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GREASE-LUBRICATED SLIDING GUIDING MEMBERS HAVING A LOW
COEFFICIENT OF FRICTION AND AN IMPROVED LIFETIME

5 The present invention relates to greased mechanical components. More specifically, the invention relates to greased mechanical components which provide, by sliding friction, a translational or rotational guiding function, in continuous or reciprocating motion, and are designed to effectively meet the concerns of many industrial
10 sectors with regard to simplifying the lubrication and reducing the frequency of maintenance.

Grease-lubricated devices are known in which, by virtue of suitable sealing means, it is possible to make two mechanical parts rub against each other, even when
15 they are subjected to very high loading stresses, with a very low coefficient of friction: examples of such are given in the article "Theory and industrial practice of friction" by JJ. CAUBET, Editor Dunod Technip, 1964, Chapter 13.

20 FR 910,999 of 2 October 1962, completed by its Certificate of Addition FR 921,708 of 17 January 1963, describes an embodiment of such a device in the case of self-aligning bearings for high loads.

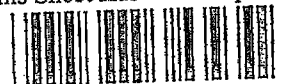
Such devices, the technical effectiveness of which
25 is recognized, do have, however, a major drawback associated with the complexity of their practical construction, which leads to high implementation costs incompatible with the current requirements of most industrial sectors in question.

30 One object of the present invention is therefore to provide a guiding device for mechanical members which makes it possible to dispense with the use of a sealing system.

Another object of the invention is to propose such
35 a device which is effective and inexpensive in the field

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in question.

Further objects and advantages of the invention will appear on reading the description below.

The invention proposes a guiding device for
5 mechanical members which consists of two parts intended
to interact by sliding friction, one of the two parts,
called the smooth part, having a smooth, functional, that
is to say friction, surface and the other part, called
the pierced part, having at least one functional, that is
10 to say friction, surface, which includes emergent
cavities intended to accommodate a grease of the
lubricating-paste type and especially an EP grease
(extreme-pressure grease) comprising a soap-type
constituent, an oil-type constituent and an extreme-
15 pressure additive, characterized in that the contact
angle between said functional surface of said smooth part
and said grease, measured at a temperature called the
measurement temperature, which is $15^{\circ} \pm 5^{\circ}\text{C}$ below the
temperature at which the onset of separation between said
20 soap-type constituent and said oil-type constituent
occurs and/or the onset of evaporation of said oil-type
constituent occurs, is between 20 and 40 degrees and in
that the material of said pierced part is chosen in such
a way that the contact angle, measured at said
25 measurement temperature, between said functional surface
of the pierced part and said grease is between 45 and 75
degrees.

The term "EP grease", denoting an extreme-pressure
grease, is well known to those skilled in the art. The
30 expression "extreme-pressure grease" should be understood
to mean a grease capable of withstanding a high load
without damage. Examples of such greases are lithium
greases of the SNR-LUB EP Class NLGI 2 type, or those of
the KLÜBER CENTOPLEX GLP 402 NLGI 2 type, or else lithium
35 greases and solid lubricants of the KLÜBER COSTRAC GL

1501 MG NLGI 2 type.

It should be noted that both the smooth part and the pierced part may each have a non-functional surface, but this is not obligatory.

5 The two parts - the smooth part and the pierced part - are intended to interact by sliding friction, translationally or rotationally, in continuous or reciprocating motion.

10 The shape of each of the two parts may be plane, cylindrical or spherical.

Although it is commonly employed by those skilled in the art, the concept of the contact angle of a drop of a liquid or viscous product placed on a solid surface is not the subject of standardization, nor even of a
15 completely standardized method of measurement, most particularly when said product is a grease.

The experimental conditions under which the contact angle is measured are therefore given below.

20 Measurement of the contact angle according to the invention:

Firstly, the surface of the solid body on which it is desired to perform the measurement is cleaned and then a straight bead of grease is deposited thereon. Next, the part is heated until the temperature of its face in
25 contact with the bead of grease reaches a value of $20 \pm 5^{\circ}\text{C}$ greater than the limit use temperature of the grease. It is maintained at this temperature for the time needed for the grease to become sufficiently liquid to start to spread out over the surface (approximately 90 seconds).
30 Heating of the part is then stopped and it is left to cool. This has the effect of freezing the shape of the drop and allows measurement of its contact angle at room temperature.

35 Suitable materials for forming the smooth part according to the invention are especially chosen from

among steels, for example case-hardened, quench-hardened and ground steels, ground HF quench-hardened steels, steels that are hardened and then coated with hard chromium, nitrided steels and carbonitrided steels, chromium and nickel, as well as from among ceramic-coated steels.

It is necessary each time to measure the contact angle between the grease and the material that is to form the smooth part, which angle must be between 20 and 40 degrees, in order to determine whether this material is really appropriate according to the invention.

The material of which the pierced part is made may be a bulk material. This will usually be chosen from among polymer materials and copolymer materials. However, it cannot be excluded that other bodies could be suitable as long as their contact angle with the grease satisfies the specified conditions.

Suitable materials for making the pierced part according to the invention are especially chosen from among polyimides, filled polyimides, for example graphite-filled polyimides, epoxy resins, filled epoxy resins, such as epoxy resins filled with molybdenum disulphide MoS_2 , polyacetal resins, polyethylene, substituted or unsubstituted fluorocarbons, and especially PFA (perfluoroalkoxy), polyethylene terephthalate, polyethersulphone, polyamides and polyetheretherketone.

It is also necessary each time to measure the contact angle between the grease and the material that is to form the pierced part, which angle must be between 45 and 75 degrees, in order to determine whether this material is really appropriate according to the invention.

The material of which the pierced part is made may also be a substrate covered with a coating. The coating

is usually deposited as a thin film, generally having a thickness of approximately 5 to approximately 50 μm .

In this case, the substrate is any material, in bulk form or in the form of a thin rolled sheet, for example a plain carbon steel, an alloy steel, a stainless steel, an aluminium alloy, a copper alloy, a titanium alloy, etc.

The thin rolled sheet is advantageously produced in accordance with the Applicant's Patent FR-B-2,693,520.

10 When the material of which the pierced part is made is a substrate covered with a coating, it is advantageously a steel which is prenitrided and then covered with a polymer.

The material of which the coating is made is then
15 chosen from among polymer materials and copolymer materials, especially from among polyimides, filled polyimides, for example graphite-filled polyimides, epoxy resins, filled epoxy resins, such as epoxy resins filled with molybdenum disulphide MoS_2 , polyacetal resins,
20 polyethylene, substituted or unsubstituted fluorocarbons, and especially PFA (perfluoroalkoxy), fluoroethylene or fluoropropylene, polyethylene terephthalate, polyethersulphone, polyamides and polyetheretherketone.

When the material of which the pierced part is made
25 is a substrate covered with a coating, it is advantageously a steel that has been subjected beforehand to a surface hardening treatment. This surface hardening treatment may be a thermochemical treatment causing a heteroelement, for example nitrogen, to diffuse into the
30 steel. Said thermochemical treatment is preferably a nitriding treatment in a molten bath of alkali metal cyanates and carbonates and furthermore advantageously containing an amount of at least one sulphur species, for example according to the Applicant's FR-B-2,708,623.

35 In one particularly advantageous embodiment of the

invention, the pierced part is made in the form of a thin rolled sheet, in accordance with the aforementioned FR-B-2,693,520, made of nitrided steel according to the aforementioned FR-B-2,708,623 and coated with a polymer.

5 In this case too, it will be necessary to check that the contact angle of the material of the coating of the pierced part with the grease is between 45 and 75 degrees in order to determine whether this coating is really appropriate according to the invention.

10 According to a preferred embodiment of the invention, the cavities, forming "support pads", are distributed over practically the entire surface of the pierced part.

15 It is then advantageous for at least three cavities to contribute to supporting a load applied to the two parts.

20 It is then also advantageous for the area occupied by the cavities on the development of the functional surface of the pierced part to represent between approximately 20 and approximately 40% of the total area of said development.

 The cavities may or may not be more or less the same as each other.

25 The cavities may or may not be distributed more or less regularly over the entire surface of the pierced part.

30 If the cavities are not more or less the same as each other and/or are distributed more or less irregularly over the entire surface of the pierced part, the shortest distance between the edges of two juxtaposed cavities will advantageously be greater than approximately 2 mm.

35 The emergent surface of each cavity usually has an area of between approximately 3 mm² and approximately 40 mm², advantageously between approximately 10 mm² and

approximately 30 mm².

According to an advantageous arrangement of the invention, the cavities emerging on the functional surface of the pierced part do not communicate with each other on the side containing said functional surface of
5 said pierced part.

The cavities may or may not communicate on the side containing a non-functional surface of the pierced part. If the cavities communicate on the side containing a non-
10 functional surface of the pierced part, for example via a system of channels, a cover will advantageously cover the cavities.

In the context of the present invention, when cavities are referred to as communicating with each other, it should be understood to mean that said cavities
15 are "connected via channels (ducts) intentionally created on the surface by the removal of material".

The cavities may, for example, be cylindrical.

The smooth part and the pierced part may be plane,
20 cylindrical or spherical in shape.

The present invention makes it possible to obtain a shaft/bearing device in which the smooth part is the shaft and the pierced part is the bearing, a slideway/runner device in which the smooth part is the
25 slideway and the pierced part is the runner, or a ball/socket device in which the smooth part is the ball and the pierced part is the socket.

Apart from the guiding devices composed of two rubbing parts, the present invention makes it possible to
30 devise an arrangement in which there are three rubbing parts, and not two. For example, in the case of a pierced part in the form of a bushing, the two surfaces (the internal bore and the external cylinder) of the pierced bushing are then functional.

35 In this configuration, the pierced bushing becomes

"floating", its speed of rotation then being only a fraction of that of the shaft, depending on the coefficients of friction.

5 The advantage of such an arrangement is relatively limited in the case of an oscillating system of the articulation type since the sliding speeds involved are then relatively low, of the order of 0.2 m/s. On the other hand, it becomes much more important for guiding systems in continuous rotation, especially those in which
10 the sliding speeds reach high speeds of approximately 8 to 10 m/s, or even higher. A bushing according to the invention may then advantageously replace, for a lower cost, a guiding member of more complex design, for example a needle roller bearing.

15 The description will be more clearly understood with reference to the appended figures in which:

 - figure 1 illustrates schematically the basic principle of the prior art according to FR 910,999 and its Certificate of Addition FR 921,708;

20 - figures 2 to 5 illustrate schematically the measurement of the contact angle according to the invention;

 - figure 6 is a schematic sectional view of a guiding member of the slideway/runner type according to
25 the invention;

 - figure 7 is a bottom view of the runner in figure 6;

 - figure 8 shows schematically a guiding member variant of the slideway/runner type in figure 6;

30 - figure 9 shows schematically a guiding member according to the invention in the shaft/bearing configuration;

 - figure 10 shows schematically the bearing bush in figure 9;

35 - figure 11 shows schematically a device of the

ball-joint type according to the invention;

- figure 12 shows schematically a device of the runner/track type in which there is tilting of the runner;

5 - figure 13 shows schematically the support of the runner by three pads;

- figure 14 shows schematically a shaft/bearing configuration in which there are three rubbing parts, with two functional surfaces;

10 - figure 15 shows schematically a shaft/bearing configuration in continuous rotation with two rubbing parts, in which a facing is shrunk-fitted onto the shaft level with the functional surface of the pierced bearing (ring);

15 - figure 16 shows schematically an arrangement with three rubbing parts and with two functional surfaces, which is a variant of that in figure 15, with two bearing sleeves, one shrunk-fitted onto the shaft and the other fitted into the bore of a casing.

20 Figure 1 shows a runner 1, in this case made of steel, intended to rub on a track 2, also made of steel, against which it bears with a resultant force F . A circular groove has been formed in the lower face of the runner 1, into which space an O-ring seal 3 has been
25 fitted, the space E thus left inside the O-ring seal being filled with grease 4. Thus designed, the runner 1 becomes "floating", being supported by an actual "pad" of grease, thereby making it possible to obtain very low coefficients of friction, typically less than 0.01, even
30 under a high load and when moving slowly.

In this regard, it will be noted that a simplified arrangement of the runner 1 in figure 1 in which the O-ring seal 3 is omitted would not be suitable. This is because, under the effect of the load pressing 1 against
35 2, the grease would in fact be very rapidly expelled from

the contact region; the rubbing of 1 on 2 would then take place by metal on metal and seizing would inevitably occur in a very short space of time. On the other hand, this does not occur when the seal 3 is in place, as then
5 the grease 4 cannot escape since the bushing is impervious.

In order to measure the contact angle θ according to the invention, the procedure is firstly to correctly clean the surface 5 of the solid body on which it is
10 desired to make the measurement. Next, a straight bead of grease 6 approximately 2 mm in diameter is deposited, using a syringe, on that surface of the solid body on which it is desired to make the measurement (figure 2).

The part is then placed on a hot plate (not shown)
15 until the temperature of its face in contact with the bead of grease reaches a value of $20 \pm 5^\circ\text{C}$ greater than the limit use temperature of the grease. It is maintained at this temperature for approximately 90 seconds. The part is then removed from the hot plate and
20 left to cool, which has the effect of freezing the shape of the drop and thus allowing its contact angle to be measured at room temperature by means of a conventional device of the binocular-magnifier type fitted with a protractor. The direction of observation is indicated by
25 "DO". The results obtained are shown schematically in figures 3 (lateral cross-sectional view of the initial bead of grease 6 before heating), 4 and 5 which each show a lateral cross-sectional view of the bead of grease after heating and then cooling, respectively in the case
30 of a smooth part 5' and of a pierced part 5''. According to the invention, it is necessary to have $\theta = 20-40^\circ$ (6') in the case of a smooth part and $\theta = 45-75^\circ$ (6'') in the case of a pierced part.

In figure 6, showing a runner 8/slideway 11 device,
35 cavities 9 are made in the lower face 7 of the runner 8,

that is to say that face which is functional and which interacts with the slideway 11 in sliding friction.

Figure 7 shows the view from underneath the runner, that is to say its functional surface 7. The cavities in the runner are cylindrical and arranged regularly. They do not communicate with each other on the side containing this face 7.

The development of the rubbing surface here is the lower face 7 of the runner 8, the area of which is equal to the product $L \times \ell$, L and ℓ being respectively the length and width of the runner.

The area occupied by the cavities is equal to $n\pi\phi^2/4$ (n being the number of cavities) and d is the shortest distance separating the facing edges of two juxtaposed cavities.

According to the preferred arrangements of the invention, it is necessary to have:

$$n\pi\phi^2/4 = 20 \text{ to } 40\% (L \times \ell)$$

$$d > \text{approximately } 2 \text{ mm}$$

$$\text{approximately } 3 \text{ mm}^2 < n\pi\phi^2/4 < \text{approximately } 40 \text{ mm}^2.$$

In the arrangement shown in figures 6 and 7, the cavities do not emerge on the non-functional side 10 of the runner.

However, it is conceivable for this to be otherwise, that is to say for the holes no longer to be blind. It is then important to prevent, by a suitable means such as a cover 12 covering the cavities (figure 8), the grease which fills the cavities from being able to escape via the non-functional rear surface 10 of the runner.

In the arrangement shown in figure 7, the cavities do not communicate with each other on the side containing the face 10. Nevertheless, it is conceivable for them to be able to do so, for example via a system of suitable channels.

In the appended figures, the cavities have been shown in the form of cylindrical holes, these being the same as each other and arranged in a regular manner. However, this is not a necessary condition and they may
5 be arranged differently without these other arrangements thereby departing from the scope of the invention.

Figure 9 shows a guiding member according to the invention in the shaft 13/bearing or bearing bush 14 configuration. The cavities are made in the bearing bush
10 14 (figure 10). In this case, we should speak of the developed surface of the bearing bush 14, this being obtained by slitting the bushing in a direction parallel to its axis and then unrolling it until a rectangular sheet is obtained. All the considerations developed
15 previously with regard to the runner/slideway type device may then be transposed to the shaft/bearing system.

Figure 11 shows a device of the ball 15/socket 16 type, produced according to the invention, the cavities 9 being formed in the sockets, that is to say the concave
20 sliding parts.

Figure 12 repeats the runner and track of figure 1, but in a configuration in which the load F of the runner does not give a resultant passing through the centre of the O-ring seal 3. In this case, the runner 1 tilts,
25 leading to undesirable phenomena of bearing surfaces on sharp edges, which generate overstresses - resulting in premature deterioration of the surfaces in sliding contact. To avoid this, the runner 1 may be supported by at least three "pads" 17, the resultant of the load
30 pressing the runner onto the track then falling inside the support polygon thus defined (figure 13).

Figure 14 shows a guiding member according to the invention in a shaft/bearing configuration which is distinguished from that in figure 9 by the fact that
35 there are three rubbing parts: the shaft 13, the bearing

(bushing 14) pierced with holes 9 and the casing 18.

According to this arrangement, there are two functional surfaces on the pierced bushing 14, one consisting of its internal bore and the other its external cylinder.

In this configuration, the pierced bushing is "floating".

Figure 15 shows an arrangement with two rubbing parts, which are the shaft 13 and the bearing (bushing 14) pierced with holes 9. A bearing sleeve 19 made of bearing steel of the 100C6 type has been shrunk-fit thereonto. The bushing 14 itself is tight-fitted via its external diameter into a bore of the casing 18.

Figure 16 is a variant of figure 15 with a "floating" pierced bearing (bushing) which rubs on two bearing sleeves 19 and 20 made of bearing steel of the 100C6 type, respectively shrunk-fit onto the shaft and fitted into the bore of the casing.

The present invention will be described in greater detail with reference to the following examples.

Example 1 (comparative)

This example illustrates tests on oscillating bearings.

The configuration is shaft/bearing (bearing bush).

Nature of the shaft: quenched case-hardened 16NC6 steel.

Nature of the bearing (bearing bush): 40% graphite-filled polyimide of the PI 5508 type.

Diameter of the shaft: 30 mm.

Width of the bearing bush: $l = 20$ mm.

Developed length of the bearing bush: $\pi \times 30 = 94.25$ mm.

Movement: alternating rotation over 90° of arc at a frequency of 1 Hz.

Calculated pressure on the projected surface:

10 MPa.

Sliding speed: 0.2 m/s.

Extreme-pressure grease: lithium soap, SNR-LUB EP type, NLGI 2 grade, use temperatures -30 to +110°C.

5 Greasing at mounting, then operation without additional supply of grease.

In order to determine the contact angles θ for shaft/grease and bearing/grease, an average of 5 measurements was made as indicated above, with beads of grease deposited on parallelepipedal specimens, heated at 10 130°C for 90 seconds and then cooled.

The results are as follows:

- in the case of the shaft (quenched case-hardened 16NC6 steel): $\theta = 30^\circ$;
- 15 - in the case of the bearing (40% graphite-filled polyimide): $\theta = 60^\circ$.

This example was made with a smooth bearing bush, that is to say outside the field of the invention.

Results of the tests:

- 20 - average coefficient of friction: 0.11;
- number of oscillations before a rapid rise in the coefficient of friction: 35,000.

Example 2 (according to the invention)

Example 1 is repeated, except that the bearing bush 25 is pierced with 40 holes (cavities), each 4 mm in diameter, arranged in a regular manner with d (shortest distance separating the facing edges of two juxtaposed cavities) = 4 mm.

Results of the tests:

- 30 - average coefficient of friction: 0.009;
- number of oscillations before a rapid increase in the coefficient of friction: > 250,000 (test stopped before its conclusion).

Example 3 (comparative)

35 Example 1 is reproduced, except that, in the case

of the material of which the bearing bush is made, the polyimide is replaced with a UE 12 P type bronze which is an alloy commonly used for bearings.

5 The bearing bush is smooth, that is to say outside the invention.

The contact angle θ for bearing bush/grease, measured under the conditions of Example 1, is 35° .

Results of the tests:

- average coefficient of friction: 0.12;
- 10 - number of oscillations before a rapid increase in the coefficient of friction: 25,000.

Example 4 (comparative)

Example 2 is repeated, except that, in the case of the material of which the pierced bearing bush is made, 15 instead of the polyimide a UE 12 P type bronze is used, which is an alloy commonly used for bearings.

The contact angle θ for bearing bush/grease, measured under the conditions of Example 1, is 35° , that is to say outside the range of the invention for the 20 pierced part.

Results of the tests:

- average coefficient of friction: 0.09;
- number of oscillations before a rapid increase in the coefficient of friction: 80,000.

25 Comments on Examples 1 to 4

1) When the bearing bushes are smooth, that is to say outside the invention, their lifetime is of the same order of magnitude, whether they are made of polyimide or of bronze. The coefficients of friction are themselves 30 comparable and correspond to a hybrid mode, this continuing as long as the lubricant remains in the contact region. When the grease, which can escape via the edges of the bearing, is completely eliminated, the coefficient of friction rapidly increases; the bearing 35 then heats up and then suffers deterioration by the

thermal effect, with the polyimide or the bronze of the bearing bush bonding onto the steel shaft.

2) The lifetimes of the pierced bearing bushes made of polyimide (according to the present invention) and made of bronze (outside the invention) are significantly longer than those of the smooth bearing bushes. On dismantling, the end of the tests, it was observed that all of the grease available in the cavities had been consumed. This reveals the beneficial aspect of the "reserves of lubricant" that the cavities constitute.

3) The coefficient of friction of the pierced bronze bearing bush is less than that of the smooth bronze bearing bush. This may be at least partly due to a more regular supply of grease to the contact region and to a more uniform distribution of this grease in this contact region, thereby reducing the risk of metal/metal contact between the bronze of the bearing and the steel of the shaft.

4) On the other hand, the explanation at 3) does not take into account the very low coefficient of friction recorded with the pierced polyimide bearing bush (according to the invention). In fact, a value of 0.009 typically corresponds to a hydrodynamic mode of lubrication, something which it is unexpected to find in a relatively highly loaded oscillating bearing in which the sliding speed is not very high.

The lifetime of the pierced polyimide bearing (more than 250,000 oscillations) is also surprising when it is compared with that of the bronze bearing bush (80,000 oscillations).

Schematically, everything happens as if the double fact of the bearing bush being made of polyimide and of it being pierced resulted, on the one hand, in an improvement in the bearing capacity effect and, on the other hand, in an increase in the length of time

necessary to exhaust the reserve of lubricant.

The theoretical modelling of these phenomena has not been carried out and explanatory hypotheses can only be advanced. These will more conveniently be illustrated with reference to figure 1. The grease 4 contained in the available space E between the runner 1, the track 2 and the O-ring seal 3 transmits laterally only a fraction of the normal pressure that it experiences, this fraction being smaller the more viscous said grease (this stems from the fact that grease obeys the laws of rheology, unlike oils which obey Pascal's law and the hydrostatic law).

A relatively high load can therefore be tolerated, that is to say an improvement in the bearing capacity effect, and a relatively large amount of play, that is to say an increase in the reserve of lubricant, before the onset of extrusion of the seal 3 and the appearance of lubricant leakage.

In the configuration of the invention, the seal 3 does not exist. This has an advantageous consequence, associated with the fact that the sliding of the runner on the track takes place without it being necessary for the friction of the seal on this same track to be overcome, thereby contributing to the creation of a low coefficient of friction.

There may also be another consequence, this being disadvantageous, in which the grease, which is no longer contained, naturally tends to escape via the edges of the runner. This may occur more easily and rapidly the better the lubricant wets the surfaces, that is to say the smaller the contact angle between the grease and the materials of which said surfaces are made.

The foregoing may be directly transposed from a runner/slideway device to another device of the shaft/bearing type, as explained in the above examples:

with a polyimide bearing bush (contact angle with the grease = 60°), the lubricant is contained better than with a bronze bearing bush (contact angle with the grease = 35°).

5 5) It is conceivable that another phenomenon occurs in order to explain the markedly superior behaviour of the oscillating bearing with a steel shaft and a polyimide bearing bush compared with that of the oscillating bearing with a steel shaft and a bronze bearing bush.

10 Although, as was seen above, the grease is better contained in the contact region with a polyimide bearing bush than with a bronze bearing bush, nonetheless the fact remains that there is consumption of lubricant in both cases.

15 Now, in the presence of two metal surfaces to be wetted, it is energetically more favourable for the lubricant to come into contact with that one which has the smallest wetting angle with the grease, in this case the steel shaft rather than the polyimide bearing bush.

20 The hypothesis may therefore be advanced that each time the surface of the steel shaft goes past a cavity of the polyimide bearing bush said surface attracts a little of the grease contained in said cavity. The rotation of the shaft therefore constantly replenishes the lubricant on its surface, which in turn helps to stabilize the lubrication regime and therefore improves the bearing capacity effect and the lifetime of the bearing.

25 In the case of the bronze bearing bush (contact angle of the same order as that of the steel), this phenomenon does not occur.

Example 5 (comparative)

30 Example 1 is repeated, except that, in the case of the material of which the bearing bush is made, the polyimide is replaced with annealed carbon steel of the

XC 38 type coated on its functional surface with 10 μm of an organic varnish based on an MoS_2 -filled epoxy resin.

The bearing bush is smooth, that is to say outside the invention.

5 The XC 38 steel + varnish/grease contact angle θ , measured under the conditions of Example 1, is 70° .

Results of the tests:

- average coefficient of friction: 0.09;
 - number of oscillations before a rapid increase in
- 10 the coefficient of friction: 45,000 (intense wear at the end of the test).

Example 6 (according to the invention)

Example 5 is repeated, except that the bearing bush is pierced by 40 holes (cavities), each 4 mm in diameter, arranged in a regular manner with d (shortest distance separating the facing edges of two juxtaposed cavities) =

15 4 mm.

The results of the tests:

- average coefficient of friction: 0.0075;
 - number of oscillations before a rapid increase in
- 20 the coefficient of friction: > 250,000 (test stopped before its conclusion).

Example 7 (comparative)

Example 5 is repeated, except that the bearing bush is made of uncoated annealed carbon steel of the XC 38 type.

25

The bearing bush remains smooth, that is to say outside the invention.

The XC 38 steel/grease contact angle θ , measured under the conditions of Example 1, is 25° .

30

Results of the tests:

- average coefficient of friction: unstable;
 - number of oscillations before a rapid increase in
- the coefficient of friction: a few tens before seizing.

Example 8 (comparative)

Example 6 is repeated, except that the pierced bearing bush is made of uncoated annealed carbon steel of the XC 38 type.

5 The XC 38 steel/grease contact angle θ , measured under the conditions of Example 1, is 25° , that is to say outside the range of the invention for the pierced part.

Results of the tests:

- average coefficient of friction: 0.15;
- 10 - number of oscillations before a rapid increase in the coefficient of friction: a few hundred before seizing.

Comments on Examples 5 to 8

15 The same comments as on Examples 1 to 4 may be made, except that the tests result in more marked degradation, of the intense-wear type, or even seizing, as a result of steel/steel contact when the reserve of grease has been consumed and/or when the varnish coating has been worn away.

20 Examples 9 to 14

Example 6 is repeated, with pierced bearing bushes made of varnish-coated steel, by varying the number of holes (with a constant diameter) in order to vary the area occupied by the cavities. This area is measured on
25 the development of the rubbing surface and is expressed as a percentage of the total area of said development.

The area occupied by the cavities as a percentage of the total area is denoted by "S".

The number of oscillations is denoted by "N".

30 The results are given in Table I.

Table I

S%	5	10	20 to 40	50	60
N	35,000	80,000	> 250,000	20,000	a few hundred

Comment

5 When the area occupied by the cavity is less than 20% of the total area of the development of the bearing, the lifetime of the latter rapidly decreases, reaching that of the bearing fitted with a smooth bearing bush.

10 Above 40%, the decrease is even more rapid and, on dismantling the bearing at the end of the tests, it is observed that the surface of the bearing bush is highly degraded, with many scratches and descaling of the varnish.

Examples 15 to 17 (according to the invention)

15 Example 2 is repeated, that is to say with a pierced polyimide bearing bush, but by varying the nature of the material of which the shaft is made.

The grease/shaft contact angle is denoted by θ .

The coefficient of friction is denoted by C_F .

20 The number of oscillations is denoted by "N".

The results are given in Table II.

Table II

Example	15	16	17
Nature of the shaft	Hard chromium	Quenched case-hardened 16 NC 6 steel	Nitro-carbo-sulphided 42 CD 4 steel
θ	35°	30°	25°
C_F	0.01	0.01	0.01
N	150,000	> 250,000	100,000

The coefficients of friction are comparable but the lifetimes, represented by the number of oscillations, vary significantly, while still remaining good.

Example 18 (comparative)

5 Example 6 is repeated, but by varying the nature of the polymer coating.

The steel of the bearing bush is coated on its functional surface with 10 μm of PTFE (polytetrafluoroethylene).

10 The grease/bearing bush contact angle θ is 85° , that is to say outside the invention.

The coefficient of friction is of the order of 0.008.

The number of oscillations is 90,000.

15 Examples 19 and 20

These examples relate to a bearing configuration in continuous rotation (guiding of a shaft rotating in the bore of a casing).

20 Examples 19 and 20 illustrate, with reference to figures 15 and 16, the cases of two rubbing parts (a single functional surface) and three rubbing parts (two functional surfaces), respectively.

The experimental conditions are as follows:

25 - material of the smooth part: 100C6-type bearing steel;

- material of the pierced part: nitrided XC 38-type carbon steel coated with 12 μm of an organic varnish made of perfluoroalkoxy;

30 - nature of the grease: same as that in Example 1;

- diameter of the shaft: 30 mm;

- width of the bearing bush: 25 mm;

- calculated pressure on the projected area: 5 bar.

The tests were conducted at various values of the rotation speed of the shaft.

35 In all cases, the motion can continue for hundreds

of hours without any operating anomaly and with a very low resisting torque, corresponding to an extremely low coefficient of the order of 0.005 to 0.0005, typical of friction in a very good hydrodynamic lubrication regime.

5 The distinction between the set-up with two rubbing parts and that with three rubbing parts appears at the two extremes of the range of the variation of the rotation speed.

10 Below 2000 to 3000 rpm, the system with two rubbing parts (Example 19) gives better reproducibility of the results (100% success), as opposed to that with three rubbing parts (Example 20: 90% success).

 Above 10,000 to 12,000 rpm, the reverse is the case.

15 Those skilled in the art will understand that although the invention has been described and illustrated in the case of particular embodiments, numerous variants are conceivable whilst still remaining within the scope of the invention as defined in the appended claims.

CLAIMS

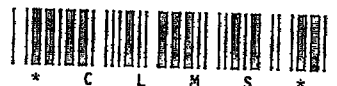
1. Guiding device for mechanical members, which consists of two parts intended to interact by sliding friction, one of the two parts, called the smooth part
5 (11), having a smooth, functional, that is to say friction, surface and the other part, called the pierced part (8), having at least one functional, that is to say friction, surface (7) which includes emergent cavities (9) intended to accommodate a grease of the lubricating-
10 paste type comprising a soap-type constituent, an oil-type constituent and an extreme-pressure additive, characterized in that the contact angle θ between said functional surface of said smooth part and said grease, measured at a temperature called the measurement
15 temperature, which is $15^\circ \pm 5^\circ\text{C}$ below the temperature at which the onset of separation between said soap-type constituent and said oil-type constituent occurs, is between 20 and 40 degrees and in that the material of said pierced part is chosen in such a way that the
20 contact angle, measured at said measurement temperature, between said functional surface of the pierced part and said grease is between 45 and 75 degrees.

2. Device according to Claim 1, characterized in that the material of which the smooth part is made is
25 chosen from among steels, chromium and nickel.

3. Device according to Claim 2, characterized in that the steel is chosen from among case-hardened, quench-hardened and ground steels, ground HF quench-hardened steels, steels that are hardened and then coated
30 with hard chromium, nitrided steels, ceramic-coated steels and carbonitrided steels.

4. Device according to any one of Claims 1 to 3, characterized in that the material of which the pierced part is made is a bulk material.

35 5. Device according to any one of Claims 1 to 3,



characterized in that the material of which the pierced part is made is chosen from among polymer materials and copolymer materials.

5 6. Device according to Claim 5, characterized in that the material of which the pierced part is made is chosen from among polyimides, filled polyimides, epoxy resins, filled epoxy resins, polyacetal resins, polyethylene, substituted or unsubstituted fluorocarbons, polyethylene terephthalate, polyethersulphone, polyamides
10 and polyetheretherketone.

 7. Device according to any one of Claims 1 to 5, characterized in that the material of which the pierced part is made is chosen from among bulk substrates, thin rolled sheets and substrates covered with a coating.

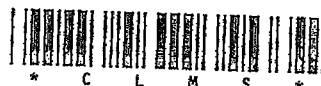
15 8. Device according to Claim 7, characterized in that the material of which the coating is made is a material chosen from among polymer materials and copolymer materials.

 9. Device according to Claim 8, characterized in
20 that the material of which the coating is made is chosen from among polyimides, filled polyimides, epoxy resins, filled epoxy resins, polyacetal resins, polyethylene, substituted or unsubstituted fluorocarbons, polyethylene terephthalate, polyethersulphone, polyamides and
25 polyetheretherketone.

 10. Device according to either of Claims 6 and 9, characterized in that the fluorocarbon is PFA (perfluoroalkoxy).

30 11. Device according to Claim 8, characterized in that the material of which the pierced part is made is chosen from among prenitrided steels.

 12. Device according to Claim 11, characterized in that the steel has been subjected before hand to a surface hardening treatment causing nitrogen to diffuse
35 into said steel.



13. Device according to Claim 12, characterized in that said hardening treatment is a thermochemical nitriding treatment in a molten bath of alkali metal cyanates and carbonates.

5 14. Device according to Claim 13, characterized in that the molten bath furthermore contains an amount of at least one sulphur species.

10 15. Device according to any one of Claims 1 to 14, characterized in that the cavities are distributed over practically the entire surface of the pierced part.

16. Device according to Claim 15, characterized in that at least three cavities contribute to supporting a load applied to the two parts.

15 17. Device according to Claim 15, characterized in that the area occupied by the cavities on the development of the functional surface of the pierced part represents between approximately 20 and approximately 40% of the total area of said development.

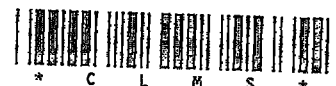
20 18. Device according to any one of Claims 1 to 17, characterized in that the cavities are more or less the same as each other.

25 19. Device according to any one of Claims 1 to 17, characterized in that the cavities are distributed more or less regularly over the entire surface of the pierced part.

20. Device according to any one of Claims 1 to 17, characterized in that the cavities are not more or less the same as each other.

30 21. Device according to any one of Claims 1 to 17 and 20, characterized in that the cavities are distributed more or less irregularly over the entire surface of the pierced part.

35 22. Device according to either of Claims 20 and 21, characterized in that the shortest distance between the edges of two juxtaposed cavities is greater than



approximately 2 mm.

23. Device according to any one of Claims 1 to 22,
characterized in that the emergent surface of each cavity
has an area of between approximately 3 mm² and
5 approximately 40 mm².

24. Device according to one of Claims 20 and 21,
characterized in that the shortest distance between the
edges of two juxtaposed cavities is greater than
approximately 2 mm and the emergent surface of each
10 cavity has an area of between approximately 10 mm² and
approximately 30 mm².

25. Device according to any one of Claims 1 to 24,
characterized in that the cavities emerging on the
functional surface of the pierced part do not communicate
15 with each other on the side containing said functional
surface of said pierced part.

26. Device according to any one of Claims 1 to 25,
characterized in that the cavities emerging on the
functional surface of the pierced part do not communicate
20 with each other on the side containing a non-functional
surface of said pierced part.

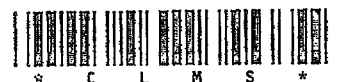
27. Device according to any one of Claims 1 to 25,
characterized in that the cavities emerging on the
functional surface of the pierced part communicate with
25 each other on the side containing a non-functional
surface of said pierced part via a system of channels.

28. Device according to Claim 27, characterized in
that a cover (12) covers the cavities.

29. Device according to any one of Claims 1 to 28,
30 characterized in that the cavities are cylindrical.

30. Shaft/bearing device according to any one of
Claims 1 to 29, characterized in that the shaft is the
smooth part and the bearing is the pierced part.

31. Slideway/runner device according to any one of
35 Claims 1 to 29, characterized in that the slideway is the



smooth part and the runner is the pierced part.

32. Ball/socket device according to any one of Claims 1 to 29, characterized in that the ball is the smooth part and the socket is the pierced part.

5 33. Device according to Claim 30, characterized in that the bearing has two functional surfaces.

