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(54) Title: ELASTICALLY DEFORMABLE SUPPORT FOR AN EXPANDABLE SEAL ELEMENT OF A DOWNHOLE TOOL

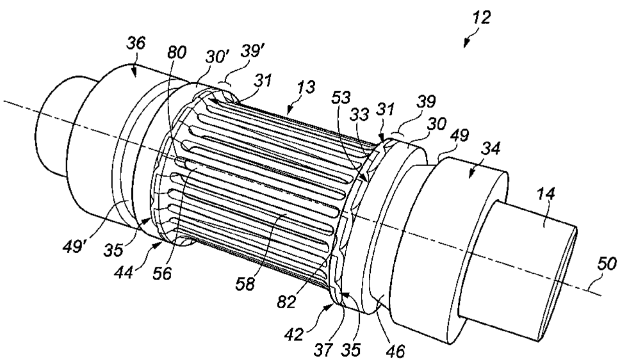

Fig. 2

(57) Abstract: There is disclosed an elastically deformable support for an expandable seal element of a downhole tool, an expandable seal assembly incorporating such a seal element and support, and a downhole tool, such as a packer, incorporating the expandable seal assembly. In one embodiment, there is disclosed a one-piece elastically deformable support (13) for an expandable seal element (30) of a downhole tool (10). The support is deformable between an unexpanded configuration (Fig. 2) and a radially expanded configuration (Fig. 5) and comprises: a plurality of base portions (31), each base portion having a surface (33) which, in use, faces towards the seal element; and a plurality of overlap portions (35), each overlap portion extending from a respective base portion so that it overlaps the surface of an adjacent base portion and having a surface (37) which, in use, faces towards the seal element. The base portions and the overlap portions are arranged to define a generally ring-shaped seal support structure (39) which forms a continuous circumferentially extending support surface (41) for abutting and supporting the seal element.

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Elastically Deformable Support for an Expandable Seal Element of a Downhole Tool

The present invention relates to an elastically deformable support for an expandable seal element of a downhole tool, and to an expandable seal assembly incorporating such a seal element and support. In particular, but not exclusively, the present invention relates to an elastically deformable support for an expandable seal element of a downhole tool such as a packer. The present invention also relates to a downhole tool, such as a packer, incorporating the expandable seal assembly.

In the oil and gas exploration and production industry, wellbore fluids comprising oil and/or gas are recovered to surface through a wellbore which is drilled from surface. The wellbore is lined with metal wellbore-lining tubing, which is known in the industry as 'casing'. The casing serves numerous purposes, including: supporting the drilled rock formations; preventing undesired ingress/egress of fluid; and providing a pathway through which further tubing and downhole tools can pass.

There are three main phases involved in bringing a well into production. The first is the drilling phase, in which the wellbore is drilled from surface and the wellbore-lining tubing installed and cemented in place. The second is the completion phase, in which the well is prepared for production by cleaning the wellbore and installing production tubing extending to surface, through which well fluids are recovered. The third is the production phase, in which well fluids are recovered to surface through the production tubing; this typically involves perforating the wellbore-lining tubing to allow the well fluids to enter the wellbore and flow into the production tubing.

During the lifetime of a well, it may be necessary to carry out an intervention procedure, in which production is halted and downhole tools and/or tubing run into the well to perform a required function. Examples of intervention activities include stimulating production by injecting water or chemicals into the producing rock formation; operating a downhole valve to close or open flow from a particular zone; and inserting a straddle to bridge across a deteriorated or corroded section of the wellbore-lining tubing.

During these various phases and subsequent intervention procedures, it is frequently necessary to seal an annular region around tubing and/or tools located in the well. This is achieved using a dedicated device known as a 'packer'. The packer includes an expandable seal element of a material having a relatively low modulus of elasticity, and which is typically of a suitable elastomeric material. The seal element is mounted on a tubular mandrel of the packer, and is compressed by applying an axially directed force on the seal element. This expands the seal element radially outwardly, to bridge the radial gap between the packer mandrel and an internal surface of the tubing in which the packer is located, or conceivably against the wall of the drilled wellbore.

Conventional packer seal elements have a main or central portion which is of a relatively low modulus of elasticity, the central portion performing the primary seal function when the seal element is radially expanded. The material adjacent the axial ends of the seal elements is of a higher modulus of elasticity than that of the central portion, to resist axial extrusion of the seal element under load. So-called 'garter springs' are moulded into the axial ends of the seal element. These consist of an outer helical spring wound in a first direction, and an inner helical spring wound in a second direction and located within the outer spring. The garter springs perform two main functions. The first is to provide additional stiffness, in an effort to resist axial extrusion of the relatively soft central portion of the seal element along the wellbore, which can lead to seal failure. The second is to provide an elastic restoring force, to facilitate return movement of the seal element to an unexpanded configuration when the packer is to be removed from the wellbore.

Packer seal elements of this type suffer from a number of disadvantages. Chief amongst these is that, when the seal element is expanded, the garter springs are expanded, opening up the spring coils. The elastomeric material forming the seal element has a tendency to extrude into the spring coils, and can hamper retraction of the seal element. In addition, the inner and outer springs, although wound in opposite directions, can still become entangled and so again hamper retraction. Another significant disadvantage is that the relatively soft material forming the bulk of the seal element, which bridges the radial gap, still has a tendency to extrude axially along the wellbore under the high fluid pressure forces which the packers experience during use. This can lead to packer failure, and so fluid migration past the packer seal element, and can also further hamper retraction. Indeed, in extreme cases, the packer can become lodged in the wellbore, requiring the packer to be drilled or milled out, for example using an overshot tool which passes around the packer and mills away the seal element.

It is amongst the objects of the present invention to obviate or mitigate at least one of the foregoing disadvantages.

According to a first aspect of the present invention, there is provided a one-piece elastically deformable support for an expandable seal element of a downhole tool, in which the support is deformable between an unexpanded configuration and a radially expanded configuration and comprises:

a plurality of base portions, each base portion having a surface which, in use, faces towards the seal element; and

a plurality of overlap portions, each overlap portion extending from a respective base portion so that it overlaps the surface of an adjacent base portion and having a surface which, in use, faces towards the seal element;

in which the base portions and the overlap portions are arranged to define a generally ring-shaped seal support structure which forms a continuous circumferentially extending support surface for abutting and supporting the seal element.

The base portions may be arranged so that they can separate to facilitate expansion of the support. The overlap portions may be arranged so that they can slide over the surface of the adjacent base portion during expansion of the support. In the expanded configuration of the support, the continuous circumferentially extending support surface may comprise the surfaces of the overlap portions and at least part of the surfaces of at least some of the base portions.

The overlap portions may function as anti-extrusion members, which term may be used interchangeably with the term overlap portion.

According to a second aspect of the present invention, there is provided an elastically deformable support for an expandable seal element of a downhole tool, in which the support is deformable between an unexpanded configuration and a radially expanded configuration and comprises:

a plurality of base portions, each base portion having a surface which, in use, faces towards the seal element; and

a plurality of overlap portions, each overlap portion extending from a respective base portion so that it overlaps the surface of an adjacent base portion and having a surface which, in use, faces towards the seal element;

in which the base portions and the overlap portions are arranged to define a generally ring-shaped seal support structure which forms a continuous circumferentially extending support surface for abutting and supporting the seal element;

in which the base portions are arranged so that they can separate to facilitate expansion of the support;

in which the overlap portions are arranged so that they can slide over the surface of the adjacent base portion during expansion of the support;

and in which, in the expanded configuration of the support, the continuous circumferentially extending support surface comprises the surfaces of the overlap portions and at least part of the surfaces of at least some of the base portions.

The deformable support of the present invention provides numerous advantages over prior supports. These include the following. One-piece construction means that the support is effectively a single piece component. This provides clear benefits over complex prior supports comprising numerous components (particularly to form a support surface), such as segments, petals or the like, in combination with support springs, screws etc. The present invention can provide good support for a seal element, and is significantly less complex and more reliable. The continuous circumferentially extending support surface restricts extrusion of the seal element (which may be of a material having a relatively low modulus of elasticity) following expansion of the support and the seal element. In particular, where the support is arranged to abut and support a seal element provided at an axial end of the support, the support may restrict axial extrusion of the seal element. Also, as the overlap portions extend from a respective base portion, the overlap portions may effectively separate when the support is expanded (facilitated by separation of the base portions). This may help to ensure that expansion of the support occurs in a smooth and predictable fashion and may also make the support less complex and easier to manufacture than prior supports. Furthermore, the arrangement whereby the base portions separate (typically circumferentially) to facilitate expansion of the support, and whereby the overlap portions slide over the surface of the adjacent base portion, may be such that at least one dimension of the seal support structure, and so of the support surface, is maintained during expansion of the support. In particular, a radial dimension of the seal support structure (typically a radial width or height), and so of the support surface, may be maintained. This may provide good support for the seal element, and may help to restrict or prevent extrusion of the seal element past the support following expansion of the support and the seal element.

In the unexpanded configuration of the support, the continuous circumferentially extending support surface may comprise or may be defined by the surfaces of the overlap portions.

In the unexpanded configuration of the support, the continuous circumferentially extending support surface may comprise or may be defined by the surfaces of the overlap portions and at least part of the surfaces of at least some of the base portions. In this case, in the expanded configuration of the support, the continuous circumferentially extending support surface may comprise the surfaces of the overlap portions and a greater proportion of the surfaces of said base portions than in the unexpanded configuration.

In the expanded configuration, the continuous circumferentially extending support surface may comprise the surfaces of the overlap portions and at least part of the surfaces of all of the base portions.

Each overlap portion may overlap the surface of a single adjacent base portion.

At least one of the overlap portions may overlap the surface of more than one adjacent base portion. At least one of the overlap portions may extend from the respective base portion in opposed first and second directions, so that it overlaps base portions located adjacent first and second sides of the base portion from which the overlap portion extends.

At least one of the overlap portions may extend across and overlap the entire surface of the adjacent base portion. Said overlap portion may extend over a surface of a further base portion.

Each overlap portion may extend in a generally circumferential direction from the respective base portion over the surface of the adjacent base portion. The base portion which is overlapped by the overlap portion may be one which is circumferentially adjacent.

The generally ring-shaped support structure may comprise a radially outer extent and a radially inner extent. The base portions may each extend across a full radial width of the support structure, and so may extend from the inner extent to the outer extent. The overlap portions may each extend across a full radial width of the support structure, and so may extend from the inner extent to the outer extent. The above may be the case both when the support is in the unexpanded configuration and the expanded configuration.

The base portions may form a base section of the generally ring-shaped seal support structure. In the unexpanded configuration of the support, the base portions may be arranged to form a ring-shaped base section. Each base portion may abut adjacent base portions in the unexpanded configuration. Expansion of the support may cause the base portions to move out of abutment and so separate.

The overlap portions may form an overlap section of the generally ring-shaped seal support structure. In the unexpanded configuration of the support, the overlap portions may be arranged to form a ring-shaped overlap section. Each overlap portion may abut adjacent overlap portions in the unexpanded configuration. Expansion of the support may cause the overlap portions to move out of abutment and slide over the adjacent base portion.

The support surface may be for abutting and supporting an axial end of the seal element. The generally ring-shaped seal support structure may be provided on, or may define, an axial end of the support. The support surface may therefore be an on axial end of the support. Advantageously, where the base portions and overlap portions extend across a full radial width of the support structure and are provided on or define the axial end of the support, this may provide good support for the seal element and help to prevent extrusion of the seal element.

The support surface may be for abutting and supporting an inner surface of the seal element, which may be a radially inner surface. The generally ring-shaped seal support structure may be provided on, or may define at least part of, an outer surface of the support, which may be a radially outer surface. The support surface may therefore be on a radially outer surface of the support.

The base portions may be spaced from the overlap portions, and may be spaced axially and/or radially. In use, the overlap portions may be located closer to the seal element than the base portions.

The overlap portions may be provided integrally with their respective base portion. The overlap portions may be provided as separate components which are attached to their respective base portion.

The base portions may be arranged so that they are generally in a first plane which is perpendicular to a main axis of the support. The overlap portions may each extend out of the first plane to overlap the surface of the adjacent base portion. The overlap portions may be arranged so that they are generally in a second plane which is parallel to the first plane, and spaced axially along the support from the first plane. The second plane may, in use, be disposed closer to the seal element than the first plane.

The overlap portions may have first and second circumferential edges. The overlap portions may be arranged to taper towards the edges, and/or the edges may be tapered or chamfered. This may facilitate return movement of the support to the unexpanded configuration, in that it may help to urge the seal element from an expanded configuration back to an unexpanded configuration and/or may prevent the seal element from restricting return movement of the support to its unexpanded configuration. The overlap portions may have a thickness or depth (in an axial direction of the support), and the overlap portions may taper in thickness towards the edges.

The base portions may have radially outer and radially inner extents, and may taper from the outer extent to the inner extent. The base portions may have first and second circumferential edges. The edges may be inclined. The edges may be disposed parallel to a radius of the support, at least in the unexpanded configuration of the support. The base portions may have a greater width at the outer extent than at the inner extent. The base portions may be generally trapezoidal, for example generally wedge-shaped.

The overlap portions may have radially outer and radially inner extents, and may taper from the outer extent to the inner extent. The overlap portions may have first and second circumferential edges. The edges may be inclined. The edges may be disposed parallel to a radius of the support, at least in the unexpanded configuration of the support. The overlap portions may have a greater width at the outer extent than at the inner extent. The overlap portions may be generally trapezoidal, for example generally wedge-shaped.

The support may comprise first and second axially opposed ends. The support may comprise a first generally ring-shaped seal support structure provided on the first axial end, and a second generally ring-shaped seal support structure provided on the second axial end. The first generally ring-shaped seal support structure may be arranged to abut and support a first seal element at the first axial end of the support. The second generally ring-shaped seal support structure may be arranged to abut and support a second seal element at the second axial end of the support. Advantageously therefore, the support may be capable of abutting and supporting two separate, axially spaced seals. The first and second generally ring-shaped seal support structures may each comprise respective base portions and overlap portions.

The base portions may each comprise a plurality of legs, arms or fingers extending in an axial direction of the support. The base portions may each comprise a pair of said legs. Where the support comprises a first generally ring-shaped seal support structure provided on a first axial end of the support, and a second generally ring-shaped seal support structure provided on a second axial end, each leg of each base portion may extend from the base portion to a different base portion on the other support structure.

The support may comprise a plurality of slots, channels or the like, each extending between an inner surface of the support and an outer surface of the support, and so which may extend through a wall of the support. Said slots may extend in an axial direction along the component, and may be positioned so that their main axes are disposed generally parallel to a main longitudinal axis of the support. The slots may be expandable to facilitate expansion of the support with the seal element. Advantageously, the seal support structure may effectively cover ends of the slots, and so may help to prevent extrusion of the seal element into the slots, following expansion. In particular, where the base portions and overlap portions extend across a full radial width of the support structure and are provided on or define the axial end of the support, the base and overlap portions may cover the ends of the slots.

Said slots may open when a force is exerted on the support to move it to the expanded configuration. Said slots may have a width in a direction around a perimeter of the support, which may be a circumferential width, and the width may increase when the support is moved to the expanded configuration. The support may therefore circumferentially expand when it is moved to the expanded configuration. At least part of said slot, which may be a main part, may have a width which is substantially constant when the component is in the unexpanded configuration. Said slots may be arranged so that, on expansion of the support, the width increases and may then be non-constant in a direction along at least said main part of the slot.

Said slots may extend inwardly from an axial end of the support part-way along a length of the support, and may terminate in an axially inner end, which may define an expansion node. Each said slot may have opposed sidewalls which extend from the axial end to the respective node, and expansion may occur by at least part of each of said sidewalls pivoting or deflecting about the node. The sidewall may pivot or deflect in a scissors-fashion about the node. The node may effectively form a root of the slot, and expansion may occur by pivoting/deflecting of said part of the sidewalls from the root so that the sidewalls diverge in a direction away from the root. Each node may have a wall which is curved, and which may have a substantially constant radius of curvature, the node wall communicating with the slot or channel sidewall. Providing a node wall which has such a substantially constant radius of curvature results in the node being generally circular, which may reduce stress concentrations under load.

The support may comprise first and second sets of slots or channels, each set comprising a plurality of slots or channels, said slots of the first set extending inwardly from a first axial end of the support, and said slots of the second set extending inwardly from a second axial end of the support opposite to the first end. Said slots of the first set may axially overlap said slots of the second set. The slots or channels of the first and second sets may be circumferentially spaced around the support. The slots or channels of the first set may be spaced alternately between slots or channels of the second set around the circumference of the support.

The support may define a gripping arrangement, which may be for gripping a downhole surface. This may enable the support to act as a slip or set of slips. The gripping arrangement may be provided on or defined by a radially outer surface of the support. The gripping arrangement may comprise a plurality of gripping elements, which may be protrusions such as teeth. The gripping arrangement may be provided by arranging at least part of said outer surface to be roughened, and/or by applying a coating to the part of said surface which is of a higher coefficient of friction than a material of the support (for example, a Tungsten Carbide coating).

The support may comprise a seal component extending around at least part of a radially outer surface of the support. This may be for sealing the support relative to a downhole surface, following expansion. Where the support comprises a plurality of slots, this may provide the advantages of: reducing junk ingress to the slots, causing it to not retract fully; and aiding return to the unexpanded configuration (i.e. to gauge OD), by increasing the ‘memory’ of the support. The seal component may extend at least partly into the slots.

The seal component may be a generally tubular sheath. The support may be encapsulated by the seal component.

The seal element may be mountable on or in the support surface, and so the support may have an integral seal element. The seal element may be an annular seal element such as an O-ring (of any suitable cross-section), and may be located in a seat defined on or in the support surface. The support element may therefore define a retractable seal seat. The seal element may be provided on or in an axial end of the support, or a radially outer surface of the support. This feature of the invention could have applications where a certain component needs to pass and seal through a second component which has a restriction prior to a sealing area, which might be of a larger diameter. There are a variety of sealing systems available, which could utilise the present invention as a back-up/support.

The support may be tubular, and may be generally annular in shape. The support may be configured so that it circumferentially expands when the support is moved to the expanded configuration.

According to a third aspect of the present invention, there is provided an expandable seal assembly for a downhole tool, the seal assembly comprising:

an expandable seal element which is radially expandable between an unexpanded configuration where the seal element is out of contact with a downhole surface, and an expanded configuration where the seal element can sealingly abut the downhole surface; and

an elastically deformable support according to the first aspect of the invention.

According to a fourth aspect of the present invention, there is provided an expandable seal assembly for a downhole tool, the seal assembly comprising:

an expandable seal element which is radially expandable between an unexpanded configuration where the seal element is out of contact with a downhole surface, and an expanded configuration where the seal element can sealingly abut the downhole surface; and an elastically deformable support for the expandable seal element which is deformable between an unexpanded configuration and a radially expanded configuration, the support comprising:

a plurality of base portions, each base portion having a surface which faces towards the seal element; and

a plurality of overlap portions, each overlap portion extending from a respective base portion so that it overlaps the surface of an adjacent base portion and having a surface which faces towards the seal element;

in which the base portions and the overlap portions are arranged to define a generally ring-shaped seal support structure which forms a continuous circumferentially extending support surface for abutting and supporting the seal element;

in which the base portions are arranged so that they can separate to facilitate expansion of the support;

in which the overlap portions are arranged so that they can slide over the surface of the adjacent base portion during expansion of the support;

and in which, in the expanded configuration of the support, the continuous circumferentially extending support surface comprises the surfaces of the overlap portions and at least part of the surfaces of at least some of the base portions.

The support may comprise first and second axially opposed ends. The seal assembly may comprise first and second expandable seal elements. The support may comprise a first generally ring-shaped seal support structure provided on the first axial end, and a second generally ring-shaped seal support structure provided on the second axial end. The first generally ring-shaped seal support structure may be arranged to abut and support the first seal element, which may be provided at the first axial end of the support. The second generally ring-shaped seal support structure may be arranged to abut and support the second seal element, which may be provided at the second axial end of the support. The first and second generally ring-shaped seal support structures may each comprise respective base portions and overlap portions.

The support may be high expansion, and so may be a high expansion support. Consequently the expandable seal assembly, and seal element, may be a high expansion assembly/element. A high expansion support may have a use where a tool of a certain diameter is to pass a restriction, and then to expand into a larger diameter area whilst sealing pressure from above and below. Such may involve a temporary (and so retractable) or permanent deployment. A ratio of an outer diameter of the support/seal element in the unexpanded configuration relative to an outer diameter in the expanded configuration may be at least about 1 : 1.2 (representing at least a 20% expansion).

The seal assembly may comprise first and second supports and the/a seal element may be disposed between the supports so that the first support abuts and supports a first surface of the seal element, and the second support abuts and supports a second, opposite surface of the seal element. It will be understood that the assembly may be operable with one or more seal elements using one or more supports.

Reference is made to contact between the seal element and a downhole surface. It will be understood that the downhole surface may be a surface on any tubing or tool deployed downhole, or potentially the wall of a wellbore (in an open-hole sealing situation). Conceivably, the seal assembly can seal by contact with any downhole surface of a suitable shape.

The support may be of a material selected from the group comprising metals, metal alloys and plastics materials. The seal element may be of an elastomeric or rubber material. The modulus of elasticity of the support may be in the range of around 180 GPa to around 200 GPa. The modulus of elasticity of the seal element may be in the range of around 0.01 GPa to around 0.1 GPa.

Further features of the support forming part of the seal assembly of the third/fourth aspect of the invention are defined above in relation to the first/second aspect of the invention.

According to a fifth aspect of the present invention, there is provided a downhole tool comprising at least one expandable seal assembly according to the third/fourth aspect of the invention.

The downhole tool may be a packer, straddle, bridge plug or similar products. The downhole tool may comprise a plurality of said seal assemblies, which may be spaced axially along a length of the tool.

The at least one seal assembly may be mounted on a main body of the downhole tool, and the downhole tool may comprise at least one actuation member which is moveable relative to the main body to urge the seal assembly to the expanded configuration. The/each actuation member may be operable to urge both the seal and support elements to their expanded configurations. The/each actuation member may comprise an expansion surface arranged to urge both the elements to their expanded configurations. The/each actuation member may comprise a seal expansion surface arranged to urge the seal element to its expanded configuration, and a support expansion surface arranged to urge the support element to its expanded configuration. The downhole tool may comprise a further actuation member, which may be fixedly or moveably mounted relative to the main body of the tool, and the actuation members may cooperate to urge the seal assembly to the expanded configuration.

Further features of the seal support/assembly forming part of the downhole tool of the fifth aspect of the invention are defined above in relation to the first to fourth aspects of the invention.

Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Fig. 1 is a schematic side view of a downhole tool, comprising at least one expandable seal assembly incorporating an elastically deformable support for an expandable seal element of the assembly, according to an embodiment of the invention;

Figs. 2 and 3 are enlarged perspective and side views, respectively, of the seal assembly of Fig. 1;

Fig. 4 is a side view which is similar to Fig. 3, but with the support of the seal assembly shown in longitudinal cross-section;

Figs. 5, 6 and 7 are views similar to Figs. 2, 3, and 4, respectively, but showing the downhole tool following actuation, in which the seal assembly has been radially expanded;

Fig. 8 is a perspective view of the support forming part of the seal assembly of Fig. 1, shown prior to expansion, as in Fig. 2;

Fig. 9 is a perspective view of the support forming part of the seal assembly of Fig. 1, shown following expansion, as in Fig. 5;

Figs. 10 and 11 are side views of the support in the configurations of Figs. 8 and 9, respectively;

Fig. 12 is a side view of downhole tool, comprising at least one expandable seal assembly incorporating an elastically deformable support for an expandable seal element of the assembly, according to another embodiment of the invention;

Fig. 13 is a side view of an elastically deformable support according to a further embodiment of the invention; and

Figs. 14 and 15 are enlarged side and end views, respectively, of part of an elastically deformable support according to a still further embodiment of the invention.

Turning firstly to Fig. 1, there is shown a side view of a downhole tool comprising at least one expandable seal assembly having an elastically deformable support, according to an embodiment of the invention. The downhole tool is indicated generally by reference numeral 10, the expandable seal assembly by reference numeral 12, and the elastically deformable support by reference numeral 13. In the illustrated embodiment, the downhole tool 10 takes the form of a packer. The packer 10 is shown coupled to a string of tubing 14, which has been located in a wellbore 16 that has been drilled from surface and lined with wellbore-lining tubing in the form of a metal casing 18. The casing 18 typically comprises a number of sections of tubing coupled together end-to-end, and has been installed and cemented in the wellbore 16 using cement 20, in a fashion which is well known in the field of the invention. The tubing 14 carrying the packer 10 defines a tool string 15, which has been run-in to the wellbore 16 to carry out a desired downhole function or functions, optionally involving the activation of a tool or tools (not shown) carried by the string. The packer 10 is employed to seal the tubing 14 relative to an inner wall 22 of the casing 18. This is desirable to enable the particular downhole function(s) to be carried out, which may involve supplying a fluid from surface down through the tubing 14, and/or recovering fluid to surface through the tubing. Migration of fluid along the wellbore 16 past the packer 10, along an annular region 26 defined between the casing inner wall 22 and the tubing 14, is prevented following activation of the packer.

The packer 10 is shown in Fig. 1 with the seal assembly 12 and support 13 in unexpanded configurations, where the seal assembly does not contact the inner wall 22 of the casing 18. The tubing 14 is positioned within the casing 18 using a dedicated tubing hanger (not shown). The packer 10 is set by applying 'weight' to the packer after the tubing 14 has been set in (or 'hung' from) the casing 18. This is achieved by exerting an axially directed load on the seal assembly 12, to radially expand it outwardly into contact with the casing inner wall 22. The application of weight to set the packer 10 will be described in more detail below.

The seal assembly 12 and support 13 are better shown in Figs. 2 to 11. Figs. 2 and 3 are enlarged perspective and side views of the seal assembly 12. Fig. 4 is a view which is similar to Fig. 3, but showing the support 13 in longitudinal cross-section. Figs. 5, 6 and 7 are views similar to Figs. 2, 3, and 4, respectively, but showing the packer 10 following actuation, in which the seal assembly 12 (and so the support 13) has been radially expanded. Fig. 8 is a perspective view of the support 13 shown prior to expansion, as in Fig. 2. Fig. 9 is a perspective view of the support 13 following expansion, as in Fig. 5. Figs. 10 and 11 are side views of the support 13 in the configurations of Figs. 8 and 9, respectively.

The expandable seal assembly 12 generally comprises an expandable seal element 30 which is radially expandable between an unexpanded configuration (Fig. 2), where the seal element is out of contact with a downhole surface (casing inner wall 22), and an expanded configuration (Fig. 5), where the seal element can sealingly abut the downhole surface. The seal assembly 12 also comprises the elastically deformable support 13, which serves for supporting the expandable seal element 30 and, as will be described below, facilitates the application of force to the seal element to radially expand it.

The support 13 is deformable between an unexpanded configuration (e.g. Figs. 2 and 8) and a radially expanded configuration (e.g. Figs. 5 and 9). The support 13 is preferably one-piece, comprising a plurality of base portions which are each given the reference numeral 31, and a plurality of overlap portions (or anti extrusion members) which are each given the reference numeral 35. Each base portion 31 has a surface 33 which faces towards the seal element 30. Each overlap portion 35 extends from a respective base portion 31 so that it overlaps the surface 33 of an adjacent base portion 31, and has a surface 37 which also faces towards the seal element 30. By way of example, and referring particularly to Fig. 9, a base portion 31a is shown which has a surface 33a, and an overlap portion 35a having a surface 37a extends from the base portion 31a so that it overlaps a surface 33b of an adjacent base portion 31b.

The base portions 31 and the overlap portions 35 are arranged to define a generally ring-shaped seal support structure 39 which forms a continuous circumferentially extending support surface 41, for abutting and supporting the seal element 30. As will be described below, the support surface 41 also serves for urging the seal element 30 to its radially expanded configuration. The base portions 31 are arranged so that they can separate to facilitate expansion of the support 13, and the overlap portions 35 are arranged so that they can slide over the surface 33 of the adjacent base portion during expansion of the support. In the expanded configuration of the support 13, the continuous circumferentially extending support surface 41 comprises the surfaces 37 of the overlap portions 35, and at least part of the surfaces 33 of at least some of the base portions 31. In use, the seal element 30 is axially compressed between the support surface 41 defined by the support

13, and a shoulder 49 of an activation member 34 of the packer 10, so that it is urged radially outwardly into contact with the casing wall 22.

The deformable support 13 of the present invention provides numerous advantages over prior supports. These include that the continuous circumferentially extending support surface 41 restricts axial extrusion of the seal element 30 following expansion of the support 13 and the seal element 30. This means that there is no extrusion gap for the seal element 30, which enables seal elements of existing sealing systems to operate at substantially higher pressures, and possibly higher temperatures, or a combination of the two. Also, as the overlap portions 35 extend from a respective base portion 31, the overlap portions effectively separate when the support 13 is expanded (facilitated by separation of the base portions). This may help to ensure that expansion of the support 13 occurs in a smooth and predictable fashion, and may also make the support less complex and easier to manufacture than prior supports.

In the unexpanded configuration of the support 13, the continuous circumferentially extending support surface 41 is defined by the surfaces 37 of the overlap portions 35. In the expanded configuration, the support surface 41 is defined by the surfaces 37 of the overlap portions 35, and part of the surfaces 33 of all the base portions 31. Each overlap portion 35 extends in a generally circumferential direction from the respective base portion 31 over the surface 33 of the circumferentially adjacent base portion 31. The generally ring-shaped support structure 39 comprise a radially outer extent 43, and a radially inner extent 45. The base portions 31 each extend across a full radial width of the support structure 39, and so extend from the inner extent 45 to the outer extent 43. The overlap portions 35 similarly extend across the full radial width of the support structure 39.

The base portions 31 are arranged so that they form a base section 47 (Fig. 10) of the support structure 39 and, in the unexpanded configuration of the support 13, the base portions 31 are arranged to form a ring-shaped base section. Each base portion 31 abuts adjacent base portions when in the unexpanded configuration; expansion of the support 13 causes the base portions to move out of abutment and so separate. The overlap portions 35 similarly form an overlap section 51 (Fig. 10) of the support structure 39 and, in the unexpanded configuration of the support 13, the overlap portions 35 are arranged to form a ring-shaped overlap section. Each overlap portion 35 abuts adjacent overlap portions when in the unexpanded configuration; expansion of the support 12 causes the overlap portions to move out of abutment and slide over the surface 33 of the adjacent base section 31.

The support structure 39 is provided on an axial end 42 of the support 13, so that the support surface 41 defined by the seal support structure is effectively a radially extending support surface which abuts and supports an axial end 53 of the seal element 30. The base portions 31 are spaced axially from the overlap portions 35, the overlap portions being located closer to the seal element 30. The overlap portions 35 are typically provided integrally with their respective base portion 31, but may be provided as separate components which are attached to their respective base portion.

The base portions 31 are arranged so that they are generally in a first plane 55 (Fig. 3) which is perpendicular to a main axis 50 of the support. The overlap portions 35 each extend out of the first plane 55, to overlap the surface 33 of the adjacent base portion 31. The overlap portions are arranged so that they are generally in a second plane 57 which is parallel to the first plane, and spaced axially along the support 13 from the first plane. The second plane 57 is disposed closer to the seal element 30 than the first plane.

As best shown in Figs. 8 and 9, the overlap portions 35 each have first and second circumferential edges 59 and 61. An edge 59 of one overlap portion 35 abuts an edge 61 of an adjacent overlap portion 35, when the support 13 is in its unexpanded configuration. The overlap portions 35 are arranged to taper towards the edges 59 and 61, so that the edges are effectively tapered or chamfered. This may facilitate return movement of the support 13 to the unexpanded configuration, in that it may help to urge the seal element 30 from an expanded configuration back to an unexpanded configuration and/or may prevent the seal element from restricting return movement of support to its unexpanded configuration. Effectively, the overlap portions 35 have a thickness in an axial direction of the support 13, and taper in thickness towards the edges 59 and 61. The overlap portions 35 also taper from the outer extent 43 to the inner extent 45, so that the first and second circumferential edges 59 and 61 are inclined. Typically, the edges 59 and 61 are disposed parallel to a radius of the support 13 (at least when in its unexpanded configuration). The overlap portions 35 have a greater width at the outer extent 43 than at the inner extent 45, and are generally trapezoidal, for example wedge-shaped.

The base portions 31 similarly have first and second circumferential edges 63 and 65. An edge 63 of one base portion 31 abuts an edge 65 of an adjacent base portion 31, when the support 13 is in its unexpanded configuration. The base portions 31 also taper from the outer extent 43 of the support structure 39 towards the inner extent 45. Once again, this is achieved by arranging the circumferential edges 63 and 65 so that they are inclined, and typically parallel to a radius of the support 13 (at least when in its unexpanded configuration). The base portions 31 also have a greater width at the outer extent 43 than at the inner extent 45, and are similarly generally trapezoidal, for example wedge-shaped.

The support 13 in fact comprises first and second axially opposed ends 42 and 44. The generally ring-shaped seal support structure 39 is provided on the first axial end 42, and forms a first such support structure. A second generally ring-shaped seal support structure 39' is provided on the second axial end 44. The first and second seal support structures 39 and 39' are of similar structure, and so each comprise respective base portions 31 and overlap portions 35. The first seal support structure 39 is arranged to abut and support the seal element 30, which forms a first seal element of the seal assembly 12, and which is provided at the first axial end 42 of the support 13. The second seal support structure 39' is arranged to abut and support a second seal element 30' at the second axial end 44 of the support 13. Advantageously therefore, the support 13 is capable of abutting and supporting two separate, axially spaced seals 30 and 30'.

The base portions 31 each comprise a pair of legs, arms or fingers 67 (Fig. 9) extending in an axial direction of the support 13. The legs 67 of each base portion 31 in the first seal support structure 30 each extend to a different base portion 31 of the second seal support structure 30'. Similarly, the legs 67 of each base portion 31 in the second seal support structure 30' each extend to a different base portion 31 of the first seal support structure 30. This facilitates circumferential expansion of the support 13, and effectively provides a continuous length of material extending around the circumference of the support 13.

The support 13 is typically of a first material and the seal element 30 of a second material having a modulus of elasticity which is less than that of the first material. The seal assembly 12 describes an inner diameter, and the inner diameter of the seal assembly in the expanded configuration (Fig. 5) is greater than the inner diameter of the seal assembly in the unexpanded configuration (Fig. 2).

The seal assembly 12 is mounted on a main body 32 of the packer 10 (Fig. 4), which is a base pipe or mandrel. The packer 10 comprises a pair of opposed actuation members 34 and 36 which cooperate to urge the seal assembly 12 to the expanded configuration. The actuation member 34 forms an upper (or uphole) actuation member of the pair, and is moveable relative to the packer mandrel 32, to urge the seal assembly 12 to the expanded configuration. In a variation on the embodiment shown in the drawings, the actuation member 36, which forms a lower (or downhole) actuation member, may be movable relative to the mandrel 32 to urge the seal assembly 12 to the expanded configuration. In a further variation, both actuation members 34 and 36 may be movable relative to the mandrel 32. The seal assembly 12 is expanded by translating the upper actuation member 34 axially towards the lower actuation member 36. This imparts an axially directed expansion force on the seal assembly 12, to urge the seal elements 30 and 30' radially outwardly to seal against the casing inner wall 22.

The support 13 comprises at least one load surface and, in the illustrated embodiment, comprises two such load surfaces 38 and 40 at the respective first and second axial ends 42 and 44. The load surfaces 38 and 40 are shaped to cooperate with corresponding load/expansion surfaces 46 and 48 on the respective actuation members 34 and 36, for moving the support 13, and so the seal assembly 12, to the expanded configuration. As can be seen from the drawings, the load surfaces 38 and 40 of the seal assembly 12 are inclined relative to the longitudinal axis 50 of the support 13. The load surfaces 46 and 48 on the packer actuation members 34 and 36 are oppositely inclined, so that axial movement of the upper actuation member 34 acts to urge the support 13 radially outwardly. The load surfaces 46 and 48, together with the support 13, act to bring the seal elements 30 and 30' into contact with the casing inner wall 22. The load surfaces 38 and 40 of the seal assembly 12 are effectively tapered, and extend in axially inward directions from the respective ends 42 and 44. The load surfaces 38 and 40 incline in such a way that the inner diameter described by the load surfaces decrease in a direction along the assembly 12 from the respective end 42, 44.

As can be seen from Figs. 4 and 7, movement of the support 13 to the expanded configuration causes the inner diameter of the support to increase, the inner diameter of the seal assembly 12 in the expanded configuration being greater than that in the unexpanded configuration. This effectively provides a radial spacing or gap (Fig. 7) between an inner surface 52 of the support 13 and an outer surface 54 of the packer mandrel 32, when the support is moved to the expanded configuration. This facilitates contraction of the seal assembly 12 back to the unexpanded configuration, and so removal of the seal assembly from the wellbore 16. This is further facilitated by providing the support 13 as an elastically deformable component; the support 13 returns to the unexpanded configuration in the absence of an applied expansion force.

The structure and performance of the seal assembly 12 during operation will now be described in more detail. As can be seen from Figs. 2 and 3, the support 13 is arranged so that it deforms uniformly. The support 13 describes an inner diameter which is uniform along a main length when it is in the expanded configuration, and also in the unexpanded configuration. The support 13 is tubular and particularly is generally annular in shape, and configured so that it circumferentially expands when the seal assembly 12 is moved to the expanded configuration. The support 13 comprises a plurality of slots, channels or the like, designated by numerals 56 and 58. Each slot 56, 58 extends between inner and outer surfaces 60, 62 of the component 28, and so extends entirely through a wall 64 of the component. The slots 56 and 58 also extend in an axial direction along the support 13 from the respective axial ends 42 and 44, and are positioned so that their respective main axes 66 and 68 are disposed generally parallel to the main longitudinal axis 50, in the unexpanded configuration.

The support 13 actually comprises a first set of the slots 56, each of which extends inwardly from the first axial end 42, and a second set of the slots 58, each of which extends inwardly from the second axial end 44. The slots 56 and 58 are alternately circumferentially spaced around the circumference of the support 13. The slots 56, 58 open when a force is exerted on the seal assembly 12, and so the support 13, to move it to the expanded configuration, and each have a circumferential width which increases when the seal assembly is moved to the expanded configuration. The support 13 therefore circumferentially expands when it is moved to the expanded configuration. Main parts of the slots 56 and 58 have a width which is substantially constant when the support 13 is in the unexpanded configuration, and the slots are arranged so that, on expansion, the width increases and is then non-constant in a direction along at least said main parts. The slots 56 and 58 extend from the axial ends 42, 44 of the support 13, the ends of the slots here being defined between adjacent base portions 31. The slots 56 and 58 define respective expansion nodes 80 and 82 at their opposite ends.

The slots 56 each have opposed sidewalls 84 which extend from the respective node 80, and the slots 58 similarly each have opposed sidewalls 86 which extend from the respective node 82. Expansion occurs by at least part of each of said slot sidewalls 84, 86 pivoting or deflecting about the respective nodes 80, 82. The sidewalls 84, 86 pivot or deflect in a scissors-fashion about the nodes 80 and 82, the nodes effectively forming roots of the slots 56, 58 with expansion occurring by pivoting/deflecting of said part of the sidewalls 84, 86 from the root so that the sidewalls diverge in a direction away from the root. Each node 80, 82 has a respective wall which is curved, and which optionally has a substantially constant radius of curvature, the node walls communicating with the slot or channel sidewalls 84, 86. Providing a node wall which has such a substantially constant radius of curvature results in the node being generally circular, which can reduce stress concentrations in the support 13 under load.

The support 13 is typically of a metal, metal alloy or plastics materials. The seal elements 30 and 30' are typically of an elastomeric or rubber material, the material selected having a modulus of elasticity which results in the seal elements 30, 30' exerting a restorative force which tends to urge the seal assembly 12 towards the unexpanded configuration, when an expansion force is removed. Typical moduli of elasticity for the material of the support 13 are in the range of around 180 GPa to around 200 GPa. Typical moduli of elasticity for the material of the seal elements 30, 30' are in the range of around 0.01 GPa to around 0.1 GPa. The support 13 is typically formed by machining a tubular body to form the required slots 56, 58.

As discussed above, movement of the seal assembly 12 to the expanded configuration provides a seal against the casing inner wall 22, thereby sealing the annular region 26. Expansion is achieved by urging the packer actuation member 34 axially downwardly (or downhole), towards the opposed actuation member 36, by imparting the necessary 'weight' on the activation member 34 from surface or via a component of the packer 10 or a tool coupled to the packer, in a known fashion. This causes the load faces 38 and 40 of the support 13 to travel along the load faces 46 and 48 of the actuation members 34 and 36, thereby radially and circumferentially expanding the support. This results in radial expansion of the seal elements 30 and 30', which are axially compressed between the support surfaces 41 and 41' defined by the support 13, shoulders 49 and 49' of the activation members 34 and 36.

This movement continues until the seal elements 30 and 30' are brought into contact with the casing inner wall 22, whereupon further axial force on the seal assembly 12 imparts a radially directed sealing force on the seal elements 30 and 30', compressing them against the casing inner wall 22. A desired axial setting force is applied to the packer 10, to ensure an adequate radial load on the seal elements 30 and 30', and so seal with the casing wall 22. The packer 10 has then been fully set, and provides a sufficient seal to ensure that fluid cannot migrate along the wellbore 16 past the packer. The desired downhole function or functions can then be carried out, employing the tool or tools carried by the string 15.

When it is desired to deactivate the packer 10, for example following completion of the desired downhole function(s), the activation member 34 is axially translated back along the packer mandrel 32 towards the start position (Fig. 2). The inherent elasticity of the support 13 tends to return it to the unexpanded configuration (Fig. 2). This may also be facilitated by the seal elements 30 and 30', which may have sufficient elasticity that they assist in movement of the support 13 back to the unexpanded configuration. The tool string 15 comprising the packer 10 and tubing 14 can then be pulled out of the wellbore 16, if required.

Turning now to Fig. 12, there is shown a side view of downhole tool, in the form of a packer or bridge plug 10a, comprising at least one expandable seal assembly 12a incorporating an elastically deformable support 13a for an expandable seal element 30a of the assembly, according to another embodiment of the invention. Like components of the assembly 12a with the assembly 12 of Figs. 1 to 11 share the same reference numerals, with the addition of the suffix ‘a’.

The assembly 12a in fact comprises two expandable seal elements 30a and 30a’, although as with the assembly 12, there may be a single seal element, and indeed two of the supports 13a for a single seal element located between the supports.

The only substantial difference between the assembly 12a and the assembly 12 is that actuation members 34a and 34a’ are provided which comprise respective seal expansion surfaces 46a, 46a’ arranged to urge the seal elements 30a, 30a’ to their expanded configuration, and support expansion surfaces 100 and 100’ arranged to urge the support element 13a to its expanded configuration. The expansion surfaces are all inclined relative to a main axis of the tool 10a, and the expansion surfaces 100, 100’ optionally have a steeper inclination than the expansion surfaces 46a, 46a’. In this way, the support element 13a is urged outwardly to its expanded configuration ahead of the seal elements 30a, 30a’ to ensure adequate support for the seal elements 30a. 30a’ under load (helping to resist unwanted axial extrusion).

Fig. 13 is a side view of an elastically deformable support 13b according to a further embodiment of the invention, which has a use in any of the assemblies disclosed herein. Like components of the support 13b with the support 13 of Figs. 1 to 11 share the same reference numerals, with the addition of the suffix ‘b’.

In this embodiment, a seal element 30b is mountable on or in a support surface 41b of the support 13b, so that the support effectively has an integral seal element which is radially and circumferentially expanded when the support is expanded. The seal element 30b is an annular seal element such as an O-ring (of any suitable cross-section and dimensions), and is located in a seat 102, which takes the form of an annular groove or recess in the support surface 41b. It will be understood that the seat 102 may be defined mainly by overlap portions 35b of the support 13b, and that part of the seal element 30b may rest upon surfaces of base portions 31b when the support 13b is in an expanded configuration. The seat 102 may effectively be provided at a radially outer peripheries of the overlap portions 35b. The support element 13b may effectively define a retractable seal seat, actuated by movement of the support between its unexpanded and expanded configurations.

In a variation, the seal element 30b may be bonded on to parts or protrusions (not shown) of the overlap portions 35b, or may just rest on an extended "ledge" defined by the overlap portions, but in each case is expanded and brought into sealing contact with the downhole surface at the same time as and along with the expansion of the support.

Whilst Fig. 13 shows only a single such annular seal element 30b, it will be understood that a similar such seal element (not shown) may be provided on or in a support surface 41b' defined at the other end of the support element 13b.

Figs. 14 and 15 are enlarged side and end views, respectively, of part of an elastically deformable support 13c according to a still further embodiment of the invention, which has a use in any of the assemblies disclosed herein. Like components of the support 13c with the support 13 of Figs. 1 to 11 share the same reference numerals, with the addition of the suffix 'c'.

The support 13c defines a continuous circumferentially extending support surface 41c for abutting and supporting a radially inner surface of a seal element (not shown). A generally ring-shaped seal support structure 39c is thus provided which is on/defines a radially outer surface 104 of the support 13c. This is achieved by providing overlap portions 35c which extend in a radially outward direction from respective base portions 31c.

The support 13c shown in this embodiment can be arranged so that it is effectively a variation on the support 13b of Fig. 13. This can be achieved by providing a seal element 30c, which is mountable on or in the support surface 41c, so that the support 13c effectively has an integral seal element. The seal element 30c is provided on or in a radially outer surface of the support 13c. Once again, the seal element 30c is an annular seal element such as an O-ring, and is located in a seat 102c, which takes the form of an annular groove or recess in the support surface 41c. The seat 102c is defined by overlap portions 35c of the support 30c, part of the seal element 30c resting upon surfaces of base portions 31c when the support 30c is in an expanded configuration.

The supports 13b/13c could have uses where a certain component needs to pass and seal through a second component which has a restriction prior to a sealing area, which might be of a larger diameter. There are a variety of sealing systems available, which could utilise the present invention as a back-up/support.

The supports disclosed herein may be ‘high expansion’, and so high expansion supports. This may have a use where a tool of a certain diameter is to pass a restriction, and then to expand into a larger diameter area whilst sealing pressure from above and below. Such may involve a temporary (and so retractable) or permanent deployment. The disclosed expandable seal assemblies and hence seal elements may similarly be high expansion assemblies/elements. A ratio of an outer diameter of the support/seal element in the unexpanded configuration relative to an outer diameter in the expanded configuration may be at least about 1 : 1.2 (representing at least a 20% expansion).

Various modifications may be made to the foregoing without departing from the spirit or scope of the present invention.

An expandable seal assembly may be provided comprising first and second supports of the type described herein, and a seal element disposed between the supports so that the first support abuts and supports a first surface of the seal element and the second support abuts and supports a second surface of the seal element. Effectively, the assembly of the present invention may be operable with one or more seal elements using one or more supports.

The support may define a gripping arrangement, which may be for gripping a downhole surface. This may enable the support to act as a slip or set of slips. The gripping arrangement may be provided on or defined by a radially outer surface of the support. The gripping arrangement may comprise a plurality of gripping elements, which may be protrusions such as teeth. The gripping arrangement may be provided by arranging at least part of said outer surface to be roughened, and/or by applying a coating to the part of said surface which is of a higher coefficient of friction than a material of the support (for example, a Tungsten Carbide coating).

The support may comprise a seal component extending around at least part of a radially outer surface of the support. The seal component may be a generally tubular sheath. Where the support comprises a plurality of slots, the seal component may extend at least partly into the slots. The support may be encapsulated by the seal component. This may provide the advantages of: reducing junk ingress to the slots, causing it to not retract fully; and aiding return to the unexpanded configuration (i.e. to gauge OD) by increasing the 'memory' of the support.

In the unexpanded configuration of the support, the continuous circumferentially extending support surface may comprise or may define the surfaces of the overlap portions and at least part of the surfaces of at least some of the base portions. In this case, in the expanded configuration of the support, the continuous circumferentially extending support surface may comprise the surfaces of the overlap portions and a greater proportion of the surfaces of said base portions than in the unexpanded configuration.

At least one of the overlap portions may overlap the surface of more than one adjacent base portion. At least one of the overlap portions may extend from the respective base portion in opposed first and second directions, so that it overlaps base portions located adjacent first and second sides of the base portion from which the overlap portion extends.

At least one of the overlap portions may extend across and overlap the entire surface of the adjacent base portion, and over a surface of a further base portion.

Claims

1. A one-piece elastically deformable support for an expandable seal element of a downhole tool, in which the support is deformable between an unexpanded configuration and a radially expanded configuration and comprises:

a plurality of base portions, each base portion having a surface which, in use, faces towards the seal element; and

a plurality of overlap portions, each overlap portion extending from a respective base portion so that it overlaps the surface of an adjacent base portion and having a surface which, in use, faces towards the seal element;

in which the base portions and the overlap portions are arranged to define a generally ring-shaped seal support structure which forms a continuous circumferentially extending support surface for abutting and supporting the seal element.

2. A support as claimed in claim 1, in which:

the base portions are arranged so that they can separate to facilitate expansion of the support;

the overlap portions are arranged so that they can slide over the surface of the adjacent base portion during expansion of the support; and

in the expanded configuration of the support, the continuous circumferentially extending support surface comprise the surfaces of the overlap portions and at least part of the surfaces of at least some of the base portions.

3. A support as claimed in either of claims 1 or 2 in which, in the unexpanded configuration of the support, the continuous circumferentially extending support surface is defined by the surfaces of the overlap portions.

4. A support as claimed in either of claims 1 or 2 in which, in the unexpanded configuration of the support, the continuous circumferentially extending support surface is defined by the surfaces of the overlap portions and at least part of the surfaces of at least some of the base portions.

5. A support as claimed in any preceding claim in which, in the expanded configuration, the continuous circumferentially extending support surface comprises the surfaces of the overlap portions and at least part of the surfaces of the base portions.

6. A support as claimed in any preceding claim, in which each overlap portion extends in a generally circumferential direction from the respective base portion over the surface of the adjacent base portion.

7. A support as claimed in any preceding claim, in which the generally ring-shaped support structure comprise a radially outer extent and a radially inner extent, and in which the base portions each extend across a full radial width of the support structure, and so from the inner extent to the outer extent.

8. A support as claimed in any preceding claim, in which the generally ring-shaped support structure comprise a radially outer extent and a radially inner extent, and in which the overlap portions each extend across a full radial width of the support structure, and so from the inner extent to the outer extent.

9. A support as claimed in any preceding claim, in which the base portions form a ring-shaped base section of the generally ring-shaped seal support structure, when the support is in the unexpanded configuration.

10. A support as claimed in any preceding claim, in which the overlap portions form a ring-shaped overlap section of the generally ring-shaped seal support structure, when the support is in the unexpanded configuration.

11. A support as claimed in any preceding claim, in which the support surface is for abutting and supporting an axial end of the seal element, the generally ring-shaped seal support structure defining an axial end of the support.

12. A support as claimed in any preceding claim, in which the base portions are spaced axially from the overlap portions so that, in use, the overlap portions are located closer to the seal element than the base portions.

13. A support as claimed in any preceding claim, in which the base portions are arranged so that they are generally in a first plane which is perpendicular to a main axis of the support, and in which the overlap portions each extend out of the first plane to overlap the surface of the adjacent base portion.

14. A support as claimed in claim 13, in which the overlap portions are arranged so that they are generally in a second plane which is parallel to the first plane, and spaced axially along the support from the first plane.

15. A support as claimed in any preceding claim, in which the overlap portions have first and second circumferential edges, and in which the overlap portions are arranged to taper in axial thickness towards the edges.

16. A support as claimed in any preceding claim, in which the base portions and the overlap portions have radially outer and radially inner extents, and have a greater width at their outer extents than at their inner extents.

17. A support as claimed in any preceding claim, comprising:

first and second axially opposed ends;

a first generally ring-shaped seal support structure provided on the first axial end; and

a second generally ring-shaped seal support structure provided on the second axial end;

in which the first generally ring-shaped seal support structure is arranged to abut and support a first seal element at the first axial end of the support, and the second generally ring-shaped seal support structure is arranged to abut and support a second seal element at the second axial end of the support.

18. A support as claimed in claim 17, in which the base portions each comprise a plurality of legs extending in an axial direction of the support, each leg of each base portion extending to a different base portion on the other seal support structure.

19. A support as claimed in any preceding claim, in which the support comprises a plurality of slots extending between an inner surface of the support and an outer surface of the support and in an axial direction along the support, the slots being expandable to facilitate expansion of the support.

20. A support as claimed in claim 19, in which the seal support structure covers ends of the slots, to prevent extrusion of the seal element into the slots following expansion.

21. A support as claimed in either of claims 19 or 20, in which the support comprises first and second sets of slots, each set comprising a plurality of slots, said slots of the first set extending inwardly from a first axial end of the support, and said slots of the second set extending inwardly from a second axial end of the support opposite to the first end.

22. A support as claimed in any preceding claim, comprising a seal component extending around at least part of a radially outer surface of the support.

23. A support as claimed in any preceding claim, in which the support has an integral seal element.

24. A support as claimed in claim 23, in which the seal element is an annular seal element located in a seat defined in the support surface.

25. A support as claimed in any preceding claim, in which the support is a high expansion support, capable of elastically deforming so that a ratio of an outer diameter of the support in the unexpanded configuration relative to an outer diameter in the expanded configuration is at least about 1 : 1.20.

26. An expandable seal assembly for a downhole tool, the seal assembly comprising:

an expandable seal element which is radially expandable between an unexpanded configuration where the seal element is out of contact with a downhole surface, and an expanded configuration where the seal element can sealingly abut the downhole surface; and

an elastically deformable support according to any one of claims 1 to 25.

27. An assembly as claimed in claim 26, comprising first and second expandable seal elements, and in which the support comprises first and second axially opposed ends, a first generally ring-shaped seal support structure provided on the first axial end and arranged to abut and support the first seal element, and a second generally ring-shaped seal support structure provided on the second axial end and arranged to abut and support the second seal element.

28. An assembly as claimed in claim 26, comprising first and second elastically deformable supports according to any one of claims 1 to 25, the seal element disposed between the supports so that the first support abuts and supports a first surface of the seal element, and the second support abuts and supports a second, opposite surface of the seal element.

29. A downhole tool comprising at least one expandable seal assembly according to any one of claims 26 to 28.

30. An elastically deformable support for an expandable seal element of a downhole tool, in which the support is deformable between an unexpanded configuration and a radially expanded configuration and comprises:

a plurality of base portions, each base portion having a surface which, in use, faces towards the seal element; and

a plurality of overlap portions, each overlap portion extending from a respective base portion so that it overlaps the surface of an adjacent base portion and having a surface which, in use, faces towards the seal element;

in which the base portions and the overlap portions are arranged to define a generally ring-shaped seal support structure which forms a continuous circumferentially extending support surface for abutting and supporting the seal element;

in which the base portions are arranged so that they can separate to facilitate expansion of the support;

in which the overlap portions are arranged so that they can slide over the surface of the adjacent base portion during expansion of the support;

and in which, in the expanded configuration of the support, the continuous circumferentially extending support surface comprises the surfaces of the overlap portions and at least part of the surfaces of at least some of the base portions.

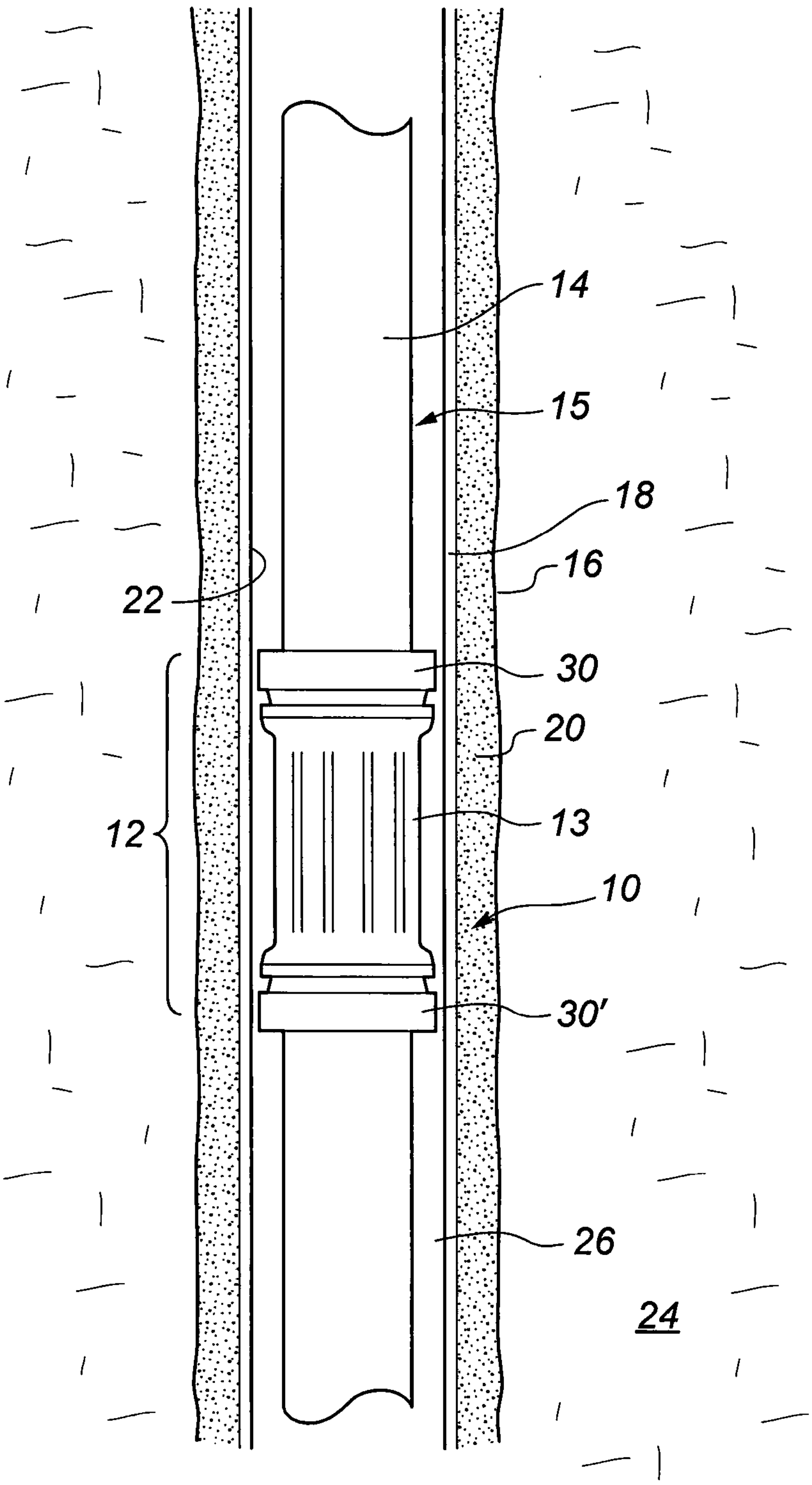
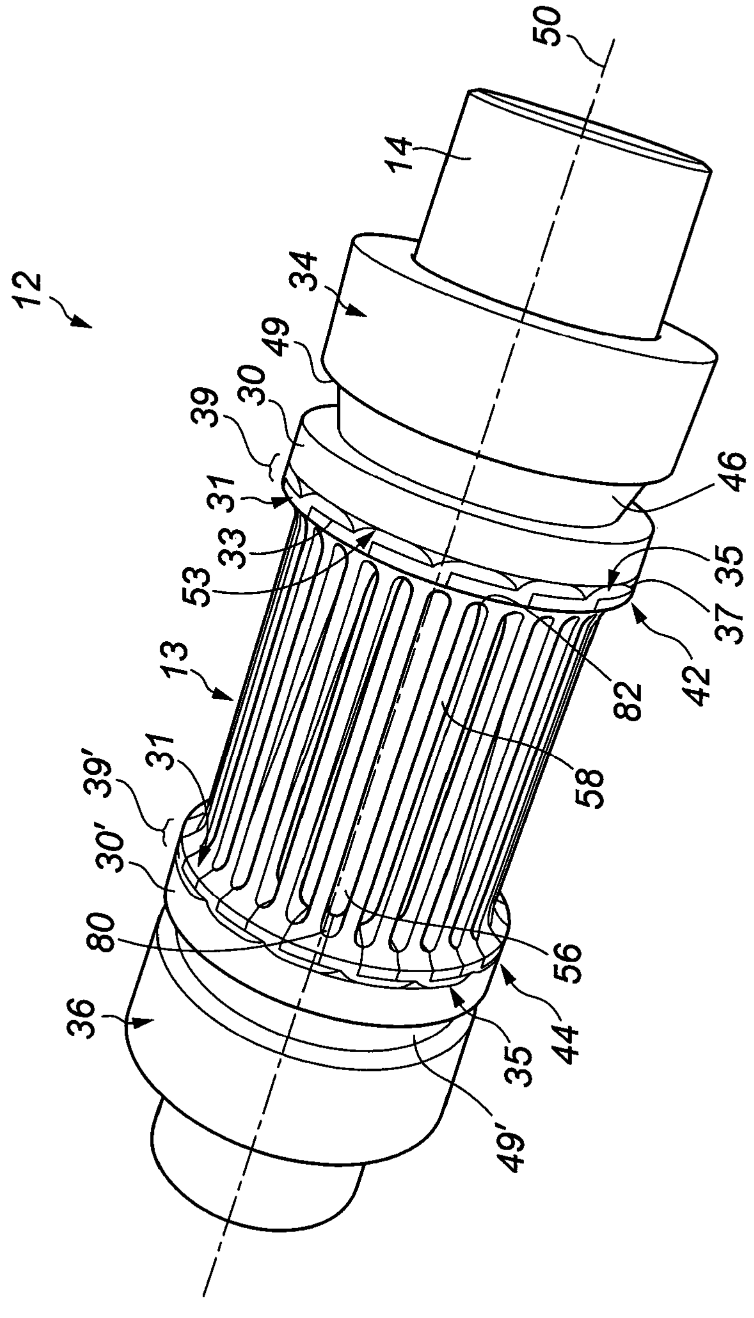


Fig. 1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12
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37
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82
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58
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39'
30'
80
56
36
44
35
49'

Fig. 2

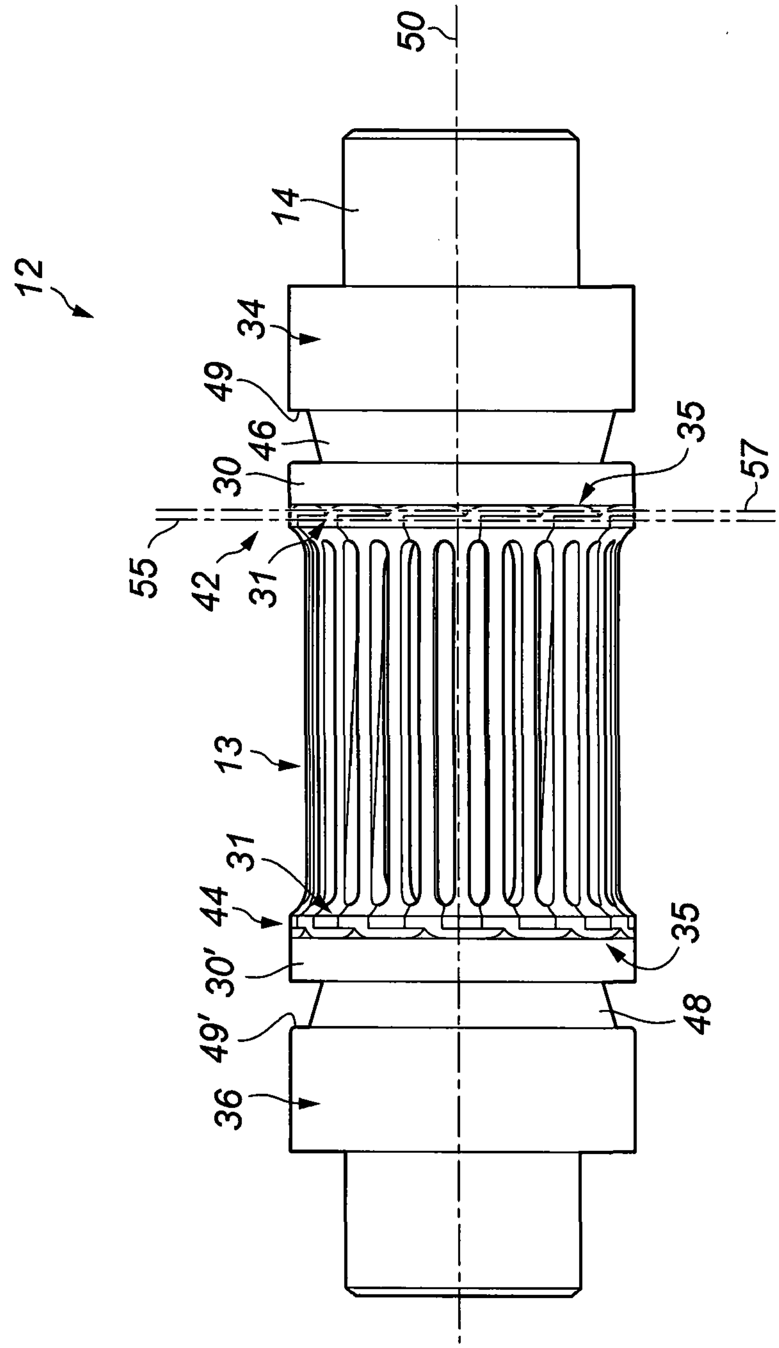


Fig. 3

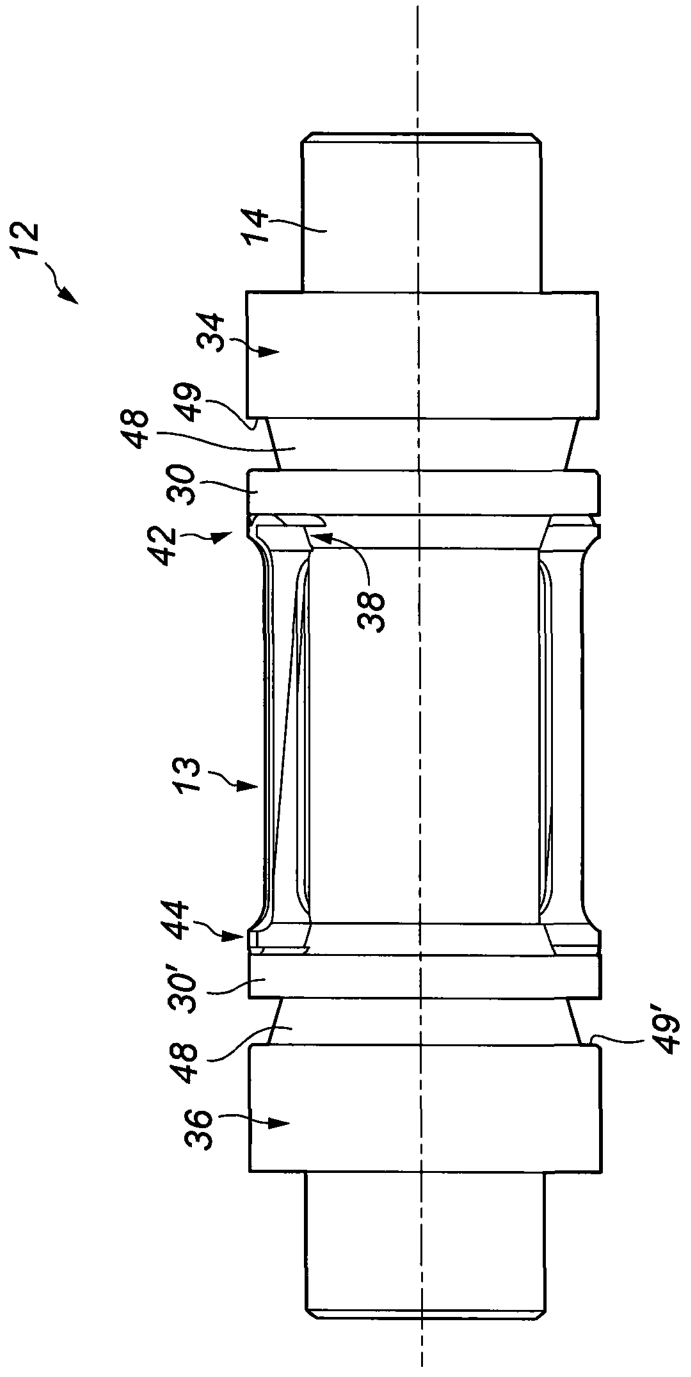


Fig. 4

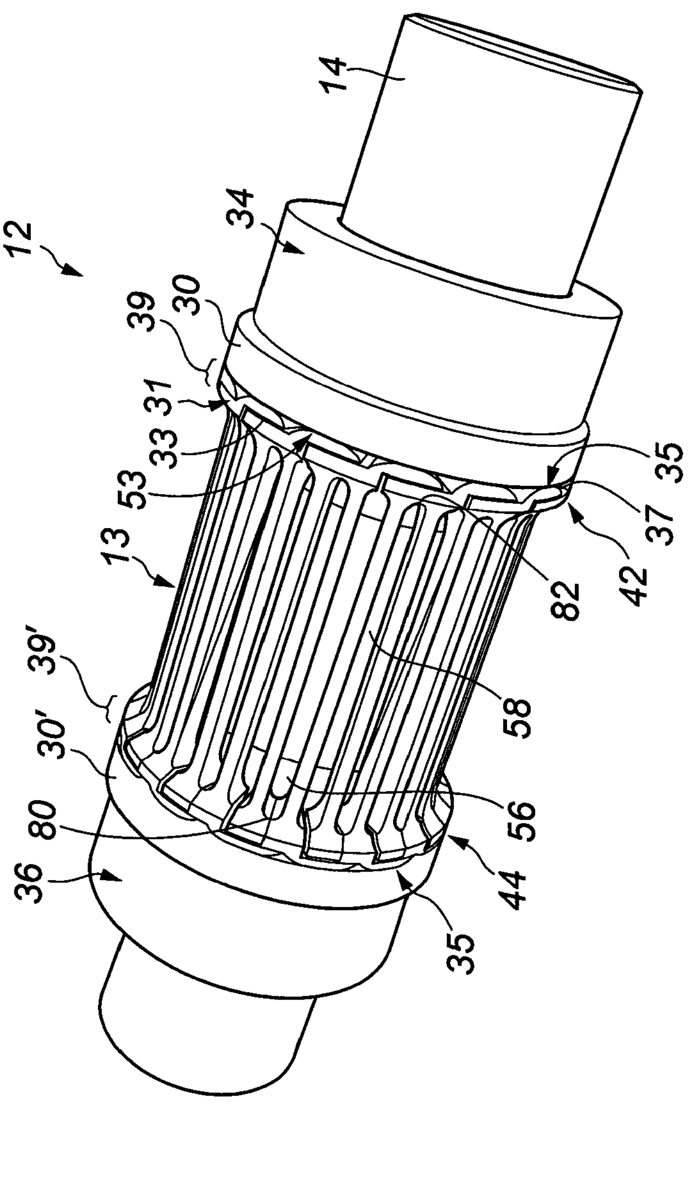


Fig. 5

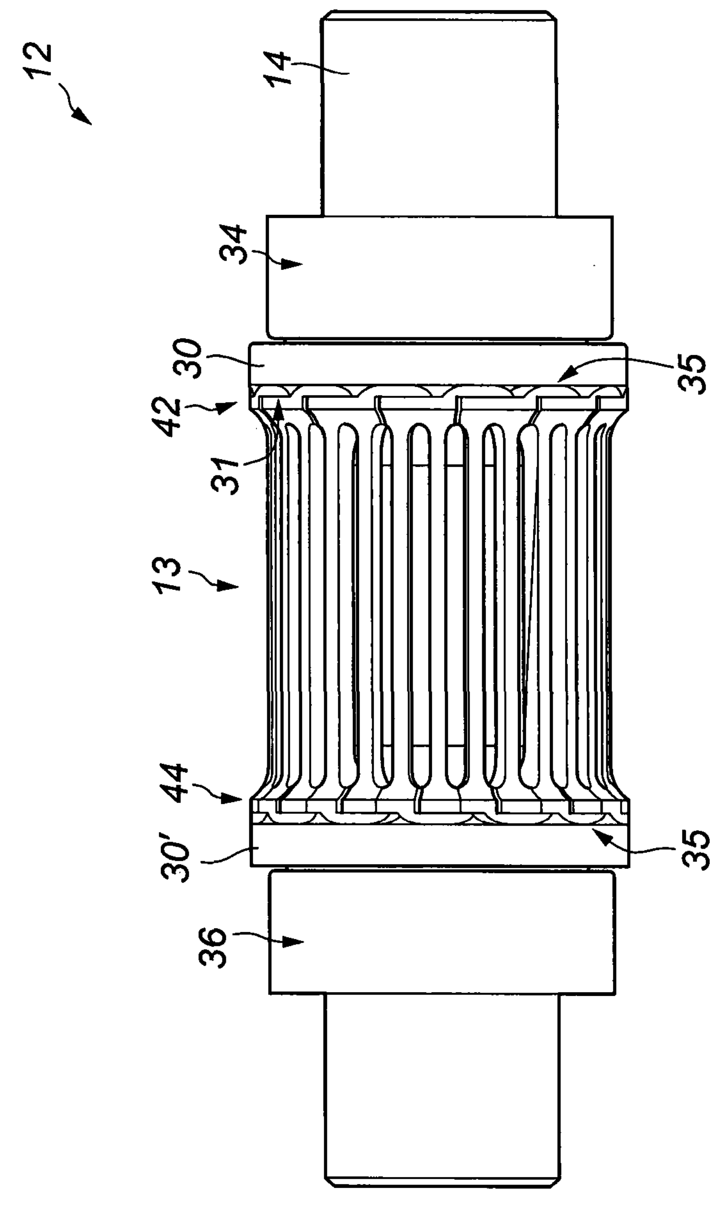


Fig. 6

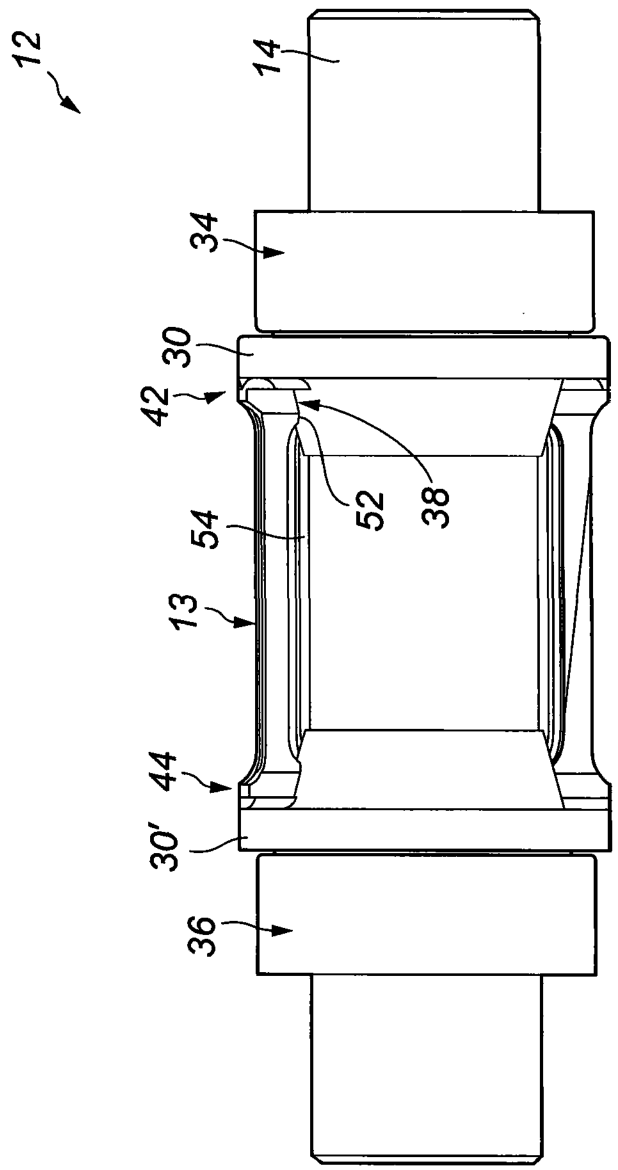
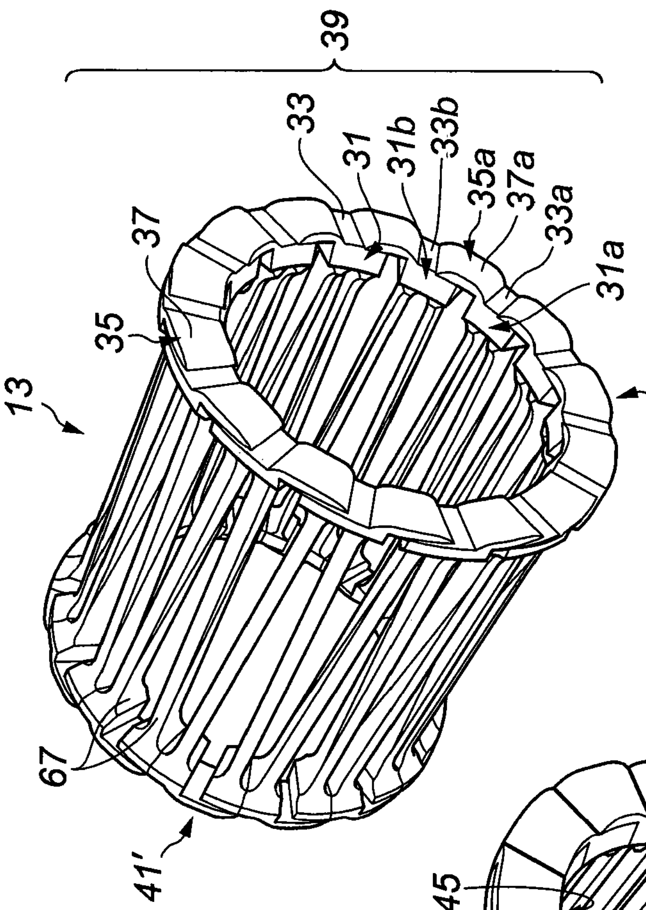


Fig. 7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33b
35a
37a
33a
31a
37
35
13
41
67
41'

Fig. 9

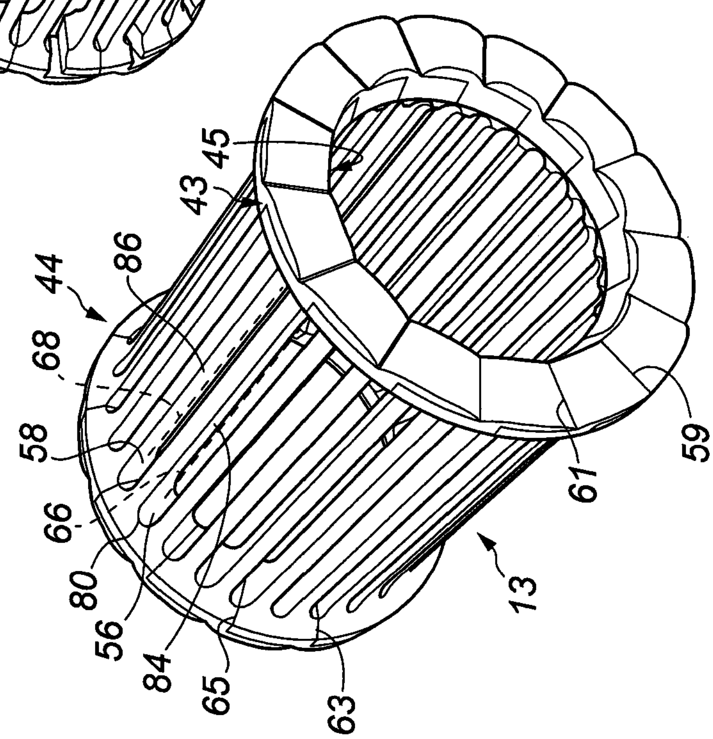
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Fig. 8

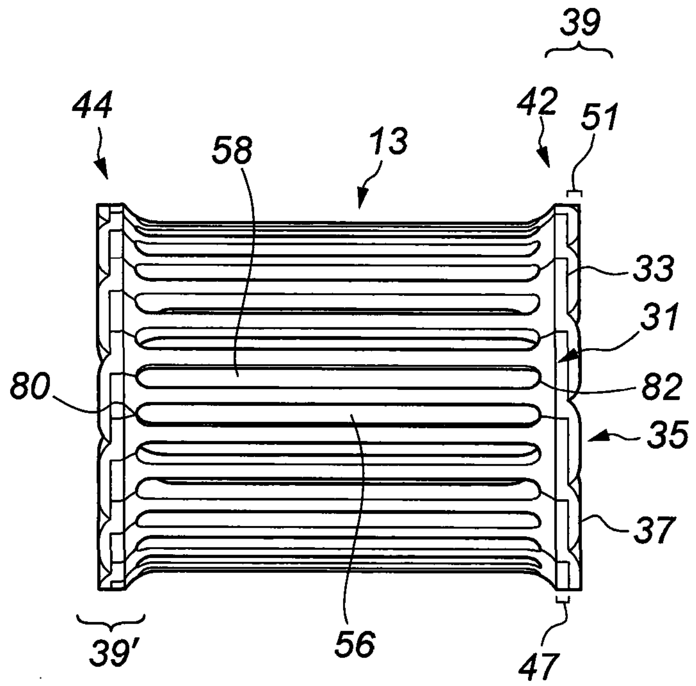


Fig. 10

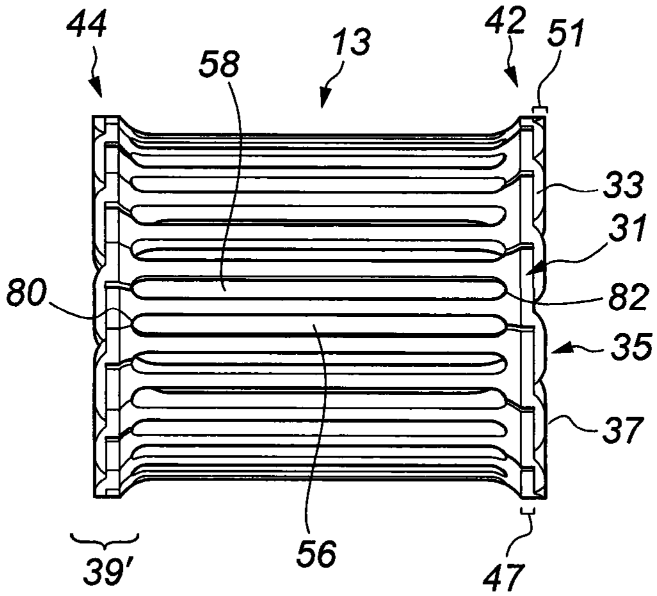


Fig. 11

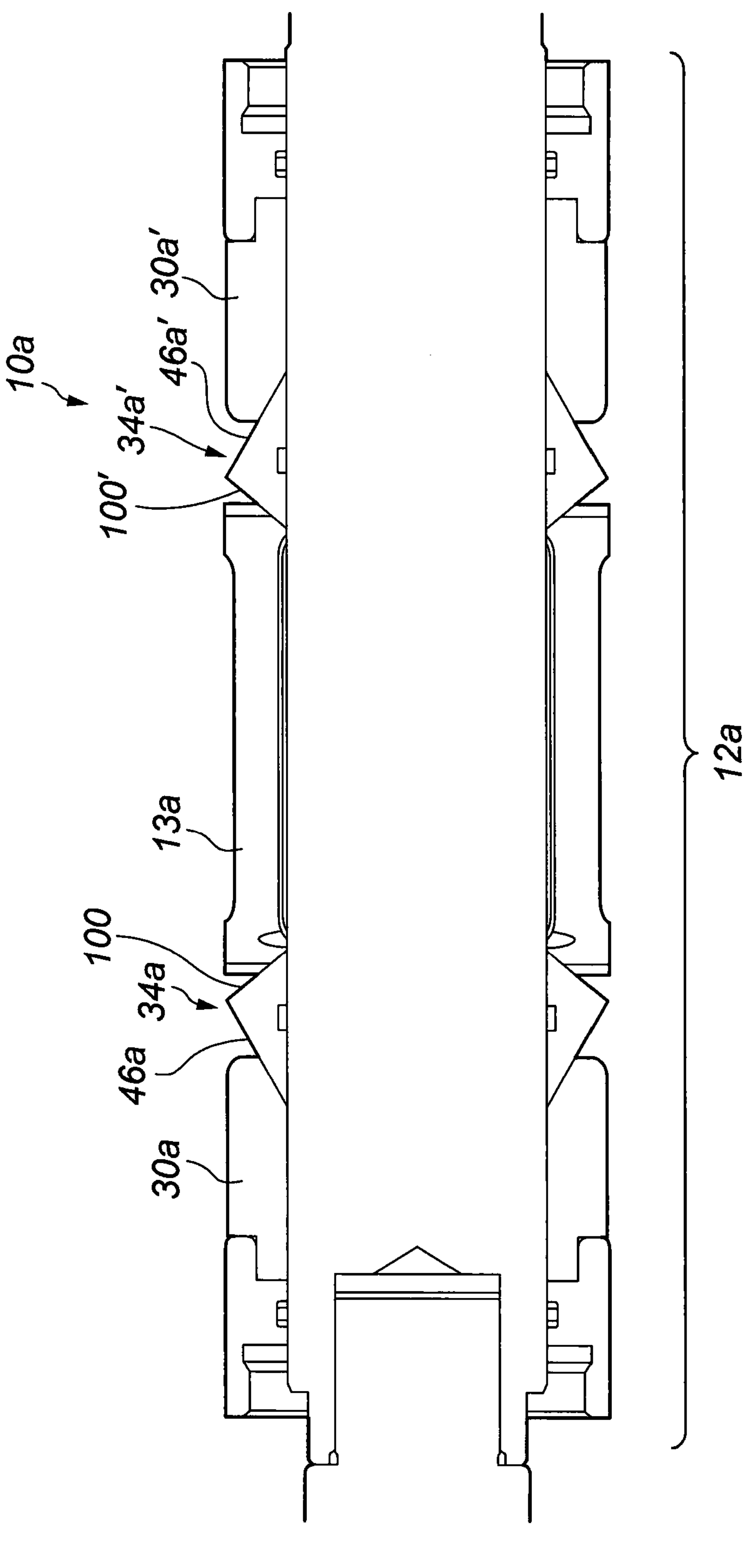


Fig. 12

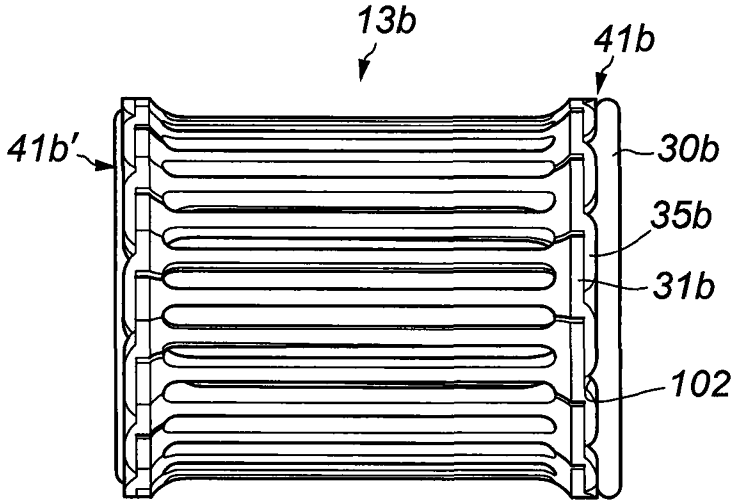
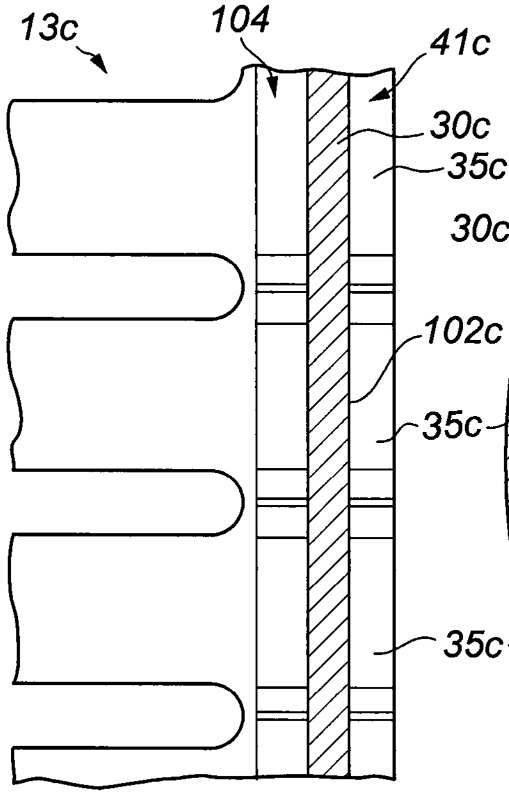


Fig. 13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104
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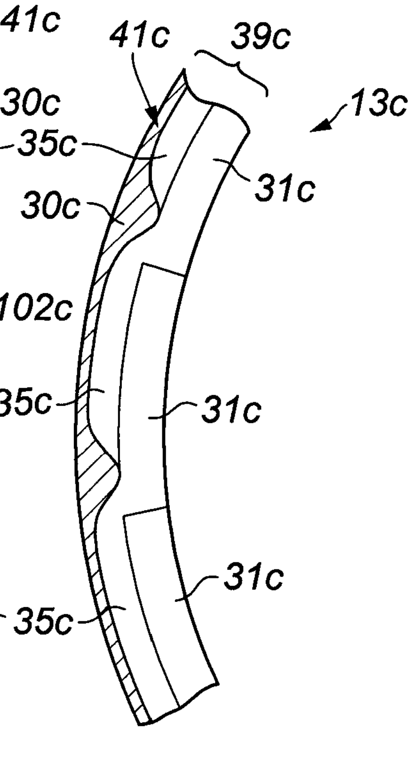
35c
102c
35c
35c

Fig. 14


41c
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13c
35c
31c
30c
31c
35c
31c
35c

Fig. 15