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(54) FLEXURE OINT AND RESILIENT UNIVERSAL COUPLING INCORPORATING THIS JOINT

(71) We, ANSCHÜTZ & Co., GMBH, a German Body Corporate, of 32-36 Mecklenburger Strasse, 2300 Kiel 14, Federal Republic of Germany,

do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed to be particularly described in and by the following statement:—

The present invention relates to a flexure joint for connecting together two bodies so that they are able to pivot, the joint comprising crossed spring leaves. This joint will be referred to as "a joint of the kind described". The invention also relates to a universal coupling which includes more than one of said flexure joints.

In a known resilient universal coupling of the kind described (U.S. Patent Specification 3,575,475) and entitled "Flexure Joint", the two crossed spring leaves forming the flexure joint extend past one another at the point where they cross because they are separated from one another at this point (see column 3, line 20 of the above patent specification). The fact that the crossed spring leaves are separated in this way means that when two of the three bodies pivot relatively to one another, the position of the axis of articulation of the resilient joint alters in relation to both of the two bodies.

The object of the invention is to provide a flexure joint which avoids the above disadvantage.

Accordingly from a first aspect the present invention consists in a flexure joint comprising a first spring leaf extending between a pair of rigid bodies and having its ends rigidly merged therewith at merger points, a second spring leaf extending between said bodies, crossing said first spring leaf and having its ends rigidly merged with said bodies at locations spaced from said merger points, said spring leaves being rigidly connected to each other at the crossing point so as to form a pivot axis extending through said crossing point transversely to said spring leaves.

From a second aspect the present invention consists in a giro having a resillient universal coupling comprising a first part connected to the rotor of the gyro and pivotally connected by a first pair of co-axial flexure joints to a spider part, the spider part being pivotally connected by a second pair of co-axial flexure joints to a third part which is in turn connected to the drive shaft of the gyro, the axes of articulation of the two pairs of flexure joints forming orthogonal axes of articulation of the universal joint, and each of the flexure joints comprising crossing spring leaves firmly connected at their ends to the parts with which they are associated, the spring leaves extending transversely of the pivot axis provided by the flexure joint and being subjected to flexure by relative pivotal displacement of the parts connected thereto, the spring leaves being rigidly connected to each other at their crossing point.

The spring leaves of the flexure joints may cross at an angle of 90° or at other angles.

To manufacture each flexure joint a method is preferably used which allows the crossed leaves to be made very thin, because otherwise, with the springs being rigidly connected at their crossing point, the joint formed by them would be too stiff.

A suitable manufacturing process is that which forms the subject matter of British patent application 30545/77 (Serial No. 1,582,857). In this process, in which each of four parallel passages in single pieces is formed by electrical erosion, use is made of a wire which can be entered into the piece over its entire length. When a resilient universal coupling according to the invention is manufactured, this wire forms two co-axial passages at the same time in a single eroding pass and thus forms simultaneously two co-axial flexure joints. Alternatively, each spring leaf may be formed by advancing along an axis of articulation an erosion tool using elecerical energy, the tool having spaced-apart spigots, the gap between which having the cross-sectional shape of the spring leaves.

It is further known to provide a flexure joint for connecting together two bodies so that they can pivot. This joint consists of only a single spring leaf which merges at its ends into the bodies via concave curved surfaces and is formed, together with the bodies, out of a single part by making two parallel bores in the part, passing from one of its side faces to the opposite side face and adding slots to the bores. It has been proposed to replace the bores by non-circular passages (German Offenlegungsschrift 25 25 530, p.39, lines 17-26). Nothing is said in this proposal about the configuration of the non-circular passages. It is proposed in this case that the passages be formed by electrical erosion.

This may also be done in the case of the present invention. The erosion electrode which is then used is preferably a wire which extends through the passage over its entire length. The use of a wire as an erosion electrode is not novel in itself.

In the known resilient universal coupling mentioned above (U.S. patent specification 3,575,475), one of the spring leaves in each of the flexure joints is perpendicular to the plane of the axes of articulation of the joint while the second spring leaf in each joint lies in this plane. When applied to a resilient universal coupling for a giro, individual flexure joints according to the invention may be arranged in this way. To achieve favourable symmetry characteristics, it is preferable for the individual spring leaves to be arranged at the same angle to the plane defined by the two axes of articulation of the joint. It is also possible for the angle at which the spring leaves cross to be other than 90°. This may be desirable to achieve isoelasticity under shear forces.

Various embodiments of the invention will now be explained in detail by way of example with reference to the accompanying drawings. In these:

Fig. 1 is a schematic side-view of a flexure joint,

Fig. 2 is a schematic view of another form of a flexure joint,

Fig. 3 shows a three-part resilient universal coupling according to the invention for driving the rotor of a gyro, partly in elevation looking in the direction of the arrows III in Fig. 4 and partly in section along the plane in 3-3 in Fig. 4, flexure joints,

Fig. 4 shows the universal coupling of Fig. 3, looking in the direction of the arrows 4,

Fig. 5 is a developed view of the circumferential surface of the universal coupling shown in Figs. 3 and 4,

Fig. 6 is a developed view, corresponding to the central portion of Fig. 5, of the circumference of a resilient universal coupling which differs from that shown in Figs. 3 to 5 by the angular position of the spring leaves of its flexure joints,

Fig. 7 is a view corresponding to Fig. 6 of a resilient universal coupling in which the spring leaves occupy the angular position of Figs. 4 and 5,

Fig. 8 is a broken-away view of a flexure joint in which the angle of intersection of the spring leaves is other than 90°.

Fig. 9 is a view similar to Fig. 3 of a three-part resilient universal coupling for a gyro together with the tools for the removal of material by the use of electrical energy, looking in the direction of the arrows 9 in Fig. 10, the coupling incorporating flexure joints according to the invention,

Fig. 10 is a side-view of the resilient universal coupling shown in Fig. 9 and the tools, partly in section along line 10-10 of Fig. 9, and

Fig. 11 is a broken-off section along line 11-11 of Figs. 9 and 10.

Fig. 1 shows two bodies 20 and 22 which are connected by a flexure joint so as to pivot about an axis of articulation 24. The flexure joint consists of crossed spring leaves 26 and 28 which are connected rigidly together at the point of crossing, i.e., on the axis 24. In the unstressed state the two spring leaves 26 and 28, which cross at an angle of 90°, and take up the position shown in broken lines. If the body 20 tilts to the position shown in solid lines, while body 22 remains in the same position, the spring leaves flex and assume approximately the form shown in solid lines. However, since they are connected rigidly together, they maintain their angle of crossing of 90° at axis 24. This axis extends at right angles to the plane of the drawing.

At their ends the two spring leaves 26 and 28 merge are firmly secured to the bodies 20 and 22. This may for example be achieved by welding the leaves on at these points. It is also possible for the spring leaves to be in one piece with the bodies. The configuration which then commends itself for the flexure joint is that shown in Fig. 2. To produce it, a single square block is provided, by electrical erosion, with four parallel passages A, B, C and D each of which adjoins two of the other passages and traverses the square block from one side face S to the parallel opposing side face S1, with passage C for example adjoining two other passages B and D. The passages are of substantially triangular cross-section and separated from each other by relatively thin walls which form the spring leaves 26 and 28. The square block is split up into two bodies 34 and 36 by slots 30 and 32. In the case of the embodiments shown in Figs. 1 and 2, each spring leaf 26 or 28 is bounded by two equidistant faces. Where the two spring leaves cross, they are connected rigidly together. In the case of the embodiment in Fig. 2 they are formed from a single part. The angle at which they cross is 90°.

The advantage of the flexure joint just described resides in the fact that the axis of articulation 24 always lies on the crossing point of the spring leaves, even where displaced by their deflection, i.e. this axis lies at a point which remains in the same position relative to both of the two bodies 20, 22 or 34, 36. If, however, as is the case with the prior art referred to above, the two spring leaves were to pass each other without being connected, this position would alter as the displacement of the axis increases.

A further advantage of the joint described is the fact that the required dimensions of the two bodies in the direction of the axis of articulation 24 are halved in comparison with the prior art referred to above, where at least two springs of the width required to support the axial load have to be arranged one behind the other in the direction of axis 24. Another advantage is the high load-bearing capacity in directions transverse to the axis 24 resulting from the fact that the rigid attachment of the spring leaves to each other increases their buckling strength. With spring leaves whose side faces are equidistant, the buckling strength can now be approximately doubled.

The new flexure joint is stiffer than one in which the two spring leaves extend past each other in the known way instead of being connected together at the crossing point. This stiffness can be reduced to the requisite level by selecting a suitable configuration for the spring leaves and in perticular by making them thin.

The manufacture of the flexure joint is considerably simplified by the fact that the four passages A, B, C and D may be made very short measured in the direction of the axis of articulation and are at least much shorter than would be the case if the two spring leaves were to extend past each other without being secured together.

Instead of using electrical erosion, the passages may be formed by electro-chemical excavation, contoured grinding or by other methods.

The application of the flexure joint to a resilient universal coupling for connecting a gyro rotor to its drive shaft will now be explained with reference to Figs. 3, 4 and 5. The resilient universal coupling in this case consists of a hollow cylindrical structure having two parallel end-faces 70 and 72 and which is divided into three bodies by slots which open onto the circumferential face. A body 74 which is rigidly secured to the gyro rotor has the end-face 70. Another body 76 which is rigidly secured to the gyro drive shaft has the end-face 72, and between the two bodies 74 and 76 lies a third body 78, the "spider". The body 78 is connected to a body 76 in such a way as to pivot about a first axis 82 of the universal coupling and to body 74 in such a way as to pivot about a second axis 84. The two axes 82 and 84 extend diametrically across the hollow cylindrical structure and are perpendicular to each other. Axis 80 of the cylindrical structure passes through the point of intersection of the axes 82 and 84 and is perpendicular to the plane defined by the axes 82 and 84. The axes 82 and 84 are the axes of articulation of respective joints.

The flexure joints provided in the universal coupling of Figs. 3, 4 and 5 have crossed spring leaves of the form described with reference to Fig. 1. Two of these joints lie on axis of articulation 82 and form one of two pivots of the universal coupling. Two further joints of the same form lie on the axis of articulation 84 and form the other pivot of the universal coupling.

The three bodies 74, 76 and 78 are connected together only by the four pairs of spring leaves of these flexure joints; otherwise they are completely separated from one another by the slots mentioned before. These are the slots 86 and 88 which extend parallel to the end-faces 70 and 72, the straight slots 90 and 92 which extend parallel to axis 80 and axes 84 and 82 respectively, and further slots 94 which also extend parallel to the end-faces 70 and 72. The slots open into the passages which are parallel to the axes 82 and 84 and define the pairs of spring leaves.

The structure shown in Figs. 3 to 5 differs substantially from the universal coupling of the prior art in respect of the outline of the passages defining the spring leaves. Whereas in the case of the prior art these passages are of circular cross-section, in the present case they are of the substantially triangular cross-section which has been explained with reference to Fig. 2.

A feature which corresponds to the prior art is that one half of the leaf springs lie in the plane containing the axes 82, 84 and the other half in a plane perpendicular to this plane.

It is of considerable advantage for the longitudinal axes of the individual spring leaves to form the same angle, e.g., an angle of 45°, with plane 98 (Fig. 4) containing the two axes 82 and 84. An embodiment of this arrangement which is thereby produced is shown on Fig .6, which corresponds to the centre portion of Fig. 5. This arrangement of the spring leaves enables favourable symmetry conditions to be obtained.

When applied to driving a gyro rotor, the body 78 forms as stated before the "spider" which is connected to the body 76 by two aligned spring leaf flexure joints, and to the body 74, by the other two aligned spring leaf flexure joints, the gyro rotor thus being able to tilt in all directions relative to the gyro shaft and being coupled to it for joint rotation.

The embodiment of Figs. 3 to 5 is shown again in Fig 7 at a larger scale.

Whereas in the case of the embodiments described before the spring leaves cross each other at right angles, it is also possible for the outline configuration of the passages to be such that the crossing angle of the spring leaves is other than 90° (Fig. 8).

Thus, the resilient universal joint described with reference to Figs. 3 and 5 has four pairs of crossed spring leaves, with each pair defined by four parallel passages E, F, G, H traversing the hollow cylindrical structure from its outer to its inner circumferential face. These four passages correspond to those marked A, B, C and D respectively in Fig. 2.

Various possible ways of forming these passages are made available by modern spark erosion techniques. Thus, the erosion may for example be performed using a tensioned wire which is led through a radial bore in the annular body in a direction parallel to an axis of articulation and which is caused to follow a path which corresponds to the desired outline of a passage. This wire then cuts a core out of the hollow cylindrical structure, the core being thereupon removed, leaving a passage behind.

It is likewise possible to erode, from a radial bore, only the two faces which form a spring leaf, with the result that the passage is in the form of a narrow curved slit of the desired shape in which case no core has to be removed.

Two pairs of crossed spring leaves are provided along each of the two axes 82 and 84 in Fig. 3, with each being defined by a group of four passages E, F, G and H around each of the axes, the four passages forming a group being exactly aligned with the four passages forming the other group around the same axis. Thus, if the length of the erosion wire is made greater than the outside diameter of the hollow cylindrical structure formed by the bodies 74, 76 and 78 then the wire can be passed through the entire structure in a direction parallel to the axis of articulation 82 or 84. If, during the erosion operation, the wire is then fed along a path corresponding to a substantially triangular outline of a passage, it cuts out two aligned cores. If, for example, the wire extends parallel to axis 82, then one core is situated to the right of axis 84 in Fig. 3 and the other to the left. The passages which are joined when the cores are taken out are then exactly aligned with one another. This considerably simplifies manufacture.

Another possibility made available by the erosion technique for producing the passages in the resilient universal joint coupling shown in Fig. 3 to 5 is the use of the electrodes illustrated in Figs. 9 to 11. In this case, a single electrode 112 is used to produce simultaneously the four passages defining a pair of crossed spring leaves. The electrode consists of a conductive bar which has near its end four parallel prismatic spigots 116, 117, 118 and 119 of equal length projecting from a lateral surface of the bar. Their length is greater than the thickness of the wall of the hollow cylinder which forms part 78, i.e., the distance between the outer circumferential wall face and the inner circumferential wall face (Fig. 9). In Fig. 11, adjacent side faces of the spigots 116 to 119 extend at right angles to the side-face of the bar 112 from which they project. The cross-sectional outline of the spigots 116 to 119 can be seen in Fig. 11. The shape of this outline is such that the outline in cross-section of the space 120 between two adjacent spigots is the same as the desired outline in the longitudinal section of a spring leaf.

To carry out the erosion operation, the electrode 112 is brought to the position shown in Figs. 9 and 10 in which the planes containing the axes 82 and 84 pass between the spigots 116 to 119. The electrode 112 is then advanced in the radial direction relative to the body 78 through a conductive liquid, a circuit thereupon being closed by the electrode and spigots. The spigots 116 to 119 penetrate into the work-piece from the exterior and as they do, form passages which between them leave only the material for the crossed spring leaves standing. After the electrode 112 has been withdrawn radially to the starting position shown in Figs. 9 and 10, a pair of spring leaves has been completed. The workpiece is then moved through 90° about its axis 80 relative to the electrode 112, after which the next pair of crossed spring leaves is formed in the same way. When all four parts of crossed spring leaves have been formed, processing of the workpiece from which the coupling is made is completed. In the case of the embodiment of Fig. 6, the positions of the passages E to H alter accordingly.

The method of manufacture described ensures that the planes of the spring leaves situated on the same axis of articulation are exactly in line. This avoids, in a flexure joint, added stiffness which may otherwise occur if opposite groups of four passages were skewed or misaligned.

WHAT WE CLAIM IS:—

1. A flexure joint comprising a first spring leaf extending between a pair of rigid bodies and having its ends rigidly merged therewith at merger points, a second spring leaf extending between said bodies, crossing said first spring leaf and having its ends rigidly merged with said bodies at locations spaced from said merger points, said spring leaves being rigidly connected to each other at the crossing point so as to form a pivot axis extending through said crossing point transversely to said spring leaves.

2. A flexure joint according to claim 1, in which said spring leaves are integral with the rigid bodies.

3. A flexure joint according to claim 1 or 2, in which said spring leaves cross at an angle of 90°.

4. A gyro having a resilient universal coupling comprising a first part connected to the rotor of the gyro and pivotally connected by a first pair of co-axial flexure joints to a spider part, the spider part being pivotally connected by a second pair of co-axial flexure joints to a third part which is in turn connected to the drive shaft of the gyro, the axes of articulation of the two pairs of flexure joints forming orthogonal axes of articulation of the universal joint, and each of the flexure joints comprising crossing spring leaves firmly connected at their ends to the parts with which they are associated, the spring leaves extending transversely of the pivot axis provided by the flexure joint and being subjected to flexure by relative pivotal displacement of the parts connected thereto, the spring leaves being rigidly connected to each other at their crossing point.

5. A gyro as claimed in claim 4, wherein the first part, the spider part and the third part have been formed from a single body.

6. A gyro as claimed in claim 5, wherein the single body from which the parts were formed was a hollow cylindrical structure, the parts being formed by slots in the structure.

7. A gyro according to any one of claims 4 to 6, in which said spring leaves are in one piece with the parts.

8. A gyro according to any one of claims 4 to 7, in which the spring leaves cross at each flexure joint at an angle of 90°.

9. A method of manufacturing a gyro having a resilient universal coupling according to claim 4 in which the spring leaves of each flexure joint are provided by the electrical erosion of four parallel passages each of which adjoins two of the other passages and passes through the part from one side face to the opposite side face, the parts pivotally connected by the flexure joint thereafter being separated by a slot.

10. A method according to claim 6, in which a wire which passes through the passage over its entire length is used as the erosion electrode.

11. A method according to claim 7, in which the wire forms two co-axial passages simultaneously on one eroding pass and thus also forms simultaneously two coaxial flexure joints.

12. A method of producing said passages in a resilient universal coupling according to claim 3, in which each leaf is formed by advancing along an axis of articulation, a tool which erodes material by the use of electrical energy and which matches the shape of the spring leaves.

13. A gyro having a resilient universal coupling substantially as described herein with reference to Figs. 3 to 7 of the accompanying drawings.

14. A method for producing a flexure joint for a gyro substantially as described herein with reference to Figs. 9 to 11 of the accompanying drawings.

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Fig.1

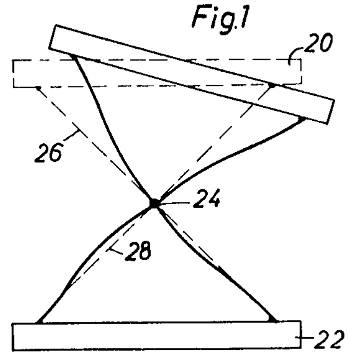
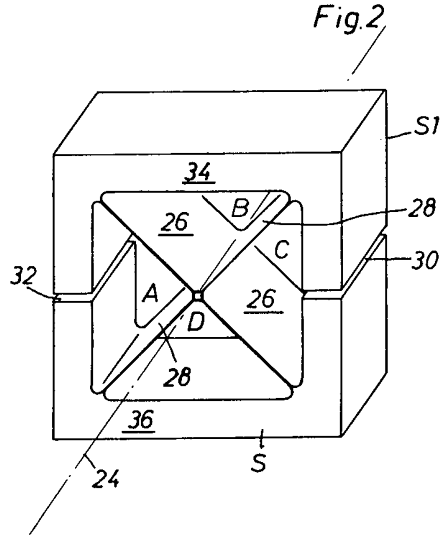


Fig.2



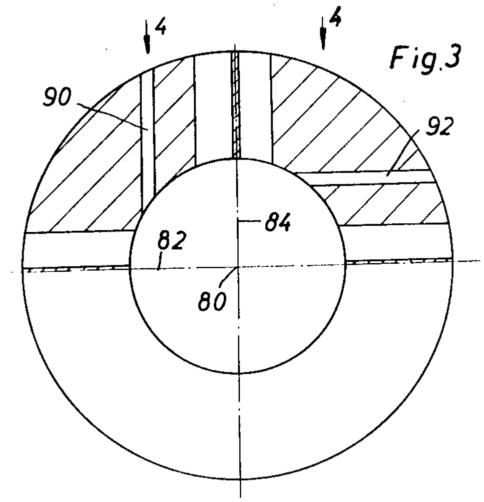


Fig.3

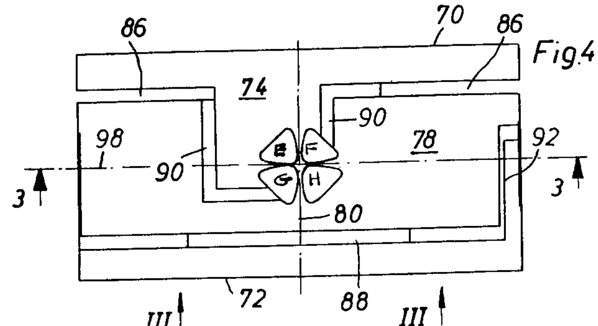


Fig.4

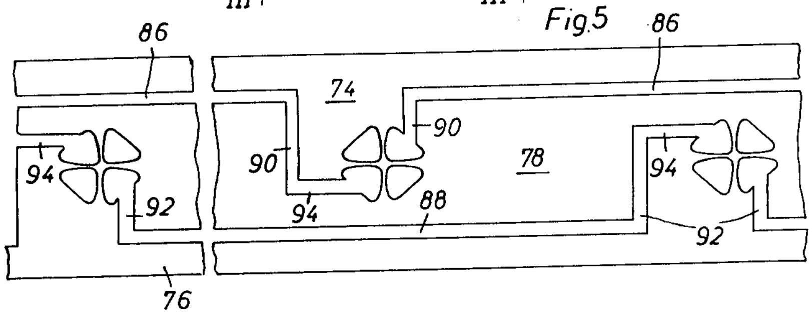


Fig.5

Fig.6

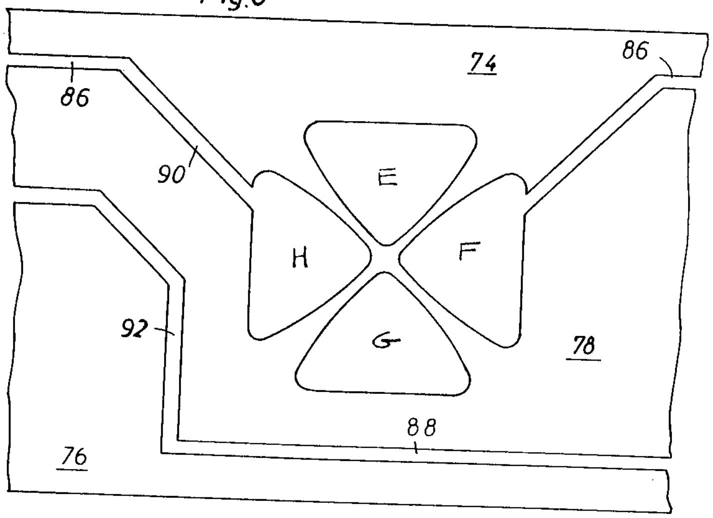


Fig.7

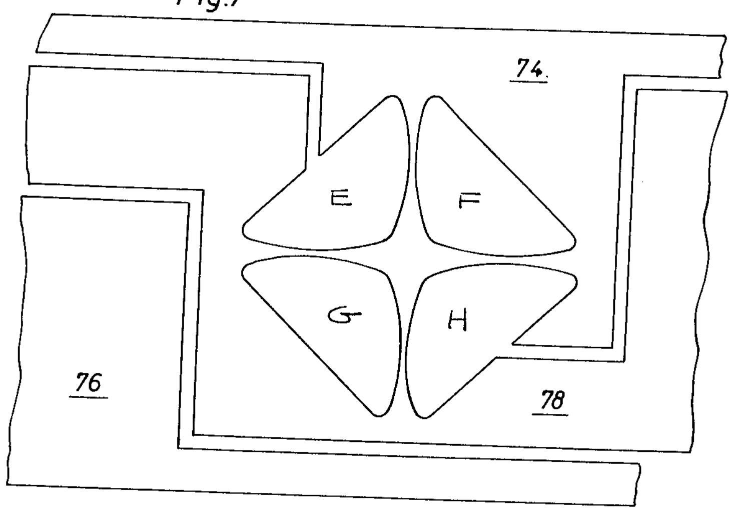
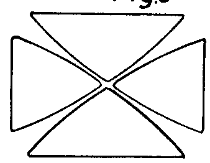


Fig.8



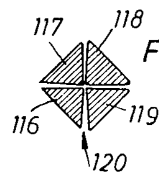


Fig.11

Fig.9

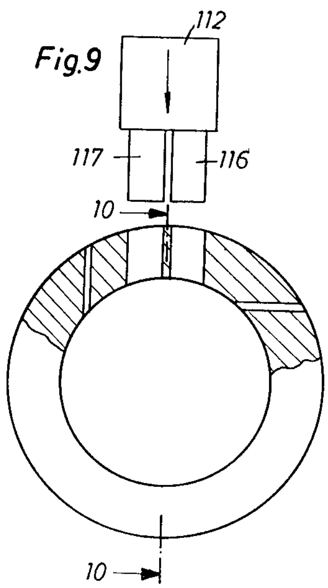


Fig.10