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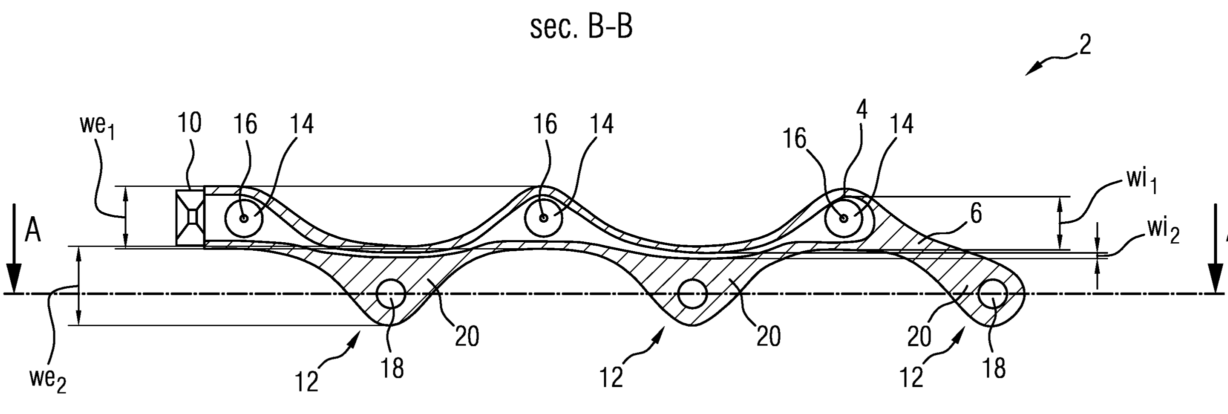
(54) **FUEL RAIL FOR A FUEL INJECTION SYSTEM AND METHOD OF MANUFACTURING SUCH A FUEL RAIL**

(57) A fuel rail (2) for a fuel injection system for an internal combustion engine comprises an elongate body (4) having a peripheral wall (6) defining a fuel reservoir (8) and having a fuel inlet (10), a plurality of fuel outlets (14) spaced along the fuel rail (2), and at least one fastening point (12) to enable the fuel rail (2) to be secured to an engine. A thickness of the peripheral wall (6) is variable along its length and is thicker in regions subject, in operation, to higher stress. The fuel rail (2) may be manufactured using an additive manufacturing technology.

FIG 3



EP 3 604 787 A1

Description

[0001] The present disclosure relates to a fuel rail for a fuel injection system for an internal combustion engine and to a method of manufacturing a fuel rail.

[0002] A fuel rail for a fuel injection system for an internal combustion engine, also known as a common rail or a main gallery, typically comprises an elongate tubular member forming a reservoir for fuel which is supplied to an inlet of the fuel rail under high pressure by a fuel pump. The fuel rail has a plurality of fuel outlets spaced along its length each of which is in hydraulic communication with a fuel injector by which fuel is injected into the engine. In one form referred to as direct injection each cylinder of a multi-cylinder internal combustion engine has a fuel injector which injects fuel directly into the combustion chamber.

[0003] When installed in a motor vehicle, such fuel rails are typically secured rigidly to the engine where they are subjected to high stresses caused by the harsh environment of high temperatures, vibration caused by the engine vibrating on its engine mounts in the vehicle and by the general vibration in the vehicle as it moves along. In addition, further stress is applied to the fuel rail by virtue of the high internal fluid pressure in the fuel rail and of pressure fluctuations caused by the fuel pump and the fuel injection process.

[0004] Furthermore, holes for mounting points to enable the fuel rail to be secured to the engine and the holes in the fuel rail forming the fuel outlets inevitably form stress concentration points where the stresses on the fuel rail are greatly increased, which can lead to premature failure and lower durability at these points.

[0005] It is, therefore, desirable to provide a fuel rail which has improved mechanical behaviour and durability and which is also compact and cost effective to manufacture.

[0006] Accordingly, the present disclosure provides a fuel rail which is compact, lightweight and which can be manufactured in a cost effective manner.

[0007] According to the present disclosure a fuel rail for a fuel injection system for an internal combustion engine comprises an elongate body having a peripheral wall defining a fuel reservoir and having a fuel inlet, a plurality of fuel outlets spaced along the fuel rail, and at least one fastening point to enable the fuel rail to be secured to an engine. The peripheral wall has a wall thickness that is variable along length of the elongate body and is thicker in regions subject, in operation, to higher stress.

[0008] The fuel rail includes integral local reinforcement of its strength in regions that are subject to higher stress, particularly when the fuel rail is in operation. These regions may be the fuel outlets and fastening points for example.

[0009] In an embodiment, the fastening point is positioned in a portion of the peripheral wall having an increased thickness to provide localised strengthening of the fuel rail and its elongate body in the region of the fastening point.

[0010] In an embodiment, the fastening point comprises a hole that extends through the portion of the peripheral wall having the increased thickness and that is separate from the fuel reservoir. The hole and, therefore, fastening point is integral with the fuel rail as it is positioned in the peripheral wall. The hole is integrally formed in the increased thickness of the peripheral wall and is not in hydraulic or fluid communication with the fuel reservoir. The portion of the peripheral wall having the increased thickness may protrude outwardly from the centre axis of the elongate body to an extent sufficient to accommodate the hole within the protruding region and to position the hole with respect to the fuel reservoir at the desired position for mounting to the engine.

[0011] The fuel reservoir has an internal cross-sectional profile and, in some embodiments, the internal cross-sectional profile of the fuel reservoir is variable along a length of the elongate body. The internal cross-sectional profile of the fuel reservoir may have a height h_i that extends in a direction upwards from and perpendicular to an inner opening of the fuel outlet and a width w_i extending perpendicular to the height h_i.

[0012] In some embodiments, a height h_{i1} of the internal cross-sectional profile of the fuel reservoir above each fuel outlet is smaller than a height h_{i2} of the internal cross-sectional profile between the fuel outlets. A width w_{i1} of the internal cross-sectional profile of the fuel reservoir above each fuel outlet may be greater than a width w_{i2} of the internal cross-sectional profile between the fuel outlets. Therefore, the internal cross-sectional profile and, in some embodiments, the cross-sectional area of the fuel reservoir may vary along the length of the fuel reservoir in order to control the fuel pressure and flow dynamics of the fuel within the reservoir, in particular with respect to the position of the fuel outlets.

[0013] The transitions between the changes in the height and width of the internal cross-section profile and cross-sectional area of the fuel reservoir are smooth in order to avoid stress concentration regions.

[0014] The fuel rail also has an external cross-sectional profile and the external cross-sectional profile may also be variable along a length of the elongate body and fuel rail.

[0015] The external cross-sectional profile has a height h_e extending parallel the fuel outlet and a width w_e extending perpendicular to the height h_e. In some embodiments, a height h_{e1} of the external cross-sectional profile of the fuel rail at each fuel outlet is smaller than a height h_{e2} of the external cross-sectional profile between the fuel outlets. A width w_{e1} of the external cross-sectional profile of the fuel rail at each fuel outlet may be greater than a width w_{e2} of the external cross-sectional profile between the fuel outlets.

[0016] The fuel rail may have an outer contour that undulates, for example has a wave-like profile. In some embodiments, the fuel rail has an undulating or wave-like profile in two perpendicular directions, for example the peaks in the height direction may be positioned at longitudinal positions along the length of the fuel rail that are intermediate peaks in the width direction.

[0017] The fuel rail may comprise a metal, for example a steel such as a stainless steel, or may comprise plastic.

[0018] The disclosure also describes a method of manufacturing a fuel rail for a fuel injection system for an internal combustion engine. The method comprising building up an elongate body of the fuel rail according to any one of the embodiments described herein layer by layer, for example using additive manufacturing.

[0019] Additive manufacturing techniques may be used to build up the elongate body and the fuel rail layer by layer. For example, the elongate body may be built up layer by layer using 3D (Three-dimensional) printing or Powder Bed Fusion or Directed Energy Deposition. The elongate body may be built up layer by layer by movement of the metal jet print head, laser or electron beam controlled according to a three dimensional model of the elongate body.

[0020] A preferred embodiment of the present disclosure will now be described by way of example with reference to the accompanying drawing.

Figure 1 illustrates a fuel rail for a three-cylinder multi-cylinder internal combustion engine,

Figure 2 illustrates a cross-section along the line A-A of Figure 3, and

Figure 3 illustrates a cross-section along the line B-B of Figure 1.

[0021] Although described with reference to a three cylinder engine it will be understood that the disclosure is readily adaptable for any size and type of engine using common rail technology.

[0022] As shown in the drawings, a fuel rail 2 comprises an elongate body 4 having a peripheral wall 6 forming a reservoir 8 for fuel. The fuel rail 2 is formed by an additive manufacturing technology. The material of the fuel rail 2 is metal such as stainless steel but in other embodiments may be formed of a plastics material. At one end the fuel rail 2 is supplied with a fuel inlet 10 connected to a high-pressure fuel pump (not shown) by which fuel is supplied to the fuel rail 2. The other end of the fuel rail 2 is closed. The fuel rail 2 also includes one or more fixtures 12 or fuel rail mounting points 12 through which the fuel rail 2 is secured to the engine. The fixtures 12 may be provided in the region intermediate each fuel outlet 14 at a position determined by the installation conditions of the engine.

[0023] The fuel rail 2 of this embodiment is adapted to provide a direct fuel injection for a three-cylinder gasoline engine and has three fuel outlets 14 spaced along the fuel rail 2, the three outlets 14 being substantially aligned along a common axis which provide a mechanical and hydraulic connection to an injector inlet port in the form of an injector cup 16 adapted to receive a fuel injector (not shown) for each cylinder. It will be understood that the present disclosure may be adapted for use for engines having one or more cylinders, particularly for example, in designs in which the fuel is injected into the engine intake manifold.

[0024] The fixture 12 has the form of a hole 18 that is positioned in a portion 20 of the peripheral wall 6 that has an increased thickness. The portion 20 may protrude outwardly from the longitudinal axis of the elongate body 4 of the fuel rail 2. The hole 18 and, therefore, the mounting fixture 12 of the fuel rail 2, is integrally formed in the peripheral wall 6 of the fuel rail 2. The hole 18 is positioned within and has side walls defined by the thickened portion 20 of the peripheral wall and open ends that are separate from and not in fluid communication with the fuel reservoir 8 defined by the inner surface of the peripheral wall 6. The increased thickness of the peripheral wall 6 in the region around the hole 18 provides additional localised reinforcement to increase the strength of the fuel rail 2 and mitigate any stress introduced by providing the hole 18 in the peripheral wall 6 of the fuel rail 2.

[0025] Referring now to Figures 2 and 3, the thickness of the peripheral wall 6 of the fuel rail 2 in the region of the mounting points 12 is increased with a smooth transition in the thickness of the peripheral wall 6 to avoid creating stress concentration zones in the peripheral wall 6. In this way, the stress forces in the peripheral wall 6 in the region of the mounting points 12 are reduced and matched more closely to the forces acting on the remainder of the fuel rail 2. The wall thickness in the region of the fuel outlets 14 is also increased to ensure that stress levels in the region of the fuel outlets 14 are more evenly matched to those in the remainder of the peripheral wall 8.

[0026] This form of the fuel rail 2 has the advantage that for a given operating pressure it is possible to form the bulk of the fuel rail 2 with a thinner wall thickness. This makes it possible to lower the weight of the fuel rail 2 or to enable the fuel rail 2 to operate with higher operating pressures and stresses without increasing the weight of the fuel rail.

[0027] Furthermore, it is possible to vary the size and shape of the inner cross-sectional profile of the fuel reservoir 8 and of the fuel rail volume along the length of the elongate body 4 and fuel reservoir 8 to locally control desired differing dynamic characteristics at particular points. The fuel reservoir 8 has an internal cross-sectional profile which varies in a longitudinal direction, i.e. along the length of the elongate body 2 from the fuel inlet 10 to the closed end.

[0028] The internal cross-sectional profile has a height h_i extending upwards from an inner opening of each fuel outlet 14 and a width w_i extending perpendicular to the height h_i. Both the height h_i and the width w_i vary in a longitudinal direction in an opposing manner. A height h_{i1} of the internal cross-sectional profile at a longitudinal position of the fuel rail 2 above each fuel outlet 14 is smaller than a height h_{i2} of the internal cross-sectional profile at a longitudinal position between the fuel outlets 14. A width w_{i1} of the internal cross-sectional profile above each fuel outlet 14 is greater than a width w_{i2} of the internal cross-sectional profile at a longitudinal position between the fuel outlets 14. The variation in the height h_i and width w_i in the longitudinal direction is smooth to avoid stress concentration regions.

[0029] As shown in Figures 2 and 3, the cross-section of the fuel reservoir over each fuel outlet 14 is wider and narrower to increase the flow speed and hence reduce the pressure over the fuel outlet 14 and to control the fluid dynamics at the fuel outlets 14.

[0030] The fuel rail 2 has an external cross-sectional profile which is variable along a length of the elongate body 4. The external cross-sectional profile has a height h_e extending parallel the fuel outlets 14 and height h_i of the fuel reservoir 8 and a width w_e extending perpendicular to the height h_e and parallel to the width w_i of the fuel reservoir 8.

[0031] A height h_{e1} of the external cross-sectional profile at a longitudinal position above each fuel outlet 14 is smaller than a height h_{e2} of the external cross-sectional profile at a longitudinal position between the fuel outlets 14. A width w_{e1} of the external cross-sectional profile at a longitudinal position above each fuel outlet 14 is greater than a width w_{e2} of the external cross-sectional profile at a longitudinal position between the fuel outlets 14. The fuel rail 2 has an outer profile which can be considered to be undulating or have a wave-like form due to the variable cross-sectional area of the fuel reservoir 8 and variable thickness of the peripheral wall 6.

[0032] In some embodiments, such as that illustrated in the figures, the fuel rail 2 and the reservoir 8 has an undulating or wave-like profile in two perpendicular directions. The peaks in the height direction h_e may be positioned at longitudinal positions along the length of the fuel rail 2 that are intermediate the peaks in the width direction w_e.

[0033] The fuel rail 2 may be formed from a metal or alloy. The fuel rail 2 with its fuel reservoir 8 and integral mounting fixtures 12 may be fabricated using additive manufacturing techniques. In additive manufacturing, a three-dimensional object is built up layer by layer in contrast to subtraction techniques in which a portion of a work piece is removed to form an object with the desired form.

[0034] The use of additive manufacturing technology, sometimes called 3D printing, enables complex shapes including the fuel rail 2 to be formed quickly and economically compared with other techniques such as extruding or drawing material from a solid blank. It enables the wall thickness to be varied at any point in thickness and extent depending on the loadings at any point. In this way the amount of material used is minimised as the additive technique ensures that material is not deposited where it is not needed for functional purposes. Significant weight saving can be achieved.

[0035] An example of an additive manufacturing technique is 3D printing in which material is deposited using a moving metal jet print head. A further example is powder bed fusion in which thermal energy from a laser of electron beam is used to selectively fuse powder in a powder bed. A further example is directed energy deposition in which thermal energy, for example from a laser, is used to fuse materials by melting them as they are deposited. The movement of the metal jet print head, laser or electron beam is computer controlled to build up an object, in this case the elongate body 4, layer by layer according to a three-dimensional model, such as a CAD (Computer Aided Design) model, of the elongate body 4.

References

[0036]

2	fuel rail
4	elongate body 4
6	peripheral wall
8	fuel reservoir
10	fuel inlet
12	fuel rail mounting fixture
14	fuel outlet
16	injector cup
18	hole
20	portion of peripheral wall with increased thickness

Claims

1. A fuel rail (2) for a fuel injection system for an internal combustion engine, the fuel rail (2) comprising an elongate body (4) having a peripheral wall (6) defining a fuel reservoir (8) and having a fuel inlet (10), a plurality of fuel outlets (14) spaced along the fuel rail (2), and at least one fastening point (12) to enable the fuel rail (2) to be secured to an engine, a thickness of the peripheral wall (6) being variable along its length, being thicker in regions subject, in operation, to higher stress.

2. A fuel rail (2) according to claim 1, wherein the fastening point (12) is positioned in a portion of the peripheral wall (6) having an increased thickness.

3. A fuel rail (2) according to claim 2, wherein the fastening point (12) comprises a hole (18) that extends through the portion of the peripheral wall (6) having the increased thickness and is separate from the fuel reservoir (8).

4. A fuel rail (2) according to any one of claims 1 to 3, wherein the fuel reservoir (8) has an internal cross-sectional profile and the internal cross-sectional profile is variable along a length of the elongate body (4).

5. A fuel rail (2) according to claim 4, wherein the internal cross-sectional profile has a height (h_i) extending in a direction upwards from an inner opening of the fuel outlet (14) and a width (w_i) extending perpendicular to the height (h_i), wherein a height (h_{i1}) of the internal cross-sectional profile above each fuel outlet (14) is smaller than a height (h_{i2}) of the internal cross-sectional profile between the fuel outlets (14).

6. A fuel rail (2) according to claim 5, wherein a width (w_{i1}) of the internal cross-sectional profile above each fuel outlet (14) is greater than a width (w_{i2}) of the internal cross-sectional profile between the fuel outlets (14).

7. A fuel rail (2) according to any one of claims 1 to 6, wherein the fuel rail (2) has an external cross-sectional profile and the external cross-sectional profile is variable along a length of the elongate body (4).

8. A fuel rail (2) according to claim 7, wherein the external cross-sectional profile has a height (h_e) extending in a direction parallel the fuel outlet (14) and a width (w_e) extending perpendicular to the height (h_e), wherein a height (h_{e1}) of the external cross-sectional profile at each fuel outlet (14) is smaller than a height (h_{e2}) of the external cross-sectional profile between the fuel outlets (14).

9. A fuel rail according to claim 8, wherein a width (w_{e1}) of the external cross-sectional profile at each fuel outlet is greater than a width (w_{e2}) of the external cross-sectional profile between the fuel outlets (14).

10. A fuel rail (2) according to any one of claims 1 to 9, wherein the fuel rail (2) comprises a stainless steel.

11. A method of manufacturing a fuel rail (2) for a fuel injection system for an internal combustion engine comprising:

building up the elongate body (4) according to any one of claims 1 to 10 layer by layer.

12. A method according to claim 1, wherein the elongate body (4) is built up layer by layer by 3D printing or Powder Bed Fusion or Directed Energy Deposition.

13. A method according to claim 11 or claim 12, wherein the elongate body (4) is built up layer by layer by movement of the metal jet print head, laser or electron beam controlled according to a three dimensional model of the elongate body (4) .

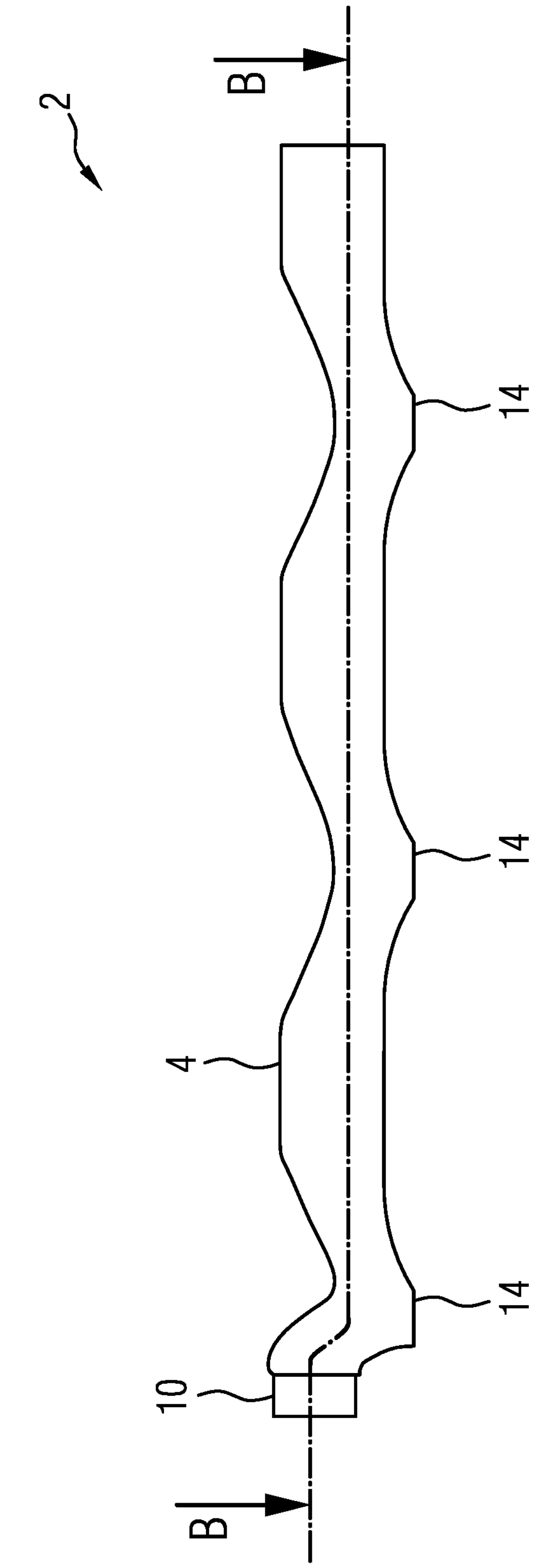
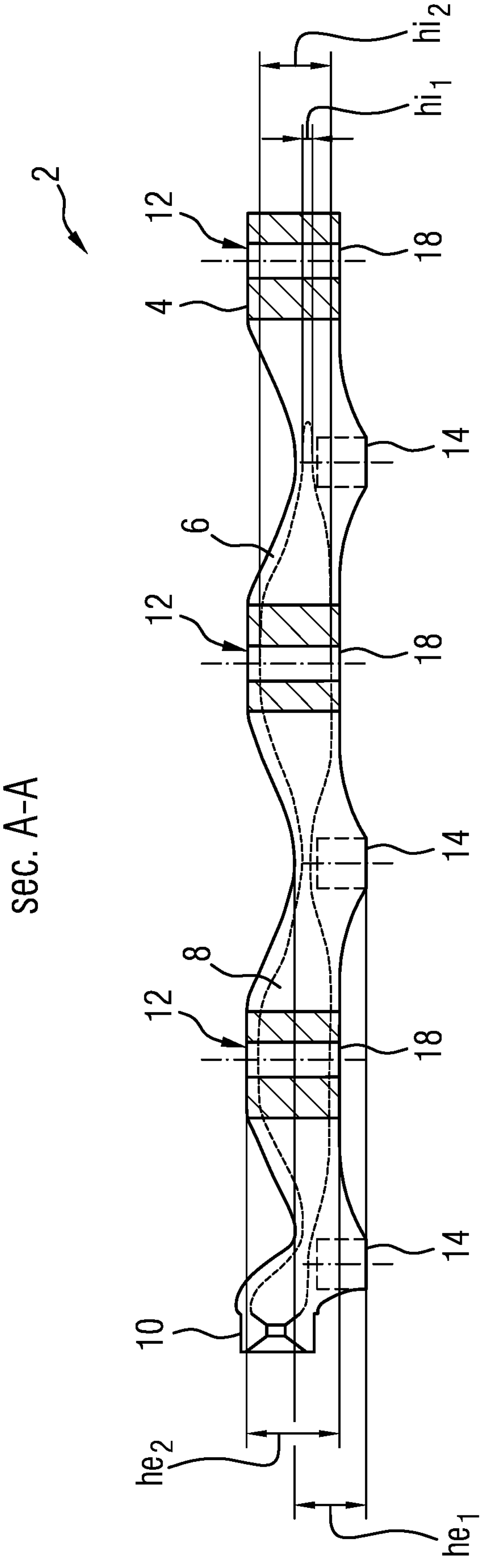


FIG 1

FIG 2



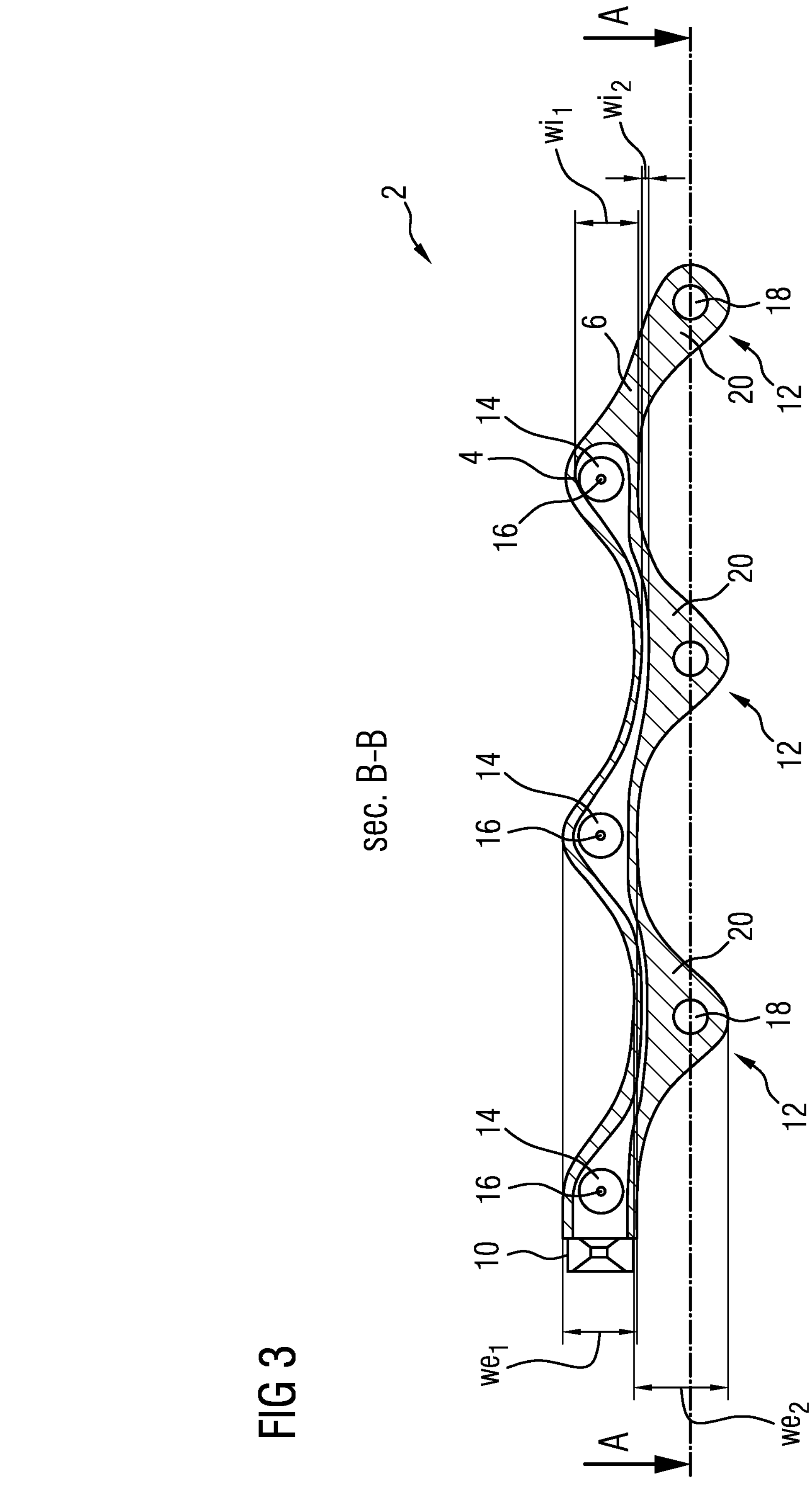


FIG 3

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EUROPEAN SEARCH REPORT

Application Number
EP 18 18 7317

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The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
The Hague	8 January 2019	Morales Gonzalez, M

CATEGORY OF CITED DOCUMENTS

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