EP/MF

Engineered Polymer Bearings

Designer´s Handbook

GGB

Quality

All the products described in this handbook are manufactured under DIN ISO 9001/2 or QS 9000 approved quality management systems.

CERTIFICATE

DQS GmbH
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GLACIER GARLOCK
BEARINGS GMBH & CO. KG
Ochsenbrunnenstraße 9
D-74078 Heilbronn
Germany

with the production sites as listed in the annex

for the scope

Manufacture and distribution of plain bearings for the automotive industry and other industrial applications with design at GLACIER GARLOCK BEARINGS E U R L Annecy, France

has implemented and maintains a

Quality Management System.

An audit, conducted in accordance with the "Rules for certification bodies to ISO/TS 16949:2002 First Edition" and documented in a report, has verified that this quality management system fulfills the requirements of the following ISO Technical Specification including ISO 9001:2000:

ISO/TS 16949:2002
Second Edition March 2002

CERTIFICATE

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DIN EN ISO 14001
October 1996 edition

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for the scope

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GLACIER GARLOCK BEARINGS E U R

has implemented and main

Quality Management

An audit, documented in a report, has
quality management system fulfills th
of the following standa

DIN EN ISO 9001 :
December 2000 editio

This certificate is valid until

Certificate Registration No.:

Frankfurt am Main, Berlin

Ass. iur. M. Drechsel

MANAGING DIRECTORS

CERTIFICAT AFAQ CERTIFICATE

N° TS/2003/21286

N° IATF : 0017381

GLACIER GARLOCK BEARINGS

CONCEPTION, INDUSTRIALISATION, FABRICATION ET VENTE DE SYSTEMES ANTI-FRICTION.

INDUSTRIALISATION, FABRICATION ET VENTE DE PALIERS DE POMPES HYDRAULIQUES A ENGRENAGES.

DESIGN, DEVELOPMENT, MANUFACTURING AND SALES OF ANTI-FRICTION SYSTEMS.

DEVELOPMENT, MANUFACTURING AND SALES OF HYDRAULIC GEAR PUMP BEARINGS BLOCKS.

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22-28, rue Henri Barbusse F-92110 CLICHY
(Liste des sites en annexes n° 1 à n° 2)
(List of locations on appendices n° 1 to n° 2)

ISO/TS 16949 : 2002

Néant

2003-11-07

2006-11-06

M. FONDEVIOLE — O. PEYRAT — JL. ZATTARA

CERTIFICATION

N° ENV/2003/21538

GLACIER GARLOCK BEARINGS

INDUSTRIALISATION, FABRICATION ET VENTE DE SYSTEMES ANTI-FRICTION.

INDUSTRIALIZATION, MANUFACTURING AND SALES OF ANTI-FRICTION SYSTEMS.

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ISO 14001 (1996)

2003-12-29

2006-12-28

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Formula Symbols and Designations

Formula Symbol	Unit	Designation
a_B	-	Bearing size factor
a_E	-	High load factor
a_I	-	Intermittant operation factor
a_M	-	Mating material factor
a_Q	-	Speed/Load factor
a_S	-	Surface finish factor
a_T	-	Temperature application factor
a_U	-	Rubbing speed factor
a_W	-	Wear factor
B	mm	Nominal bush length
B_{fl}	mm	Nominal flange thickness
C	1/min	Oscillating movement frequency
C_D	mm	Installed diametral clearance
C_o	mm	OD chamfer length
C_i	mm	ID chamfer length
D_H	mm	Housing Diameter
D_i	mm	Nominal bush ID/nominal thrust washer ID
$D_{i,a}$	mm	Bush ID when assembled in middle H7 housing
D_o	mm	Nominal bush OD/nominal thrust washer OD
D_{fl}	mm	Flange diameter
D_J	mm	Shaft diameter
E_1	N/mm^2	Elastic modulus in tension
F	N	Bearing load
f	-	Coefficient of friction
K_W	-	Material wear constant
k_1	-	Heat dissipation factor
k_2	-	Heat dissipation factor
L_H	h	Bearing service life
N	1/min	Rotational speed
$\bar{N}$	1/min	Rotational speed for oscillating motion

Formula Symbol	Unit	Designation
$\bar{p}$	N/mm^2	Specific load
$\bar{p}_{sta,lim}$	N/mm^2	Maximum static load
$\bar{p}_{dyn,lim}$	N/mm^2	Maximum dynamic load
R_a	mm	Surface roughness (DIN 4768, ISO/DIN 4287/1)
s	mm	Bush wall thickness
T	°C	Temperature
T_{amb}	°C	Ambient temperature
t_{off}	s or min	down time
t_{on}	s or min	operating time
$T_{s,max}$	°C	Maximum temperature
$T_{s,min}$	°C	Minimum temperature
T_M	°C	mean bearing temperature
T_S	°C	Sliding surface temperature
Δ_T	-	Temperature difference
U	m/s	Sliding speed
U_{lim}	m/s	Maximum sliding speed
α_1	$1/10^6K$	Coefficient of linear thermal expansion
σ_c	N/mm^2	Compressive Yield strength
σ_f	N/mm^2	Bending strength
σ_t	N/mm^2	Tensile strength
Δ_{sa}	-	Permissible radial wear (0.2 mm)
Δ_{sh}	-	Rubbing wear rate
τ	-	Application correction exponent
λ	W/mK	Thermal conductivity
λ_B	W/mK	Thermal conductivity of bearing material
λ_J	W/mK	Thermal conductivity of shaft material
φ	°	Angular displacement
Θ	-	amplitude either side of a mean position
η	Ns/mm^2	Dynamic Viscosity
Z_T	-	Total number of osscillating movements

Contents

1 Introduction

The purpose of this handbook is to provide comprehensive technical information on the characteristics of GGB maintenance-free, self-lubricating, injection moulded thermoplastic bearing materials. The information given permits designers to establish the appropriate material required for a particular application. GGB applications and development services are available to assist with unusual design problems.

GGB is continually refining and extending its experimental and theoretical knowledge and, therefore, when using this brochure it is always worthwhile to contact the Company should additional information be required.

As it is impossible to cover all conditions of operation which arise in practice, customers are advised to carry out prototype testing wherever possible.

1.1 Characteristics and Advantages

EP, MF15 and MF41 offer the following advantages:

- **Maintenance free operation**
- **No external lubrication required**
- **Seizure resistant**
- **Good frictional properties**
- **Corrosion resistant**
- **Compact assembly**
- **Simple installation**
- **Low noise**

2 Materials

GGB thermoplastic injection moulded bearings are complementary to GGB's maintenance free metal-polymer bearing materials for dry and pre-lubricated applications.

2.1 Standard Stock Products

EP

EP is a homogeneous composite material based on an aromatic polyamide with solid lubricant polytetrafluorothylene (PTFE) and glass fibre fillers specially formulated to provide excellent wear resistance and low friction over a wide range of light duty operating conditions.

EP bearings are self lubricating and maintenance free with excellent dimensional stability, low coefficient of friction, high compressive strength and creep resistance, low thermal expansion and good thermal conductivity.

MF 15

MF 15 is a homogeneous composite material based on polyetheretherketone (PEET), one of the highest performance thermoplastics available.

MF 15 is self lubricated and maintenance free. It has been specially formulated to provide good friction and wear properties under high loads and temperatures. In addition the material has excellent chemical resistance and good hydrolytic stability.

MF 41

MF41 is a homogeneous composite material based on polybutylene terephthalate (PBT) with solid lubricant and bronze powder fillers specially formulated to provide good friction and wear properties under light duty conditions at moderate cost.

MF41 bearings are self lubricating and maintenance free with good dimensional stability, low coefficient of friction, high compressive strength, low thermal expansion and good thermal conductivity.

Basic Forms

EP, MF15 and MF41 materials are available from stock as standard components, manufactured to standard dimensions in the following forms:

Metric Sizes

- Cylindrical Bushes
- Flanged Bushes

These standard dimensions are designed such that EP, MF15 and MF41 are directly interchangeable with the standard range of DU metal-polymer bearings.

For more severe duty application reference should be made to the DU/DU-B Dry Bearings Designers' Handbook.

Fig. 1: Standard Components

Non Standard Components not available from stock

These products can also be manufactured to customers' requirements with or without GGB recommendations, including for example:

- Modified standard components
- Spherical bearings and components
- Thrust washers
- Complex components suitable for manufacture by injection moulding

Fig. 2: Non Standard Components

Thermoplastic Injection Moulded Materials not available from stock

Also available from GGB is an extensive range of alternative injection moulded thermoplastic bearing materials formulated to meet specific application requirements. These materials are not available from stock but can be manufactured to the same dimensions as the standard stock material ranges of cylindrical and flanged bushes in addition to special components to customer's requirements.

GGB are able to supply multi-layer injection moulded bearing components in which different materials are used for the sliding and supporting layers. The properties of each material can thus be optimised to meet the tribological and structural requirements of the application. For applications where the bearing is greased on assembly it is possible to provide a bearing surface with a uniform moulded pattern of indents, which thus act as a grease reservoir.

GGB are also able to supply injection moulded bearings complete with integral sealing elements.

The materials available include the following:

Material Grade	Polymer	Fillers	Comments
MF31	Polybutylene terephthalate (PBT)	aramid +bronze powder + PTFE	Good for dry or marginally lubricated applications. Economic cost.
MF38	Polybutylene terephthalate (PBT)	glass fibre + bronze powder + PTFE	For special parts at economic cost
MF52	Polyoxymethylene (POM)	PTFE	Good for dry or marginally lubricated applications. FDA approval possible.
MF62	Polyphenylene sulphide (PPS)	glass fibre + PTFE	Good for marginally lubricated applications. Very low water absorption and good chemical resistance.
MF15	Polyetheretherketone (PEEK)	carbon fibre + graphite + PTFE	High temperature applications up to 250 °C. Good chemical resistance.
Torlon 4203	Poly(amide-imide) (PAI)	PTFE +TiO_2	High strength material, good chemical resistance.
Torlon 4301	Poly(amide-imide) (PAI)	graphite + PTFE	Good for dry applications at elevated temperatures.

Table 1: Other Thermoplastic Bearing Materials

Applications

GGB injection moulded thermoplastic bearings are suitable for rotating, oscillating, reciprocating and sliding movements, and typical applications include:

- Domestic appliances
- Office equipment
- Automotive components
- Valves
- Presses
- Electric motors
- Machine tools
- Mechanical handling equipment
- Printing machines
- Food and pharmaceutical handling equipment

3 Composition and Structure

EP

EP is a polyamide resin containing both aromatic and aliphatic elements with the addition of solid lubricant and glass fibre fillers formulated to provide the optimum combination of physical and mechanical properties and bearing performance.

EP, as for all the injection moulded bearing materials described here, has a homogeneous structure and hence the wear performance is uniform throughout. The allowable wear is limited only by the bearing wall thickness and the mechanical constraints of the application.

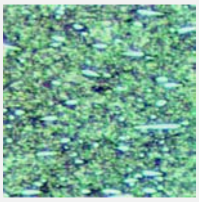


Fig. 3: EP Microstructure

MF15

MF 15 is a polyetheretherketone (PEEK) polymer with the addition of polytetrafluorethylene (PTFE), graphite and carbon fibre to provide an optimum balance of physical and mechanical properties. The carbon fibres significantly enhance the mechanical properties and enable the composite to withstand high loads.

Fig. 4: MF 15 Microstructure

MF41

MF41 is a PBT polyester resin with the addition of PTFE and bronze powder fillers formulated to provide the optimum combination of physical and mechanical properties and bearing performance.

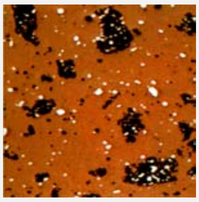


Fig. 5: MF41 Microstructure

4 Chemical Resistance

Chemical	Concen-tration %	Tempera-ture °C	Rating								
			EP	MF15	MF41	MF31	MF38	MF52	MF62	Torlon 4203	Torlon 4301
Strong Acids											
Hydrochloric Acid	5	23	-	+	-	-	-	-	-	+	+
Nitric Acid	5	23	-	+	-	-	-	-	-	+	+
Sulphuric Acid	5	23	-	+	+	+	+	-	+	+	+
Weak Acids											
Acetic Acid	5	23	-	+	+	+	+	+	+	+	+
Formic Acid	5	23	-	+	+	-	+	+	+	+	+
Bases											
Ammonia	10	23	+	-	-	-	-	+	+	-	-
Sodium Hydroxide	5	23	+	+	+	+	+	+	-	-	+
Solvents											
Acetone		23	+	+	+	-	+	+	+	+	na
Carbon Tetrachloride		23	+	+	+	+	+	+	+	+	+
Lubricants and fuels											
Paraffin		23	+	+	+	+	+	+	+	+	+
Gasolene		23	+	+	+	+	+	+	+	+	+
Kerosene		23	+	+	+	+	+	+	+	+	+
Diesel fuel		23	+	+	+	+	+	+	+	+	+
Mineral Oil		70	+	+	+	+	+	+	+	+	+
HFA-ISO46 High Water fluid		70	+	+	+	+	+	+	+	+	+
HFC-Water-Glycol		70	+	+	+	+	+	+	+	+	+
HFD-Phosphate Ester		70	na	+	na	na	na	+	+	+	+
Water		20	+	+	+	+	+	+	+	+	+
Sea Water		20	+	+	+	+	+	+	+	+	+

Table 2: Chemical Properties

+	**Satisfactory:** Damage is unlikely to occur.
-	**Unsatisfactory:** Damage will occur and is likely to affect either the structural integrity and/or the tribological performance of the material.
na	**Not Available:** This information is not available.

5 Material Properties

Material Type	EP	MF15	MF41	MF31	MF38	MF52	MF62	TORLON 4203	TORLON 4301
BASIC POLYMER + Fillers	PA6.6T + GF + PTFE + Graphite	PEEK + CF + PTFE + Graphite	PBT + Bronze Powder + PTFE	PBT + Aramide + Bronze Powder + PTFE	PBT + LGF + Bronze Powder + PTFE	POM + PTFE	PPS + GF + PTFE	PAI + TIO2 + PTFE	PAI + Graphite + PTFE
PHYSICAL PROPERTIES									
Colour	black	black	brown	olive	grey	white	light brown	yellow brown	dark brown
Thermal conductivity λ_B [W/mK]	0.40	0.60	0.26	0.27	0.26	0.32	0.34	0.26	0.54
Coeff. of linear thermal expansion α_1 [10^{-5}/k]	2.2	3.0	1.4	1.3	2.5	12	3.0	3.1	2.5
Density [g/cm^3]	1.52	1.53	1.65	1.80	1.73	1.52	1.74	1.38	1.45
Water absorption [%]									
Water vapour [50 % rH/24h]	0.26	0.10	0.10	0.15	0.30	0.2	0.05	0.33	0.2
MECHANICAL PROPERTIES									
Tensile strength σ_t [N/mm^2]	100	150	65	100	100	50	155	190	160
Modulus of elasticity in tension E_t [N/mm^2]	11000	6500	2800	4200	6400	2500	13000	5000	6600
BEARING PROPERTIES									
Material Wear Constant K_W	1	3.25	7.25	2.5	10	1	8.5	6.25	1
Max. specific load $\bar{p}_{stat\,max}$[N/mm^2]	80	150	70	80	90	60	120	200	150
Max. sliding speed U_{lim} [m/s]									
Dry, rotating	1	1.5	1	1	1.2	1	1.2	2.5	2.5
Dry, sliding	3	5	3	4	4.5	4	4.5	5	5
Max. $\bar{p}U$ [N/mm^2 x m/s] - dry	1.0	3.5	0.8	1.0	1.1	0.6	2.6	4.0	4.0
Min./max. sliding surface temperature $T_{s\,lim}$[°C]	-40 +140	-100 +250	-40 +100	-40 +120	-50 +130	-40 +80	-40 +200	-200 +260	-200 +260
Unloaded, short-time max. temperature	+240	+310	+150	+200	+200	+140	+260	+260	+260
Dynamic coefficient of friction f									
Dry against steel	0.15 - 0.25	0.10 - 0.20	0.10 - 0.20	0.10 - 0.20	0.10 - 0.20	0.07- 0.20	0.15- 0.30	0.10 - 0.20	0.08 - 0.15
lubricated	0.04 - 0.12								

Table 3: Physical, Mechanical and Bearing Properties

6 Wear and life calculations under dry running conditions

Because the operating conditions of a bearing can rarely be defined with absolute precision it is difficult to forecast wear rates exactly. However the following formulae, diagrams and tables will enable a useful approximations of the total wear rate Δs_h and life L_H to be calculated.

Description	Formula symbol	Unit	Value
Internal diameter	D_i	[mm]	
Outer diameter	D_o	[mm]	
Bush width	B	[mm]	
Wall thickness	s	[mm]	
Bearing load	F	[N]	
Rotational speed	N	[1/min]	
Average Rotational speed for oscillating motion			
$\bar{N} = \frac{4 \cdot \Theta \cdot C}{360}$	$\bar{N}$	[1/min]	
where Θ = amplitude either side of a mean position		[°]	
and C = frequency in cycles per minute		[1/min]	
Ambient temperature	T_{amb}	[°C]	
Maximum specific load (Table 3)	$\bar{p}$	[N/mm^2]	
Maximum sliding velocity (Table 3)	U_{lim}	[m/s]	
Coefficient of friction Dry (Fig. 6)	f	[-]	
Correction factor for rubbing speed (Fig. 7)	a_U	[-]	
Correction factor for mating material (Table 4)	a_M	[-]	
Correction factor for surface finish (Fig. 8)	a_S	[-]	
Correction factor for bearing size (Fig. 9)	a_B	[-]	
Correction factors for heat dissipation qualities of bearing design (Table 5)	k_1, k_2		
Thermal conductivity			
Bearing material (Table 3)	λ_B	[W/mk]	
Shaft material (Table 6)	λ_J	[W/mk]	
Correction factor for intermittant operation (Fig. 10)	a_i	[-]	
Wear factor (Fig. 11)	a_W	[-]	
Material Wear Constant (Table 3)	K_W	[-]	

Effect of specific bearing load $\bar{p}$

The coefficient of friction depends upon the specific load $\bar{p}$ and the surface roughness of the mating surface. Fig. 6 shows the relationship between the specific load and the coefficient of friction for mating surface roughness of R_a = 0.4-0.8 µm.

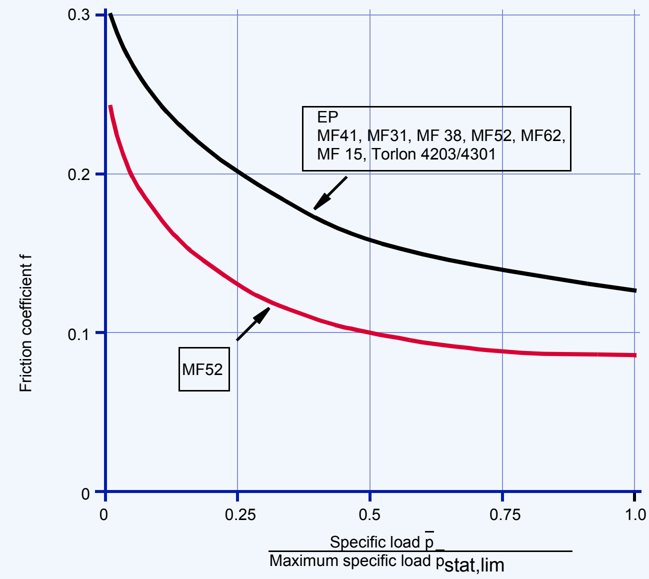


Fig. 6: Friction coefficient f vs specific load $\bar{p}$

Effect of sliding speed

The wear rate increases with sliding speed under constant $\bar{p}U$ conditions. Fig. 7 shows the relationship between rubbing speed factor a_U and sliding speed U.

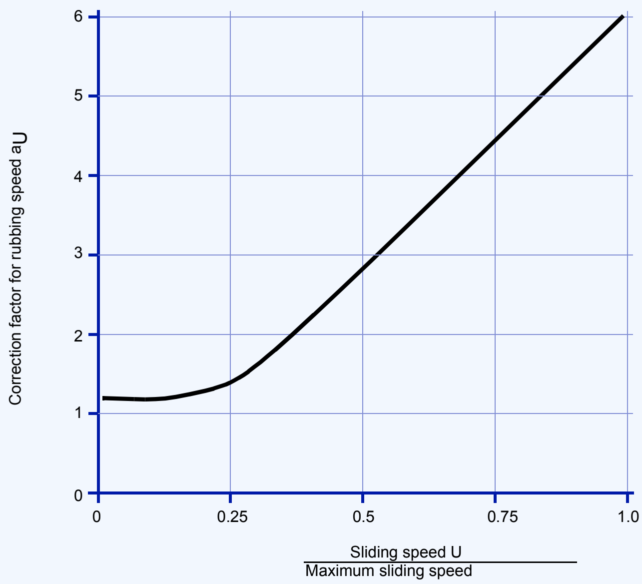


Fig. 7: Correction factor for sliding speed a_U as function of rubbing speed U

Effect of surface finish

The finish of the mating surface significantly affects the bush wear rate. Both excessively fine and coarse finishes can produce heavy wear.

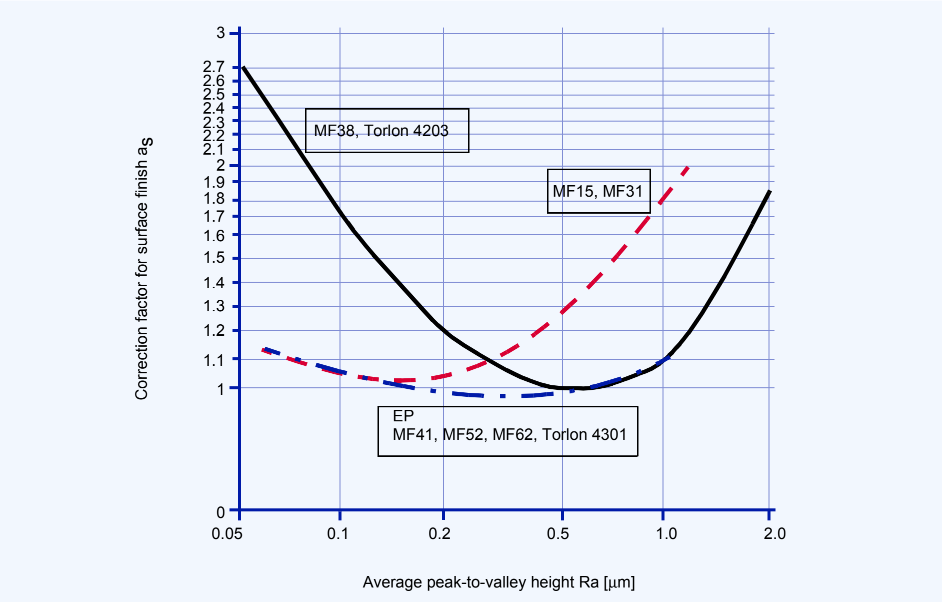


Fig. 8: Correction factor for surface finish a_S

Effect of bearing diameter

The temperature rise due to frictional heating is dependent upon the bearing diameter. Fig. 9 shows the relationship between the bearing size correction factor a_B and the bearing diameter D_i.

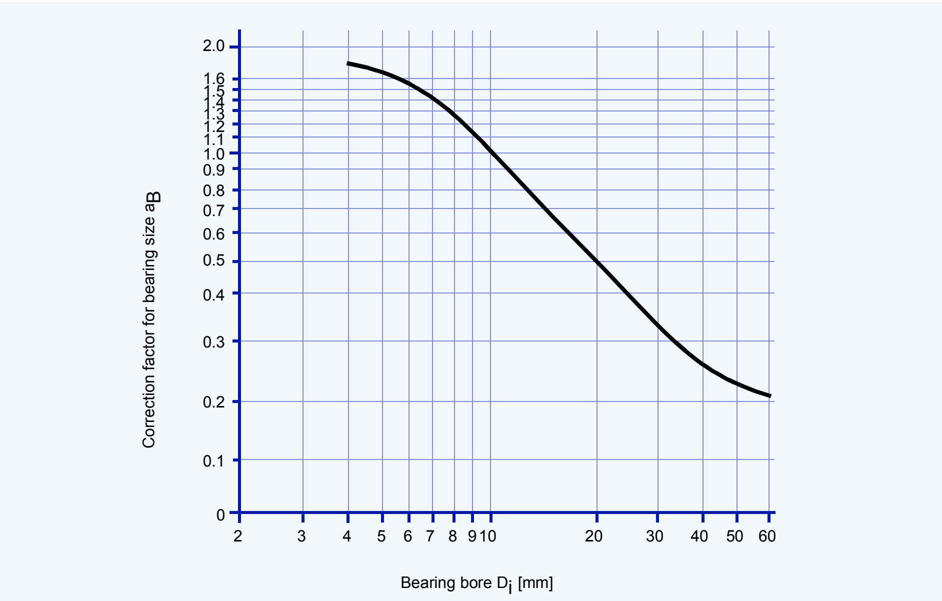


Fig. 9: Correction factor for bearing size a_B

Effect of intermittent operation

The temperature rise due to frictional heating is generally lower for a bearing operating intermittently than one operating continuously under the same $\overline{p}U$ conditions. Fig. 10 shows the relationship between the intermittent operation correction factor a_i and the operating cycle ratio t_{off}/t_{on}.

For example:

down time t_{off} = 40 sec

operating time t_{on} = 20 sec

operating cycle ratio = 40/20 = 2

For 20 seconds operation the correction factor a_I = 2.7 can be read off curve 2.

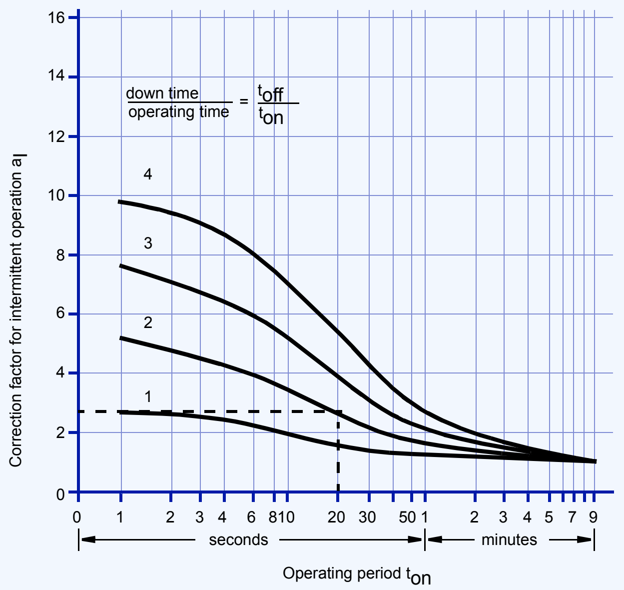


Fig. 10: Correction factor for intermittent operation a_I as function of load duration

Effect of specific load $\overline{p}$ and sliding surface temperature

The wear rate depends upon the specific load p and the sliding surface temperature T_s. Fig. 11 shows the relationship between wear rate correction factor a_W, specific load $\overline{p}$ and sliding surface temperature T_s.

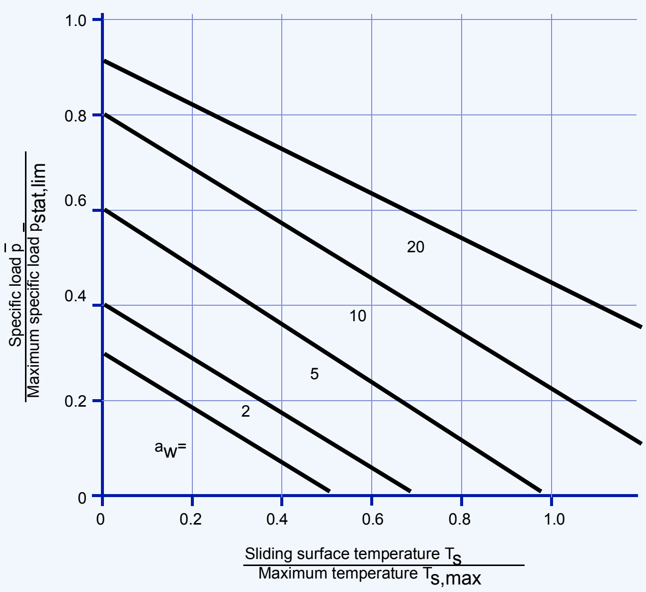


Fig. 11: Wear factor a_W as function of specific load $\overline{p}$ and sliding surface temperature T_s

Correction factor for mating material a_M

Material	Correction factor a_M	
Iron	2.5	Other materials are currently being tested!
Carbon steel	1	
Alloy steel	1	
Stainless steel	0.8	

Table 4: Correction factor for mating material a_M

Correction factors for heat dissipation qualities of bearing design

Bush wall thickness S [mm]	Correction factors		
	k_1	k_2	
2	0.5	0.042	k_1 and k_2 are factors, which take into account how heat dissipation is affected by bearing design
>2	0.75	0.058	

Table 5: Correction factors for heat dissipation qualities of bearing design

Thermal conductivity of mating surfaces λ_J

Material	Thermal conductivity λ_J [W/mK]
Cast iron	60
Carbon steel	46
Low alloy steel	55
Stainless steel	14.5
Aluminium alloy	150
Bronze	46
Phosphor bronze	75
Brass	80
Aluminium bronze	120

Table 6: Thermal conductivity of mating surfaces λ_J

Sliding friction coefficient for lubricated applications

Type of lubrication	Sliding friction coefficient	
Initial grease lubrication	0.12	Mixed lubrication ispresent when: $N_{tr} < \frac{F \cdot 10^5}{\eta \cdot V} [min^{-1}]$ in which: η = dynamic viscosity in cP, V = bearing volume $V = \frac{D_i^2 \cdot \pi \cdot B}{4} [mm^3]$
Grease reservoir	0.09	
Oil mist	0.09	
Water lubrication (mixed lubrication)	0.04	
Oil lubrication	0.04	

Table 7: Sliding friction coefficient for lubricated applications

Calculation Procedure

	Equations	Calculations
1.	**Specific bearing load $\bar{p}$ [N/mm^2]** $\bar{p} = \frac{F}{D_i \cdot B}$	
2.	**Sliding speed U [m/s]** $U = \frac{D_i \cdot \pi \cdot N}{60000}$ **or** $U = \frac{D_i \cdot \pi \cdot \bar{N}}{60000}$	
3.	**$\bar{p}$U Value [N/mm^2 x m/s]** $\bar{p} \cdot U$	
4.	**Temperature rise ΔT [°C]** $\Delta T = \frac{(\bar{p}U)^{\tau} \cdot 1000 \cdot f \cdot a_S}{\pi \cdot (A_B + A_J) \cdot a_B \cdot a_i} \cdot \frac{1}{2.5}$ **where τ is the correction exponent for the following conditions** **τ = 1.4 for rotational movement** **τ = 1.3 for oscillating movement, amplitude Θ > 22.5°** **τ = 1.2 for oscillating movement, amplitude 12.5° $\le \Theta \le$ 22.5°** **τ = 1.0, amplitude Θ < 12.5°** **in which** $A_B = \frac{\lambda_B \cdot k_1}{s_B}$ **and** $A_J = \frac{\lambda_J \cdot k_2}{2 \cdot B}$ **and a_i = 1 for continuous operation (for intermittant operation see Fig. 10)**	
5.	**Mean bearing temperature T_M[°C]** $T_M = \Delta T + T_{amb}$	
6.	**Sliding surface temperature T_S [°C] ($T_{s,max}$ = 140 °C)** $T_S = T_{amb} + \left(1.15 + \frac{T_M}{170}\right) \cdot \Delta T$	
7.	**Wear rate Δs_h [μm/h]** $\Delta s_h = \bar{p} \cdot U \cdot K_W \cdot a_W \cdot a_U \cdot a_M \cdot a_S$	
8.	**Life L_H [h]** $L_H = \frac{\Delta s_a \cdot 10^3}{\Delta s_h}$ **with Δs_a as permissible radial wear in mm (for which 0.2 mm can be assumed for normal applications)**	
9.	**The above calculations are modified as follows:** **Flanged bushes** $D_i = \frac{1}{2} \cdot (D_{fl} + D_i)$ **and** $B = \frac{\pi}{2} \cdot (D_{fl} - D_i)$ **where D_{fl} = Flange diameter and D_i = Internal diameter** **Thrust washers** $D_i = \frac{1}{2} \cdot (D_o + D_i)$ **and** $B = \frac{\pi}{2} \cdot (D_o - D_i)$ **where D_o = Thrust washer OD and D_i = Thrust washer ID**	

Worked Example

Calculation

Given		
unlubricated		
Bush 2015 EP		
Bush ID	D_i	20 mm
Bush OD	D_0	23 mm
Wall thickness	s_B	1.5 mm
Bush length	B	15 mm
Bearing load	F	40 N
Rotational speed	N	750 1/min
Ambient temperature	T_{amb}	20 °C
Shaft material		
Steel		HRC 50
Surface finish	R_a	0.6 µm
Establish: whether proposed bearing size is adequate, expected life of bearing and appropriate bearing clearance		

	Equations	Results
1.	**Specific bearing load $\bar{p}$ [N/mm²]** $\bar{p} = \frac{F}{D_i \cdot B} = \frac{40}{20 \cdot 15}$	0.133 N/mm²
2.	**Sliding speed U [m/s]** $U = \frac{D_i \cdot \pi \cdot N}{60000} = \frac{20 \cdot \pi \cdot 750}{60000}$	0.785 m/s
3.	**$\bar{p}$U Value [N/mm² x m/s]** $\bar{p} \cdot U = 0.133 \cdot 0.785$	0.105W/mm²
4.	**Temperature rise ΔT [°C], in which:** τ = 1.4 for rotational movement f = 0.3 from Fig. 6 a_S = 1 from Fig. 8 a_B = 0.5 from Fig. 9 a_i = 1 for continuous operation k1 = 0.5 from Table 5 k2 = 0.042 from Table 5 λ_J = 46 from Table 6, λ_B = 40 from Table 6 $A_B = \frac{\lambda_B \cdot k_1}{s_B} = \frac{0.40 \cdot 0.5}{1.5}$ $A_J = \frac{\lambda_J \cdot k_2}{2 \cdot B} = \frac{46 \cdot 0.042}{2 \cdot 15}$ $\Delta T = \frac{(\bar{p}U)^{\tau} \cdot 1000 \cdot f \cdot a_S}{\pi \cdot (A_B + A_J) \cdot a_B \cdot a_i} \cdot \frac{1}{2.5} = \frac{(0.105)^{1.4} \cdot 1000 \cdot 0.3 \cdot 1}{\pi \cdot (0.133 + 0.064) \cdot 0.5 \cdot 1} \cdot \frac{1}{2.5}$	0.133 0.064 16.407 °C
5.	**Mean bearing temperature T_M [°C]** $T_M = \Delta T + T_{amb} = 16.41 + 20$	36.41 °C
6.	**Sliding surface temperature T_s [°C] ($T_{S\ lim}$ = 140 °C)** $T_S = T_{amb} + \left(1.15 + \frac{T_m}{170}\right) \cdot \Delta T = 20 + \left(1.15 + \frac{36.41}{170}\right) \cdot 16.407$	42.38 °C
7.	**Wear rate Δs_h [µm/h], in which** a_W = from Fig. 11 a_U = from Fig. 7 a_M = from Table 4 a_S = from Fig. 8 K_W = from Table 3 $\Delta s_h = \bar{p} \cdot U \cdot K_W \cdot a_W \cdot a_U \cdot a_M \cdot a_S = 0.105 \cdot 1 \cdot 1.48 \cdot 1 \cdot 1$	0.504 µm/h
8.	**Life L_H [h]** **in which Δs_a = 0.2 mm** $L_H = \frac{\Delta s_a \cdot 10^3}{\Delta s_h} = \frac{0.2 \cdot 1000}{0.504}$	397 h

Result

Should the calculated life of 397 hours be insufficient, increase the bearing length and/or diameter.

The sliding surface temperature is <80 °C, so no increase in bearing clearance is necessary (see section 7)

7 Bearing Design

Housings

GGB injection moulded bearings are manufactured suitable for press fitting into housings machined to H7 tolerance. The press fit interference is 0.5-1.5 % depending upon the diameter.

For GGB injection moulded thermoplastic bearings the interference is maintained at temperatures between -40 °C and the maximum temperature, although some reduction in the press-fit force will occur at temperatures above 100 °C.

The bore of installed bushes will generally lie within the following tolerance range: EP bushes D11-D12, MF bushes F10.

Journals

Journals finished to h7 tolerance are preferred. For EP and MF bearings optimum wear performance is obtained with a journal surface finish ground to R_a 0.4-0.8 µm.

A minimum shaft hardness of HRC 50 is recommended.

Bearing Clearance

The bearing clearance is designed for bush operating temperatures in the range

-10 °C to +80 °C. Attention should be paid to the effect of thermal expansion. Where the normal operating temperature is above 80 °C, the clearance should be increased by about 0.15 o/oo per 10 °C increment.

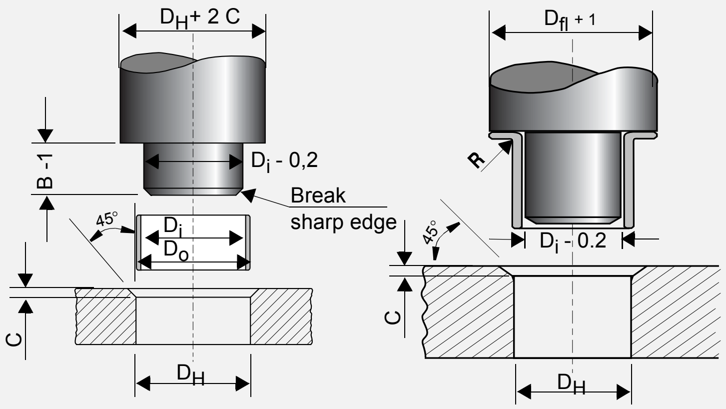
Installation

A GGB injection moulded bearing should be assembled into its housing with the aid of a stepped mandrel, preferably made from case-hardened mild steel.

To assist assembly a lead-in chamfer should be machined according to Fig. 12.

The bush, mandrel and housing must be correctly aligned during assembly.

Recommended mandrel and chamfer dimensions are given in Fig. 12.



Chamfer C	
D_H	C
≤ 12	0.8
> 12 ≤ 65	1.2
> 65	2.3

Fig. 12: Fitting instructions for bushes and flanged bushes

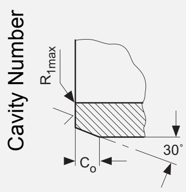
Machining

GGB injection moulded bushes can be machined with conventional tools at normal speeds.

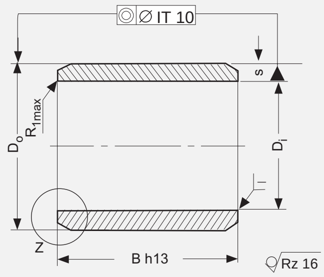
For materials containing glass fibres, such as EP, machining of the running surfaces is not recommended due to the increased exposure of glass fibre to the bearing surface which may result in excessive wear of the mating surface.

8 Product Size Tables

8.1 EP cylindrical bushes



Detail Z



s	C_0	R_1 max
1.0	0.5	0.1
1.5 - 2	0.8	0.2

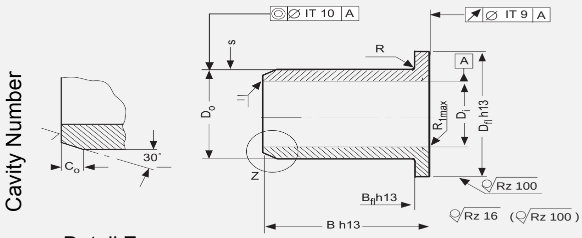
Recommended Shaft Tolerance h7

All dimensions in mm

Part No.	Dimensions [mm]			Weight [g]	Installed tolerance [H7]	
	ID-∅ D_i	OD-∅ D_0	Width B		Housing-∅ D_H [H7]	Bush bore $D_{i,a}$ after assembly in middle H7 housing
0505 EP	5	7	5	0.14	+0.015 0	+0.105 +0.030
0508 EP			8	0.22		
0510 EP			10	0.28		
0606 EP	6	8	6	0.20		
0608 EP			8	0.26		
0610 EP			10	0.33		
0806 EP	8	10	6	0.25		+0.130 +0.040
0808 EP			8	0.34		
0810 EP			10	0.42		
0812 EP			12	0.50		
0815 EP			15	0.63		
1004 EP	10	12	4	0.20	+0.018 0	
1006 EP			6	0.31		
1008 EP			8	0.41		
1010 EP			10	0.51		
1015 EP			15	0.77		
1020 EP			20	1.02		
1210 EP	12	14	10	0.60		+0.160 +0.050
1212 EP			12	0.73		
1215 EP			15	0.91		
1220 EP			20	1.21		
1415 EP	14	16	15	1.05		
1420 EP			20	1.40		
1425 EP			25	1.74		
1515 EP	15	17	15	1.12		
1520 EP			20	1.49		
1525 EP			25	1.86		

Part No.	Dimensions [mm]			Weight [g]	Installed tolerance [H7]	
	ID-∅ D_i	OD-∅ D_0	Width B		Housing-∅ D_H [H7]	Bush bore $D_{i,a}$ after assembly in middle H7 housing
2015 EP	20	23	15	2.25	+0.021 0	+0.195 +0.065
2020 EP			20	3.00		
2030 EP			30	4.50		
2515 EP	25	28	15	2.77		
2520 EP			20	3.70		
2530 EP			30	5.55		
3020 EP	30	34	20	5.95	+0.025 0	+0.240 +0.080
3030 EP			30	8.93		
3040EP			40	11.90		

8.2 EP Flanged bushes



Detail Z

s	C_0	R_1 max
1.0	0.5	0.1
1.5 - 2	0.8	0.2

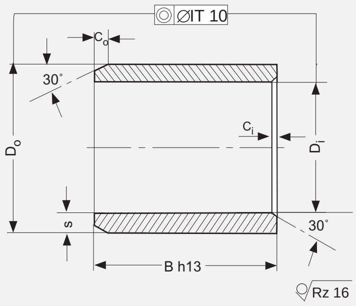
s	R (mm)
ð 1	0.3
> 1	0.5

Recommended Shaft Tolerance h7

All dimensions in mm

Part No.	Dimensions [mm]				Flange Thick-ness B_{fl}	Weight [g]	Installed tolerance [H7]	
	ID-∅ D_i	OD-∅ D_0	Flange-∅ D_{fl}	Width B			Housing-∅ D_H [H7]	Bush bore $D_{i,a}$ after assembly in middle H7 housing
BB 0505 EP	5	7	11	5	1	0.22	+0.015 0	+0.105 +0.030
BB 0604 EP	6	8	12	4	1	0.22		
BB 0606 EP				6		0.29		
BB 0608 EP				8		0.35		
BB 0610 EP				10		0.42		
BB 0806 EP	8	10	15		1	0.38		+0.130 +0.040
BB 0808 EP				6		0.46		
BB 0810 EP				10		0.54		
BB 1007 EP	10	12	18		1	0.57	+0.018 0	
BB 1009 EP						0.57		
BB 1012 EP						0.82		
BB 1015 EP				7		0.97		
BB 1017 EP				17		1.08		
BB 1207 EP	12	14	20		1	0.66		+0.160 +0.050
BB 1209 EP						0.78		
BB 1212 EP						0.96		
BB 1215 EP						1.15		
BB 1217 EP				10		1.27		
BB 1220 EP				12		1.46		
BB 1415 EP	14	16	22	15	1	1.10		
BB 1430 EP				30		1.45		
BB 1517 EP	15	17	23		1	0.95		
BB 1517 EP						1.17		
BB 1517 EP						1.54		
BB 1517 EP				17		1.76		
BB 2012 EP	20	23	30	12	1.5	2.37	+0.021 0	+0.195 +0.065
BB 2015 EP				15		3.12		
BB 2020 EP				20		3.87		
BB 2522 EP	25	28	35		1.5	2.89		
BB 2522 EP				22		3.82		
BB 2532 EP				32		4.74		

8.3 MF15 Cylindrical bushes



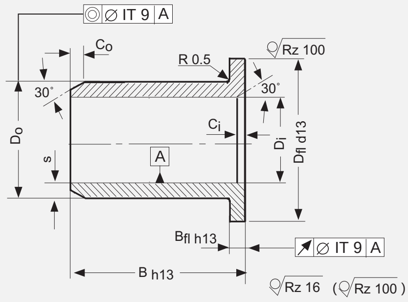
C_o = 0,5 x s, alternatively R ≤ 0,5
C_i = 0,5 x s, alternatively R ≤ 0,5 x 45°

Recommended Shaft Tolerance h7

All dimensions in mm

Part No.	Dimensions [mm]			Weight [g]	Installed tolerance [H7]	
	ID-∅ D_i	OD-∅ D_0	Width B		Housing-∅ D_H [H7]	Bush bore $D_{i,a}$ after assembly in middle H7 housing
0306 MF15	3	4,5	6	0,08	+0,012 0	+0,058 +0,010
0505 MF15	5	7	5	0,14	+0,015 0	
0515 MF15			15	0,42		
0620MF15	6	8	20	0,66		
0815 MF15	8	10	15	0,63		+0,071 +0,013
1012 MF15	10	12	12	0,62	+0,018 0	
1020 MF15			20	1,03		
1220 MF15	12	14	20	1,22		+0,086 +0,016
1412 MF15	14	16	12	0,84		
1425 MF15			25	1,75		
1525 MF15	15	17	25	1,87		
2015 MF15	20	23	15	2,26	+0,021 0	+0,104 +0,020
2030 MF15			30	4,53		
2530 MF15	25	28	30	5,58		
3015 MF15	30	34	15	4,49	+0,025 0	
3040 MF15			40	11,98		
3550 MF15	35	39	50	17,31		+0,125 +0,025
4050 MF15	40	44	50	19,65		
4525 MF15	45	50	25	13,89		
5050 MF15	50	55	50	30,70	+0,030 0	+0,125 +0,025
5060 MF15			60	36,84		
6070 MF15	60	65	70	51,17		+0,150 +0,030
7040 MF15	70	75	40	33,92		
7080 MF15			80	67,84		
7570 MF15	75	80	70	63,45		
8080 MF15	80	85	80	77,20	+0,035 0	
9090 MF15	90	95	90	97,37		+0,176 +0,036
10090 MF15	100	105	90	107,90		

8.4 MF15 Flanged bushes



C_o = 0.5 x s, alternatively R ≤ 0.5

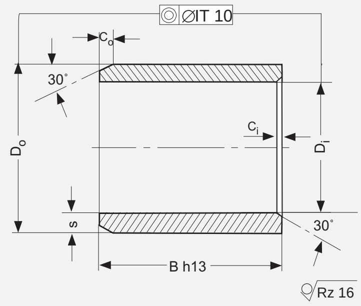
C_i = 0.5 x s, alternatively R ≤ 0.5 x 45°

Recommended Shaft Tolerance h7

All dimensions in mm

Part No.	Dimensions [mm]				Flange Thick-ness B_{fl}	Weight [g]	Installed tolerance [H7]	
	ID-∅ D_i	OD-∅ D_0	Flange-∅ D_{fl}	Width B			Housing-∅ D_H [H7]	Bush bore $D_{i,a}$ after assembly in middle H7 housing
BB 0505 MF15	5	7	11	5	1	0,22	+0,015 0	+0,058 +0,010
BB 0610 MF15	6	8	10	10		0,42		
BB 0810 MF15	8	10	15	9,5		0,55		+0,071 +0,013
BB 1012 MF15	10	12	18	12		0,83	+0,018 0	
BB 1017 MF15				17		1,09		
BB 1220 MF15	12	14	20	20		1,46		+0,086 +0,016
BB 1417 MF15	14	16	22	17		1,46		
BB 1520 MF15	15	17	23	20		1,55		
BB 1612 MF15	16	18	24	12		1,25		
BB 1620 MF15				20		1,89		
BB 1814 MF15	18	20	26	14		1,57	+0,021 0	
BB 1820 MF15				20		2,10		
BB 2017 MF15	20	23	30	16,5	1,5	3,14		+0,104 +0,020
BB 2022 MF15				21,5		3,89		
BB 2522 MF15	25	28	35	21,5		4,77		
BB 3026 MF15	30	34	42	26	2	9,21	+0,025 0	
BB 3540 MF15	35	39	50	40		16,14		+0,125 +0,025
BB 3550 MF15				50		19,60		
BB 4016 MF15	40	44	55	16		8,84		
BB 4040 MF15				40		18,27		
BB 4526 MF15	45	50	58	26	2,5	16,97		
BB 5050 MF15	50	55	65	50		34,21	+0,030 0	+0,150 +0,030
BB 5560 MF15	55	60	70	60		44,15		
BB 6060 MF15	60	65	75	60	2,5	47,96	+0,030 0	+0,150 +0,030
BB 6560 MF15	65	70	80	60		51,76		
BB 7070 MF15	70	75	75	70		64,04		
BB 7570 MF15	75	80	90	70		68,42		
BB 8080 MF15	80	85	95	80		82,46	+0,035 0	
BB 9090 MF15	90	95	110	90		106,37		+0,176 +0,036
BB 10090 MF15	100	105	130	90		125,08		

8.5 MF41 Cylindrical bushes



C_0 = 0.5 x s, alternatively R ≤ 0.5

C_i = 0.5 x s, alternatively R ≤ 0.5 x 45°

Recommended Shaft Tolerance h7

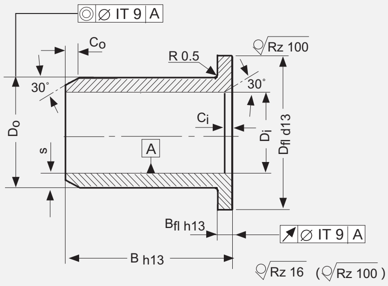
All dimensions in mm

Part No.	Dimensions [mm]			Weight [g]	Installed tolerance [H7]	
	ID-∅ D_i	OD-∅ D_0	Width B		Housing-∅ D_H [H7]	Bush bore $D_{i,a}$ after assembly in middle H7 housing
0505 MF41	5	7	5	0.16	+0.015 0	+0.058 +0.010
0606 MF41	6	8	6	0.22		
0610 MF41			10	0.36		
0810 MF41	8	10	10	0.47		+0.071 +0.013
0815 MF41			15	0.70		
1008 MF41	10	12	8	0.46	+0.018 0	
1009 MF41			9	0.51		
1010 MF41			10	0.57		
1012 MF41			12	0.68		
1015 MF41			15	0.85		
1020 MF41			20	1.14		
1210 MF41	12	14	10	0.67		+0.860 +0.016
1212 MF41			12	0.81		
1214 MF41			14	0.94		
1215 MF41			15	1.01		
1220 MF41			20	1.35		
1415 MF41	14	16	15	1.17		
1420 MF41			20	1.55		
1425 MF41			25	1.94		
1515 MF41	15	17	15	1.2		
1520 MF41			20	1.7		
1525 MF41			25	2.1		
1607 MF41	16	18	7	0.6		
1610 MF41			10	0.9		
1615 MF41			15	1.3		
1620 MF41			20	1.8		
1815 MF41	18	20	15	1.5	+0.021 0	
1820 MF41			20	2.0		
1825 MF41			25	2.5		

Part No.	Dimensions [mm]			Weight [g]	Installed tolerance [H7]	
	ID-∅ D_i	OD-∅ D_0	Width B		Housing-∅ D_H [H7]	Bush bore $D_{i,a}$ after assembly in middle H7 housing
2010 MF41	20	23	10	1.7	+0.021 0	+0.104 +0.020
2015 MF41			15	2.5		
2020 MF41			20	3.3		
2025 MF41			25	4.2		
2215 MF41	22	25	15	2.7		
2220 MF41			20	3.7		
2225 MF41			25	4.6		
2415 MF41	24	27	15	3.0		
2420 MF41			20	4.0		
2515 MF41	25	28	15	3.1		
2520 MF41			20	4.1		
2525 MF41			25	5.1		
2530 MF41			30	6.2		
2828 MF41	28	32	28	8.7	+0.025 0	
3020 MF41	30	34	20	6.6		
3025 MF41			25	8.3		
3030 MF41			30	9.9		
3040 MF41			40	13.3		
3225 MF41	32	36	25	8.8		+0.125 +0.025
3230 MF41			30	10.6		
3240 MF41			40	14.1		
3250 MF41			50	17.6		
3520 MF41	35	39	20	7.7		
3525 MF41			25	9.6		
3530 MF41			30	11.5		
3550 MF41			50	19.2		
3625 MF41	36	40	25	9.8		
3640 MF41			40	15.8		
3650 MF41			50	19.7		
3825 MF41	38	42	25	10.4		
4020 MF41	40	44	20	8.7		
4025 MF41			25	10.9		
4030 MF41			30	13.1		
4040 MF41			40	17.4		
4050 MF41			50	21.8		
4520 MF41	45	50	20	12.3		
4525 MF41			25	15.4		
4530 MF41			30	18.5		
4540 MF41			40	24.6		
4545 MF41			45	27.7		
4550 MF41			50	30.8		
4560 MF41			60	36.9		

Part No.	Dimensions [mm]			Weight [g]	Installed tolerance [H7]	
	ID-∅ D_i	OD-∅ D_0	Width B		Housing-∅ D_H [H7]	Bush bore $D_{i,a}$ after assembly in middle H7 housing
5025 MF41	50	55	25	17.0	+0.030 0	+0.125 +0.025
5030 MF41			30	20.4		
5040 MF41			40	27.2		
5050 MF41			50	34.0		
5060 MF41			60	40.8		
5070 MF41			70	47.6		
5540 MF41	55	60	40	29.8		+0.150 +0.030
6030 MF41	60	65	30	24.3		
6040 MF41			40	32.4		
6060 MF41			60	48.6		
6070 MF41			70	56.7		
6540 MF41	65	70	40	35.0		
6560 MF41			60	52.5		
7040 MF41	70	75	40	37.6		
7060 MF41			60	56.3		
7080 MF41			80	75.1		
7525 MF41	75	80	25	25.1		
7540 MF41			40	40.2		
7580 MF41			80	80.3		
8040 MF41	80	85	40	42.7	+0.035 0	
8080 MF41			80	85.5		
8540 MF41	85	90	40	45.3		+0.176 +0.036
8580 MF41			80	90.7		
9050 MF41	90	95	50	59.9		
9090 MF41			90	107.8		
10050 MF41	100	105	50	66.4		
10095 MF41			95	126.1		
12050 MF41	120	125	50	79.3	+0.040 0	
12530 MF41	125	130	30	49.5		+0.203 +0.043
12560 MF41			60	99.1		
13060 MF41	130	135	60	103.0		
15060 MF41	150	155	60	118.5		

8.6 MF41 Flanged bushes



C_0 = 0.5 x s, alternatively R ≤ 0.5

C_i = 0.5 x s, alternatively R ≤ 0.5 x 45°

Recommended Shaft Tolerance h7

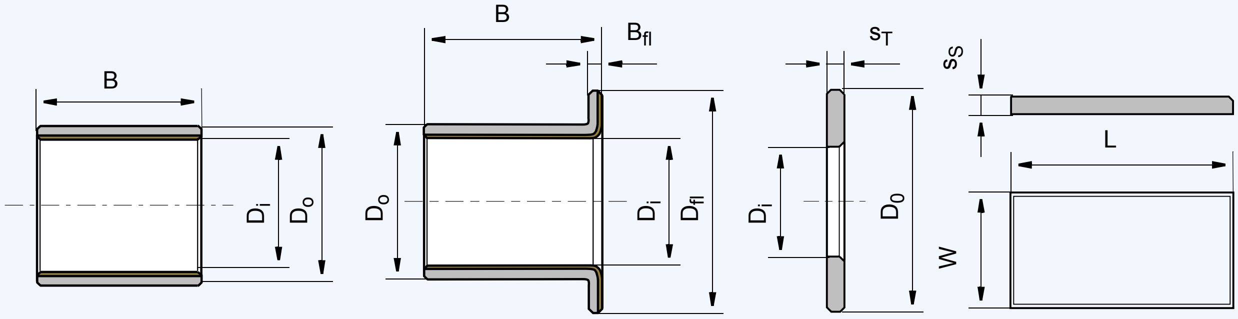
All dimensions in mm

Part No.	Dimensions [mm]				Flange Thickness B_{fl}	Weight [g]	Installed tolerance [H7]	
	ID-∅ D_i	OD-∅ D_0	Flange-∅ D_{fl}	Width B			Housing-∅ D_H [H7]	Bush bore $D_{i,a}$ after assembly in middle H7 housing
BB 0606 MF41	6	8	12	6	1	0.3	+0.015 0	+0.058 +0.010
BB 0608 MF41				8	1	0.4		
BB 0806 MF41	8	10	14	6	1	0.4		+0.071 +0.013
BB 0810 MF41				10	1	0.6		
BB 1007 MF41	10	12	18	7	1	0.6	+0.018 0	
BB 1017 MF41				17	1	1.2		
BB 1210 MF41	12	14		10	1	1		+0.086 +0.016
BB 1212 MF41				12	1	1.0		
BB 1415 MF41	14	16	22	15	1	1.5		
BB 1430 MF41				30	1	2.6		
BB 1517 MF41	15	17	23	17	1	1.7		
BB 1817 MF41	18	20		17	1	1.8	+0.021 0	
BB 1822 MF41				22	1	2.3		
BB 2012 MF41	20	23	30	12	2	3.0		+0.104 +0.020
BB 2015 MF41				15	2	3.5		
BB 2020 MF41				20	2	4.3		
BB 2022 MF41				22	2	4.6		
BB 2025 MF41				25	2	5.1		
BB 2422 MF41	24	27	32	22	2	5.1		
BB 2522 MF41	25	28	35	22	2	5.7		
BB 2532 MF41				32	2	7.7		
BB 2817 MF41	28	32	38	17	2	6.4	+0.025 0	
BB 2828 MF41				28	2	9.8		
BB 3018 MF41	30	34	45	18	2	8.2		
BB 3022 MF41				22	2	9.5		
BB 3032 MF41				32	2	12.9		

Part No.	Dimensions [mm]				Flange Thick-ness B_{fl}	Weight [g]	Installed tolerance [H7]	
	ID-∅ D_i	OD-∅ D_0	Flange-∅ D_{fl}	Width B			Housing-∅ D_H [H7]	Bush bore $D_{i,a}$ after assembly in middle H7 housing
BB 3232 MF41	32	36	40	32	2	12.1	+0.025 0	+0.125 +0.025
BB 3513 MF41	35	39	50	13	2	7.5		
BB 3522 MF41				22	2	11.0		
BB 3532 MF41				32	2	14.8		
BB 3540 MF41				40	2	17.9		
BB 3550 MF41				50	2	21.7		
BB 4025 MF41	40	44	55	25	2	13.7		
BB 4040 MF41				40	2	20.2		
BB 4532 MF41	45	50	60	32	2,5	23.2		
BB 4538 MF41				38	2,5	26.9		
BB 4545 MF41				45	2,5	31.2		
BB 5020 MF41	50	55	65	20	2,5	17.5	+0.030 0	
BB 5024 MF41				24	2,5	20.2		
BB 5032 MF41				32	2,5	25.6		
BB 5050 MF41				50	2,5	37.9		
BB 5540 MF41	55	60	70	40	2,5	34.0		+0.150 +0.030
BB 5560 MF41				60	2,5	48.9		
BB 6040 MF41	60	65	75	40	2,5	36.9		
BB 6060 MF41				60	2,5	53.1		
BB 6540 MF41	65	70	80	40	2,5	39.8		
BB 6560 MF41				60	2,5	57.3		
BB 7040 MF41	70	75	85	40	2,5	42.7		
BB 7070 MF41				70	2,5	70.9		
BB 7540 MF41	75	80	90	40	2,5	45.7		
BB 7570 MF41				70	2,5	75.8		
BB 8040 MF41	80	85	95	40	2,5	48.6	+0.035 0	
BB 8080 MF41				80	2,5	91.3		
BB 9050 MF41	90	95	110	50	2,5	69.9		+0.176 +0.036
BB 9090 MF41				90	2,5	117.8		
BB 10050 MF41	100	105	120	50	2,5	77.3		
BB 10090 MF41				90	2,5	130.4		
BB 11090 MF41	110	115	130	90	2,5	143.0		
BB 14060 MF41	140	145	160	60	2,5	125.6	+0.040 0	+0.203 +0.043

9 Technical Data Sheet

Application: ____________________



☐ Cylindrical Bush ☐ Flanged Bush ☐ Thrust Washer ☐ Slideplate ☐ Special (Sketch)

☐ Rotational movement ☐ Steady load ☐ Rotating load ☐ Oscillating movement ☐ Linear movement

☐ Existing Design ☐ New Design

Quantity ______

Dimensions in mm

Inside Diameter	D_i	
Outside Diameter	D_0	
Width	B	
Flange Diameter	D_{fl}	
Flange Thickness	B_{fl}	
Length of slideplate	L	
Width of slideplate	W	
Thickness of slideplate	s_S	

Load

Radial load	F [N]	
or specific load	$\bar{p}$ [N/mm^2]	
Axial load	F [N]	
or specific load	$\bar{p}$ [N/mm^2]	

Movement

Rotational speed	N [1/min]	
Speed	U [m/s]	
Length of Stroke	L_S [mm]	
Frequency of Stroke	[1/min]	
Oscillating cycle	φ [°]	
Oscillating frequency	N_{osz} [1/min]	

Service hours per day

Continuous operation	
Intermittent operation	
Operating time	
Days per year	

Fits and Tolerances

Shaft	D_J	
Bearing Housing	D_H	

Operating Environment

Ambient temperature	T_{amb} [°]	

Housing with good heat transfer properties ☐

Light pressing or insulated housing which poor heat transfer properties ☐

Non metal housing with poor heat transfer properties ☐

Alternate operation in water and dry ☐

Mating surface

Material		
Hardness	HB/HRC	
Surface finish	R_a [µm]	

Lubrication

Dry ☐

Continuous lubrication ☐

Process fluid lubrication ☐

Initial lubrication only ☐

Hydrodynamic conditions ☐

Process Fluid		
Lubricant		
Dynamic viscosity	η	

Service life

Required service life	L_H [h]	

Customer Data
Company: City:
Street: Post Code:

Project:
Name:
Tel.:

Date:
Signature:
Fax:

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