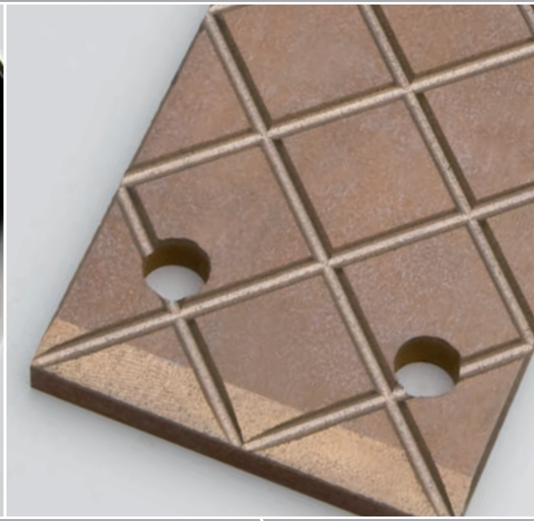
FEDERAL-MOGUL POWERTRAIN

World Class Bearing Technology



deva.metal® sliding bearings
Maintenance-free, self-lubricating

deva.metal®

High performance material – Solid lubricants embedded in metal matrix

Modern designs place huge demands on today's bearing materials, requiring zero maintenance even under severe to extreme operating conditions and maximum loads.

Moreover, the permanent cost pressure calls for increasing uptime availability of machines and plants and uncompromising standards of operational reliability.

With the **DEVA** range of maintenance-free, self-lubricating, heavy-duty friction materials it is possible to produce self-lubricating bearings with guaranteed long-term reliability.

deva.metal materials are suitable for applications with high static and dynamic loads. Due to the micro-distribution of the lubricant, all deva.metal materials are also equally suitable for small movements.

At the same time the form of movement, whether translational, rotational or a combination of both, is insignificant. The **deva.metal** material range is also characterised by the following properties:

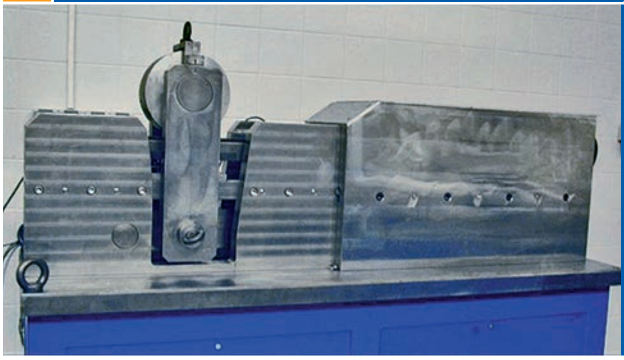
- high wear resistance
- insensitive to impact stress
- resistant to harsh operational and ambient conditions of mechanical or chemical nature

The deva.metal material range provides the design engineer with countless opportunities wherever environmentally-friendly lubrication is either desired or required, or where conventional lubrication is not possible.

Our bearing service

- Profit from more than 60 years of experience in self-lubricating sliding bearings
- Make use of our extensive material and application expertise spanning a very wide range of industries
- Let our application engineering team assist you in the
  - selection of the bearing materials
  - design, purpose-built to your requirements
  - assembly and installation
  - calculation of estimated life time
- Benefit from the latest material developments, tested using state of the art facilities
- Ask for a simulation of your bearing application on our test rigs
- Expect the highest quality standards, certified to DIN ISO 9001:2008, ISO/TS 16949:2009 and DIN EN ISO 14001:2004

One of eight of our test benches



Content

1 Material properties

deva.metal® is a family of high performance, self-lubricating bearing materials. The **deva.metal** system is based on four main groups – bronze, iron, nickel and stainless steel – each containing dry solid lubricant, most commonly graphite, uniformly dispersed within the metal matrix. Important selection criteria are the sliding speed, specific load, temperature and other application specific influences.

deva.metal

- normally requires no lubrication.
- provides maintenance free operation.
- has high static and dynamic load capacity.
- has good frictional properties with negligible stick-slip.
- can be used in dusty environments.
- can be used dependent on alloy in a temperature range of -200 °C to +800 °C.
- grades may be selected to tolerate corrosive applications.
- has no water absorption and is therefore dimensionally stable, suitable for use in sea water and many commercial liquids.
- alloys are available for use in radioactive environments.
- is electrically conductive. No signs of electrostatic charging occur.
- is suitable for translatory, rotational and oscillating movements with cylindrical guide or also for direct surface use. These movements can occur individually or in combination.
- is used where conventional lubrication is not possible.
- offers advantages for low-cost lubrication in comparison to conventional bearing materials.
- can be used as back-up bearing for hydrodynamic lubrication.
- can be used with hydrodynamic water lubrication.

2 Material structure

2.1 Alloys

All **deva.metal** alloys share a common metallurgical microstructure of a solid lubricant uniformly distributed throughout a metal matrix. The properties of the metal matrix determine the general physical, mechanical and chemical properties of the material and are the basis on which an initial alloy selection is made for a specific application.
A selection of four main groups is available:

Bronze base

Iron base

Nickel base

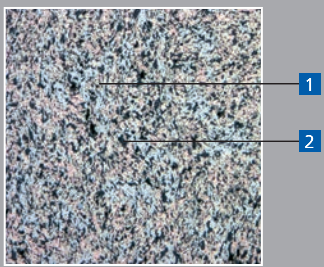
Stainless-steel base

2.2 Solid lubricants

deva.metal® solid lubricant distribution structures show the following microstructures, which are used according to the application-specific requirement.
These different structures and distributions can be used in all four main groups.

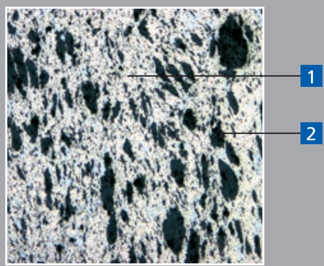
Solid lubricant distribution structures of different deva.metal alloys — Figure 2.2.1

Fine distribution



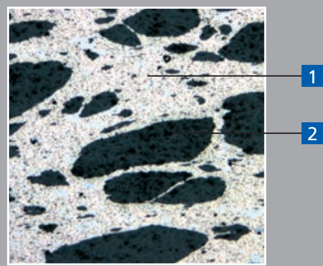
1 Alloy
2 Solid lubricant

Medium distribution



1 Alloy
2 Solid lubricant

Coarse distribution



1 Alloy
2 Solid lubricant

Solid lubricants properties — Table 2.2.1

Properties	Graphite	MoS_2
Crystal structure	hexagonal	hexagonal
Specific gravity	2.25	4.7
Coefficient of friction in air	0.1 to 0.18	0.08 to 0.12
Operating temperature range	-120 °C to +600 °C	-100 °C to +400 °C
Chemical resistance	very good	good
Corrosive resistance	good	limited
Nuclear radiation resistance	very good	good
Performance in air	very good	good
Performance in water	very good	limited
Performance in vacuum	not suitable	good

The amount and characteristics of the solid lubricant largely determine the bearing properties of a particular **deva.metal** alloy composition within each of the four metal matrix types.

The solid lubricants are:

- Graphite – C
- Molybdenum Disulphide – MoS_2

Graphite is the most frequently used solid lubricant and may occur as fine or agglomerated particles within the metal matrix according to the requirements of the application.

The dry wear mechanism that enables **deva.metal** alloys to operate in the absence of conventional lubricants is the same for each of the metal matrix and solid lubricant materials of the **deva.metal** system.

All solid lubricants have a lamella structure characterised by a low interfacial shear strength between adjacent intermolecular layers within the material.

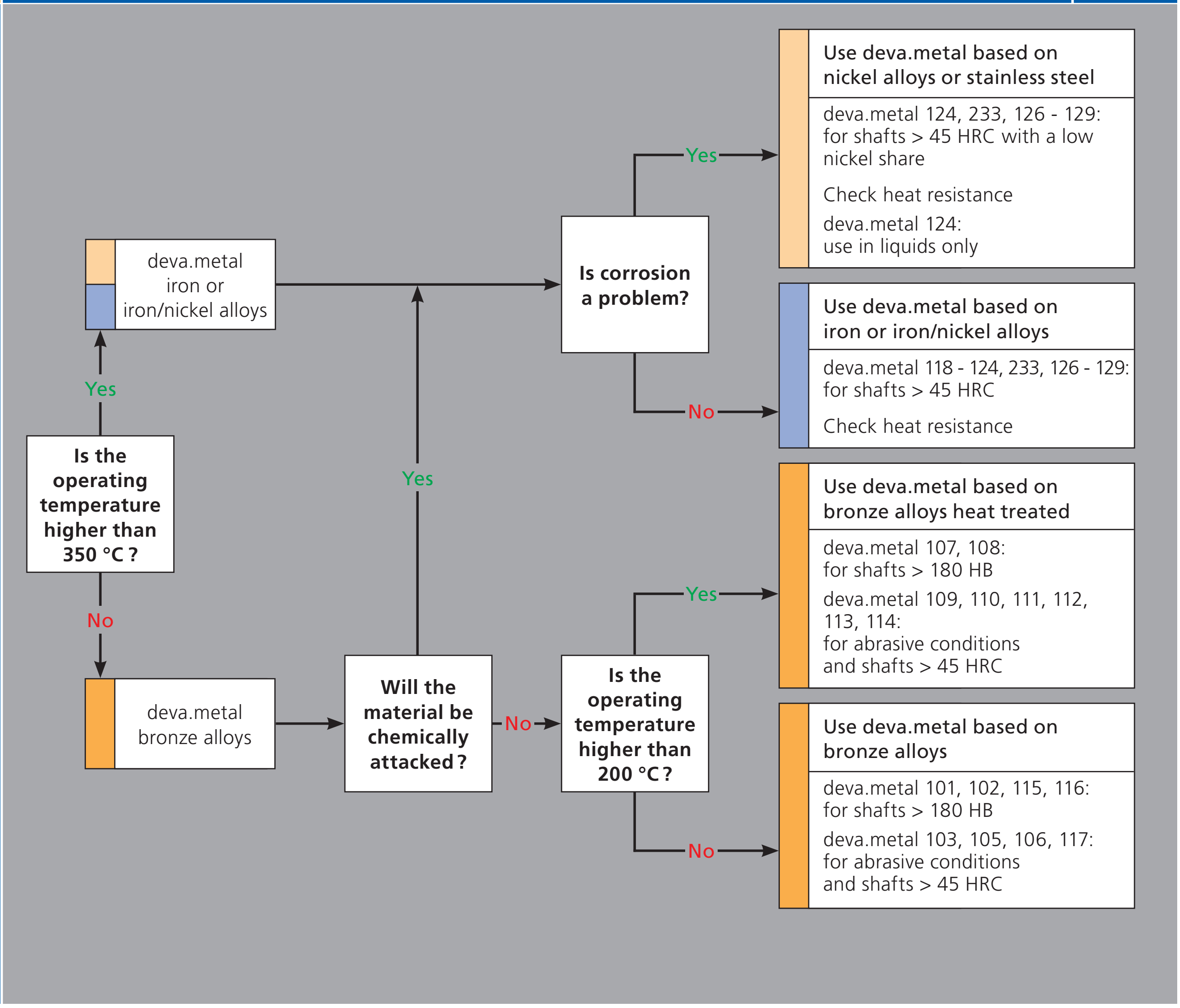
The preloaded solid lubricant is released by the relative movement between the running surface and the **deva.metal** bearing and is deposited mechanically in the running surface. A solid lubricant film is formed on the sliding partners with low coefficients of friction. The micro-wear of the bearing during relative movement continually releases new lubricant and thus ensures a sustained supply of new lubricant to the system. This enables many applications to be free of maintenance.

Materials

3.1 Material selection

The following decision chart provides guidance on the selection of the appropriate **deva.metal®** alloy according to the environmental conditions of the application.

deva.metal material selection scheme — Figure 3.1.1



Typical applications for some deva.metal alloys — Table 3.1.1

Designation deva.metal alloy	Application	Characteristic
deva.metal 101	General	Standard material for most applications
deva.metal 111/112	Iron and steel industry	High abrasion
deva.metal 113/114	Furnace construction	Temperature
deva.metal 115	Hydro-mechanical applications	High load, corrosion-resistant/sea water
deva.metal 116	Bottle deaning/filling machines	High speed
deva.metal 117	Heavy industry	High load/abrasion
deva.metal 118	Furnace construction	Temperature
deva.metal 233/126	Exhaust/flue gas register	Temperature and corrosion
deva.metal 128	Hot valves	Very high temperature

3.2 Chemical resistance

The following table indicates the chemical resistance of the **deva.metal®** bronze alloys to various chemical media. It is recommended that the chemical resistance of the selected **deva.metal** alloy is confirmed by testing.

Definitions

- ✓ Resistant
- O Resistant depending on construction, oxygen content, temperature, etc.
- × Not recommendable
- – No data available

Chemical resistance of deva.metal — Table 3.2.1

Medium / chemical substance	Conc. in %	Temp. in °C	Bronze alloys deva.metal	Iron alloys deva.metal			Nickel alloys deva.metal			Stainless steel deva.metal	
			101-103, 105-117	118-119	120-121	122-123	124	233, 126	127	128	129
Strong acids	5	20									
Hydrochloric acid	5	20	O	×	O	×	×	O	×	✓	×
Hydroflouric acid	5	20	O	O	×	×	✓	✓	O	✓	×
Nitric acid	5	20	×	×	×	×	×	×	×	✓	×
Sulphuric acid	5	20	✓	×	O	×	O	✓	×	✓	×
Phosphoric acid	5	20	✓	×	×	×	✓	O	O	✓	O
Weak acids											
Acetic acid	5	20	✓	×	×	×	×	✓	✓	✓	✓
Formic acid	5	20	✓	×	×	×	×	✓	✓	✓	✓
Boric acid	5	20	✓	×	×	×	✓	✓	✓	✓	✓
Citric acid	5	20	✓	O	O	O	✓	✓	✓	✓	✓
Bases											
Ammonium hydroxide	10	20	×	✓	✓	✓	✓	✓	✓	✓	✓
Potassium hydroxide	5	20	✓	✓	✓	✓	✓	✓	✓	✓	✓
Sodium hydroxide	5	20	✓	✓	✓	✓	✓	✓	✓	✓	✓
Solvents											
Acetone		20	✓	✓	✓	✓	✓	✓	✓	✓	✓
Carbon tetrachloride		20	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ethanol		20	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ethyl acetate		20	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ethyl chloride		20	✓	×	×	×	✓	✓	✓	✓	✓
Glycerin		20	✓	✓	✓	✓	✓	✓	✓	✓	✓
Salts											
Ammonuim nitrate			×	O	O	O	✓	×	✓	✓	✓
Calcium chloride			✓	✓	✓	✓	✓	✓	✓	✓	✓
Magnesium chloride			✓	O	O	O	✓	O	O	✓	✓
Magnesium sulphate			✓	O	O	O	✓	O	O	✓	✓
Sodium chloride			✓	O	O	O	✓	✓	✓	✓	✓
Sodium nitrate			✓	✓	✓	✓	✓	✓	✓	✓	✓
Zinc chloride			×	×	×	×	✓	×	O	✓	✓
Zinc sulfate			✓	O	O	O	✓	×	O	✓	✓
Gases											
Ammonia			O	✓	✓	✓	×	O	O	✓	✓
Chlorine			×	×	×	×	–	O	×	×	×
Carbon dioxide			✓	O	O	O	O	×	O	✓	✓
Fluorine			×	O	O	O	✓	✓	✓	✓	✓
Sulphur dioxide			✓	×	×	×	O	O	O	✓	✓
Hydrogen sulphide			O	×	×	×	O	✓	O	✓	✓
Nitrogen			✓	✓	✓	✓	✓	✓	✓	✓	✓
Hydrogen			✓	✓	✓	✓	✓	✓	✓	✓	✓
Fuels and lubricants											
Paraffin		20	✓	✓	✓	✓	✓	✓	✓	✓	✓
Gasolene		20	✓	✓	✓	✓	✓	✓	✓	✓	✓
Kerosene		20	✓	✓	✓	✓	✓	✓	✓	✓	✓
Diesel fuel		20	✓	✓	✓	✓	✓	✓	✓	✓	✓
Mineral oil		70	✓	✓	✓	✓	✓	✓	✓	✓	✓
HFA - ISO46 water-in-oil		70	✓	✓	✓	✓	✓	✓	✓	✓	✓
HFC - water-glycol		70	✓	✓	✓	✓	✓	✓	✓	✓	✓
HFD - phosphate ester		70	✓	✓	✓	✓	✓	✓	✓	✓	✓
Others											
Water		20	✓	✓	×	×	✓	✓	✓	✓	✓
Seawater		20	✓	×	×	×	✓	✓	✓	✓	✓
Resin			✓	✓	✓	✓	✓	✓	✓	✓	✓
Hydrocarbon			✓	✓	✓	✓	✓	✓	✓	✓	✓

3.3 Material properties

The **deva.metal®** bronze and lead bronze alloys are the most widely used of the **DEVA** materials and are particularly suitable for water lubrication. They are also suitable for elevated temperature applications, however due to problems of dimensional stability the bronze alloys are generally limited to a maximum service temperature of about 200 °C.

Physical, mechanical and bearing properties of deva.metal [1]

	Alloys	Physical properties			Mechanical properties			Max. load	
		Density	Hardness	Linear coefficient of thermal expansion	Tensile strength	Compressive strength	Young's modulus	static [3]	dynamic [3]
Symbol		ρ		α_1	R_m	σ_{dB}	**E**	$\bar{p}_{stat/max}$	$\bar{p}_{dyn/max}$
Unit		g/cm³	HBmin	10^{-6}/K	MPa	MPa	MPa	MPa	MPa
Bronze alloys									
	deva.metal 101	6.8	40	18	50	300	52000	200	100
	deva.metal 102	6.0	50	18	35	180	42000	140	70
	deva.metal 103	6.4	50	18	55	250	53000	180	90
	deva.metal 105	6.6	65	18	85	340	53000	230	115
	deva.metal 106	6.1	45	18	50	240	49000	160	80
Bronze alloys (heat treated)									
	deva.metal 107	6.3	35	18	57	250	43000	170	85
	deva.metal 108	6.3	35	18	57	250	43000	170	85
	deva.metal 109	6.4	50	18	55	250	43000	170	85
	deva.metal 110	6.4	50	18	55	250	43000	170	85
	deva.metal 111	6.4	40	18	65	320	46000	220	110
	deva.metal 112	6.4	40	18	65	320	46000	220	110
	deva.metal 113	6.3	50	18	40	220	44000	200	100
	deva.metal 114	6.3	50	18	40	220	44000	200	100
Lead bronze alloys [2]									
	deva.metal 115	7.2	50	18	85	380	57000	260	130
	deva.metal 116	5.8	50	18	30	220	26000	150	75
	deva.metal 117	6.6	65	18	85	340	48000	230	115
Iron alloys									
	deva.metal 118	6.0	80	13	80	550	–	150	60
	deva.metal 120	6.0	120	12	100	460	73000	70	30
	deva.metal 121	6.4	50	12	50	180	–	70	30
	deva.metal 122	5.9	50	13	50	180	–	70	30
	deva.metal 123	5.7	140	13	60	400	–	70	30
Nickel alloys									
	deva.metal 124	6.4	45	15	60	400	–	100	50
Nickel/copper alloys									
	deva.metal 233	6.2	40	16	70	380	–	100	50
	deva.metal 126	6.2	65	–	30	300	–	–	–
Nickel/iron alloys									
	deva.metal 127	6.0	45	13	50	240	–	100	50
Stainless steel									
	deva.metal 128	5.8	55	13	120	180	–	150	70/10/1 [4]
	deva.metal 129	5.8	75	13	130	–	–	150	10/1 [4]

[1] Current properties and values are listed in the DEVA material sheets. These are provided on request.
[2] For bearings containing lead please refer to our DEVA standards sheet DN 0.14
[3] For minimum permissible temperature
[4] 70 at 350 °C
10 at 550 °C
1 at 800 °C

For prolonged use at temperatures above 200 °C it is necessary to stabilize the material by an additional heat treatment process, after which the heat treated bronze materials may be used at temperatures up to 350 °C.

The **deva.metal** nickel based alloys are generally used in those applications requiring the highest resistance to corrosion.

Table 3.3.1

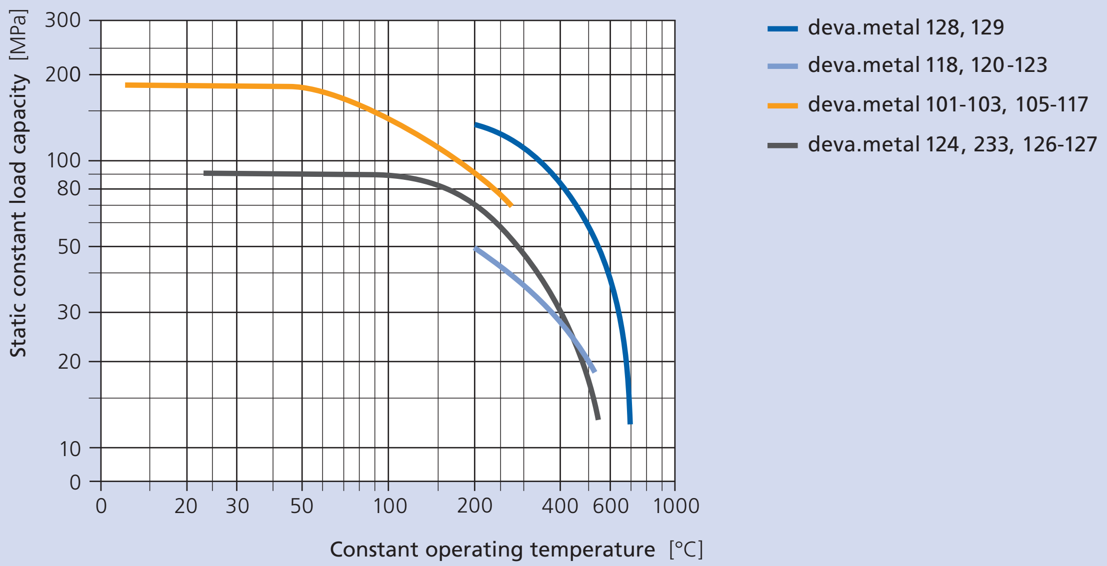
Bearing properties									Alloys
Max. sliding velocity [dry]	Max. p̄U value [dry]	Temperature range [max]	[min]	Coefficient of friction [5) 8)] [dry]	[in water]	Min. shaft hardness	Shaft surface finish [optimum]		
U_{max} m/s	$\bar{p}U_{max}$ MPa × m/s	T_{max} °C	T_{min} °C	f	f	HB/HRC	R_a µm	*Symbol* *Unit*	
									Bronze alloys
0.3	1.5	150	-50	0.13 - 0.18	0.11 - 0.16	>180HB	0.2 - 0.8		deva.metal 101
0.4	1.5	150	-50	0.10 - 0.15	0.09 - 0.12	>180HB	0.2 - 0.8		deva.metal 102
0.3	1.5	150	-50	0.11 - 0.16	0.10 - 0.13	>35HRC	0.2 - 0.8		deva.metal 103
0.3	1.5	150	-50	0.13 - 0.18	0.11 - 0.16	>45HRC	0.2 - 0.8		deva.metal 105
0.4	1.5	150	-50	0.10 - 0.15	0.09 - 0.12	>45HRC	0.2 - 0.8		deva.metal 106
									Bronze alloys (heat treated)
0.3	1.5	350	-100	0.13 - 0.18	0.11 - 0.16	>180HB	0.2 - 0.8		deva.metal 107
0.3	1.5	350	-100	0.13 - 0.18	0.11 - 0.16	>180HB	0.2 - 0.8		deva.metal 108
0.4	1.5	350	-100	0.11 - 0.16	0.10 - 0.13	>35HRC	0.2 - 0.8		deva.metal 109
0.4	1.5	350	-100	0.11 - 0.16	0.10 - 0.13	>45HRC	0.2 - 0.8		deva.metal 110
0.3	1.5	350	-100	0.11 - 0.16	0.10 - 0.13	>45HRC	0.2 - 0.8		deva.metal 111
0.3	1.5	350	-100	0.11 - 0.16	0.10 - 0.13	>45HRC	0.2 - 0.8		deva.metal 112
0.4	1.5	350	-100	0.10 - 0.15	0.09 - 0.12	>45HRC	0.2 - 0.8		deva.metal 113
0.3	1.5	350	-100	0.10 - 0.15	0.09 - 0.12	>45HRC	0.2 - 0.8		deva.metal 114
									Lead bronze alloys [2)]
0.3	1.5	200	-50	0.15 - 0.22	0.13 - 0.18	>180HB	0.2 - 0.8		deva.metal 115
0.3	1.5	200	-50	0.13 - 0.18	0.11 - 0.16	>180HB	0.2 - 0.8		deva.metal 116
0.3	1.5	200	-50	0.13 - 0.18	0.11 - 0.16	>45HRC	0.2 - 0.8		deva.metal 117
									Iron alloys
0.2	1.0	600	0	0.30 - 0.45		>45HRC	0.2 - 0.8		deva.metal 118
0.2	1.0	600	0	0.25 - 0.43		>45HRC	0.2 - 0.8		deva.metal 120
0.2	1.0	450	280	0.30 - 0.45		>45HRC	0.2 - 0.8		deva.metal 121
0.2	1.0	450	280	0.30 - 0.45		>45HRC	0.2 - 0.8		deva.metal 122
0.2	1.0	600	0	0.28 - 0.45		>45HRC	0.2 - 0.8		deva.metal 123
									Nickel alloys
0.2	0.8	200	-200	0.30 - 0.45		>45HRC	0.2 - 0.8		deva.metal 124
									Nickel/copper alloys
0.2	0.8	450	-200	0.30 - 0.45		>45HRC	0.2 - 0.8		deva.metal 233
0.2	0.8	450	-200	0.30 - 0.45		>45HRC	0.2 - 0.8		deva.metal 126
									Nickel/iron alloys
0.2	0.5	650 [7)]	-200	0.25 - 0.43		>45HRC	0.2 - 0.8		deva.metal 127
									Stainless steel
0.2	0.5	800	-100	0.35 - 0.49		>60HRC	0.2 - 0.8		deva.metal 128
0.05	0.5	800 [9)]	350	0.40 [6)]		>200HB	0.2 - 0.8		deva.metal 129

5) Friction decreases at operating temperature
6) Fluctuates according to temperature
7) In a hot steam environment: < 450 °C
8) The coefficients of friction cited are not guaranteed properties. They have been ascertained on our test benches using practical parameters.
These do not have to coincide with the immediate application of our products and their application environment.
We can offer customer-specific friction and wear tests on request.
9) In case of direct contact to oxygen (or air) limited to 750°C.

3.4 Effect of temperature

The maximum specific load which can be supported by **deva.metal®** alloys decreases with temperature.

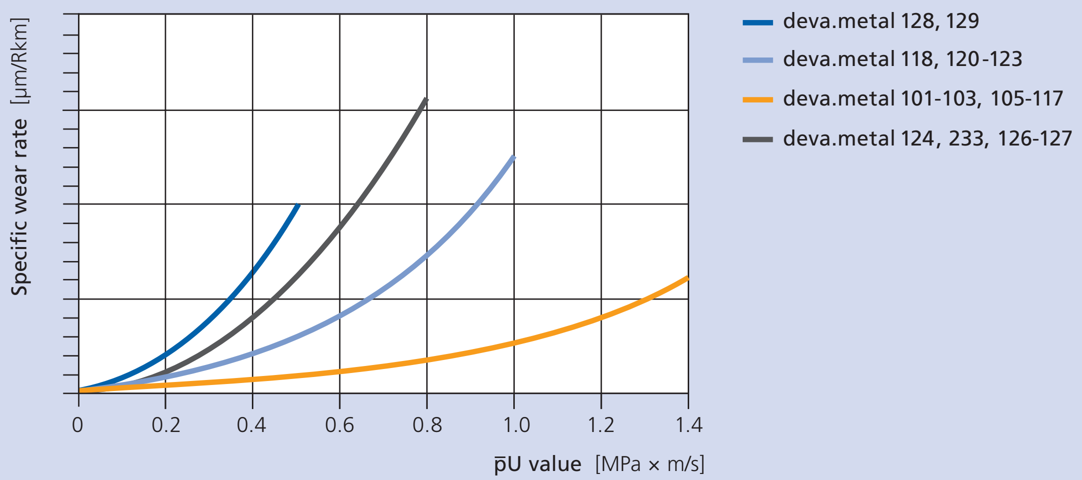
Effect of temperature on the specific load capacity of deva.metal — Figure 3.4.1



3.5 Specific wear rate

The effect of p̄U-factor on the specific wear rate (ΔS_h) for each of the three **deva.metal** alloy groups is shown in figure 3.5.1.

Effect of temperature on the specific load capacity of deva.metal — Figure 3.5.1



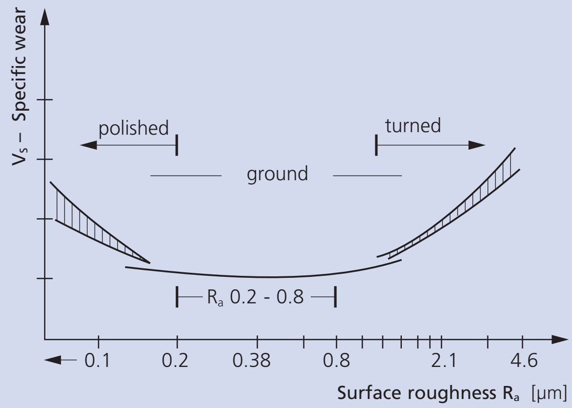
Mating material

The deva.metal sliding materials can only be used with counter material hardness of at least 180 HB. If an additional lubricant is introduced into the sliding contact, hardness values of >130 HB are also admissible. In abrasive environments, a hardened 35 HRC/45 HRC surface should be used.

The ideal mating surface roughness for deva.metal is R_a = 0.2 to 0.8 µm (obtained by grinding). Rougher surfaces are also acceptable depending on the operating conditions. To obtain the right surface roughness, it is also possible to use bushings of a suitable hardness. Hard-faced layers or galvanised protective layers (normally coated, hard-chrome and nickel-plated) can be used to a limited extent. The corrosion criteria for the counter materials should be determined on the basis of the relevant operating conditions. The adjacent table provides an overview of some of the possible counter materials.

Surface roughness — Figure 4.1

Influence of mating material surface roughness on the microwear of composite (Model representation, based on various tests and studies)



Mating materials for standard applications — Table 4.1.A

Material number	DIN designation	Comparable standards		
		USA – ANSI	GB – B.S. 9 70	F – AFNOR
1.0543	ZSt 60-2	Grade 65	55C	A60-2
1.0503	C45	1045	080M46	CC45
1.7225	42CrMo4	4140	708M40	42CD4

Mating materials for corrosive environments — Table 4.1.B

Material number	DIN designation	Comparable standards		
		USA – ANSI	GB – B.S. 9 70	F – AFNOR
1.4021	X20Cr13	420	420S37	Z20C13
1.4057	X17CrNi-16-2	431	432S29	Z15CN16.02
1.4112	X90CrMoV18	440B	–	(Z70CV17)
1.4122	X35CrMo17-1	–	–	–

Mating materials for seawater applications — Table 4.1.C

Material number	DIN designation	Comparable standards		
		USA – ANSI	GB – B.S. 9 70	F – AFNOR
1.4460	X3CrNiMoN27-5-3	329	–	–
1.4462	X2CrNiMoN22-5-3	UNS531803	318513	Z3CND24-08
2.4856	Inconel 625	–	–	–

Fits and tolerances

In order to ensure satisfactory performance, the bearing outside diameter, bearing bore, shaft diameter and the bore of the housing should be finished to the recommended limits.

Interference fit

deva.metal® bearings should be installed into the housing with an interference fit between the outside diameter of the bush and the bore of the housing.

Housing bore

The housing bore should be finished to H7 tolerance with a maximum surface finish of R_a = 3.2 µm.

Outer diameter of bearing

Sufficient close fitting of a bearing depends on its wall thickness and the operating conditions.
Additionally the bearings must be mechanically protected against displacement or rotation, if they operate continuously at temperatures above 150 °C or if they have to absorb axial loads (see Fig. 5.1).

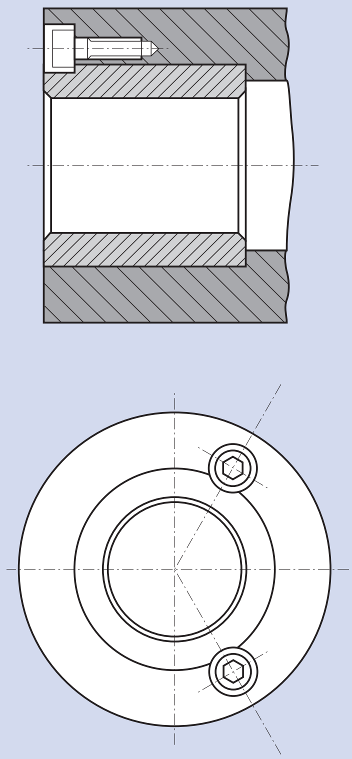
Clearance

The required assembled clearance for **deva.metal** bearings operating under dry conditions depends upon the bearing load and the operating temperature. In order to ensure satisfactory operation it is essential that the correct running clearance is used. Under dry running conditions any increase in the clearance recommended will result in a proportional reduction in performance. Bearing bores are manufactured pre-finished. Consider the contraction of the bearing bore when the bearing is installed into the housing.
The inner diameter of the bearing is reduced by approximately 75 to 95% of the actual excess dimension by press fitting the bearing into the housing. **deva.metal** sliding bearings are manufactured in such a way that finishing work is not necessary for normal installation after assembly. The resulting contraction is already taken into consideration during production.

Recommended tolerances — Table 5.1

	Tolerances
Housing bore	H7
Bearing outer diameter	r6

Mechanical fixation of deva.metal cylindrical bearings — Figure 5.1



Recommended fitting and tolerance ranges — Table 5.2

	Fits		
	Standard		Precision
	Operating temp. < 100 °C	Operating temp. > 100 °C	
Bearing bore (machined before installation)	C7	to be determined	D7
Bearing bore (machined after installation)	D8	to be determined	E8
Shaft	h7	to be determined	h7

Machining allowance for precision bearings

Precision bearings with an assembled bore tolerance of IT7 or IT6 are obtained by finish machining the bearing bore after assembly in the housing. In this case a machining allowance of 0.15 - 0.2 mm is recommended.

Wall thickness

The bearing wall thickness must be sufficient to meet both the manufacturing and application strength requirements. Table 5.3 gives the recommended minimum wall thickness for **deva.metal®** bearings according to the specific load and bearing diameter.

Wall thickness of deva.metal bearings — Table 5.3

Specific load	Recommended minimum wall thickness
MPa	mm
< 10	$\sqrt{0.5\,D_1}$
10-25	$\sqrt{0.6\,D_1}$
25-50	$\sqrt{0.8\,D_1}$
> 50	$\sqrt{D_1}$

D_1 = Bearing inner diameter

Chamfers

In order to facilitate the installation of **deva.metal** bearings both the housing bore and the bush outside diameter should be provided with chamfers as indicated in figure 5.2.

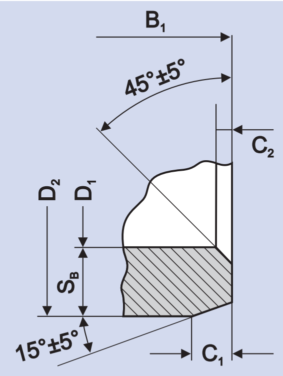
For all diameters: $C_2 = S_B/5$

Housing bore chamfer: 1 × 15° - 20°

Chamfers — Table 5.4

Bearing width B_1	Chamfer C_1
mm	mm
< 10	1.0
10-25	1.5
25-50	2.0
50-80	3.0
> 80	4.0

Chamfers — Figure 5.2



Bearing width

deva.metal alloys are manufactured using powder metallurgy methods. Resulting manufacturing restrictions in relation to the width/diameter ratios [$B_1 : D_2$].

Practical values $B_1 : D_2$ have proven to be from 0.5 to 1.0. Difficulties on account of edge loading are to be expected for ratios greater than 1, sliding bearings with a width/diameter ratio >1.5 are not recommended.

Allowances for thermal expansion

Many **deva.metal** applications operate at high temperatures, in which case the following factors must be considered at the design stage:

a) Thermal expansion of the housing
b) Thermal expansion of the **deva.metal** bearing
c) Thermal expansion of the shaft, the consequential effects on the interference fit of the bush in the housing and the clearance of the bush on the shaft.

The following formula allow the designer to calculate the required manufactured bearing clearance to ensure that the correct running clearance is maintained at the anticipated operating temperature of the application.

Example for the calculation of bearing installation clearance at increased temperatures

The condition is typical of many furnace and oven conveyer applications.

$$C_{DM} = C_D + [D_J \times \Delta T\,(\alpha_J + \alpha_1 + \alpha_G)]$$

where:

C_{DM} = manufactured clearance
C_D = required operating clearance
D_J = shaft diameter
ΔT = operating temperature – ambient temperature
α_J = linear thermal expansion coefficient of shaft material
α_1 = linear thermal expansion coefficient of **deva.metal** alloy
α_G = linear thermal expansion coefficient of housing material

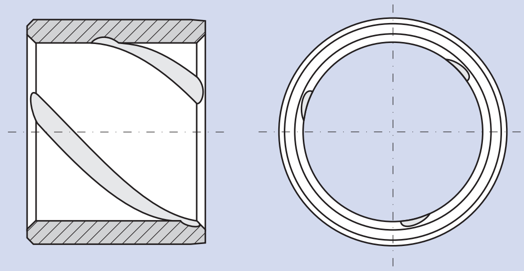
If the bearing arrangement is subject to changing temperatures please contact our application engineers.

Design

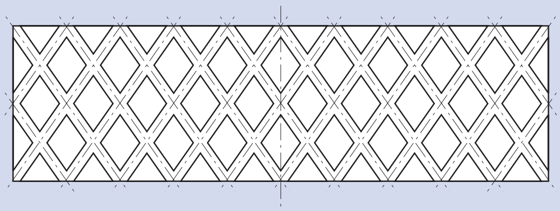
6.1 Design of sliding surfaces

Experience has shown that the dry wear performance of **deva.metal®** is improved by grooves in the bearing surface to assist in the removal of wear debris and dirt from the bearing. The drawings below show two possible designs.

Helical cleaning grooves — Figure 6.1.1

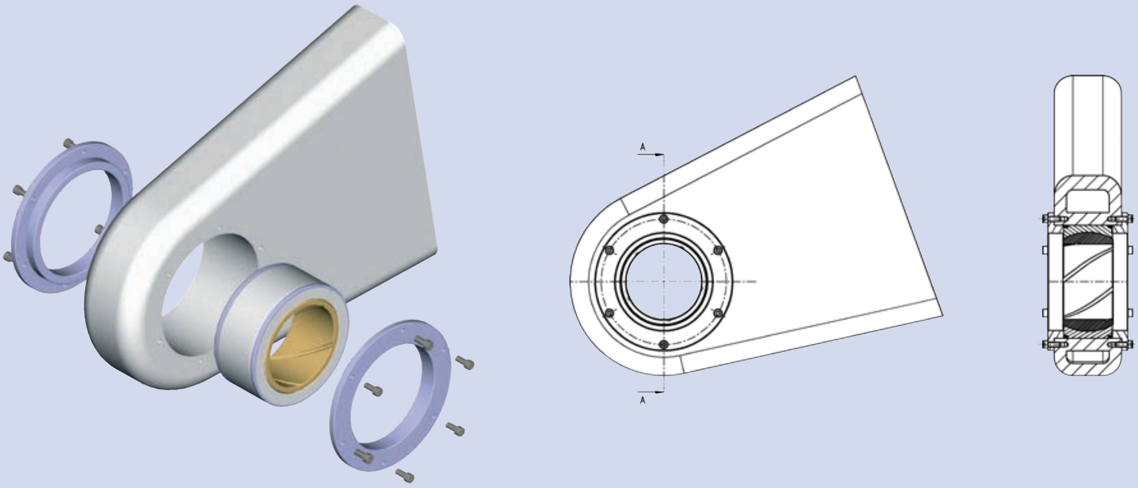


Cleaning grooves in diamond pattern — Figure 6.1.2

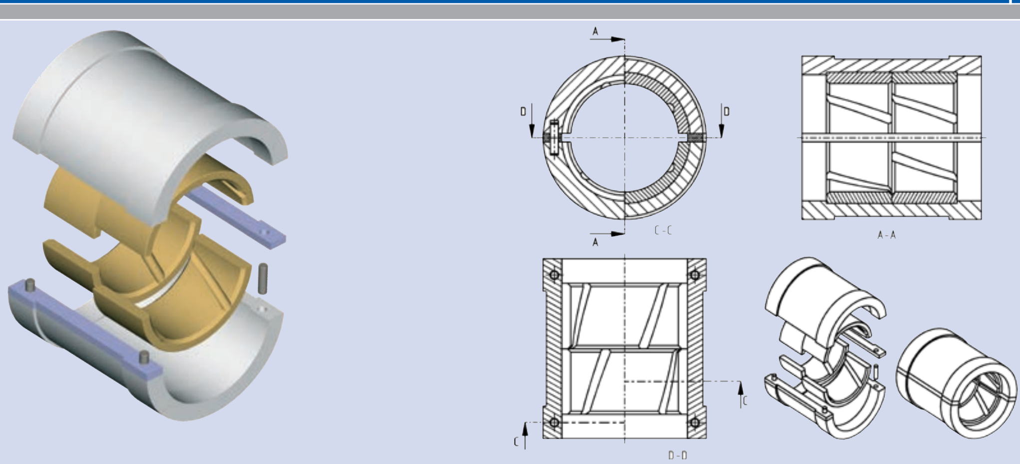


6.2 Special design solutions

Bracket bearing — Figure 6.2.1

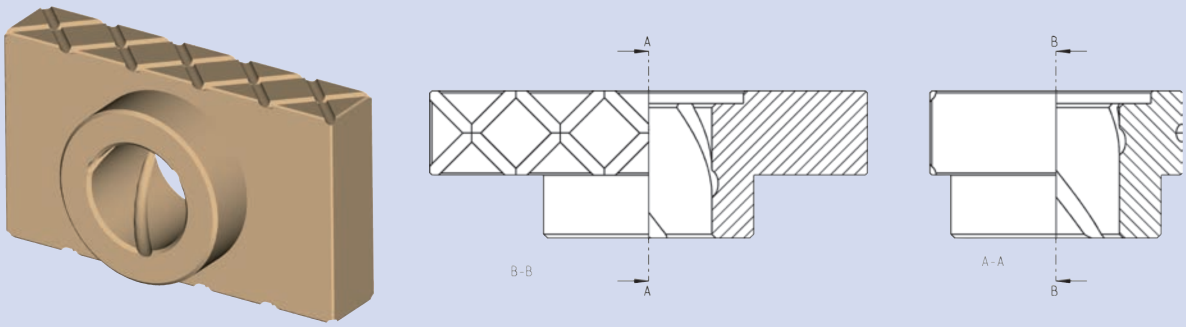


Middle bearing for conveyor worm — Figure 6.2.2



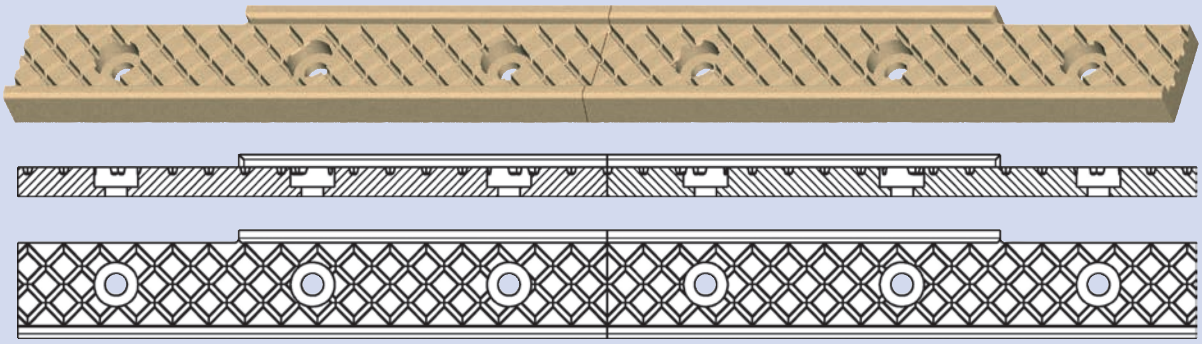
Sliding piece

Figure 6.2.3



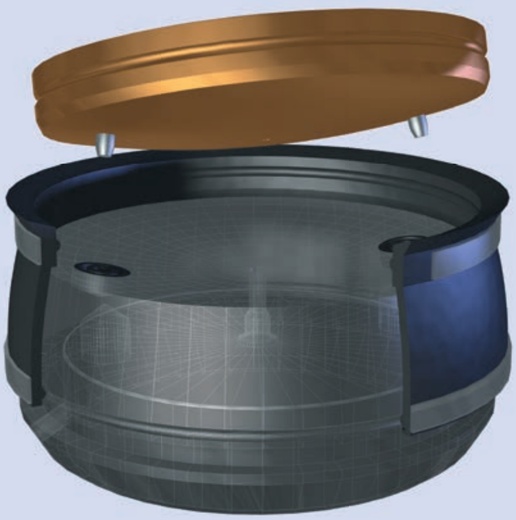
Sliding bar

Figure 6.2.4



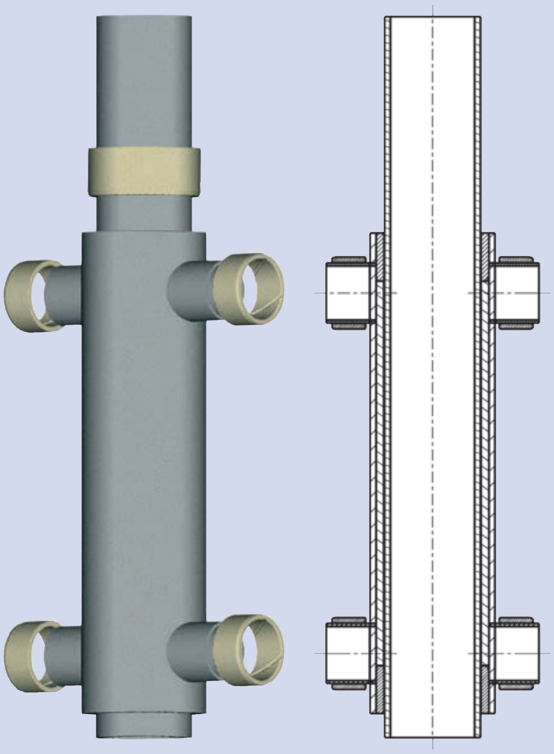
DEVA turret bearing

Figure 6.2.5

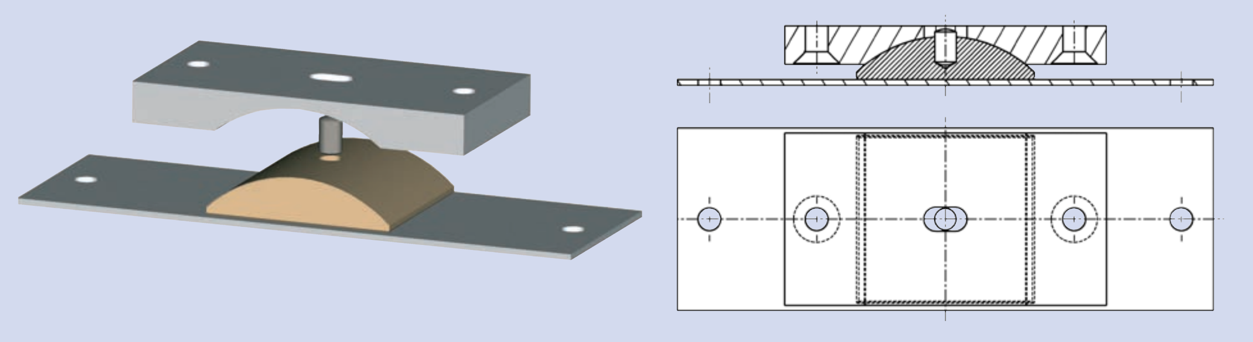


Piston guide rod with balance bearings

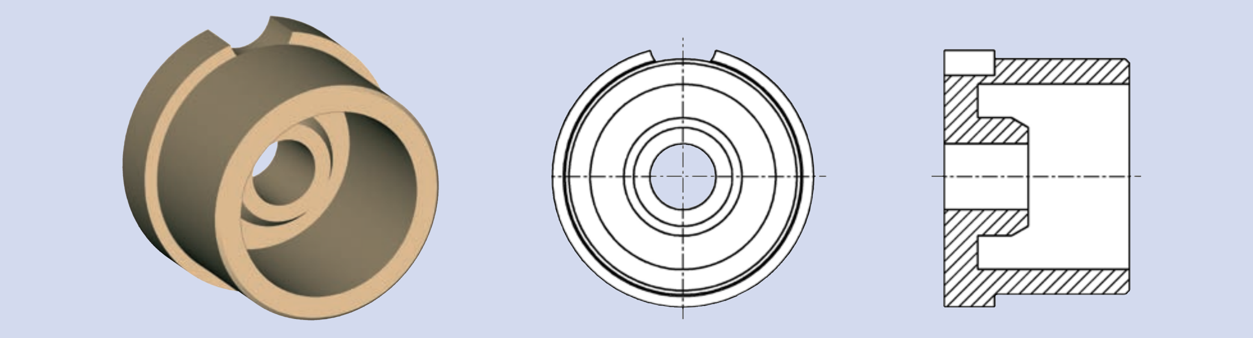
Figure 6.2.6



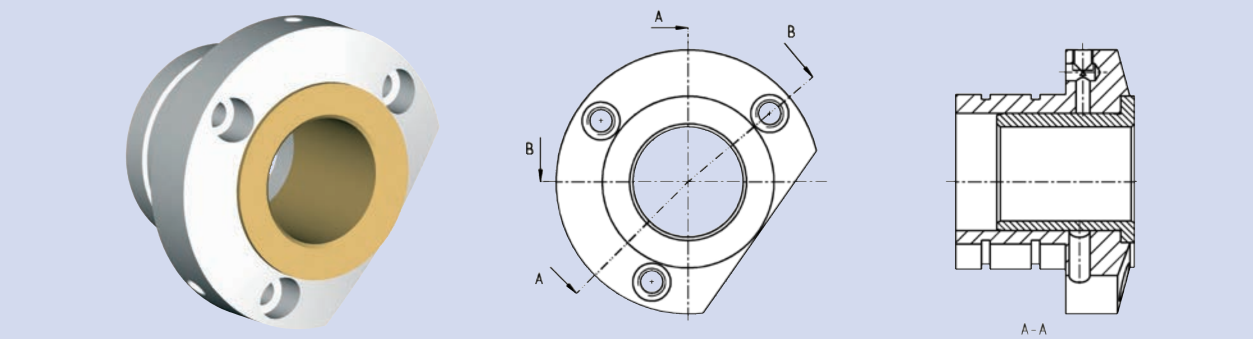
Angle compensation piece — Figure 6.2.7



Guide bearing — Figure 6.2.8



Flange bearing — Figure 6.2.9

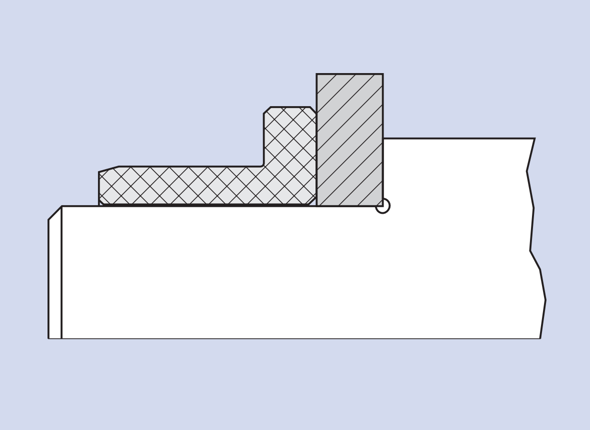


6.3 Design considerations of running surfaces

Shafts and counter faces which run against **deva.metal**® are normally produced from steel. It is recommended to use stainless steel or hard-chrome plated steel as mating materials for damp and corrosive environments – particularly if neither oil nor grease are available as basic protection. The determination of the counter material surface qualities and hardness has already been discussed in chapter four.

Shafts and counter surfaces operating against the **deva.metal** bearings or thrust washers must extend beyond the bearing surface in order to avoid cutting into it. The mating surface must also be free from grooves or flats. The end of the shaft should be given a lead-in chamfer and all sharp edges or projections which may damage the **deva.metal** bearing must be removed.

Design considerations of running surfaces — Figure 6.3.1

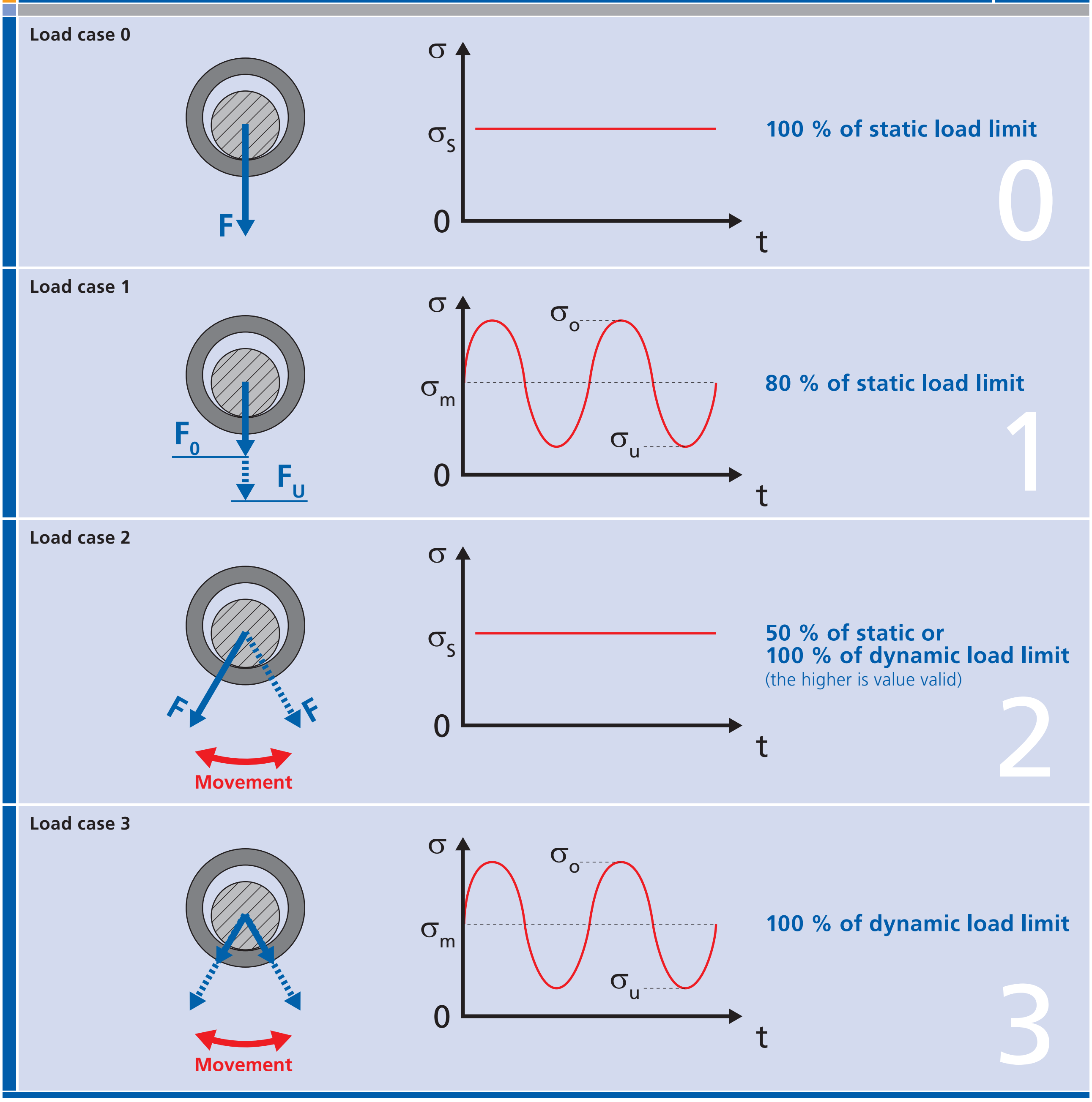


6.4 Description what values to be considered for design

DEVA® differentiates load cases (0 to 3) regarding the character of load stressing a bearing. This is to consider fatigue influences in case of dynamic pressure. The percentage values are refering to the limit values described in the material data sheet or technical handbooks.

This worksheet is related to **DEVA** work instruction A 616 (see also "Qualitäts-, Umwelt- und Arbeitsschutz-Management Handbuch, Verfahrensanweisungen + Arbeitsanweisung").

Load cases 0-3 — Figure 6.4.1



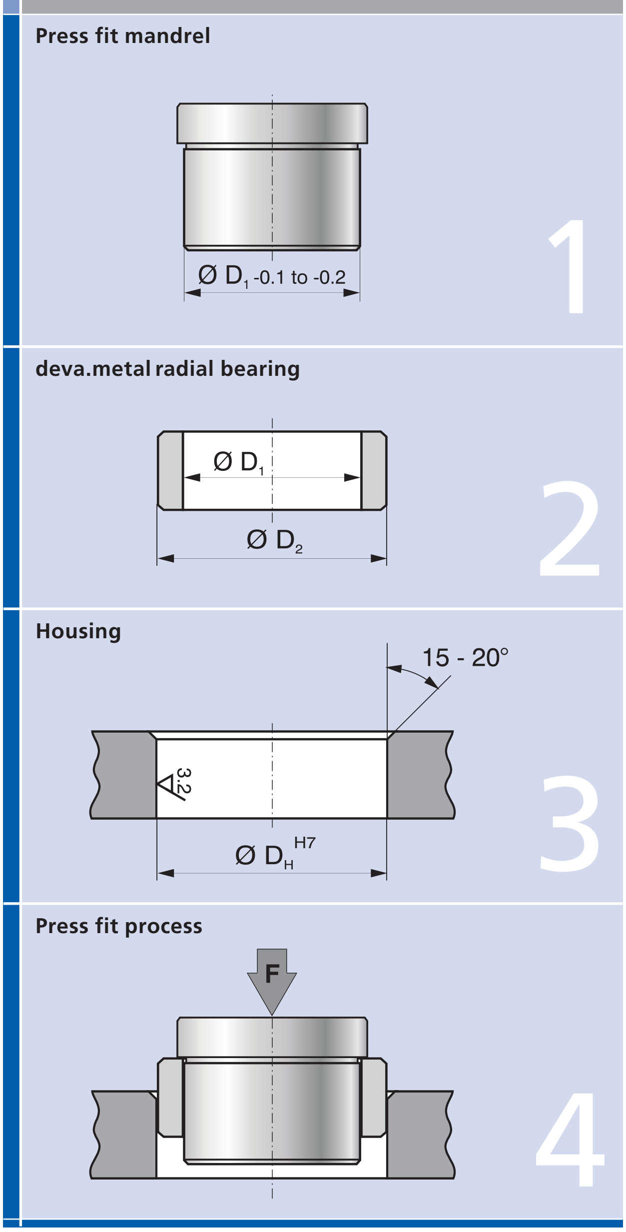
Installation

7.1 Installation of deva.metal radial bearings

Press fitting

Press fitting is a universally applicable installation method for all **deva.metal**® materials.
deva.metal radial bearings can be installed with a screw press or hydraulic press. It is important to ensure that the mounting force is applied centrically. See also figure 7.1.1, installation by press fitting.
Driving in using a hammer is not permitted, as this can result in damage to the **deva.metal** material.
For **deva.metal** flanged bearings the transition radius between the flange rear and outer diameter of the radial bearing must be taken into consideration by machining a small chamfer.

Installation of deva.metal by press fitting — Figure 7.1.1



Supercooling (bronze alloys only)

The supercooling installation method is only permitted for **deva.metal** bronze alloys.
To all other **deva.metal** alloys supercooling can cause structural changes which affect the dimensional stability or alter the material behavior.
To check whether supercooling the bearing is the correct installation method, the shrinkage allowance **s** must be calculated. This can be calculated according to the following equation:

$$s = 0.8 \times \alpha_1 \times \Delta T \times D_2 \text{ mm}$$

where:

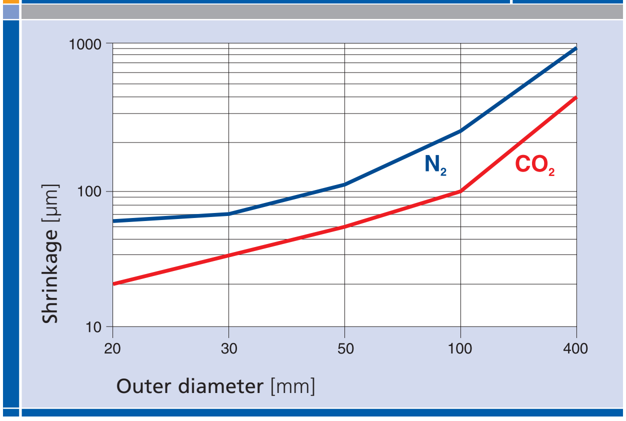
α = linear coefficient of thermal expansion [1/K]
= 18×10^{-6} 1/K for bronze alloys

The media used most frequently for supercooling are dry ice and liquid nitrogen. Both substances are classified as hazardous substances.

We expressly draw attention to dealing with hazardous substances. Safety data sheets are available on request.

To achieve a uniform supercooling, the dry ice should be crushed to about the size of a walnut. The sliding bearings should be completely immersed when using liquid nitrogen. The time required for complete supercooling of the bearings is between 0.5 to 2 hours depending on the volumes of the parts to be cooled.

Shrinkage of deva.metal dependent on outer diameter — Figure 7.1.2



The supercooled parts can be inserted without effort into the housing bore. Ensure that the parts to be mounted are correctly aligned, especially where large parts are involved.
Sliding bearings can be cemented in the housing as an additional protection against rotation or displacement during operation. The instructions of the adhesive manufacturer must be followed.

7.2 Installation of thrust washers

deva.metal® thrust washers should be located on the outside diameter in a recess as shown in figure 7.2.1. If there is no recess for the thrust washer one of the following methods of fixing may be used:

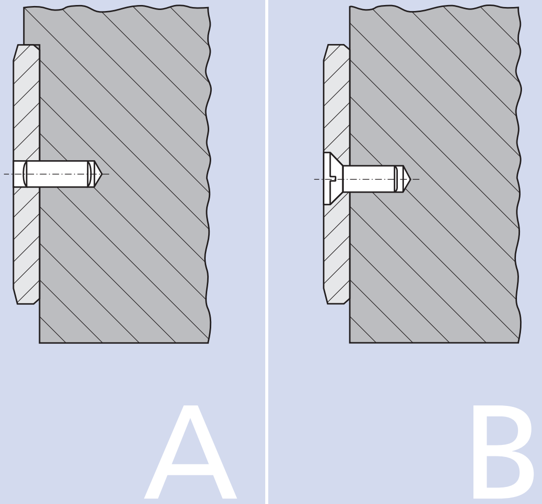
- Two locking pins
- Two screws
- Adhesive
- Soldering

Important notes:

- Locking pins must be recessed below the bearing surface sufficient to allow for the anticipated wear of the **deva.metal** washer.
- Screws must be countersunk below the bearing surface sufficiently to allow for the anticipated wear of the **deva.metal** thrust washer.
- Contact adhesive manufacturer for selection of suitable adhesives.
- Protect the bearing surface to prevent contact with adhesive.
- Ensure the washer inner diameter does not touch the shaft after assembly.

Locating deva.metal® thrust washers — Figure 7.2.1

Locking pins | **Screws**



7.3 Installation of sliding plates

deva.metal sliding plates should be mounted as follows:

- With **DEVA** special bolts in accordance with **DEVA** works standard DN 0.34 (figure 7.3.1)
- Through mechanical fixing, e.g. form fit (figure 7.3.1)
- By adhesion

The higher expansion coefficient of **deva.metal** in comparison to steel must be observed when using **deva.metal** sliding plates at increased temperatures. The running clearance must be selected accordingly.

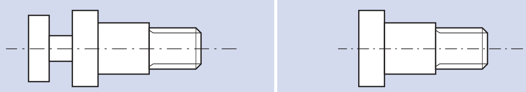
Adhesive bonding

Sliding bearings can be cemented in the housing as an additional protection against displacement during operation. The instructions for use of the adhesive manufacturer must be followed in this case.

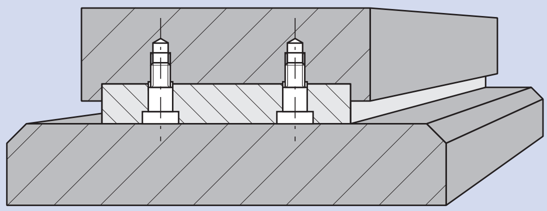
Special bolts

Installation of a deva.metal sliding plate with DEVA special bolts — Figure 7.3.1

DEVA special bolt before installation | **DEVA special bolt** after installation



Installed deva.metal sliding plate



7.4 Maximum screw tightening torque for deva.metal® screw connections

Under consideration of the maximum static loading capacity $\bar{p}_{stat/max}$ of the respective **deva.metal** material, the maximum permissible surface pressure under the screw head or washer can be calculated according to the formula below.

$$M_{A/max} = \bar{p}_{stat/max} \times A_{contact} \times (0.16 \times P + \mu_{ges} \times 1.5\, d_2)$$

In the calculation, the following applies:

$M_{A/max}$ = max. permissible screw tightening torque [Nm]
$\bar{p}_{stat/max}$ = max. static loading capacity of the selected. deva.metal alloy according to Tab. 3.3.1 [N/mm²]
$A_{Kontakt}$ = contact surface between the screw head surface and the deva.metal component [mm²]
μ_{ges} = total coefficient of friction (thread and screw head to deva.metal = 0.1)
d_2 = pitch diameter [mm]
P = thread pitch [mm]

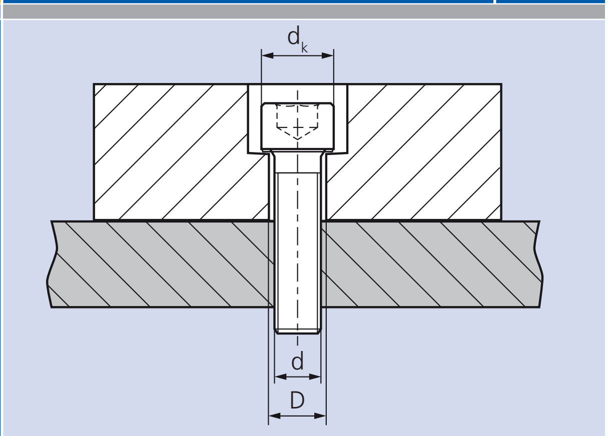
Example 1

Screw M8 according to DIN 912 in deva.metal 101 with
d_k = 13 mm ((screw head Ø DIN 912 / ISO 4762)
d_2 = 7.19 mm (pitch Ø bei M8)
P = 1.5 mm (pitch of coarse thread M8)
D = 9 mm (according to DEVA drawing)
$A_{contact}$ = $(Ds^2 - D^2)\ \pi/4 = (13^2 - 9^2) * \pi/4 = 69$ mm²
$\bar{p}_{stat/max}$ = 200 N/mm² (for deva.metal 101)
μ_{ges} = 0.1

Calculation of the maximum permissible screw tightening torque:

$M_{A/max}$
= $(\bar{p}_{stat/max} \times A_{contact}) \times (0.16 \times P + \mu_{ges} \times 1.5\, d_2)$
= (200 N/mm² × 69 mm²) × (0.16 × 1.5 mm + 0.1 × 1.5 × 7.19 mm)
= 13,800 N (0.24 mm + 2.16 mm) = 13,800 N × 1.2 mm ≈ **16.5 Nm**

deva.metal screw connection with screw M8 according to DIN 912 — Figure 7.4.1



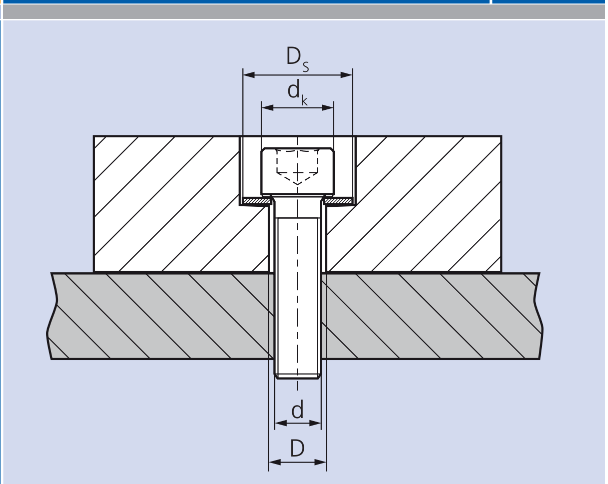
Example 2

Screw M8 according to DIN 912 in deva.metal 101 with
D_S = 16 mm (washer DIN 125 or ISO 1789)
d_2 = 7.19 mm (pitch Ø for M8)
P = 1.5 mm (pitch of coarse thread M8)
D = 9 mm (according to DEVA drawing)
$A_{contact}$ = $(Ds^2 - D^2)\ \pi/4 = (16^2 - 9^2) * \pi/4 = 137$ mm²
$\bar{p}_{stat/max}$ = 200 N/mm² (for deva.metal 101)
μ_{ges} = 0.1

Calculation of the maximum permissible screw tightening torque:

$M_{A/max}$
= $(\bar{p}_{stat/max} \times A_{contact}) \times (0.16 \times P + \mu_{ges} \times 1.5\, d_2)$
= (200 N/mm² × 137 mm²) × (0.16 × 1.5 mm + 0.1 × 1.5 × 7.19 mm)
= 27,400 N × 1.32 mm = 36,168 Nmm ≈ **36 Nm**

deva.metal screw connection with screw M8 and washer according to DIN 125 — Figure 7.4.2



Finishing

General

deva.metal® sliding bearings are supplied as finished parts. The standard tolerances are sufficient for most applications. In cases where a sufficient accuracy can only be attained by finishing work after installation, **deva.metal** sliding bearings can be mechanically finished. This also applies for mounting holding grooves or similar.
The guidelines for working with **deva.metal** materials are set out in the **DEVA** works standard DN 0.37 and can be supplied on request. **deva.metal** is classified as a hazardous substance on account of its composition. The legal requirements must be adhered to during the work. For details see also the chapter on machining work.

Machining work

Carbide tipped tools in accordance with ISO-Norm K10 are recommended. The cutting edges must always be kept sharp in order to attain an optimum surface smoothness. Recommended surface quality: R_a=1.2 µm. Please consult our application engineers when working with thick-walled workpieces. Thin-walled workpieces which tend to twist during machining or treatment, should be worked with a lower cut depth and a lower feed.
deva.metal can be machined like grey cast iron. Health and work safety regulations must always be observed. Machining work – except grinding – is carried out dry (without coolant). The air must be permanently extracted in accordance with regulations (keep inhaled air clean). The air speed at the suction point should be 20 m/s.

Turning

A three or four jaw chuck can be used for preliminary machining at wall thicknesses > 10 mm. Collet chucks or bushings must be used for thin-walled bearings and finishing work in order to prevent deformations resulting from restraint pressure.
The workpieces must be removed from the clamping chucks before finishing work so that potential deformations can relax again.

Drilling

HSS drills are recommended at a cutting speed of 15 - 26 m per minute and a feed of 0.05 - 0.1 mm per cut. Reduce the feed before boring through in order to prevent damage to the **deva.metal** workpiece.

Milling

The same cutting tool requirements apply as for machining. It is important to adhere to the tool angle in order to prevent edge chipping on the **deva.metal** workpiece if the milling cutter reaches the material edge.

Grinding

The sliding surfaces should not be ground, as abrasion particles could be pressed into the running surface causing damage during operation. If grinding is absolutely necessary it must be carried out with 5CG 10C 80/100JT 12 V82 (Dilumit) grinding discs or similar. Vacuum plates can be used for fixing.

Surface roughness

An average roughness R_a of approximatly 1.2 µm should be attained with the above mentioned methods.

Recommended dimensions

deva.metal can be manufactured in nearly any shape. However, as a sintered material it is subjected to production limitations, especially related to wall thickness and length to diameter ratio.
Recommended maximum sizes for cylindrical bushes (not split) are approximatly 500 mm inner diameter and 110 mm length, for approximately cylindrical plugs 280 mm diameter and 100 mm length, for plates 125 mm width, 220 mm length and 55 mm thickness. Specific dimensions on request.
Because of the wide range of alloys and special material properties **deva.metal** is suitable for many applications. The **DEVA** application engineers develop the optimized solution for your application.

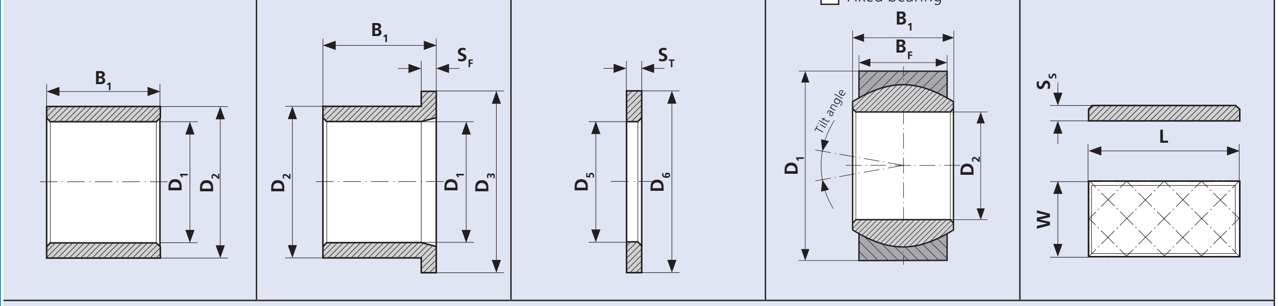
Data relevant to the design of DEVA® bearings

Questionaire 10.1.A

Description of application

☐ Steel Industry	☐ Steam and Gas Turbines	☐ Railway	☐ New design
☐ Wind Energy	☐ Offshore and Marine	☐ Hydro Power	☐ Existing design
☐ Rubber and Plastic Industry	☐ Heavy-duty Vehicles	☐ Others	Project No.

☐ Plain bearing	☐ Flanged bearing	☐ Thrust washer	☐ Spherical bearing	☐ Sliding plate
			☐ Floating bearing ☐ Fixed bearing	



☐ Shaft rotates ☐ Bearing rotates ☐ Angular motion ☐ Axial motion

		Item 1	Item 2	Item 3
Quantity				
Dimensions [mm]		Item 1	Item 2	Item 3
Inner diameter	D_1 (D_5)			
Outer diameter	D_2 (D_6)			
Bearing width	B_1			
Outer ring width	B_F			
Flange outer diameter	D_3			
Flange thickness	S_F			
Wall thickness	S_T			
Plate length	L			
Plate width	W			
Plate thickness	S_S			
Loading		Item 1	Item 2	Item 3
Static		☐	☐	☐
Dynamic		☐	☐	☐
Alternating		☐	☐	☐
Impact		☐	☐	☐
Radial load [kN]				
Axial load [kN]				
Surface pressure				
Radial [MPa]				
Axial [MPa]				
Mating material		Item 1	Item 2	Item 3
Material no./type				
Hardness [HB/HRC]				
Roughness R_a [µm]				
Housing material		Item 1	Item 2	Item 3
Material no./type				
Lubrication		Item 1	Item 2	Item 3
Dry running		☐	☐	☐
Permanent lubrication		☐	☐	☐
Medium lubrication		☐	☐	☐
Medium				
Lubricant				
Initial lubrication		☐	☐	☐
Hydrodyn. lubrication		☐	☐	☐
Dynamic viscosity				

Motion	Item 1	Item 2	Item 3
Speed [rpm]			
Sliding speed [m/s]			
Stroke length [mm]			
Double strokes [/min]			
Rotating angle [°]			
Frequency [n/min]			
Tilt angle (spherical bearing) [°]			
Operating time	Item 1	Item 2	Item 3
Continuous operation			
Intermittent operation			
Duty operation [%/h]			
Days/year			
Frictional distance [km]			
Fits/tolerances	Item 1	Item 2	Item 3
Shaft			
Bearing housing			
Environmental conditions	Item 1	Item 2	Item 3
Temperature at bearing			
Contact medium			
Other influences			
Lifetime	Item 1	Item 2	Item 3
Desired operating time [h]			
Permissible wear [mm]			

Company	
Company name	
Address	
Contact person	
Phone	
Fax	
Cell-phone	
E-mail	

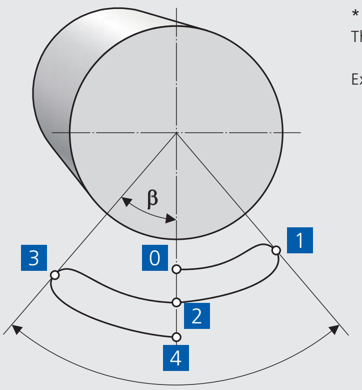
02.13

Questionaire 10.1.B

Remarks

	yes	no
Certificate required (e.g. 3.1)	☐	☐
Acceptance procedure (e.g. 3.2)	☐	☐

Explaination



* angle: According to DEVA® definition, one cycle is four times the angle **β**.
This is the basis to calculate the expected sliding distance.

Example: Bushing D_1 = 50 mm and agle **β** = 5° → 1 cycle shows a sliding distance of 8.73 mm

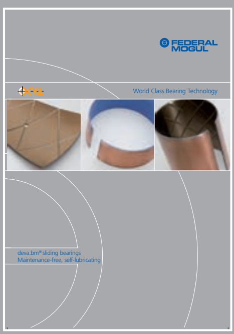
Portfolio

DEVA® in marine/offshore

DEVA® in heavy-duty

DEVA® in the steel industry

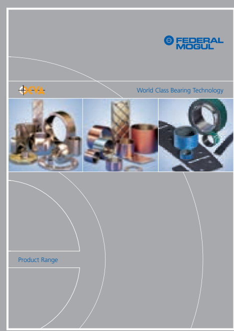
Industry solutions



deva.bm®

deva.glide®

deva.tex®



Product range

Spherical bearings

Product information

Disclaimer

The present technical documentation has been prepared with care and all the information verified for its correctness. No liability, however, can be accepted for any incorrect or incomplete information. The data given in the documentation are intended as an aid for assessing the suitability of the material. They are derived from our own research as well as generally accessible publications.

The sliding friction and wear values stated by us or appearing in catalogues and other technical documentation do not constitute a guarantee of the specified properties. They have been determined in our test facilities under conditions that do not necessarily reflect the actual application of our products and their service environment or permit comprehensive simulation in relation to them.

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