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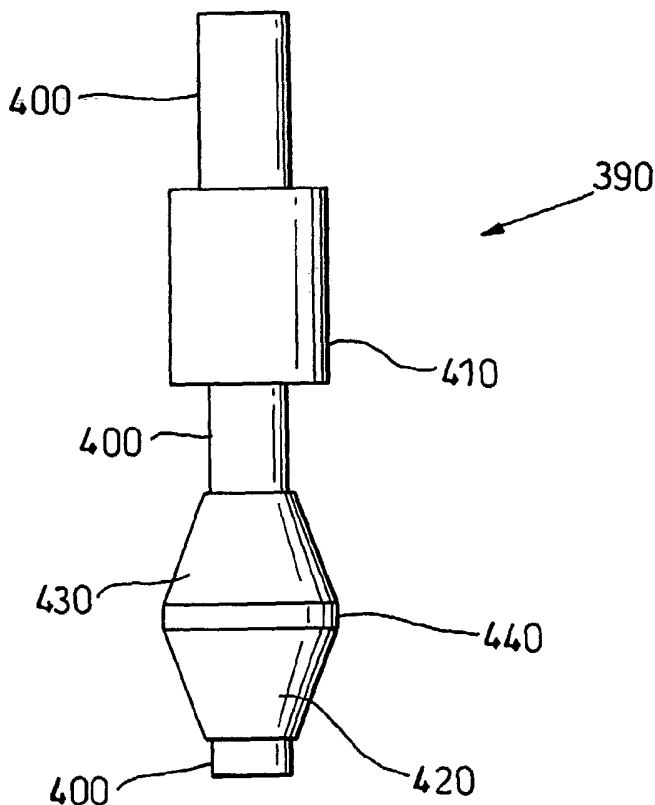
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(54) Title: A METHOD FOR DEFORMING A TUBULAR MEMBER



(57) Abstract: The invention relates to a method for deforming the internal profile of a bore of a tubular member by providing a percussive deformation tool (420) having an external profile for producing a desired profile for the bore then inserting said deformation tool (420) into the bore and striking the deformation tool with a reciprocating impact means (40) to advance the deformation tool (420) through the bore thereby deforming the internal profile of the bore. The percussive deformation tool used in the method can be provided with rollers (530) that reduce the frictional loading on the surface of the bore.



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A method for deforming a tubular member

The present invention relates to a method for deforming a tubular member and, more
5 specifically, to a method for deforming the diameter of the bore of a tubular member
used in a downhole environment.

The deforming of tubular members finds particular application in casing repair, sealing
of perforated casings, liner hangers and monobore well construction.

10

A tubular member is deformed by forcing a deformation tool through the tubular
member, the deformation tool having, for example, a larger diameter than the diameter
of the tubular member. However, problems are associated with known methods of
advancing the deformation tool through the tubular member.

15

For example, where a top down hydraulic deforming method is utilized, hydraulic fluid
is forced down an inner tubular to advance the deformation tool through the tubular
member. This creates a high-pressure region above the deformation tool with a low-
pressure region below it. The continued application of hydraulic fluid shuts off the well
20 and any downward movement of the tool increases the pressure of the well fluid and the
formation. Top down rotational systems which may use a tool provided with rollers to
reduce the frictional forces between the tool and the bore of the tubular member, require
significant downward force for optimum deformation. Additionally, factors such as
hole orientation, deformation ratio, depth of deformation and hole conditions determine
25 which system or process can be used.

Bottom up deformation methods require sustained pressure to be applied through an
inner tubular to the back of the deformation tool at the base of the tubular and forces the
deformation tool to move upwards away from the base of the tubular thereby deforming
30 the tubular. With hydraulic deformation, factors such as hydraulic or mechanical
integrity to maintain a seal between the tool and the internal bore of the tubular
member, hole orientation, diameter restrictions and well criteria are all problematic
areas.

It is an object of the present invention to improve upon existing types of deformation methods in terms of reducing the force required to deform tubulars and to reduce the costs associated with the deformation process. It is also an object of the present invention to provide a method which utilises the circulation of drilling fluids, thus removing the need for high-pressure equipment whilst also allowing debris removal either in front of the deformation tool or around the tubular section. It is independently an object of the present invention to provide a method for deformation which allows rotation and retrieval of the deformation tool. It is also an object of the present invention to provide a top down method of deformation.

According to a first aspect of the present invention, there is provided a method for deforming the internal profile of a bore of a tubular member comprising the steps of providing a percussive deformation tool having an external profile for producing a desired profile for the bore; inserting said deformation tool into the bore, and striking the deformation tool with a reciprocating impact means to advance the deformation tool through the bore thereby deforming the internal profile of the bore.

An essential area of consideration in this field of deformation systems is the load required to deform the tubular and the application of that load to the system. During normal drilling operations, heavyweight drill collars above the bit provide downward force or "weight on bit". In most cases this method is impractical for deforming tubulars because the force required is greater than the available weight of drill collars, especially in non-vertical or curved wellbores. One aspect of the present invention is to reduce the continuous force required so that conventional methods of deformation as described above become possible. The present invention is capable of applying a percussive load to the deformation system, which enables the force required to deform the tubular member to be reduced. This provides a significant advantage over current systems which require a greater load. Furthermore, by reducing the load required to deform the tubular member, a reliable and economical mechanical top-down deformation system is achievable. As sealing is not required for this method of deformation it is possible to expand perforated or slotted tubulars such as slotted liners

or expandable sand screens. The present invention enables the tool used in the deformation process to be pulled out of a bore at any time if problems occur.

Said impact means may operate with a substantially constant frequency or a variable
5 frequency. The reciprocal striking of the impact means upon the deformation tool creates a dynamic load which forces the tubular to be deformed with less force than continuous deformation currently allows. This rate of deformation may therefore be controlled depending upon the deformability of the material being deformed.

10 A distinct advantage of the present invention over known conventional methods is its ability to deform tubular members which are not substantially vertical, such as those found in horizontally inclined wells. A substantial proportion of the continuous load applied with this method is lost in those parts of the tubular which begin to deviate from a vertical position, i.e. where the well begins to curve or incline towards a
15 horizontal position. The dynamic nature of the loading applied by the present invention ensures that the load is applied at the point of percussive contact between the deformation tool and tubulars in a bore hole, for example, a curved or inclined well. The system may enable rotation to be transmitted to the deformation tool. Advantageously, rotation of the deformation tool allows different processes to be used
20 as the means can also rotate downwards instead of relying solely upon being pushed. Furthermore, rollers may be used for the deformation tool to achieve rotation and this provides a rolling contact thereby reducing friction. Such a rotational system may also be used in a top-down method which is connected to the surface and this provides a better weight transfer, especially in deviated wells.

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Preferably, a bearing is used to assist linear movement of the of the deformation tool through the bore. The bearings may be provided by at least one roller on the external profile of the bore. Optionally, the at least one roller is arranged to provide linear and rotational movement of the deformation tool. Optionally, a plurality of rollers are
30 arranged in rows on the surface of the deformation tool, the rollers in a first row being off-set with respect to rollers in a second row.

Optionally, bearing is provided by at least one ball and socket device, the ball being freely rotatable in a socket on the external profile of the deformation tool.

Optionally, a plurality of ball and socket devices are arranged in rows on the surface of the deformation tool, the balls in a first row being off-set with respect to balls in a
5 second row.

Said deformation tool may be substantially hollow. Said deformation tool may be substantially tapered. Said tool may be provided with at least one tapered surface. Said tool may be provided with at least one parabolic surface. Said tool may be a rotational
10 tool. Said tool may be attached to a drill string. Said tool may be provided with a profile which is adjustable. This will allow selective expansion of the tool downhole which is not possible with pressure driven tools in light of the sealing requirements to maintain the pressure discussed previously. Said drill string may be rotated. Said tool may be attached to a drill bit.

15

Said impact means may comprise a power driven tool. Said power driven tool may be a hammer tool. The reciprocating impact means may be actuated by hydraulic means. Said means may form part of a drill string. The method of the present invention is suitable for use in monobore wells and for expanding slotted or perforated tubulars. In
20 this latter case, pressure activated devices do not work effectively because holes in the tubular prevent a build up of pressure.

According to a second aspect of the present invention there is provided a percussive deformation tool comprising bore profiling means for producing a desired profile in a
25 bore upon movement of the deformation tool through the bore in an axial direction, the profiling means being attached to a bearing to reduce friction between the bore and the deformation tool during said axial movement of the deformation tool.

Preferably, the bearing is arranged to provide linear and rotational movement of the
30 deformation tool.

Optionally, the bearing is provided by at least one roller.

Optionally, the bearing is provided by at least one ball and socket device, the ball being freely rotatable in the socket.

- 5 The continuous forces available through conventional methods may be insufficient to effectively deform a tubular member but the method described above applies a reciprocal impact to the deformation tool which produces sufficient dynamic loading to deform the tubular member.

10 **BRIEF DESCRIPTION OF THE DRAWINGS**

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

- 15 Fig. 1 shows the general arrangement of a drill string used in accordance with the present invention;

 Figs. 2 and 3 show a detailed cross-section of a hammer tool used in accordance with the present invention;

- Fig. 4 shows a deformation assembly used in conjunction with the hammer tool
20 shown in Figs 2 and 3 above;

 Fig. 5 shows a cross sectional view of a deformation tool housing a set of friction reducing rollers;

 Fig. 6 shows a cross sectional view of a deformation tool having two sets of friction reducing rollers arranged at different diameters along the deformation tool;

- 25 Fig. 7 shows an arrangement of rollers on the surface of the deformation tool angled to provide linear and rotational movement;

 Fig. 8 shows an arrangement of rollers on the surface of a deformation tool wherein rows of rollers are off-set with respect to one another;

- Fig. 9 shows an arrangement of balls on the surface of a deformation tool, the
30 angles across the surface of the tool;

 Fig. 10 shows an arrangement of balls on the surface of a deformation tool wherein rows of balls are off-set with respect to one another; and

Fig. 11 shows a deformation assembly similar to that shown in Fig. 4 with rollers included on the frusto-conical surface.

DETAILED DESCRIPTION OF THE EMBODIMENTS

5 Referring to Fig. 1 of the drawings, there is shown a bottom hole assembly 10 which comprises a series of heavyweight drill collars 20 which are connected to a drill pipe 30 rising to the surface above the collars 20 through a well bore 35. This provides a connection from a hammer tool 40 to the surface where it is controlled by a hydraulic system. The hammer tool 40 will now be described in more detail with reference to
10 Figs 2 and 3.

Turning now to Figs 2 and 3 of the drawings, the hammer tool 40 comprises a series of cylindrical housings, namely a stator housing 50, a piston housing 60, a guide bush 70, a coil spring housing 80 and a mass housing 90, which are all provided with a threaded
15 connection portion at either end to allow assembly.

Fig. 2 shows a top end of the hammer tool provided with a top sub 100 to connect the hammer tool to the drill string at an end remote from an impact mass 110. The top sub is generally cylindrical and is provided with a plurality of bore diameters, which allow
20 fluid communication between the hammer tool and a hydraulic unit (not shown). The top sub 100 is threadably engaged with a first end 120 of the stator housing 50 and abuts a rotor end stop 130 located inside the stator housing.

The end stop is generally cylindrical and has an abutment face 140 provided with a
25 plurality of apertures 150 which allow passage of fluid from the top sub into the stator housing. A rotor 160 has a spiral profile formed thereon and rotates in a manner which is eccentric to the central axis of the housing. A second end 170 of the rotor 160 has a generally cylindrical connection means 180 formed thereon which is provided with a female threaded portion 185 eccentric to an outer diameter of the connection means
30 180. The means 180 are attached to a generally cylindrical valve mount 190 provided with a male threaded portion 195, which will matingly engage with the female portion 185 of the connection means 180. The valve mount 190 is provided with an eccentric

diameter 200, which forms a shoulder on an end remote from the male threaded portion. In turn, the shoulder has a counter-bore 210 which fits onto a blank cylindrical valve plate 220. This enables an eccentric rotation to be translated to a valve which will be explained below.

5

The blank valve plate 220 abuts an end of a cylindrical valve plate 230, which is provided with two apertures 231, 232 which are diametrically opposed to each other. The rotation of the shaft 160 will cause the blank valve plate 220 to rotate eccentrically and so block off at least a portion of one of these apertures 231, 232 at any given time thereby creating an alternating flow of fluid. The valve plate 230 is provided with a male thread onto which a valve clamp 240 provided with a female thread is engaged. This generally hollow valve clamp engages not only with the male thread provided on the valve plate 230 but also with a male thread provided on a first end 250 of the piston housing 60. This threaded first end 250 also engages with a female thread provided at a second end 260 of the stator housing 50. This arrangement allows the valve clamp 240 to hold the valve plate 230 in place by screwing the valve clamp onto both the valve plate and the first end 250 of the piston housing 60. This end 250 of the piston housing 60 is in turn secured to the stator housing 50 by screwing the second end 260 of the stator housing 60 onto the first end 250 of the piston housing 60.

20

Attached to the valve plate 230 is a flow chamber 270, which is provided with two flow channels 280, 290 which are aligned with the apertures 231, 232 of the valve plate 230. The first channel 280 directs the fluid flow into an annular space 285 formed in the piston housing 60 by a piston chamber 300, attached to the flow chamber 270 by a threaded portion 305, and the second channel 290 directs the fluid flow into the piston chamber 300. By blocking off the fluid flow in the manner describe previously, the flow alternates between entering the piston chamber 300 and the annular space 285 to maintain a pulsed flow.

30 The piston housing 60 is connected to a guide bush 70, which, in turn, is connected to a coil spring housing 80. The piston chamber 300, located within the piston housing 60, supports a first end 310 of a piston shaft 320.

As shown in Figs 1 and 2, the shaft 320 extends through the remainder of the piston housing 60, the guide bush 70 and the coil spring housing 80 and into the mass housing 90 where a second end 330 of the shaft 320 is connected to the impact mass 110.

5

Referring to Fig. 2, it can be seen that the shaft has a coil spring 340 provided around it, which abuts against a shoulder 350 in the coil spring housing 80.

The impact mass 110, during operation, strikes an anvil 360, which is connected to a spring loaded impact mandrel 370. The impact mandrel 370 is located inside a lower housing 380, which is connected to an end 390 of the mass housing 90.

During use, pressurised fluid enters the stator housing via the top sub 100. Rotation of the rotor shaft 160 causes an eccentric rotation of the blank valve plate 220, which blocks off the flow to one of the channels 280, 290 via apertures 231, 232. When the channel 280 is closed by the blank valve plate 220, fluid will flow into the channel 290 and into the piston chamber 300. This forces the piston 320 to move downwards, against the bias of the coil spring 340, and so cause the impact mass 110 to strike the anvil 360, thereby moving the spring loaded impact mandrel 370 downwards. With the channel 290 now closed, the pressurised fluid flows into the annular space 285, thus releasing pressure from the coil spring 340 and thereby allowing the bias of the coiled spring to move the impact mass 110 upwards. The upward movement of the impact mass 110 releases the force on a spring stack 400 located within the spring-loaded impact mandrel 370, thereby allowing the bias of the spring stack 400 to pull the spring-loaded impact mandrel 370 upwards into the lower housing 380. An alternating flow of pressurised fluid allows repeated striking of the anvil 360 by impact mass 110 at a specific rate. The frequency of said flow is directly proportional to the fluid flow rate, however, a frequency of 10Hz is envisaged.

Fig. 4 shows a deformation assembly 390 which is connected to an end of the impact mandrel 370 whereby striking of the impact mass upon the anvil forces the impact mandrel 370, and hence the deformation assembly 390, to move downwards. The

deformation assembly 390 comprises a hollow cylinder 400. A deformation tool 420 is provided at an end of the cylinder distal from the impact mandrel 370 and is threaded onto the cylinder 400. The tool 420 is a hollow cylindrical body which, in this embodiment, is provided with an external surface 430 which tapers outwards from either end of the tool 420 generally towards its centre. A deformation surface 440 of the required diameter is provided to enable deformation of the diameter of the tubular member.

During operation, the drill string of Figs 2 and 3 is positioned directly over the tubular member by means of well-known procedures involving derricks or drilling rigs for example. The hammer tool 40 is then activated, for example, by fluid flow normally provided by rig pumps, which supply fluid to the hammer tool in such a manner to cause the piston 320, the impact mass 110 and the impact mandrel 370 to reciprocate at a given rate as previously described. On the downward stroke, the impact mass 110 of the hammer tool 40 is accelerated to a high velocity by means of the fluid and impacts upon the anvil portion 360 causing the impact mandrel 370, and the deformation assembly 390 connected thereto, to move downwards. This repetitive striking action applies a load sufficient to cause the tool 420 to pass through the tubular member plastically deforming the bore of the tubular member to a desired size. As the hammer tool 40 continues to reciprocate and apply this dynamic load on the downward stroke, the deformation assembly 390 travels further inside the tubular member 70, deforming the bore as it moves to the required depth, or length, of travel

Figs. 5 to 11 show one or more bearings used to reduce the frictional load experienced between the surface of the deformation tool and the bore.

Fig. 5 shows a deformation tool 520 in a bore 510. The deformation tool 520 is provided with a set of rollers 530 arranged around the surface of the deformation tool 520 such that when the repetitive striking action acts upon the tool 520 the rollers 530 rotate while the deformation tool is progressing linearly through the bore. The presence of these rollers 530 reduces the frictional force experienced by the bore 510 and reduces the load required to force the deformation tool through the bore 510.

Fig. 6 shows a similar deformation tool in which a first set of rollers 630 and a second set of rollers 635 are spaced along the length of the deformation tool 620 and arranged around the circumference of the tool. In this example, deformation of the bore 610 to the required diameter occurs in two stages, the first deformation being caused by roller 630 and the second deformation being caused by roller 635.

Figs. 7 and 8 show examples of the manner in which rollers can be arranged on the surface of a deformation tool. Rollers 650 shown in Fig. 7 are arranged at an angle with respect to the direction of motion 652 such that when a repetitive striking force is applied the rollers 650 will rotate the deformation tool and will also assist in the linear movement of the deformation tool. In Fig. 8, two rows of rollers 730 and 735 are shown. It will be noted that these rollers are off-set with respect to one another so that the deformation caused by the first set of rollers 730 will be off-set with respect to the deformation caused by the second set of rollers 735. This will result in a smoother overall deformation and prevent the inner surface of the bore from becoming rutted.

Fig. 9 shows a similar arrangement to Fig. 7 but with a plurality of balls fitted into sockets to allow them to be freely rotatable. As with Fig. 7 the balls are arranged in a diagonal pattern across the surface of the deformation tool. Fig. 10 shows two rows of balls 830 and 835 wherein the balls are off-set with respect to one another to reduce rutting in the internal surface of the bore.

Fig. 11 shows a deformation tool similar to that of Fig. 4 in which two sets of rollers 730 and 735 are arranged on the deforming surface of the deformation tool 900. All other features in this figure are of a similar type to those shown in Fig. 4.

The use of this process offers significant cost reductions when used in applications such as casing repair where a deficient, corroded or perforated casing may have a second tubular deformed inside the existing casing thereby providing a seal to shut off the damaged or perforated areas. The wall thickness of the second tubular may be optimised to provide maximum through-bore and flow capacity. This also means that

an internal liner can be deformed across a perforated section to seal off the flow between the formation and the tubing. This enables new perforations to be made elsewhere in the tubing. In a similar application, when a seal between a main bore and a lateral bore is required, this method may be used to deform a liner around the lateral
5 junction to provide an effective seal mechanism.

The present application finds particular utility during the process of hanging of an open hole liner at the end of a cased section of the wellbore. The section of open hole may have been under-reamed hole below the existing casing string to provide a larger
10 diameter than that of the casing. A tubular liner can then be deformed to a diameter similar to that of the existing casing string.

Typically, deformable tubular threaded connections are run pin up. However, utilising the method of the present invention as described above, the thread can be run in the
15 more conventional pin down orientation.

Initial testing of the percussive deformation process has provided a 30% reduction in the load required to deform a tubular over a continuous deformation process.

20 Whilst the embodiment described in the figures shows the deformation tool attached to the impact mandrel, in an alternative embodiment of the present invention, the deformation tool may be provided as a separate device which is pre-loaded into the tubular member at any selected location prior to deformation.

25 Furthermore, whilst the deformation tool is shown as having a tapered profile, it is envisaged that the profile may be selected to suit the desired result and therefore in some embodiments the profile may be, for example, circular or parabolic.

The examples described are given as examples only, and are not intended to limit the
30 scope of the invention in any way.

Claims

1. A method for deforming the internal profile of a bore of a tubular member comprising the steps of:
 - 5 providing a percussive deformation tool having an external profile for producing a desired profile for the bore; inserting said deformation tool into the bore; and striking the deformation tool with a reciprocating impact means to advance the deformation tool through the bore thereby deforming the internal profile of the bore.
- 10 2. A method for deforming the internal profile of a bore of a tubular member as claimed in claim 1 wherein the reciprocating impact means operate with a substantially constant frequency.
- 15 3. A method for deforming the internal profile of a bore of a tubular member as claimed in claim 1 wherein the reciprocating impact means operate with a variable frequency.
4. A method for deforming the internal profile of a bore of a tubular member as claimed in any preceding claim wherein loading is applied at the point of percussive
20 contact, between the deformation tool and tubulars.
5. A method for deforming the internal profile of a bore of a tubular member as claimed in Claim 4 wherein the point of percussive contact is in a curved or inclined well.
25
6. A method for deforming the internal profile of a bore of a tubular member as claimed in any preceding claim wherein rotation is transmitted to the deformation tool.
7. A method for deforming the internal profile of a bore of a tubular member as
30 claimed in claim 6 wherein rollers are used for rotation of the deformation tool.

8. A method for deforming the internal profile of a bore of a tubular member as claimed in any preceding claim wherein a bearing is used to assist linear movement of the deformation tool through the bore.

5 9. A method for deforming the internal profile of a bore of a tubular member as claimed in Claim 8 wherein the bearing is provided by at least one roller on the external profile of the deformation tool.

10 10. A method for deforming the internal profile of a bore of a tubular member as claimed in Claim 9 where the at least one roller is arranged to provide linear and rotational movement of the deformation tool.

15 11. A method for deforming the internal profile of a bore of a tubular member as claimed in Claim 9 or Claim 10 wherein a plurality of rollers are arranged in rows on the surface of the deformation tool, the rollers in a first row being off-set with respect to rollers in a second row.

20 12. A method for deforming the internal profile of a bore of a tubular member as claimed in Claim 8 wherein the bearing is provided by at least one ball and socket device, the ball being freely rotatable in a socket on the external profile of the deformation tool.

25 13. A method for deforming the internal profile of a bore of a tubular member as claimed in Claim 12 wherein a plurality of ball and socket devices are arranged in rows on the surface of the deformation tool, the balls in a first row being off-set with respect to balls in a second row.

14. A method for deforming the internal profile of a bore of a tubular member as claimed in any preceding claim wherein said deformation tool is substantially hollow.

- 15 A method for deforming the internal profile of a bore of a tubular member as
claimed in any preceding claim wherein said tool is provided with at least one tapered
surface.
- 5 16. A method for deforming the internal profile of a bore of a tubular member as
claimed in any preceding claim wherein said tool is provided with at least one parabolic
surface.
17. A method for deforming the internal profile of a bore of a tubular member as
10 claimed in any preceding claim wherein said tool is a rotational tool.
18. A method for deforming the internal profile of a bore of a tubular member as
claimed in any preceding claim wherein said tool is attached to a drill string.
- 15 19. A method for deforming the internal profile of a bore of a tubular member as
claimed in any preceding claim wherein said tool is provided with a profile which is
adjustable.
20. A method for deforming the internal profile of a bore of a tubular member as
20 claimed in claim 18 wherein said drill string may be rotated.
21. A method for deforming the internal profile of a bore of a tubular member as
claimed in any preceding claim wherein said tool is attached to a drill bit.
- 25 22. A method for deforming the internal profile of a bore of a tubular member as
claimed in any preceding claim wherein said impact means comprises a power driven
tool.
23. A method for deforming the internal profile of a bore of a tubular member as
30 claimed in any preceding claim wherein said power driven tool is a hammer tool.

24. A method for deforming the internal profile of a bore of a tubular member as claimed in any preceding claim wherein the reciprocating impact means is actuated by hydraulic means.

5 25. A method for deforming the internal profile of a bore of a tubular member as claimed in any preceding claim wherein said means forms part of a drill string.

26. A method for deforming the internal profile of a bore of a tubular member as claimed in any preceding claim wherein the bore is a monobore well.

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27. A method for deforming the internal profile of a bore of a tubular member as claimed in Claims 1 to 25 wherein the bore contains a slotted or perforated tubular.

15 28. A method for deforming the internal profile of a bore of a tubular member in accordance with claim 1 in combination with any of claims 8 to 13 further comprising the step of further deforming the internal profile of the bore using a deformation tool having a substantially smooth external profile to provide a substantially smooth internal bore surface.

20 29. A percussive deformation tool comprising, bore profiling means for producing a desired profile in a bore upon movement of the deformation tool through the bore in an axial direction, the profiling means being attached to a bearing to reduce friction between the bore and the deformation tool during said axial movement of the deformation tool.

25

30. A percussive tool as claimed in claim 29 wherein the bearing is arranged to provide linear and rotational movement of the deformation tool.

30 31. A percussive tools as claimed in claim 29 or claim 30 wherein the bearing is provided by at least one roller.

32. A percussive tools as claimed in claim 29 or claim 30 wherein the bearing is provided by at least one ball and socket device, the ball being freely rotatable in the socket.

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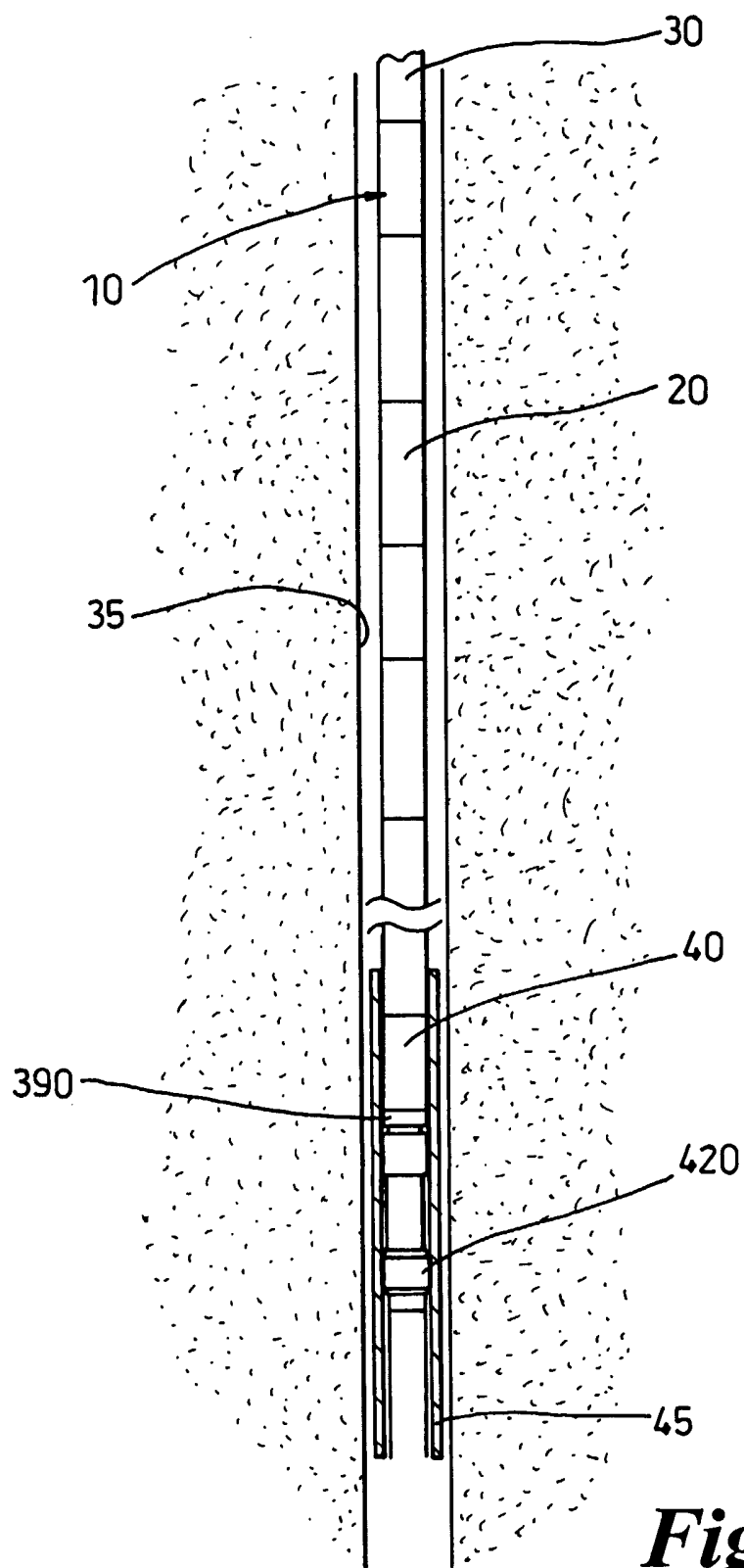
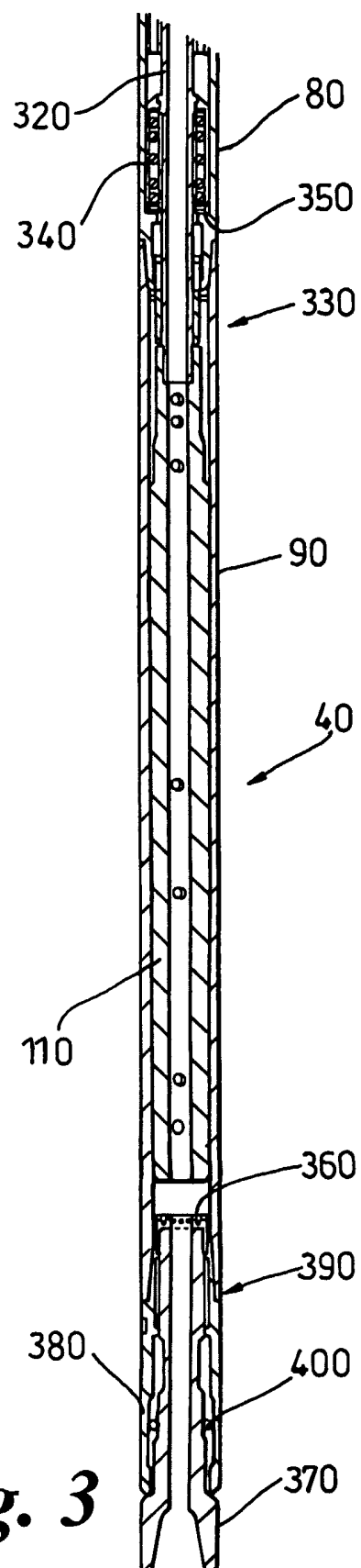
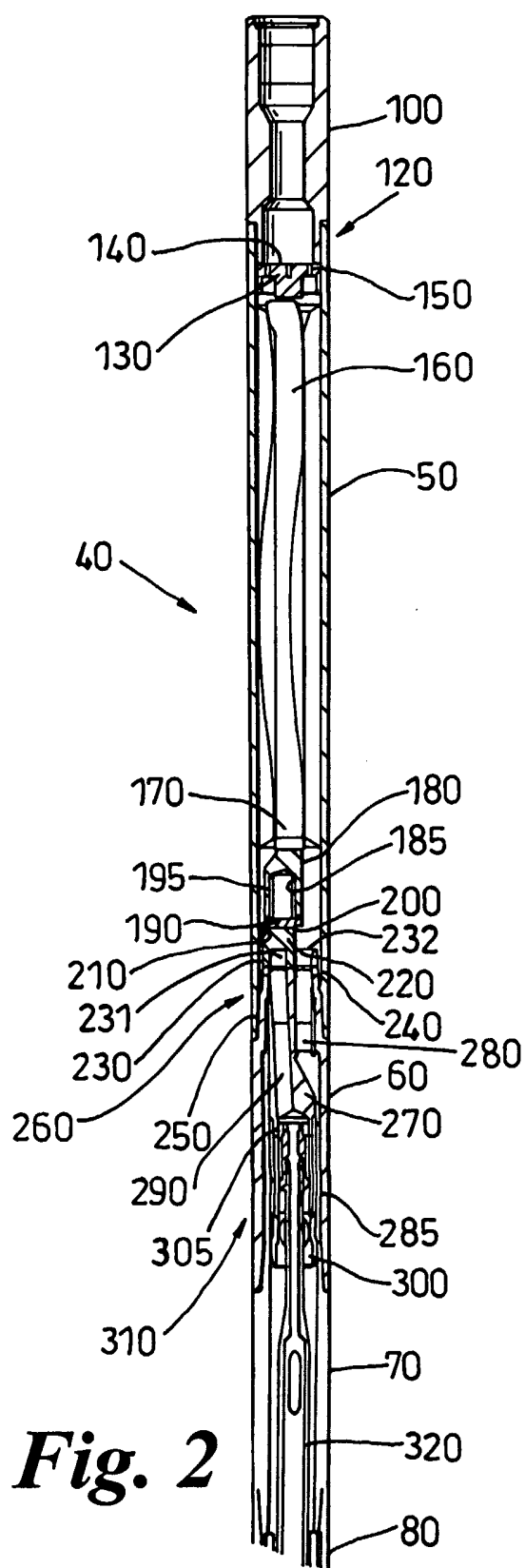
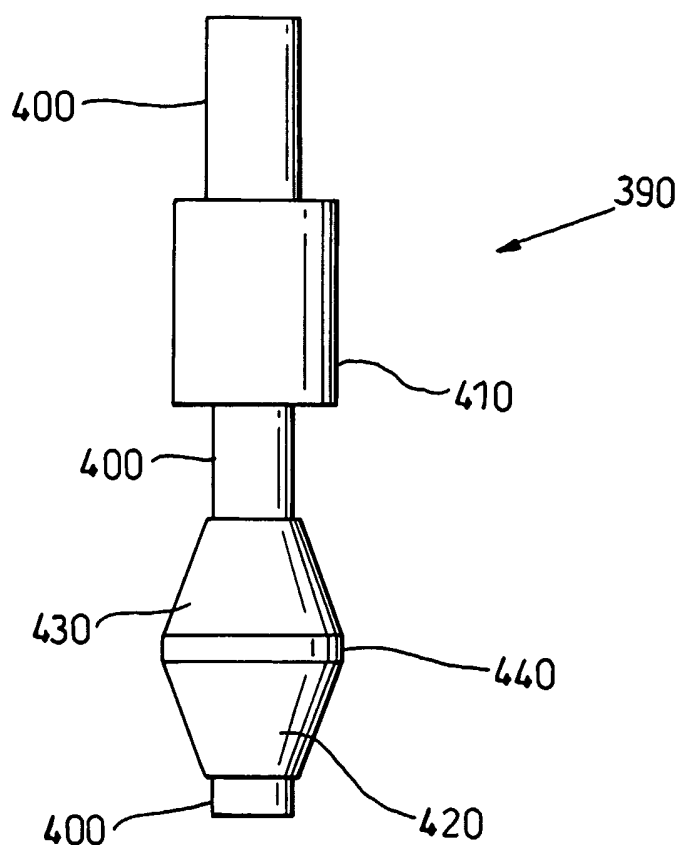


Fig. 1

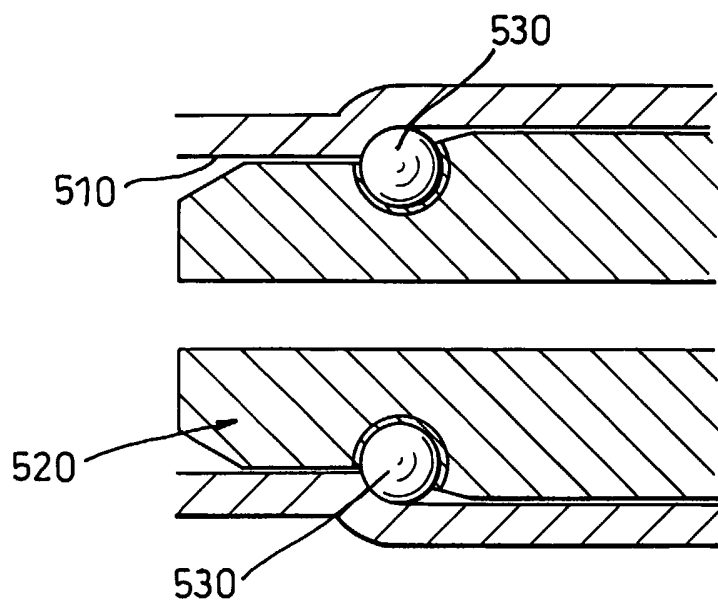
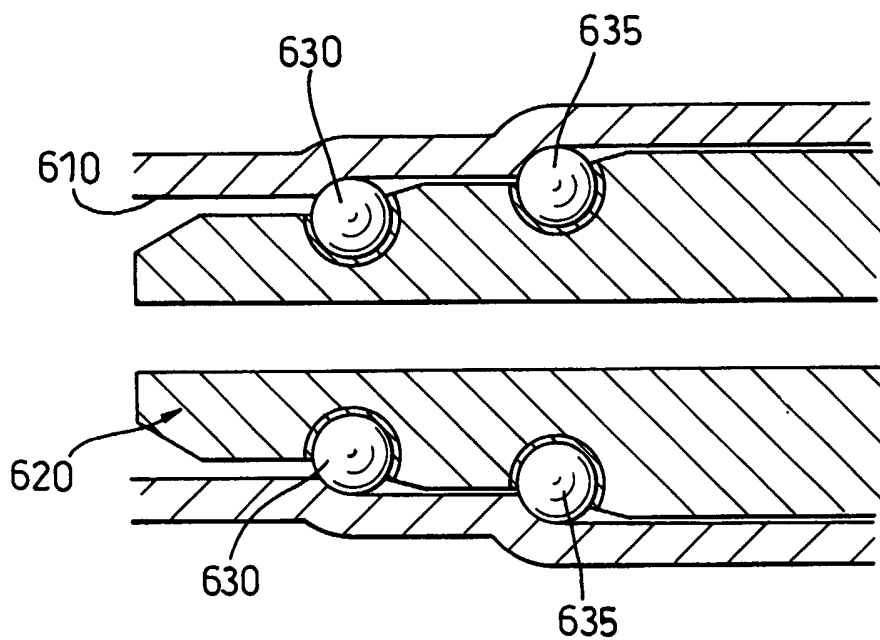
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*Fig. 4*

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***Fig. 5******Fig. 6***

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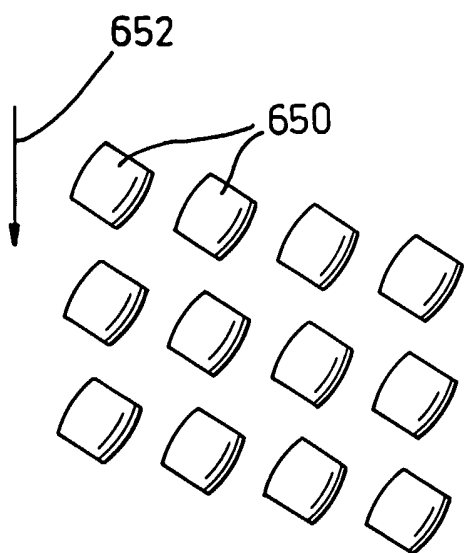


Fig. 7

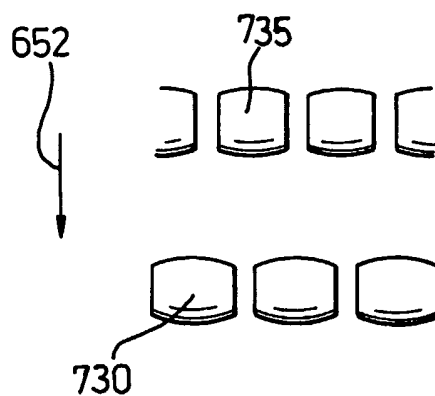


Fig. 8

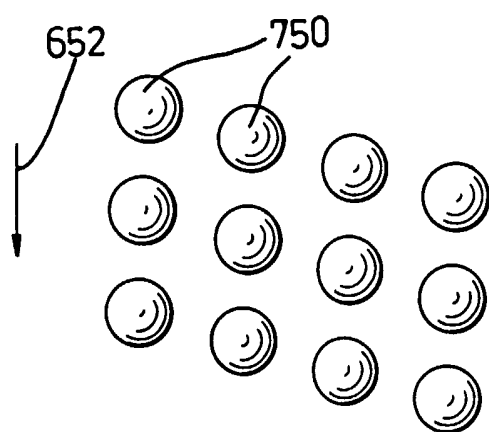


Fig. 9

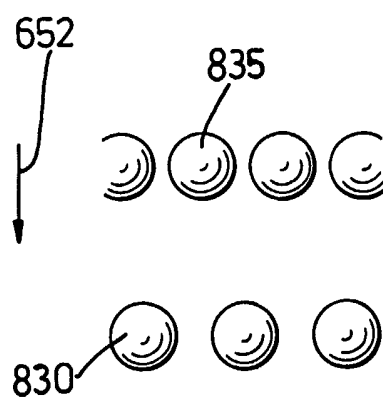
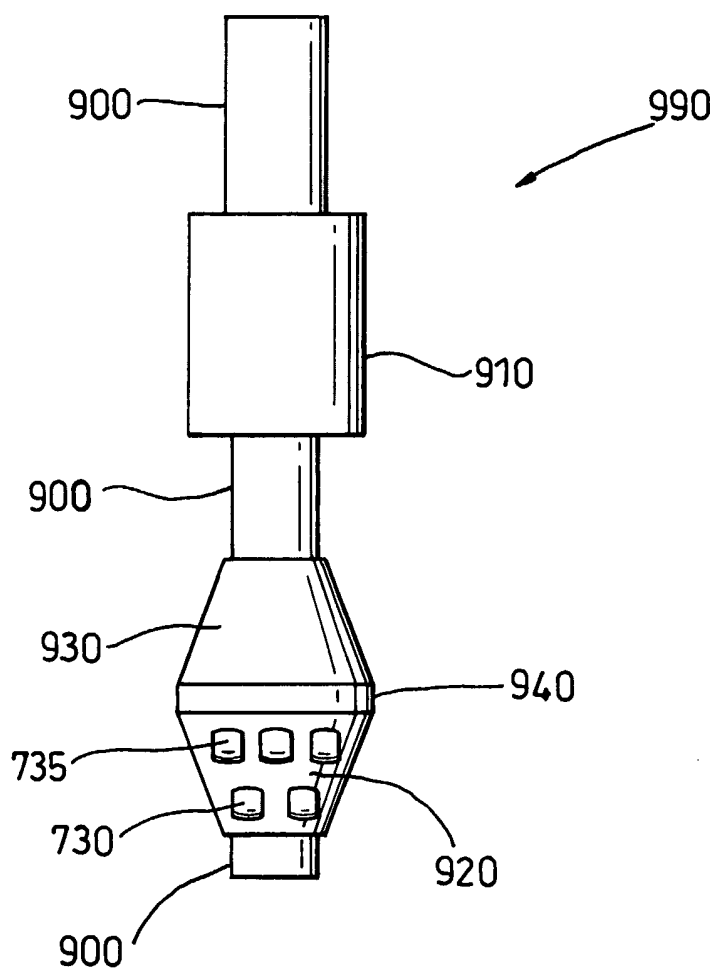


Fig. 10

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*Fig. 11*

INTERNATIONAL SEARCH REPORT

International Application No
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A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 E21B43/10 E21B29/10 E21B4/10 E21B4/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

28 July 2003

Date of mailing of the international search report

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