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Figure 1a

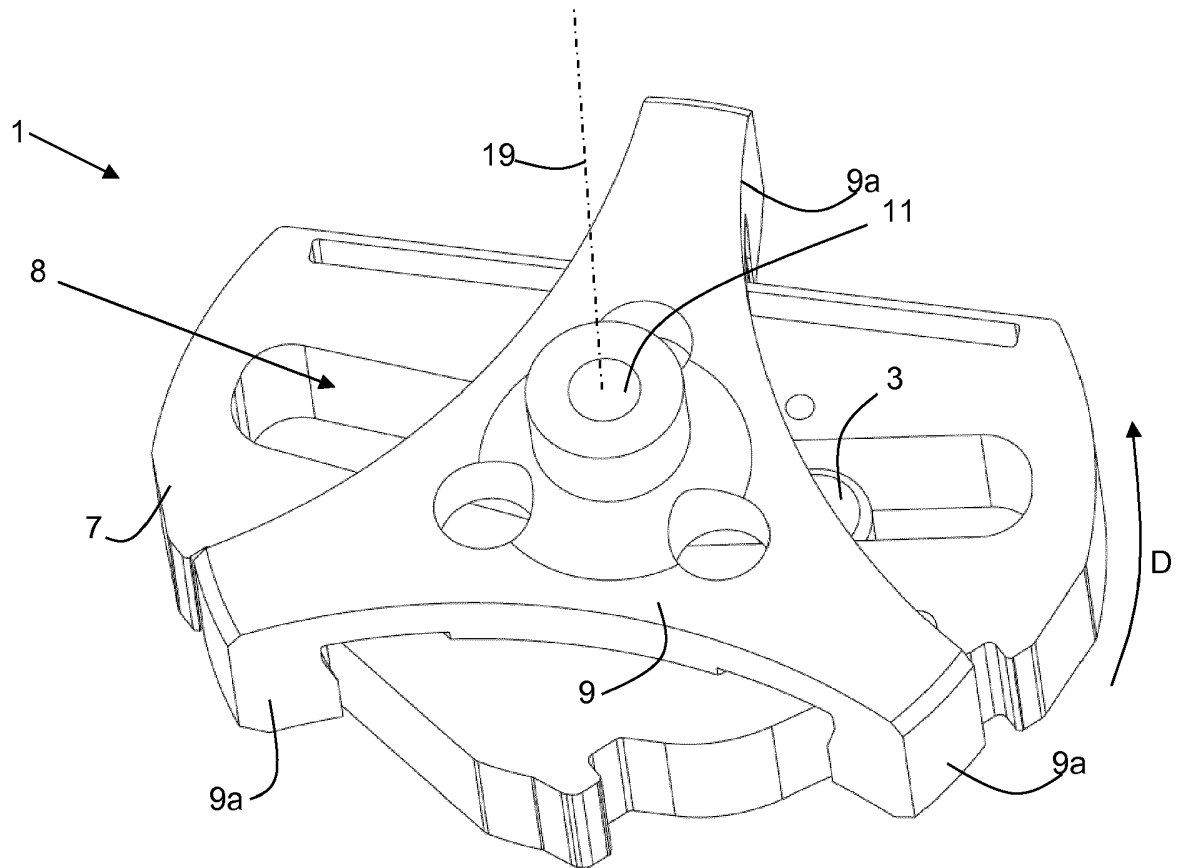


Figure 1b

Description

Technical Field

[0001] The present invention relates to the technical field of mechanical oscillators. More particularly, it relates to a crank arrangement for continuously driving mechanical oscillators such as horological oscillators.

State of the art

[0002] Although the most common type of horological oscillator today is by far and away the balance/hairspring oscillator driven by a so-called Swiss lever escapement, crank-driven oscillators have previously been explored in the prior art.

[0003] For instance, US1222757 describes a conical pendulum driven by an eccentric crank arm arranged proximate to the pendulum's point of suspension, the rotational movement of the pendulum governing the angular velocity of the driving crank arm. FR359117 describes a similar but inverted arrangement in which the edge of an arm driven rotationally by the movement exerts a force on the tip of the pendulum bob to drive it in a substantially circular path. CH5564 describes a similar arrangement, in which the lever comprises a slit in which the tip of the pendulum bob is situated. In each of these cases, the lever or arm drives the pendulum, and its movement governs the speed at which the driving lever can rotate about its axis of rotation.

[0004] Another type of crank-driven oscillator is described in US1595169. In this document, an inertial mass supported by three flexible blades is driven in a (quasi-) circular path by means of a simple eccentric pin and connecting rod crank, itself driven by a spring motor.

[0005] In the field of wristwatches, FR1044957 describes a simple crank-driven balance wheel, in which a rod is connected by eccentrically-arranged pins to both a disk driven by a spring motor and to the balance wheel such that rotation of the disk causes a back-and-forth oscillation of the balance wheel about its axis of rotation. This oscillation of the balance wheel serves as a governor to limit the angular velocity of the disk and thereby to regulate the speed of the movement.

[0006] Such arrangements were generally unsatisfactory due to poor isochronism and fell into abeyance until relatively recently, when interest in crank-driven oscillators was re-awakened.

[0007] For instance, US9465363 describes an oscillator system comprising four coupled oscillators, each comprising an inertial mass supported by a flexure pivot which also provides the restoring force for each oscillator. The four oscillators are arranged in a rotationally-symmetrical configuration with their respective axes of rotation parallel to each other, and they are each connected to a central driving ring by means of a respective rigid lever and a long, flexible blade. By driving the ring by means of a crank in a circular or oval pathway situated

in a plane perpendicular to the axes of rotation, the individual oscillators are caused to oscillate back and forth. As before, this oscillation regulates the angular velocity at which the crank can turn.

[0008] WO 2015/104692 and WO 2015/104693 describe a number of variants of two-degree-of-freedom oscillators, both acting in a single plane or in rotation. In many embodiments, the oscillator comprises a driving pin which penetrates into a radial slot formed in a crank arm (see for instance figure 26 of WO 2015/104692 or figure 13 of WO 2015/104693).

[0009] In order to be self-starting without requiring the oscillator to be deliberately perturbed e.g. by acting directly thereupon or by shaking the timepiece, and indeed to prevent the crank from rotating uncontrollably, the pin must be prevented from being in a position in which it is substantially coaxial with the axis of rotation of the crank when the oscillator is at rest.

[0010] Furthermore, in such simple arrangements, if the oscillator is suddenly stopped, the elastic restoring force of the oscillator will cause the pin to impact the proximal extremity of the slot in the crank (i.e. the extremity nearest the axis of rotation of the crank). This can cause significant shocks, which can mechanically damage the pin, the proximal end of the slot or the bearing of the crank, or any combination of them. In addition, a mechanical shock to the oscillator which causes the pin to impact the proximal extremity of the slot can have a similar damaging effect.

[0011] The obvious solution to this problem would be to provide an elastic stop at or near the proximal extremity of the slot, for instance as shown in the arrangement illustrated in figures 7a and 7b. The former of these figures is an isometric view of such a crank arrangement 101, and the latter is an isometric cutaway view illustrating also the pin 103 in contact with the elastic stop 110. In this variant, the slot 108 is formed between two plates 112 screwed to a spacer 114 which holds the plates 112 parallel and a predetermined distance apart. The spacer 114 is integral with an interface element 116 arranged to be mounted on an arbor (not illustrated) such that the crank arrangement 101 can rotate about an axis of rotation 118, the slot 108 extending radially with respect to the axis 118. The elastic stop 110 is formed here as a cantilevered blade spring extending along the axis of rotation 118 when in its neutral position, although different positions are possible, particularly one biased towards the distal end of the working-side of the slot 108, and different blade orientations are possible. Alternatively, the elastic stop 110 can be formed by e.g. an elastomeric or rubber insert or similar.

[0012] As can be seen in figure 7b, the cantilevered blade spring can be arranged such that the pin can momentarily pass through a position in which it is coaxial with the axis of rotation of the crank. The spring is arranged to restore the pin to a position which is eccentric with respect to the axis of rotation of the crank, on the correct working side thereof such that, when the oscillator

is re-started, the pin can travel along the slot 108 and the crank cannot "free-wheel", i.e. rotate freely without being influenced by the oscillator when staying at the kinematic singularity (i.e. with the pin coaxial with crank rotation axis). In such an arrangement, although the pin can momentarily be coaxial with the axis of rotation of the crank, it cannot remain in such a position due to the action of the spring. As a result, the spring absorbs shocks and prevents the pin from stopping in the singular central position. Additionally, the spring locates the resting position of the pin at a position which is very close to the rotation axis of the crank, which makes the self-starting energy of the system very low, hence increasing the chances self-starting of the system when driving torque is restored after the system has been stopped. Indeed, self-starting happens when the driving torque is greater than friction torque of the pin-crank interface, the friction torque being at a minimum when the pin is the closest to the rotation axis of the crank.

[0013] However, in view of the relatively small dimensions of a crank of a size adapted for use in a wristwatch, manufacture and assembly of such a spring-based shock absorbing arrangement is difficult and hence expensive. Indeed, such an arrangement generally implies a multi-part crank construction such as that illustrated, which can require difficult assembly steps.

[0014] An object of the present invention is hence to at least partially overcome the above-mentioned drawbacks of the prior art.

Disclosure of the invention

[0015] More specifically, the invention relates to a crank arrangement for driving a pin-driven mechanical oscillator having two degrees of freedom in either rotation or in translation, as defined in claim 1. Such an oscillator typically comprises an inertial mass displaceable against a restoring force supplied by elastic elements such as springs, arranged such that it the inertial mass can oscillate with two degrees of freedom in translation or in rotation.

[0016] This crank arrangement comprises a crank element arranged to be rotationally driven about an axis of rotation by means of a mechanical source of energy such as a spring motor housed in a barrel, the crank element comprising a crank slot adapted to receive a driving pin arranged to cause the inertial mass of said oscillator to oscillate in response to rotation of said crank element under the torque provided by the mechanical source of energy. The pin can for instance be fixed directly or indirectly on said inertial mass, or on an element connected thereto.

[0017] The crank slot comprises a driving section at least partially delimited by a drive surface and by a guide surface situated opposite at least part of the drive surface. Both of these surfaces can be straight or curved (concave or convex), and said drive surface is arranged to drive said pin in response to rotation of said crank element. In

the case in which the drive surface is straight, it can extend parallel to a radial direction of said crank element considered with respect to the axis of rotation.

[0018] According to the invention, the crank slot further comprises a return section adjoining said driving section, said return section being delimited by:

- a braking surface adjoining said driving surface so as to form an obtuse interior angle therewith (when viewed from the interior of the slot; in the case in which the driving surface is curved, this angle is considered with respect to a tangent thereto at the point where the two surfaces join), and
- a return surface arranged at least partially opposite said braking surface at an acute angle (which can be zero or nonzero) with respect thereto.

[0019] This crank slot is furthermore shaped such that said axis of rotation is situated in said return section at a distance of less than one radius of said drive pin from said braking surface, that is to say considered at the closest point of the braking surface to the axis of rotation.

[0020] As a result, in case of shock or sudden stopping of the oscillator, the pin rides up the angled braking surface and is decelerated gently rather than impacting the end of the slot as in a conventional linear crank slot construction. This significantly reduces the stress on the bearing and on the crank element in such a situation. Furthermore, due to the position of the axis of rotation with respect to the braking surface, the axis of the pin is prevented from ever being coincident with the axis of rotation of the crank arrangement, and hence freewheeling of the crank arrangement cannot occur, and the oscillator can self-start from a stopped condition. Indeed, the angle of the braking surface with respect to the drive surface ensures that the pin, at rest, is situated towards the drive section, making self-starting more likely. Finally, the angle of the return surface with respect to the braking surface contributes to returning the pin to the drive surface in case of a shock causing it to enter into the return section.

[0021] Advantageously, said obtuse interior angle between the drive and braking surfaces is between 120° and 180°, preferably between 150° and 170°

[0022] Advantageously, said nonzero acute angle interior angle between the abutment and return surfaces is between 0° (i.e. the surfaces are parallel) and 10°, preferably between 2° and 5°

[0023] Advantageously, said braking surface comprises a curved portion adjoining said drive surface. This curved portion may be a radius which is tangential to the drive surface and to the rest of the braking surface, or any other convenient curved form. This minimises the impact of the pin on the braking surface when it enters into contact therewith in case of shock or sudden stopping of the movement.

[0024] Advantageously, said curved portion has a radius of curvature greater than the driving pin radius R_p .

Practically, a circular fillet with radius at least 10% greater than the driving pin radius can be used, ideally around 10% to 20% greater.

[0025] Advantageously, said return surface meets said guiding surface at a point directly opposite said drive surface, i.e. at a point which intersects a normal to the drive surface. As a result, the guiding surface is shorter than the drive surface.

[0026] Advantageously, said slot is configured such that, under normal operation, said pin remains out of contact with an end surface joining said drive surface to said guiding surface. This prevents the pin being forced to the end of the driving section of the slot at its maximum kinetic energy, which would cause it to be over-driven such that it would rotate at a frequency greater than the natural frequency of the oscillator.

[0027] Advantageously, said crank slot is configured such that, under the greatest anticipated shock in use, said pin remains out of contact with an end surface joining said braking surface to said return surface. The pin is hence prevented from causing impact damage to said end surface.

[0028] Advantageously, said guiding surface is substantially parallel to said drive surface so as to best guide the pin bilaterally during normal operation.

[0029] This crank arrangement can of course be incorporated in a timepiece movement so as to drive a two degree of freedom oscillator by means of a driving pin connected directly or indirectly with said oscillator. This movement can be incorporated in a timepiece such as a wristwatch, pocket watch, clock or similar.

Brief description of the drawings

[0030] Further details of the invention will appear more clearly upon reading the description below, in connection with the following figures which illustrate:

- Figures 1a and 1b: isometric schematic views of a crank arrangement according to the invention together with the associated driving pin, from two different angles;
- Figure 2: a schematic view of the crank arrangement of the invention integrated into a timepiece movement;
- Figure 3: a schematic overview of the various parts of the crank slot;
- Figure 4: another schematic view of the various sections of the crank slot;
- Figures 5 and 6: dimensioned drawings of different forms of crank slot; and
- Figures 7a and 7b: an isometric exterior view and an isometric cutaway view of an obvious solution to the problem of driving pin impact on the crank.

Embodiments of the invention

[0031] Figures 1a and 1b illustrate a nonlimiting em-

bodiment of a crank arrangement 1 according to the invention, together with a driving pin 3 illustrated in isolation. Figure 2 illustrates a timepiece movement 23 in which this crank arrangement 1 is integrated, the movement 23 also comprising a source of mechanical energy M such as a spring motor kinematically linked to the crank arrangement 1 by a gear train 17 (represented schematically by a dotted arrow), which also drives indicator means 25 as is generally known.

[0032] The driving pin 3 is arranged to be driven by the crank arrangement 1, and to this end is fixed directly or indirectly to a part of an oscillator 5 in order to drive the latter in oscillation according to two degrees of freedom in translation and/or rotation.

[0033] Oscillator 5 has been illustrated analogously to that of figure 26 of WO 2015/104692 or figure 13 of WO 2015/104693, and hence comprises an inertial mass 5a which carries the pin 3 and which is attached to a frame 6 by means of springs. These springs may for instance be formed as a flexure pivot arrangement (or any other convenient spring arrangement) which provides a restoring force and guides the inertial mass 5a such that it can translate along two perpendicular axes of displacement. The other embodiments of oscillators disclosed in these documents, or equally in EP3339969, can also be applied here, irrespective of whether they relate to translational or rotational inertial masses with two degrees of freedom in rotation or translation. In any case, it should be noted that the inertial mass constitutes at least 75%, preferably 90%, further preferably 95% of the inertia of the oscillator.

[0034] Alternatively, the oscillator 5 may be of the type described in US9465363, the pin being fixed into the central driving ring by any appropriate means. Indeed, the crank arrangement 1 of the present invention can be used with any known two degree of freedom crank-driven oscillator, and is not limited to those mentioned above.

[0035] In the illustrated embodiment, the crank arrangement 1 comprises a slotted crank element 7 and an interface element 9. The crank element 7 is provided with a crank slot 8 arranged to receive the drive pin 3 such that this latter can slide therein, and the interface element 9 is arranged to support the crank element 7 and to interface with the remainder of the movement 23. To this end, the interface element 9 comprises an axial opening 11 arranged to be fixed to an arbor 13 e.g. by force fitting, bonding, welding, pinning, riveting or similar, this arbor 13 defining an axis of rotation 19 and having a gear wheel 15 fixed thereupon by similar means, as is generally known.

[0036] The interface element 9 furthermore comprises three arms 9a designed to support the crank element 7, this latter being clipped into the interface element 9 between the three arms 9a, and held in place by a lug 7a elastically connected to the remainder of the crank element 7 by a pair of blade springs 7b integrally-formed therewith. These blade springs 7b urge the lug 7a to press against the arms 9a, and thereby causing a significant friction force fixing the crank element 7 into the interface

element 9.

[0037] This arrangement is particularly advantageous in the case in which the crank element 7 is made of a brittle material (i.e. one which does not undergo plastic deformation before breaking) such as silicon, silicon oxide, silicon nitride, silicon carbide, alumina (ruby, sapphire, corundum etc.), diamond-like carbon, glasses, ceramics, glass-ceramics, brittle steel alloys, certain metallic glasses or similar. These materials may be monocrystalline, polycrystalline, nanocrystalline, microcrystalline or amorphous as appropriate for the material(s) in question, and can be micromachined by means of processes such as LIGA, sintering in a mould, masking and etching from a wafer or plate of material by wet (chemical) or dry (DRIE, plasma, laser, reactive ion, etc.) etching techniques as appropriate for the given material. The interface element can be formed by e.g. multilayer micromachining techniques, 3D printing (e.g. selective laser melting, selective laser sintering or similar), conventional machining from solid metal or similar.

[0038] It goes without saying that other arrangements are possible. For instance, the crank element 7 can simply be force fitted, welded, soldered, glued, pinned, riveted or similar to the interface element, without use of a detente arrangement. Furthermore, the crank arrangement 1 can be monobloc, being formed by conventional machining from solid or by multi-layer micromachining techniques.

[0039] In any case, the overall outside form of the crank element 7 can be chosen at will, and can be e.g. circular, polygonal, or any desired shape.

[0040] However it is constructed, the crank arrangement 1 can be supported by any convenient known bearing arrangement 21 (illustrated schematically) such that it can rotate about its axis of rotation 11.

[0041] The core of the present invention lies in the particular form of the crank slot 8, and it should be noted that although the crank slot 8 traverses the entire thickness of the crank element 7, this is not obligatory, particularly (but not exclusively) in the case in which the entire crank arrangement 1 is formed as a single piece.

[0042] Figure 3 illustrates in detail the shape of the crank slot 8, the driving pin 3 being shown at 3 different positions indicated as positions A, B and C which will be described below. In the orientation of figure 3, the crank element 7 is arranged to be driven in the counter-clockwise direction, as indicated by the arrow D.

[0043] Since the crank slot 8 is delimited by its side-walls, these will be described in sequence, with reference to the axis of rotation 19 as datum point.

[0044] As is common with all slot-type cranks, crank slot 8 comprises a drive surface 8a which extends parallel to a radius R, at a distance r therefrom which substantially corresponds to the radius R_p of the driving pin 3. As a result, as the driving pin 3 is driven by drive surface 8a and slides along it when the oscillator is in normal operation, the central axis of the pin will travel along radius R. However, it is not excluded that the drive surface 8a

can in principle be arranged at a distance greater than or less than R_p from the radius R, at which point the axis of the pin 3 will travel along a direction parallel to radius R when it is in contact with the drive surface 8a. Furthermore, the drive surface 8a can be curved in a convex or concave manner.

[0045] After the distal extremity of the drive surface 8a, the sidewall curves around to form an end surface 8b of the slot 8 on the driving side thereof, and hence defines a stop. The maximum distance from the centre of rotation that the axis of the pin 3 can have is indicated on figure 3 as L_1 . To prevent the oscillator 5 being over-driven by the crank arrangement 1, which would accelerate the oscillator 5 above its natural frequency, the length L_1 should be chosen such that when the maximum elastic potential energy of the oscillator 5 during normal operation is attained (maximum distance of the pin 3 from the centre), the pin 3 does not contact the end surface 8b.

[0046] The sidewall surface 8c which is situated opposite the drive surface 8a and parallel thereto is a guiding surface and defines, together with the portion of the drive surface 8a immediately opposite thereto, a parallel section of the slot 8. This surface 8c is situated a distance $r + L_6$ from the radius R, where L_6 is the working play enabling the pin 3 to slide in the parallel section of the slot 8. In the ideal theoretical case with perfectly smooth operation, the pin 3 would not come into contact with surface 8c. However, in reality the motion is jittery and minor shocks often occur. As a result, the pin 3 constantly rebounds between the sidewalls of the parallel section. While the pin 3 is between positions B and C, therefore, it is bilaterally guided by the slot 8. However, when the pin 3 is in contact with the drive surface 8a at a point which is not directly opposite the parallel surface 8c, it is not constrained within the parallel section of the slot 8 and is hence only unilaterally guided. The distance L_5 is that between the centre of rotation 19 and the axis of the pin 3 when it is in contact with the drive surface 8a at the very start of the parallel section (position B), i.e. where the axis of the pin 3 is directly opposite the vertex q which delimits the start of guiding surface 8c.

[0047] As a final point regarding the guiding surface 8c, although it is distinctly advantageous that this surface be substantially parallel to drive surface 8a, this is not obligatory, and it could alternatively be situated at an angle thereto and/or be curved in a convex or concave manner. In such a case, the pin 3 would have more play in the slot 8 towards the axis of rotation 19 than towards the braking surface 8b, and hence the bilateral guidance of the pin would be worse at lower oscillator energies. In such a configuration the term "parallel section" would naturally be inappropriate, and can be generalised as a "bilaterally guided section".

[0048] Looking now to the proximal extremity of the drive surface 8a, i.e. its extremity which is closest to the axis of rotation 19, drive surface 8a stops short of the point at which the axis of the pin 3 would otherwise be coincident with the axis of rotation 19, in order to prevent

the crank arrangement 1 from being able to turn without also acting on the pin 3. This also permits the system to self-start once a driving couple is reapplied to the crank arrangement 1.

[0049] In order to prevent the axis of the pin 3 from being coaxial with the axis of rotation 19 of the crank arrangement 1, the point p on an braking surface 8d which is closest to the axis of rotation 19 (i.e. the point on the surface 8d at which the normal to said surface intersects the axis of rotation 19) is situated at a distance of less than the radius R_p of the pin 3 therefrom. As a result, the distance from the centre of rotation 19 to the closest point at which the axis of the pin 3 can be situated on radius R is indicated as L_2 , and to achieve this effect, braking surface 8d extends from the proximal extremity of the drive surface 8a with its straight portion at an acute angle α to the extension thereof, such that the interior angle between the surfaces 8a and 8d is obtuse when viewed from inside the slot 8. The junction between these two surfaces 8a, 8d is ideally formed as a radius which is tangential to both surface 8a and to the remainder of surface 8d, in order to provide a smooth transition between the two and to minimise shocks, but this is not obligatory, and other forms of transition are possible. Although the majority of the length of the braking surface 8d, aside from the radiused portion immediately adjacent to the drive surface 8a is planar, it can also be curved, in which case angle α is considered at every tangent to the braking surface 8d. Furthermore, in the case in which the drive surface 8a is curved, α is considered with respect to a tangent to the drive surface 8a where it meets the radius defining the start of the braking surface 8d.

[0050] As a result, in case of shock in a direction which causes the pin 3 to approach and pass the axis of rotation 19, the pin 3 will travel down the parallel section of the slot 8, impact the braking surface 8d, and ride along this surface, attaining a distance which is a function of the kinetic energy of the oscillator 5 and the magnitude of the shock.

[0051] As the pin 3 rides along braking surface 8d, the acute angle α of this latter with respect to the plane of the drive surface 8a will cause the pin to 3 to decelerate angularly with respect to the crank arrangement 1 until such time that it has slowed sufficiently that the rotation of the crank arrangement 1 starts to "overtake" the pin. At this point, the pin 3 then leaves the braking surface 8d and crosses to the return surface 8e, which is situated opposite the braking surface 8d and which adjoins the guiding surface 8c at a reflex interior angle thereto (considered with respect to the interior of the slot 8 and clearly visible on the figures at point q), once the return surface 8e has "caught up" with the pin 3. This vertex can be radiused or otherwise curved if desired.

[0052] The return surface 8e is straight and is at a zero or nonzero acute angle β to the braking surface 8d, this angle being preferably situated between 0° and 10° , further preferably between 2° and 5° . As a result, once the pin 3 is in contact therewith, further rotation of the crank

arrangement 1 causes the pin 3 to return along the return surface 8e in the direction of the drive surface 8a, the pin 3 leaving the return surface before reaching surface point q (junction of surface 8e with the surface 8c) and arriving on the drive surface 8a at a point which may vary in function of the velocity of the pin 3 and the angular velocity of the crank arrangement 1.

[0053] The portion 8f of the sidewall of the slot 8 which joins braking surface 8d and return surface 8e forms the end surface of the return portion of the slot 8. In a similar manner to the end surface 8b of the driving section of the slot 8, the end surface 8f of the return portion also forms an abutment. When the pin 3 is in abutment here, its axis (indicated with a "+" symbol) is at a distance L_4 from the centre of rotation 19. However, the length of the surfaces 8d and 8e is ideally chosen such that the pin 3 does not reach abutment under the worst-case scenario shock anticipated. L_1 and L_4 can be the same or different.

[0054] In the case of the movement suddenly being stopped, the pin 3 will travel down the parallel section of the slot 8, impact the braking surface 8d, and ride along this surface, attaining a distance which is a function of the kinetic energy of the oscillator 5. The pin 3 will then oscillate within the slot 8 either side of the centre of rotation 19 at least partly in contact with the braking surface 8d and the drive surface 8a, until such time as all of the kinetic energy of the oscillator has been expended. When this has occurred, the pin 3 ends up at rest at position A, which represents the state of minimum stored elastic energy of the oscillator 5. In this position, the axis of the pin 3 is situated at a distance L_0 from the axis of rotation 19. In this position, the pin 3 is maintained in contact with the braking surface 8d under the influence of the oscillator's springs 5b. The component of the distance L_0 of its axis from the axis of rotation 19 considered parallel to the radius R is defined as L_3 , on the drive surface 8a side of the axis of rotation 19.

[0055] Due to the axis of the pin 3 being situated on the driving side of the axis of rotation 19 when at rest (position A, i.e. slightly displaced from the axis of rotation 19 in the direction of the end surface 8b), self-starting is made more likely when the movement starts again, which causes the pin 3 to move along the braking surface 8d until it reaches the drive surface 8a again.

[0056] As can be seen from the foregoing and with further reference to figure 4, the slot 8 is hence divided into a driving section and a return section, delimited on figure 4 by means of the line A-A which intersects on the one hand the vertex between surfaces 8c and 8e, and on the other hand the end of the drive surface 8a.

[0057] The driving section is hence delimited by line A-A and surfaces 8a, 8b and 8c, the pin 3 being situated in this section during normal operation. This section incorporates not only the parallel section which bilaterally guides the pin 3, but also the triangular section between the parallel section and the line A-A in which the pin 3 is unilaterally guided, and when the axis of the pin 3 is in this section, it can be driven by the crank arrangement 1.

[0058] The return section is contiguous with the driving section and is delimited by line A-A and surfaces 8d, 8e and 8f. This section serves to return the pin 3 to the driving section in case of stopping and restarting the movement, or in case of a shock in a direction which causes the pin 3 to enter into the return section.

[0059] Figures 5 and 6 illustrate concrete examples which have been experimentally tested. In each of these examples, the pin 3 has a diameter of 398 μm (i.e. R_p is 199 μm), and a maximum amplitude of 1.23mm. The values of L_0 to L_6 , α , β and the working play of the pin 3 in the parallel section of the slot 8 are indicated in the table below:

Dimension	Figure 5	Figure 6
L_0	24 μm	50 μm
L_1	1.23 mm	1.23 mm
L_2	80 μm	160 μm
L_3	8 μm	17 μm
L_4	1.23 mm	1.23 mm
L_5	430 μm	528 μm
L_6	15 μm	15 μm
α	19.5°	19.5°
β	3.5°	3.5°

[0060] As a further note, it should be underlined again that the above-described crank arrangement functions not only with translational oscillators, in which the axis of the driving pin 3 remains parallel to the axis of rotation 19 of the crank arrangement, but also to rotational oscillators such as those disclosed in EP3339969. In such arrangements, the axis of the pin inclines slightly with respect to the axis of rotation 19, this inclination being compensated for by means of appropriate tolerancing of the slot 8, particularly insofar as it concerns the dimension L_6 , which is the working play in the parallel section.

[0061] Although the invention has been described in terms of specific embodiments, variations thereto are possible without departing from the scope of protection as defined in the appended claims.

Claims

1. Crank arrangement (1) for driving a pin-driven two degree of freedom mechanical oscillator (5), comprising:

- a crank element (7) arranged to be rotationally driven about an axis of rotation (19) by means of a mechanical source of energy (M),
- a crank slot (8) provided in said crank element, said crank slot being adapted to receive a driving

pin (3) arranged to cause an inertial mass (5a) of said oscillator (5) to oscillate in response to rotation of said crank element (7),

wherein said crank slot (8) comprises a driving section at least partially delimited by a drive surface (8a) and by a guiding surface (8c) situated opposite at least part of said driving surface (8a), said drive surface (8a) being arranged to drive said pin (3) in response to rotation of said crank element (7);

characterised in that said crank slot (8) further comprises a return section adjoining said driving section, said return section being delimited by:

- a braking surface (8d) adjoining said driving surface (8a) so as to form an obtuse interior angle ($180^\circ - \alpha$) therewith,
- a return surface (8e) arranged opposite said braking surface (8d) at an acute angle (β) with respect thereto,

wherein said crank slot is (8) configured such that said axis of rotation (19) is situated in said return section at a distance of less than one radius (R_p) of said drive pin (3) from said braking surface (8d).

2. Crank arrangement (1) according to the preceding claim, wherein said obtuse interior angle ($180^\circ - \alpha$) is between 120° and 180° , preferably between 150° and 170°
3. Crank arrangement according to the preceding claim, wherein said nonzero acute angle interior angle (β) is between 0° and 10° , preferably between 2° and 5°
4. Crank arrangement (1) according any the preceding claim, wherein said braking surface (8d) comprises a curved portion adjoining said drive surface (8a).
5. Crank arrangement (1) according to the preceding claim, wherein said curved portion has a radius of curvature greater than the radius R_p of said driving pin (3).
6. Crank arrangement (1) according to any preceding claim, wherein said return surface (8e) meets said guiding surface (8c) at a point (q) directly opposite said drive surface (8a).
7. Crank arrangement (1) according to any preceding claim, wherein said crank slot (8) is configured such that, under normal operation, said pin (3) remains out of contact with an end surface (8b) joining said drive surface (8a) to said guiding surface (8c).
8. Crank arrangement (1) according to any preceding claim, wherein said crank slot (8) is configured such

that, under the greatest anticipated shock in use, said pin (3) remains out of contact with an end surface (8f) joining said braking surface (8d) to said return surface (8e).

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9. Crank arrangement (1) according to any preceding claim, wherein said guiding surface (8c) is substantially parallel to said drive surface (8a).

10. Crank arrangement (1) according to any preceding claim, wherein said guiding surface (8c) is shorter than said drive surface (8a).

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11. Timepiece movement (23) comprising a two degree of freedom oscillator (5) and a crank arrangement (1) according to any preceding claim, said crank arrangement (1) being arranged to drive said oscillator (5) by means of a driving pin (3) connected with said oscillator, said driving pin (3) interacting with said driving slot (8).

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12. Timepiece comprising a timepiece movement (23) according to the preceding claim.

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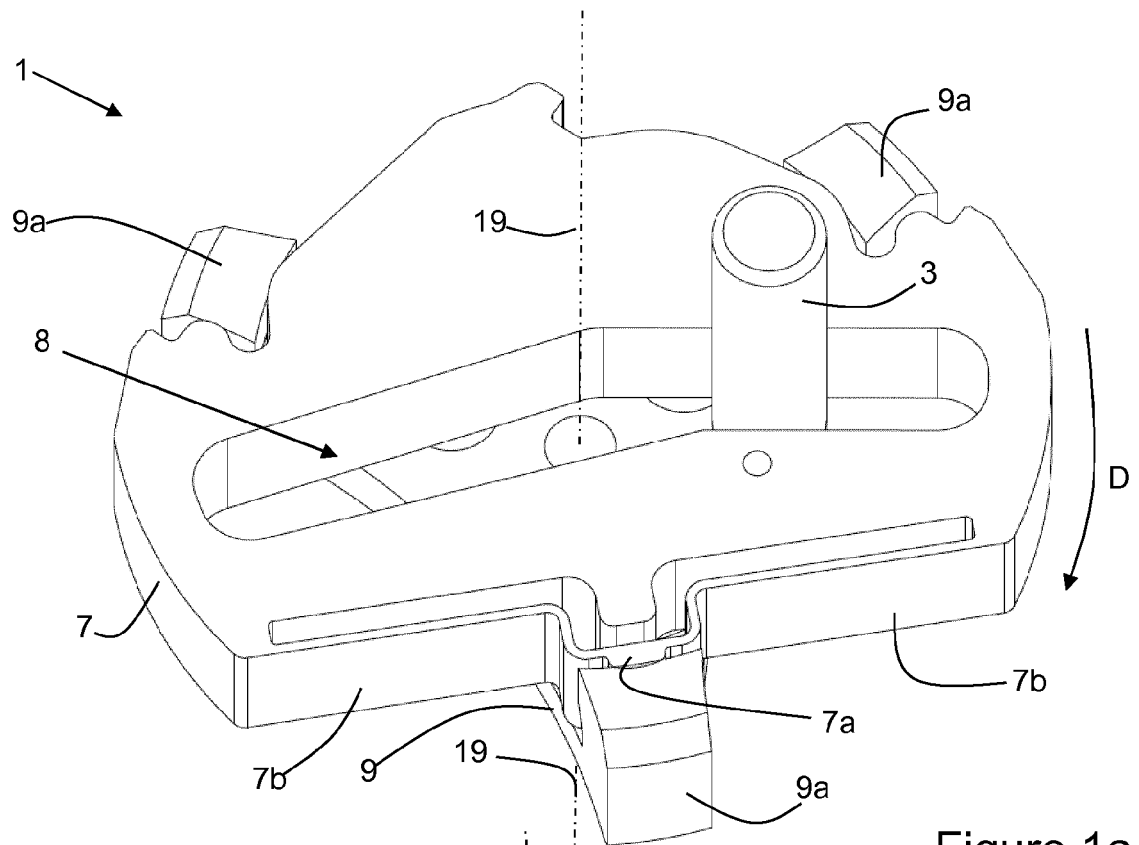


Figure 1a

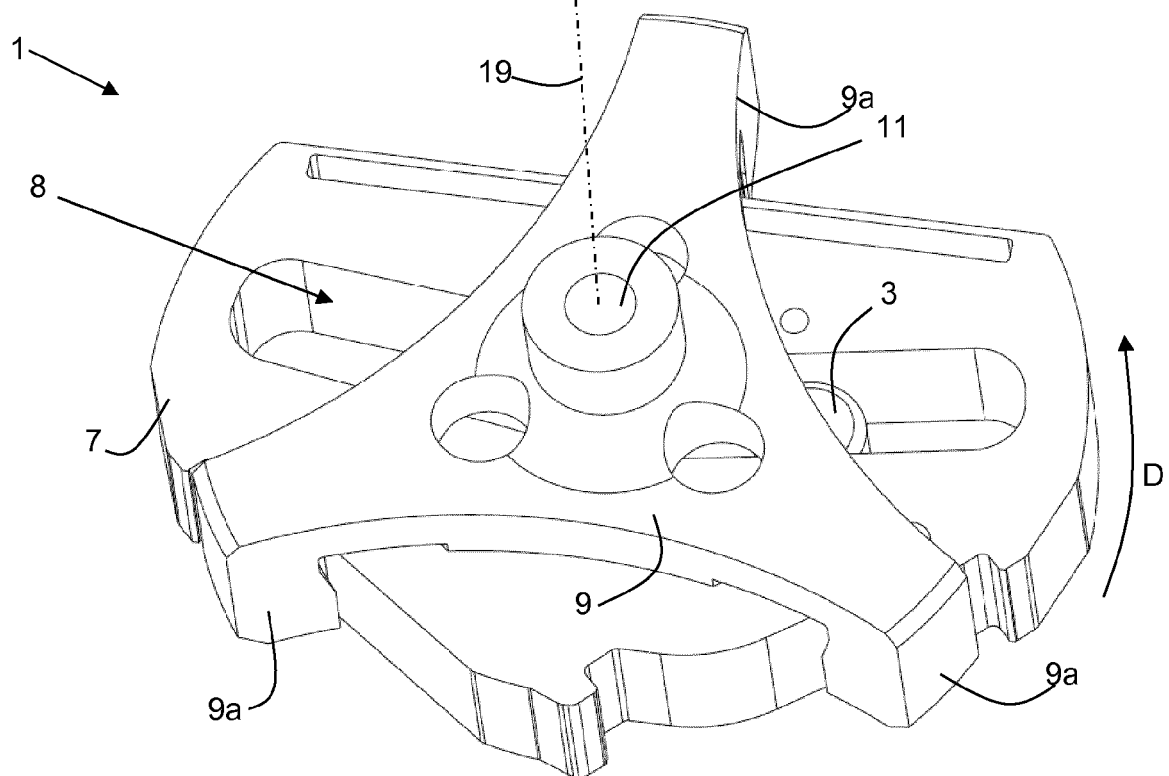
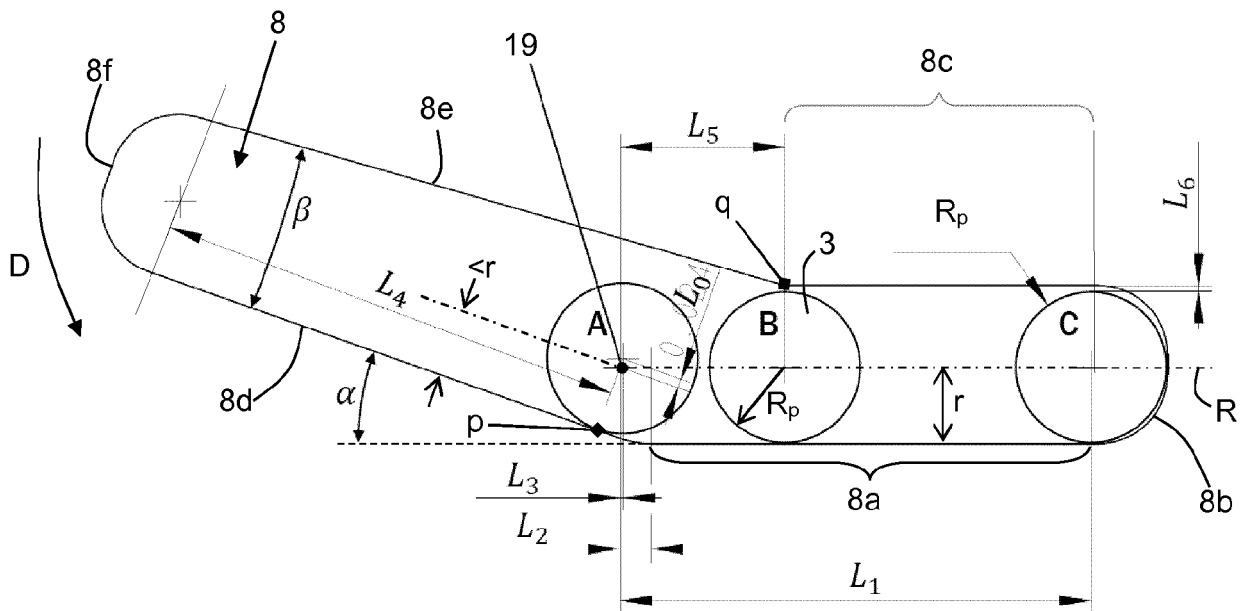
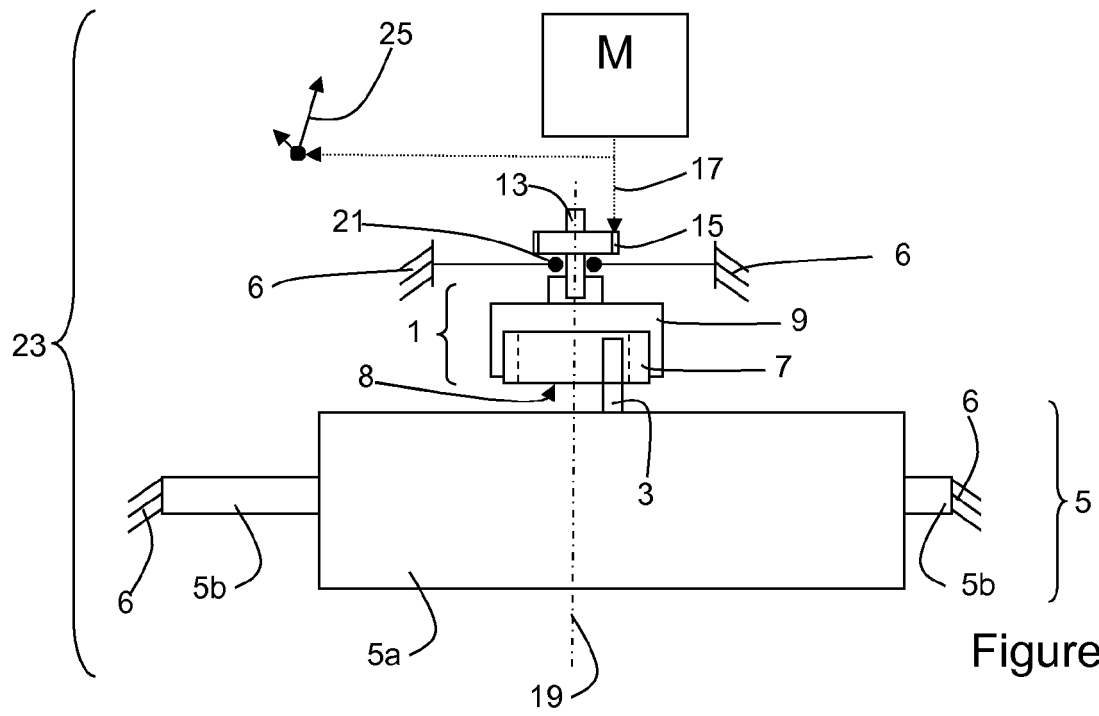


Figure 1b



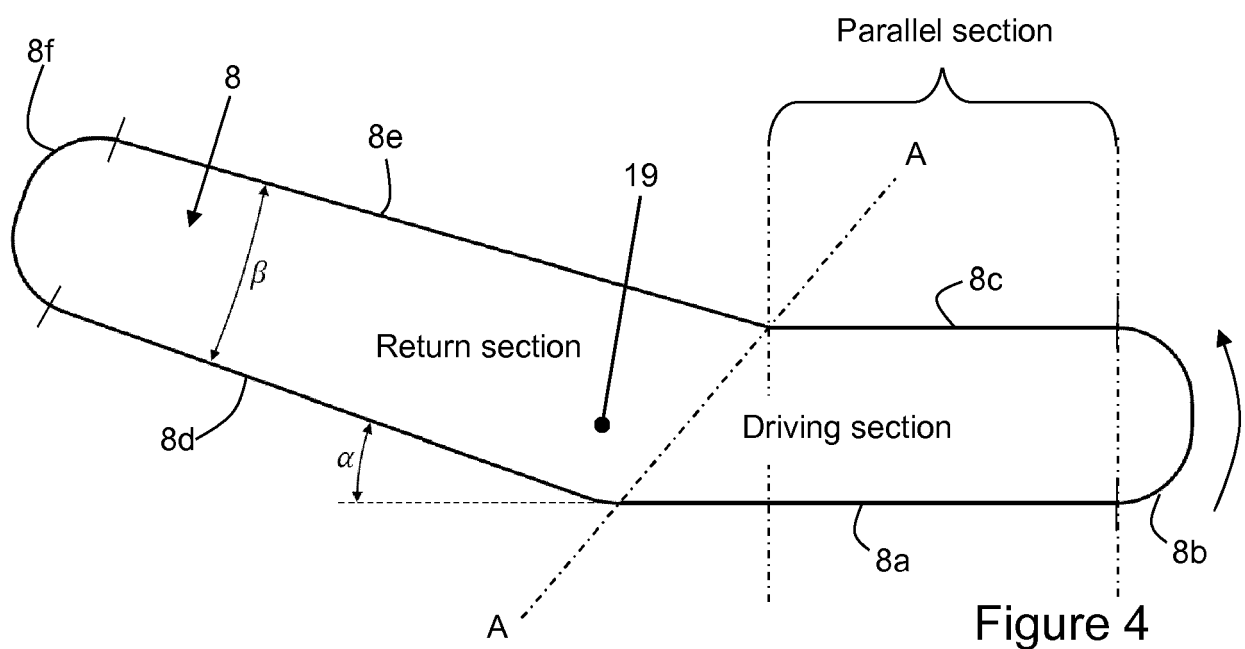


Figure 4

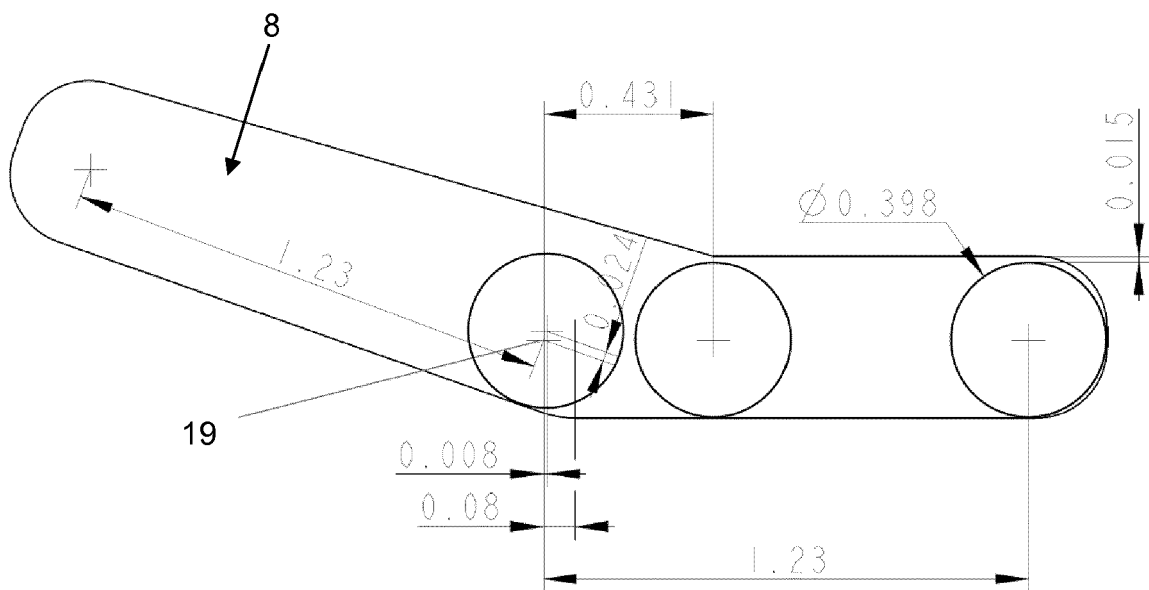


Figure 5

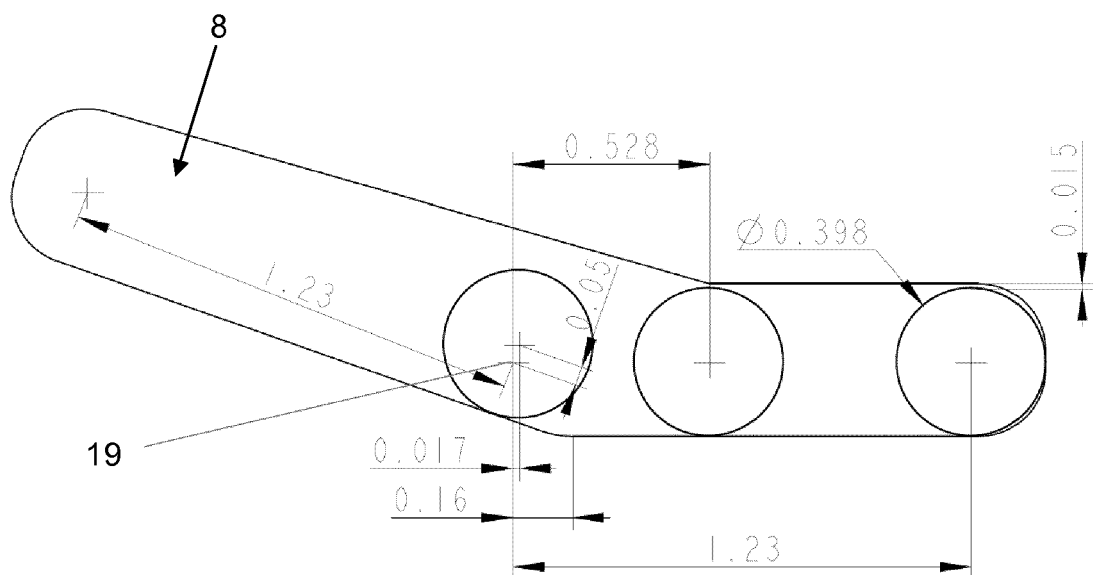


Figure 6

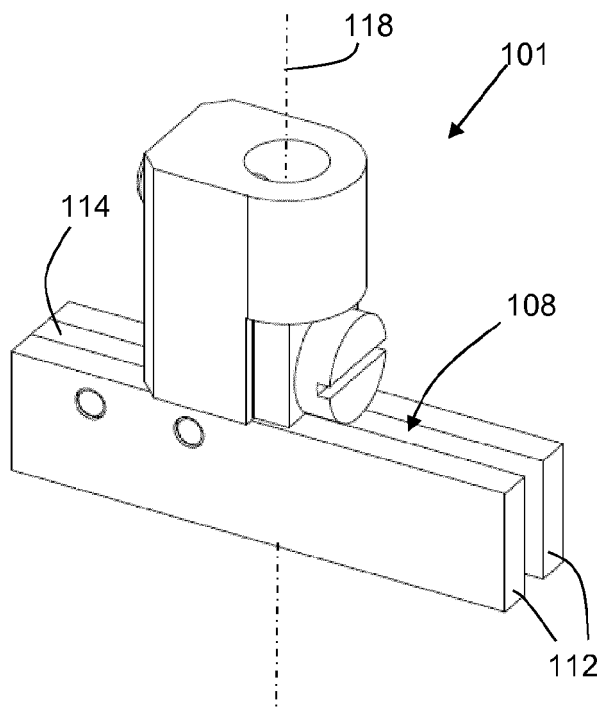


Figure 7a

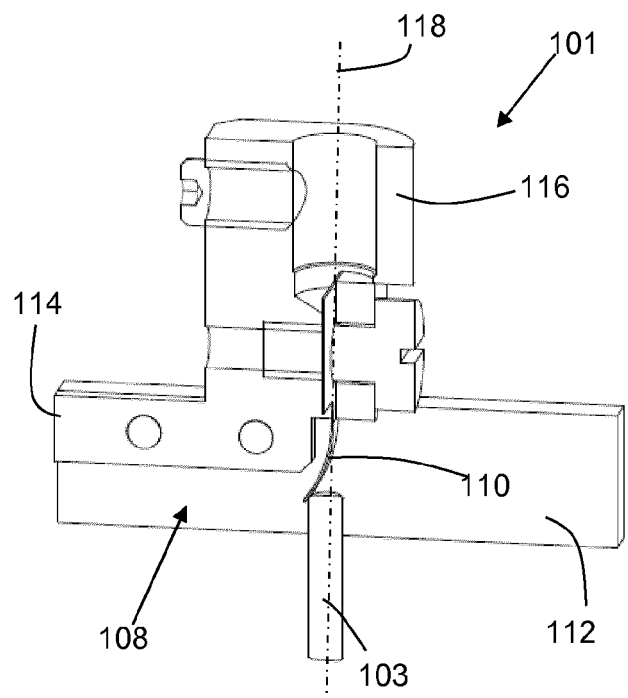


Figure 7b



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Place of search The Hague		Date of completion of the search 26 November 2019	Examiner Camatchy Toppé, A
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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