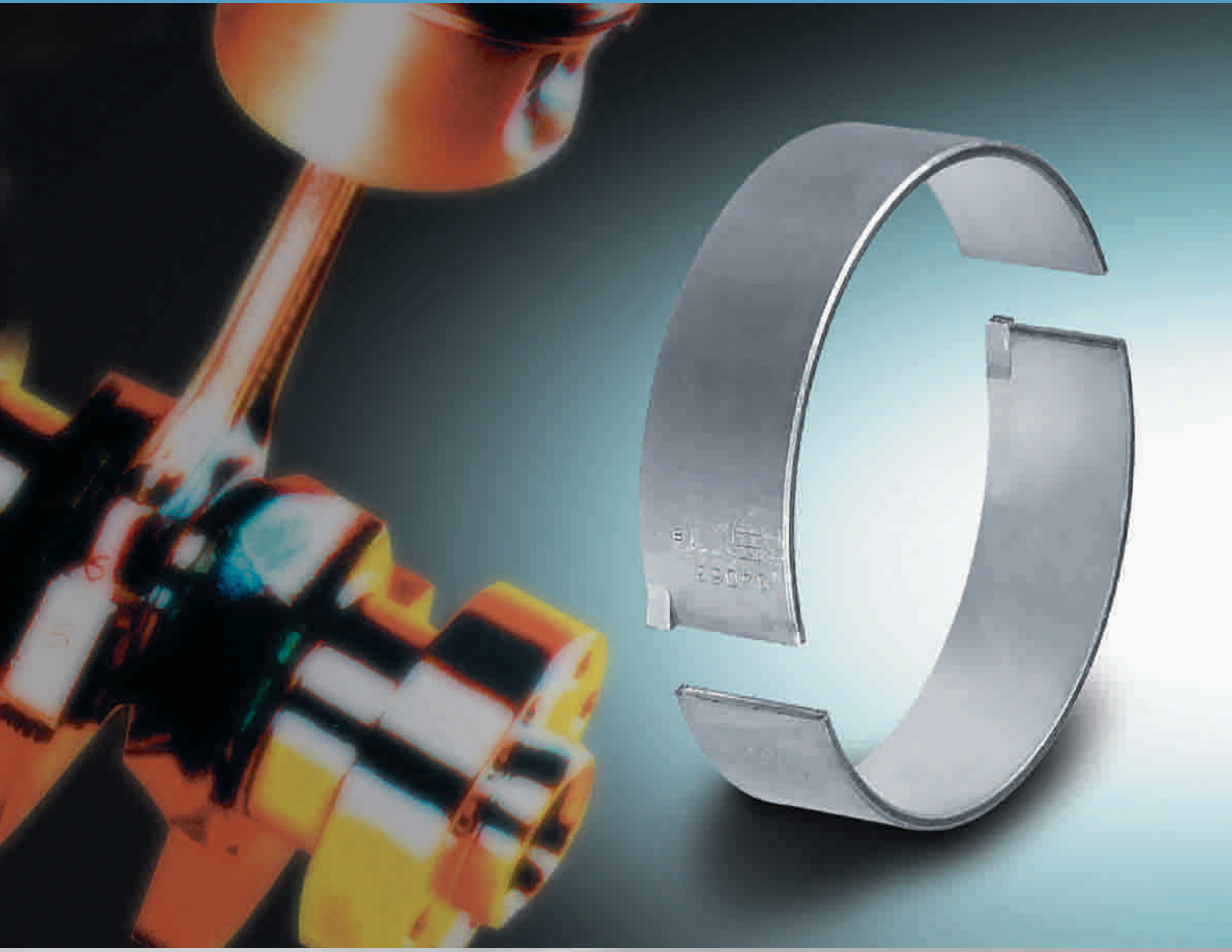
PVD-COATED HIGH-PERFORMANCE BEARINGS



GLEITLAGER

Three-Metal Bearings reached their limits

Three-metal plain bearings have been used successfully for decades as plain bearing materials for applications in engines. They consist of a steel back with a cast or sintered lead bronze layer and an electroplated lead-tin-copper sliding layer. These bearings are distinguished by their high loading capacity and good tribological properties. In the course of the ongoing further development of engines to enhance performance and reduce fuel consumption still further, the loads in diesel engines in particular have increased so much that three-metal bearings have reached their limits as con rod bearings, Figure 2. The galvanic sliding layer shows signs of fatigue in the form of hen track patterns and erosion.

It therefore became necessary to develop a new material to withstand higher loading combined with similarly good tribological properties such as resistance to wear and emergency running properties. In the development of plain bearing materials we exploit the fact that a bearing material's loading capacity depends on the thickness of the bearing material. The thinner a layer is, the greater its loading capacity will be. On the known three-metal bearings, an approximately 20 µm thick lead-tin-copper layer with outstanding tribological properties is electroplated onto the lead bronze bearing metal. This composite material withstands loading of up to 65 MPa, while comparable bearing metal composites with a 400 µm thick sliding layer will only withstand loading up to 30 MPa.

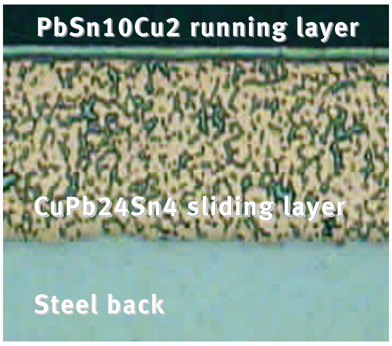


Fig. 1: Three-metal bearing KS S43G with sintered sliding layer

Bearing Material AlSn20Cu

The bearing metal AlSn20Cu, which has also been in successful use for years, was therefore the obvious choice. It is distinguished by a loading capacity superior to that of bearing metals combined with similarly good tribological properties.

However, we were still left with the problem of coating a half bearing with the demanded precision. With the known methods for the production of composites, e.g. casting, sintering, rolling and electroplating, it was not possible to apply an AlSn20Cu layer to the half bearings. A totally new coating process – PVD coating – had to be developed.

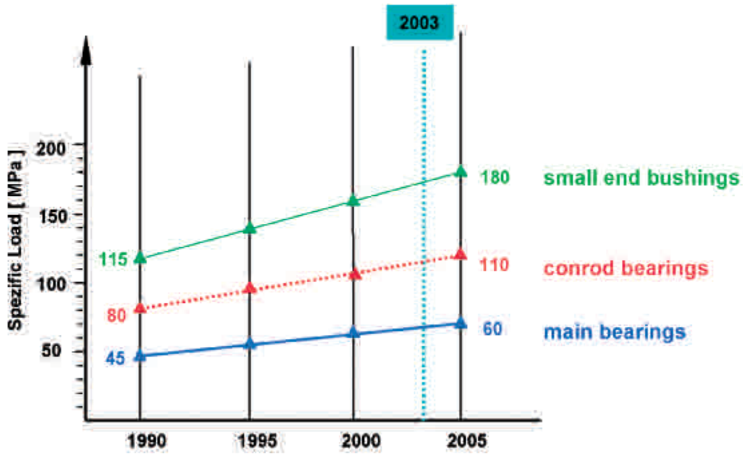


Fig. 2: Development trend in plain bearings in engines

PVD Coating

At KS Gleitlager the development of such coating methods started at the beginning of the 1980s in close cooperation with the metal laboratory of Metallgesellschaft (the Group's parent company at that time) and Balzers in Liechtenstein. The still valid patents for the PVD coating of half bearings that KS Gleitlager holds today date back to this period. The following table lists chronologically the milestones in our development work:

1983	Start of development work together with the Metallgesellschaft metal laboratory and Balzers, Liechtenstein.
1988	First samples supplied to customer
1989	First supply of series components (VW Corrado)
1994	First supply of series components for highly-charged turbo diesel engines (VW)
1995	Series supplier to Audi
1996	Series supplier to Daimler Chrysler
1998	Installation of a coating unit at the Papenburg site (HGL unit 1 / multi-chamber unit with round target)
2001	Installation of a second coating unit at the Papenburg site (HGL unit 2 / single chamber unit with turntable)
2003	Approval for series production at BMW.

Principle of PVD Coating

During PVD (Physical Vapour Deposition) coating atoms are ejected (or sputtered) from a target (coating material) by accelerated argon ions in a high vacuum. The atoms are then deposited on the workpiece (half bearing).

Unlike electroplating, in which a voltage is applied between the anode and the half bearing acting as the cathode, thus facilitating a uniform deposition of metal ions over the entire surface of the half bearing, the atoms sputtered from the target cannot be “controlled”. Statistically speaking they leave the target in a cos (φ) function.

This is of considerable importance when one considers that half bearings with a semicircular surface have to be coated. Figure 3.
The surface being coated has to be exceptionally clean. Only the very slightest contamination of the surface would cause local bonding problems and hence failure of the half bearing. For technical reasons, it has proven necessary to clean and activate the half bearings within the unit before coating. For this purpose the sputtering process is reversed, with the half bearings serving as the target. From the surface of the bearing metal, the uppermost layers of atoms are removed to leave a clean and reactive metal surface ready for coating. In order to ensure that the aluminium, tin and copper atoms can be ejected simultaneously from the aluminium-tin-copper target by the argon ions, the latter have to have a certain energy distribution. The energy depends on the applied voltage and the distance covered by the argon atoms. This is in turn dependent on the distance between the plasma source and the target and the existing volume of gas.
It is equally important for the heat generated by the impact of the aluminium, tin and copper atoms to be discharged in a controlled manner. To this end the half bearings are placed in coolable mountings. Heat management has a highly decisive influence on the formation of the sputtered layer. If the coating temperature is too low, the layer is very hard and brittle; if the coating temperature is too high, the layer is soft. In extreme cases low-melting tin can even melt.

Coating Process
Coating takes place in several stages. First of all, the half bearings are placed in their holder (mounting). The mounting containing the half bearings is then placed in the unit, the air is evacuated from the unit and the unit is flushed with argon. In the next step, the half bearings are cleaned. To this end, as explained above, the sputter process is reversed. The argon ions clean the surface of the half bearings, removing oxides and contaminants. After cleaning, the barrier layer is applied. This consists of pure nickel or nickel-chrome or nickel-copper alloys. After this, the sliding layer of AlSn20Cu is deposited. When air has been re-admitted to the unit, the mountings can be removed and the half bearings taken out.

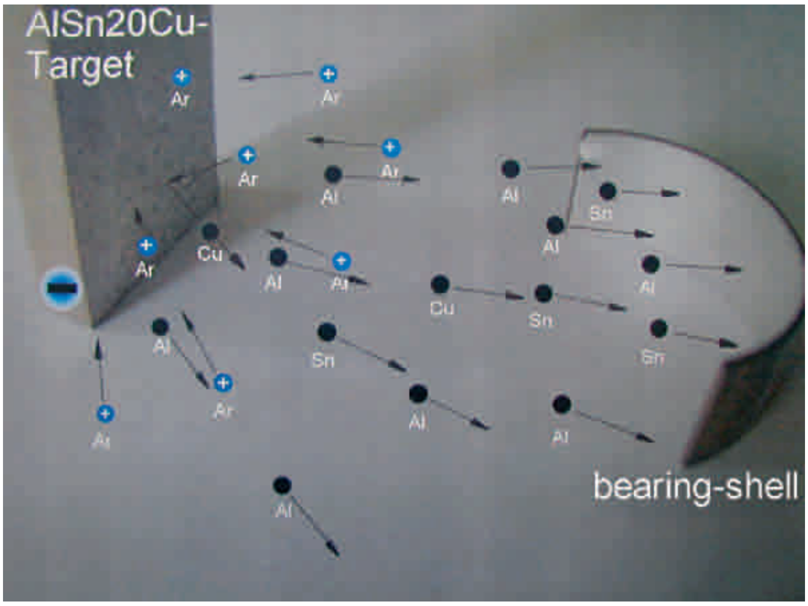


Fig. 3: Principle of PVD coating

PVD Concepts
For the commercial-scale coating of half bearings, three PVD unit concepts are employed today, differing in their design and the arrangement of the half bearings. In multi-chamber units the individual steps – evacuation, cleaning, application of the barrier layer, coating and admission of air – take place in separate chambers, while in single-chamber units the entire process takes place in just one chamber.

a) Figure 4 shows a multi-chamber unit with a flat target (type A). The entire unit consists of an air lock chamber, cleaning chamber, coating chamber for the barrier layer, one or more coating chambers for the running layer and another air lock chamber. Plate-like targets are used for coating.

b) Figure 5 shows a multi-chamber unit with a round target (type B). The entire unit consists of an air lock chamber, cleaning chamber, coating chamber for the barrier layer, one or more coating chambers for the running layer and another air lock chamber. The half bearings are arranged in a star-like pattern around the round target.

c) Figure 6 shows a single-chamber unit with a turntable.
The entire unit consists of a single chamber in which all the process steps take place. In this unit type a turntable is loaded with half bearings and the plate-like targets are arranged around the turntable.

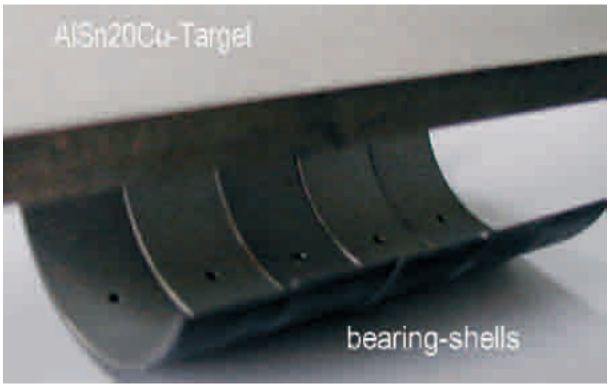


Fig. 4: Half bearing/target arrangement

Two of these unit concepts are employed today at KS Gleitlager GmbH for the coating of half bearings on the commercial scale – the multi-chamber unit with a round target and the single-chamber unit.

The following cross section, figures 7 and 8, shows the layers of a high-performance plain bearing. The AlSn20Cu layer has a very fine and uniform distribution of tin.

Applications

On direct-injection diesel engines, the con rod half bearings on the rod side are exposed to extremely high ignition pressures. Specific loads of over 100 MPa occur today. This is the typical field of application for high-performance plain bearings. In the cup half bearings exposed to lower loads, three-metal half bearings are still employed today. In order to meet the demand for lead-free materials under the EU Directive on End-of-Life vehicles the three-metal half bearings in many engines are being replaced with lead-free aluminium-tin-copper bearing metals.

Figure 9 shows con rod bearings after 500h endurance test. In the cup side, bimetal bearings KS R30 (steel back with roll bonded AlSn15Cu2 sliding layer) and trimetal bearings KS S43G (steel back with CuPb24Sn4 sliding layer and PbSn10Cu2 running layer) are mounted alternately.

In the rod side, high performance bearings (KS S30S) are mounted, in the cup side bearings 1 and 3 are bimetal bearings (KS R30) and the bearings 2 and 4 are three-metal bearings (KS S43G).

Fig. 5: Half bearing/target arrangement (multi-chamber unit, type B)

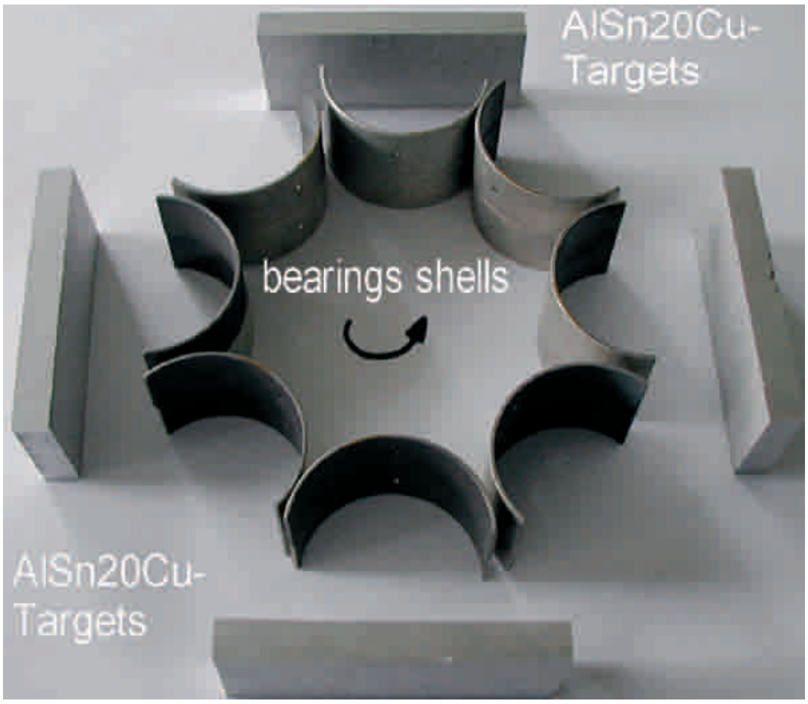


Fig. 6: Single chamber unit with a turntable

Literature:
(1) H. Pfestorf, F. Weiss, K.H. Matucha, P. Wincierz: Bearing Materials in Ullmann's Encyc-lopedia of Industrial Chemestry, VCH, Weinheim 1985
(2) K.H. Matucha, H. Pfestorf, F. Weiss: Gleitlagerwerkstoffe in: O. Asbeck, K.H. Matucha Beiträge zur Metallkunde, DGM Informationsgesellschaft Oberursel 1989
(3) M. Müller: Moderne Motoren benötigen Gleitlager aus modernen Werkstoffen in: Werkstoffe im Automobilbau 97/98, Sonderausgabe von ATZ und MTZ.
(4) K. Deicke, Dr. K.-H. Matucha, Dr. T. Steffens, W. Schubert: KS R41B, ein Stahl-Aluminium-Verbundwerkstoff für hohe Belastungen in: MTZ 7-8/2002

High-performance bearing KS S30S

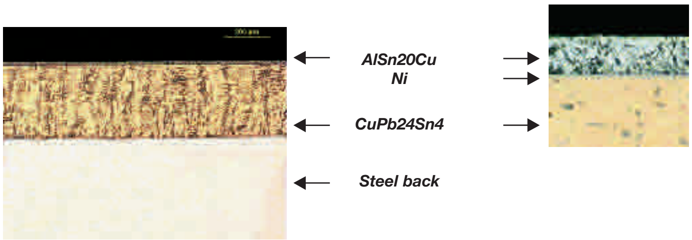


Fig. 7: overview

Fig. 8: detail

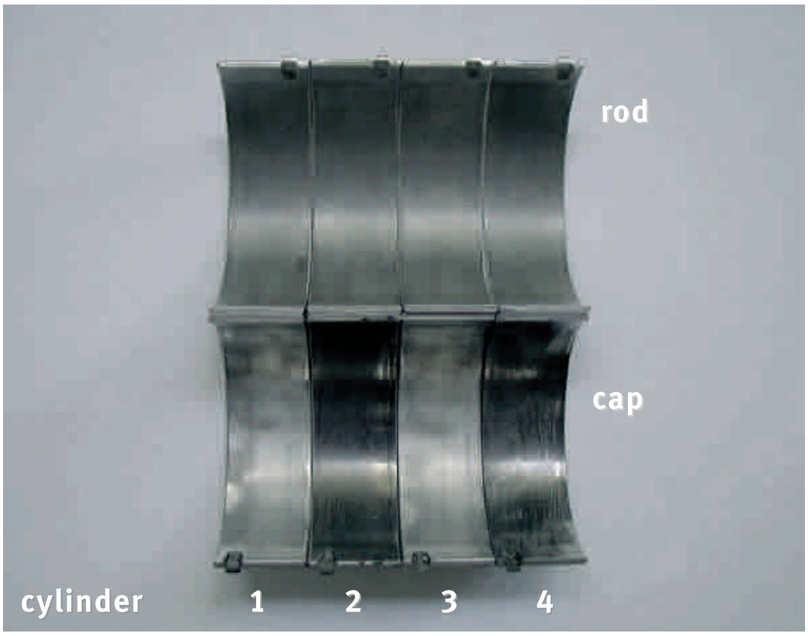


Bild 9: Bearing after test

GLEITLAGER

St. Leon-Rot, Germany

KS Gleitlager GmbH
St. Leon-Rot
Am Bahnhof 14
D-68789 St. Leon-Rot
Phone +49 (0) 62 27-56-0
Fax +49 (0) 62 27-56-3 02

www.kolbenschmidt-pierburg.com

Papenburg, Germany

KS Gleitlager GmbH
Papenburg
Von Arenberg Str. 5
26871 Papenburg
Phone +49 (0) 4961 986-0
Fax +49 (0) 4961 986-103

Fountain Inn, USA

KS Bearings, Inc.
5 Southchase Court
Fountain Inn, SC 29644-9018
USA
Phone +1 864 688 1400
Fax +1 864 688 1401

1515 West Main Street
Greensburg, IN 47240
USA
Phone +1 812 663 3401
Fax +1 812 663 1637

Nova Odessa, Brazil

KS Bronzinas Ltda.
Rodovia Arnaldo Julio
Mauerberg, nº 3920
Distrito Industrial nº 01
Nova Odessa - SP 13460 - Brazil
Phone +55 (0) 193 466 9849
Fax +55 (0) 193 466 9833

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Kolbenschmidt Pierburg AG

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