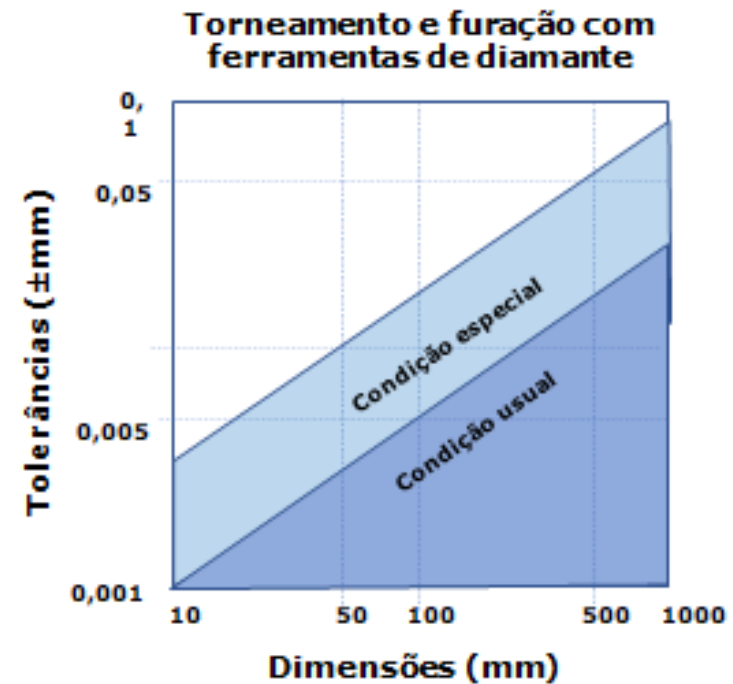
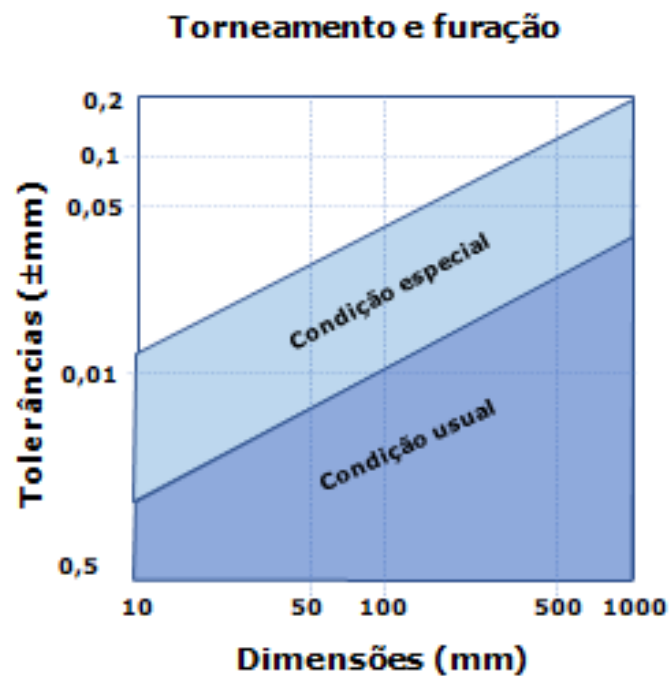
Mesmo processo com materiais diferentes





Relação entre processos de fabricação e tolerâncias

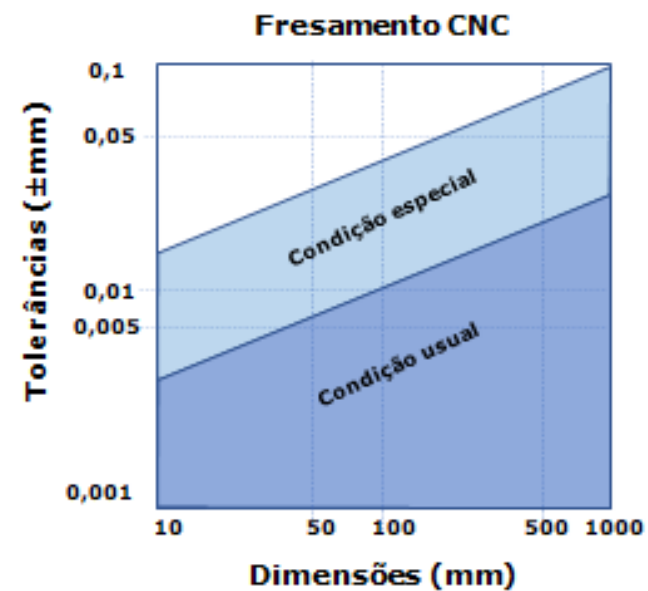
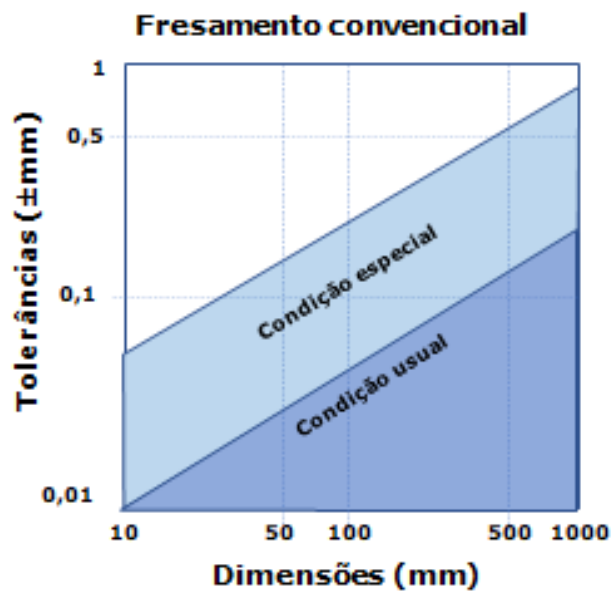
Mesmo processos com ferramentas diferentes





Relação entre processos de fabricação e tolerâncias

Mesmo processos com tecnologias diferentes





Relação entre processos de fabricação e acabamento superficial

Para cada grupo de dimensões (medidas nominais), tem-se 18 qualidades de trabalho, denominadas como *tolerâncias fundamentais*.

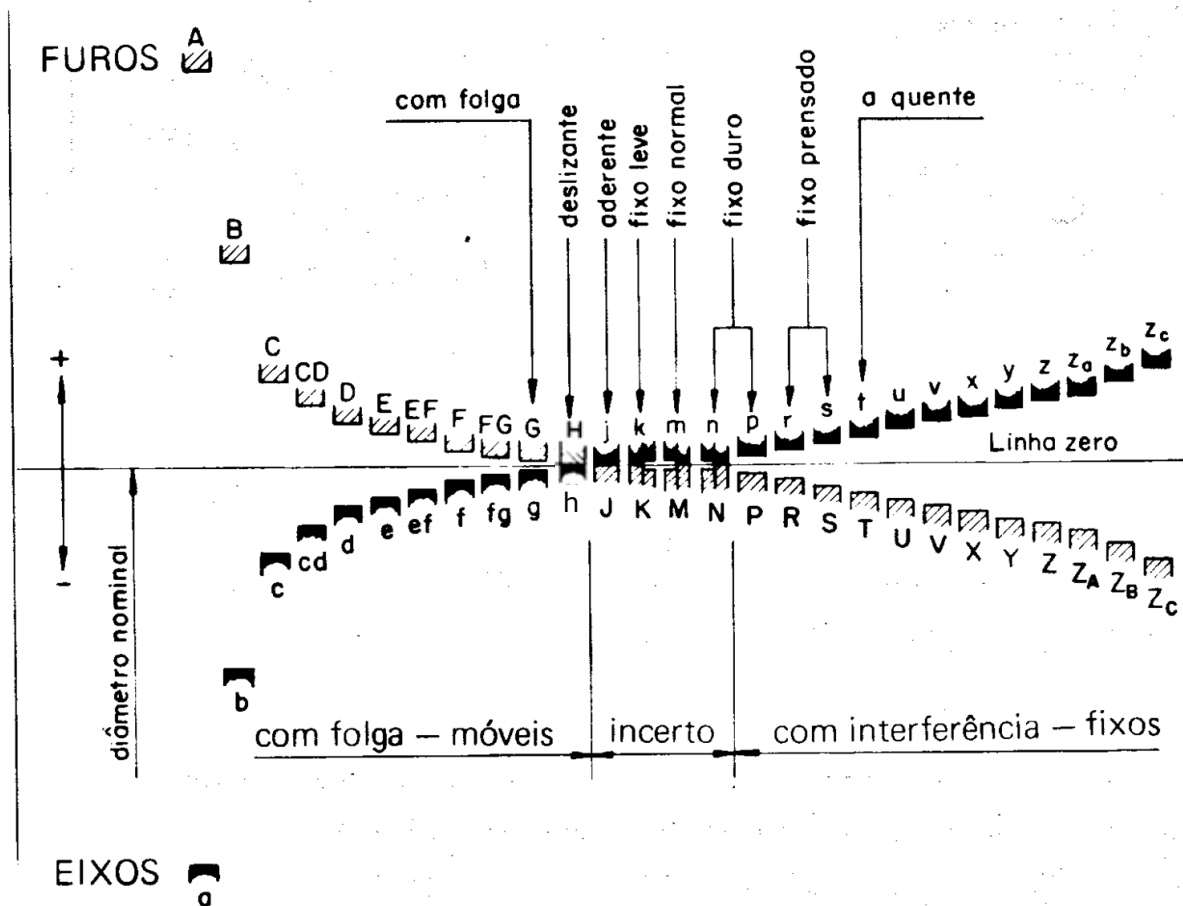


A cada uma das qualidades de trabalho corresponde um valor de tolerância.



Relação entre processos de fabricação e acabamento superficial

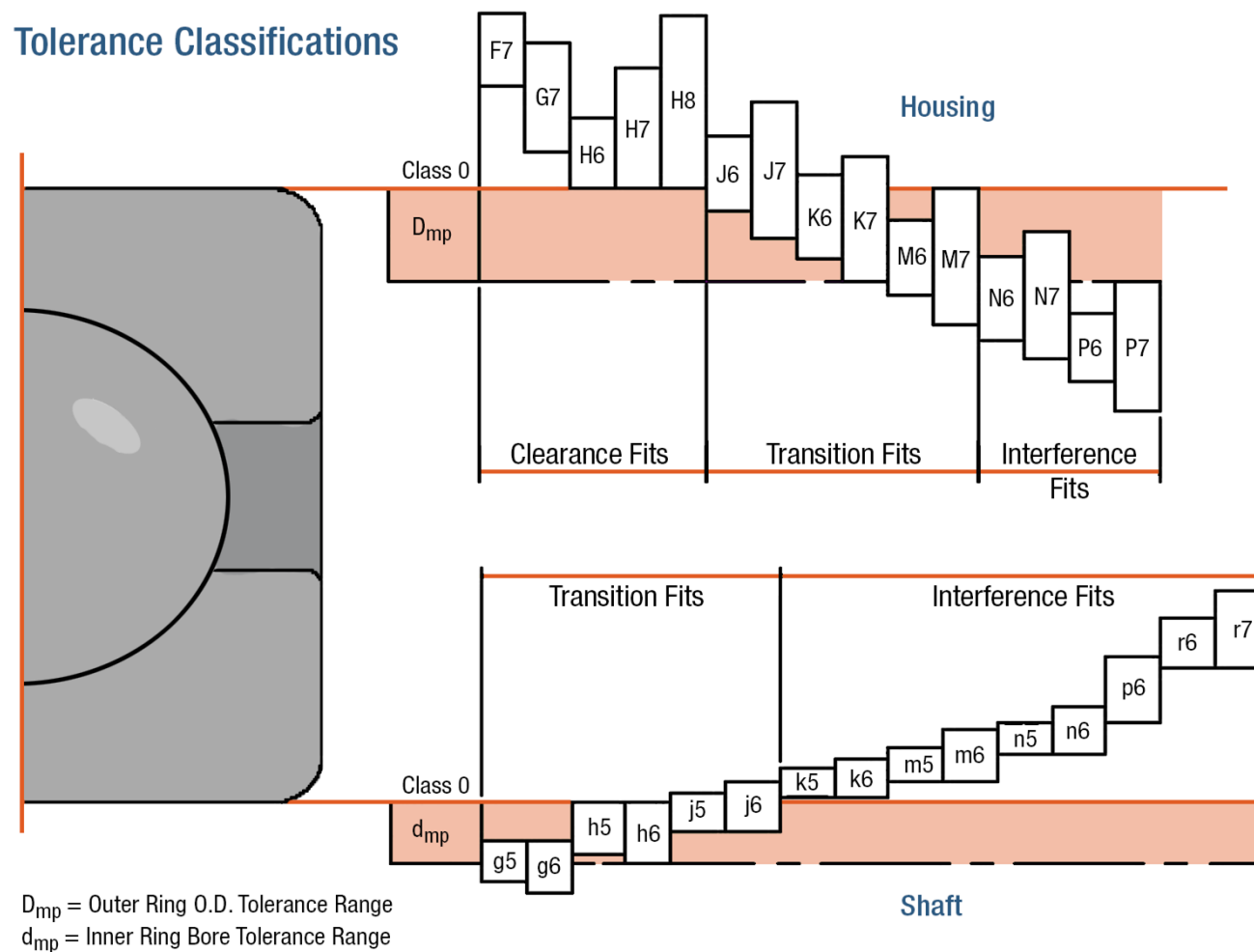
Posição de campo de tolerâncias.





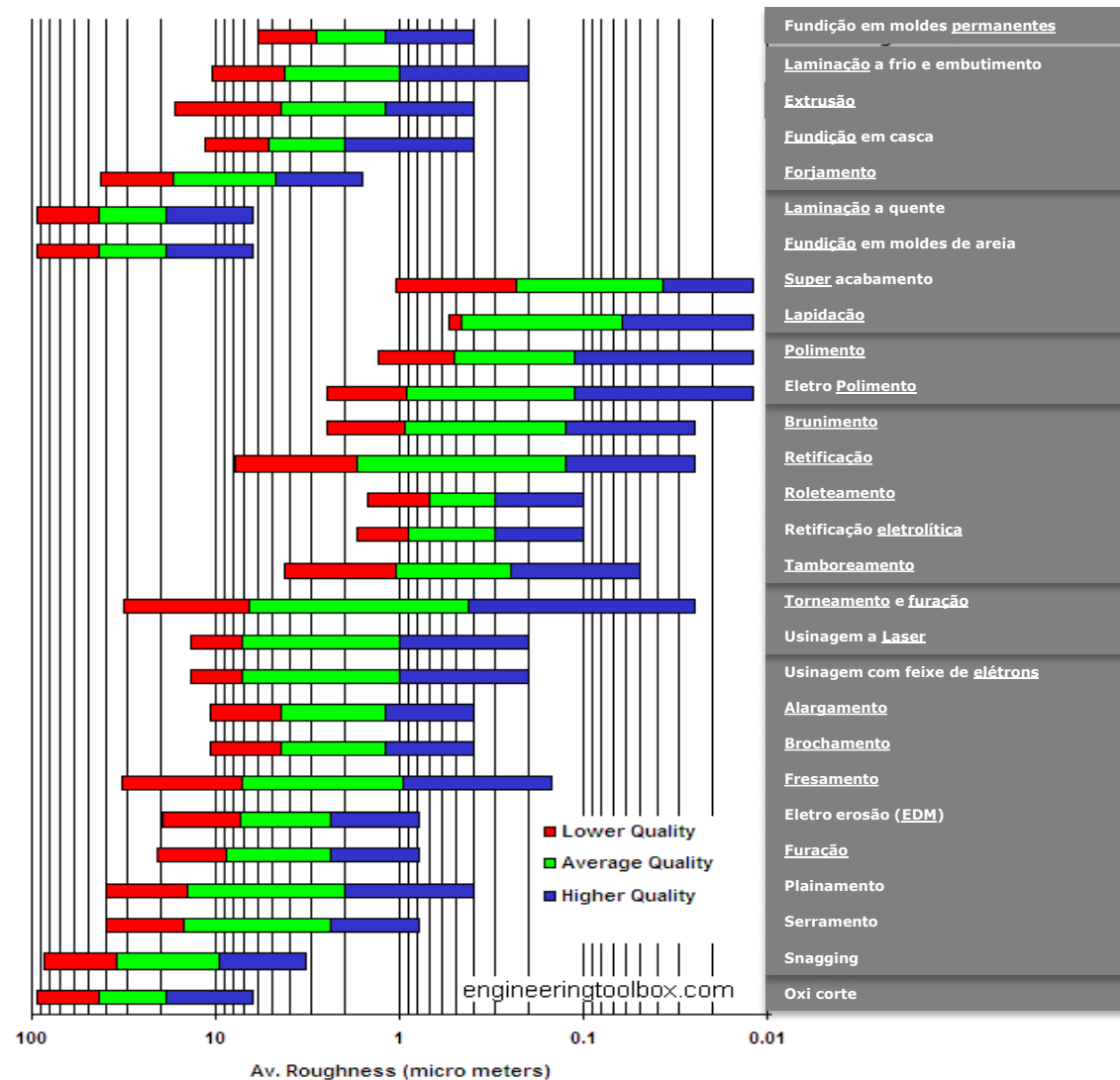
Relação ente processos de fabricação e acabamento superficial

Posição de campo de tolerâncias.





Relação ente processos de fabricação e acabamento superficial

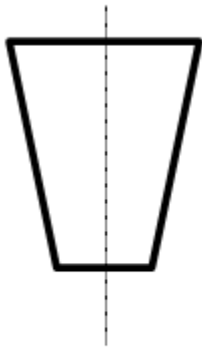




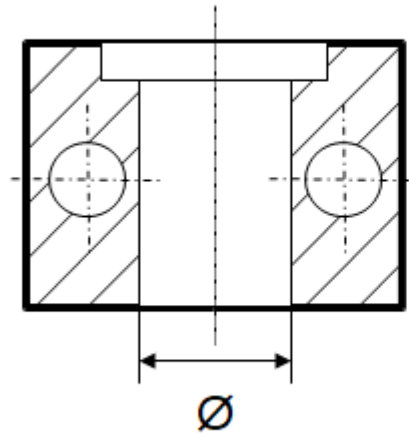
Análise dos desenhos de fabricação

Um desenho de fabricação contém informações relativas a:

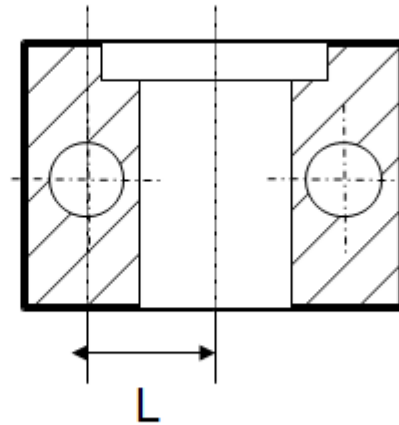
FORMA



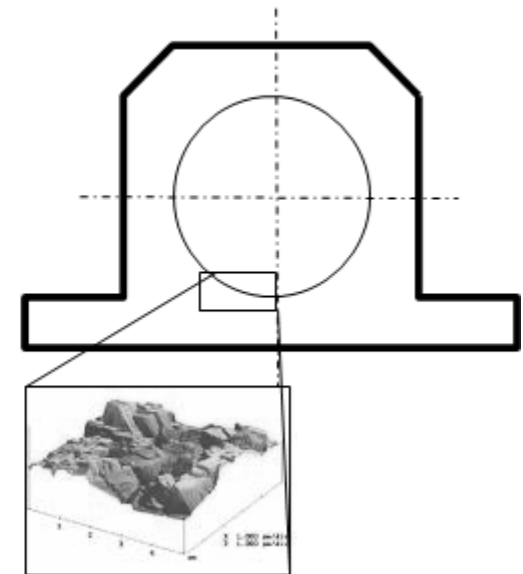
DIMENSÃO



POSIÇÃO



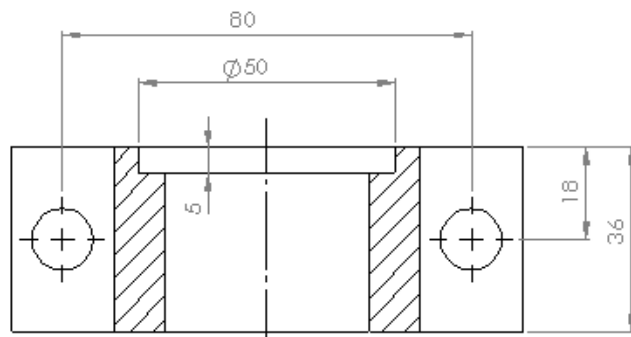
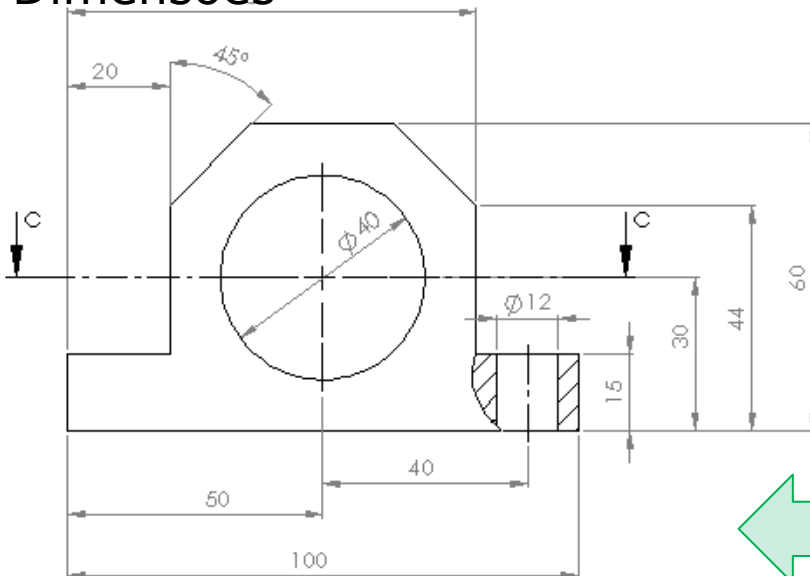
TEXTURA





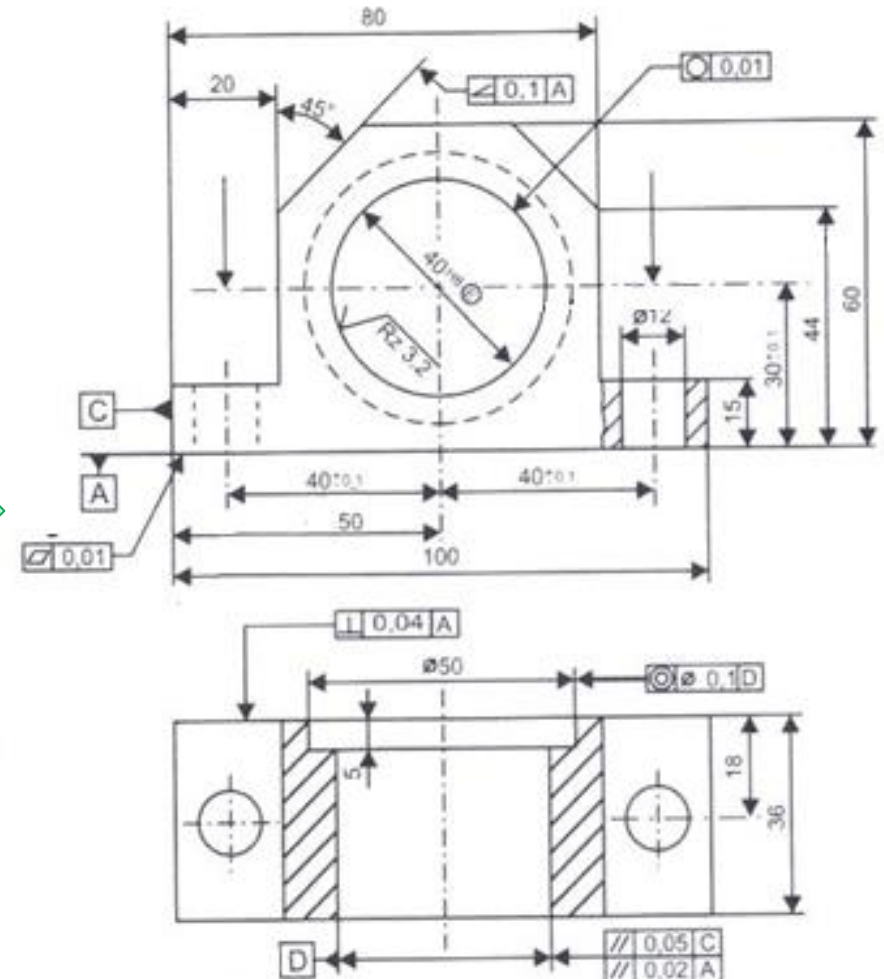
Desenho de Fabricação

Etapa 1: Definição das Dimensões



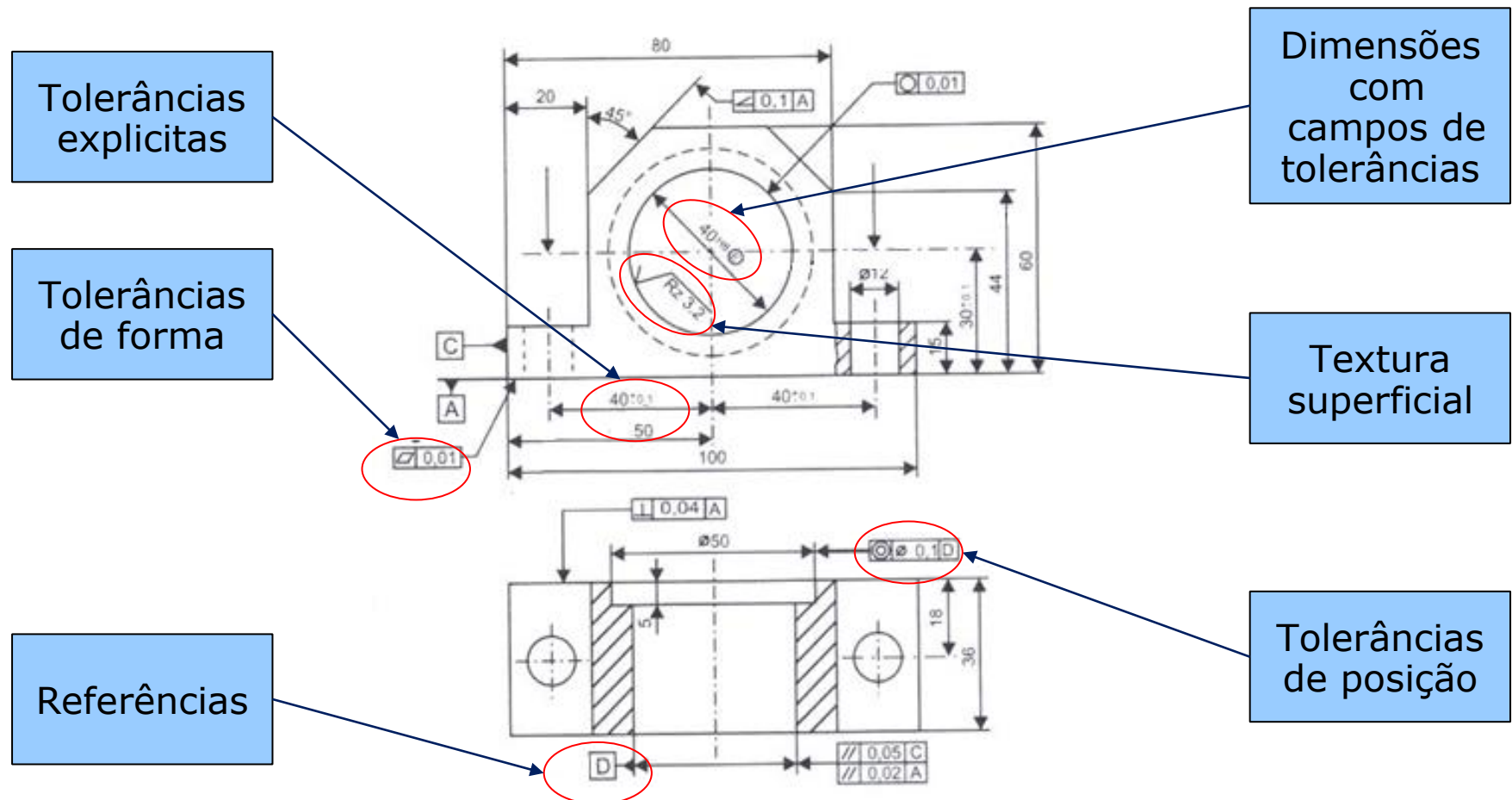
SEÇÃO C-C
ESCALA 1:1

Etapa 2: Definição das Tolerâncias





Um **desenho de fabricação** deve conter todas as informações e relações dimensionais e geométricas, suas devidas tolerâncias, além de informações relativas ao acabamento superficial e tratamento térmico.





Análise dos desenhos de fabricação

Tolerâncias dimensionais conforme norma DIN 7168, se não
houver especificação vale a norma

DESVIOS MÉDIOS ADMISSÍVEIS SEM TOLERÂNCIAS INDICADAS (DIN 7168-m)					
1	6	30	120	400	1000
a	a	a	a	a	a
6	30	120	400	1000	2000
$\pm 0,1$	$\pm 0,2$	$\pm 0,3$	$\pm 0,5$	$\pm 0,8$	$\pm 1,2$

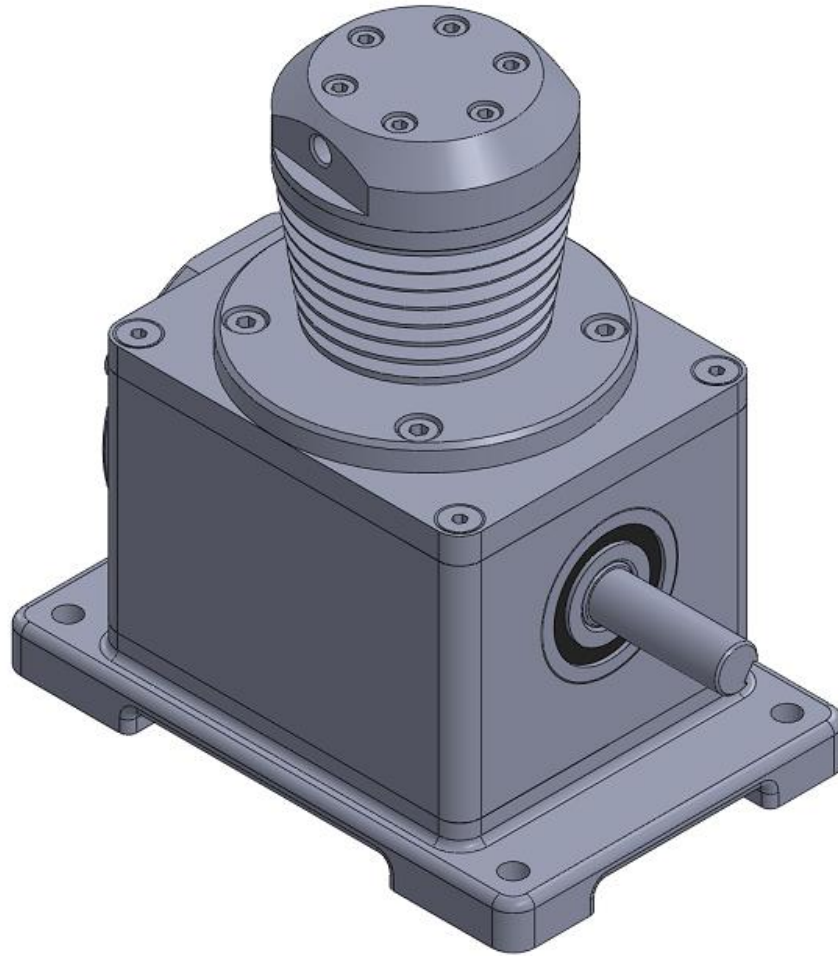


Tolerâncias geométricas mais comuns

	TIPO DE TOLERÂNCIA	CARACTERÍSTICA	SIMBOLO
FEATURES INDIVIDUAIS	FORMA	Linearidade	—
		Planeza	
		Circularidade	○
		Cilindricidade	
FEATURES RELATIVAS	PERFIL	Perfil de uma linha	⌒
		Perfil de uma superfície	D
FEATURES RELACIONADAS	ORIENTAÇÃO	Inclinação	
		Perpendicularismo	
		Paralelismo	
	BATI-MENTO	Batimento circular	
		Inclinação	
	LOCALIZAÇÃO	Posição	⊕
		Concentricidade	⊙
		Simetria	



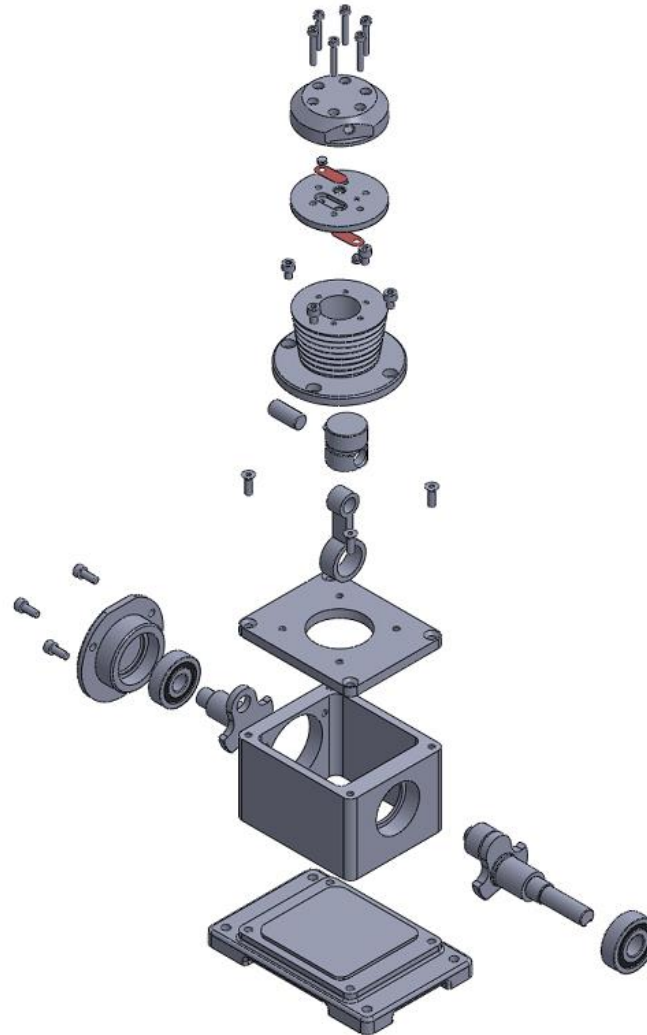
Exemplo do compressor monocilíndrico



Desenho em perspectiva do compressor mono cilíndrico



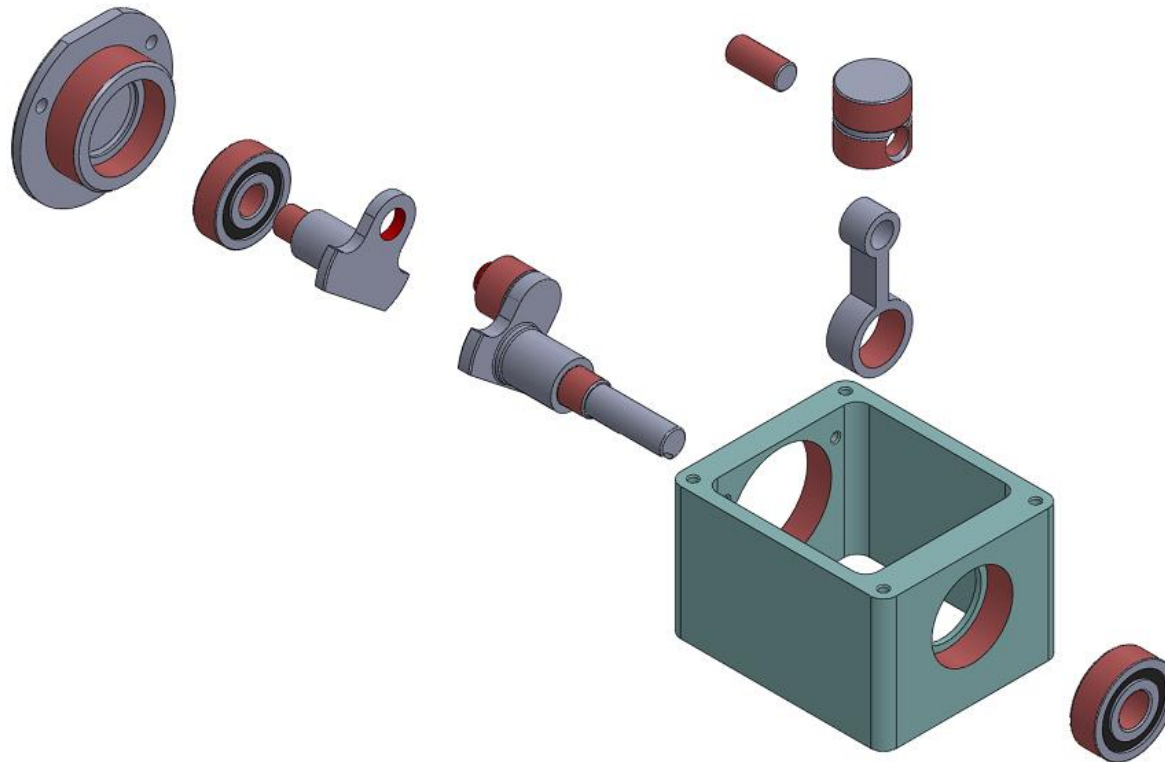
Exemplo do compressor monocilíndrico



Vista explodida do compressor mono cilíndrico



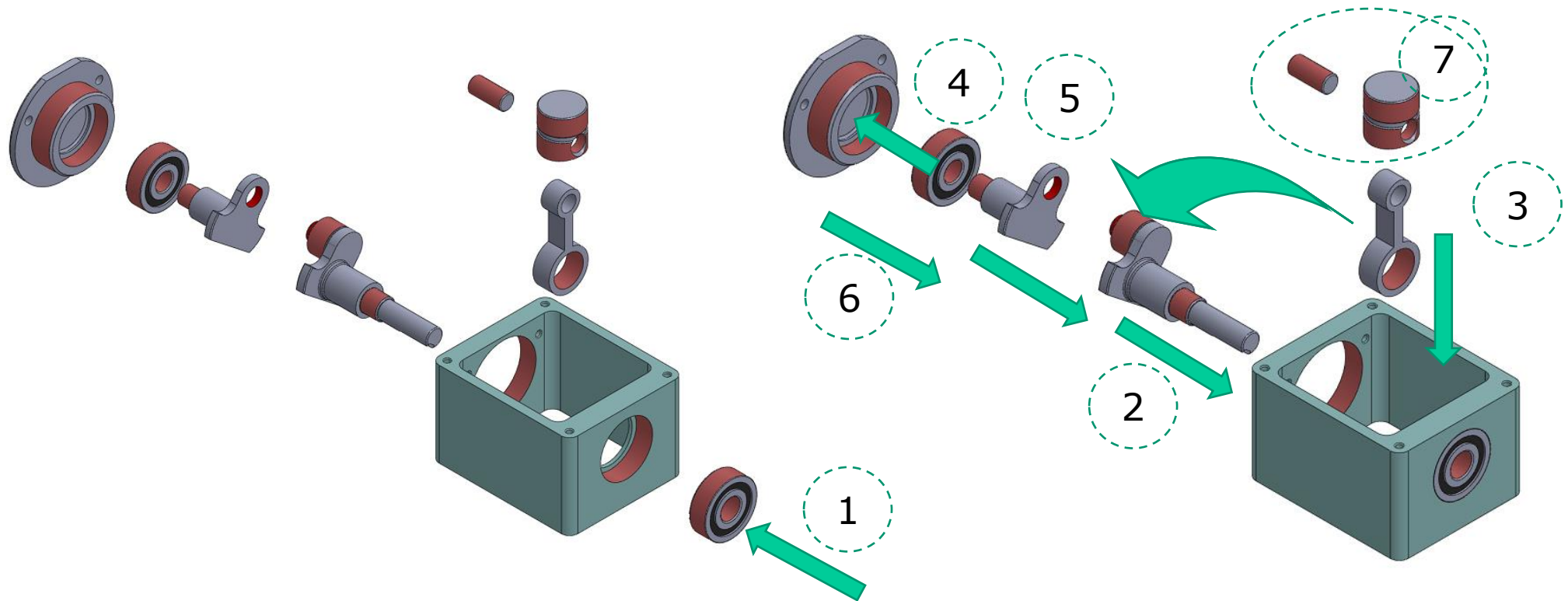
Exemplo de componentes onde as relações dimensionais, geométricas e superficiais são críticas



Montagem dos conjuntos eixo/mancais, eixo/biela, biela/pistão



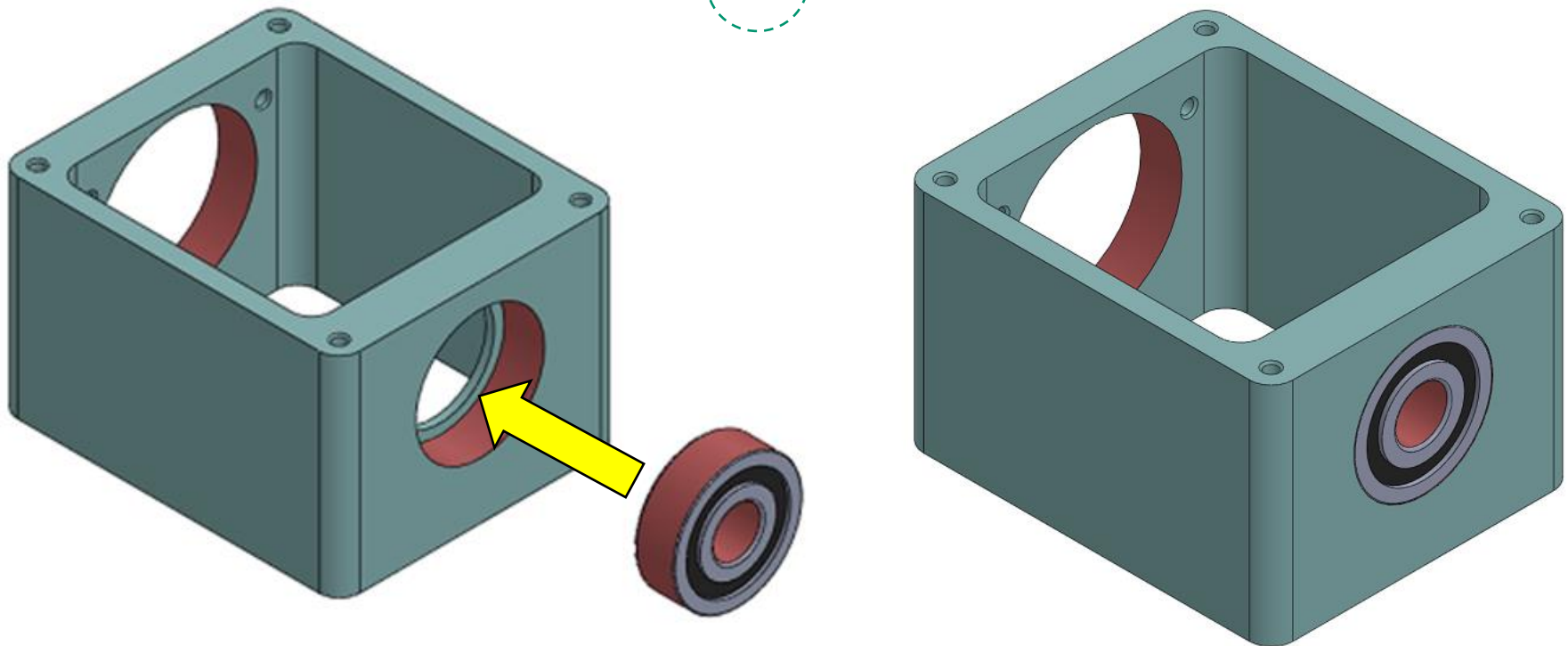
Sequência de montagem dos conjuntos





Sequência de montagem dos conjuntos

1



Montagem do rolamento esquerdo

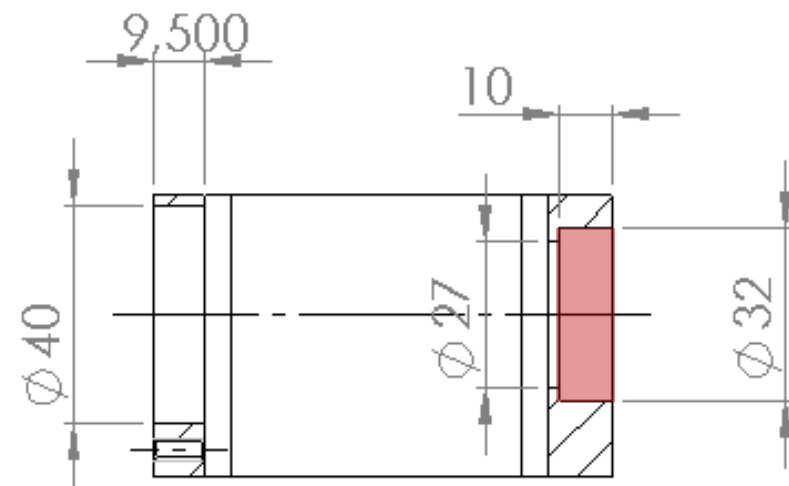
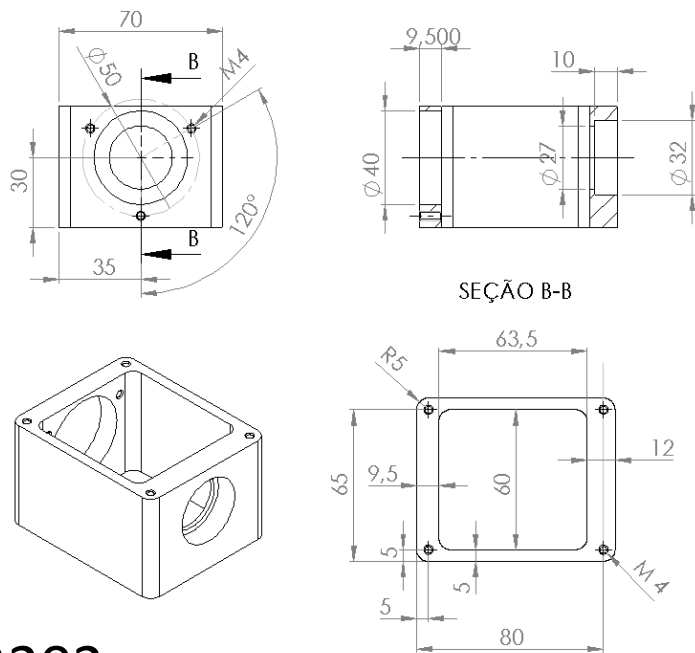


Montagem do rolamento esquerdo

O rolamento deve entrar sem folga na carcaça e a montagem deve ser feita com um mínimo esforço, no máximo com auxílio de um martelo de borracha. Pesquise:

- Qual deve ser a tolerância recomendada para o furo da carcaça ($\varnothing 32\text{mm}$)?
- Quais as tolerâncias padrão (normal) para o diâmetro externo de rolamentos?

<https://www.nsk.com/common/data/ctrGpdf/e1102m.pdf>

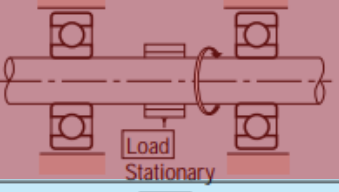
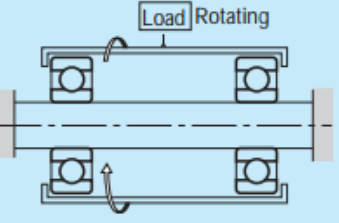
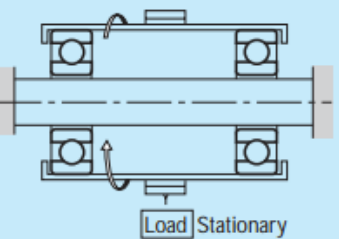
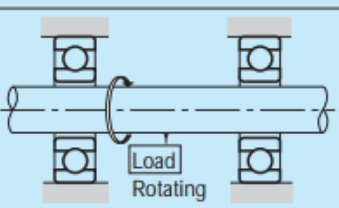




Tolerância de Montagem de rolamentos radiais

O rolamento deve entrar sem folga na carcaça e a montagem deve ser feita com um mínimo esforço, no máximo com auxílio de um martelo de borracha.

Table 9.1 Loading Conditions and Fits

Load Application	Bearing Operation		Load Conditions	Fitting	
	Inner Ring	Outer Ring		Inner Ring	Outer Ring
	Rotating	Stationary	Rotating Inner Ring Load	Tight Fit	Loose Fit
	Stationary	Rotating	Stationary Outer Ring Load		
	Stationary	Rotating	Rotating Outer Ring Load	Loose Fit	Tight Fit
	Rotating	Stationary	Stationary Inner Ring Load		
Direction of load indeterminate due to variation of direction or unbalanced load	Rotating or Stationary	Rotating or Stationary	Direction of Load Indeterminate	Tight Fit	Tight Fit



Tolerância de Montagem de rolamentos radiais

- Qual deve ser a tolerância recomendada para o furo da carcaça ($\emptyset$ 32mm)?

Table 9.4 Fits of Radial Bearings with Housings

Load Conditions			Examples	Tolerances for Housing Bores	Axial Displacement of Outer Ring	Remarks	
Solid Housings	Rotating Outer Ring Load	Heavy Loads on Bearing in Thin-Walled Housing or Heavy Shock Loads	Automotive Wheel Hubs (Roller Bearings) Crane Travelling Wheels	P7	Impossible	—	
		Normal or Heavy Loads	Automotive Wheel Hubs (Ball Bearings) Vibrating Screens	N7			
		Light or Variable Loads	Conveyor Rollers Rope Sheaves Tension Pulleys	M7			
	Direction of Load Indeterminate	Heavy Shock Loads	Traction Motors	K7	Generally Impossible	If axial displacement of the outer ring is not required.	
		Normal or Heavy Loads	Pumps Crankshaft Main Bearings Medium and Large Motors ⁽¹⁾				
	Solid or Split Housings		Normal or Light Loads		JS7 (J7)	Possible	Axial displacement of outer ring is necessary.
Rotating Inner Ring Load		Loads of All kinds	General Bearing Applications, Railway Axleboxes	H7	Easily possible	—	
		Normal or Light Loads	Plummer Blocks	H8			
		High Temperature Rise of Inner Ring Through Shaft	Paper Dryers	G7			
Solid Housing		Direction of Load Indeterminate	Accurate Running Desirable under Normal or Light Loads	Grinding Spindle Rear Ball Bearings High Speed Centrifugal Compressor Free Bearings	JS6 (J6)	Possible	—
				Grinding Spindle Front Ball Bearings High Speed Centrifugal Compressor Fixed Bearings	K6	Generally Impossible	
	Rotating Inner Ring Load	Accurate Running and High Rigidity Desirable under Variable Loads	Cylindrical Roller Bearings for Machine Tool Main Spindle	M6 or N6	Impossible		
		Minimum noise is required.	Electrical Home Appliances	H6	Easily Possible	—	

Note ⁽¹⁾ Refer to Tables 9.13.1 and 9.13.2 for the recommended fits of housing bores of deep groove ball bearings and cylindrical roller bearings for electric motors.

Remarks 1. This table is applicable to cast iron and steel housings. For housings made of light alloys, the interference should be tighter than those in this table.
2. Refer to the introductory section of the bearing dimension tables (blue pages) for special fits such as drawn cup needle roller bearings.



Tolerância de Montagem de rolamentos radiais

- Qual deve ser a tolerância recomendada para o furo da carcaça ($\varnothing 32\text{mm}$)?

Afastamentos fundamentais para furos

GRUPOS		AFASTAMENTO INFERIOR - EI												AFASTAMENTO SUPERIOR - ES																				Valores de delta - Δ											
DIMENSÕES		Todos os graus de Tolerância Padrão - ITn												AFASTAMENTO SUPERIOR - ES																				Valores de delta - Δ											
Acima	Abaixo	A	B	C	CD	D	E	EF	F	FG	G	H	JS	J6	J7	J8	K6	k6	M6	M8	N6	N8	P & Zc	P	R	S	T	U	V	X	Y	Z	ZA	ZB	ZC	IT3	IT4	IT5	IT6	IT7	IT8				
0	3	270	140	60	34	20	14	10	6	4	2	0	2	4	8	0	0	-2	-2	-4	-4	-6	-10	-14	-18	-23	-28	-35	-42	-50	-60	-80	0	0	0	0	0	0	0	0	0	0			
3	6	270	140	70	46	30	20	14	10	6	4	0	5	6	10	-1+Δ	-4+Δ	-6	-10+Δ	0	-12	-15	-19	-23	-28	-35	-42	-50	-60	-80	1	1,5	1	3	4	6									
6	10	280	150	80	56	40	25	18	13	8	5	0	5	8	12	-1+Δ	-6+Δ	-6	-10+Δ	0	-15	-19	-23	-28	-34	-42	-52	-67	-87	-117	1	1,5	2	3	6	7									
10	14	290	150	95	60	32	20	16	10	6	4	0	6	10	15	-1+Δ	-7+Δ	-7	-12+Δ	0	-18	-23	-28	-33	-40	-50	-64	-80	-130	1	2	3	3	7	9										
14	18	290	150	110	65	32	20	16	10	6	4	0	6	10	15	-1+Δ	-7+Δ	-7	-12+Δ	0	-18	-23	-28	-33	-39	-45	-60	-77	-108	-150	1	2	3	3	7										
18	24	300	160	110	65	40	20	20	7	0	0	0	8	12	20	-2+Δ	-8+Δ	-8	-15+Δ	0	-22	-28	-35	-41	-47	-54	-63	-73	-98	-136	-188	1,5	2	3	4	8	12								
24	30	300	160	110	65	40	20	20	7	0	0	0	8	12	20	-2+Δ	-8+Δ	-8	-15+Δ	0	-22	-28	-35	-41	-48	-55	-64	-75	-98	-118	-160	-128	1,5	2	3	4	8	12							
30	40	310	170	120	80	50	25	25	9	0	0	0	10	14	24	-2+Δ	-9+Δ	-9	-17+Δ	0	-26	-34	-43	-48	-60	-68	-80	-112	-148	-200	-274	1,5	3	4	5	9	14								
40	50	320	180	130	80	50	25	25	9	0	0	0	10	14	24	-2+Δ	-9+Δ	-9	-17+Δ	0	-26	-34	-43	-54	-70	-81	-97	-114	-136	-180	-242	-325	1,5	3	4	5	9	14							
50	65	340	190	140	100	60	30	30	10	0	0	0	13	18	28	-2+Δ	-11+Δ	-11	-20+Δ	0	-32	-41	-53	-66	-87	-102	-122	-144	-172	-226	-300	-405	2	3	5	6	11	16							
65	80	360	200	150	100	60	30	30	10	0	0	0	13	18	28	-2+Δ	-11+Δ	-11	-20+Δ	0	-32	-43	-53	-66	-87	-102	-120	-146	-174	-210	-274	-360	-480	2	3	5	6	11	16						
80	100	380	220	170	120	72	36	36	12	0	0	0	16	22	34	-3+Δ	-13+Δ	-13	-23+Δ	0	-37	-51	-71	-91	-124	-146	-178	-214	-258	-335	-445	-585	2	4	5	7	13	19							
100	120	410	240	180	120	72	36	36	12	0	0	0	16	22	34	-3+Δ	-13+Δ	-13	-23+Δ	0	-37	-54	-73	-104	-144	-172	-210	-254	-310	-400	-525	-630	2	4	5	7	13	19							
120	140	460	260	200	145	85	43	43	14	0	0	0	18	26	41	-3+Δ	-15+Δ	-15	-27+Δ	0	-43	-63	-92	-122	-170	-202	-248	-300	-365	-470	-620	-800	3	4	6	7	15	23							
140	160	520	280	210	145	85	43	43	14	0	0	0	18	26	41	-3+Δ	-15+Δ	-15	-27+Δ	0	-43	-65	-100	-134	-190	-228	-280	-340	-415	-535	-700	-900	3	4	6	7	15	23							
160	180	580	310	230	145	85	43	43	14	0	0	0	18	26	41	-3+Δ	-15+Δ	-15	-27+Δ	0	-43	-68	-108	-146	-210	-252	-310	-380	-465	-600	-780	-1000	3	4	6	7	15	23							
180	200	660	340	240	170	100	50	50	15	0	0	0	22	30	47	-4+Δ	-17+Δ	-17	-31+Δ	0	-50	-77	-122	-160	-236	-284	-350	-425	-520	-670	-880	-1150	3	4	6	9	17	26							
200	225	740	380	260	170	100	50	50	15	0	0	0	22	30	47	-4+Δ	-17+Δ	-17	-31+Δ	0	-50	-80	-130	-180	-258	-310	-385	-470	-575	-740	-960	-1250	3	4	6	9	17	26							
225	250	820	420	280	170	100	50	50	15	0	0	0	22	30	47	-4+Δ	-17+Δ	-17	-31+Δ	0	-50	-84	-140	-196	-284	-340	-425	-520	-640	-820	-1050	-1350	3	4	6	9	17	26							
250	280	920	480	300	190	110	56	56	17	0	0	0	25	36	55	-4+Δ	-20+Δ	-20	-34+Δ	0	-56	-94	-158	-218	-315	-385	-475	-580	-710	-920	-1200	-1550	4	4	7	9	20	29							
280	315	1060	540	330	190	110	56	56	17	0	0	0	25	36	55	-4+Δ	-20+Δ	-20	-34+Δ	0	-56	-98	-170	-240	-350	-425	-525	-650	-790	-1000	-1300	-1700	4	4	7	9	20	29							
315	355	1200	600	360	210	125	62	62	18	0	0	0	29	39	60	-4+Δ	-21+Δ	-21	-37+Δ	0	-62	-108	-190	-268	-390	-475	-590	-730	-900	-1150	-1500	-1900	4	5	7	11	21	32							
355	400	1350	680	400	210	125	62	62	18	0	0	0	29	39	60	-4+Δ	-21+Δ	-21	-37+Δ	0	-62	-114	-208	-294	-435	-530	-660	-820	-1000	-1300	-1650	-2100	4	5	7	11	21	32							
400	450	1500	760	440	230	135	68	68	20	0	0	0	33	43	66	-5+Δ	-23+Δ	-23	-40+Δ	0	-68	-126	-232	-330	-490	-600	-740	-920	-1100	-1450	-1850	-2400	5	5	7	13	23	34							
450	500	1650	840	480	230	135	68	68	20	0	0	0	33	43	66	-5+Δ	-23+Δ	-23	-40+Δ	0	-68	-132	-252	-360	-540	-640	-820	-1000	-1250	-1600	-2100	-2600	5	5	7	13	23	34							
500	560				260	145	76	76	22	0	0	0				0	-26	-26	-44	-44	-78	-150	-280	-400	-600																				
560	630				260	145	76	76	22	0	0	0				0	-26	-26	-44	-44	-78	-155	-310	-450	-660																				
630	710				290	160	80	80	24	0	0	0				0	-30	-30	-50	-50	-88	-175	-340	-500	-740																				
710	800				290	160	80	80	24	0	0	0				0	-30	-30	-50	-50	-88	-185	-380	-560	-840																				
800	900				320	170	86	86	26	0	0	0				0	-34	-34	-56	-56	-100	-210	-430	-620	-940																				
900	1000				320	170	86	86	26	0	0	0				0	-34	-34	-56	-56	-100	-220	-470	-680	-1050																				
1000	1120				360	195	96	96	28	0	0	0				0	-40	-40	-66	-66	-120	-250	-520	-780	-1150																				
1120	1250				360	195	96	96	28	0	0	0				0	-40	-40	-66	-66	-120	-260	-580	-840	-1300																				
1250	1400				390	220	110	110	30	0	0	0				0	-48	-48	-78	-78	-140	-300	-640	-960	-1450																				
1400	1600				390	220	110	110	30	0	0	0				0	-48	-48	-78	-78	-140	-330	-720	-1050	-1600																				
1600	1800				430	240	120	120	32	0	0	0				0	-58	-58	-92	-92	-170	-370	-820	-1200	-1850																				



Tolerância de Montagem de rolamentos radiais

- Qual deve ser a tolerância recomendada para o furo da carcaça ($\varnothing 32\text{mm}$)?

Grupos de Dimensões	TABELA DOS VALORES NUMÉRICOS DE GRAUS DE TOLERÂNCIA-PADRÃO IT (tolerâncias em μm)																	
mm	IT 1	IT 2	IT 3	IT 4	IT 5	IT 6	IT 7	IT 8	IT 9	IT 10	IT 11	IT 12	IT 13	IT 14	IT 15	IT 16	IT 17	IT 18
≤ 3	0,8	1,2	2	3	4	6	10	14	25	40	60	100	140	250	400	600	1000	1400
$> 3 \leq 6$	1	1,5	2,5	4	5	8	12	18	30	48	75	120	180	300	480	750	1200	1800
$> 6 \leq 10$	1	1,5	2,5	4	6	9	15	22	36	58	90	150	220	360	580	900	1500	2200
$> 10 \leq 18$	1,2	2	3	5	8	11	18	27	43	70	110	180	270	430	700	1100	1800	2700
$> 18 \leq 30$	1,5	2,5	4	6	9	13	20	33	52	84	130	210	330	520	840	1300	2100	3330
$> 30 \leq 50$	1,5	2,5	4	7	11	16	25	39	62	100	160	250	390	620	1000	1600	2500	3900
$> 50 \leq 80$	2	3	5	8	13	19	30	46	74	120	190	300	460	740	1200	1900	3000	4600
$> 80 \leq 120$	2,5	4	6	10	15	22	35	54	87	140	220	350	540	870	1400	2200	3500	5400
$> 120 \leq 180$	3,5	5	8	12	18	25	40	63	100	160	250	400	630	1000	1600	2500	4000	6300
$> 180 \leq 250$	4,5	7	10	14	20	29	46	72	115	185	290	460	720	1150	1850	2900	4600	7200
$> 250 \leq 315$	6	8	12	16	23	32	52	81	130	210	320	520	810	1300	2100	3200	5200	8100
$> 315 \leq 400$	7	9	13	18	25	36	57	89	140	230	360	570	890	1400	2300	3600	5700	8900
$> 400 \leq 500$	8	10	15	20	27	40	63	97	155	250	400	630	970	1550	2500	4000	6300	9700
$> 500 \leq 630$	9	11	16	22	32	44	70	110	175	280	440	700	1100	1750	2800	4400	7000	11000
$> 630 \leq 800$	10	13	18	25	36	50	80	125	200	320	500	800	1250	2000	3200	5000	8000	12500
$> 800 \leq 1000$	11	15	21	28	40	56	90	140	230	360	560	900	1400	2300	3600	5600	9000	14000
$> 1000 \leq 1250$	13	18	24	33	47	66	105	165	260	420	660	1050	1650	2600	4200	6600	10500	16500
$> 1250 \leq 1600$	15	21	29	39	55	78	125	195	310	500	780	1250	1950	3100	5000	7800	12500	19500
$> 1600 \leq 2000$	18	25	35	46	65	92	150	230	370	600	920	1500	2300	3700	6000	9200	15000	23000
$> 2000 \leq 2500$	22	30	41	55	78	110	175	280	440	700	1100	1750	2800	4400	7000	11000	17500	28000
$> 2500 \leq 3150$	26	36	50	68	96	135	210	330	540	860	1350	2100	3300	5400	8600	13500	21000	33000

Montagem do rolamento esquerdo

- Qual deve ser a tolerância recomendada para o furo da carcaça ($\phi 32\text{mm}$)?

Solução: H6 ($32 +0, +0,016$)

- Quais as tolerâncias padrão (normal) para o diâmetro externo de rolamentos?

Solução: Tabela 8.2 da NSK

D Brg outside dia., nominal
 Δ_{Ds} Deviation of a single outside dia.
 Δ_{Dmp} Single plane mean outside dia. Deviation
 V_{Dp} Outside dia. Variation in a single radial plane
 V_{Dmp} Mean outside dia. Variation

C Outer ring width, nominal
 Δ_{Cs} Deviation of a single outer ring width
 V_{Cs} Outer ring width variation

K_{ea} Radial runout of assembled brg outer ring
 S_D Variation of brg outside surface generatrix inclination with outer ring reference face (backface)
 S_{ea} Assembled brg outer ring face (backface) runout with raceway

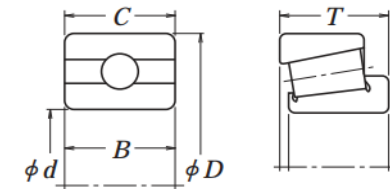


Table 8. 2 Tolerances for Radial Bearings
 Table 8. 2. 2 Tolerances

Nominal Outside Diameter D (mm)		Δ_{Dmp}										Δ_{Ds}			
		Normal		Class 6		Class 5		Class 4		Class 2		Class 4		Class 2	
over	incl.	high	low	high	low	high	low	high	low	high	low	high	low	high	low
2.5 ⁽¹⁾	6	0	- 8	0	- 7	0	- 5	0	- 4	0	- 2.5	0	- 4	0	- 2.5
6	18	0	- 8	0	- 7	0	- 5	0	- 4	0	- 2.5	0	- 4	0	- 2.5
18	30	0	- 9	0	- 8	0	- 6	0	- 5	0	- 4	0	- 5	0	- 4
30	50	0	- 11	0	- 9	0	- 7	0	- 6	0	- 4	0	- 6	0	- 4
50	80	0	- 12	0	- 11	0	- 9	0	- 7	0	- 4	0	- 7	0	- 4
80	120	0	- 15	0	- 13	0	- 10	0	- 8	0	- 5	0	- 8	0	- 5
120	150	0	- 18	0	- 15	0	- 11	0	- 9	0	- 5	0	- 9	0	- 5
150	180	0	- 25	0	- 18	0	- 13	0	- 10	0	- 7	0	- 10	0	- 7
180	250	0	- 30	0	- 20	0	- 15	0	- 11	0	- 8	0	- 11	0	- 8
250	315	0	- 35	0	- 25	0	- 18	0	- 13	0	- 8	0	- 13	0	- 8
315	400	0	- 40	0	- 28	0	- 20	0	- 15	0	- 10	0	- 15	0	- 10
400	500	0	- 45	0	- 33	0	- 23	-	-	-	-	-	-	-	-
500	630	0	- 50	0	- 38	0	- 28	-	-	-	-	-	-	-	-
630	800	0	- 75	0	- 45	0	- 35	-	-	-	-	-	-	-	-
800	1 000	0	- 100	0	- 60	-	-	-	-	-	-	-	-	-	-
1 000	1 250	0	- 125	-	-	-	-	-	-	-	-	-	-	-	-
1 250	1 600	0	- 160	-	-	-	-	-	-	-	-	-	-	-	-
1 600	2 000	0	- 200	-	-	-	-	-	-	-	-	-	-	-	-
2 000	2 500	0	- 250	-	-	-	-	-	-	-	-	-	-	-	-

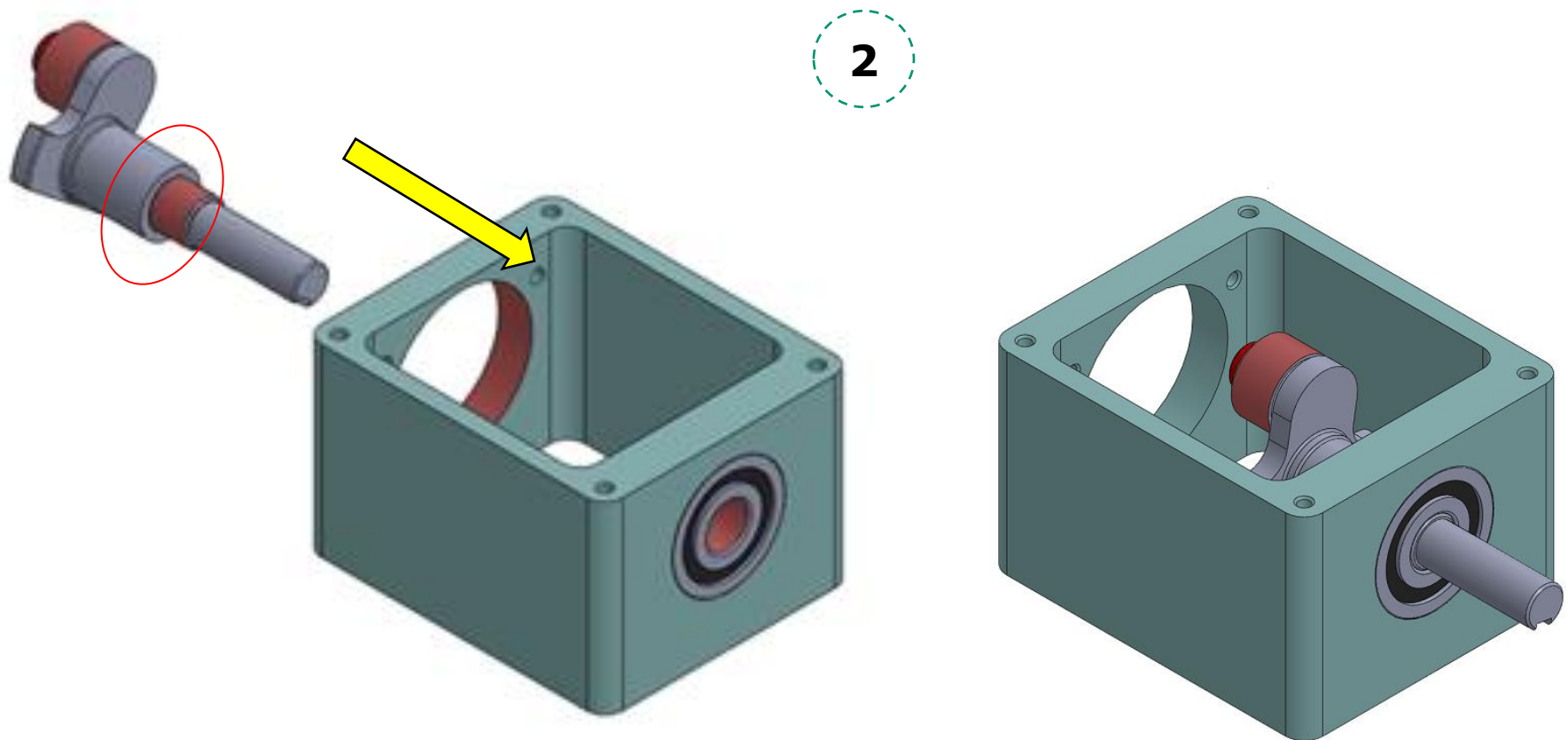
(excluding Tapered Roller Bearings)
 for Outer Rings

V_{Dp} (°)															V_{Dmp} (°)				
Normal					Class 6					Class 5					Class 4				
Open Type					Shielded Sealed					Open Type					Open Type				
Diameter Series					Diameter Series					Diameter Series					Diameter Series				
9	0, 1	2, 3, 4	2, 3, 4	2, 3, 4	9	0, 1	2, 3, 4	0,1,2,3,4	9	0,1,2,3,4	9	0,1,2,3,4	9	0,1,2,3,4	9	0,1,2,3,4	0,1,2,3,4	Normal	Class 6
max.					max.					max.					max.				
10	8	6	10	9	7	5	9	5	4	4	3	2.5	6	5	3	2	1.5		
10	8	6	10	9	7	5	9	5	4	4	3	2.5	6	5	3	2	1.5		
12	9	7	12	10	8	6	10	6	5	5	4	4	7	6	3	2.5	2		
14	11	8	16	11	9	7	13	7	5	6	5	4	8	7	4	3	2		
16	12	10	20	14	11	8	16	9	7	7	5	4	10	8	5	3.5	2		
19	19	11	26	16	16	10	20	10	8	8	6	5	11	10	5	4	2.5		
23	23	14	30	19	19	11	25	11	8	9	7	5	14	11	6	5	2.5		
31	31	19	38	23	23	14	30	13	10	10	8	7	19	14	7	5	3.5		
38	38	23	-	25	25	15	-	15	11	11	8	8	23	15	8	6	4		
44	44	26	-	31	31	19	-	18	14	13	10	8	26	19	9	7	4		
50	50	30	-	35	35	21	-	20	15	15	11	10	30	21	10	8	5		
56	56	34	-	41	41	25	-	23	17	-	-	-	34	25	12	-	-		
63	63	38	-	48	48	29	-	28	21	-	-	-	38	29	14	-	-		
94	94	55	-	56	56	34	-	35	26	-	-	-	55	34	18	-	-		
125	125	75	-	75	75	45	-	-	-	-	-	-	75	45	-	-	-		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		

Units : μm



Sequência de montagem dos conjuntos



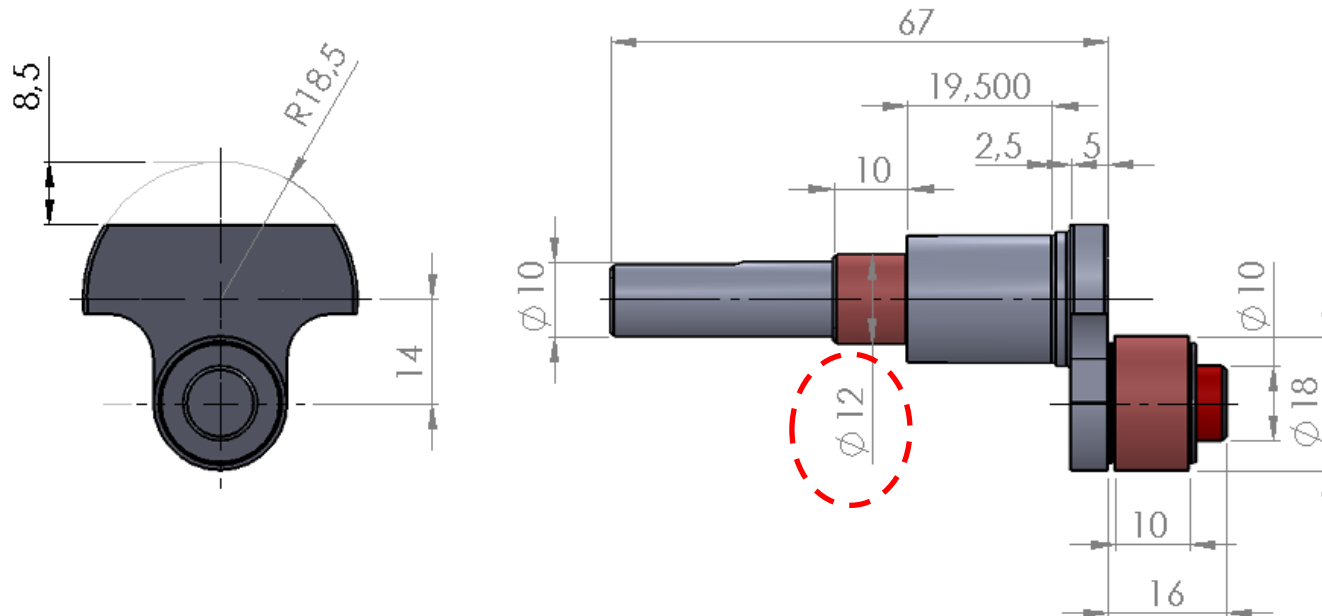
Montagem do semieixo no rolamento esquerdo



Montagem do semieixo no rolamento esquerdo

O semieixo esquerdo deve entrar sem folga no furo do rolamento, e deve ser feita com um mínimo esforço. Determine:

- Qual deve ser a tolerância recomendada para o eixo (assinalado no detalhe)?
- Qual deve ser o acabamento do eixo (assinalado no detalhe)?
- Quais as tolerâncias padrão para o diâmetro interno de rolamentos?





Tolerância de Montagem eixos em rolamentos radiais

Table 9.2 Fits of Radial Bearings with Shafts

Load Conditions		Examples	Shaft Diameter (mm)			Tolerance of Shaft	Remarks
			Ball Brgs	Cylindrical Roller Brgs, Tapered Roller Brgs	Spherical Roller Brgs		
Radial Bearings with Cylindrical Bores							
Rotating Outer Ring Load	Easy axial displacement of inner ring on shaft desirable.	Wheels on Stationary Axles	All Shaft Diameters			g6	Use g5 and h5 where accuracy is required. In case of large bearings, f6 can be used to allow easy axial movement.
	Easy axial displacement of inner ring on shaft unnecessary	Tension Pulleys Rope Sheaves				h6	
Rotating Inner Ring Load or Direction of Load Indeterminate	Light Loads or Variable Loads ($< 0.06C_r^{(1)}$)	Electrical Home Appliances Pumps, Blowers, Transport Vehicles, Precision Machinery, Machine Tools	< 18	—	—	js5	k6 and m6 can be used for single-row tapered roller bearings and single-row angular contact ball bearings instead of k5 and m5.
			18 to 100	< 40	—	js6(j6)	
			100 to 200	40 to 140	—	k6	
			—	140 to 200	—	m6	
	Normal Loads (0.06 to $0.13C_r^{(1)}$)	General Bearing Applications, Medium and Large Motors ⁽²⁾ , Turbines, Pumps, Engine Main Bearings, Gears, Woodworking Machines	< 18	—	—	js5 or js6 (j5 or j6)	
			18 to 100	< 40	< 40	k5 or k6	
			100 to 140	40 to 100	40 to 65	m5 or m6	
			140 to 200	100 to 140	65 to 100	m6	
			200 to 280	140 to 200	100 to 140	n6	
			—	200 to 400	140 to 280	p6	
			—	—	280 to 500	r6	
			—	—	over 500	r7	
	Heavy Loads or Shock Loads ($> 0.13C_r^{(1)}$)	Railway Axleboxes, Industrial Vehicles, Traction Motors, Construction Equipment, Crushers	—	50 to 140	50 to 100	n6	
			—	140 to 200	100 to 140	p6	
			—	over 200	140 to 200	r6	
			—	—	200 to 500	r7	
Axial Loads Only		All Shaft Diameters			js6 (j6)	—	
Radial Bearings with Tapered Bores and Sleeves							
All Types of Loading	General bearing Applications, Railway Axleboxes	All Shaft Diameters			h9/IT5 ⁽²⁾	IT5 and IT7 mean that the deviation of the shaft from its true geometric form, e. g. roundness and cylindricity should be within the tolerances of IT5 and IT7 respectively.	
	Transmission Shafts, Woodworking Spindles				h10/IT7 ⁽²⁾		

Notes (1) C_r represents the basic load rating of the bearing.

(2) Refer to Appendix Table 11 on page C22 for the values of standard tolerance grades IT.

(3) Refer to Tables 9.13.1 and 9.13.2 for the recommended fits of shafts used in electric motors for deep groove ball bearings with bore diameters ranging from 10 mm to 160 mm, and for cylindrical roller bearings with bore diameters ranging from 24 mm to 200 mm.

Remarks This table is applicable only to solid steel shafts.



ESCOLA POLITÉCNICA DA UNIVERSIDADE DE SÃO PAULO

Sequência de montagem dos conjuntos

Afastamentos fundamentais para eixos

GRUPOS		Afastamento superior - es											Afastamento inferior - ei																			
DIMENSÕES		Todos os graus de Tolerância Padrão - ITn											Todos os graus de Tolerância Padrão - ITn																			
Acima	Ate	a	b	c	cd	d	e	ef	f	fg	g	h	js	j6	j7	j8	≥k4	≤k3														
																	≤k7	≥k8	m	n	p	r	s	t	u	v	x	y	z	za	zb	zc
0	3	-270	-140	-60	-34	-20	-14	-10	-6	-4	-2	0	-2	-4	-6		0	0	2	4	6	10	14	0	18		20		26	32	40	60
3	6	-270	-140	-70	-46	-30	-20	-14	-10	-6	-4	0	-2	-4			1	0	4	8	12	15	19	0	23		28		35	42	50	80
6	10	-280	-150	-80	-56	-40	-25	-18	-13	-8	-5	0	-2	-5			1	0	7	10	15	19	23	0	28		34		42	52	67	97
10	14	-290	-150	-95		-50	-32		-16		-6	0	-3	-6			1	0	7	12	18	23	28	0	33		40		50	64	90	130
14	18	-290	-150	-95		-50	-32		-16		-6	0	-3	-6			1	0	7	12	18	23	28	0	33	39	45		60	77	108	150
18	24	-300	-160	-110		-65	-40		-20		-7	0	-4	-8			2	0	8	15	22	28	35	0	41	47	54	63	73	98	136	188
24	30	-300	-160	-110		-65	-40		-20		-7	0	-4	-8			2	0	8	15	22	28	35	41	48	55	64	75	88	118	160	228
30	40	-310	-170	-120		-80	-50		-25		-9	0	-5	-10			2	0	9	17	26	34	43	48	60	68	80	94	112	148	200	274
40	50	-320	-180	-130		-80	-50		-25		-9	0	-5	-10			2	0	9	17	26	34	43	54	70	81	97	114	136	180	242	325
50	65	-340	-190	-140		-100	-60		-30		-10	0	-7	-12			2	0	11	20	32	41	53	66	87	102	122	144	172	226	300	405
65	80	-360	-200	-150		-100	-60		-30		-10	0	-7	-12			2	0	11	20	32	43	59	75	102	120	146	174	210	274	360	480
80	100	-380	-220	-170		-120	-72		-36		-12	0	-9	-15			3	0	13	23	37	51	71	91	124	146	178	214	258	335	445	585
100	120	-410	-240	-180		-120	-72		-36		-12	0	-9	-15			3	0	13	23	37	54	79	104	144	172	210	254	310	400	525	690
120	140	-460	-260	-200		-145	-85		-43		-14	0	-11	-18			3	0	15	27	43	63	92	122	170	202	248	300	365	470	620	800
140	160	-520	-280	-210		-145	-85		-43		-14	0	-11	-18			3	0	15	27	43	65	100	134	190	228	280	340	415	535	700	900
160	180	-580	-310	-230		-145	-85		-43		-14	0	-11	-18			3	0	15	27	43	68	108	146	210	252	310	380	465	600	780	1000
180	200	-660	-340	-240		-170	-100		-50		-15	0	-13	-21			4	0	17	31	50	77	122	160	236	284	350	425	520	670	880	1150
200	225	-740	-380	-260		-170	-100		-50		-15	0	-13	-21			4	0	17	31	50	80	130	180	258	310	385	470	575	740	960	1250
225	250	-820	-420	-280		-170	-100		-50		-15	0	-13	-21			4	0	17	31	50	84	140	196	284	340	425	520	640	820	1050	1350
250	280	-920	-480	-300		-190	-110		-56		-17	0	-16	-26			4	0	20	34	56	94	158	218	315	385	475	580	710	920	1200	1550
280	315	-1060	-540	-330		-190	-110		-56		-17	0	-16	-26			4	0	20	34	56	98	170	240	350	425	525	650	790	1000	1300	1700
315	355	-1200	-600	-360		-210	-125		-62		-18	0	-18	-28			4	0	21	37	62	108	190	268	390	475	590	730	900	1150	1500	1900
355	400	-1350	-680	-400		-210	-125		-62		-18	0	-18	-28			4	0	21	37	62	114	208	294	435	530	660	820	1000	1300	1650	2100
400	450	-1500	-760	-440		-230	-135		-68		-20	0	-20	-32			5	0	23	40	68	126	232	330	490	490	740	920	1100	1450	1850	2400
450	500	-1650	-840	-480		-230	-135		-68		-20	0	-20	-32			5	0	23	40	68	132	252	360	540	540	820	1000	1250	1600	2100	2600
500	560					-260	-145		-76		-22	0					0	0	26	44	78	150	280	400	600							
560	630					-260	-145		-76		-22	0					0	0	26	44	78	155	310	450	660							
630	710					-290	-160		-80		-24	0					0	0	30	50	88	175	340	500	740							
710	800					-290	-160		-80		-24	0					0	0	30	50	88	185	380	560	840							
800	900					-320	-170		-86		-26	0					0	0	34	56	100	210	430	620	940							
900	1000					-320	-170		-86		-26	0					0	0	34	56	100	220	470	680	1050							
1000	1120					-360	-195		-98		-28	0					0	0	40	66	120	250	520	780	1150							
1120	1250					-360	-195		-98		-28	0					0	0	40	66	120	260	580	840	1300							
1250	1400					-390	-220		-110		-30	0					0	0	48	78	140	300	640	960	1450							
1400	1600					-390	-220		-110		-30	0					0	0	48	78	140	330	720	1050	1600							
1600	1800					-430	-240		-120		-32	0					0	0	58	92	170	370	820	1200	1850							
1800	2000					-430	-240		-120		-32	0					0	0	58	92	170	400	920	1350	2000							
2000	2240					-490	-260		-130		-34	0					0	0	68	110	195	440	1000	1500	2300							
2240	2500					-490	-260		-130		-34	0					0	0	68	110	195	460	1100	1650	2500							
2500	2800					-520	-290		-145		-38	0					0	0	76	135	240	550	1250	1900	2900							
2800	3150					-520	-290		-145		-38	0					0	0	76	135	240	580	1400	2100	3200							

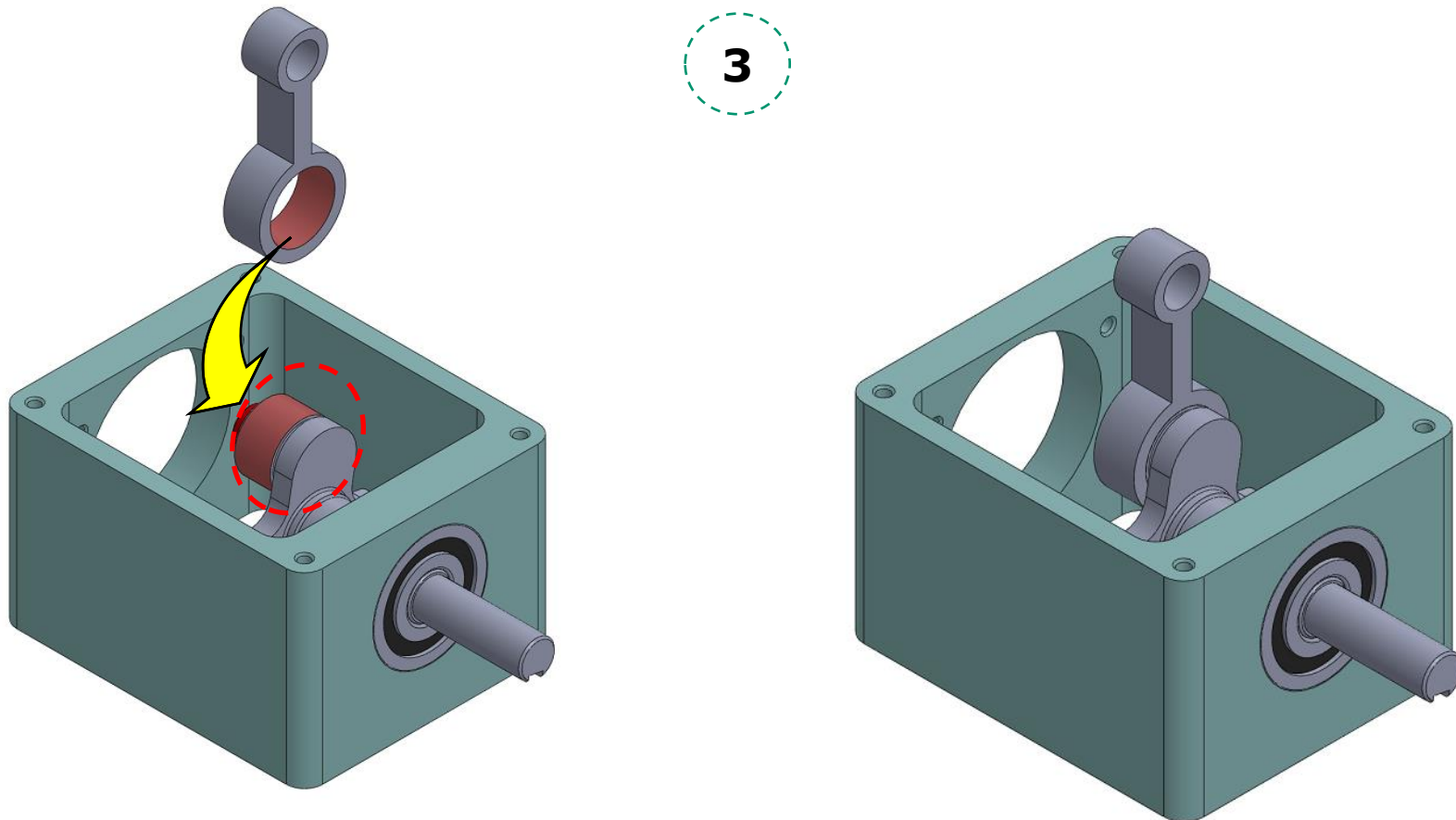
- Qual deve ser a tolerância recomendada para o eixo (assinalado no detalhe)?
- Solução:** k5 ou **k6** (12 +0,001/+0,012)
- Qual deve ser o acabamento do eixo (assinalado no detalhe)? **Solução:** Retificado
- Quais as tolerâncias padrão para o diâmetro interno de rolamentos? **Solução:** tabela 8.2.1 (+0/-0,008)

32



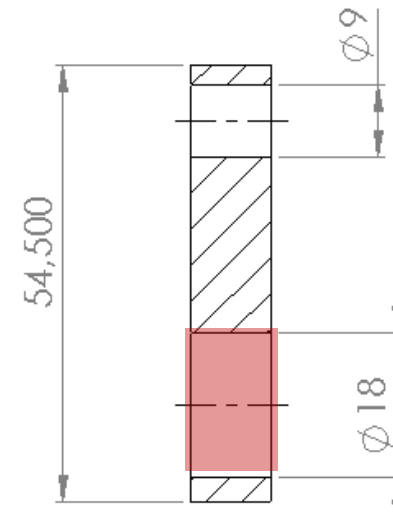
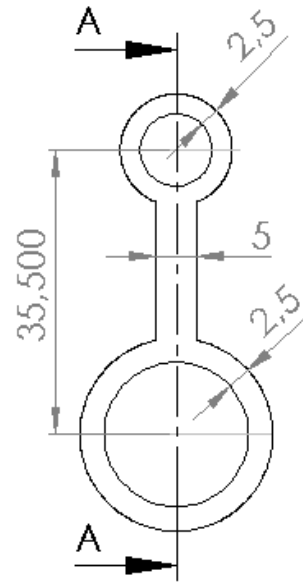
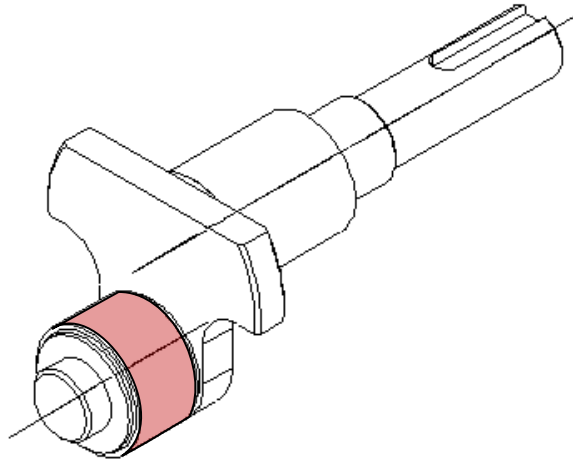
Sequência de montagem dos conjuntos

Montagem da biela no semieixo esquerdo

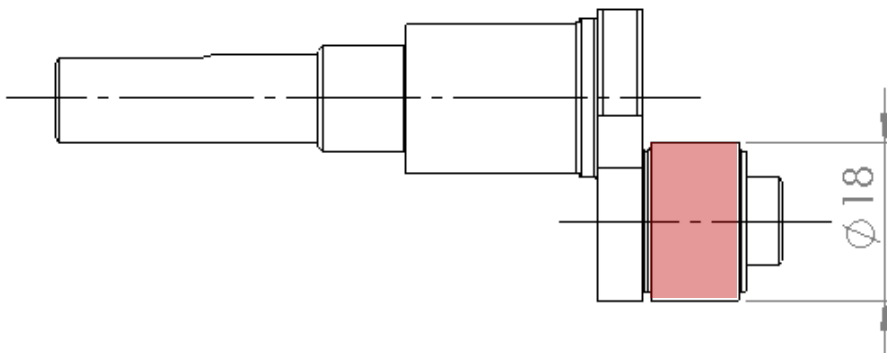
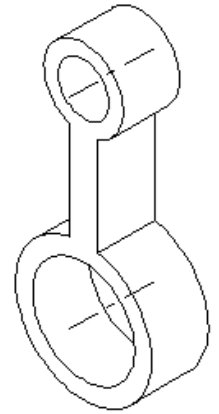




Montagem da biela no semieixo esquerdo



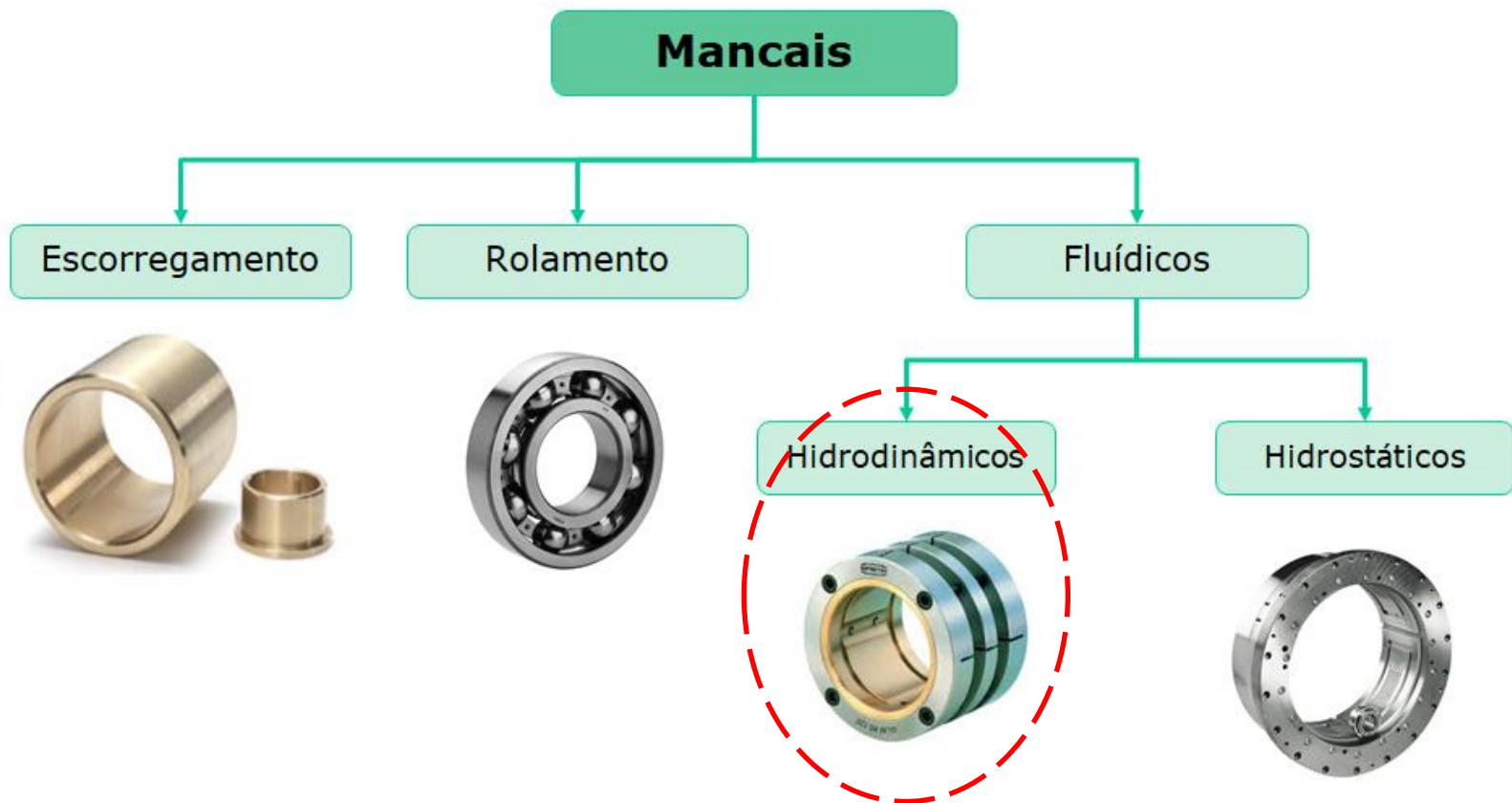
SEÇÃO A-A





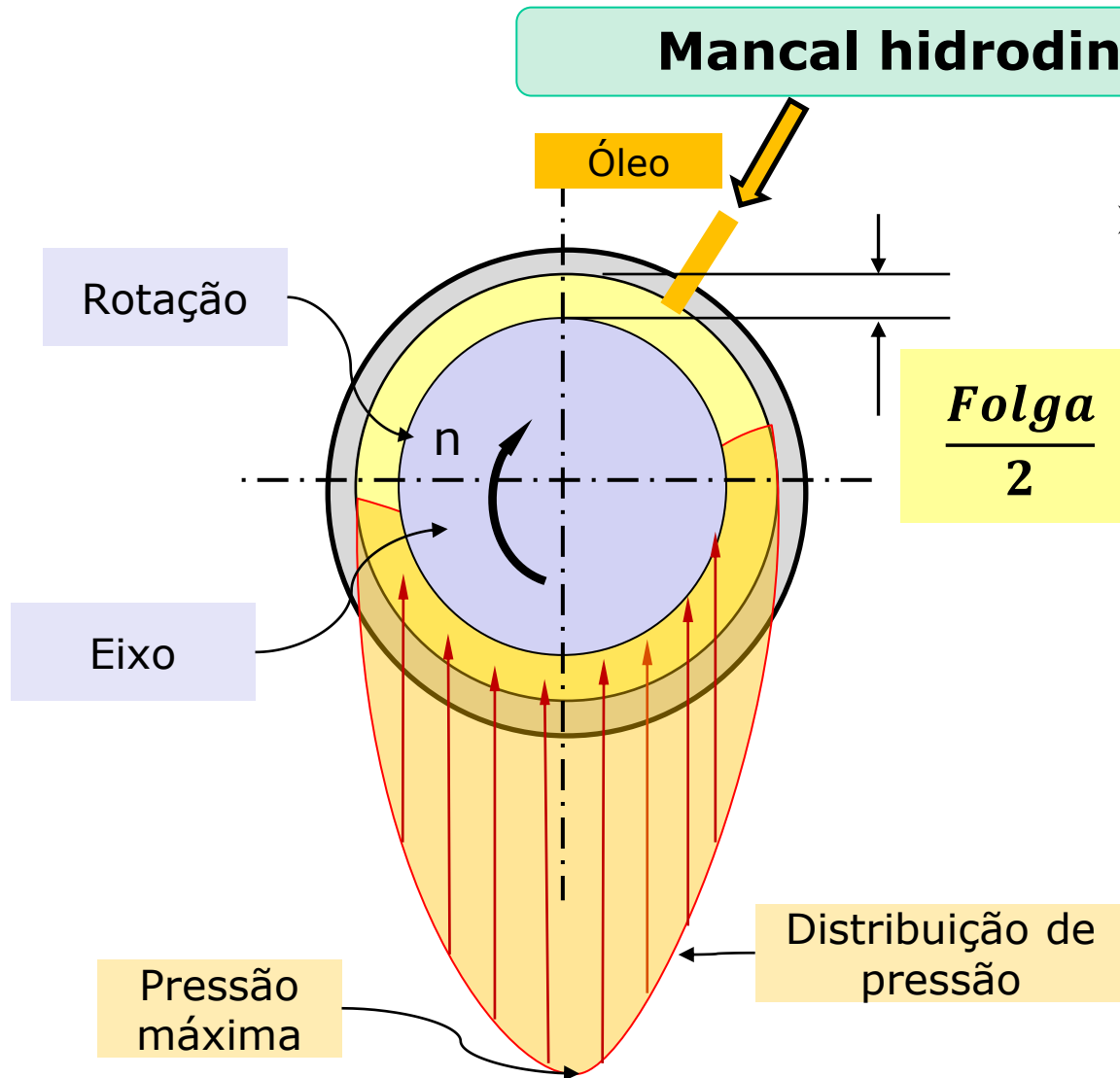
Montagem da biela no semieixo esquerdo

Nessa situação as tolerâncias devem assegurar o funcionamento do conjunto como um mancal hidrodinâmico.





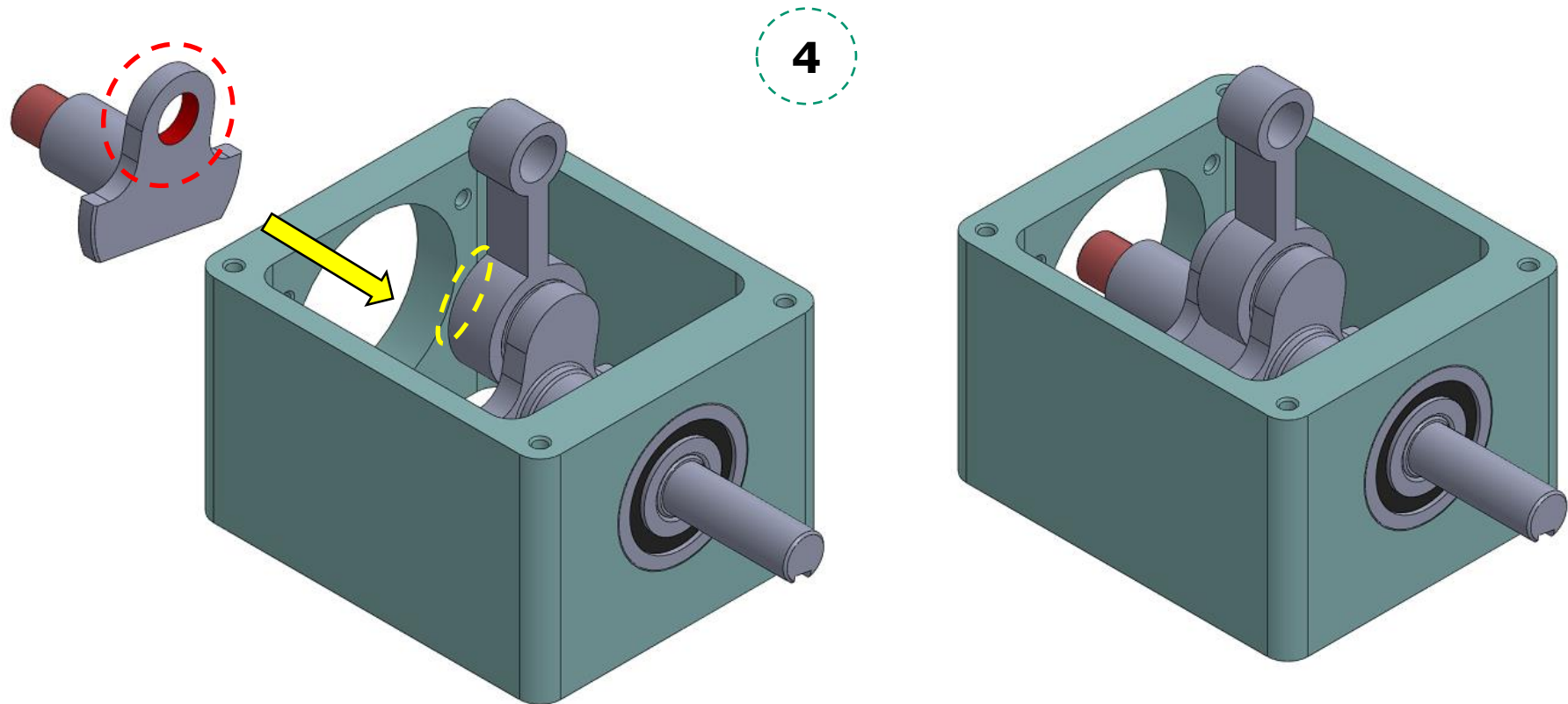
Montagem da biela no semieixo esquerdo



- No caso da montagem funcionar como um mancal hidrodinâmico. A folga é na ordem de 40 a 200 μm no diâmetro, e depende da carga a ser suportada, da rotação do eixo e da viscosidade do óleo a ser empregado.



Sequência de montagem dos conjuntos



Montagem do semieixo direito no semieixo esquerdo



Montagem do semieixo direito no semieixo esquerdo

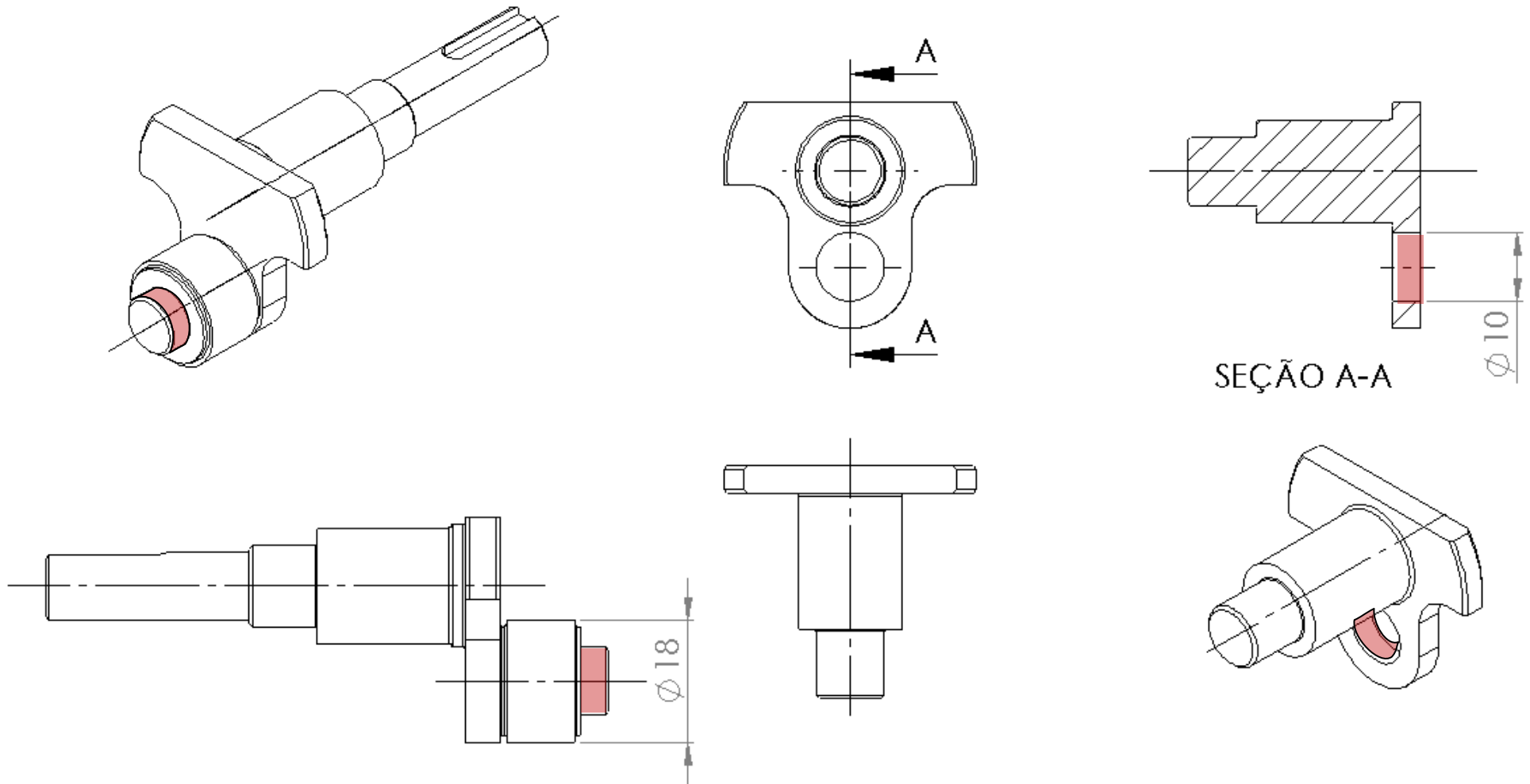
O semieixo direito deve entrar sem folga no ressalto do acento do semieixo esquerdo e deve ser feita com um mínimo esforço.

Pesquise:

- Nesta condição de montagem sem folga e sem esforço, o que você recomendaria para manter os dois semieixos unidos?



Montagem do semieixo direito no semieixo esquerdo





Montagem do semieixo direito no semieixo esquerdo

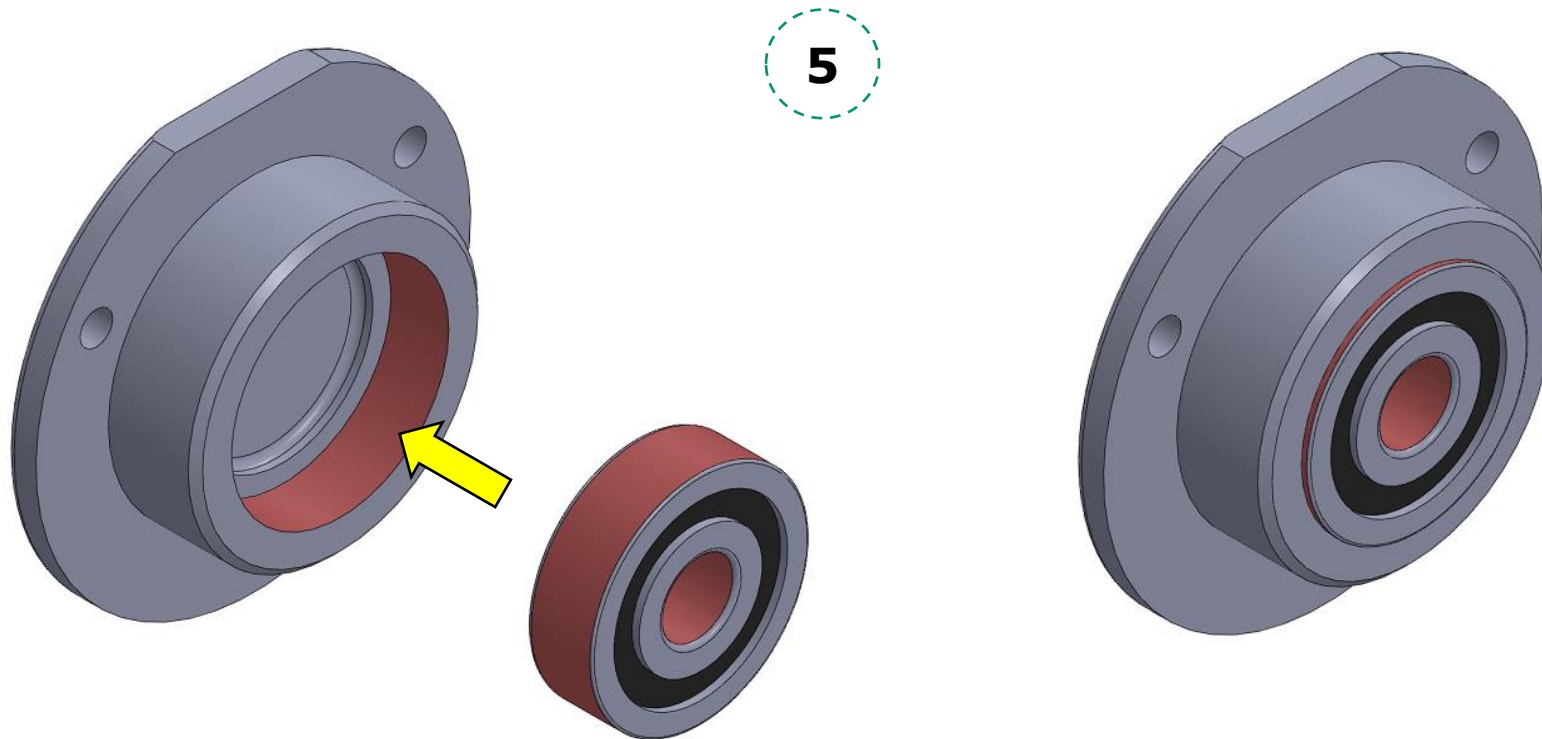
O semieixo direito deve entrar sem folga no ressalto do acento do semieixo esquerdo e deve ser feita com um mínimo esforço.

Pesquise:

- Nesta condição de montagem sem folga e sem esforço, o que você recomendaria para manter os dois semieixos unidos?
- **Solução: a montagem biela semieixo sem folga no ressalto do acento do semieixo esquerdo pode ser H6/h7, H7/g6, montagem com interferência leve**



Sequência de montagem dos conjuntos



Montagem do rolamento direito na flange



Montagem do rolamento direito na flange

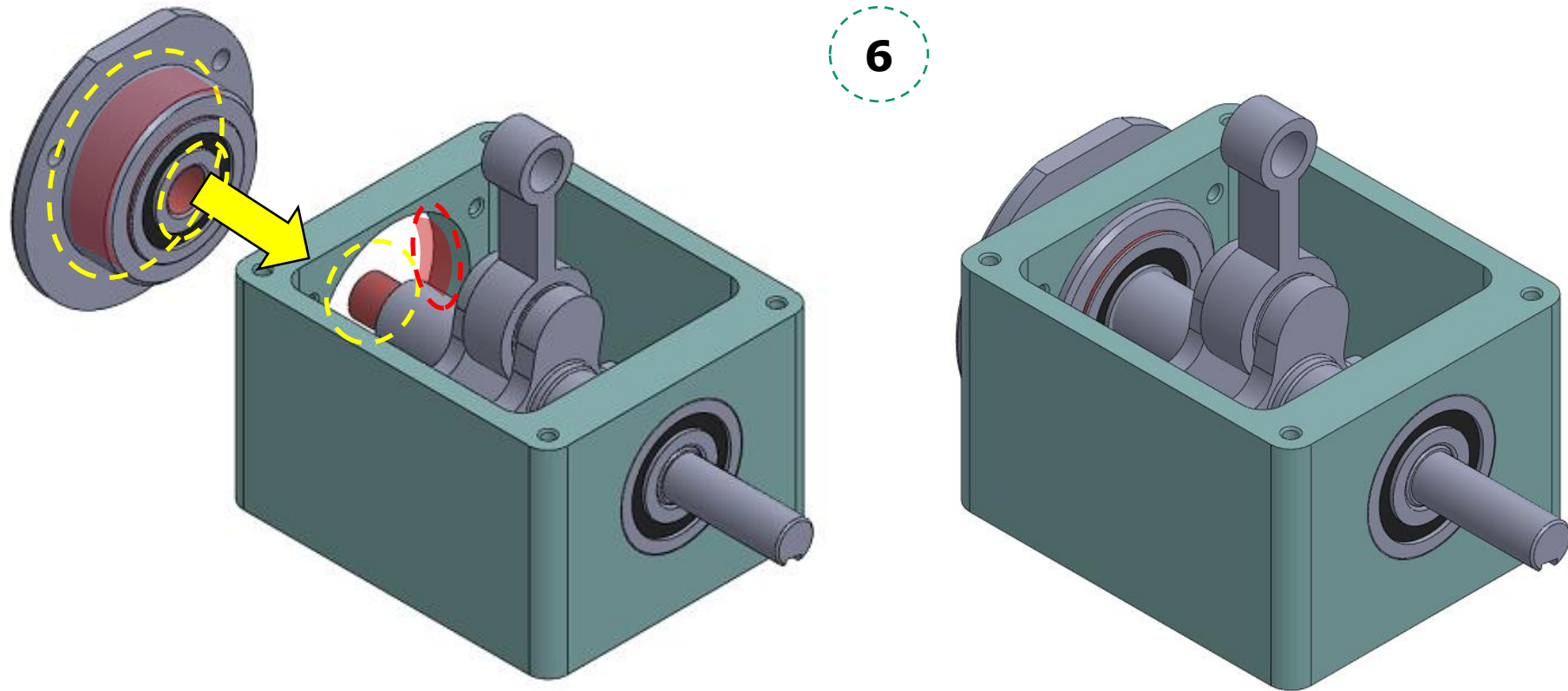
O rolamento deve entrar sem folga na flange e a montagem deve ser feita com um mínimo esforço, no máximo com auxílio de um martelo de borracha. Pesquise:

- As tolerâncias especificadas para a montagem 1 podem ser repetidas?

➤ **Solução: Sim**



Sequência de montagem dos conjuntos



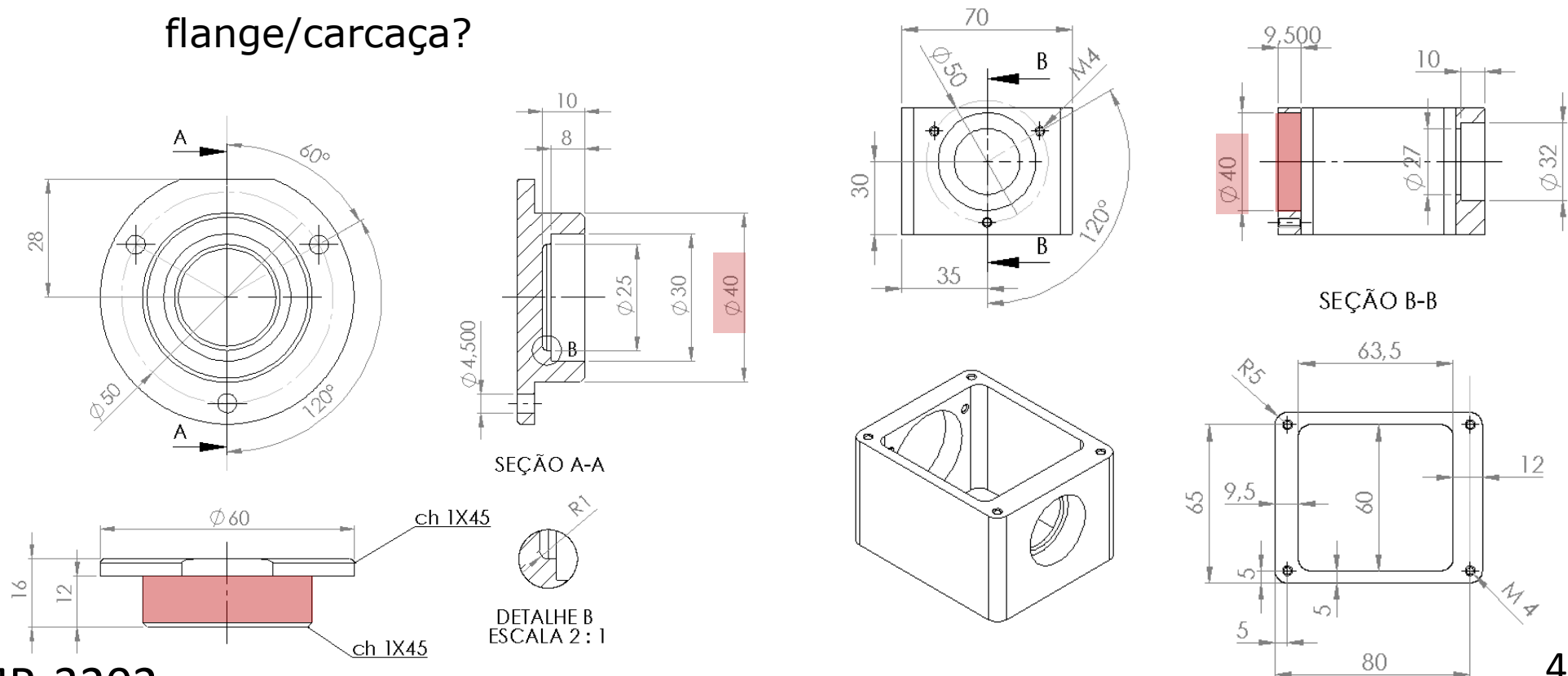
**Montagem do conjunto rolamento direito / flange
no semieixo direito / carcaça**



Montagem do conjunto rolamento direito / flange no semieixo direito / carcaça

A flange deve ser montada na carcaça sem esforço e com um mínima folga. Pesquise:

- Quais devem ser as tolerâncias recomendadas o conjunto flange/carcaça?





Montagem do conjunto rolamento direito / flange no semieixo direito / carcaça

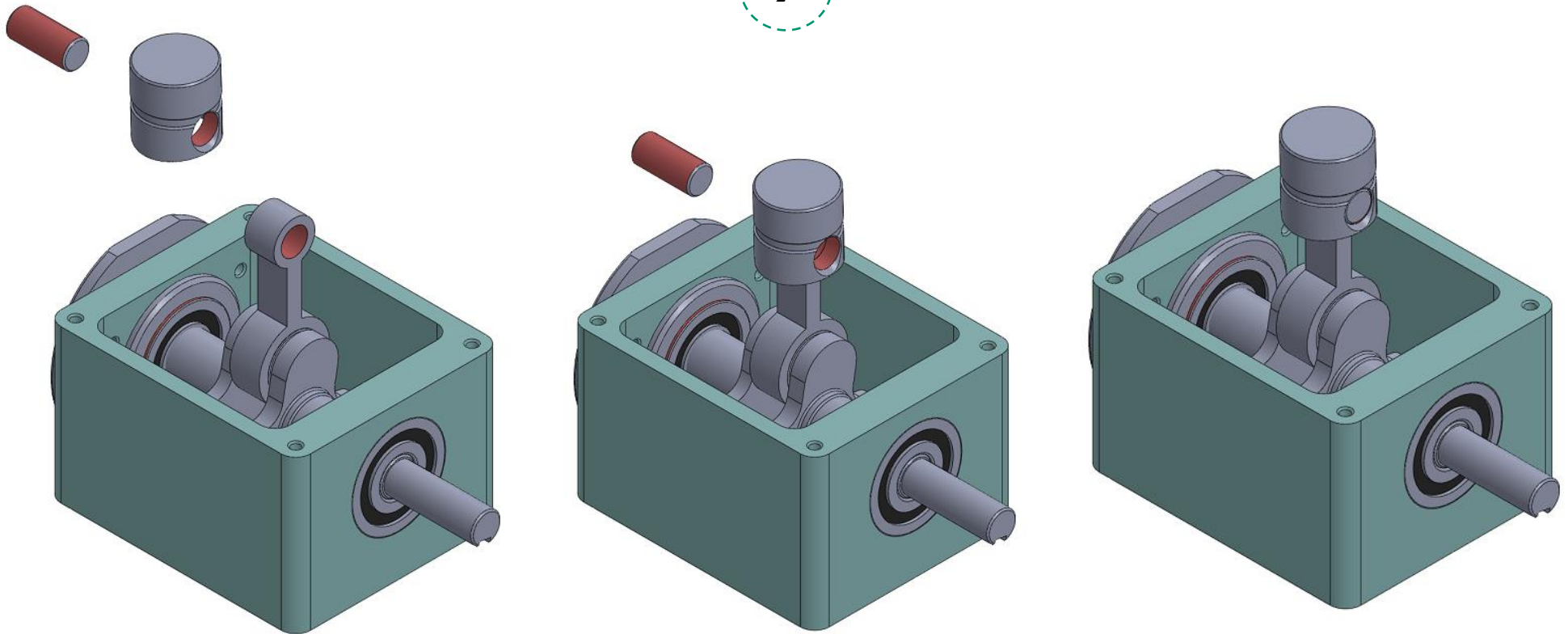
A flange deve ser montada na carcaça sem esforço e com um mínima folga. Pesquise:

- Quais devem ser as tolerâncias recomendadas o conjunto flange/carcaça?
- **Solução: Para a flange (40 +0/+0,2), para o furo (40 +0/-0,1)**



Sequência de montagem dos conjuntos

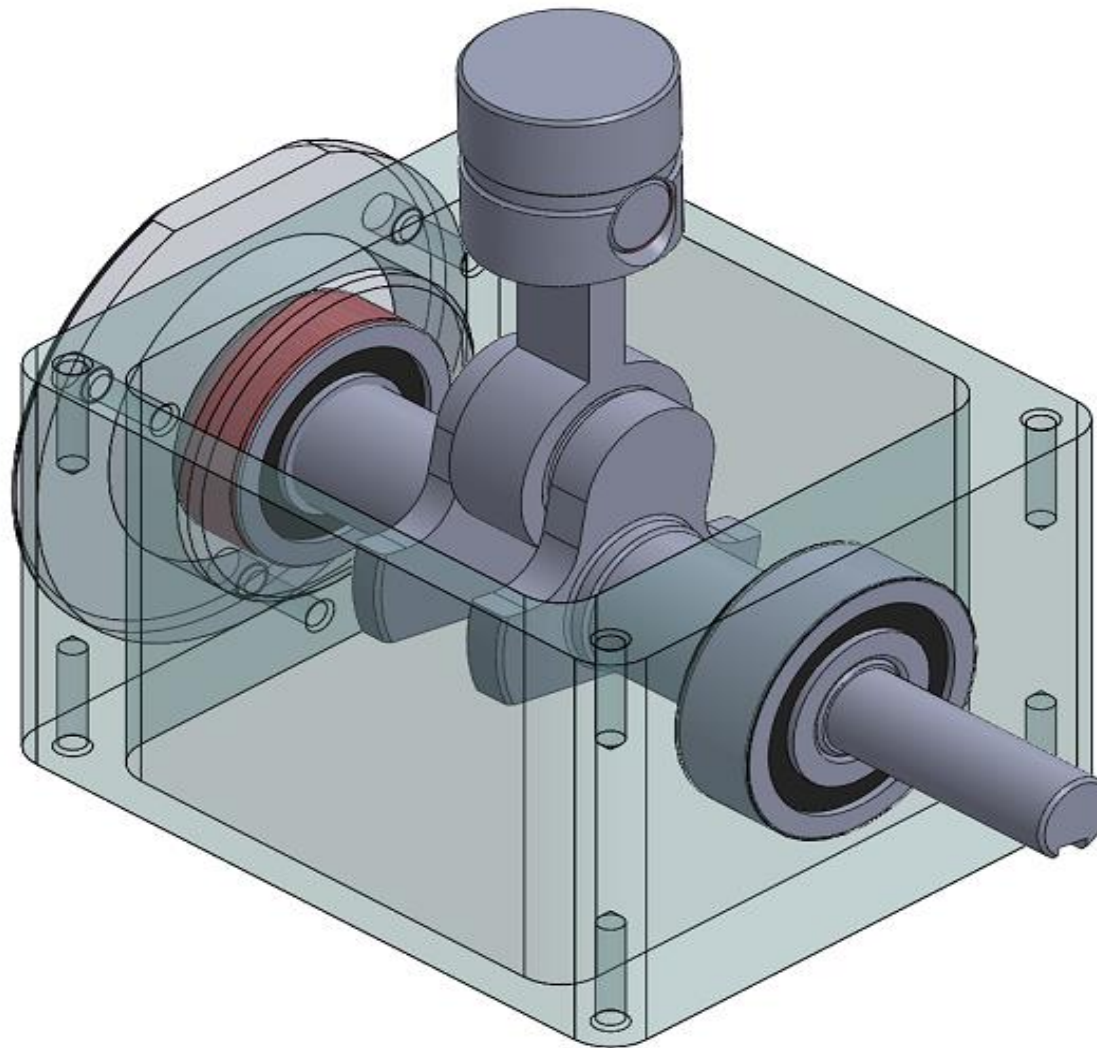
7



Montagem do pistão na biela



Conjunto montado





Tolerâncias geométricas – Guia completo

GD&T GUIDE PER ASME Y14.5M - 1994						IIGDT				
Feature Categories	Tolerance Types	ASME Symbol	Drawing Callout Example	Drawing Callout Meaning	Manual or Functional Gaging Method	Pictorial View	Tolerance Zone Definition (For Example)	Zone Modifiers Allowed	Datums Used	Additional Comments
for Individual Features	Form	Straightness (6.4.1)					Parallel lines, within which the surface element must lie	No (Surface)	No	- Refinement of size. - Tolerance value must be less than the size tolerance.
							Cylindrical boundary, within which the axis of the feature must lie (derived median line)	Yes (Axis)	No	- Not a refinement of size. - Rule #1 of ANSI (2.7.1) only applies to each circular element. - MMC or RFS only. - Where necessary the geometric tolerance may be greater than the size tolerance.
		Flatness (6.4.2)					Parallel Planes, within which the elements of a surface must lie	No	No	- Refinement of size. - Tolerance value must be less than the size tolerance.
		Circularity (6.4.3)					Concentric circles, within which each circular element of the surface must lie	No	No	- Refinement of size. - Does not control straightness or taper. - Tolerance value must be less than the size tolerance.
		Cylindricity (6.4.4)					Concentric cylinders, within which all surface elements must lie	No	No	- Refinement of size. - Tolerance value must be less than the size tolerance. - Cylindricity is a composite control of form which includes circularity, straightness and taper of a cylindrical feature.
for Individual or Related Features	Profile of a Surface	Profile of a Surface (6.5.2 a)					A uniform boundary equally disposed along the true (theoretically exact) profile within which the elements of the surface must lie	No	Yes	- Used to control form or combinations of size, form, orientation, and location. - Tolerance zone can be bilateral or unilateral. - Basic dimensions must be used to establish the true profile.
							Parallel planes, within which the elements of both surfaces must lie simultaneously	No	No (In this example)	- Used as a refinement of size, the profile tolerance must be contained within the size limits. - Also controls flatness of each ind. surface. - If a datum was used with a linear dimension it would also control parallelism. - Datum with a basic dimension would control the tolerance around the true profile.
		Profile of a Line (6.5.2 b)					A uniform boundary equally disposed along the true (theoretically exact) profile, within which the surface elements of each cross-section must lie	No	No (In this example)	- Used to control form, or combination of size, form, orientation, and location. - Tolerance zone can be bilateral or unilateral. - Can be used as refinement of size. - Datums can be used where necessary to define design intent differently (in other examples).



Tolerâncias geométricas – Guia completo

Dimensional Form and Feature Related Surface Axis Feature Feature Feature Feature Feature Feature Feature Feature	Irregularity (6.6.2)				Parallel planes, at a specified basic angle from a datum plane(s) within which the elements must lie.	No (Surface)	Yes	- Also controls surface flatness. - A basic angle must be used from the tolerance feature to the datum referenced. - MBC can be used when angularity is applied to an axis or centerplane of a feature.
	Perpendicularity (6.6.4)				Parallel planes, at 90 degrees basic (perpendicular) to a datum plane(s) within which the elements of a surface must lie.	No (Surface)	Yes	- A refinement of size. - Also controls surface flatness.
	Parallelism (6.6.3)				Cylindrical boundary, at 90 degrees basic (perpendicular) to a datum plane within which the axis of the feature must lie.	Yes (Axis)	Yes	- Not a refinement of size. - Hole must also be within size limits. - Calculation $\sqrt{x^2 + y^2}$
	Position (5.2)				Parallel planes, parallel to a datum plane (or axis) within which the elements of a surface must lie.	No (Surface)	Yes	- Refinement of size. - Also controls surface flatness. - Can be applied to an axis of a feature in which the zone could be parallel planes or a cylindrical tolerance zone. - MBC can be used when parallelism is applied to an axis or centerplane of a feature.
	Concentricity (5.12)				Cylindrical boundary, within which the center axis of a cylindrical feature of size is permitted to vary from the true (theoretically exact) position.	Yes	Yes	- Primary control for features of size. - Tol. zone also defines the limits of variation in attitude (perpendicularity) of the axis of a cylinder or slot in relationship to a datum(s). - Where feature control frames contain the same datum in the same order of precedence with the same modifying symbols, they are considered a single composite pattern. If not required, it must state "SEPARATE REQUIREMENT". - Calculation $2\sqrt{\Delta x^2 + \Delta y^2}$ - Note: For non-diameter tolerance zone, you will only have either a Δx or Δy, not both.
	Symmetry (5.14)				Parallel planes, within which the center plane of a slot is permitted to vary from the true (theoretically exact) position.	Yes	Yes	- Calculation $2\sqrt{\Delta x^2 + \Delta y^2}$ - Note: For non-diameter tolerance zone, you will only have either a Δx or Δy, not both.
	Circular Runout (6.7.1.2.1)				Cylindrical boundary, within which the axis of all cross-sectional elements of a surface of revolution are common to the axis of the datum feature.	No	Yes	- Median points to axis control. - The specified tol. and the datum reference apply only on an RFS basis. - Used primarily for dynamically balanced comp. - Involves complex analysis of the surface to determine axis location. - Consider using position or profile before specifying concentricity.
	Total Runout (6.7.1.2.2)				Parallel planes, within which the median points of all opposed or correspondingly located elements of a surface(s) are common to the center plane of the datum feature.	No	Yes	- The specified tol. and the datum reference apply only on an RFS basis. - Involves complex analysis of the surface to determine location. - Consider using position or profile before specifying symmetry.
	Circular Runout (6.7.1.2.1)				Two concentric circles, within which each circular element must lie in relationship to the datum axis.	No	Yes	- An axis to surface control. - A composite control which includes roundness and axis offset. - Applies to each circular element independently. - Datum applied on an RFS basis only.
	Total Runout (6.7.1.2.2)				Two concentric cylinders, within which all circular elements must lie (simultaneously) in relationship to the datum axis.	No	Yes	- An axis to surface control. - Provides composite control of all surface elements. Used to control cumulative variations of circularity, straightness, taper, and axis offset. - Datum applied on an RFS basis only.