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**US-A- 3 536 367**  
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# DESCRIPTION

## TECHNICAL FIELD

[0001] The present invention relates to kinematic pairs and more specifically to kinematic pairs allowing rotational and/or sliding movements.

## BACKGROUND

[0002] Kinematic pairs of different types are well known and widely used. One example of such a pair is disclosed in WO2007/084901A2, where a ball joint has a ball with an attached shank, an inner bearing and an outer bearing both having a wear surface, and a biasing element made from a Belleville washer type spring. Furthermore, the ball joint has a socket which is closed at its inner end and which has an opening at its outer end. The ball joint is assembled in a first step where the biasing element is inserted into the socket and in a second step where the inner bearing is inserted into the socket, followed by the ball with the attached shank and the outer bearing. In this arrangement, the inner bearing rests on the biasing element and the ball is kept between the wear surfaces of the inner and the outer bearing, while the shank - which is attached to the ball - is passed through an opening in the outer bearing. In order to finalize the assembly of the ball joint, the outer bearing is pressed into the socket against the preload force of the biasing element and the outer rim of the socket is folded inside towards a centre of the socket's opening. Due to the folded rim, the outer bearing is kept in place inside the socket and the compression of the ball between the inner and the outer bearing is maintained for providing a stiffness of the ball joint.

[0003] This known ball joint has a number of disadvantages: it comprises a large number of parts and there are production-related deviations in the shape and size of the ball and the inner and outer bearing. Furthermore, due to the limiting accuracy with which rim is folded inwards, the compression of the ball between the inner and the outer bearing varies for every ball joint.

[0004] Further background art is disclosed for instance in US2004/208406A1.

## SUMMARY

[0005] An object of the present invention is to provide improvements over prior art. This object is achieved by a technique defined in the appended independent claims; certain embodiments being set forth in the related dependent claims.

[0006] In a first aspect, there is provided a housing element for a kinematic pair, the kinematic

pair comprising the housing element and an engagement element, wherein the engagement element is arranged at least partly within the housing element and configured to achieve a rotational and/or sliding movement relative the housing element. The housing element comprises at least one first carbon fiber composite material layer surrounding at least a part of the engagement element, a carbon fiber composite material wrapping arranged around at least a part of the first layer, and at least one second carbon fiber composite material layer arranged on the outside of the wrapping. This structure of a housing element creates a strong and precise construction with respect to the engagement element located within. Furthermore, the structure has a pre-tension which means that there is no play or backlash between the housing element and the engagement element. Another advantage is the use of the carbon fiber composite material which is strong, durable and has a low weight. The material has a high strength-weight-ratio which is very desirable for a housing element of a kinematic pair.

**[0007]** In an embodiment, the first and second layers comprise a braided texture of a carbon fiber composite material. This braided texture provides the material with an even distribution of tension along the entire piece of material.

**[0008]** In another embodiment, the first layer and said second layers form parts of one and the same carbon fiber composite material piece. This is advantageous since the components of the structure are held tightly together by one piece of material. Also, the distribution of tension in the material is evenly distributed over an area so that the engagement element does not grab hold of or stick to the seat of the housing element.

**[0009]** In another embodiment, the housing element further comprises a coating element which is arranged on the surface of the first carbon fiber composite material layer facing the engagement element and where the coating element comprises a graphite based material, such as, but not limited to vapor grown carbon nano tubes. The coating element makes sure that the engagement element may rotate and/or slide freely without unnecessary friction; it provides even better anti-friction properties.

**[0010]** In a second aspect, there is provided a kinematic pair comprising at least a housing element as described above and an engagement element, wherein the engagement element is arranged at least partly within the housing element and configured to achieve a rotational and/or sliding movement relative the housing element. The kinematic pair will have all the above described advantages.

**[0011]** In an embodiment, the housing element is a socket and the engagement element is a ball, together forming a ball and socket joint.

**[0012]** In a third aspect, there is provided a method for manufacturing a housing element for a kinematic pair, wherein the kinematic pair comprises a housing element and an engagement element and wherein the engagement element is arranged at least partly within the housing element and configured to achieve a rotational and/or sliding movement relative the housing element. The method comprises the steps of:

- arranging at least one first carbon fiber composite material layer around at least a part of the engagement element;
- winding a carbon fiber composite material around at least a part of said first layer forming at least one wrapping; and
- arranging at least one second carbon fiber composite material layer on the outer most wrapping.

**[0013]** This method produces a housing element which is of strong and precise structure with respect to the engagement element located therein and with all the above mentioned advantages.

**[0014]** In an embodiment, the method further comprises the step:

- winding said carbon fiber composite material around at least a part of said second layer forming at least one outer wrapping. By adding an outer wrapping the second layer and the structure is locked in position.

**[0015]** In another embodiment, the step of arranging at least one second carbon fiber composite material layer further comprises:

- folding a portion of the first layer over the wrapping forming the second layer.

**[0016]** This is advantageous since the components of the structure are held tightly together by one piece of material. Also, the distribution of tension in the material is evenly disposed over an area so that the engagement element does not grab hold of the seat of the housing element.

**[0017]** A fourth aspect concerns use of a carbon fiber composite material wound around at least a part of a first carbon fiber composite material layer forming at least one wrapped layer of a kinematic pair.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

**[0018]** Embodiments of the invention will be described in the following, reference being made to the appended drawings which illustrate non-limiting examples of how the inventive concept can be reduced into practice.

Figs 1a-e show a kinematic pair according to a first embodiment of the invention;

Figs 2a-b show a kinematic pair according to a second embodiment of the invention;

Figs 3a-b show a kinematic pair according to a third embodiment of the invention;

Figs 4a-b show a kinematic pair according to a fourth embodiment of the invention;

Figs 5a-b show a kinematic pair according to a fifth embodiment of the invention;

Figs 6a-b show a kinematic pair according to a sixth embodiment of the invention; and

Fig 7 shows a material used when manufacturing kinematic pairs.

## **DETAILED DESCRIPTION OF EMBODIMENTS**

**[0019]** With reference to Fig. 1a-c a kinematic joint in the shape of a ball and socket joint 10 is illustrated in different views. The ball and socket joint 10 comprises an engagement element 20 with a ball 21 and a shaft 22, and a housing element or a socket 30 which is arranged to receive at least a part of the ball 21. The ball 21 is thus at least partly arranged within a seat 31 of the socket 30 and configured to achieve a rotational and/or sliding movement relative the socket 30 and relative an axis A. The engagement element 20 may be tilted downwards, shown by the arrow B, until the shaft 22 abuts an upper edge portion 32 of the seat 31. The upper edge portion 32 has a peripheral rim 33 which continuously extends around an upper part 23 of the ball 21 and which is the upper most engaging point between the ball 21 and the housing element 30. The location of the rim 33 should be provided in an upper plane X, above the plane Y of a center point C of the ball 21.

**[0020]** The upper plane X, which defines the rim 33 of the upper edge portion 32, is therefore arranged at a distance from the center plane Y forming an angle  $\alpha$  relative the center point C of the ball 21. The angle  $\alpha$  is between  $5^\circ$  and  $85^\circ$ , preferably between  $25^\circ$  and  $55^\circ$ . The range of the angle  $\alpha$  also means that a distance D1 between the rim 33 and the shaft 22, when the shaft 22 is located in an upright position shown in Figs 1a-b, is affected. The shorter the distance D1 is between the shaft 22, in the upright position, and the rim 33 the less freedom of movement the shaft 22 has. The distance D1 may also be measured between the rim 33 and the axis A. Later will be described in more detail how it is possible to arrange the rim 33 at an angle  $\alpha$  of as little as  $5^\circ$ .

**[0021]** Further, the housing element 30 comprises a main engaging portion which is the seat 31, where the shape of the surface of the seat 31 corresponds to the shape of the outer surface of the ball 21. Later will be described how the seat 31 and the housing element 30 are manufactured around the ball 21.

**[0022]** The housing element 30 further comprises a lower edge portion 35 with a corresponding lower rim 36 which extends continuously around the lower part 24 of the ball 21 and which is the lower most engagement point between the ball 21 and the housing element

30. The lower rim 36 is provided in a lower plane Z which is located below the center plane Y forming an angle  $\beta$  relative the center point C of the ball 21. The angle  $\beta$  is between  $5^\circ$  and  $90^\circ$ , preferably between  $25^\circ$  and  $85^\circ$ . The range of the angle  $\beta$  also means that a distance D2 between the rim 36 and the axis A is affected. It is preferred not to enclose the entire lower part 24 of the ball 21 since the inner layer 51, shown in Figs 1d-e, should be folded back during the manufacturing process.

**[0023]** The manufacturing process of the housing element 30 appears from Figs 1d-e which show the process steps in a schematic way. In order to be able to manufacture the housing element 30, a manufacturing tool (not shown) is preferably used to hold the ball 21. An inner layer 51, made of a carbon fiber material, is arranged around the manufacturing tool, in close contact with the ball 21. Preferably, the carbon fiber material is made as a braided texture in the shape of a sock or a tube which easily may be pulled up over the manufacturing tool, forming the inner layer 51. The carbon fiber material and its braided texture are further described below with reference to Fig. 7.

**[0024]** Once the inner layer 51 is in place, a tow 52 of a carbon fiber composite material is wound around a part of the inner layer 51 with an angle between  $10^\circ$  and  $90^\circ$ , preferably in an essentially transverse direction, i.e. close to  $90^\circ$ , with respect to a longitudinal direction of the first layer 51, i.e. about the axis A. The tow 52 is tightly wound several layers, essentially around a desired part of the ball 21 and thus forming a wrapping 53 for the seat 31 of the housing element 30. The tight wrapping 53 of the tow 52 forms a compact seat 31 with the shape of the ball 21. The wrapping may have different sizes and shapes depending on e.g. the size of the ball and/or the field of application of the ball and socket joint. Also the wrapping may include other carbon fiber structures, such as uni-directional fibers or weaves.

**[0025]** When the wrapping 53 is sufficient, an outer layer 55 is arranged over the wrapping 53 in order to prevent the wrapping 53 from moving out from the ball 21. The outer layer 55 is preferably formed of an extension of the inner layer 51, where the tube-shaped carbon fiber composite material of the inner layer 51 is folded over the wrapping 53, thereby enclosing the wrapping 53 between the inner layer 51 and the outer layer 55, which is shown in Fig. 1d. Optionally, an outer wrapping 56 of the carbon fiber composite material tow or weave is also provided on the outside of the outer layer 55 for extra tightening and locking of the outer layer 55. The compact wrapping 53 and the arrangement of the inner and outer layer 51, 55 enable the housing element 30 to maintain its shape around the ball 21 when the matrix material of the composite, i.e. the components of the carbon fiber composite material which is not carbon fiber, e.g. thermoset or thermo plastic, is hardened.

**[0026]** Due to the compact wrapping 53 and the features of the carbon fiber composite material, the rims 33, 36 create a very strong locking which prevents the ball 21 from escaping its position within the seat 31 of the housing element 30 when high tensile and compressive forces are applied to the ball 21. The carbon fiber composite material and the manufacturing process of the housing element 30 also enable the position of the upper rim 33 to be lowered towards the center plane Y, i.e. decreasing the angle  $\alpha$  and increasing the distance D1 and

thereby increasing the freedom of movement of the shaft 22, which is one of many advantages over prior art.

**[0027]** The housing element 30 may further comprise a coating element 57 which is arranged on the surface of the first carbon fiber composite material layer 51 facing the engagement element 20. The coating element 57 comprises a graphite based material, such as, but not limited, to vapor grown carbon nano tubes. This enhances the tribological properties between the engagement and housing element.

**[0028]** Since the housing element 30 is manufactured around the engagement element 20, very small tolerances of the fit and the precision between the housing element 30 and the engagement element 20 can be achieved. The engagement element 20, or its different parts, may be made entirely of either metal or carbon fiber composite, or of a combination thereof. The ball 21 may be provided with a covering or coating material (not shown), such as, but not limited to, CVD, CVA, DLC, or PVD coatings. The coating material enables the ball 21 to easily release from the seat 31 of the housing element and gives a low friction contact surface between the engagement element 20 and the housing element 30.

**[0029]** Figs 2a-b show a kinematic pair 110 according to a second embodiment of the present invention comprising an engagement element 120 in the shape of a threaded element, and a housing element 130 which accommodates at least a part of the engagement element 120. The engagement element 120 is arranged to rotate about a longitudinal axis A of the engagement element 120 within the housing element 130. A similar kinematic pair 210 is shown in Fig. 3, but with the difference that the engagement element 220 is not a threaded element. This engagement element 220 is therefor arranged to both perform a rotational and a sliding movement within the housing element 230.

**[0030]** The housing elements 130, 230, shown in Figs 2a-b and 3a-b, are manufactured in basically the same way, with an inner layer 151, 251, and outer layer 155, 255 and a wrapping 153, 255, as described above but with a manufacturing tool suitable for the size and shape of the specific engagement element 120, 220. The length of the housing element 130, 230 may be manufactured in various ways depending on the desired application.

**[0031]** Figs 4a-b show a kinematic pair according to yet another embodiment, comprising an engagement element 320 which has a quadrangular shape, and which is adapted to achieve a sliding movement within a housing element 330. The housing element 330 has, due to the same manufacturing process as described above with an inner and outer layer 351, 355 and a wrapping 353, an inner portion or seat with the same quadrangular shape as the outer portion of the engagement element 320.

**[0032]** Figs 5a-b show a part of a kinematic pair according to an embodiment, where an engagement element 420 is allowed to rotate about the axis A within a housing element 430. Both housing element 430 and engagement element 420 has a cylindrical (rotational symmetrical) shape but where the outer surface of the engagement element 420 has a groove

460 and the housing element 430 is manufactured with a protrusion 461 which runs in the groove 460. In an alternative embodiment the groove and protrusion may also be the other way around (not shown), where the groove is in the housing element and the protrusion is coming from the engagement element. In yet another alternative embodiment (not shown) there may be multiple grooves and protrusions of different sizes and shapes.

**[0033]** During the manufacturing process of the housing element 430 an inner layer 451 is applied in the groove 460 which then is followed by a wrapping 453 for filling the groove 460 and which is applied until the proper size of the housing element 430 is achieved. After the wrapping 453 is applied, an outer layer 455 is achieved, like previously described, by folding the material piece, which also forms the inner layer 451, back around the wrapping 453. An optional outer wrapping 456 may then be applied to the outer surface of the outer layer 455 for fixing the structure.

**[0034]** Figs 6a-b show a kinematic pair 510 according to yet another embodiment comprising an engagement element 520, with a groove 560, and a housing element 530 with a protrusion 561 which is able to engage the groove 560. The engagement element 520 is only able to rotate within the housing element 530 similar to the housing element 430 in Fig. 5, and/or similar to the housing element 230 shown in Fig. 3. The housing element 530 is manufactured in basically the same way as described above but instead of only using a wrapping when forming the housing element 530 a distance element may be used. A distance element of any type and material may be used which is beneficial for the intended application. In an alternative embodiment, the housing element 530 may be connected to or manufactured with a second housing element (not shown) which is e.g. mirror-inverted. Also more than two housing element may be connected to each other.

**[0035]** Throughout the manufacturing process of the different elements, a carbon fiber composite material is used. The described inner and outer layers are made of a braided fabric 1 of the carbon fiber composite which is shown in Fig. 7. The fabric 1 is achieved by braiding together portions 2 of the carbon fiber composite at an angle  $\gamma$  of about  $45^\circ$ . In other embodiments of the braided fabric the angle is between  $1^\circ$  and  $89^\circ$ , i.e. more than  $0^\circ$  and less than  $90^\circ$ , preferably between  $40^\circ$  and  $50^\circ$  and most preferably  $45^\circ$ . The fabric 1 is also preferably manufactured as a sock or a tube. The tube-shape makes it easy to pull over and attach to the portion of the engagement element and the possible tools forming the inside of the manufactured housing element, and fold over and enclose the wrapping as described above. Several layers of the braided fabric may be used in the same manufacturing process if so desired. The carbon fiber composite material may preferably comprise a thermoset carbon fiber composite, but can in other embodiments be any carbon fiber composite, such as, but not limited to thermoplastic, crystalline, or metal.

**[0036]** The tows, which are wound around the inner layer/layers, are made of the same carbon fiber composite material as the braided fabric 1, but may in another embodiment be made of any carbon fiber composite. The same tow is preferably also used in the wrapping around the outer layer. The wrapping of the tow is very tight with an average fiber volume fraction up to

86%.

**[0037]** The choice of the carbon fiber composite material does not only make the weight of the elements low but the elements are also very strong depending on the type of carbon fiber type used and resistant against great tensile and compression forces which may be applied to at least the engagement element and which the housing element must endure.

**[0038]** The carbon fiber composite material may be manufactured using any manufacturing method; such as - but not limited to - wet lay-up, vacuum injection, resin transfer molding (RTM), VARTM, or pre-preg manufacturing in autoclave.

**[0039]** Finally, although the inventive concept has been described above with reference to specific embodiments, it is not intended to be limited to the specific form set forth herein. Rather, the invention is limited only by the accompanying claims and, other embodiments than the specific above are equally possible within the scope of these appended claims.

## REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

### Patent documents cited in the description

- [WO2007084901A2](#) [0002]
- [US2004208406A1](#) [0004]

KINEMATISKE PARPatentkrav

1. Huselement til et kinematisk par (10; 110; 210; 310; 410; 510), hvilket kinematisk par omfatter huselementet (30; 130; 230; 330; 430; 530) og et indgrebselement (20; 120; 220; 320; 420; 520), idet indgrebselementet er indrettet i det mindste delvist inde i huselementet og konfigureret til at opnå en roterende og/eller glidende bevægelse i forhold til huselementet, hvor huselementet omfatter: mindst ét første materialeglag, der i brug omgiver i det mindste en del af indgrebselementet, en fiberkompositmaterialeomslutning, der er indrettet omkring i det mindste en del af det første lag, og mindst ét andet materialeglag, der er indrettet på ydersiden af omslutningen, kendetegnet ved, at nævnte første lag er et kulfiberkompositlag (51), nævnte omslutning er en kulfiberkompositmaterialeomslutning (53), og nævnte andet lag er et kulfiberkompositlag (55).  
15
2. Huselement ifølge krav 1, hvor det første og andet lag (51, 55) omfatter en flettet struktur af et kulfiberkompositmateriale.
3. Huselement ifølge krav 1 eller 2, hvor nævnte første lag (51) og nævnte andet lag (55) udgør dele af et og samme kulfiberkompositmaterialeelement.  
20
4. Huselement ifølge et hvilket som helst af de foregående krav, hvor kulfiberkompositmaterialet omfatter et termohærdende plastmateriale, termoplastisk materiale, krystallinsk materiale eller metalmateriale.  
25
5. Huselement ifølge et hvilket som helst af de foregående krav, der endvidere omfatter et belægningselement (57), som er indrettet på overfladen af det første kulfiberkompositmateriale-lag (51) vendende mod indgrebselementet, hvor belægningselementet (57) omfatter et grafit-baseret materiale, såsom, men ikke begrænset til, dampudfældede kulstofnanorør.  
30
6. Huselement ifølge et hvilket som helst af de foregående krav, hvor huselementet er en muffe (30) i et kugleled (10).
- 35 7. Kinematisk par, der omfatter:

mindst ét huselement (30; 130; 230; 330; 430; 530) ifølge et hvilket som helst af kravene 1-5, og  
et indgrebselement (20; 120; 220; 320; 420; 520),  
hvor indgrebselementet er indrettet i det mindste delvist inde i huselementet og  
5 konfigureret til at opnå en roterende og/eller glidende bevægelse i forhold til huselementet.

8. Kinematisk par ifølge krav 7, hvor huselementet er en muffe (30), og indgrebselementet er en kugle (21), der tilsammen danner et kugleled (10).  
10

9. Fremgangsmåde til fremstilling af et huselement (30; 130; 230; 330; 430; 530) til et kinematisk par (10; 110; 210; 310; 410; 510), hvilket kinematisk par omfatter huselementet og et indgrebselement (20; 120; 220; 320; 420; 520), idet indgrebselementet er indrettet i det mindste delvist inde i huselementet og  
15 konfigureret til at opnå en roterende og/eller glidende bevægelse i forhold til huselementet, hvilken fremgangsmåde omfatter følgende trin:

- indretning af mindst ét første materialelag omkring i det mindste en del af indgrebselementet,
- indretning af et fiberkompositmateriale omkring i det mindste en del af nævnte  
20 første lag til dannelse af mindst én omslutning, og
- indretning af mindst ét andet materialelag på den yderste omslutning (53), kendetegnet ved, at nævnte første lag tilvejebringes som et kulfiberkompositlag (51), nævnte omslutning tilvejebringes som en kulfiberkompositomslutning (53), og nævnte andet lag tilvejebringes som et kulfiberkompositlag (55), hvor nævnte  
25 omslutning (53) vikles omkring nævnte første lag (51).

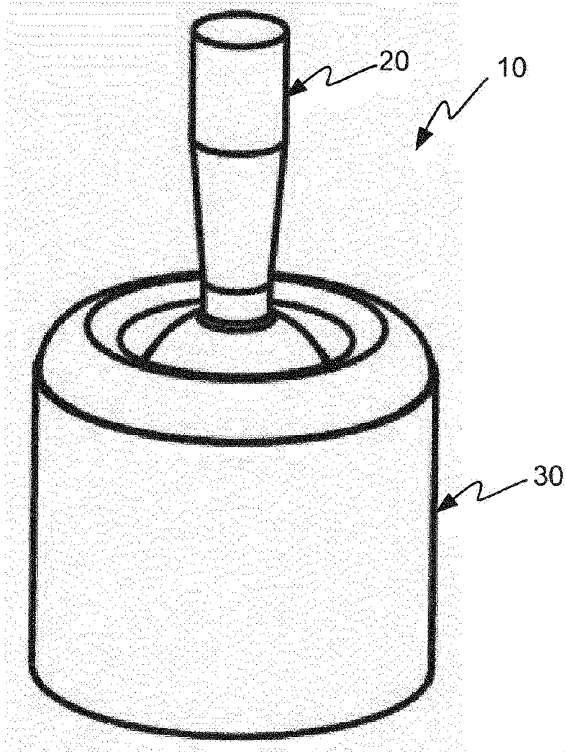
10. Fremgangsmåde ifølge krav 9, der endvidere omfatter trinnet til:  
- vikling af nævnte kulfiberkompositmateriale omkring i det mindste en del af nævnte andet lag (55) til dannelse af mindst én ydre omslutning (56).  
30

11. Fremgangsmåde ifølge krav 9 eller 10, hvor trinnet til indretning af mindst ét andet kulfiberkompositmaterialelag (55) endvidere omfatter:  
- foldning af en del af det første lag (51) over omslutningen (53) til dannelse af det andet lag (55).  
35

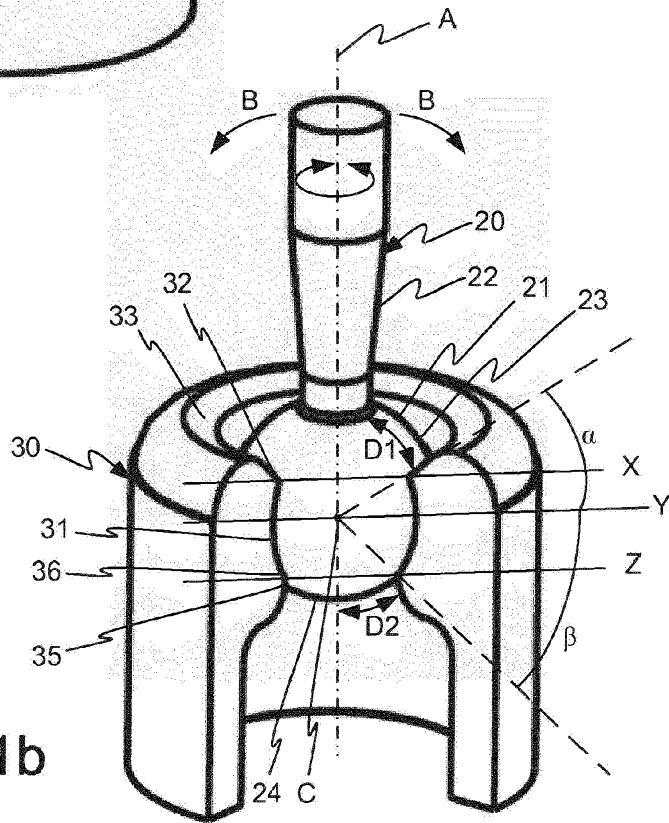
12. Anvendelse af et kulfiberkompositmateriale, der er viklet omkring i det mindste en del af et første kulfiberkompositmaterialelag (51) til dannelse af mindst

ét omsluttet lag (53) af et kinematisk par (10; 110; 210; 310; 410; 510) ifølge krav 7 eller 8.

**DRAWINGS**



**Fig. 1a**



**Fig. 1b**

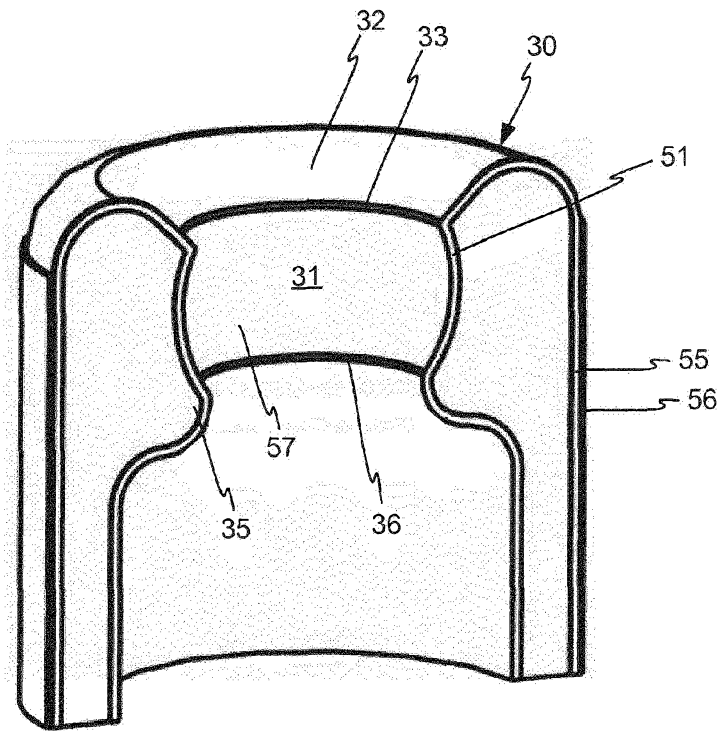
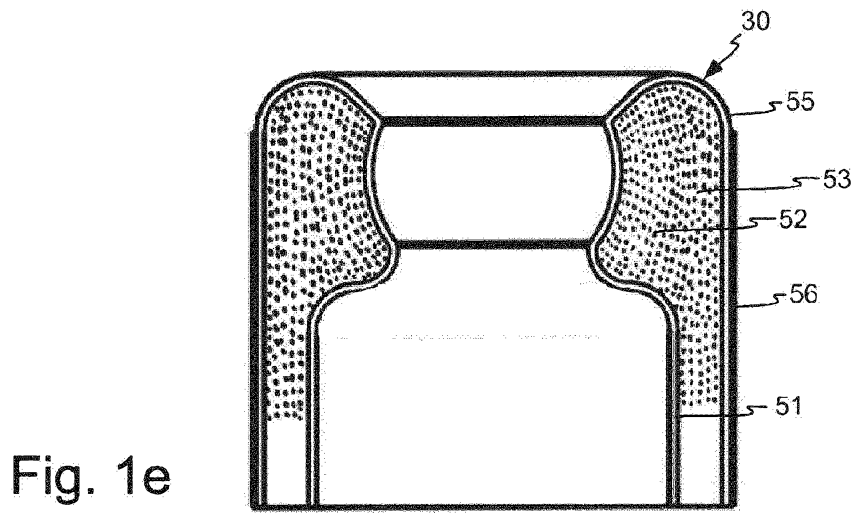
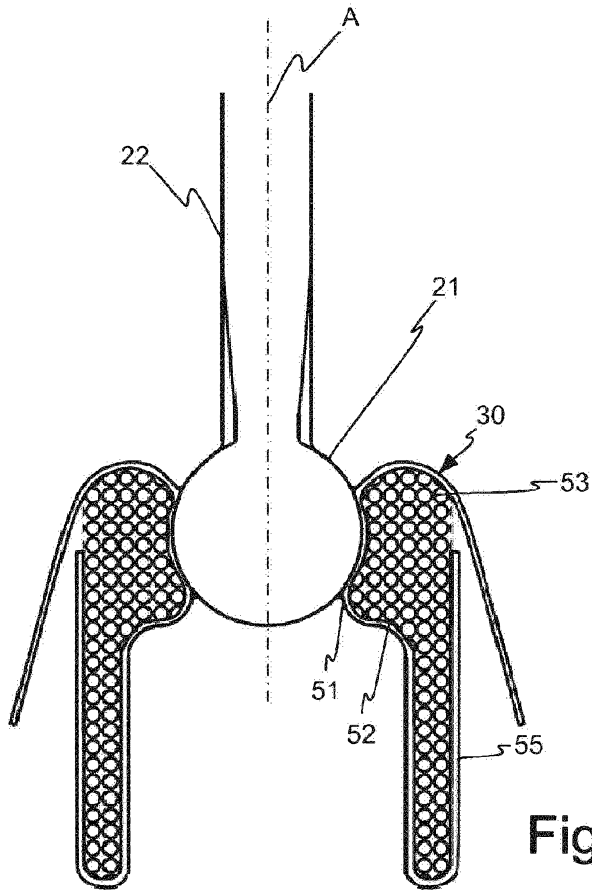


Fig. 1c



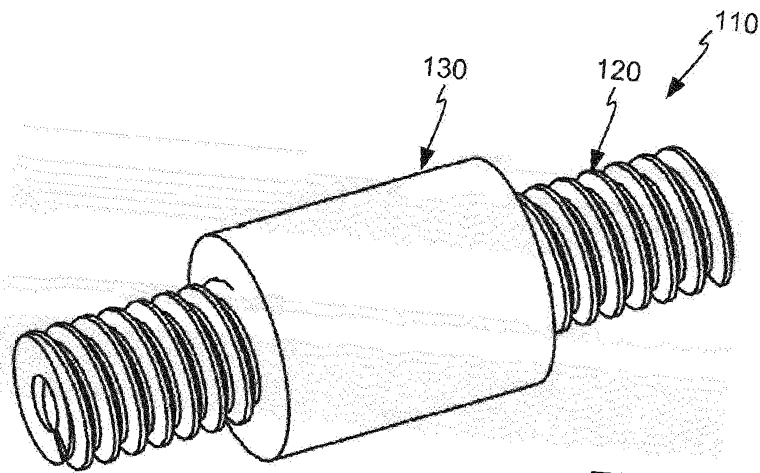


Fig. 2a

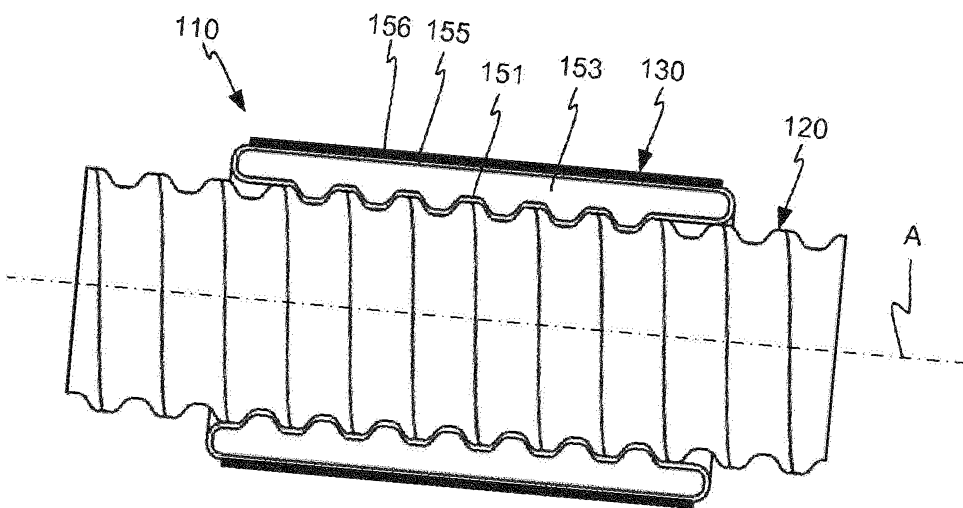
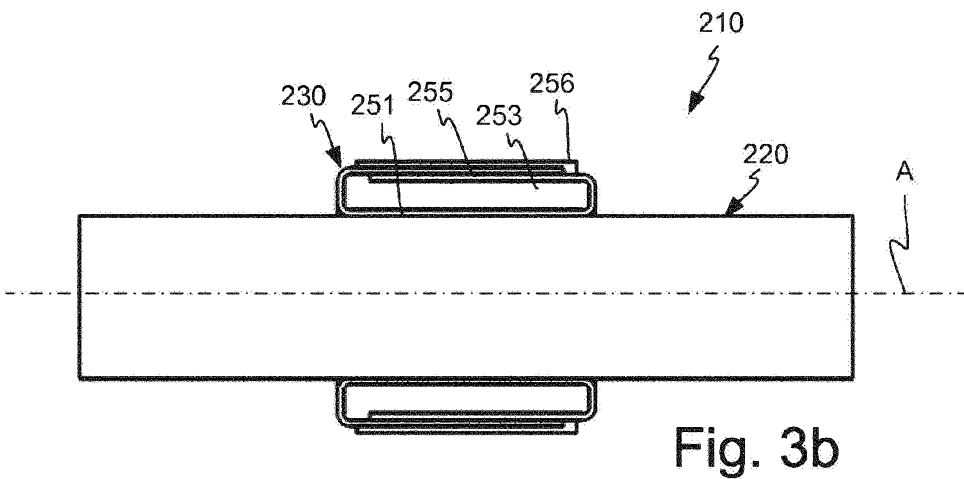
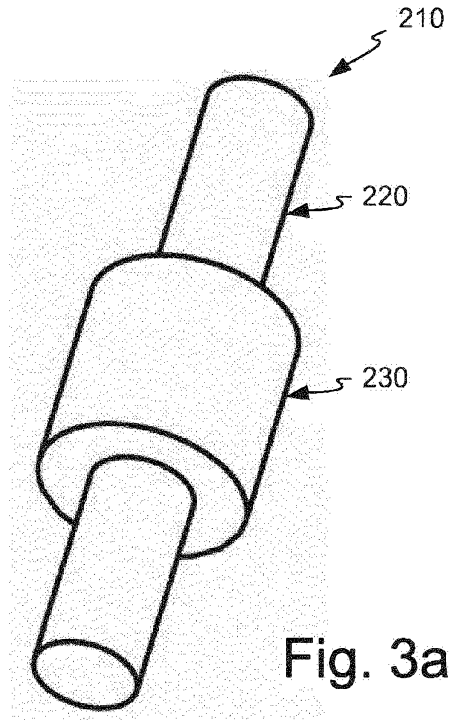


Fig. 2b



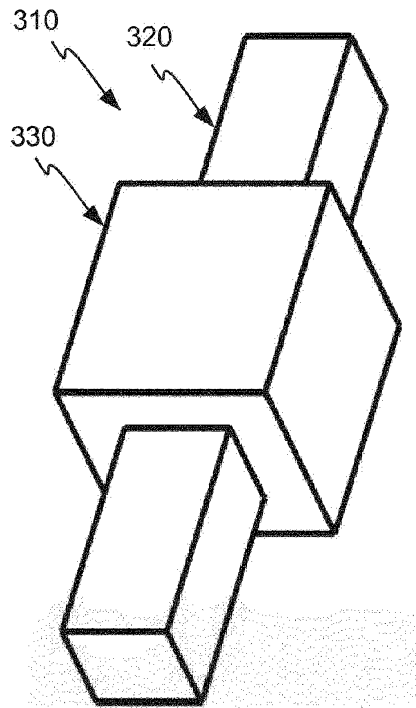


Fig. 4a

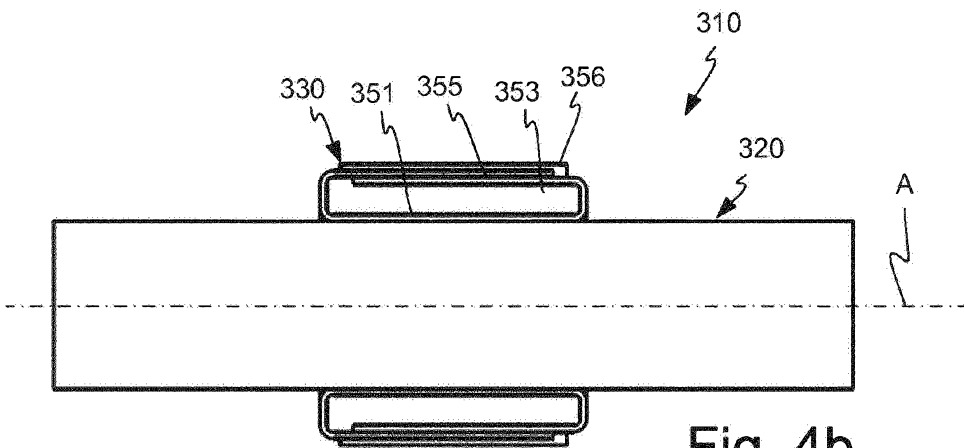


Fig. 4b

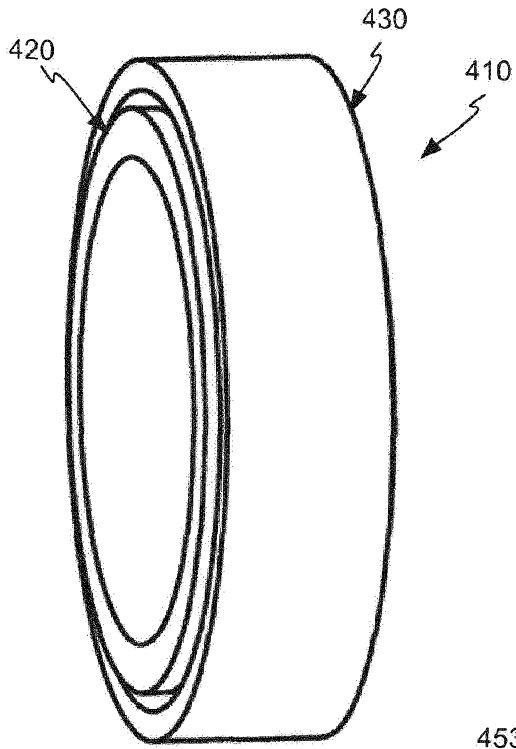


Fig. 5a

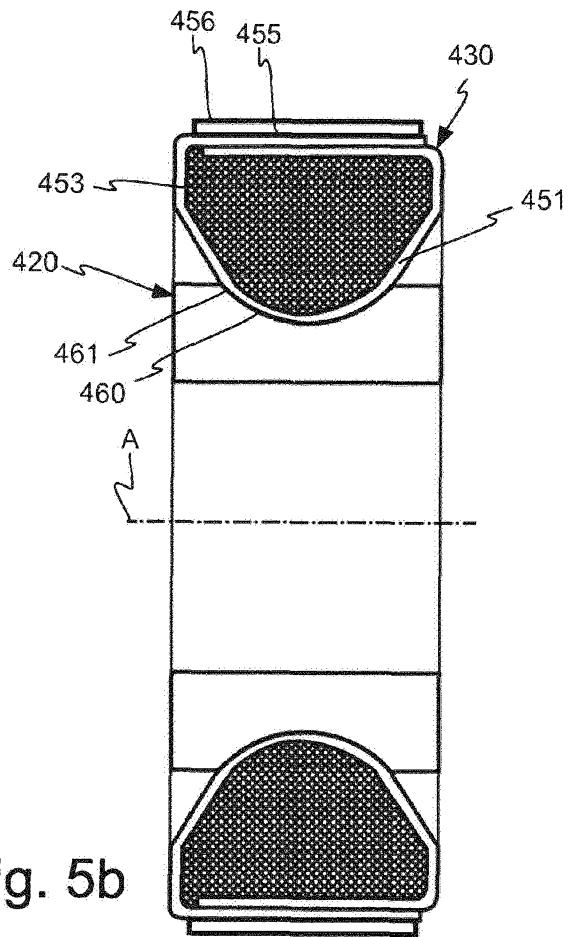
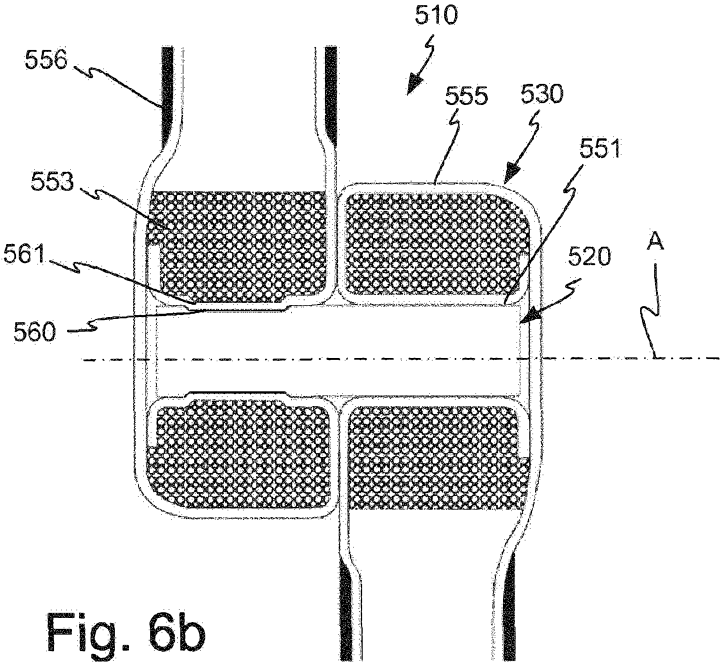
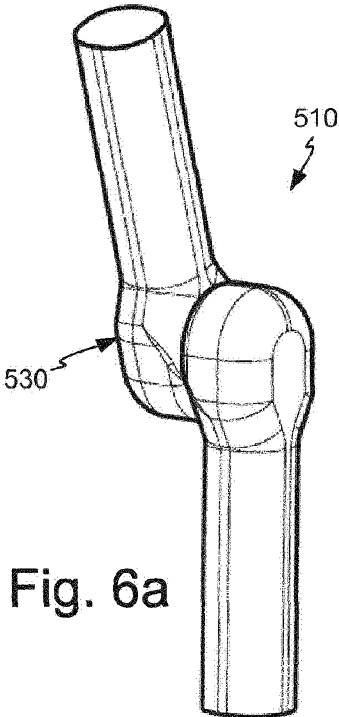


Fig. 5b



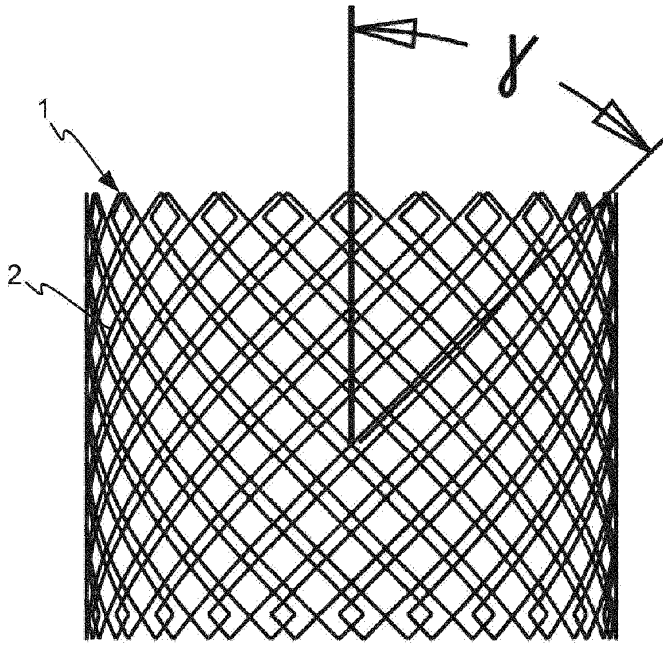


Fig. 7