GLACIER
INDUSTRIAL BEARINGS

GAR-MAX®

High Performance Plain Polymer Bearings

Technical Information

1 Contents

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Formula Symbols and Designations

Formula Symbol	Unit	Designation
a_A		Correction factor for B/D ratio
a_B		Correction factor for bearing size
a_E		Correction factor for type of loading
a_M		Correction factor for the mating material
a_S		Correction factor for the surface roughness
a_T		Correction factor for temperature
B_1	mm	Bush nominal width
D_1	mm	Bush internal diameter, nominal dimension
D_2	mm	Bush external diameter, nominal dimension
F	N	Nominal loading (bearing strength)
F_i	N	Bush - press-fitting force
f		Coefficient of friction
L_H	days	Working life
Z		Load cycles
$\bar{p}$	N/mm^2	Specific bearing loading
R_a	µm	Median roughness value (DIN 4768, ISO / DIS 4287/1)
S_B	mm	Bush wall thickness
U	m/s	Circumference speed, sliding speed
Δs_a	mm	Permissible radial wear (standard 0.2 mm)
Δs_h	µm/Rkm	Sliding wear rate
φ	degree	Angle of oscillation (angle moved either side of mean position)
N_{OSZ}	1/min	Frequency of oscillations (number per minute)

Introduction 3

GAR-MAX® is a composite plain bearing material combining the excellent low friction properties of PTFE with the high strength of glass fibres to produce high performance bearings suitable for a wide range of applications.

GAR-MAX® is noted for the following:

- **Maintenance-free dry running**
- **Economical**
- **Good chemical resistance**
- **High load capacity**
- **Suppresses vibration**
- **Heat resistant**
- **Low weight**
- **Tolerates impact and shock loadings**
- **Tolerant of contamination**
- **Low weight**
- **Tolerant of some edge loading**
- **Low noise running**
- **Particularly suited to oscillating and rotating movements**

4 Material Structure

GAR-MAX® consists of two layers combining the excellent bearing properties of a low-friction surface with the high strength of a load carrying backing. Stretched PTFE filaments and high strength polymer fibres embedded in a graphite filled epoxy resin form the bearing surface. The high durability of GAR-MAX® is produced by a special cross-winding manufacturing technique that builds up the bearing material thus preventing delamination of the carrier layer from the bearing surface layer.

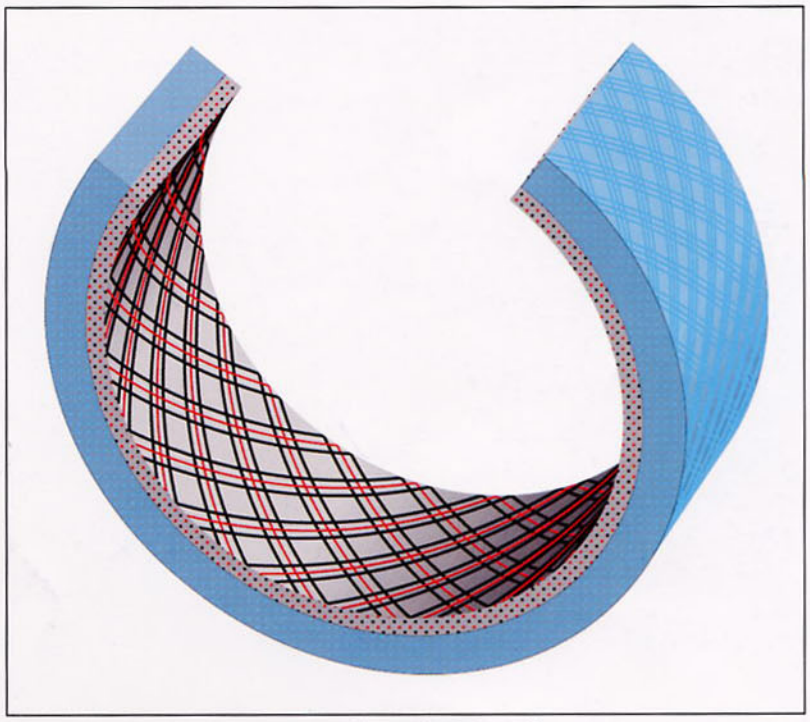


Fig. 1: Schematic of the construction of GAR-MAX®

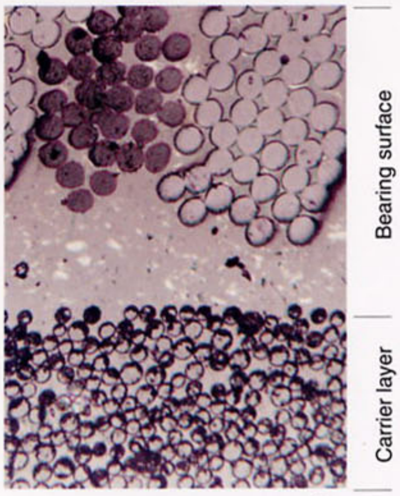


Fig. 2: Structure of GAR-MAX® in cross-section

Mechanical Properties

Maximum compressive strength	[N/mm²]	415
Radial rupture strength	[N/mm²]	500
Static loading strength	[N/mm²]	200
Fatigue strength (obtained experimentally, see Fig. 3)	[N/mm²]	132
Operating temperature range	[°C]	from -100 to +160
Coefficient of thermal expansion	[x 10^{-6}/°K]	13
Thermal conductivity	[W/m°K]	0.4
Density	[g/cm³]	1.96

Table 1: Mechanical Properties of GAR-MAX®

The dimensional stability of GAR-MAX® is outstanding, even under shock and impact loads. The high dynamic load bearing capacity (140N/mm²) and the resistance to abrasion provide a solution for many difficult plain bearing problems. Since the coefficient of thermal expansion of GAR-MAX® is similar to that of steel, interference fits and radial clearances remain acceptable throughout the temperature operating range unlike many polymer based bearings.

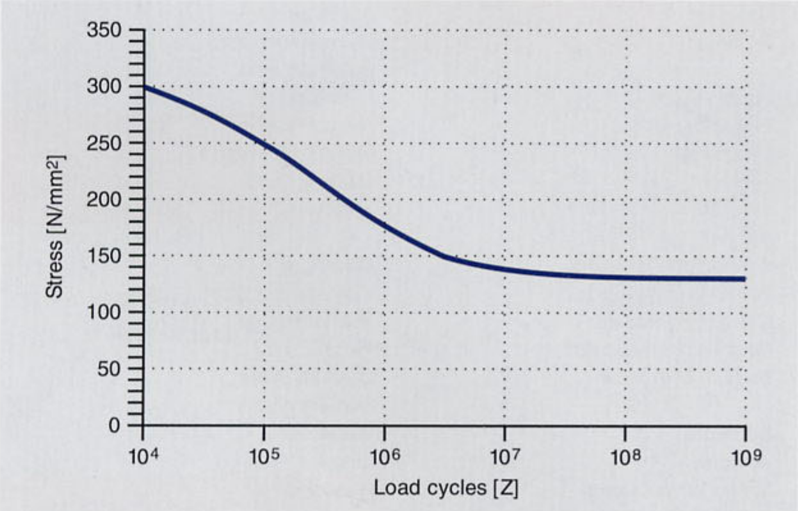


Fig. 3: GAR-MAX® dynamic load performance determined experimentally

Chemical Resistance

GAR-MAX® plain bearings have a high resistance to corrosive media. The following table gives a guide to its resistance in a wide range of chemicals. Its suitability for other media should be determined experimentally.

Resistant	Non-resistant
Alcohols	**Oils**
Amyl alcohol	Cotton seed oil
Ethyl alcohol	Petroleum
Hydroxyacetone	Gear oil
Isobutyl alcohol	Hydraulic oil
Isopropyl alcohol	Linseed oil
Methyl alcohol	Motor oil
Propyl alcohol	
Allyl alcohol	**Salts**
Butyl alcohol	Ammonium chloride
	Ammonium nitrate
Gases	Ammonium sulphate
Acetylene	Iron chloride
Ether	Calcium chloride
Butane	Magnesium chloride
Natural gas	Magnesium carbonate
Carbon dioxide	Magnesium sulphate
Ozone	Sodium acetate
Propane	Sodium bisulphate
Sulpur dioxide	Sodium carbonate
Nitrogen	
Hydrogen	**Acids - 10%**
Bromine	Boric acid
Chlorine	Acetic acid
Fluorine	Hydrochloric acid
	Sulphuric acid
Fuels	Citric acid
Petrol	Arsenic acid
Diesel fuel	Hydrofluoric acid
Jet fuel	Carbonic acid
Kerosine	Nitric acid
Alkalies	
Ammonium hydroxide	**Others**
Potassium hydroxide	Ethylene glycol
Calcium hydroxide	Formaldehyde
Magnesium hydroxide	Freon
Sodium hydroxide	Calcium oxide
	Sodium nitrate
Solvents	Water 20°C
Acetone	Zinc sulphate
Methyl ethyl ketone	Ammonia
Naphtalene	Water 100°C
Toluene	
Benzene	
Chloromethane	
Trichloroethane	

Table 2: Chemical resistance of GAR-MAX®

Loading

GAR-MAX® offers the designer a bearing with an exeptional dynamic load carrying capacity. However, the values quoted in Table 3 are given as basic information and should be adjusted to suit actual operating conditons - see Life Calculations from page 13.

Load range		dry (unlubricated)	mixed lubrication 1)
Dynamic load-bearing capacity $\bar{p}_{max}$ 2)	[N/mm²]	120	140
Sliding speed U_{max} 3)	[m/s]	0.2	0.3
$(\bar{p} \times U)_{max}$ 2)	[W/mm²]	1.8	2.0
Operating temperature 4)	[°C]	-20 to	+ 160
Factors which influence:			
- point loads		0.4	0.4
- use in bogies		0.4	0.4
- misalignment		0.5	0.5

1) With oil or grease lubrication
2) At room temperature
3) Dependent on heat dissipation from bearing assembly
4) At temperatures below - 20°C the coefficient of friction rises inversely proportional to temperature. If friction is not critical, it is possible to operate up to the static load limit (see also Fig.6).

Table 3: GAR-MAX® dynamic load limits

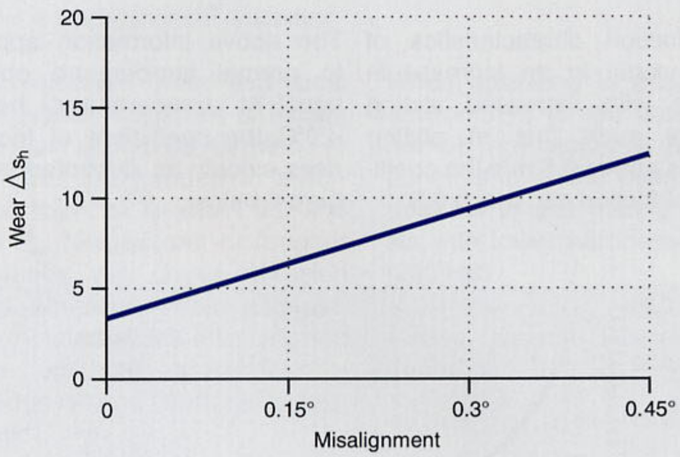


Fig. 4: The effect of misalignment on GAR-MAX®

The effect of misalignment on the wear of GAR-MAX® is shown in Fig. 4.

Friction

The self lubricating properties of GAR-MAX® ensure minimum friction even under dry conditions. This makes it suitable for applications where it is difficult or impossible to lubricate with oil or grease. Under favourable conditions of low speeds and high bearing loads, the coefficient of friction will be about 0.14 at specific bearing loads [p̄] of 40 N/mm² and will decrease to below 0.05 as load increases - see Figure 5.

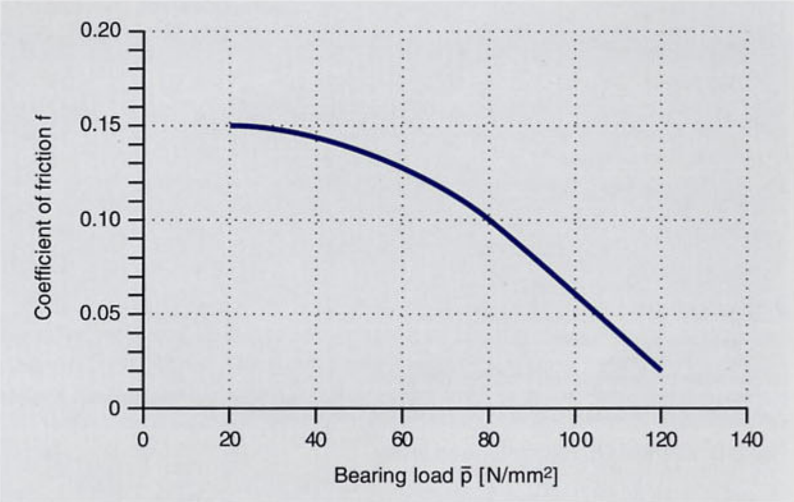


Fig. 5: Friction value in relation to load (U= 0.025 m/s)

The friction characteristics of PTFE result in an increase in friction with increased sliding speeds such that at sliding speeds above 0.5 m/s the coefficient of friction can reach 0.3. The above information applies to normal temperature operation. At temperatures below -20°C the coefficient of friction rises steeply as illustrated in Figure 6 below.

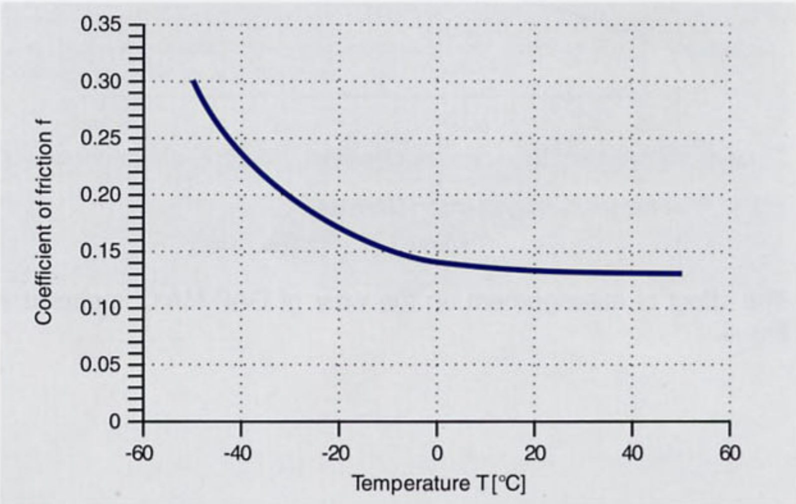


Fig.6: Influence of lower temperatures on the coefficient of friction f (p̄= 50 N/mm², U= 0.01 m/s)

GAR-MAX® is designed for dry running, however, under certain circumstances the use of grease can reduce wear. This is particularly true with higher sliding speeds where the lubricant can reduce friction or where dirt particles are present and may be removed by intermittent relubrication. Calcium-soap mineral oil based greases have proved particularly effective.

If grease-lubricated bearings are subjected to cyclic oscillations, damage to the fibres may occur. In this case it is safer to run the bearing dry, unlubricated.

Mating Materials

The shaft material hardness and surface finish have a significant effect on the bearing performance. The shaft material must also have adequate corrosion resistance to suit the application.

Only suitable steels with hardened surfaces should be used.

Surface hardness	[HRC]	50
Surface roughness (R_a)	[µm]	0.2-0.4

Table 4: Mating material properties

For minimum wear and most favourable coefficient of friction the shaft should be hardened to 50 HRC and ground to a surface finish of between 0.2 and 0.4 R_a. Non-ground or rougher surfaces will cause abrasion and accelerate wear. Ground, hard-plated shafts often provide the optimum properties of hardness and corrosion resistance.

When operating in a dust-free environment where there cannot be any abrasive particles penetrating to the bearing it is possible to use mating materials with lower hardness values (220 HB).

Please consult Glacier if in doubt.

Bearing Clearances and Tolerances

The correct clearance is important for the performance of the bearing. The interference fits given below are suitable for temperatures up to 100°C.

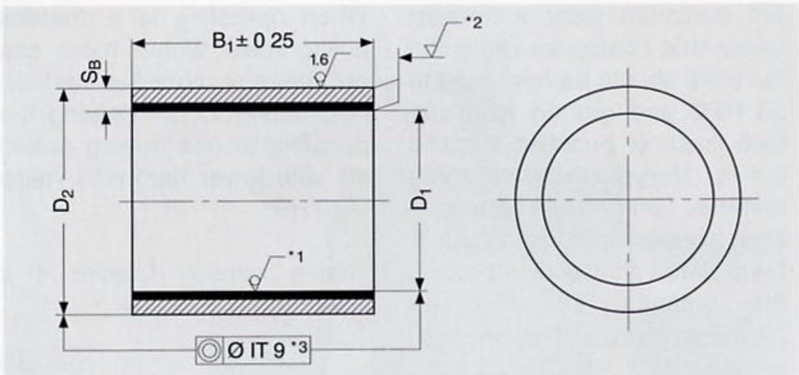
	Tolerance
Housing bore	H7
Bearing outside diameter D_2	s8
Bearing bore D_1, as manufactured	C10
Bearing bore after installation	D11
Shaft diameter	h8

Table 5: Recommended fits for GAR-MAX® bushes

The high rigidity and thermal expansion characteristics of GAR-MAX® ensure a secure and firm installation.

7 Dimensional Tables

Standard Sizes to DIN 1850 Part 1, Series 2



**1) Bearing surface layer thickness*

**2) Barrel deburred*

**3) In installed condition*

Part No.	Nominal sizes			Weight
	D_1	D_2	B_1	appr. [g]
162015GM	16	20	15	3.3
162020GM	16	20	20	4.4
202415GM	20	24	15	4.1
202420GM	20	24	20	5.4
202425GM	20	24	25	6.8
222615GM	22	26	15	4.7
222620GM	22	26	20	6.5
222625GM	22	26	25	8.0
253020GM	25	30	20	8.5
253025GM	25	30	25	10.6
253030GM	25	30	30	12.7
253040GM	25	30	40	16.9
283420GM	28	34	20	11.5
283430GM	28	34	30	17.2
283435GM	28	34	35	20
283440GM	28	34	40	23
303625GM	30	36	25	15.2
303630GM	30	36	30	18
303635GM	30	36	35	21
303640GM	30	36	40	24.5
354130GM	35	41	30	21
354135GM	35	41	35	24.5
354140GM	35	41	40	28
354150GM	35	41	50	35
404820GM	40	48	20	21.5
404830GM	40	48	30	32.5
404840GM	40	48	40	43.5
404850GM	40	48	50	54
455335GM	45	53	35	42
455345GM	45	53	45	54.5
455350GM	45	53	50	60.5
455355GM	45	53	55	66.5
455360GM	45	53	60	72.5
505830GM	50	58	30	40
505840GM	50	58	40	53
505850GM	50	58	50	66.5
505860GM	50	58	60	80
556340GM	55	63	40	58
556350GM	55	63	50	72.5
556355GM	55	63	55	80
556370GM	55	63	70	101
607040GM	60	70	40	80
607045GM	60	70	45	90
607050GM	60	70	50	100
607060GM	60	70	60	120
607075GM	60	70	75	150
657550GM	65	75	50	107.5
657560GM	65	75	60	129.5
657565GM	65	75	65	140
657580GM	65	75	80	172.5
708040GM	70	80	40	92.5
708055GM	70	80	55	127
708070GM	70	80	70	161.5
708085GM	70	80	85	196
758550GM	75	85	50	123
758560GM	75	85	60	147.5
758575GM	75	85	75	184.5
758590GM	75	85	90	221
809060GM	80	90	60	157
809070GM	80	90	70	183
809080GM	80	90	80	209
809090GM	80	90	90	235
8090100GM	80	90	100	261
859565GM	85	95	65	180
859585GM	85	95	85	235
8595100GM	85	95	100	277
8595105GM	85	95	105	291
9010570GM	90	105	70	315
9010580GM	90	105	80	360
9010590GM	90	105	90	405
90105110GM	90	105	110	495
90105120GM	90	105	120	540
9511075GM	95	110	75	355
9511095GM	95	110	95	449
95110100GM	95	110	100	473
95110115GM	95	110	115	544
10011580GM	100	115	80	397
10011590GM	100	115	90	447
100115100GM	100	115	100	496
100115120GM	100	115	120	595
100115130GM	100	115	130	645
11011585GM	110	115	85	461
110115100GM	110	115	100	542
110115110GM	110	115	110	597
110115120GM	110	115	120	651
110115135GM	110	115	135	732
12013590GM	120	135	90	530
120135100GM	120	135	100	589
120135120GM	120	135	120	706
120135130GM	120	135	130	765
120135150GM	120	135	150	883
130145100GM	130	145	100	635
130145120GM	130	145	120	762
130145130GM	130	145	130	825
130145150GM	130	145	150	952
130145160GM	130	145	160	1016
140155100GM	140	155	100	681
140155110GM	140	155	110	749
140155120GM	140	155	120	817
140155130GM	140	155	130	885
140155140GM	140	155	140	953
140155150GM	140	155	150	1021
140155170GM	140	155	170	1158
150165100GM	150	165	100	727
150165120GM	150	165	120	873
150165130GM	150	165	130	945
150165150GM	150	165	150	1091
150165180GM	150	165	180	1309
160180120GM	160	180	120	1256
160180130GM	160	180	130	1361
160180150GM	160	180	150	1570
160180160GM	160	180	160	1675
160180180GM	160	180	180	1884
180200120GM	180	200	120	1404
180200140GM	180	200	140	1638
180200180GM	180	200	180	2106
180200200GM	180	200	200	2340
180200220GM	180	200	220	2574
200220180GM	200	220	180	2327
200220200GM	200	220	200	2586

Table 6: GAR-MAX® bushes - Standard bush dimensions available from stock. Other dimensions on request.

8 Installation

Assembly

GAR-MAX® bearings are designed to be press-fitted into their housings with the interference fits given in Table 6. This will provide adequate retention both axially and radially. The housing bore must have a lead-in chamfer as shown in Figure 7 to prevent damage during insertion.

A hydraulic press is recommended to insert the bushes into their housings with the assistance of a stepped mandrel as shown in Figure 7.

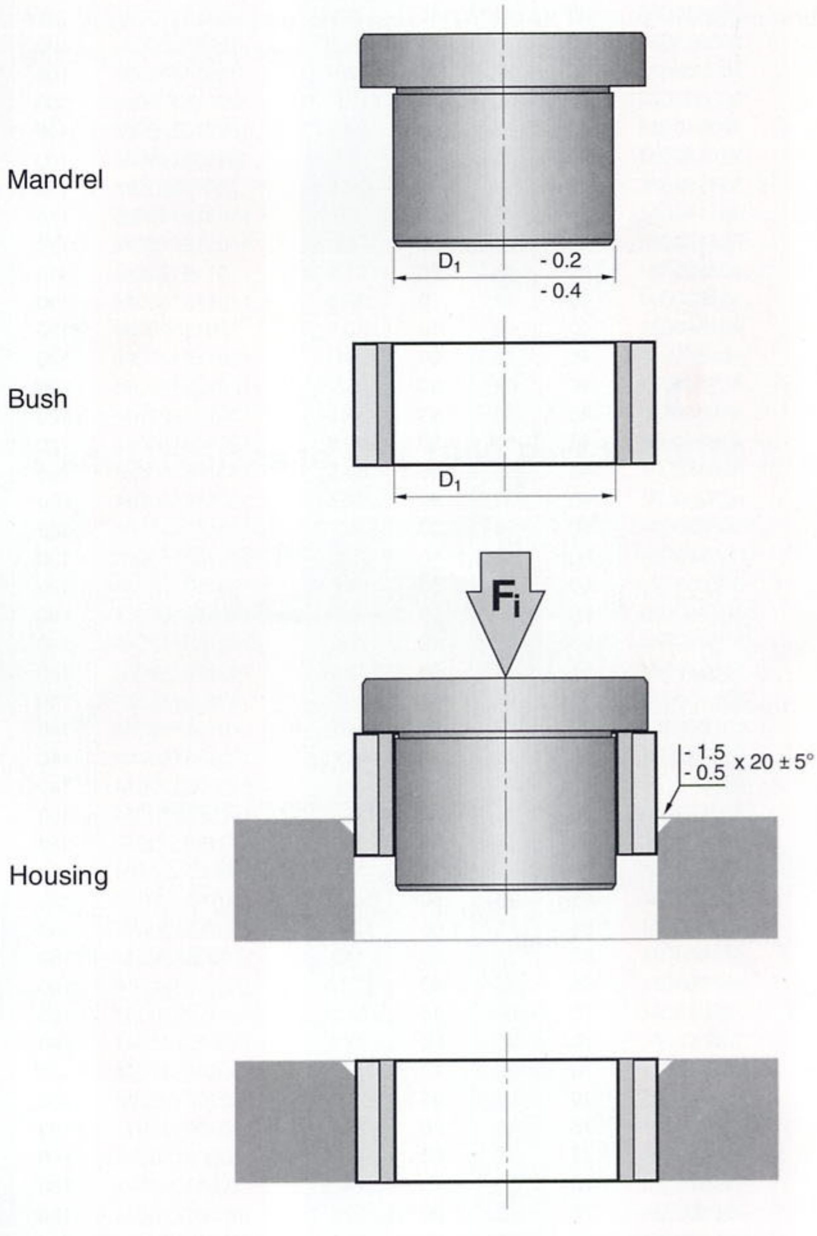


Fig. 7: Press-fitting a GAR-MAX® bush using a mandrel

The life of GAR-MAX® plain bearings can be estimated with the following calculation method. It uses the p̄U-factor amended by correction factors for variables such as bearing geometry, temperature, material and surface finish of the shaft etc. Please note, for complex applications the predicted bearing lives should be taken as indicators only and actual lives determined by test.

Calculation Parameters

The calculation method requires the following:

- Bearing width B_1 [mm]
- Bearing diameter D_1 [mm]
- Load F [N]
- Angle of movement φ [degrees]*
- Frequency of oscillations N_{OSZ} [number/min]

* Note: The angle of movement φ is the angle moved either side of the mean position

p̄U-Value

The p̄U-value is the essential parameter for calculating the performance of self-lubricating plain bearings. It is used to obtain the specific wear rate for a particular operating situation. The p̄U-value is the product of the specific load p̄ [N/mm2] and the sliding speed U [m/s].

The specific load p̄ is the applied load F divided by the supporting bearing area. For a bush it is obtained by the formula:

$$\bar{p} = \frac{F}{D_1 \, x \, B_1}$$

The speed U for oscillating movements is calculated by:

$$U = 1.45 \, x \, 10^{-7} \, x \, D_1 \, x \, N_{OSZ} \, x \, \varphi$$

The p̄U-value is subsequently extrapolated to calculate specific wear. The values for specific wear are based on numerous wear tests at different loads and sliding speeds.

Specific Wear △sh

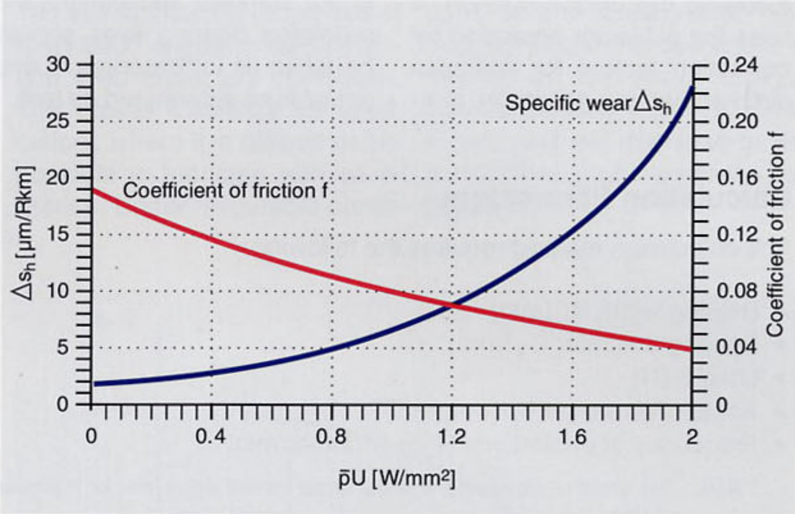


Fig. L1: Wear and the coefficient of friction as function of $\bar{p}U$

The specific wear is the wear per unit of sliding distance (rubbing kilometer) [µm/Rkm]. For GAR-MAX® plain bearings it can be estimated as a function of the $\bar{p}U$-value:

$$\Delta s_h \left[\frac{\mu m}{Rkm}\right] \cong 2 \; x \; exp \left\{ \frac{3}{2} \; x \; \bar{p}U \left[\frac{N}{mm^2} \; x \; \frac{m}{s} \right] \right\}$$

GAR-MAX® Working Life L_H

The calculation of the plain bearing's working life is given as follows:

$$L_H \, [days] \cong 8 \, x \, 10^7 x \left(\frac{\Delta s_a{}^*}{\Delta s_h \, x \, D_I x \varphi x N_{OSZ}} \right) x \, a_A \, x \, a_T \, x \, a_E \, x \, a_M \, x \, a_S \, x \, a_B$$

* Δs_a is the maximum permissible depth of wear in [mm] or the bearing surface thickness [s], whichever is the least.

If the working life is calculated as the number of load cycles, then:

$$Z \, [Load \; cycles] \cong 1440 \, x \, N_{OSZ} \, x \, L_H$$

Influencing Factors

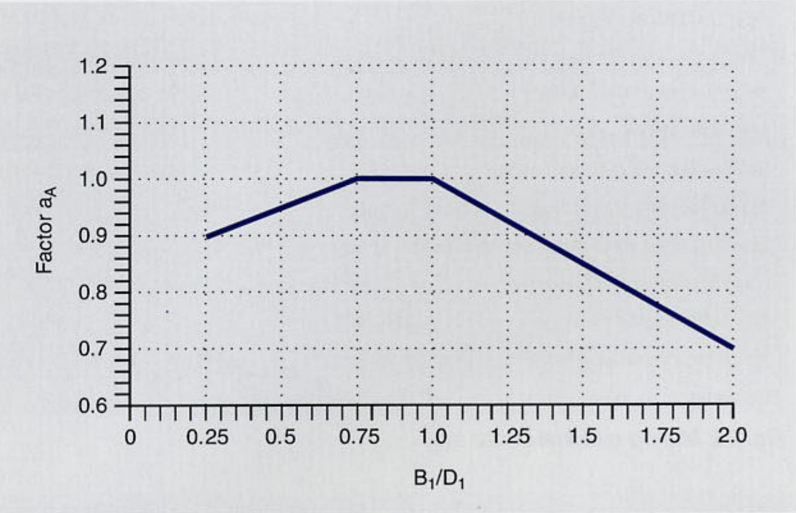


Fig. L2: Bush B_1/D_1 ratio factor a_A

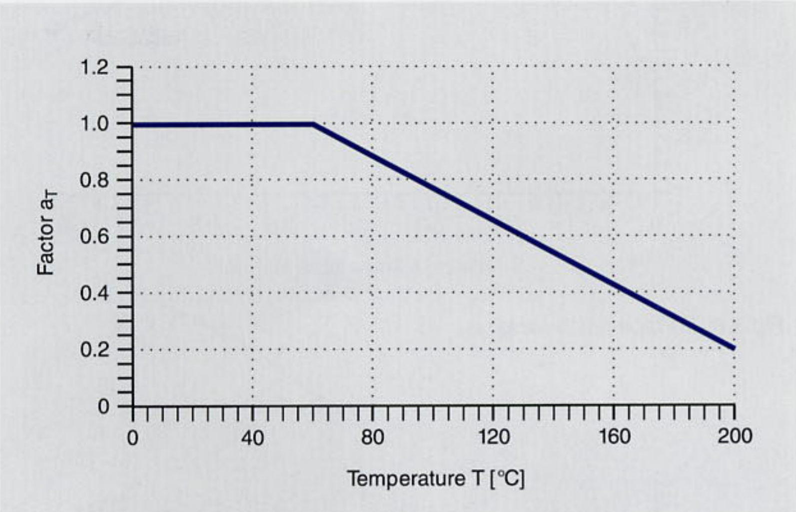


Fig. L3: Temperature factor a_T

Static load with oscillating motion	$a_E = 1$
Dynamic load with oscillating motion	$a_E = 0.7$

Fig. L4: Load factor a_E

Steels	a_M
Case-hardened steel	1
Structural steel	1
Nitride steel	1
Stainless steel (hardened)	1.2
Non-ferrous metals	
Bronze & copper-based alloys	0.1 - 0.4
Aluminium (hard anodised to approx. 25µm)	1.5
Steel (plated to a minimum thickness of 10µm)	
Hard chromed (and polished)	1.2
Tin-nickel plated	1.2
Tungsten carbide plated	1.5
Galvanised	0.3

Fig. L5: Mating material factor a_M

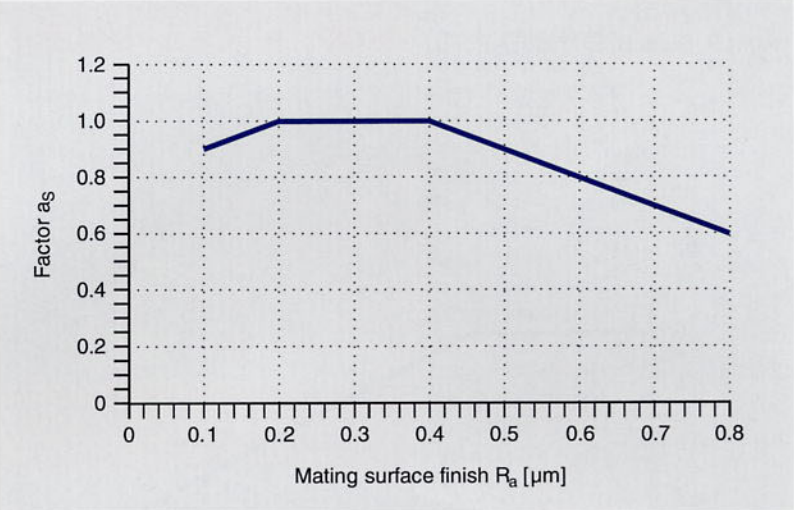


Fig. L6: Surface finish factor a_S

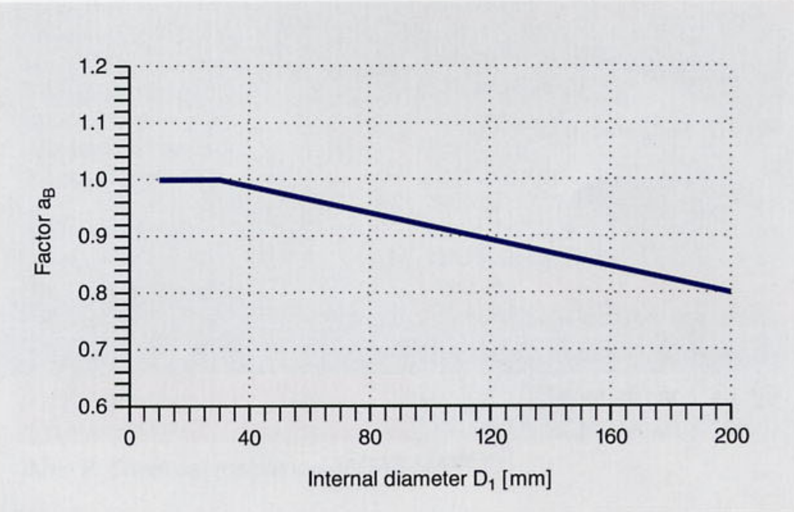


Fig. L7: Bearing size factor a_B

Example Calculation

The working life of a GAR-MAX® plain bearing operating under the following conditions:

- Bearing width: B_1 = 70 mm
- Diameter: D_1 = 70 mm
- Load: F = 245000 N
- Angle of movement: φ = 10 degrees
- Number of cycles: N_{OSZ} = 5/min
- Temperature: T = 20 °C
- Mating material: hard chromed R_a = 0.5 µm
  Dynamic Loading, oscillating motion
  maximum allowable wear Δs_a = 0.5 mm

Influencing Factors

- a_A = 1 since B_1/D_1 = 1 see Fig. L2
- a_T = 1 since T_{amb} = 20°C see Fig. L3
- a_E = 0.7 since motion is dynamic, oscillating see Fig. L4
- a_M = 1.2 since hard chromed see Fig. L5
- a_S = 0.9 since R_a = 0,5 µm see Fig. L6
- a_B = 0.96 since D_1 = 70 mm see Fig. L7

Specific Loading

$$\bar{p} = \frac{F}{D_1 \cdot B_1} = \frac{245000\ N}{70\ mm \cdot 70\ mm} = 50\ \frac{N}{mm^2}$$

Sliding Speed

$$U = 1.45 \cdot 10^{-7} \cdot D_1 \cdot \varphi \cdot N_{OSZ} = 1.45 \cdot 10^{-7} \cdot 70 \cdot 40 \cdot 5 = 0.0021 \frac{m}{s}$$

p̄U-Factor

$$\bar{p}U = 50\ \frac{N}{mm^2} \cdot 0.0021\ \frac{m}{s} = 0.105\ \frac{N \cdot m}{mm^2 \cdot s}$$

Specific Wear

$$\Delta s_h = 2 \cdot exp\left\{\frac{3}{2} \cdot \bar{p}U\right\} = 2 \cdot exp\left\{\frac{3}{2} \cdot 0.105\right\} = 2.34\ \frac{\mu m}{Rkm}$$

Bearing Life [days]

$$L_H = 8 \cdot 10^7 \cdot \left(\frac{0,5}{2.34 \cdot 70 \cdot 40 \cdot 5}\right) \cdot 1 \cdot 1 \cdot 0.7 \cdot 1.2 \cdot 0.9 \cdot 0.96 = 886\ days$$

Bearing Life [cycles]

$$Z = 1440 \cdot Z \cdot L_H = 1440 \cdot 5 \cdot 886 = 6.4 \cdot 10^6\ Load\ cycles$$