

POT BEARING FOR CONSTRUCTIONS

The present invention concerns in general the sector of structural supports for building constructions, and in particular a pot bearing that allows rotation between two
5 elements of a construction.

In the construction of civil, industrial and road infrastructures, such as road and rail bridges and viaducts, civil buildings and other types of buildings, structural supports are generally used that define between two or more parts of the structure slider or hinge constraints, as well as combinations thereof. The bearings have the function of allowing
10 relative movements between the parts of the structure, typically translations and/or rotations, both in exceptional conditions, such as in the case of seismic events, and in normal operating conditions in which such relative movements occur as a result of the weight of the construction, viscous deformations and shrinkage of building materials, thermal actions, as well as actions related to wind and normal use of the construction,
15 such as the effects of traffic in the case of bridges and viaducts.

Structural bearings for buildings are codified in technical standards that form the state of the art, such as the European standard EN 1337 "Structural Bearings" or the American standard AASHTO LRFD "Bridge Design Specifications" (8th edition, 2017).

20 One of the types of bearings currently widely used in road and rail bridges and viaducts to transfer vertical loads and allow the deck to rotate in relation to the pillars, or to the abutments, consists of elastomeric disc bearings or pot bearings, described in part 5 of the EN 1337 standard (EN 1337-5:2005 "Structural Bearings. Part 5: Pot bearings") and in section 14 of the AASTHO LRFD standard. In the following, the two
25 names, elastomeric disc bearing and pot bearing, will be used indifferently to refer to the same type of structural bearing as defined in standard EN 1337-5:2005, which will be taken as a reference in this description.

Pot bearings consist of a base plate, also called a "pot", an elastomeric pad, generally in the shape of a disc, accomodated in the base plate, and a top plate, also
30 called a "piston", which protrudes at least partially inside the base plate and rests on the elastomeric pad. Both the base plate and the top plate are typically made of metal alloys,

for example steel. In bridges and viaducts, where pot bearings are mainly used because of their compact size and ability to transfer high vertical loads that make them superior to other categories of structural bearings (such as elastomeric bearings, metal rolling bearings and metal tilting bearings), the base plate is normally connected to the substructure (abutment or pillar) and the top plate to the superstructure (deck), although the pot bearings can be used in reverse configuration.

The pot bearing allows the superstructure to rotate relative to the substructure by deforming the elastomeric pad. The elastomer accommodated inside the pot is confined in every direction and, under the high pressures to which it is subjected as a result of the vertical load transmitted by the top plate, it deforms, acting as an incompressible fluid, thus allowing the relative rotation between the pot and the top plate around a generic horizontal axis. For the correct functioning of the pot bearing, the presence of an internal seal is fundamental, which circumferentially surrounds the rim of the elastomeric disc and prevents the escape of elastomeric material through the clearance between the walls of the pot and the piston, especially in the presence of high stresses due to the vertical loads coming from the superstructure. Pot bearings are generally fitted with an additional external seal, located between the top plate and the top of the base plate, in order to prevent moisture and debris from entering the gap between the two elements.

The internal seal is typically inserted between the rim of the elastomeric pad and the wall of the internal cavity of the base plate, usually in an annular-shaped seat formed at the rim of the elastomeric pad, or it can be formed as an integral part of the elastomeric pad during the vulcanization process. According to standard EN 1337-5:2005 the internal seal can be manufactured in one of the following materials: stainless steel, brass, polyoxymethylene (POM), and polytetrafluoroethylene (PTFE) filled with 25% carbon by weight. In particular, the polytetrafluoroethylene seal is made from a semi-finished band-shaped product that is calendered around the circumference of the elastomeric pad, and joining the ends of the band, as described in Figure A.1 of the above standard.

As an alternative material for the manufacture of the internal seal, the use of ultra-high molecular weight polyethylene (UHMWPE), such as in WO 2006/042571 A1, and

a polyoxymethylene (POM) with a melt flow index (MFI 190/2.16) lower than the value specified in EN 1337-5:2005, such as in EP 2784220, has recently been proposed.

The characteristics of the internal seal are of fundamental importance for defining the performance and durability of the elastomeric disc bearing. In fact, since the internal seal prevents the elastomeric material from rising through the clearance between the pot and the piston, it determines the maximum pressure (i.e. the maximum vertical force per unit area) applicable to the pad of elastomeric material. For pot bearings manufactured in accordance with EN 1337-5:2005, the value of the maximum pressure applicable to the elastomeric pad, defined and verified according to the standard, is 60 MPa. This value depends, in addition to the properties of the internal seal, also on the size of the clearance between the pot and the piston, which according to the technical standard EN 1337-5:2005 must not exceed 0,8 mm when using a PTFE seal with carbon and 1,0 mm for other types of seal.

In addition, the oscillations of the angle of rotation produced by the variable loads, due for example to the passage of vehicles or trains on a bridge or viaduct, produce a sliding of the internal seal on the wall of the internal cavity of the pot, which determines the life of the seal itself. The total distance travelled by the internal seal while maintaining its functionality, also referred to in standard EN 1337-5:2005 as the "accumulated slide path", is one of the criteria used to define the useful life of the elastomeric disc bearing. The standard EN 1337-5:2005 defines different values of the accumulated slide path according to the type of internal seal, namely 500 m for stainless steel seals, 1000 m for brass seals and 2000 m for POM and carbon-filled PTFE seals.

The accumulated slide path is checked experimentally through a test conducted according to the method described in Annex E of EN 1337-5:2005, and consists in subjecting a pot bearing to a sinusoidal rotation around a horizontal axis with a total amplitude equal to 0,005 radians, i.e. the maximum amplitude of rotation due to the frequent combination of variable loads prescribed by the standard, at a frequency between 0,25 and 2,5 Hz. The rotation frequency is a fundamental parameter for checking the accumulated slide path, since increasing the rotation frequency increases in proportion the sliding speed of the internal seal on the surface of the internal cavity of the pot, leading to an increase in friction and accelerating the wear of the seal itself.

It should be noted that the total distance travelled by the internal seal during the service life of the elastomeric disc bearing depends on the amplitude of the rotations due to the variable loads, on the total number of rotations, but also on the dimensions of the elastomeric pad. In fact, with the same angle of rotation, both the displacement of the internal seal on the wall of the internal cavity of the pot and the speed at which this displacement occurs are proportional to the diameter of the elastomeric pad. As a consequence, increasing the diameter of the elastomeric disc results in a reduction in the total number of rotations that the pot bearing is able to undergo, keeping the other parameters constant, in particular the amplitude and frequency of rotation.

Pot bearings have found wide application in road and rail bridges and viaducts thanks to their simplicity, compact size, economy and low maintenance requirements. In particular, for traditional railway bridges, the EN 1337-5:2005 standard recommends the use of pot bearings with internal seals in POM or PTFE with carbon. However, in the last decade, the continuous increase in both heavy and light traffic, and the advance of high-speed railway lines have introduced ever higher performance requirements, higher than those that conventional pot bearings can meet.

In fact, the passage of high-speed trains produces rotational oscillations, at the supports, which occur in very short periods; for example, assuming a train speed between 300 and 350 km/h and a distance between the bogies of a carriage equal to 18,70 m, the frequency of oscillation of the support is between 4,45 and 5,20 Hz. This frequency, which is twice as high as the maximum frequency at which the internal seal is checked according to EN 1337-5:2005, leads to a significant increase in the speed of wear of the seal itself, reducing disadvantageously the accumulated slide path compared to the value defined and verified according to the standard.

The continuous increase in heavy and light traffic has a negative effect on the service life of the elastomeric disc bearings also due to other factors:

- first of all, the increase in the number of daily passages leads to an increase in the number of rotations carried out daily by the bearing, and therefore in the sliding distance travelled daily by the seal;
- secondly, the increase in vertical loads resulting from the increase in both the number and weight of vehicles and trains leads to an increase in the size of the

elastomeric pad, in order to maintain the pressure on the bearing within the limits defined by the standard.

As mentioned above, the increase in the size of the elastomeric pad in turn determines a proportional increase in the displacement of the seal during a single rotation, as well as in the speed with which this displacement occurs. In conclusion, there are disadvantageous effects in terms of both an increase in the size of the pot bearing, and therefore in the costs of manufacture, transport and installation, and a reduction in the useful life of the bearing (in the sense of a reduction in the number of permitted rotary movements).

To deal with the latter problem of contact pressure, EP 2784220 describes a pot bearing with internal POM seal in which the seal material is modified to have a flow index (MFI 190/2.16 according to EN ISO 1133) with a value lower than the range required by the standard. This allows to obtain an increase in the contact pressure of the elastomeric pad up to twice the value required by the standard, as well as an increase in the accumulated slide path up to 1,6 times the value required by the standard, but no further advantages are described in terms of increase in the sliding speed that can be withstood by the seals.

As an alternative to pot bearings, in railway bridges there are now used spherical bearings of the type described in the EN 1337-7:2004 standard "Structural Bearings. Part 7: PTFE spherical and cylindrical bearings", in which the rotation of the bearing is achieved through the rotation of a spherical metal cap inside a concave metal base. A sheet of polytetrafluoroethylene (PTFE), generally lubricated with silicone grease, is placed between the surfaces of the two metal elements to minimize friction in order to reduce resistance to rotation and increase the duration of the bearing.

However, these bearings are more complex to construct than elastomeric disc bearings, due to the need to create extremely precise spherical surfaces, therefore they are more expensive and require more maintenance. In addition, the spherical bearings according to EN 1337-7:2004 have performance limits related to PTFE wear, the duration of which is defined and verified on a accumulated slide path of 10000 m and at the maximum sliding speed of 2 mm/s, which also makes them not optimal for use in bridges of high-speed railway lines.

Some manufacturers have developed special spherical bearings, such as those described for example in EP 1523598, where the PTFE sheet is replaced by an ultra-high molecular weight polyethylene (UHMWPE) sheet characterised by greater wear resistance and a higher permissible sliding speed than the PTFE sheet, thus making
5 these bearings suitable for use in bridges and viaducts of high-speed railway lines. However, these are still complex and expensive solutions which, moreover, due to the use of UHMWPE, which is not among the materials required by the technical standards, require a long time to obtain from the regulatory authorities the necessary approvals for their use in civil constructions.

10 There is therefore still a need to find effective solutions for the creation of a simple, economic and easy to maintain structural support, which has a long life and is compatible with the rapid oscillations of the superstructure due to traffic, and in particular the rail traffic of high-speed lines, which is a purpose of this invention.

This purpose is achieved by means of a pot bearing, the main features of which
15 are set out in claim 1, while other features are set out in the remaining claims.

The idea of a solution underlying this invention is to make the internal seal, preferably of the annular type, of the pot bearing starting from a semi-finished product, such as, for example, a band obtained by drawing, which consists entirely or at least
20 mainly of PTFE modified with the addition of perfluoropropylvinylether (PPVE) in percentages between 0,1% and 0,3% in weight.

The addition of PPVE in the above percentages gives PTFE particular properties, some of which, such as weldability, impermeability to gases and liquids and low porosity, are already exploited in the manufacture of seals and seats for ball valves, non-stick coatings and components with complex geometric shapes that can be
25 advantageously achieved by welding, for example in the production of fittings and transport systems of industrial fluids for applications in the chemical, pharmaceutical and electronic sectors.

The addition of PPVE as a PTFE modification agent for use in structural bearings is already described in WO 2015/136457, by the same inventor, which concerns a
30 sliding bearing of the type described in EN 1337-7:2004. In that case, PTFE modified with PPVE is used in the form of a sheet, obtained from a semi-finished product

moulded by compression, and allows to obtain a lower coefficient of friction and a greater resistance to creep than pure PTFE at low temperatures and in particular at temperatures below -35°C and down to -50°C , allowing the application of sliding bearings for the construction sector beyond the limits imposed by current technical standards.

In the present invention, PTFE modified with PPVE is instead used for the internal seal of an elastomeric disc bearing, obtained from a semi-finished product consisting of a band, preferably obtained by drawing. The inventor has in fact discovered that the addition of PPVE to PTFE allows the seal to withstand significantly higher sliding speeds than those tolerated by seals manufactured according to EN 1337-5:2005, including those manufactured with PTFE without a modifying agent, at the same time presenting an advantageously lower wear.

The fact that by increasing the rotation frequency of the bearing, and therefore the sliding speed of the seal, there is no reduction in the accumulated slide path but even an increase in it compared to the values defined and verified according to the standard, with the consequent beneficial effect of increasing the service life of the elastomeric disc bearing, is a surprising effect as it is generally known that for plastic materials, such as PTFE, in sliding contact on a metal surface, the rate of wear increases as the sliding speed increases.

Moreover, the addition of PPVE as a modifying agent increases the resistance of the internal seal, allowing it to withstand higher pressures on the elastomeric pad than the value defined and verified according to EN 1337-5:2005. The allowable increase in pressure on the elastomeric pad therefore makes it possible to make pot bearings, capable of withstanding high loads, more compact than those defined in EN 1337-5:2005.

These characteristics make it possible to manufacture an internal seal for pot bearing suitable to withstand high oscillation frequencies, with higher accumulated slide paths and which allows an increase in the pressure on the elastomeric pad, compared to the limits set in the standard. This allows the application of the pot bearings with this new internal seal beyond the limits of prior art pot bearings, and in particular to meet the high performance requirements required by the applications of the bearings as

supports of bridges and viaducts in high-speed railway lines.

The pot bearings according to the present invention, thanks to the characteristics of increased durability of the internal seal even in the presence of high sliding speeds such as those produced by the passage of trains at high speed, and increased pressure applicable to the elastomeric pad provided by the new internal seal, allow the creation of bearings more compact, less bulky and heavy, and with reduced maintenance requirements, resulting in an advantageous reduction in costs, not only of the bearing but of the entire construction and of its maintenance.

To confirm this, the applicant carried out a campaign of experimental tests on elastomeric disc bearings equipped with the new internal seal made of PTFE modified with the addition of perfluoropropylvinylether (PPVE) in percentages between 0.1% and 0.3% by weight and filled with 25% by weight of carbon, from which the following results emerged, proposed here in comparison with the performance of traditional pot bearings taking as a reference the bearings with internal seal made of PTFE filled with 25% by weight of carbon as required by current technical standards.

a) The pot bearing according to the present invention withstands sinusoidal rotations with a total amplitude of 0,005 radians at a frequency of at least 5 Hz, verified on an accumulated slide path of at least 2000 m according to the method described in Annex E of EN 1337-5:2005, equal to twice the maximum rotation frequency provided for in the standard.

b) The internal seal of the pot bearing according to the present invention exceeds an accumulated slide path of at least 4000 m with a sliding speed of at least 15 mm/s, equal to twice the accumulated slide path foreseen in the standard for the technical class of carbon-filled PTFE seals.

c) The pot bearing according to the present invention allows to apply to the elastomeric pad a contact pressure of at least 120 MPa, defined and verified according to the method described in Annex E of EN 1337-5:2005, equal to double the characteristic contact pressure of the elastomeric pad foreseen in the standard.

The internal seal of the pot bearing according to the present invention can also be lubricated initially with a grease, preferably silicone grease, to reduce the coefficient of friction and increase wear resistance and durability. The preferred type of silicone

grease is methyl phenyl silicone oil thickened with lithium soap.

The internal seal of the pot bearing according to the present invention is inserted between the rim of the elastomeric pad and the wall of the internal cavity of the pot, within a recess formed in the pad rim. The internal seal can be simply inserted into the
5 recess by circumferentially surrounding the pad, or formed as an integral part of the elastomeric pad during the curing process, or even glued with an adhesive to the elastomeric pad.

The joint between the two ends of the calendered band from which the seal is obtained can be made not only according to the type described in Figure A.1 of EN
10 1337-5:2005, but other embodiments of the joint are also possible.

A further advantage of the material used to manufacture the internal seal of the elastomeric disc bearing is the fact that its characteristic properties are scarcely temperature dependent. In particular, the requirements defined in EN 1337-5:2005 are met at temperatures between -50°C and +70°C. This means that the pot bearing
15 according to the invention can also be used advantageously in extreme environmental conditions, in which the bearings described in EN 13375-:2005 cannot be used, their range of use being limited between -40°C and +50°C.

Incidentally, it is noted that the advantages provided by the pot bearing according to the invention do not only concern the comparison with standard EN 1337-5:2005, but
20 also the national standards of several countries which are essentially comparable, in essential respects, to said standard.

The present invention has been described so far with reference to a traditional embodiment of a pot bearing, but it is clear that other embodiments that belong to the same inventive concept are possible, as defined by the scope of protection of the claims
25 set out below.

For example, the pot bearing according to the present invention can be advantageously coupled with a flat sliding element, as described in Part 2 of EN 1337 (EN 1337-2:2004 "Structural bearings. Part 2: sliding elements") or in EP 2784220 (Fig.4), in order to allow translation movements of the superstructure with respect to the
30 substructure, for example movements due to thermal actions resulting from temperature variations or the effects of cable pre-tensioning. One or more sliding guides may be

coupled to the flat sliding element, as described in EN 1337-2:2004, to allow the translation movement in one horizontal direction only.

Similarly, the elastomeric pad, as an alternative to the disc shape, can have an oval or an annular shape as shown, respectively, in figures 5-7 and figures 8-9 of the above-mentioned EP 2784220. In the latter case, of course, there will be two internal seals to
5 achieve the sealing also in correspondence of the central tubular structure of the pot.

In this regard, it should be noted that although the standard EN 1337-5:2005, in the case of pot bearings with internal seals in carbon-filled PTFE, provides for the presence of only one internal seal, in this pot bearing it is certainly possible to provide
10 for a plurality of seals depending on specific construction requirements.