(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

CORRECTED VERSION

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
8 January 2015 (08.01.2015)

WIPO | PCT

(10) International Publication Number
WO 2015/001420 A9

(51) International Patent Classification: Not classified

(21) International Application Number:
PCT/IB2014/001284

(22) International Filing Date:
14 May 2014 (14.05.2014)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
P201300017 17 May 2013 (17.05.2013) EE

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to the identity of the inventor (Rule 4.17(i))*

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

(48) Date of publication of this corrected version:
19 March 2015

[Continued on next page]

(54) Title: APPARATUS AND METHOD FOR OPTICAL SWITCHING PARTICLE PREPARATION

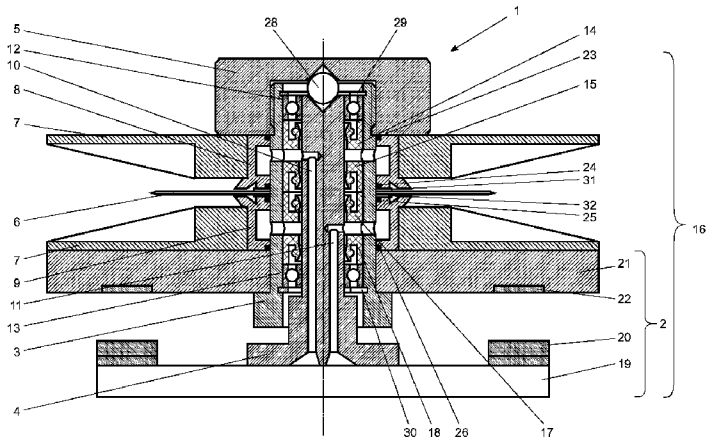

FIG 3

(57) Abstract: The present invention relates to apparatus and method for preparing optical switching particles used in electrophoretic displays whereas the apparatus (16) comprises two main parts -spinner assembly (1) and motor (2) for driving the spinner assembly (1). The disclosed apparatus is driven by flat brushless motor (2) that is mounted on the spinner assembly (1) and is the integral part of the whole apparatus and not standing separately.

WO 2015/001420 A9

(15) Information about Correction:
see Notice of 19 March 2015

Description

APPARATUS AND METHOD FOR OPTICAL SWITCHING PARTICLE PREPARATION

Technical Field

[0001] The invention relates to apparatus and method for preparing optical switching particles used in electrophoretic displays.

Background Art

[0002] An electrophoretic display has benefits in terms of several information display application fields such as readability in sun light, power saving due to display image memory of display medium, wide viewing angles. Currently available and known electrophoretic display technologies are featuring their display media's own image memory capability. The display medium's image memory effect means that once optical state is changed by externally applied stimulation such as electric field, application stays in its state when the external stimulation is removed. This is different compared to widely used flat panel display technologies including CRTs (Cathode ray Tubes), LCDs (Liquid crystal Displays), OLEDs (organic Light Emitted Diodes), where the optical state goes back to the previous state immediately after the external stimulation is removed. Therefore, it is required to continuous pumping with so-called refreshing excitation to keep the image, unlike electrophoretic displays cases.

[0003] Electrophoretic display image memory function is due to the nature of the display medium. Display medium contains bichromal switching particles and sustaining medium. Switching particle is non-spherical and/or spherical particle with hemispheres or substantially equal parts of contrasting colour (black and white; red and white or other) that are sustained in the sustaining medium, wherein the particles are controlled by an electric field. In this invention purpose quality of the switching particle means that substantially equal parts of two hemispheres have a straight line between the two contrasting colours (FIG 2). In order to have a good enough light scattering performance which is important for paper like display image, the optical switching particle must satisfy mu-light scattering that means the particle size must be large enough compared to

visible light wavelength. The particle quality and size have influence on electrophoretic display device image quality. However, inventors are not considering these factors sole impacts to the image quality.

[0004] In the known art multiple ways are disclosed to prepare the bichromal switching particles for electrophoretic display devices. Herein, described apparatus utilize spin disk type design in order to fabricate bichromal particles. Described prior art designs have multiple different elements that enable to improve switching particle quality and trying to reduce the particle size. The apparatus described in the current invention is also spin disk type. However, this invention has a different approach to crucially improve the mechanical rotation properties of the spin disk and through this improve the quality of the particles and vary the particle size as needed.

[0005] It has been found that the particle formation is influenced by high frequency noise e.g. unwanted vibration. In this invention purpose high frequency noise means unwanted mechanical vibration. Unwanted vibrations are enhancing the breakup of the stream of liquid into the randomly sized droplets by increasing the instability of the forward end of the streams, therefore, affecting the particle forming. The quality and size of the particles are dependent on the frequency of the vibration. When unwanted vibration wave length is less than the size of the particle, the quality is affected. However, the most crucial for determining the size of the particle is the rotation speed of the disk, but vibration has influence for monodispersity. The common technical problem that conventional prior art inventions have is that the unwanted vibration factor is not controlled by any means. Particles produced by conventional designs have non-linear line between the two contrasting colours of hemispheres, as shown on the FIG 1. Use of low quality particles is one factor, why the contrast ratio of the image of the switching particle based electrophoretic displays is low. More particularly, conventional designs do not describe motor for rotating the spin disk and supporting constructions of the apparatus. Based on the prior art articles it is seen that the motor rotating the spin disk is far from the disk (motor is not shown in prior art designs), this causes the instability

of the apparatus and potential misalignment between the two hemispheres is high. The long axis of the apparatus causes the resonance (long drive shaft has attendance for resonance).

[0006] Typical spin disk device design with multiple embodiments is described in US patent No. **US 5262098** B (XEROX CORPORATION) 16.11.1993 . The embodiments deal with premature collision of the ball and cooling of the balls. Established electric field between the electrodes and spinning disk is related to the response time of the ball switching and do not have any influence on the quality of the ball. Although, cooling is influence for the quality and straightness of line between the different colour hemispheres, this is only one factor. More intrinsic factor, unwanted vibration is not controlled here. As mentioned above the motor rotating the spin disk is not disclosed and described in the design, unwanted vibration problem is not dealt with. Some of the prior art designs focus on reducing the size of the balls with multiple methods and elements i.e. **EP 0928681** B (XEROX CORPORATION) 14.07.1999 , **EP 0929060** B (XEROX CORPORATION) 14.07.1999 . Although those prior arts discussed smaller particles preparation methods, they did not suggest any design or method for spin disk machine instability issue originated form machine structure. Further, spin disk apparatuses in patent applications Nos **US 6485280** B (XEROX CORPORATION) 26.11.2002 , **US 7232533** B (XEROX CORPORATION) 19.06.2007 , **US 7244377** B (PALO ALTO RESEARCH CENTER) 17.07.2007 disclose methods and designs for spreading the two hardenable liquids onto the disk uniformly and through this obtain the balls necessary for good enough electrophoretic display image. US patent No **US 6485280** B (XEROX CORPORATION) 26.11.2002 disclosed Taylor instability influence on the particle preparation, on the other hand this invention focuses on the spin disk machine originated instability that would be more intrinsic factor to obtain better quality particles. None of the prior art inventions have considered the instability and vibration caused by machine structure to have an influence the particle preparation and formation. This invention purpose is to improve the mechanical rotation properties of the spin disk apparatus, improve machine origin instability,

where unwanted vibration is brought to minimum.

Disclosure of Invention

[0007] One object of the present invention is to provide an apparatus for preparing optical switching particles that allows producing particles for electrophoretic display device. Herein, described apparatus utilize spin disk type design that has a different approach to crucially improve the mechanical rotation properties of the spin disk that none of the conventional designs have touched.

[0008] In addition, another object of the invention is to provide method for manufacturing the optical switching particles with necessary size for satisfy mu-light scattering used in electrophoretic displays (FIG 2).

[0009] According to the invention, there is provided an apparatus for preparing the particles, including spinner assembly and motor for driving the spinner assembly. Motor is mounted on the spinner assembly and is an integral part of the whole apparatus and not standing separately (shown on FIG 3). This means that the longitude axis of the assembly is shortened and resonance is brought to minimum.

[0010] A spinner assembly including a rotating spinner body, where spinning disk in between the pair of shrouds is mounted on the body, an insert and a locking not for supporting together the spinner assembly. Spinning disk is mounted between the shrouds, however it is attached so that up and down and sideways movement of the disk is minimum. This type of design provides compact, easily cleanable and easy maintainable assembly with three supporting points, wherein a driving motor is mounted on the assembly, so that vibration (e.g. high-frequency noise) is brought to minimum. With described design the rotating mass of the apparatus is reduced as much as possible in order to avoid unbalance of the machine.

Brief Description of Drawings

[0011] FIG 1 Technical problem with prior art apparatuses that provide schematically illustrated particles for electrophoretic displays;

[0012] FIG2 Particles provided by present invention apparatus;

[0013] FIG3 Apparatus design;

[0014] FIG 4 Second embodiment of the apparatus;

[0015] FIG 5, 6 show schematically design and section view of the rotating spinner body;

[0016] FIG 7, 8 show schematically design and section view of the liquid rings;

[0017] FIG 9 shows in the perspective the section view to the apparatus according to the present invention;

[0018] FIG 10 shows in more detail the section view of the spinner assembly according to present invention.

Best Mode for Carrying Out the Invention

[0019] One of the main obstacles that current known apparatuses have is the vibration of the spinning disk apparatus. It is known that the quality of the particle is sensible to vibration e.g. high-frequency noise; this means that vibration causes liquid jet uneven break up and imperfectly formed line between the two colours of the particle. Imperfectly formed line between the different coloured hemispheres or parts is one of the factors that affect the display image contrast. Currently presented spinner assembly design overcomes the vibration issue. Further, the presented design enables compact, easily cleanable and easy maintainable assembly with three supporting points, wherein a driving motor is mounted on the assembly, so that vibration (high-frequency noise) is brought to minimum. With described design the rotating mass of the apparatus is reduced as much as possible in order to avoid unbalance of the machine.

[0020] Further advantages of the invention will become apparent as following detailed apparatus design is described.

[0021] Apparatus 16 cross-section is shown in the Fig3. From Fig 3 it is seen that the apparatus consists of two main parts spinner assembly 1 and motor 2 for driving the spinner assembly 1. Unlike prior art apparatuses herein disclosed apparatus is driven by flat brushless motor 2 that is mounted on the spinner assembly 1 and is the integral part of the whole apparatus and not standing separately.

[0022] Spinner assembly 1 is formed by a rotating spinner body 3, an insert 4 and a locking not 5 for supporting together the spinner assembly 1. The rotating spinner body 3 is the main mean for holding the spinner assembly together with support of locking not 5. The body 3 consists of a spinning

disk 6 sandwiched between the two rotating shrouds 7 that are attached to the liquid delivery rings 8 and 9. The spinning disk 6 is attached to the body 3 itself in order to reduce sideways disc movement and attached to the liquid delivery rings 8 and 9 for reduce the up and down movement. The spinner body 3 has two liquid delivery rings 8 and 9 for directing the two different hardenable liquids on the disk 6. Liquid delivery ring 8 is directing the liquid from the canal 10 to the upper surface of the disk 6. Liquid delivery ring 9 is directing the liquid from the canal 11 to the lower disk 6 surface. Liquid delivery rings 8 and 9 direct the liquid path to the disk 6 in the preferred amount and spread the liquid on the surface of disk 6 equally through the multiple holes 33 (see fig 7, 8). The spinner body 3 is rotating together with disk 6, shrouds 7 and liquid delivery rings 8 and 9. To ensure that the liquid is spread on the surface of disk 6 through the holes 33 the upper washer 31 is arranged between the upper surface of the disk 6 and liquid delivery ring 8 and correspondingly the lower washer 32 is arranged between the lower surface of the disk 6 and liquid delivery ring 9.

[0023] The rotating spinner body 3 and insert 4 are supported with supporting points 12 and 13. Supporting points 12 and 13 (for example plain bearings, rolling-element bearings etc) or any support the assembly 1 in latitude-axis. The spinner assembly 1 third supporting point steel ball 28 support the whole assembly 1 in the longitude axis. Between the supporting points 12 and 13 four simmering seals 14, 15, 17, 18 seal the hardenable liquids from four different points of the assembly 1. Simmering seals 14 and 15 seal the liquid directed through liquid delivery ring 8 and canal 10. Simmering seals 17 and 18 seal the liquid directed through liquid delivery ring 9 and canal 11. Addition to the simmering seals 14, 15, 17 and 18 the assembly 1 is sealed with o-seals 23, 24, 25 and 26 in order to tighten the upper and lower surface of the corresponding liquid delivery rings 8 and 9 to avoid the liquid coming out of the rings before it researches to the disk 6.

[0024] Two different hardenable liquids run into the spinner body 3 through canals 10, 11 in insert 4, this means that the liquids are fed to the spinner

body 3 through the same shaft (mentioned as insert 4) wherein the whole apparatus is mounted. The insert 4 or the shaft wherein the whole apparatus is assembled is steady and not rotating. Insert 4 is the part of the assembly 1 through which the liquid is fed to the disk 6. More specifically preheated hardenable liquid runs through two canals 10, 11 dredged into the intake part of the insert 4. Insert 4 is steady part of the assembly 1 upon the body 3 is mounted. Two canals 10, 11 that come from the stator disk 19 centre to the lower part of the insert 4 direct the liquids through two holes (not shown in the Fig 3) of the insert 4. One canal 10 directs the liquid to the upper surface of the disk 6 through the upper holes 34 (see fig 5) in the spinner body 3 and liquid delivery ring 8, the other canal 11 directs the liquid to the lower part of the disk 6 through the lower holes 35 (see fig 5 and 6) in the spinner body 3 and corresponding liquid delivery ring 9. Hardenable liquids run through the holes of the insert 4 and through the holes 34, 35 of the spinner body 3 to the liquid delivery rings 8, 9 that spread through the holes 33 the liquid accordingly to the disk 6 surfaces. Insert 4 is mounted on the stator disk 19 that has stator coils 20, stator disk 19 and stator coils 20 are parts of the motor described below.

[0025] The spinner assembly 1 is driven by the flat brushless motor that consists of rotor 21, magnet 22 mounted on the rotor 21, stator disk 19 and multiple stator coils 20 mounted on the stator. This type of flat brushless motor enables minimum sideways force. The fact that the motor is assembled with the apparatus reduces the high-frequency noise and enables to reduce the mass of the apparatus. The flat motor enables to use two sidewise supporting points for spinner assembly and to deliver liquid through the axis of the spinner assembly, more particularly through insert 4. The longitude- and latitude-axis supporting members and flat brushless motor assembled with the spin disk assemble reduces the vibration significantly and enables to fabricate high quality particles with straight line between the two opposite colour hemispheres.

[0026] The other issue with controlling the optical switching particle quality and size is controlling the temperature of liquids fed to the apparatus and

temperature of the apparatus itself in order to keep the preferred temperature. The optimal temperature of the hardenable liquids and the assembly 1 itself is important from particles quality point of view. It is important that the particles cool down quickly after leaving the disc 6. In order to fabricate small enough and good quality particles all the parts of the apparatus 16 are made of good heat conduct, except the shrouds 7 and motor 2. This particular factor is important to hold the equal optimal temperature of the apparatus. Prior art designs disclose various examples, how to give the proper heating to the apparatus and the liquids, however, it is not disclosed how to control and measure the heat. Proper temperature is important factor for particle formation.

[0027] In the second embodiment Fig 4 describes an apparatus and method, how to measure the optimal temperature of the apparatus and liquids fed thereof. Infrared temperature sensor 27 is introduced to measure the temperature of the assembly. In this embodiment extra heat is given by hot air or with other methods to the assembly. Infrared means i.e. infrared temperature measuring sensor 27, is above the assembly 1, the infrared beam is pointed on the locking not 5 of the assembly 1. This mentioned locking not 5 is made also from heat conducting material and is the closest flat part to the liquid, therefore the temperature measurement is most accurate. As the whole assembly is made of heat conducting material this gives us very close feedback of the liquids temperature.

[0028] Hereinafter, the method for preparing the optical switching particles of the present invention is described in detail below.

[0029] The method for preparing switching particles include passing two differently coloured preheated hardenable liquids through the bottom of the apparatus through stator disk centre to the lower part of the insert, where the liquids are directed through the holes into the two separated canals. One canal of the insert directs the liquid to the upper surface of the disk through the corresponding liquid delivery ring, the other to the lower part of the disk through the corresponding liquid delivery ring. Two liquids are sealed with two simmering seals and o-seals. Hardenable differently coloured liquids run through the holes of the canals to the liquid delivery

rings' multiple holes that spread the liquid accordingly to the disk surfaces. Liquids move toward the edge region of the disk and arrive to the edge at substantially the same flow rate, forming a reservoir of the two liquids outboard of the edge. Reservoir comprises of side-by-side regions of two coloured liquids. Mentioned side-by-side regions fly out of the reservoir into a bichromal streams having side-by-side portion of different colours, causing the forward end of the each stream to be unstable and to break up into droplets that form particles, each comprising two opposite colour hemispheres. Above described design enables the method wherein the breakup stream is stable due to the stability of the forward end of the streams.

[0030] List of details:

1 – spinner assembly

2 – motor

3 – rotating spinner body

4 – insert (non-rotating)

5- locking not

6- spinning disk

7 – rotating shrouds

8 – liquid delivery ring (upper)

9 – liquid delivery ring (lower)

10 – canal (directing liquid to the upper surface of the spinning disk 6)

11 – canal (directing liquid to the lower surface of the spinning disk 6)

12 – supporting point

13 – supporting point

14 – simmering seal

15 – simmering seal

16 – apparatus for preparing the optical switching particles

17 – simmering seal

18 – simmering seal

19 – stator disk

20 – stator coils

21 – rotor

22 – rotor magnets

23 – o-seal

24 – o-seal

25- o-seal

26 – o-seal

27 – temperature sensor (infrared)

28 – supporting point (steel ball)

29 – retaining ring

30 – retaining ring

31 – upper washer

32 – lover washer

33 – holes

34 – upper holes

35 – lower holes

Claims

1. An apparatus for preparing optical switching particles comprising a spinner assembly 1 and a motor 2 combined into an integral assembly, wherein the said spinner assembly comprises a non-rotating insert 4 which is arranged to a stator disk 19 of the motor 2, a rotating spinner body 3 mounted on the insert 4 and supported to the insert in three supporting points 12, 13, 28, a rotor 21 of the motor 2 which rests on a collar in the lower part of the rotating spinner body 3, a spinning disk 6 attached to the rotating spinner body 3 and arranged between the upper and lower liquid delivery rings 8, 9, wherein the lower liquid delivery ring rests on the rotor 21 of the motor 2 and the upper liquid delivery ring 8 rests on the spinning disk 6, wherein canals 10 and 11 have been provided in the insert 4 for directing hardening liquid through upper and lower holes 34, 35 provided in the rotating spinner body 3 and through the holes 33 provided in the liquid delivery rings 8, 9 to the spinning disk 6, a lower rotating shroud 7 resting on the rotor of the motor, an upper rotating shroud 7 resting on the upper liquid ring 8, simmering seals 14, 15, 17, 18 arranged between the insert 4 and the rotating spinner body 3 so as to prevent leaking of the hardening liquid between the insert and the rotating spinner body, a locking not 5 for fixing the rotor 21 of the motor, liquid delivery rings 8, 9, shrouds 7 and the spinning disk 6 to the rotating spinner body 3 and through the supporting point 28 on the insert 4, wherein a groove has been provided in the upper and lower parts of the rotating spinner body 3 for the retaining rings 29, 30 for fixating the supporting points 12, 13 and the simmering rings 14, 15, 17, 18 to the inner surface of the rotating spinner body 3 and the outer surface of the insert 4.

2. The apparatus according to claim 1 characterized in that the upper supporting point of the rotating spinner body 3 between the upper end of the insert 4 and the locking not 5 is a steel ball which rests in the conical area provided in the insert and the conical area provided in the locking not.

3. The apparatus according to claim 1 characterized by stator coils 20 which are arranged on the stator disk 19, and by rotor magnets 22 arranged on the rotor 21 of the motor.

4. The apparatus according to claim 1 characterized by the upper washer and the lower washer 31, 32 arranged between the spinning disk 6 and the upper and lower

liquid delivery rings 8, 9, respectively, for assuring the passage of hardening liquid through the openings provided in the liquid rings to the spinning disk.

5. The apparatus according to any of the previous claims characterized by the temperature sensor 27 fitted on the locking not for measuring the hardening temperature fed into the apparatus.

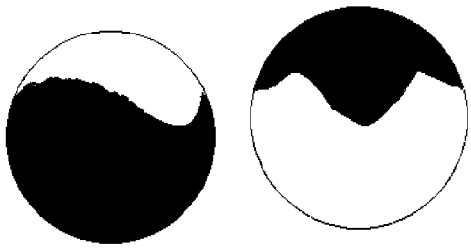

FIG 1

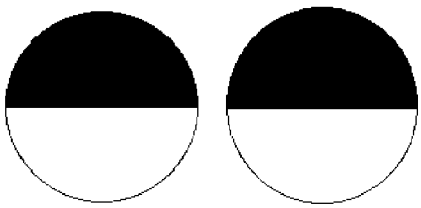

FIG 2

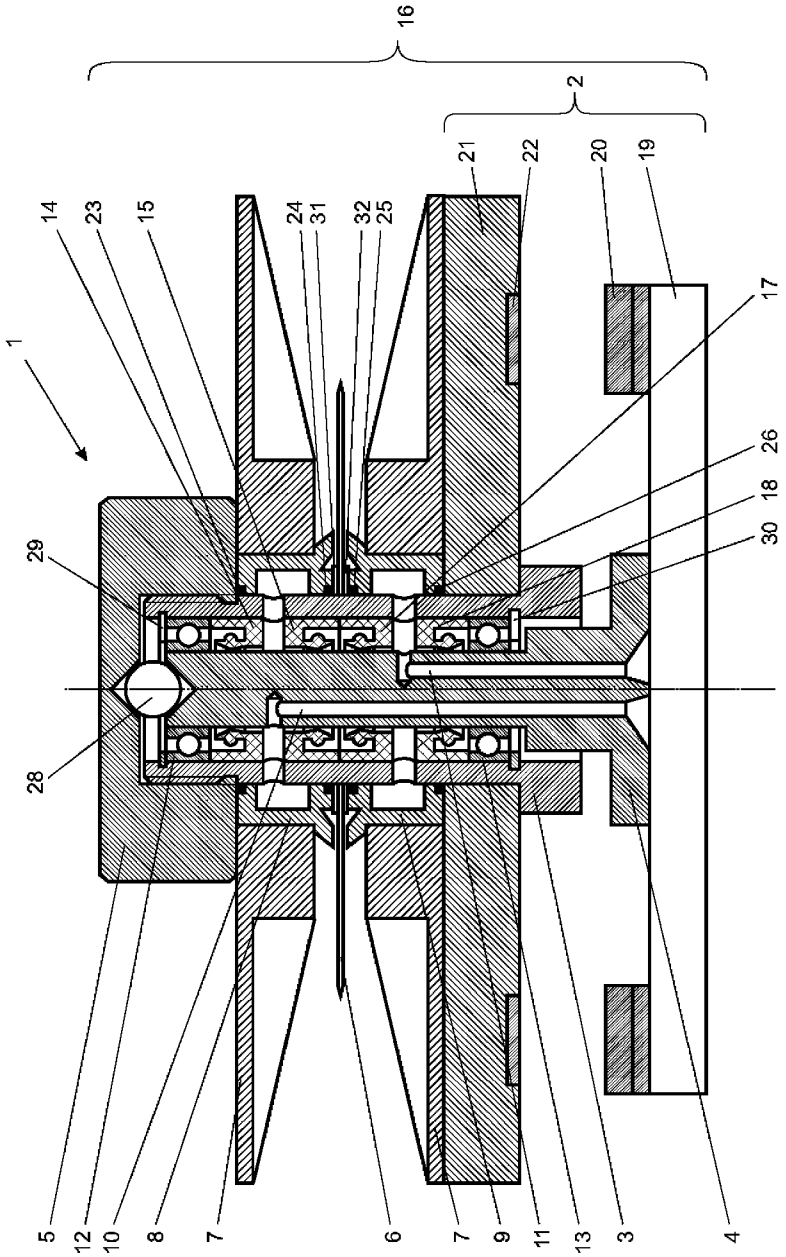
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FIG 3

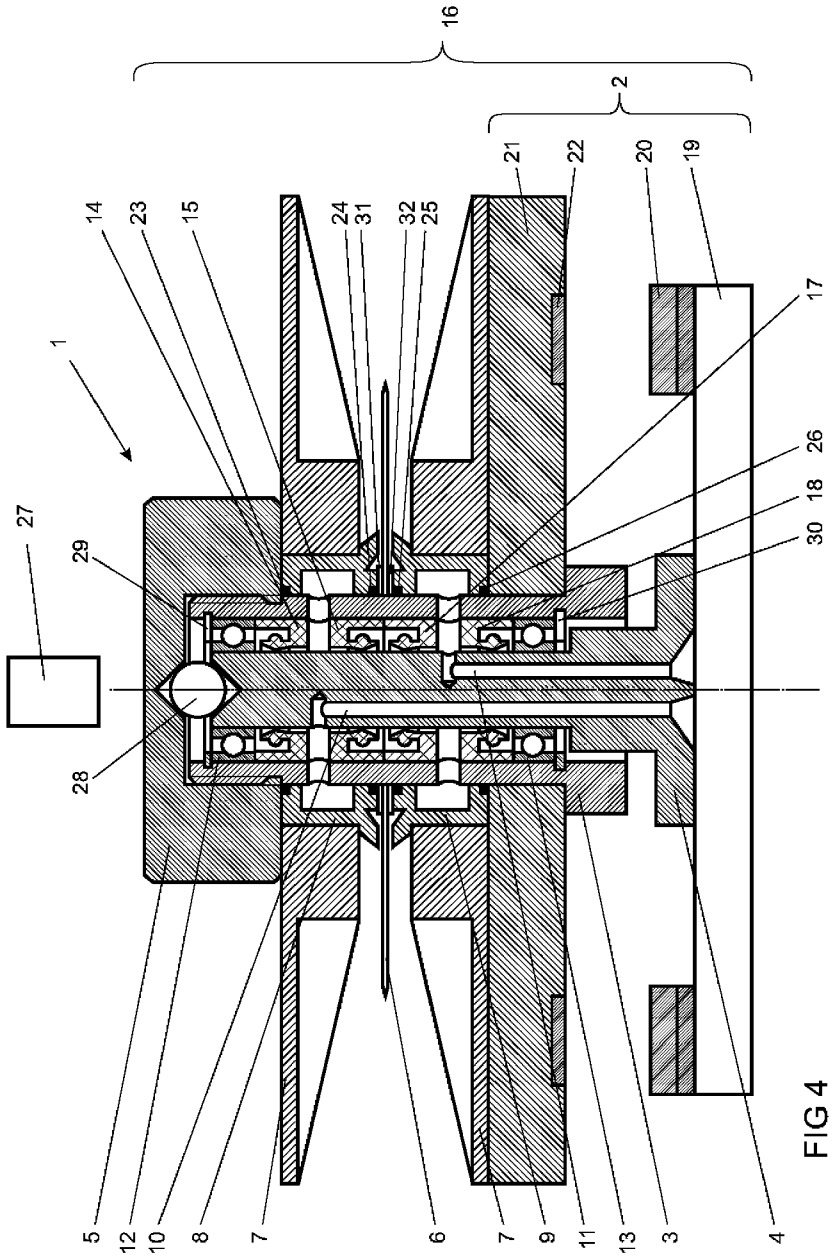
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FIG 4

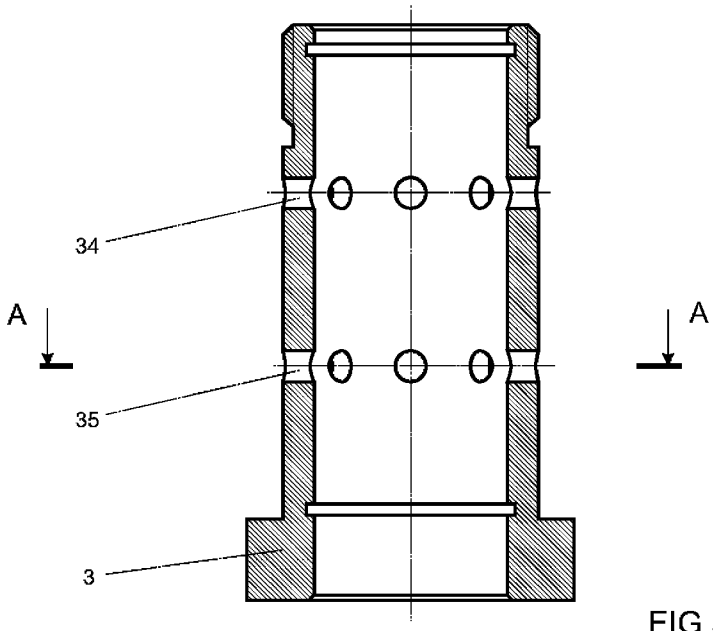

FIG 5

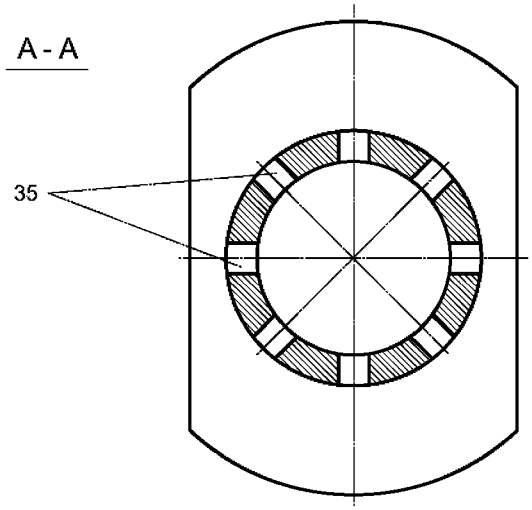

FIG 6

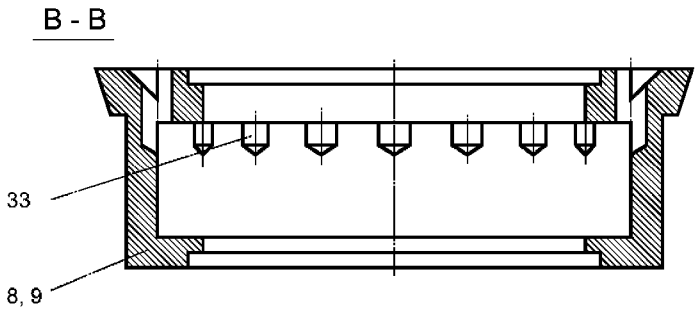

FIG 7

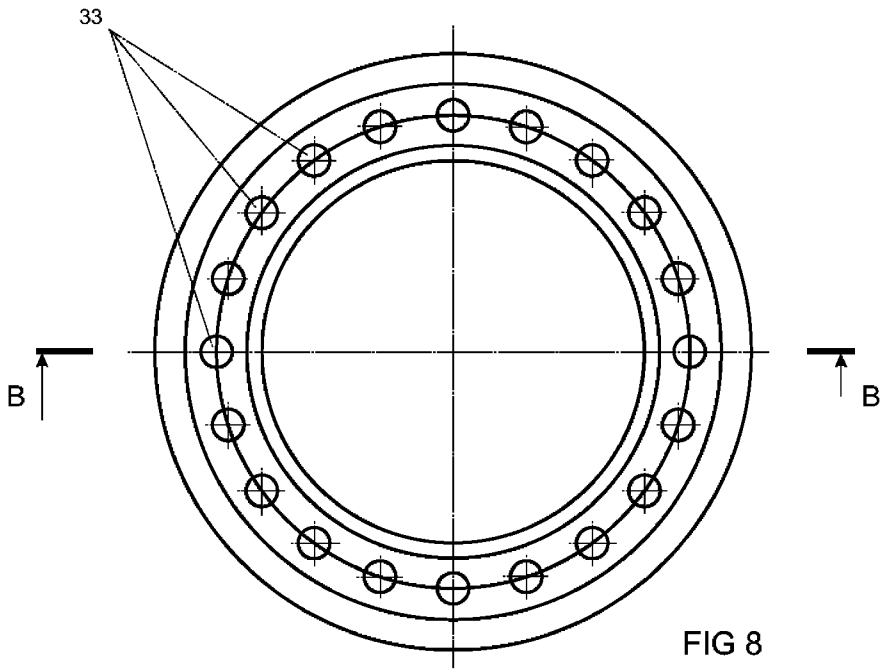

FIG 8

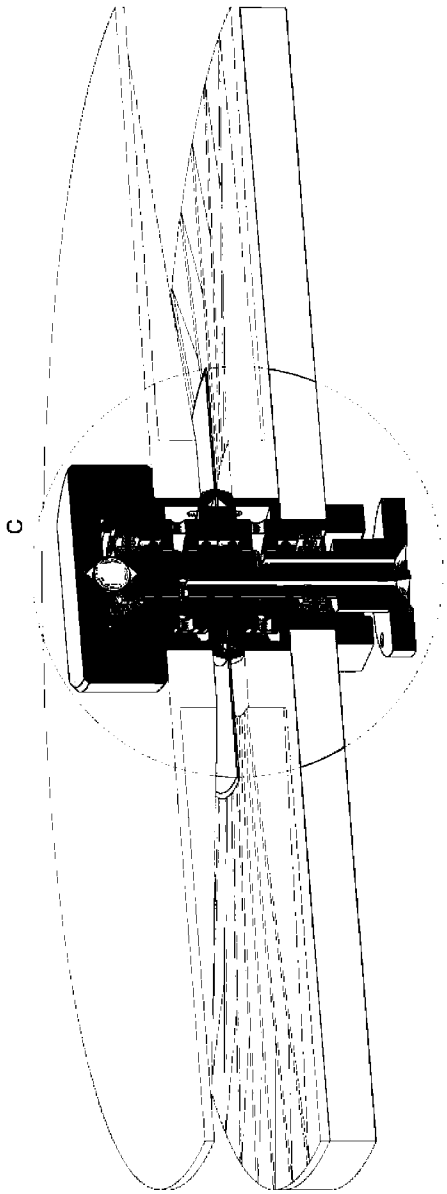

FIG 9

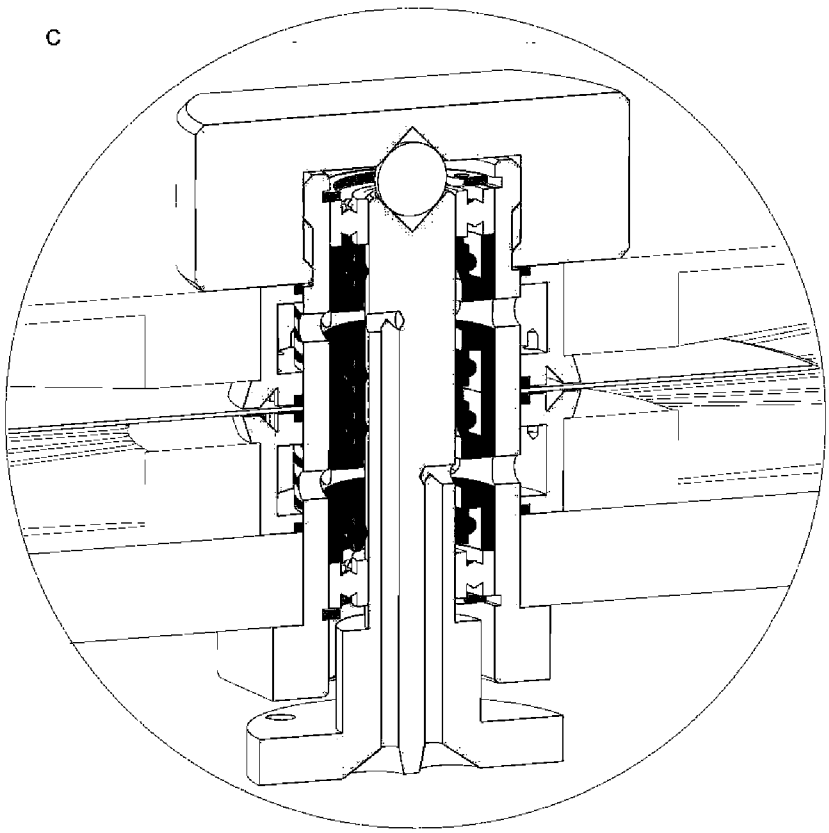

FIG 10