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(54) **FUEL PUMP AND DRIVESHAFT ASSEMBLY THEREFOR**

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Description**FIELD OF THE INVENTION**

[0001] This invention relates to a driveshaft assembly, and in particular a driveshaft assembly for transmitting drive in a pump suitable for high-pressure fuel supply in a fuel injection system, such as a diesel injection system.

BACKGROUND

[0002] Known driveshaft assemblies for high pressure fuel pumps comprise an elongate shaft element and a cam member fastened to the elongate shaft element by way of an interference fit. Document KR 2016 0095154 A shows a drive shaft that can be used in a high pressure fuel pump.

[0003] During the assembly process, the cam member is heated up in order to expand an internal bore of the cam member. The cam member is then pushed onto the elongate shaft element and then cooled down to shrink-fit the cam member on the elongate shaft element. This can lead to the development of high hoop stresses in the cam member, which can cause failure of the cam member during high load conditions.

[0004] It is against this background that the invention has been devised.

STATEMENTS OF INVENTION

[0005] According to an aspect of the invention, there is provided a driveshaft assembly for a high-pressure fuel pump comprising an elongate shaft element and a cam member comprising a concentric oval bore, the cam member is an interference fit on the elongate shaft element by way of a thermal shrink fitting, wherein the cam member and the concentric oval bore each comprise a major axis of symmetry perpendicular to a minor axis of symmetry, the concentric oval bore being arranged with respect to the cam member such that the major and minor axes of symmetry of the concentric oval bore and the cam member are coaxially aligned.

[0006] The portion of the elongate shaft element forming the interference fit has a circular cross-section.

[0007] Preferably, the ovality of the oval bore is substantially within the range of 0.02% and 0.10%. In particular, it is preferably if the ovality of the oval bore is substantially 0.095%.

[0008] According to another aspect of the invention, there is provided a high-pressure fuel pump comprising a driveshaft assembly according to the previous aspect of the invention.

BRIEF DESCRIPTION OF DRAWINGS

[0009] The above and other aspects of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a cross-sectional view of a high-pressure fuel pump comprising a known driveshaft assembly;

Figure 2a is an exploded isometric view of the driveshaft assembly of Figure 1;

Figure 2b is an assembled isometric view of the driveshaft assembly of Figure 1;

Figure 3 is a plan view of a cam member of the driveshaft assembly of Figure 1 showing the hoop stress distribution in the cam member;

Figure 4a is a plan view of the a cam member of a driveshaft assembly in accordance with the invention;

Figure 4b is a plan view of the cam member of Figure 4a showing the hoop stress distribution in the cam member;

Figure 5 is a plot showing how the maximum hoop stress, along the y-axis, experienced at the bore and the outer diameter of the cam member of Figure 4a varies with respect to ovality, along the x-axis; and,

Figure 6 is a plot showing how an average contact pressure, along the y-axis, varies with respect to the ovality of the bore, along the x-axis, of the cam member of Figure 4a.

[0010] In the drawings, like features are denoted by like reference signs.

SPECIFIC DESCRIPTION

[0011] The following description refers to accompanying drawings that show, by way of illustration, an embodiment in which the invention may be practiced. This embodiment is described in sufficient detail to enable those skilled in the art to practice the invention. Other embodiments may be utilised and structural changes may be made without departing from the scope of the invention as defined in the appended claims. Moreover, references in the following description to "inner", "outer" or any other terms having an implied orientation are not intended to be limiting and refer only to the orientation of the features as shown in the accompanying drawings.

[0012] Figure 1 shows a known high-pressure fuel pump, generally designated by 2, for a compression-ignition internal combustion engine. The high-pressure fuel pump (hereinafter "the pump 2") comprises a housing 4 and a driveshaft assembly 6 arranged for rotation within a bore 8 provided in the housing 4.

[0013] The driveshaft assembly 6 comprises an elongate shaft element 10 (hereinafter "the shaft 10") and a cam member 12 secured to the shaft 10 by an interference fit formed by thermal shrink fitting. During a pumping

cycle, the driveshaft assembly 6 is caused, by a cam drive mechanism (not shown), to rotate relative to the housing 4 about longitudinal axis A. Rotation of the driveshaft assembly 6 causes a reciprocating force to be imparted to a plunger 14, via a roller 16, thereby causing fuel within a pumping chamber 18 to become pressurised.

[0014] Figures 2a and 2b illustrate the driveshaft assembly 6 in isolation in an exploded view and an assembled view respectively. The shaft 10 has a circular cross-section and comprises a first journal portion 20 towards a first end 22 and a second journal portion 24 towards a second end 26. A mid-portion 28 is provided between the first journal portion 20 and the second journal portion 24. As mentioned above, the cam member 12, comprising a thrust face 30, is secured to the mid-portion 28 of the shaft 10 by a thermal shrink fit.

[0015] When assembling the driveshaft assembly 6, the cam member 12 is heated, thereby causing a diameter a concentric circular through bore 32 (hereinafter "the bore 32") of the cam member 12 to radially expand. In this example, the diameter of the bore 32 prior to heating is 21mm. The heated cam member 12 is then inserted onto the shaft 10 via the second end 26 of the shaft 10, over the second journal portion 24, until it is located over the mid-portion 28 of the shaft 10. The cam member 12 is subsequently allowed to decrease in temperature *in situ* until its temperature equalises to room temperature. As the temperature of the cam member 12 decreases, the diameter of the bore 32 also decreases forming an interference fit on the mid-portion 28 of the shaft 10. That is, an inner radial surface 34 defining the bore 32 of the cam member 12 is an interference fit on the outer radial surface 36 of the mid-portion 28 of the shaft 10. In the example, the interference between inner radial surface 34 and the outer radial surface 36 is in the region of 80 μ m, resulting in an average contact pressure of approximately 225 MPa. Relative movement of the cam member 12 on the shaft 10 during use of the pump 2 is therefore prevented by the interference fit.

[0016] A problem when assembling the driveshaft assembly 6 is that thicker sections of the cam member 12 deform more than thinner sections during the thermal shrink fitting of the cam member 12 on the shaft 10. This can result in an uneven hoop stress distribution in the cam member 12. Figure 3 illustrates the hoop stress distribution in the cam member 12, and shows that the process described above results in a hoop stress concentration at narrow sections 37 of the cam member 12 having a peak value of approximately 680 MPa. It is because of this concentration of hoop stress that failure is seen at the narrow sections 37 of the cam member 12 during high load conditions.

[0017] The present invention overcomes this problem by increasing the ovality of the bore 32 of the cam member 12 to provide an improved hoop stress distribution at the contact between the inner radial surface 34 of the cam member 12 and the outer radial surface 36 of the

shaft 10.

[0018] Figure 4a shows an embodiment of a cam member 12 for use in a driveshaft assembly 6 in accordance with the invention. The cam member 12 comprises a concentric oval bore 38, having a minimum diameter of 21mm and a maximum diameter of 21.02mm. Accordingly, the ovality of the bore 38 is 0.095%. The shape of the cam member 12, defined an outer radial surface 40, and the oval bore 38 each comprises a major axis of symmetry, shown as line B - B, arranged perpendicularly with respect to a minor axis of symmetry, shown as line C - C. It can be seen from the figure that the oval bore 32 is arranged such that its the major and minor axes of symmetry are coaxially aligned with the respective major and minor axes of symmetry of the cam member 12.

[0019] Figure 4b shows the hoop stress distribution in this embodiment of the cam member 12. It can be seen that the peak hoop stress at the narrow sections 37 of the cam member 12 is approximately 610 MPa, representing an 11% reduction in the peak hoop stress experience by the cam member 12 when compared to the cam member 12 having the circular bore 32. There are two reasons for this reduction in the peak hoop stress. Firstly, the presence of the oval bore 38 means that the circumferential interference between the inner radial surface 34 of the bore 38 and the outer radial surface 36 of the shaft 10 is not even. For example, in the embodiment shown, the interference at the narrow sections 37 of the cam member 12 is reduced to within the in the region of 60 μ m, whereas the interference at the thicker sections of the cam member 12 stays within the region of 80 μ m. This reduction in the interference at the narrow sections 37 of the cam member 12 leads to a corresponding reduction in the peak hoop stress experienced by the cam member 12 at those sections 37. Secondly, during thermal shrink fitting, a circular cam bore does not uniformly deform. Instead, the sides of the cam bore associated with the thicker sections of the cam member deform comparatively more than those associated with the thinner sections. This results in an uneven hoop stress distribution in the cam member and a large peak hoop stress. The deformation of the oval bore 38 during thermal shrink fitting is more uniform, allowing for a more even hoop stress distribution and a lower peak hoop stress.

[0020] The graphs of Figures 5 and 6 show that the peak hoop stress around the oval bore 38 (Cam bore) and the outer radial surface 40 (Cam OD) decreases with respect to ovality, and that the contact pressure between the inner radial surface 34 of the bore 38 and the outer radial surface 36 of the shaft 10 also decreases as the ovality of the bore 38 increases, respectively. Figure 6 shows that at an ovality of 0.095%, the average contact pressure between the inner radial surface 34 of the bore 38 and the outer radial surface 36 of the shaft 10 is approximately 225 MPa. This level of contact pressure is sufficient to prevent relative movement of the cam member 12 on the shaft 10 during use of the pump 2. A substantially lower contact pressure, produced by increasing

the ovality of the bore 38, may not be sufficient to prevent relative movement between the cam member 12 and the shaft 10 during use of the pump 2. On the other hand, decreasing the ovality of the bore 38 too much would result in peak hoop stresses similar to those experienced by the cam member 12 having a circular bore 32, as shown in Figure 5. Accordingly, it is preferable that the ovality of the bore 38 is within a range of 0.02% to 0.10%.

[0021] It will be appreciated by a person skilled in the art that the invention could be modified to take many alternative forms to that described herein without departing from the scope of the appended claims. According to the present invention, the shaft 10 described above has a circular cross-section. In an alternative not belonging to the present invention, at least the region of the shaft 10 to which the cam member 12 is secured by a thermal shrink fit, in this case the mid-portion 28, has an oval cross-section. In such an alternative not belonging to the present invention, the ovality of the mid-portion 28 may be substantially equal to the ovality of the bore 38. Moreover, the major and minor axes of symmetry of the mid-portion 38 of the shaft 10 may be aligned with the respective major and minor axes of symmetry of the bore 38.

REFERENCES USED:

[0022]

High-pressure fuel pump 2
Housing 4
Driveshaft assembly 6
Bore 8
Elongate shaft element 10
Cam member 12
Plunger 14
Roller 16
Pumping chamber 18
First journal portion 20
First end 22
Second journal portion 24
Second end 26
Mid-portion 28
Thrust face 30
Circular bore 32
Inner radial surface 34 of the bore 8
Outer radial surface 36 of the shaft 10
Narrow sections 37 of the cam member 12
Oval bore 38
Outer radial surface 40 of the cam member 12

Claims

1. A driveshaft assembly (6) for a high-pressure fuel pump (2), the driveshaft assembly (6) comprising an elongate shaft element (10) and a cam member (12) comprising a concentric oval bore (38), the cam member (12) is an interference fit on the elongate

shaft element (10), wherein the cam member (12) and the concentric oval bore (38) each comprise a major axis of symmetry perpendicular to a minor axis of symmetry, the concentric oval bore (38) being arranged with respect to the cam member (12) such that the major and minor axes of symmetry of the concentric oval bore (38) and the cam member (12) are coaxially aligned and, **characterised in that** the portion (28) of the elongate shaft element (10) forming the interference fit has a circular cross-section.

2. A driveshaft assembly (6) according to the preceding claim, wherein the ovality of the oval bore (38) is substantially within the range of 0.02% and 0.10%.
3. A driveshaft assembly (6) according to any preceding claim, wherein the ovality of the oval bore (38) is substantially 0.095%.
4. A high-pressure fuel pump (2) comprising a driveshaft assembly (6) according to any preceding claim.

Patentansprüche

1. Antriebswellenanordnung (6) für eine Hochdruckkraftstoffpumpe (2), die Antriebswellenanordnung (6) umfassend ein längliches Wellenelement (10) und ein Nockenelement (12), umfassend eine konzentrische ovale Bohrung (38), wobei das Nockenelement (12) eine Presspassung auf dem länglichen Wellenelement (10) ist, wobei das Nockenelement (12) und die konzentrische ovale Bohrung (38) jeweils eine Hauptsymmetrieachse umfassen, die zu einer Nebensymmetrieachse senkrecht ist, wobei die konzentrische ovale Bohrung (38) in Bezug auf das Nockenelement (12) derart angeordnet ist, dass die Haupt- und Nebensymmetrieachsen der konzentrischen ovalen Bohrung (38) und des Nockenelements (12) koaxial ausgerichtet sind und **dadurch gekennzeichnet, dass** der Abschnitt (28) des länglichen Wellenelements (10), der die Presspassung ausbildet, einen kreisförmigen Querschnitt aufweist.
2. Antriebswellenanordnung (6) nach dem vorhergehenden Anspruch, wobei die Ovalität der ovalen Bohrung (38) im Wesentlichen innerhalb des Bereichs von 0,02 % bis 0,10 % liegt.
3. Antriebswellenanordnung (6) nach einem der vorhergehenden Ansprüche, wobei die Ovalität der ovalen Bohrung (38) im Wesentlichen 0,095 % beträgt.
4. Hochdruckkraftstoffpumpe (2), umfassend eine Antriebswellenanordnung (6) nach einem der vorhergehenden Ansprüche.

Revendications

1. Ensemble arbre de transmission (6) pour une pompe à carburant haute pression (2), l'ensemble arbre de transmission (6) comprenant un élément arbre allongé (10) et un élément came (12) comprenant un alésage ovale concentrique (38), l'élément came (12) est un ajustement serré sur l'élément arbre allongé (10), dans lequel l'élément came (12) et l'alésage ovale concentrique (38) comprennent chacun un grand axe de symétrie perpendiculaire à un petit axe de symétrie, l'alésage ovale concentrique (38) étant agencé par rapport à l'élément came (12) de sorte que les grands et petits axes de symétrie de l'alésage ovale concentrique (38) et de l'élément came (12) sont alignés coaxialement et, **caractérisé en ce que** la partie (28) de l'élément arbre allongé (10) formant l'ajustement serré a une section transversale circulaire.
2. Ensemble arbre de transmission (6) selon la revendication précédente, dans lequel l'ovalité de l'alésage ovale (38) est sensiblement comprise dans la plage de 0,02 % à 0,10 %.
3. Ensemble arbre de transmission (6) selon une quelconque revendication précédente, dans lequel l'ovalité de l'alésage ovale (38) est sensiblement de 0,095 %.
4. Pompe à carburant haute pression (2) comprenant un ensemble arbre de transmission (6) selon une quelconque revendication précédente.

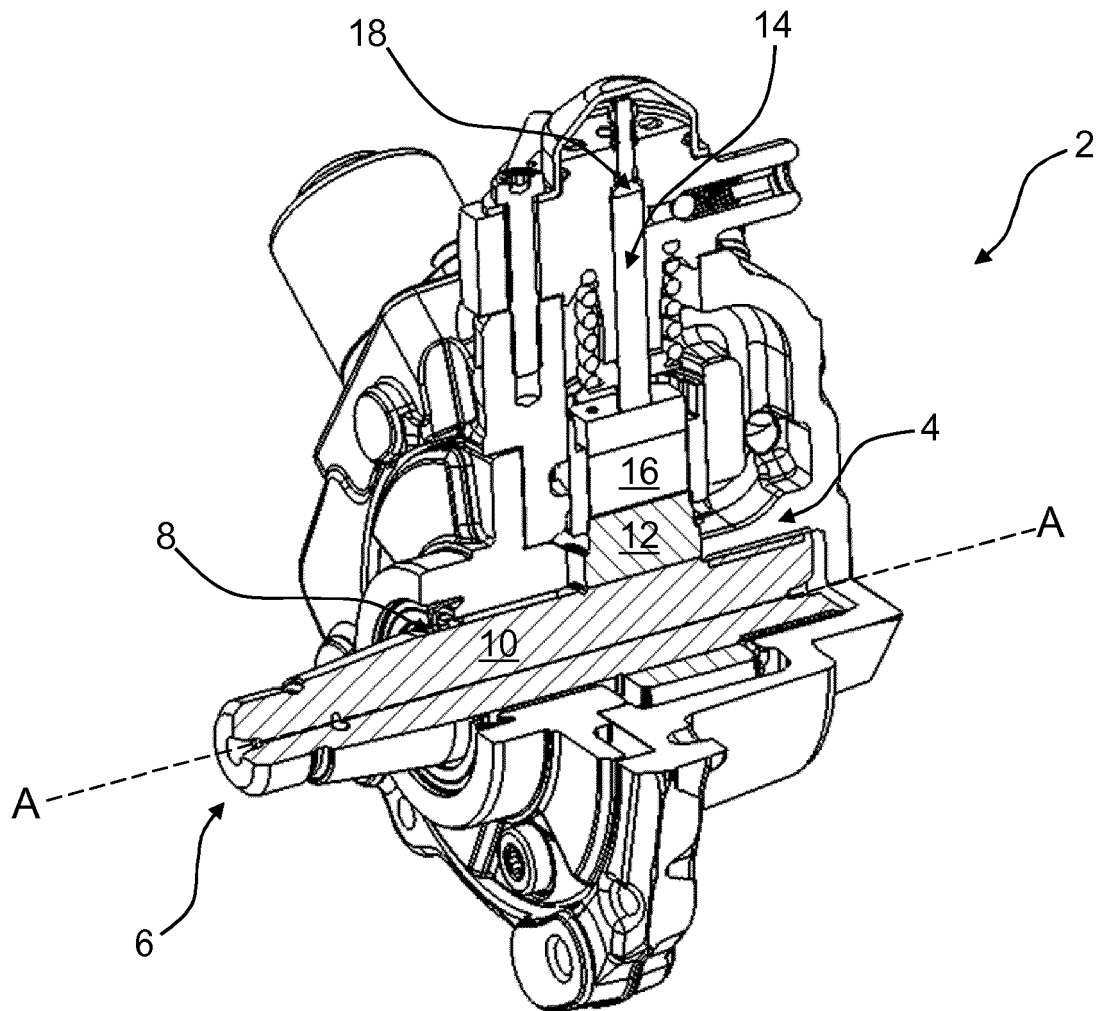


FIG. 1

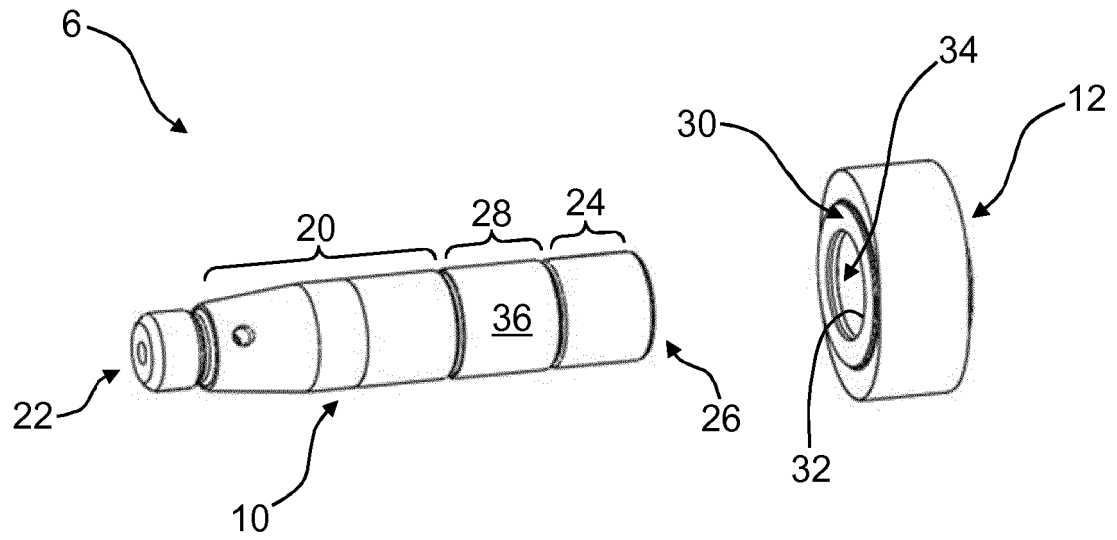


FIG. 2a

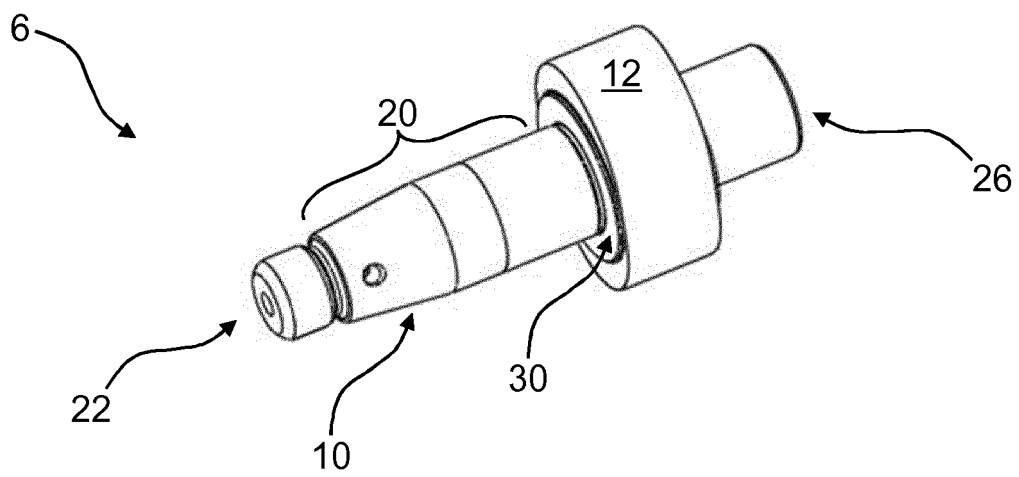


FIG. 2b

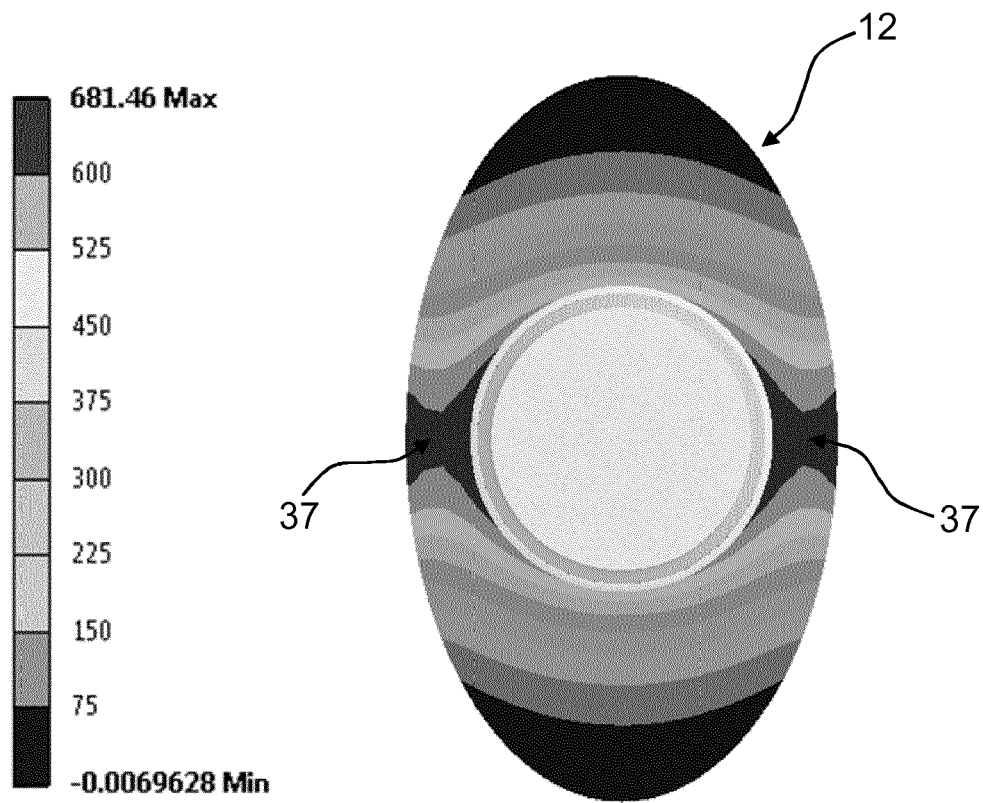


FIG. 3

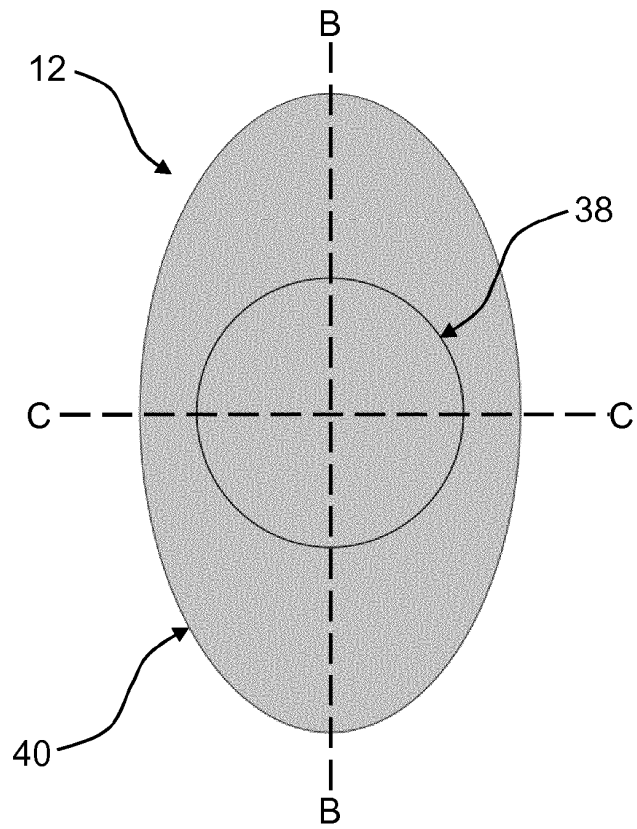


FIG. 4a

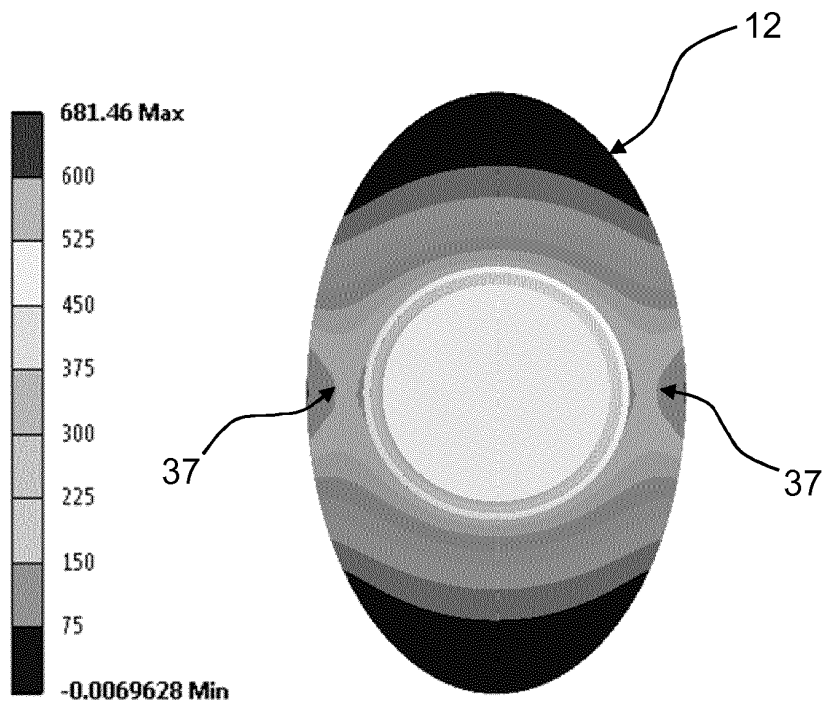


FIG. 4b

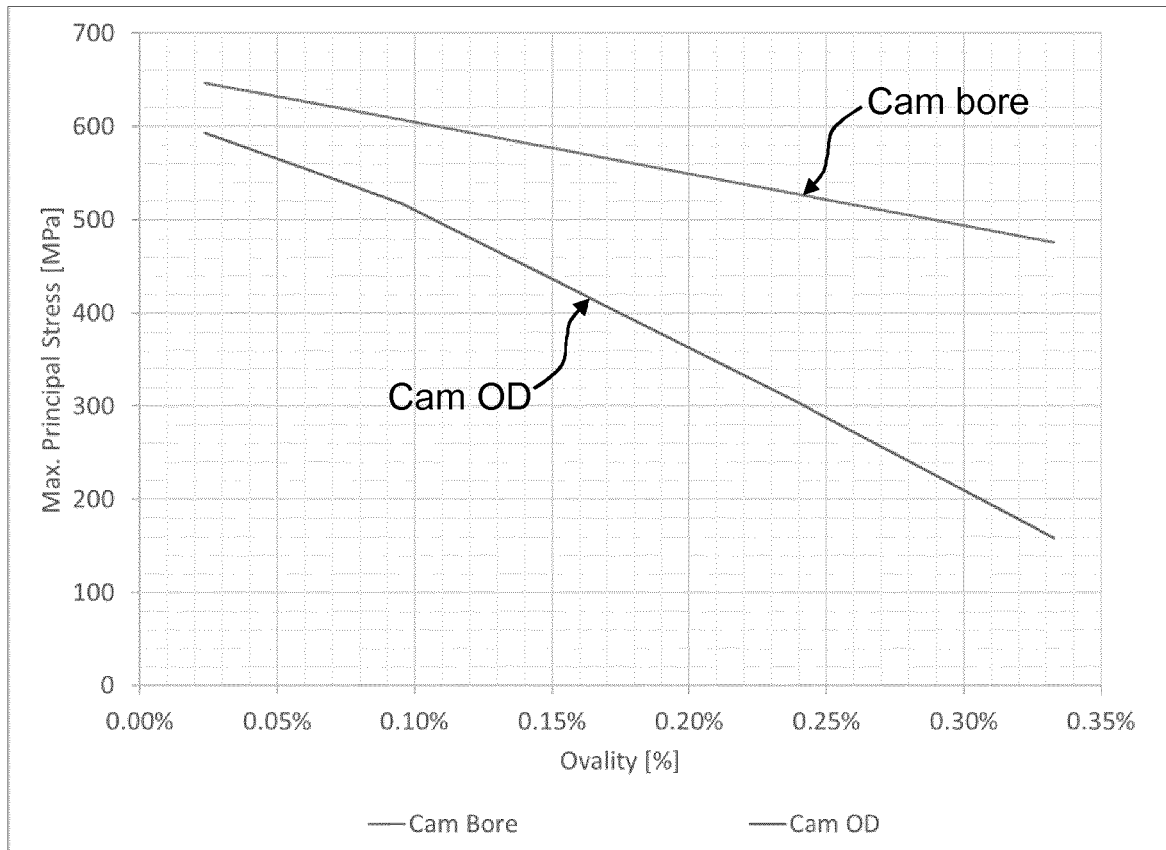


FIG. 5

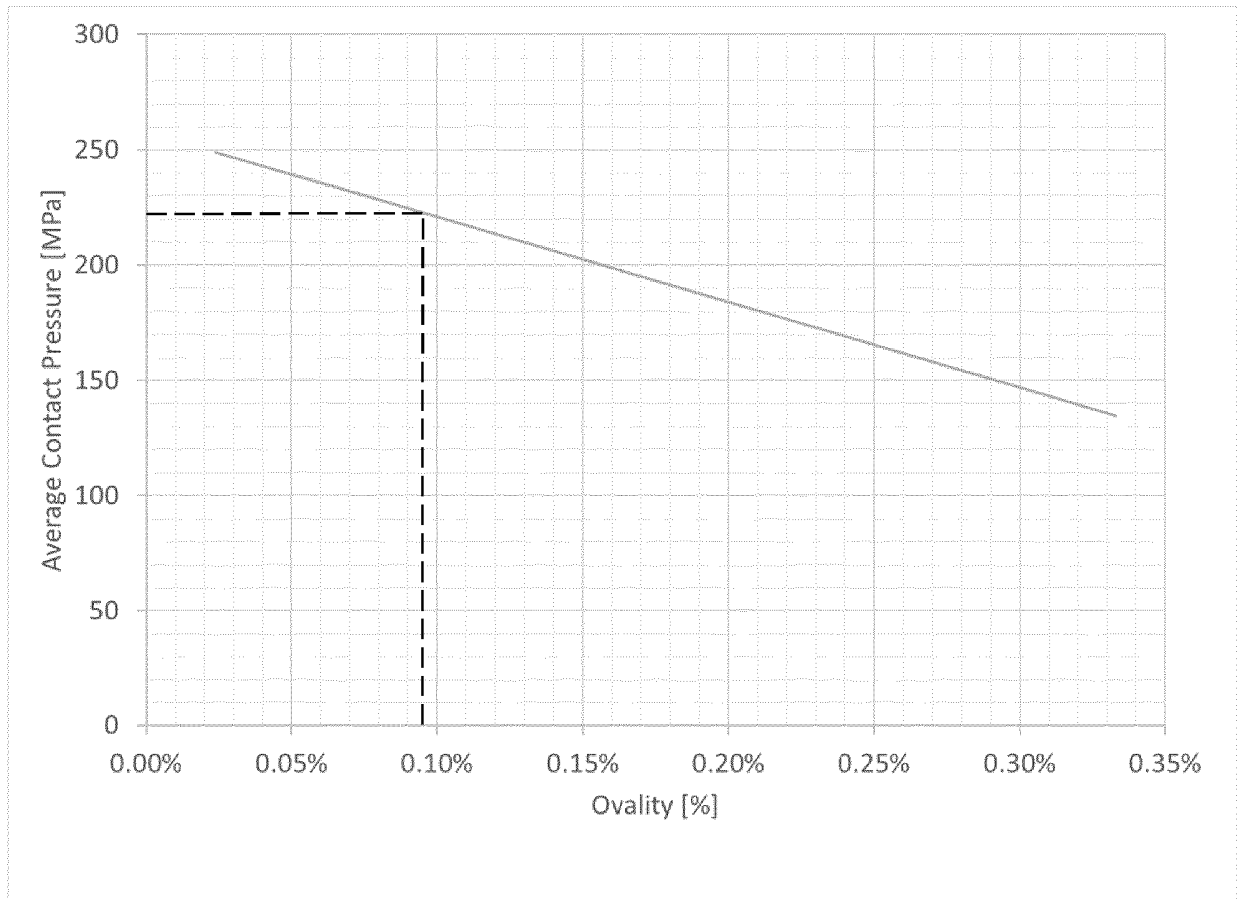


FIG. 6

REFERENCES CITED IN THE DESCRIPTION

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