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(54) Title:  WELLBORE DRILLING ACCELERATOR AND TUBULAR CONNECTION

(57) Abstract:  A drilling accelerator that is driven from a rotational drive to generate a percussive axial motion on a drill bit. The drilling accelerator includes a drive connection to mechanically convert rotational drive to axially directed percussive motion. A wellbore tubular connection is also disclosed that transitions torque to resist back off when left hand or right hand torque is applied.
Wellbore Drilling Accelerator and Tubular Connection

Field

The present invention relates to down hole tools and, in particular, a wellbore drilling accelerator for applying an axially directed percussive effect to a drill bit and a tubular connection.

Background

If one could add a percussive force to the drill bit while drilling a wellbore, it is believed that the rate of drilling penetration could be significantly increased, the required weight on bit could be significantly reduced and torque required to turn the drill bit could be significantly reduced. A "percussionized" drill bit should be an efficient drilling tool.

Many previous attempts at developing percussion adapters have focused on hydraulically driven devices. These devices use the flow of drilling fluid to drive pistons with a percussion adapter to create an axially directed percussive effect at the drill bit.

A common problem experienced in down hole operations relates to the effect of torque on tubular connections. This problem may be exaggerated when torque is generated in the operation of a tool down hole.
Summary

In accordance with a broad aspect of the present invention, there is provided a method for accelerating the drilling penetration of a rotary driven drill bit, the method comprising: providing a positive displacement motor including a motor housing, a fluid discharge and a rotor powered by fluid pressure; providing a drill bit; providing a drilling accelerator including a housing and a drive connection to mechanically convert rotational drive to axially directed percussive motion; connecting the drilling accelerator below the motor including connecting the housing to move with the motor housing, connecting the drive connection to be driven rotationally by the rotor and bringing the fluid passage into communication with the fluid discharge; connecting the drill bit below the drilling accelerator with the drive connection in drive communication with the drill bit; pumping fluid through the motor to drive the rotor and the drive connection to rotate and to generate axial percussive motion which is communicated from the drive connection to the drill bit and; discharging fluid from the fluid discharge to pass through the drilling accelerator and the drill bit.

In accordance with another broad aspect of the present invention, there is provided drilling accelerator comprising: a housing including an upper end and a lower end; a drive connection including an upper axially rotatable drive shaft for receiving an input of rotational motion, a rotational to axial mechanical drive converter in communication with the upper axially rotatable drive shaft for converting the input of rotational motion to an axial sliding motion; a lower longitudinally moveable drive shaft in communication with the rotational to axial mechanical drive converter to receive the axial sliding motion from the rotational to axial mechanical drive converter and a lower drill bit installation site connected to the lower longitudinally moveable drive shaft for receiving the axial sliding motion and capable of conveying axial percussive motion there through, the lower drill bit installation site telescopically mounted adjacent the lower end of the housing and slidably moveable relative thereto.
In accordance with another broad aspect of the present invention there is provided a wellbore string tubular connection comprising: a first tubular including a first threaded pin end with a right hand thread form and a protrusion extending from its pin end face to create a stepped region thereon, a second tubular including a second threaded pin end with a left hand thread form and a recess on its pin end face forming a shoulder sized to accept the stepped region of the first pin end seated thereagainst, and a collar including a first threaded box with a first selected thread form selected to threadedly engage the right hand thread form of the first threaded pin end and a second threaded box with a second thread form selected to threadedly engage the left hand thread form of the second threaded pin end.

In accordance with a broad aspect of another invention, there is provided a method for making up a wellbore connection, the method comprising: providing a first wellbore tubular with a threaded pin end and an tooth extending from a pin end face thereof, a second tubular with a threaded pin end and recess in a pin end face thereof, the recess sized to accept the tooth of the first wellbore tubular and a collar including a first threaded box end and an opposite threaded box end; aligning the first wellbore tubular and the second wellbore tubular to be threaded into the box ends of the collar and with the tooth aligned with the recess and rotating the collar about its long axis to engage the threaded pin ends of the first wellbore tubular and the second wellbore tubular and draw the threaded pin ends into the collar.

It is to be understood that other aspects of the present invention will become readily apparent to those skilled in the art from the following detailed description, wherein various embodiments of the invention are shown and described by way of illustration. As will be realized, the invention is capable for other and different embodiments and its several details are capable of modification in various other respects, all without departing from the spirit and scope of the present invention. Accordingly the drawings
and detailed description are to be regarded as illustrative in nature and not as restrictive.

**Brief Description of the Drawings**

Referring to the drawings, several aspects of the present invention are illustrated by way of example, and not by way of limitation, in detail in the figures, wherein:

Figure 1 is a schematic sectional view along a portion of a drill string.

Figure 2 is an axial sectional view along one embodiment of a drilling accelerator.

Figure 3 is an axial sectional view along another drilling accelerator.

Figure 3A is an elevation, partly in section, of a drive shaft useful in a drilling accelerator.

Figure 4 is an axial sectional view along another drilling accelerator.

Figure 4A is perspective view of a cam-type drive converter useful in the present invention.

Figure 4B is an axial section through a cam-type converter useful in the present invention.

Figure 4C is an axial section through a roller-type cam insert useful in the present invention.

Figure 4D is a front elevation of the insert of Figure 4C.
Figure 5A is an exploded, axial section through a tubular connection useful in the present invention.

Figure 5B is an assembled, axial section through a tubular connection useful in the present invention.

Figure 5C is a section along line l-l of a pin end of Figure 5A.

**Description of Various Embodiments**

The detailed description set forth below in connection with the appended drawings is intended as a description of various embodiments of the present invention and is not intended to represent the only embodiments contemplated by the inventor. The detailed description includes specific details for the purpose of providing a comprehensive understanding of the present invention. However, it will be apparent to those skilled in the art that the present invention may be practiced without these specific details.

A drilling accelerator can be installed in a drill string to facilitate wellbore drilling operations. Drilling accelerators are sometimes alternately called percussive adapters, drilling hammers, and fluid hammers. A drilling accelerator creates a percussive effect applied to the drilling bit that alone or with rotary drive of the bit causes the drill bit to drill into a formation.

With reference to Figure 1, the lower end of a drill string is shown. A drilling accelerator 10 can include a drive converter connection that accepts rotational drive about axis x from a torque generating device 12 above and converts that rotational drive to an axially directed percussive force that is output to a bit box sub 14 positioned below the drilling accelerator. When such a drill string is in use with a drill bit 16 installed in the bit box
and the drill bit being rotationally driven, arrow R, the axially directed percussive force, arrow P, applied to the bit box sub is conveyed to the drill bit and can facilitate drilling at the drill bit.

One embodiment of drilling accelerator 10 is shown in Figure 2. Drilling accelerator 10 may include an outer housing 18 including an upper end 18a and a lower end 18b. Outer housing 18 is rugged, being exposed on its external surface 18c to the wellbore annulus and houses therewithin the drive components for generating a percussive force.

To facilitate construction of the drilling accelerator, as will be appreciated, the housing can be formed in sections and connected together by various means such as by welding, interlocks or threaded engagement, as shown at connections 21.

Upper end 18a of the housing is formed for connection into a drill string, such as by forming as a threaded connection. Lower end 18b of the housing is formed for connection, shown herein directly but may be indirect, to a bit box sub 14. Bit box sub 14 has formed therein a site, such as, for example, threaded bit box 20, for accepting connection of a drill bit.

Bit box sub 14 is connected for rotational movement with housing 18 through a splined connection 22. However, connection 22 permits axial sliding motion of the bit box sub within housing 18, such axial sliding motion being generated by a connection to the drive connection of drilling accelerator 10, the drive connection is intended to drive the bit box sub axially to apply a percussive force at any drill bit connected into the bit box during drilling. Seals may be provided, such as O-rings and wiper seals 24 to resist fluid passage between the housing and the bit box sub, etc.

In one embodiment, the drive connection includes an axial shaft 30 supported in bearings 32 to convey rotational drive from an input end 30a to an output end 30b which
carries a bevel gear 34. This bevel gear 34 meshes with a second bevel gear 36 mounted on transverse shaft 38 which is rotatably supported in the housing. Transverse shaft 38 includes an eccentric 40 thereon which drives a drive shaft 42. Drive shaft 42 includes a strap 44 with a bearing 46 therein in which eccentric 40 rotates. Drive shaft 42 at its opposite end includes an eye 48 through which the drive shaft is pinned via pin 50 to a percussion adapter 52 secured to bit box sub 14 for a drill bit.

Rotation in shaft 30 through reduction gears 34, 36 will impart on the percussive adapter 52 an axially directed reciprocation determined by the throw of eccentric 40. This axially directed reciprocation is then conveyed directly to any bit secured in the bit box 20 of the bit box sub.

The input torque may be generated by a mud motor. For example, axial shaft 30 may be connected to a rotor of a mud motor such that any rotation of the rotor, by flow of drilling fluid through the motor, may be conveyed to the drive connection. In one embodiment, the mud motor may include a positive displacement-type motor (PDM), which uses pressure and flow of the drilling fluid to turn a rotor within a stator. Shaft 30 can be connected directly or indirectly to the rotor, as through threaded connection 60. Where a bent sub is positioned between the motor and the drilling accelerator, a universal connector may be positioned therebetween to convey rotation from the rotor to the axial shaft.

The fluid that drives the motor can continue down through the accelerator and to the bit. As such, the accelerator may include drilling fluid passages 54 that can be connected in communication with the motor discharge and that extends from end 18a, about the drive connection components, to passages 62 through adapter 52 into a bore 56 of bit box sub 14. Passages 54 may be formed, as by milling, etc. through outer housing 18 and can be directed by ports, seals, etc. from the discharge of the pump to passages 62 into
the inner bore of the bit box. In some embodiments, outer housing 18 may require thickening or laminate/telescopic construction to accommodate the passages.

Gears 34, 36 and other moving parts may be grease packed for lubrication thereof. A compensator may be provided, for example, in end 30a to accommodate or alleviate pressure differentials which may occur during down hole operations.

The embodiment of Figure 2 operates to drill a borehole by applying a percussive force through the drill bit to the formation, with or without rotating the drill string from surface. In another embodiment shown in Figure 3, the drilling accelerator may include a drive system for conveying rotational drive from the motor to the drill bit in addition to the percussive forces generated thereby.

Referring, therefore to Figures 3, a drilling accelerator is shown including an outer housing 118 including a lower end 118b, an axial shaft 130 (shown in part) to convey rotational drive from an input to a gear transmission, a shaft 138 including an eccentric 140 for driving a drive shaft 142 and a percussion adapter 152 formed integral with a bit box sub 114 for a drill bit.

In this embodiment, the gear transmission includes gears to convey both rotational and axially reciprocal motion to the bit box sub. As illustrated, for example, gear transmission includes a first gear 135 that accepts input from bevel gear 134 and meshes with a gear 136 that drives shaft 138. Gear 136 also meshes with a second bevel gear 139 that drives the rotation of an inner housing 166. Inner housing 166 extends and rotates within outer housing 118. Inner housing 166 is connected at its lower end for rotational transmission to bit box sub 114. In particular, as shown, bit box sub 114 is connected for rotational movement with housing 166 through a splined connection 122 such that any bit installed in the bit box can be driven to rotate by rotation conveyed from shaft 130.
Connection 122 also permits axial sliding motion of the bit box sub within housing 166, such axial sliding motion being generated by a connection to shaft 138 of the drilling accelerator, the shaft intended to drive the bit box sub axially to apply a percussive force at any drill bit connected into the bit box during drilling, while gear 139 and housing 166 drive rotation of the bit box sub. Seals may be provided, such as O-rings and wiper seals 124 to resist fluid passage between the housing and the bit box sub, etc. Outer housing 118 can extend down to protect the inner housing. Bearings 168 and seals 124a may be provided to facilitate rotation and seal against fluid and debris migration between the parts.

In this embodiment, drive shaft 142 experiences differential rotation therealong: where upper portion 142a is not rotatably driven, but lower portion 142b is pinned to percussion adapter and is rotatably driven. In order to accommodate differential rotation along shaft 142, a bearing 170 can be provided along its length. Bearing 170 allows rotational motion therein of part 142b about its long axis relative to part 142a, but resists axial sliding motion such that axial percussive movement generated by the throw of eccentric 140 is conveyed along the shaft rather than being absorbed.

The input torque may be generated by a mud motor. For example, axial shaft 130 may be connected to a rotor of a mud motor such that any rotation of the rotor, by flow of drilling fluid through the motor, may be conveyed to the drive connection.

It is to be understood that a cam and cam follower can be used to replace an eccentric and connected drive shaft (i.e. items 40, 42 of Figure 2). When using cams, it may be useful to use weight on bit to maintain the contact between the cam parts.

For example, as shown in Figures 4, another drilling accelerator 210 may include an outer housing 218 including an upper end 218a and a lower end 218b. Outer housing
218 is rugged, being exposed on its external surface 218c to the wellbore annulus and houses therewithin the drive components for generating a percussive force to be applied to a bit connected therebelow.

To facilitate construction of the drilling accelerator, as will be appreciated, the housing can be formed in sections and connected together by various means such as by welding, interlocks or threaded connections 280.

Upper end 218a of the housing is formed for connection at the distal end of a drill string. Lower end 218b of the housing accommodates a bit box sub 214, which telescopically extends from lower end 218b.

Bit box sub 214 has formed therein a site, such as, for example, threaded bit box 220, for accepting connection of a drill bit (not shown). A bushing and safety catch 224 acts between housing 218 and sub 214 to allow rotation of the sub within the housing and may secure the sub against fully passing out of the housing lower end 218b. Safety catch 224 allows some axial sliding motion of sub 214 within the housing, such axial motion, for example, resulting from moving the sub between a lower position (as shown) and an upper, weight on bit position and being that as a result of the percussive force. In one embodiment, safety catch 224 may be eliminated with the safety provisions thereof instead taken up entirely by interacting shoulders 225a, 225b on the parts. This allows housing end 218b to be thicker along its length.

Bit box sub 214 is connected to an axial shaft 230, the combination of sub 214 and shaft 230 acting to transmit drive energy from an input end 230a of the shaft to a drill bit installed in box 220. Bit box sub 214 and axial shaft 230 may be connected by a telescoping splined connection 222 that ensures continuous rotational drive conveyance while permitting axial sliding motion of the bit box sub relative to shaft 230.
The input torque applied to end 230 may be generated by a mud motor. For example, axial shaft 230 may be connected to a rotor of a mud motor such that any rotation of the rotor, as by flow of drilling fluid through the motor, may be conveyed to the bit box sub. In one embodiment, the mud motor may include a positive displacement-type motor (PDM), which uses pressure and flow of the drilling fluid to turn a rotor within a stator. Shaft 230 can be connected directly or indirectly to the rotor, as through threaded connection 260. Where a bent sub is positioned between the motor and the drilling accelerator, a universal connector may be positioned therebetween to convey rotation from the rotor to the axial shaft.

The fluid that drives the motor can continue down through the axial shaft and sub 214 and to the bit. As such, these parts may include drilling fluid passages such as axial bores 254 passing therethrough that can be connected in communication with the motor discharge.

Bearings 268a, 268a and bushings may be positioned between the axial shaft and the housing to accommodate radial and on bottom and off bottom thrust loads. A safety catch may also be provided between these parts.

Drilling accelerator 210 further includes a drive converter intended to convert the rotational drive from the motor to an axial, reciprocating motion to drive the bit box sub axially to apply a percussive force at any drill bit connected into the bit box during drilling.

In the illustrated embodiment, the drive converter includes a pair of cam surfaces 270a, 270b. The first cam surface 270a is installed in the housing and the second cam surface 270b is installed to move with bit box sub 214. Cam surfaces 270a, 270b are positioned to be separated by a gap 272 when the bit box is in its lower position, as shown, but can come together when weight is placed on bit. In other words, gap 272...
closes when bit box sub is moved into its upper, weight on bit position. Because the housing and shaft/bit box sub 230/214 rotate at different speeds, the cam surfaces act to ride over each other. Generally, rotation of sub 214 within and at a faster rate than any rotation of the housing causes cam surface 270b to ride over cam surface 270a and cam surface 270a effectively becomes the cam follower. Cam surfaces 270a, 270b include one or more cam protrusions 274a, 274b that are oriented and configured to act with consideration of the direction of relative rotation therebetween such that the cam surfaces ride up over each other and drop down thereby generating an axial percussive force to be applied to the bit box sub 214. Cam protrusions 274a, 274b have a ramped approach side, a peak and an exit side. The ramped approach side inclines upwardly to allow the cam protrusions to ride easily up over each other toward the peak. The exit side of the protrusions can be ramped down away from the peak, but a more significant percussive effect may be provided by forming the exit side as shown with an abrupt height change forming a drop off such that the forces (i.e. weight on bit) that drive the cam surfaces together force the parts to abruptly close any gap between them, the gap formed when the protrusions exit off each other. The gap closing develops an abrupt, hammering vibration as the surfaces again come together. While one or more cam protrusions can be provided, it may be useful to position the cam protrusions in a balanced fashion about surfaces 270a, 270b, for example, by positioning the protrusions each equally spaced about the circumference of the cam surface such that all protrusions are on the approach side at the same time. As shown, for example, protrusions 274a, 274b can be in pairs on each surface with a first protrusion of the pair diametrically opposed from the second protrusion of the pair on their cam surface. This may reduce adverse lateral forces in the accelerator.

Cam surfaces 270a, 270b may be formed from materials that accommodate considerable wear without rapid break down.
In another embodiment, one or both of the cam surfaces may be include bearings to facilitate movement of the surfaces over one another and reduce detrimental wear to increase tool longevity. For example, in one embodiment, as shown in Figures 4C and 4D, the cam protrusions on one of the cam surfaces, for example, surface 270a of Figure 4 may be replaced by a cam insert 275a carrying rollers 279 on the cam surface 270c. Rollers 279 are installed to ride up over the cam protrusions 274b of the opposite surface (i.e. surface 270b) and drop down the exit side of the protrusions to create a vibratory effect. In one embodiment, the rollers may be ball bearing type rollers carried in the selected cam surface. Alternately, the rollers may be cylindrical rollers, as shown, or conical type rollers held to rotate along an axis extending radially from the tool long axis x.

Rotation in shaft 230 and bit box sub 214 relative to housing 218 will impart on sub 214 axially directed reciprocation determined by the throw of cam protrusions 274a, 274b of surfaces 270a, 270b. This axially directed reciprocation is then conveyed as a vibratory effect to any bit secured in, directly or indirectly, the bit box 220 of the bit box sub.

The vibratory effect may be created by axially reciprocating movement created at the interacting cam surfaces which causes a hammering effect when the two parts impact against one another. However, in one embodiment, the tool may be selected to create the vibratory effect by first generating axially reciprocating movement at the interacting cam surfaces that in turn cause a hammering effect at surfaces apart from the cam surfaces. In such an embodiment, the form of the cam surfaces may be preserved by reducing the detrimental wear caused by the parts striking against one another. In particular, while the reciprocating action is generated at the cam surfaces, the impact creating the hammering effect is generated elsewhere. Such an embodiment may be provided, for example, by provision of a two part mandrel, as provided by axial shaft 230 and bit box sub 230, selected to take up and generate the hammering effect caused by the throw of the cam surfaces. In the illustrated embodiment, for example, while the
cam surfaces 270a, 270b create an axially reciprocating motion, the hammering effect generated by that motion occurs at the telescoping splined connection 222. The axially sliding motion that is created by the cam surfaces riding over one another causes the upper cam surface 270a, housing 218 and axial shaft 230 to be raised relative to bit box sub 214, as by axial movement between axial shaft 230 and bit box sub 214 at the telescoping splined connection 222. As the cam surfaces continue to ride over one another, the cam protrusions 274a, 274b (which may or may not include rollers) will drop off each other on their exit sides and this, in turn, causes upper cam surface 270a, housing 218 and axial shaft 230 to drop down. When this happens, end 230a of shaft 230 will strike against upper end 214a of bit box sub 214 (inside connection 222) creating a hammering effect that is conveyed to the bit in bit box 220. To ensure that the major striking force occurs at connection 222 between parts 214a and 230a, any operational gap between parts 214a, 230a, which is the maximum gap distance achieved when there is weight on bit driving sub 214 up into the housing and the cams have driven parts 214a, 230a apart, should be at least slightly less than the maximum, unrestricted throw of cam surfaces, which is the maximum unrestricted distance that could be traveled by upper cam surface 270a as its cam protrusions 274 or rollers drop off the cam protrusions or rollers on lower cam surface 270b. If the gap between parts 214a and 230a is more than the throw of the cam surfaces, the cam surfaces will strike each other before the axial shaft and bit box sub can come together. Although this will create a percussive effect, it does cause greater wear at the cam surfaces and requires the use of adequate thrust and radial bearings along the axial shaft. However, by selecting the gap distance between parts 214a, 230a to be less than the throw of the cam surfaces, the hammering is taken up and generated along the shaft, which maintains the force in line, concentrated around the center axis x of the tool and between more rugged parts. In such an embodiment, the cam surfaces also are protected from at least some wear, reducing their need for repair or replacement.
In one embodiment, the contact surfaces between parts, where the hammering effect is generated may be supplemented with percussion plates that have a greater wear resistance than the other materials of these parts. In one embodiment, seals or structures may be provided to facilitate fluid flow through bore 254 past the impact area between parts 214a, 230a. For example, in one embodiment, a sleeve/nipple may provided on one part 214a or 230a that inserts into an enlarged region of the bore formed on the other of the two parts and seals, such as o-rings may be provided therebetween to prevent fluid from passing from bore 254 into the impact region between the parts.

In the illustrated embodiment, first cam surface 270a is provided by a ring 275 installed in housing 218. Ring 275 forms surface 270a annularly with protrusions 274a downwardly facing. A bore 276 in the ring provides an opening through which a portion of shaft 230 (as illustrated) or bit box sub 214 extends. Second cam surface 270b, in the illustrated embodiment, is provided by a ring 277 that includes threads 278 for securing on an end of sub 214 such that surface 270b is facing upwardly to position its cam protrusions 274b for engagement against those on surface 270a.

Ring 275 and housing 218, at shoulder 218c, bear against each other such that movement, such as upward movement caused by interaction of the cam surfaces, is transferred to the housing. In addition, ring 275 and housing, at shoulder 230c, also may bear against each other such that upward movement caused by interaction of the cam surfaces is as well transferred to the shaft 230.

The embodiment of Figure 4 operates to drill a borehole by applying a percussive force through the drill bit to the formation when weight is applied on bit. When the bit is lifted off bottom, the bit box sub 214 is able to drop into its lower position which separates the cam surfaces and discontinues the percussive force.
When weight on bit is resumed and axial shaft 230 is driven to rotate, cam surfaces 270a, 270b will be rotated at different speeds such that their cam surfaces will ride up over one another and drop off the exit side causing housing 218 and axial shaft to be lifted away from bit box sub 214, as that sub and the bit it carries remains on bottom, and, thereafter, as the cam protrusions exit off one another, the housing and the axial shaft drop down. When the housing and axial shaft 230 drop down, a hammering effect is applied to bit box sub, as by surface 230a striking surface 214a.

The use of a percussive adapter to apply a percussive, axially directed reciprocation to a drill bit may generate left hand torque in the drill string. Such torque may adversely effect standard threaded connections along the string, such as connections 280, causing them to become loosened or to unthread completely. As such, with reference to Figures 5, a threaded connection can be used at connection 280 or in connections in other string components that can accommodate left hand torque substantially without weakening the connection. In one embodiment, such a connection includes a collar 380 including a pair of threaded box ends 382, 384. Box end 382 includes a thread form extending in a direction opposite from the thread form of box end 384. For example, if box end 382 includes a left hand thread, box end 384 includes a right hand thread. As will be appreciated by persons skilled in the art of wellbore tubular strings, a collar is the term used to describe a substantially cylindrical connector that is formed to accept threaded engagement of a pair of tubulars, each with a threaded pin end. The box ends each have thread forms that start adjacent the collar end face 382a, 384a, respectively, and extend fully or partially toward a crest 385. Crest 385 may be threaded or smooth, depending on the type of collar.

The illustrated connection further includes a first wellbore tubular 386 and a second wellbore tubular 388, each formed with a pin end 386a, 388a, respectively. Tubulars 386, 388 can by housing sections of a drilling accelerator, mud motor, or other tubular portions of a down hole assembly or drill string. Each pin end has a pin end face 386b,
388b, respectively. The pin ends each include a thread form selected to thread into their respective box end 382 or 384. Pin ends 386a, 388a further have corresponding stepped regions formed by axial extensions from their pin end faces such that the pin ends can engage each other to restrict or possibly eliminate relative rotational movement therebetween about their long axis \( \chi_t \), when they are held end face adjacent to end face in collar 380. The stepped regions are formed by varying the pin end's length from its pin base to its end face, creating an axially extending stepped area along the pin end face. For example, one pin end face 386b includes a stepped extension where the face has a length change creating a shoulder 389a while the other pin end face 388b includes a stepped recess along its circumference also creating a shoulder 389b, the stepped recess is formed to correspond to and, for example, follow in the reverse, the stepped extension of the first pin end such that the two shoulders can be seated against each other, preventing the two pin ends from rotating relative to each other. To most effectively prevent relative rotation between the pin ends, the stepped regions may be formed of abrupt length changes creating sharper corners, rather than being curved undulations that could ride over each other. Also, to allow the pin ends to mesh, as by being advanced towards each other along their long axis, it will be appreciated that the stepped regions may form the shoulders along a line substantially aligned with the tubular's long axis.

It will be appreciated that such shoulders formed by stepped regions and recesses, form at least one tooth 390a, 390b extending from each pin end face 386b, 388b, each formed so that the pin end faces can mesh and be prevented from rotating relative to each other.

The shoulders may be positioned to resist the relative rotation that is adverse to the threaded condition of the connection. For example, in one embodiment, the shoulders may be positioned to provide resistance to back off by left hand torque. Alternately, each pin end face may include at least one left hand facing shoulder and at least one
right hand facing shoulder such that the tubulars are substantially prevented from rotating in either direction relative to each other. In the illustrated embodiment, the tubulars each include a plurality of left and right hand facing shoulders forming, in effect, a plurality of teeth with gaps therebetween. The teeth on the first wellbore tubular are formed to mesh closely between the teeth on the second wellbore tubular. In particular, the teeth 390a of the first tubular are formed to fit tightly between the teeth 390b on the second tubular such that, if the pins are brought together, end to end, the teeth 390a fit into the gaps between teeth 390b with the sides 390a₁ of teeth 390a positioned closely alongside the sides 390b₁ of teeth 390b. In this position, engagement between the shoulders 389a, 389b formed by the sides of the teeth prevents rotation of one pin end relative to the other, when they are held pin end to pin end in the collar.

Forces tending to urge the pin ends to rotate about their long axis to unthread from the connection are resisted by contact between the shoulders of the pin ends. As such, it is useful to provide a reasonable surface area for contact between the shoulders of opposite pin ends. In one embodiment, for example, corresponding shoulders may have sides 390a₁, 390b₁ that are cut substantially radially, in other words substantially along a radial line extending out from the center axis of the tubular.

Pin end faces and shoulders may have close tolerances. If some flex is desired at the connection, such that the lateral rigidity at the connection is reduced, tolerances may be relaxed between pin end faces, such that the length of the shoulder extension on one tubular does not quite equal the depth of the shoulder on the opposite tubular. In other words, the length L of the teeth, measured from tip 392 to base 393 (Figure 5C) on one tubular is more than the length of the teeth on the other tubular. The gap formed between the tips of one tubulars teeth and the bases of the other tubulars teeth allows some lateral flex at the connection. Another option to provide for more lateral deflection at the connection, in addition or alternately to the foregoing, may be to indent the outer surface of the teeth. This reduces the thickness t (Figure 5C) of the pin end along the
length of the teeth and may create a space between the tooth and the inner surface of the collar, when the pin is threaded into the collar. The surface indentation can be initiated at a tapering surface 391 adjacent the base 393 of the teeth to provide more landing space for lateral deflection.

The type of thread form, including for example, taper and pitch, used in the connection is not particularly important. In one embodiment, a modified Acme thread may be used to enhance seating and to deter fluid migration through the threaded interfaces at the connection, but other thread forms may be used, as desired.

Seals may be provided in the connection, such as for example o-rings 392 in the collar at the crest and/or at interfacing surfaces, for example surfaces 394a, 394b with close tolerances, to enhance the fluid sealing properties of the collar.

To make up the connection, the first and second wellbore tubulars are aligned to be threaded into their respective box ends of the collar and also, the tubulars are aligned with their teeth offset so that the teeth of each tubular are aligned to mesh into the openings between the teeth of the other tubular. In this way, the stepped regions formed by the teeth on one tubular may be set against the shoulders formed by the teeth on the other tubular. With the teeth alignment preserved, the first and second wellbore tubulars are then brought into a position such that their threads can be engaged by the threads of the collar and the collar is rotated about its long axis to engage the tubular pin ends and draw the pin ends into the collar. As the tubulars are drawn in by the collar, the teeth become meshed at the thread crest.

Once threaded together, the interlock provided by the intermeshed teeth act against, and may prevent completely, back off in the connection even where there is considerable left hand torque. In addition, torque tends not to be transferred through the threads of the connection. Also, by allowing some tolerance between the pin end
faces, the connection can allow for lateral flexing, such that the connection may not become too stiff.

When using the connection, it may be useful to position the right hand threaded pin end on the uphole end of the connection. Generally in wellbore operations, torque input from surface is most often to the right. As such, placing the right hand threaded pin end on the upper end of the connection ensures that even if the connection itself binds down hole, the string will in its normal rotation continue to drive the pin end into the connection, rather than backing off. That being said, it is believed that such a condition would be rare. It is believed that with the pin to pin locking provided by the teeth, the only way the torque won't transition through the connection is if the collar completely binds down hole such that it cannot rotate, while the tubulars both have opposite torque applied thereto sufficient to overcome the interlock of the teeth.

Left hand torque is common and often problematic in mud motor applications such as the current motor driven drilling hammer. However, the connection may also be useful for other applications where left hand torque tends to act adversely on tubular connections such as in subs adjacent any rotationally driven drill bit.

To release the connection, the collar is reverse rotated about the connection's axis $\chi_t$, again while the tubulars are held stationary.

The previous description of the disclosed embodiments is provided to enable any person skilled in the art to make or use the present invention. Various modifications to those embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without departing from the spirit or scope of the invention. Thus, the present invention is not intended to be limited to the embodiments shown herein, but is to be accorded the full scope consistent with the claims, wherein reference to an element in the singular, such as by use of the
article "a" or "an" is not intended to mean "one and only one" unless specifically so stated, but rather "one or more". All structural and functional equivalents to the elements of the various embodiments described throughout the disclosure that are known or later come to be known to those of ordinary skill in the art are intended to be encompassed by the elements of the claims. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the claims. No claim element is to be construed under the provisions of 35 USC 112, sixth paragraph, unless the element is expressly recited using the phrase "means for" or "step for".
I claim:

1. A method for accelerating the drilling penetration of a rotary driven drill bit, the method comprising: providing a positive displacement motor including a motor housing, a fluid discharge and a rotor powered by fluid pressure; providing a drill bit; providing a drilling accelerator including a housing and a drive connection to mechanically convert rotational drive to axially directed percussive motion; connecting the drilling accelerator below the motor including connecting the housing to move with the motor housing, connecting the drive connection to be driven rotationally by the rotor and bringing the fluid passage into communication with the fluid discharge; connecting the drill bit below the drilling accelerator with the drive connection in drive communication with the drill bit; pumping fluid through the motor to drive the rotor and the drive connection to rotate and to generate axial percussive motion which is communicated from the drive connection to the drill bit and; discharging fluid from the fluid discharge to pass through the drilling accelerator and the drill bit.

2. The method of claim 1 wherein the drive connection mechanically converts rotational drive by use of a gear assembly.

3. The method of claim 1 wherein the drive connection mechanically converts rotational drive by use of a cam assembly.

4. The method of claim 1 further comprising stopping the generation of axial percussive motion by eliminating weight on bit.

5. The method of claim 1 further comprising rotating the drill bit by rotation of a drill string to which the drilling accelerator is connected.
6. The method of claim 1 further comprising rotating the drill bit by conveying rotational drive through the drive connection to the drill bit.

7. The method of claim 1 wherein the axial percussive motion is generated by a hammering effect of one part of drive shaft of the drive connection dropping down on another part of a drive shaft of the drive connection.

8. The method of claim 1 further comprising providing a threaded connection to accommodate left hand torque in the housing, the threaded connection including a collar including an upwardly facing box formed to accept a right hand thread form and a downwardly facing box formed to accept a left hand thread form.

9. A drilling accelerator comprising: a housing including an upper end and a lower end; a drive connection including an upper axially rotatable drive shaft for receiving an input of rotational motion, a rotational to axial mechanical drive converter in communication with the upper axially rotatable drive shaft for converting the input of rotational motion to an axial sliding motion; a lower longitudinally moveable drive shaft in communication with the rotational to axial mechanical drive converter to receive the axial sliding motion from the rotational to axial mechanical drive converter and a lower drill bit installation site connected to the lower longitudinally moveable drive shaft for receiving the axial sliding motion and capable of conveying axial percussive motion there through, the lower drill bit installation site telescopically mounted adjacent the lower end of the housing and slidably moveable relative thereto.

10. The drilling accelerator of claim 9 wherein the lower longitudinally moveable drive shaft includes a drill bit box sub.

11. The drilling accelerator of claim 9 wherein the lower drill bit installation site is a drill bit box.
12. The drilling accelerator of claim 9 wherein the lower drill bit installation site is connected for rotational movement with the housing.

13. The drilling accelerator of claim 9 wherein the lower drill bit installation site is connected for rotational movement with the upper axially rotatable drive shaft.

14. The drilling accelerator of claim 9 wherein the rotational to axial mechanical drive converter includes a gear assembly driving an eccentric member.

15. The drilling accelerator of claim 14 wherein the gear assembly includes gears to convey rotational motion to the lower drill bit installation site.

16. The drilling accelerator of claim 9 wherein the rotational to axial mechanical drive converter includes a cam assembly.

17. The drilling accelerator of claim 16 wherein the cam assembly is in operable except when the lower longitudinally moveable drive shaft is driven upwardly into the housing by weight on bit.

18. The drilling accelerator of claim 16 wherein wherein the cam assembly includes cam surfaces that separate out of operational contact when the drilling accelerator is not positioned with weight on bit.

19. The drilling accelerator of claim 16 wherein upper axially rotatable drive shaft is secured to move axially with the housing and the cam assembly includes an upper cam surface on the housing and a lower cam surface on the lower longitudinally moveable drive shaft and the upper cam surface of the housing is driven by the lower cam surface to lift the housing and the upper axially rotatable drive shaft and drop the upper axially
rotatable drive shaft onto the lower longitudinally moveable drive shaft to create the axial percussive motion.

20. The drilling accelerator of claim 9 wherein the upper axially rotatable drive shaft and the lower longitudinally moveable drive shaft are connected by a telescoping connection such that the lower longitudinally moveable drive shaft can slide axially relative to the upper axially rotatable drive shaft.

21. The drilling accelerator of claim 20 wherein the telescoping connection is configured to convey rotational drive therethrough.

22. The drilling accelerator of claim 9 the housing includes a threaded connection connecting a first tubular section of the housing and a second tubular section of the housing, the first tubular section including a first threaded pin end with a right hand thread form and a protrusion extending from its pin end face to create a stepped area thereon, the second tubular section of the housing including a second threaded pin end with a left hand thread form and a recess on its pin end face forming a shoulder sized to accept the stepped area of the first pin end seated thereagainst, and the threaded connection including a collar having a first threaded box with a first selected thread form selected to threadedly engage the right hand thread form of the first threaded pin end and a second threaded box with a second thread form selected to threadedly engage the left hand thread form of the second threaded pin end.

23. The drilling accelerator of claim 9 further comprising a positive displacement motor including a stator housing and a rotor within the stator housing, the housing connected at its upper end below and for movement with the stator housing of the positive displacement motor and the rotor providing the input of rotational motion to the drive connection and a drill bit connected below the lower drill bit installation site.
24. A wellbore string tubular connection comprising: a first tubular including a first threaded pin end with a right hand thread form and a protrusion extending from its pin end face to create a stepped region thereon, a second tubular including a second threaded pin end with a left hand thread form and a recess on its pin end face forming a shoulder sized to accept the stepped region of the first pin end seated thereagainst, and a collar including a first threaded box with a first selected thread form selected to threadedly engage the right hand thread form of the first threaded pin end and a second threaded box with a second thread form selected to threadedly engage the left hand thread form of the second threaded pin end.

25. The wellbore string tubular connection of claim 24 wherein the first tubular and the second tubular 388 are housing sections of a mud motor-containing down hole assembly.

26. The wellbore string tubular connection of claim 24 wherein the protrusion includes a left hand facing stepped region and a right hand facing stepped region and the recess includes a right hand facing shoulder and a left hand facing shoulder forming a gap therebetween sized to accept the protrusion.

27. The wellbore string tubular connection of claim 24 wherein the stepped region extends along a line substantially aligned with the first tubular's long axis.

28. The wellbore string tubular connection of claim 24 wherein the stepped region creates a tooth extending out from the first tubular pin end face and the recess forms a gap in the second tubular pin end face and wherein the tooth is sized to fit closely into the gap.

29. The wellbore string tubular connection of claim 24 wherein the first tubular includes a plurality of protrusions and the second tubular includes a plurality of recesses...
and the plurality of protrusions of the first tubular, the plurality of recesses of the second tubular being selected to mesh together when the first and the second tubulars are brought into pin-end to pin end contact to resist relative rotation between the first tubular and the second tubular about their long axis.

30. The wellbore string tubular connection of claim 24 wherein the stepped region includes a face formed to extend substantially along a radial line extending out from a center axis of the first tubular.

31. The wellbore string tubular connection of claim 24 wherein gaps are provided in the connection to provide for lateral flex.

32. A method for making up a wellbore connection, the method comprising: providing a first wellbore tubular with a threaded pin end and an tooth extending from a pin end face thereof, a second tubular with a threaded pin end and recess in a pin end face thereof, the recess sized to accept the tooth of the first wellbore tubular and a collar including a first threaded box end and an opposite threaded box end; aligning the first wellbore tubular and the second wellbore tubular to be threaded into the box ends of the collar and with the tooth aligned with the recess and rotating the collar about its long axis to engage the threaded pin ends of the first wellbore tubular and the second wellbore tubular and draw the threaded pin ends into the collar.

33. The method of claim 32 wherein the threaded pin end of the first tubular includes a right hand thread form and the first threaded box end of the collar includes a thread form to accept the right hand thread form and the method further comprises, positioning the wellbore connection with the first tubular on the uphole end.
**A. CLASSIFICATION OF SUBJECT MATTER**

IPC: *E21B 17/042 (2006.01), E21B 17/07 (2006.01), E21B 6/00 (2006.01)*

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: E21B 17/042, E21B 17/07, E21B 6/00

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

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)

Canadian Patent Database, Delphion, Questel-Orbit

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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[X] Further documents are listed in the continuation of Box C. [X ] See patent family annex.

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**Date of the actual completion of the international search**

29 June 2009 (29-06-2009)

**Date of mailing of the international search report**

02 July 2009 (02-07-2009)

**Name and mailing address of the ISA/CA**

Canadian Intellectual Property Office

Place du Portage I, C1 14 - 1st Floor, Box PCT

50 Victoria Street

Gatineau, Quebec K1A 0C9

Facsimile No.: 001-819-953-2476

**Authorized officer**

Darren Hubley 819-994-7655
**INTERNATIONAL SEARCH REPORT**

**Box No. II  Observations where certain claims were found unsearchable (Continuation of item 2 of the first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [ ] Claim Nos because they relate to subject matter not required to be searched by this Authority, namely

2. [ ] Claim Nos because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically

3. [ ] Claim Nos because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

**Box No. III  Observations where unity of invention is lacking (Continuation of item 3 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows

Group A Claims 1-23 are directed to a drilling accelerator comprising a housing, drive, drive shaft, a rotational to mechanical converter, and a drill bit, and a method for accelerating the drilling penetration of a drill bit comprising such a drilling accelerator

Group B Claims 24-33 are directed to a string tubular connection and a method for making up a wellbore connection using such a string tubular connection

1 [ ] As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims

2 [X] As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees

3 [ ] As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claim Nos

4 [ ] No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims, it is covered by claim Nos

**Remark on Protest** [ ] The additional search fees were accompanied by the applicant’s protest and, where applicable, the payment of a protest fee

[ ] The additional search fees were accompanied by the applicant’s protest but the applicable protest fee was not paid within the time limit specified in the invitation

[ ] No protest accompanied the payment of additional search fees
## DOCUMENTS CONSIDERED TO BE RELEVANT

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