



**International  
Standard**

**ISO 8838**

**Plain bearings — Water-lubricated  
plain bearing materials**

*Paliers lisses — Matériaux de paliers lisses lubrifiés à l'eau*

**First edition  
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## Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

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This document was prepared by Technical Committee ISO/TC 123, *Plain bearings*, Subcommittee SC 7, *Special types of plain bearings*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

## Introduction

Water-lubricated bearings are widely used in fields such as submersible pumps, marine stern tubes, hydroelectric generator turbines, water treatment equipment, water valves and rolling equipment for steelmaking.

Water-lubricated plain bearings are used for the following conditions or reasons:

- a) oil or greases cannot be used due to equipment usage conditions;
- b) there is plenty of water available as a lubricant around the equipment;
- c) even if water for lubrication leaks, it does not pollute the environment like oil or grease.

However, when using water as a lubricant, it is necessary to take the following into account:

- water freezes at 0 °C or below and becomes vapor at 100 °C or above, at normal pressure, therefore losing load carrying capacity;
- water has low viscosity in comparison with oil;
- water cannot support a high load because the increase in viscosity that occurs in oil lubrication (elastohydrodynamic lubrication: EHL) when it is under high pressure cannot be expected in water.
- water does not have the ability that oil and grease have to prevent corrosion on shafts and bearings.

While water-lubricated plain bearings have been used in various fields around the world and the water that is used as a lubricant has its own specific features differing from oil, there have been no International Standards that apply to water-lubricated plain bearings thus far.

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# Plain bearings — Water-lubricated plain bearing materials

## 1 Scope

This document specifies requirements for the selection and use of water-lubricated plain bearing materials used in different equipment and plants under various lubrication conditions, such as

- fluid-film lubrication condition,
- mixed lubrication condition, and
- condition comprising a non-lubrication condition which shifts to a fluid-film lubrication condition.

In addition, this document also specifies requirements for mating (shaft) material, the lubrication method and for items to consider during the design of water-lubricated plain bearing materials.

The water used as a lubricant is pure water, tap water, river water or seawater. This document does not apply to the water solution of chemicals, refrigerants, liquid fuels, etc.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1043-1, *Plastics — Symbols and abbreviated terms — Part 1: Basic polymers and their special characteristics*

ISO 4378-1, *Plain bearings — Terms, definitions, classification and symbols — Part 1: Design, bearing materials and their properties*

ISO 4378-2, *Plain bearings — Terms, definitions, classification and symbols — Part 2: Friction and wear*

ISO 4378-3, *Plain bearings — Terms, definitions, classification and symbols — Part 3: Lubrication*

ISO 8044, *Corrosion of metals and alloys — Vocabulary*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1043-1, ISO 4378-1, ISO 4378-2, ISO 4378-3 and ISO 8044 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

## 4 Plain bearing materials and mating (shafts) materials

### 4.1 Bearing materials

#### 4.1.1 General

Depending on the equipment, bearings are used in the following lubrication conditions:

- a) bearing is constantly immersed in water;
- b) there is no lubrication at first and water is supplied after the start of operation;
- c) water is forcibly supplied from the beginning.

When required to operate without lubrication, a bearing material with a self-lubricating property shall be selected. When used in seawater, a bearing material that does not cause galvanic corrosion shall be selected.

NOTE In addition to the materials listed below, the bearing materials listed in ISO 19259 and ISO 20054 are also used for water-lubricated bearing materials.

#### 4.1.2 Wood-based material

Lignum vitae or materials such as maple and beech impregnated with wax can be used.

Wood-based material has self-lubricating properties.

#### 4.1.3 Carbon-based material

Artificial graphite with or without the following can be used:

- a) impregnated resin (phenolic resin, etc.);
- b) low melting point metals (such as Cu, Sn, Cu-Sn alloy, etc.).

Carbon-based material has self-lubricating properties, however, there is a risk of galvanic corrosion when used in seawater.

NOTE Terms related to galvanic corrosion are defined in ISO 8044.

#### 4.1.4 Rubber-based material

Natural rubber (NR) or synthetic rubber, such as chloroprene rubber (CR), acrylonitrile-butadiene rubber (NBR), and styrene-butadiene rubber (SBR), can be used.

NOTE Other rubber-based materials are defined in ISO 1629.

These rubber-based materials are typically bonded to the inner surface of the metal tube or fibre-reinforced plastic tube. They are resistant to abrasive wear, however, they do not have self-lubricating properties.

#### 4.1.5 Thermosetting resin-based material

Thermosetting resin such as phenolic resin and unsaturated polyester resin reinforced with fibre or woven fabric, and, as needed, added with fillers such as graphite, carbon fibre and polytetrafluoroethylene (PTFE) to improve sliding characteristics can be used.

Thermosetting resin-based material has self-lubricating properties and impact load resistance.

#### 4.1.6 Fluoro resin-based material

Fluoro resin such as PTFE, tetrafluoroethylene-perfluoroalkylvinylether copolymer resin (PFA) and tetrafluoroethylene-hexafluoropropylene copolymer resin (FEP) added with fillers such as glass fibre and carbon fibre to improve wear resistance can be used.

Fluoro resin-based material is used as solid type or multilayer type bonded to a metal substrate. It has self-lubricating properties.

#### 4.1.7 Thermoplastic resin-based material

Thermoplastic resin such as polyamide (PA), polyoxymethylene (POM), polyphenylenesulfide (PPS), polyetheretherketone (PEEK), polyurethane (PU) and polyethersulfone (PES) added with fillers such as glass fibre, carbon fibre and PTFE to improve wear resistance and lubricity can be used.

Thermoplastic resin-based material has self-lubricating properties.

#### 4.1.8 Ceramic-based material

Silicon nitride ( $\text{Si}_3\text{N}_4$ ), silicon carbide (SiC) or Sialon ( $\text{Si}_3\text{N}_4\text{-Al}_2\text{O}_3$ ) can be used.

These ceramic-based materials are resistant to abrasive wear, however, they do not have self-lubricating properties.

#### 4.1.9 Cermet-based material

Composite materials of ceramics and metals, such as tungsten carbide (WC) based alloy or titanium carbide (TiC) based alloy, are the most commonly used among cermet-based materials. Chromium carbide ( $\text{Cr}_3\text{C}_2$ ) alloy is used for a coating on a metal substrate.

These cermet-based materials are resistant to abrasive wear, however, they do not have self-lubricating properties.

### 4.2 Mating (shaft) materials

#### 4.2.1 General

Lubricating water does not prevent corrosion like oil or grease, so the mating shaft selected shall be corrosion resistant. A material with high surface hardness, preferably HV 600 or higher and wear resistance should be selected, in case hard foreign matter, such as sand, enters between sliding surfaces of the bearing and mating shaft.

However, when using a rubber bearing, the shaft does not need to have a hard surface, because the elastic deformation of the rubber traps hard foreign matters resulting in less damage to the shaft.

#### 4.2.2 Copper alloy

A bronze sleeve should be fitted on to a steel shaft for marine propulsion shafts.

#### 4.2.3 Stainless steel

Austenitic, martensitic, two-phase precipitation hardening stainless steel, high nitrogen steel or the like should be used.

NOTE Chemical composition, mechanical properties, etc. of stainless steels are described in ISO 16143-2.

#### 4.2.4 Plating

Hard chromium plated steel shaft should be used.

#### 4.2.5 Ceramics

Ceramic material such as silicon carbide (SiC), silicon nitride (Si<sub>3</sub>N<sub>4</sub>) and Sialon (Si<sub>3</sub>N<sub>4</sub>-Al<sub>2</sub>O<sub>3</sub>) should be used.

For small size, e.g. shaft diameters of 20 mm or less, it is recommended to use for a solid type, and for larger size than that, it is recommended to fit on a steel shaft as a sleeve, but the aforementioned values are not limiting as the dimensions depend on the manufacturing capacity of the shaft.

#### 4.2.6 Cermet

A WC based alloy or TiC based alloy should be used by fitting it as a sleeve on a steel shaft.

### 5 Characteristics, applications, manufacturing method and compatible combinations

In order to assist in selecting material, an outline of the characteristics, applications and the manufacturing method of water-lubricated bearings, and the compatible combinations of water-lubricated bearing materials and shaft materials is given in [Annex A](#).

### 6 Water supply method

#### 6.1 General

Water lubrication may be achieved by the following means:

- a) water surrounding the equipment;
- b) water in a tank attached to the equipment;
- c) or tap water supply where pressure is needed.

#### 6.2 Forced water supply

Where this method is used, water such as river water and seawater are forcibly supplied to the sliding surface of a plain bearing from the outside by using a pump or the like. For tap water, supplied water pressure is used.

A great cooling effect is expected when using river water and seawater. A filter or a centrifugal separator is often used in order to remove foreign matters. Both are used together when high cleanliness is required.

#### 6.3 Circulating water supply

Water stored in a tank that is attached to the equipment is mechanically circulated and supplied to the sliding surface of a bearing.

As the tank attached to the equipment has a small capacity, the cooling effect is limited. However, it has the benefit that it limits foreign matters from entering the equipment.

#### 6.4 Immersed in water

The sliding surface of the bearing is immersed in the surrounding water such as seawater and river water without the use of force-feed means.

This method is suitable when a large amount of water exists around the equipment.

It is recommended to use a filter or a centrifugal separator in order to remove foreign matter from water supplied to the sliding surface.

## 7 Design considerations

### 7.1 General

The selection of material for water-lubricated plain bearings should take into account the operating conditions of the equipment and the water supply method.

### 7.2 Water temperature

The quantity of force-feed lubricating water shall be controlled on the basis of the temperature of the water discharged. That is, if the temperature is higher than a predetermined temperature, the amount of water is increased. For example, the temperature is controlled to be 60 °C or less.

If the ambient temperature of the equipment is expected to be low, the lubricating water shall be warmed in order to prevent freezing.

### 7.3 Removal of foreign matters

#### 7.3.1 General

The most important thing to be considered when supplying lubricating water to water-lubricated bearings is the presence of foreign matters. Foreign matters affecting water-lubricated bearings are mainly hard matters such as sand, mud, metal rust, barnacles and shells, but soft matters such as algae and other aquatic plants and sludge can also affect them.

When hard foreign matter enters with the lubricating water, it rolls through the gap between the shaft and bearing, causing abrasive wear on the bearing. If hard foreign matter is inlaid on the bearing surface, it causes wear on the shaft and as a result, wear debris from the shaft, as well as hard matters, can scrape the bearing and then inlaid on the bearing surface, causing increased wear on both the bearing and shaft, resulting in major damage.

Aquatic plants and sludge do not directly wear the shaft or bearing, but they can interfere with normal fluid lubrication and increase the friction surface temperature, causing bearing damage.

#### 7.3.2 Methods of removing foreign matters

##### 7.3.2.1 General

The removal of foreign matters from different sources of lubricating water is described below, and an outline of basic countermeasures for some problems including foreign matters is given in [Annex B](#).

##### 7.3.2.2 When pure water or tap water is used

In principle, no countermeasures are required.

However, when a steel pipe is used, rust particles can be formed, therefore, it is recommended to use a filter.

##### 7.3.2.3 When lake or river water is used

Filter or centrifugal separator shall be used in order to remove foreign matters.

##### 7.3.2.4 When seawater is used

Filter or centrifugal separator shall be used in order to remove foreign matters.

##### 7.3.2.5 When water storage tank is attached to the equipment

Control that algae does not grow on the inside of the storage tank, and install a filter at the inlet.

## 7.4 Operating conditions

The selection of material for water-lubricated plain bearings shall take into account the characteristics of the bearing material, the usage conditions of the equipment, the structure of the equipment and the water quality.

- a) When used under frequent start and stop conditions or under boundary lubricating conditions, the lubricating water film can be easily broken. Therefore, self-lubricating materials shall be selected.
- b) In vertical shaft axial flow pump, the lower-side bearing is constantly immersed in water and the intermediate bearing (the bearing located in the centre of the large vertical pump) is under non-lubrication conditions until water is introduced after start. Therefore, rubber bearings shall be used for the lower-side bearing and self-lubricating bearings shall be used for the intermediate bearing.
- c) When used in seawater, galvanic corrosion can occur in some combinations of bearing and shaft (including sleeve) materials. Therefore, the combination of materials that causes galvanic corrosion shall not be used. Shafts made of general steel that have not been treated for corrosion resistance shall not be used either, because they will corrode in seawater.
- d) When used under partial loading conditions or under impact loading conditions, rubber bearings or plastic bearings shall be selected.
- e) Ceramic bearings are easily broken by extreme partial contact or impact load. Therefore, when the bearing is used under such conditions, the outside of the bearing shall either be spherically shaped or wrapped with a rubber bush in order to reduce the effects of the partial contact and impact load.

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## Annex A (informative)

# Characteristics, applications, manufacturing methods and compatible combinations

### A.1 Characteristics and principal applications

[Table A.1](#) gives an outline of the characteristics and applications of water-lubricated bearings made of various materials.

**Table A.1 — Characteristics and principal applications of water-lubricated plain bearings**

Base material	Characteristics	Principal applications
Wood	Can be used under boundary lubrication conditions as well as fluid-film lubrication conditions because of its self-lubricating properties. Ordinarily used under relatively light load conditions.	Principal applications include bearings for the stern tubes of small ships and for simple water pumps.
Carbon	Can be used under boundary lubrication conditions as well as fluid-film lubrication conditions because of its self-lubricating properties and hydrophilicity. Ordinarily used under relatively light load conditions. Careful handling is required because of the brittle fracture. It can cause galvanic corrosion and is not used in seawater.	Principal applications include bearings for water pumps, chemical pumps, agitators, and electric water pumps for automobiles.
Rubber	Requires water lubrication at all times. Elastic deformation of the bearing contributes to hard foreign material resistance. Used under light load conditions. They have vibration absorption capacity.	Principal applications include bearings for the stern tubes for vessels, rudder, water pumps, and under seawater excavators (dresser cutter).
Thermosetting resin	Can be used under boundary lubrication conditions as well as fluid-film lubrication conditions because of its self-lubricating properties and hydrophilicity. Excellent impact load resistance. Used under light to heavy load conditions.	Principal applications include bearings for hydroelectric generator turbines, water treatment equipment, valves for water supply, roll mill for steel making plants, and water pumps.
Fluoro resin	It is not hydrophilic but has excellent self-lubricating properties. Used under light load to medium load conditions.	Principal applications include bearings for water pumps and hydroelectric generator turbines.

Table A.1 (continued)

Base material	Characteristics	Principal applications
Thermoplastic resin	Can be used under boundary lubrication conditions as well as fluid-film lubrication conditions because of its self-lubricating properties. Used under light load conditions.	Principal applications include bearings for water pumps, electric water pumps for automobiles, and vane pumps.
Ceramic	Can be used under boundary lubrication conditions as well as fluid-film lubrication conditions. Used under light load conditions. Due to brittle fracture properties, care should be taken in handling. Excellent abrasive wear resistance and corrosion resistance.	Principal applications include bearings for water pumps, hydraulic cylinders, and screw compressors.
Cermet	Can be used under boundary lubrication conditions as well as fluid-film lubrication conditions. Used under light loads. Excellent abrasive wear resistance. WC alloy cermet sometimes creates galvanic corrosion in the seawater.	Principal applications include bearings for water pumps.

## A.2 Compatible combinations

Table A.2 gives an outline of compatible combinations of water-lubricated bearing base materials and shaft materials.

Table A.2 — Compatible combination of bearing base material and shaft material

Base material	Shaft material				
	Bronze sleeved steel	Stainless steel	Hard chromium plated steel	Ceramic	Cermet
Wood	X <sup>a</sup>	X			
Carbon		X	X	X	X
Rubber	X	X	X	X	X
Thermosetting resin	X	X	X	X	X
Fluoro resin		X	X	X	X
Thermoplastic resin		X	X	X	X
Ceramic		X	X	X	X
Cermet		X	X	X	X

<sup>a</sup> Compatible combinations of bearing base materials and shaft materials are shown with "X".

## A.3 Manufacturing methods of water-lubricated bearings and their dimensions

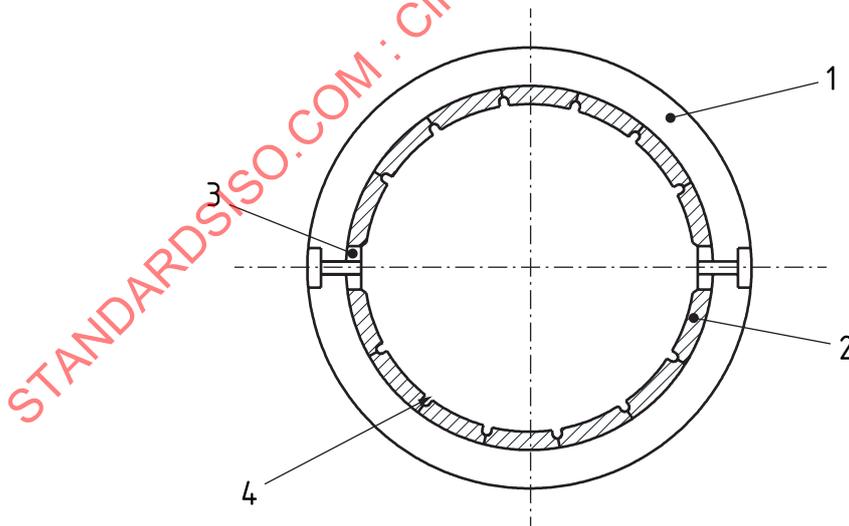
Table A.3 gives an outline of the manufacturing methods of water-lubricated bearings and their dimensional characteristics.

Table A.3 — Manufacturing methods of water-lubricated plain bearings and their dimensions

Base material	Manufacturing method	Dimensions
Wood	<p>Since raw materials are grown in a natural environment, production and supply are unstable.</p> <p>The properties change depending on how the wood is cut, including position and direction of the cut, due to the influence of annual rings, etc.</p> <p>For large products, multiple plates are glued together or bolted together to assemble into a barrel shape (see <a href="#">Figure A.1</a>).</p> <p>Woods other than lignum vitae are usually impregnated with wax in order to improve lubricity.</p>	<p>Bearings ranging from small to large sizes can be manufactured.</p> <p>The dimensional stability of the bearing is low due to water absorption and dehydration.</p>
Carbon	<p>Block pieces are produced by sintering at a high temperature in an electric furnace and bearings are produced by machining the block piece to a predetermined shape.</p> <p>The bearing produced is porous, so it can be impregnated with resin or a low melting point metal. In the case of resin impregnation, the carbon product is immersed in a resin solution to impregnate the resin to the carbon product, and then it is heated to cure the resin. In the case of metal impregnation, the carbon product is immersed in the molten metal.</p>	<p>Bearings ranging from small to medium sizes can be manufactured.</p> <p>Bearings have high dimensional accuracy and dimensional stability.</p>
Rubber	<p>A small sized bearing is produced by compression moulding.</p> <p>Large sized bearings can be produced by the following means:</p> <p>a) By vulcanizing and bonding rubber with several grooves on its bore to the inner surface of a cylindrical shell made of cast bronze, high strength cast brass, fibre reinforced thermosetting resin, etc. (full-mould type, see <a href="#">Figure A.2 a</a>);</p> <p>b) By consisting of a cylindrical shell with dovetail grooves on its bore and segments, each comprising a metal plate on which rubber is vulcanized and bonded in advance and assembling to the dovetail groove (segmental type, see <a href="#">Figure A.2 b</a>).</p>	<p>Bearings ranging from small to large sizes can be manufactured.</p> <p>Bearings have low dimensional accuracy due to the elastic deformation of bearing.</p>
Thermosetting resin	<p>Small sized bearings can be produced by compression moulding or injection moulding, so they are able to be mass-produced.</p> <p>Large sized bearings are manufactured by combining compression-moulded members in a barrel shape.</p> <p>Cylindrical-type bearings are manufactured, for example, by a rolled forming method. This method involves winding a prepreg consisting of a cloth impregnated with thermosetting resin composition around a core die under heating and pressurizing (see <a href="#">Figure A.3</a>).</p> <p>Cotton chips or a cotton cloth are used as a reinforcing material to improve the mechanical strength of the bearing.</p> <p>In order to improve lubricity, either graphite or PTFE are mixed with a resin solution in advance and moulding is performed.</p>	<p>Bearings ranging from small to large sizes can be manufactured.</p> <p>Deformation due to water absorption and dehydration of the resin and cotton cloth can occur, so the dimensional stability of the bearing is slightly inferior.</p> <p>Deformation can be reduced by using a two-layer laminated structure comprising an inner sliding surface layer with cotton cloth and an outer backing layer with glass cloth (see <a href="#">Figure A.3</a>).</p>

Table A.3 (continued)

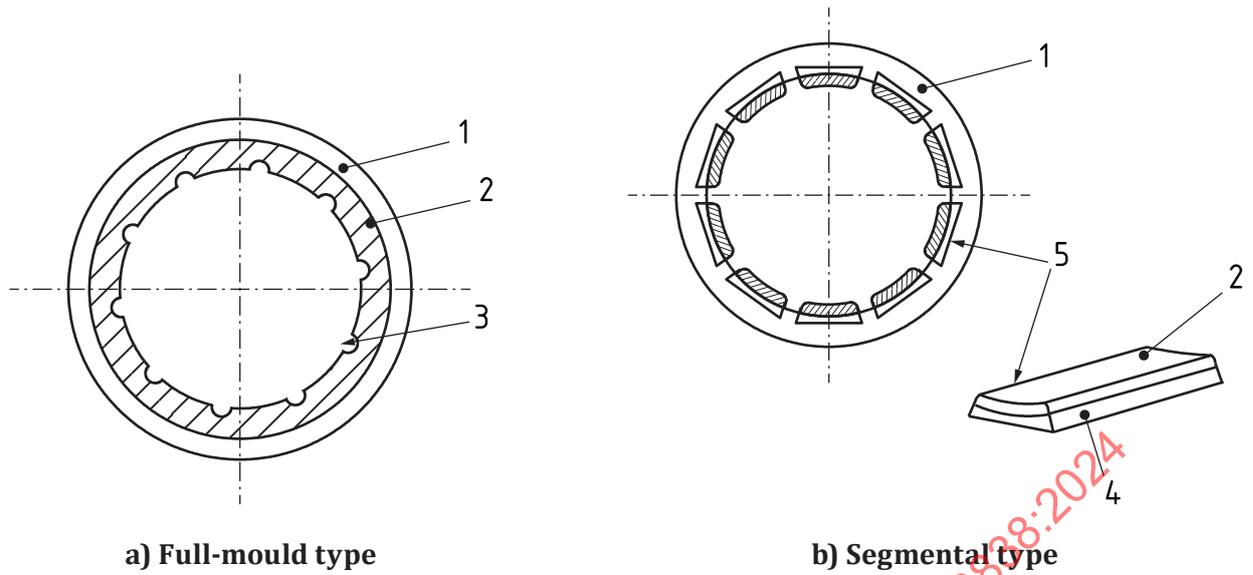
Base material	Manufacturing method	Dimensions
Fluoro resin	<p>Small sized bearings can be produced by compression moulding, so they are able to be mass-produced.</p> <p>In order to improve wear resistance, glass fibre or carbon fibre are mixed in advance and moulding is performed.</p> <p>Dimensional stability and load bearing capacity can be improved by bonding a thin fluoro resin sheet to a metal substrate (see <a href="#">Figure A.4</a>). From the point of view of corrosion resistance, stainless steel is mainly used as a metal substrate.</p>	<p>Bearings ranging from small to large sizes can be manufactured.</p> <p>Since the thermal expansion coefficient is large, the dimensional stability of these bearings is slightly inferior.</p> <p>The dimensional stability can be improved by compounding with fibres such as glass, carbon and ceramic or metal powders such as bronze.</p> <p>The dimensional stability and mechanical strength can be improved by bonding thin fluoro-resin layer to a metal plate.</p>
Thermoplastic resin	<p>Bearings can be produced by injection moulding, so they are able to be mass-produced.</p> <p>Fillers are kneaded into base resin during the manufacture of resin pellets for injection moulding.</p>	<p>Production is limited to small sized bearings, but complex shapes can be easily produced.</p> <p>The dimensional stability of bearings is slightly inferior for materials with a large thermal expansion coefficient.</p>
Ceramic	<p>The powder sintering method is used for ceramic bearings.</p> <p>In order to prevent impact load and partial contact, a rubber bush can be joined to the outer circumference of the bearing [see <a href="#">Figure A.5 a</a>] or a spherical seat can be provided [see <a href="#">Figure A.5 b</a>].</p>	<p>Bearings ranging from small to large sizes can be manufactured.</p> <p>The dimensional stability of the bearing is excellent because of its small thermal expansion coefficient.</p>
Cermet	<p>The powder sintering method is used for cermet bearings.</p> <p>The thermal spraying coating method is also used.</p>	<p>Bearings ranging from small to large sizes can be manufactured.</p> <p>The dimensional stability of the bearing is excellent because of its small thermal expansion coefficient.</p>



Key

- 1 shell
- 2 wood plate
- 3 clasp
- 4 groove

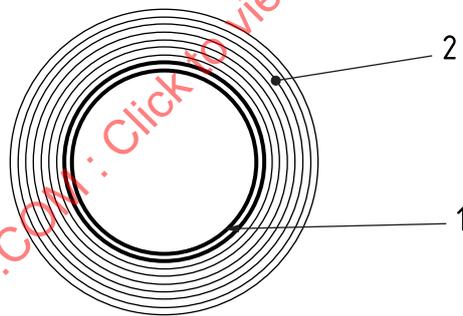
Figure A.1 — Bearing of wood-based material



**Key**

- 1 shell
- 2 rubber
- 3 groove
- 4 metal plate
- 5 segment

**Figure A.2 — Bearing of rubber-based material**



**Key**

- 1 inner sliding surface layer
- 2 outer backing layer

**Figure A.3 — Bearing of thermosetting resin-based material (two-layer laminated type)**