METHOD OF EXPANDING A TUBULAR MEMBER IN A WELLBORE

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ABSTRACT

The present invention provides methods for expanding a tubular with the aid of a compressive force. A tubular, such as a string of casing, is run into a wellbore on a working string, e.g., drill pipe. A carrying mechanism such as a collet is used to releasably attach the first tubular to the working string during run-in. The tubular is then expanded into frictional engagement with another tubular therearound within the wellbore. During the expansion process, a compressive force is applied to the portion of the tubular being expanded. In one aspect of the invention, a hydraulic ram is positioned above the string of casing and is activated by the injection of fluid under pressure in order to apply the compressive force to the expandable tubular. In another aspect of the invention, the portion of casing or other expandable tubular to be expanded is pre-stressed, such as to impart a barrel shape, in order to bias the tubular to more easily buckle outwardly during expansion.
METHOD OF EXPANDING A TUBULAR MEMBER IN A WELBORE

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to methods for wellbore completions. More particularly, the invention relates to completing a wellbore by expanding tubulars therein. More particularly still, the invention relates to the expansion of a tubular within a wellbore through the use of compressive forces.

[0003] 2. Description of the Related Art

[0004] Hydrocarbon and other wells are completed by forming a borehole in the earth and then lining the borehole with steel pipe or casing to form a wellbore. After a section of wellbore is formed by drilling, a section of casing is lowered into the wellbore and temporarily hung therein from the surface of the well. Using apparatus known in the art, the casing is cemented into the wellbore by circulating cement into the annular area defined between the outer wall of the casing and the borehole. The combination of cement and casing strengthens the wellbore and facilitates the isolation of certain areas of the formation behind the casing for the production of hydrocarbons.

[0005] It is common to employ more than one string of casing in a wellbore. In this respect, a first string of casing is set in the wellbore when the well is drilled to a first designated depth. The first string of casing is hung from the surface, and then cement is circulated into the annulus behind the casing. The well is then drilled to a second designated depth, and a second string of casing, or liner, is run into the well. The second string is set at a depth such that the upper portion of the second string of casing overlaps the lower portion of the first string of casing. The second liner string is then fixed or “hung” off of the existing casing by the use of slips which utilize slip members and cones to wedgingly fix the new string of liner in the wellbore. The second casing string is then cemented. This process is typically repeated with additional casing strings until the well has been drilled to total depth. In this manner, wells are typically formed with two or more strings of casing of an ever decreasing diameter.

[0006] Apparatus and methods are emerging that permit tubulars to be expanded in situ. The apparatus typically includes expander tools which are fluid powered and are run into the wellbore on a working string. The hydraulic expander tools include radially expandable members which, through fluid pressure, are urged outward radially from the body of the expander tool and into contact with a tubular therearound. As sufficient pressure is generated on a piston surface behind these expansion members, the tubular being acted upon by the expansion tool is expanded past its point of plastic deformation. In this manner, the inner and outer diameter of the tubular is increased in the wellbore. By rotating the expander tool in the wellbore and/or moving the expander tool axially in the wellbore with the expansion member actuated, a tubular can be expanded along a predetermined length in a wellbore.

[0007] Multiple uses for expandable tubulars are being discovered. For example, an intermediate string of casing can be hung off of a string of surface casing by expanding a portion of the intermediate string into frictional contact with the lower portion of surface casing therearound. This allows for the hanging of a string of casing without the need for a separate slip assembly. Additional applications for the expansion of downhole tubulars exist. These include the use of an expandable sand screen, employment of an expandable seat for seating a diverter tool, and the use of an expandable seat for setting a packer.

[0008] There are problems associated with the expansion of tubulars. One problem particularly associated with rotating expander tools is the likelihood of obtaining an uneven expansion of a tubular. In this respect, the inner diameter of the tubular that is expanded tends to assume the shape of the compliant rollers of the expander tool, including imperfections in the rollers. Also, the inside surface of the tubular is necessarily roughened by the movement of the rollers of the expander tool during expansion. Moreover, the compliant rollers are of a limited length, meaning that the working string must be moved up and down in order to apply the actuated rollers to different depths of a tubular to be expanded. This creates the likelihood that some portions of a tubular may be missed in the expansion process. The overall result is that the inner diameter of the expanded tubular no longer has a uniform inner circumference. This problem is exacerbated by the amount of force needed to expand many tubular members.

[0009] Another problem encountered pertains to a change in wall thickness which results from the expansion of a tubular, regardless of the type of expander employed. It has been discovered that the expansion process results in a reduction in wall thickness of that portion of casing or other tubular being expanded. As the wall begins to thin, the amount of force needed to expand that portion of tubular decreases. The roller or other expander member tends to push the tubular material out radially at the expense of the material on the flanks of the roller. The tubular material in the flank region essentially acts as a sacrificial zone for the expansion process as it provides the bulk of the material for the expansion process.

[0010] There is a need, therefore, for an improved method for expanding a portion of casing or other tubular within a wellbore. Further, there is a need for expanding a tubular downhole which alleviates the problem of pipe thinning. Still further, a need exists for expanding a tubular which requires less outward force against the inner surface of the tubular. There is yet a further need for a method for expanding a tubular which reduces the risk of uneven expansion of the tubular by reducing the amount of force needed for the expansion operation.

SUMMARY OF THE INVENTION

[0011] The present invention provides methods for expanding a tubular within a wellbore. According to the present invention, the tubular to be expanded is run into a wellbore on a working string. The tubular is supported by a collet or other carrying mechanism at the lower end of the working string.

[0012] Above the collet is an expander tool. The expander tool is a rotary expander tool, meaning it is rotated by rotating the working string or, perhaps, a rotary mud motor. The expander tool employs a series of rollers which are actuated by hydraulic pressure. In this regard, the expander...
tool has a hollow bore in fluid communication with a series of rollers. Injection of fluid under pressure into the working string causes the rollers to move outwardly from the body of the expander tool, and to apply an outward force against the inner surface of the expandable tubular.

[0013] Above the expander tool, and also in series with the working string, is a hydraulically actuated ram. The ram is positioned on top of the tubular to be expanded, such as a lower string of casing, or liner. The ram has a mandrel which serves as a tubular for transporting fluids from the working string downward to the expander tool. The ram further has a body surrounding the mandrel. An annulus is thus defined between the mandrel and the body.

[0014] Seals are circumferentially fitted between the mandrel and an inner surface of the body in order to seal the annulus. The diameter of the annulus is greater at the location of the upper seal than at the location of the lower seal. Thus, a difference in cross-sectional area is provided within the sealed annulus. Because the lower casing string 140 is held in place by the carrying mechanism 150, a compressive force is applied to the lower casing string 140 along the portion designated for expansion.

[0015] A through-opening is placed in the mandrel between the upper seal and the lower seal. The through-opening allows fluid to flow down the working string, through the mandrel, and into the annulus. The annulus is sealed above and below the through-opening by the upper and lower seals. Thus, fluid under pressure is injected into an annular region defined by the body, the mandrel, and the upper and lower seals. The application of pressure in the annulus acts on the net hydraulic area between the upper and lower seals to create a downward force. The result is that fluid injected into the annulus applies a force downward against the expandable tubular. At the same time, the expandable tubular is supported and held in place within the wellbore by the carrying mechanism at the lower end of the working string. Thus, a compressive force is exerted onto that portion of the tubular to be expanded.

[0016] Once the compressive force is applied, the expander tool is actuated against the inner surface of the expandable tubular. In one aspect, the expandable tubular is a portion of a string of casing, or liner. The expander tool acts against the lower string of casing, causing the lower string of casing to be expanded radially into a surrounding string of casing. The application of compressive force serves to assist in the expansion process, meaning that less radial force is needed in order to achieve a sufficient frictional engagement between the two strings of casing. Further, a more uniform wall thickness and expansion job is achieved.

[0017] Optionally, and in addition, a bias is machined into that portion of a tubular to be expanded. For example, the tubular could be pre-stressed outwardly into a barrel configuration. This would cause the tubular to more readily buckle outwardly upon application of an expansive force from within the expandable tubular, thus aiding the expander rollers. This process, in turn, would further alleviate the thinning effect which would otherwise occur on the flanks of the expander members. The ultimate benefit is a stronger transition zone that will carry more weight axially and also enjoy stronger resistance to collapse.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] So that the manner in which the above recited features of the present invention are attained and can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to the embodiments thereof which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0019] FIG. 1 is a cross-sectional view of a wellbore having an upper string of casing. In this view, a lower string of casing has been run into the wellbore on a working string. Also visible at a lower end of the working string is an expander tool for expanding the lower string of casing at the desired depth in the wellbore, and a hydraulic ram for applying a compressive load onto the lower string of casing during the expansion process.

[0020] FIG. 2 is an exploded view of a rotary expander tool as might be used in the methods of the present invention.

[0021] FIG. 3 is an enlarged sectional view of a hydraulic ram as might be used to apply a compressive load onto an expandable tubular during the expansion process.

[0022] FIG. 4 is a sectional view of a wellbore having an upper string of casing, and showing a lower string of casing being expanded into frictional contact with the upper string of casing. In this view, a compressive load is being applied to the lower string of casing. Further, the rollers of the expander tool are being activated and rotated.

[0023] FIG. 5 is a sectional view of the wellbore of FIG. 4, showing the portion of expandable tubular in complete, frictional communication with the upper string of casing. The working string and associated tools are being removed from the wellbore.

[0024] FIG. 6 is a partial section view of the wellbore of FIG. 5, illustrating the upper section of the lower casing string expanded into the upper casing string after the expander tool and run-in string have been removed. This view more fully illustrates the portion of the lower string of casing, including optional slip and sealing members, having been expanded into the upper string of casing therearound.

[0025] FIG. 7 is a cross-sectional view of a wellbore illustrating an alternate means for assisting in the expansion of a tubular. Visible in this view is a barrel-shaped configuration for a portion of the expandable tubular where expansion is to begin.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0026] FIG. 1 is a cross-sectional view of a wellbore 100 having an upper string of casing 110 disposed therein. The upper string of casing 110 has been set within the wellbore 100 through a cementing process. The cement layer is visible in the annulus 120, defined by the upper string of casing 110 and the surrounding formation 130.

[0027] Visible also in FIG. 1 is a working string 200. The working string 200 is a tubular such as drill pipe having a
hollow bore therein. The working string 200 is used to run various tools into the wellbore 100 during the completion process, as well as to inject fluids such as cement as needed. In the view of FIG. 1, the working string 200 is also used to run in a lower string of casing 140 into the wellbore 100.

[0028] The lower string of casing 140 is supported on the working string 200 by a carrying mechanism 150. The carrying mechanism 150 may be a threaded connection, a fluid actuated connection, or other known carrying device. In the embodiment of FIG. 1, an expandable collet is used as the carrying mechanism 150. The collet 150 is landed into a radial profile 155 within the lower string of casing 140 so as to support the lower string of casing 140. The collet 150 is hydraulically or mechanically actuated as is known in the art, and supports the lower string of casing 140 until such time as the lower string of casing 140 has been expandably set by actuation of the expander tool 300.

[0029] Above the carrying mechanism 150 is a swivel 160. The swivel 160 allows the working string 200 to rotate within the wellbore 100 without upsetting the connection between the expandable tubular 140 and the working string 200. As will be shown, the working string 200 must rotate within the wellbore 100 so that it may rotate the expander tool 300, thereby radially expanding the lower string of casing 140 or other expandable tubular at the desired depth in the wellbore 100. The swivel 160 allows the body 350 of the expander tool 300 to be rotated by the working tubular 200 while the carrying mechanism 150 remains stationary.

[0030] The expander tool 300 is a rotary expander tool. This means that the desired expansion is accomplished by rotating expanded rollers 365 against the inner surface of the expandable tubular 140. Preferably, rotation of the expander tool 300 is imparted by rotating the working string 200. However, rotation may also be imparted by a downhole mud-type motor (not shown).

[0031] FIG. 2 is an exploded view of an exemplary expander tool 300. The expander tool 300 consists of a cylindrical body 350 having a plurality of windows 355 formed therein. Within each window 355 is an expansion assembly 360 which includes a roller 365 disposed on an axle 370 which is supported at each end by a piston 375. The piston 375 is optionally retained in the body 350 by a pair of retention members 372 that are held in place by screws 374. The assembly 360 includes a piston surface 380 formed opposite the piston 375 which is actuated by pressurized fluid in the bore 390 of the expander tool 300. The pressurized fluid causes the expansion assembly 360 to extend radially outward and into contact with the inner surface of the lower string of casing 140. With a predetermined amount of fluid pressure acting on the piston surface 380 of piston 375, the lower string of casing 140 is expanded past its elastic limits and into plastic deformation.

[0032] The expander tool 300 shown in FIG. 2 is intended to serve only as an example. Various other embodiments of rotary expander tools exist. It is within the scope of the present invention to utilize any type of rotary expander tool to accomplish the methods of the present invention. However, it is preferred that an expander tool 300 having multiple rows of rollers 365 be used, allowing for a greater length of tubular expansion while the tubular 140 is under compression.

[0033] Referring again to FIG. 1, the wellbore 100 of FIG. 1 includes a compressive force apparatus 400. The compressive force apparatus 400 is disposed in the wellbore 100 above the expander tool 300, and serves to apply a force downward on the top of the lower string of casing 140. FIG. 3 presents an enlarged sectional view of a hydraulically actuated ram 400 as might be used to apply a compressive load onto the lower string of casing 140 during the expansion process. The ram 400 first comprises an inner mandrel 420. In the embodiment of FIG. 3, the mandrel 420 is generally tubular such that it defines a hollow bore 422 therein. The mandrel 420 has a top end 425 which is threadedly connected to the working string 200. The mandrel 420 also has a bottom end 430 which is in fluid communication with the expander tool 300 (shown in FIG. 1). In the embodiment of FIGS. 1 and 3, the bottom end 430 is threadedly connected to a make-up joint 320, which itself is connected to the expander tool 300. In this manner, the mandrel 420 creates a hollow bore 422, placing the ram 400 in fluid communication with the bore 210 of the working string 200 and the bore 390 (FIG. 2) of the expander tool 300.

[0034] The ram 400 also comprises a body 450 surrounding the mandrel 420. The body 450 has a top surface 412, a bottom surface 414, and an inner surface 415 therebetween facing the mandrel 420. An annular region 470 is left between the outer body 450 and the mandrel 420.

[0035] In order to apply the desired downward force against the expandable tubular 140, fluid is injected from the surface into the annulus 470. In order to accomplish this injection, at least one through-opening 435 is fabricated into the mandrel 420 of the hydraulic ram 400. Fluid can then travel from the hollow bore 210 of the working string 200, through the bore 422 defined within the mandrel 420, and into the annulus 470. The annulus 470 is configured such that the cross-sectional area of fluid above the through-opening 435 is greater than the cross-sectional area of fluid below the through-opening 435.

[0036] In order to hold injected fluid in the annulus 470, it is necessary to seal the annulus 470 above and below the through-opening 435. In the embodiment of FIG. 3, the annulus 470 is sealed by the use of an upper seal ring 440 and a lower seal ring 445. Both the upper seal 440 and the lower seal 445 are disposed circumferentially around the tubular mandrel 420. The through-opening 435 resides between the upper and lower seals 440, 445, allowing fluid to be injected under pressure into the annulus 470. Pressure injected into the annulus 470 acts on the net hydraulic area between seals 440 and 445 to create a downward force. This downward force causes the ram 400 to apply a force downward on the expandable tubular 140 below.

[0037] Various arrangements may be proffered in order to achieve the desired area differential between the upper seal 440 and the lower seal 445. In the arrangement shown in FIG. 3, the body 450 of the ram 400 is configured to have an outer surface 410 and an inner surface 415. The inner surface 415 is tapered such that the diameter of the inner surface at an upper end 412 is greater than the diameter of the inner surface at the bottom 414. This creates the desired area differential between the seals 440 and 445 when pressure is injected into the annulus. The ram 400 in FIG. 3 includes an optional shoulder area 426 along the mandrel 420. The seals are circumferentially fitted between the mandrel 420 and the inner surface 415 of the body 450 in
order to seal the annulus 470 so as to hold injected fluid. Again, this pressure creates a downward force that in turn causes the ram 400 to apply a force downward on the expandable tubular 140.

[0038] It is shown in FIG. 3 that the body 450 of the ram 400 is a separate body from the mandrel 420. This is necessary in order to allow a downward movement of the body 450 relative to the mandrel 420 when the ram 400 is actuated. In one aspect, the lower seal ring 445 travels with the body 450 during actuation, while the upper seal ring 440 is affixed external to the mandrel 420 and does not travel. With this arrangement, sufficient distance is provided in the design between the upper seal ring 440 and the top end 412 of the body 450 to accommodate the stroke of the body 450 downward without losing hydraulic integrity.

[0039] An optional feature for the hydraulic ram 400 in FIG. 3 is the use of shearable screws 460. One or more shearable screws 460 maintain the position of the outer body 450 relative to the mandrel 420 of the ram 400 during run-in. In this way, shearable screws 460 serve to prevent premature actuation of the ram 400 and also support the body 450 during run-in. At least one shearable screw 460 is optionally run through the mandrel 420 and the body 450. When additional pressure is injected so as to actuate the ram 400, the screws 460 are sheared, allowing the body 450 to move downward against the lower string of casing 140.

[0040] In operation of the compressive force apparatus 400, fluid is injected into bore 210 of the working string 200 under pressure. From there, fluid travels into the bore 422 of the mandrel 420 where it encounters the through-opening 435. The through-opening 435 permits fluid to flow into the annulus 470 of the ram 400, still under pressure. The application of pressure in the annulus 470 acts on the net hydraulic area between seals 440 and 445 to create a downward force on the lower string of casing 140. Because the lower casing string 140 is held in place by the carrying mechanism 150, a compressive force is applied to the lower casing string 140 along the portion designated for expansion.

[0041] It is noted that the embodiment for a hydraulic ram 400 of FIG. 3 is only an example, and is not to scale. The scope of the present invention includes the use of any hydraulic ram which creates a difference in cross-sectional area for receiving an application of hydraulic pressure, thereby accomplishing a movement or relative motion between two parts. Further, the embodiment for a compressive force apparatus 400 of FIG. 3 is only an example such that it is within the scope of the present invention to utilize any compressive force apparatus 400 which applies a compressive force onto a portion of expandable tubular, with the force being directed opposite a carrying mechanism 150. In addition, the present invention is not limited to the use of a compressive force apparatus which is on top of the expandable tubular. For example, and by way of example only, a compressive force apparatus could be disposed below an expandable tubular, with an upward force being applied therefrom. In such an embodiment (not shown), the portion of tubular to be expanded would be above the compressive force apparatus, and below the carrying mechanism.

[0042] FIG. 4 presents a sectional view of the wellbore 100 of FIG. 1, having the upper string of casing 110 in place, and showing the lower string of casing 140 being expanded into frictional contact with the upper string of casing 110. In this view, a compressive load is being applied to the lower string of casing 140 by virtue of hydraulic pressure being injected into the ram annulus 470, as described above. In this view, the rollers 365 of the expander tool 300 are being activated. In this regard, the same hydraulic pressure which activates the compressive force apparatus 400 is also used to activate the rollers 365, as described above in connection with FIG. 2.

[0043] In the step demonstrated in FIG. 4, the expander tool 300 is also being rotated. Rotation is accomplished by rotating the working string 200. In order to rotate the expander tool 300, it is noted that a sleeve must be able to rotate through the ram 400. In the particular compressive force apparatus 400 shown in FIG. 3, the mandrel 420 of the hydraulic ram 400 serves as the sleeve. This means that the working string 200 rotates the mandrel 420 of the hydraulic ram 400, which in turn rotates the expander tool 300. The compressive force apparatus 400 is designed so that the mandrel 420 is able to rotate within the upper 440 and lower 445 seal rings. Rotation of the working string 200 also assists in shearing the screws 460.

[0044] During the expansion process, fluid is circulated from the surface and into the wellbore 100 through the working string 200. A bore 390, shown in FIG. 2, runs through the expander tool 300, placing the working string 200 and the expander tool 300 in fluid communication. A fluid outlet 395 is provided at the lower end of the expander tool 300. In the arrangement shown in FIGS. 1 and 2, a tubular member serves as the fluid outlet 395.

[0045] By actuation of the expander tool 300 against the inner surface of the lower string of casing 140, a portion of the lower string of casing 140 is expanded into the upper string of casing 110. In this manner, the top portion of the lower string of casing 140 is placed in essentially sealed fluid communication with the upper string of casing 110. In order to provide a more complete expansion job, the working string 200 is optionally raised from the surface after the initial expansion of the lower string of casing 140 has taken place. Alternatively, an apparatus (not shown) may be placed downhole which translates the expander tool 300 within the wellbore 100 without pulling the working string 200. Hydraulic pressure continues to be provided to the expander tool 300 while the working string 200 is raised.

[0046] In order to raise the expander tool 300 during expansion, the connection between the carrying mechanism 150 and the lower string of casing 140 must be released. In the arrangement shown in FIG. 4, the collet 150 has been released from the profile 155. Such release mechanisms are known in the art.

[0047] FIG. 5 is a sectional view of the wellbore of FIG. 4, showing the upper portion 140U of expandable tubular 140 in complete, frictional engagement with the upper string of casing 110. The working string 200 and associated tools, e.g., expander tool 300 and hydraulic ram 400, are being removed from the wellbore 100. At this stage in the expansion operation, the expander tool 300 has been deactivated. In this regard, fluid pressure supplied to the pistons 375 is reduced or released, allowing the pistons 375 to return to the recesses 355 within the central body 350 of the tool 300. The expander tool 300 can then be withdrawn from the wellbore 100 by pulling the working string 200.
It is noted that pulling the working string 200 also produces the removal of the hydraulic ram 400 from the wellbore 100. While the shearable screws 470 have been sheared from the hydraulic ram 400, the hydraulic ram body will be raised from the wellbore 100 when the expander tool 300 is raised. In this regard, the expander tool 300 will catch the bottom of the hydraulic ram 400 on the way out of the hole 100.

FIG. 6 is a sectional view of the wellbore of FIG. 5, illustrating the upper portion 140U of the lower casing string 140 expanded into the upper casing string 110 after the expander tool 300 and working string 200 have been removed. This view more fully illustrates the frictional engagement between the upper 110 and lower 140 strings of casing. FIG. 6 demonstrates that the lower string of casing 140 has also been cemented into the wellbore 100. Cement is shown in the annulus 500 behind the lower string of casing 140. In the view of FIG. 6, optional slip 195 and sealing 190 members are shown disposed around the lower string of casing 140.

First, a sealing ring 190 is shown disposed on the outer surface of the lower string of casing 140. In the preferred embodiment, the sealing ring 190 is an elastomeric member circumferentially fitted onto the outer surface of the casing 140. However, non-elastomeric sealing materials may also be used. The sealing ring 190 is designed to seal an annular area 500 formed between the outer surface of the lower string of casing 140 and the inner surface of the upper string of casing 110 upon expansion of the lower string 140 into the upper string 110.

Also positioned on the outer surface of the lower string of casing 140 at least one slip member 195. In the view of FIG. 6, the slip member 195 defines a pair of rings having grip surfaces formed thereon for engaging the inner surface of the upper string of casing 110 when the lower string of casing 140 is expanded. In FIG. 6, one slip ring 195 is disposed above the sealing ring 190, and one slip ring 195 is disposed below the sealing ring 190. The grip surface includes teeth formed on each slip ring 195. However, the slips could be of any shape and the grip surfaces could include any number of geometric shapes, including button-like inserts (not shown) made of high carbon material.

It should again be noted that the separate slip 195 and sealing 190 members are optional. Further, other arrangements for slip and sealing members could be employed. For example, an elastomeric sealing material could be disposed in a matrix of grooves (not shown) within the outer surface of the upper portion 140U of the lower string of casing 140. Carbide buttons (not shown) or other gripping members could be placed between the grooves.

FIG. 7 is a cross-sectional view of a wellbore illustrating an alternate means for assisting in the expansion of a tubular. Visible in this view is a barrel-shaped configuration for a portion of the expandable tubular where expansion is to begin. The barrel-shaped portion is identified at 140B. The barrel-shaped portion 140B of the lower string of casing 140 is created by pre-stressing the tubular 140 before it is run into the hole 100. Pre-stressing the tubular 140 causes the tubular 140 to more readily buckle outwardly upon application of an expansive force from within the expandable tubular 140, thus aiding the expander rollers 365. This, in turn, further alleviates the thinning effect which would otherwise occur on the flanks of the expander members 365. The ultimate benefit is a stronger transition zone in the casing 140U that will carry more weight axially and also enjoy stronger resistance to collapse.

The view of FIG. 7 demonstrates the use of both a compressive force apparatus 400 and a barrel-shape pre-formed in the expandable tubular 140B. However, it will be appreciated that the use of a compressive force apparatus 400 is optional where a pre-stressing or other bias has been applied to the expandable tubular 140B. Further, it is within the spirit and scope of the present invention to utilize other biasing means for more easily expanding a tubular. An example would be a biasing feature or structure machined into the expandable tubular.

In operation, the method of the present invention in one embodiment is useful in a wellbore 100 having a first string of cemented casing 110. The wellbore 100 is drilled to a new depth so that a second string of casing, or liner, may be set. Thereafter, the drill string and drill bit are removed, and a rotary expander tool 300 is run into the wellbore 100 on a working string 200. A carrying mechanism 150 is utilized for carrying the second string of casing 140 into the hole 100 on the working string 200. The second string of casing 140 is then positioned within the wellbore 100 so that the upper portion 140U of the second string of casing 140 overlaps with the bottom portion of the first string of casing 110.

Along with the expander tool 300, a compressive force apparatus 400 is run into the wellbore 100. In the preferred embodiment of the method of the present invention, the compressive force apparatus 400 defines a hydraulically actuated ram. The ram 400 is positioned downhole over the top of the lower string of casing 140. Fluid is then injected into the working string 200 from the surface. Fluid enters the annulus 470 of the ram 400, thereby causing a downward force to be applied onto the top of the lower string of casing 140. Compression is thereby achieved between the top of the lower string of casing 140 and the point of connection between the lower string of casing 140 and the carrying mechanism 150.

The application of hydraulic pressure into the wellbore 100 also activates the rotary expander tool 300. The rotary expander tool 300 applies an outward force from the inner surface of the lower string of casing 140, bringing the outer surface of the lower string of casing 140 into frictional engagement with the inner surface of the first, or upper string of casing 110. The expander tool 300 may optionally be raised within the wellbore 100 during the expansion process so as to obtain expansion of the lower string of casing 140 along a desired length. This step would require release of the connection between the carrying mechanism 150 and the tubular 140 being expanded. Alternatively, roller assemblies 300 could be positioned along the entire length of desired expansion.

After expansion is completed, the working string 200 is removed from the wellbore 100 along with the expander tool 300 and the compressive force apparatus 400. The result is in an effective hanging of the lower string of casing 140 upon the upper string of casing 110 within the wellbore 100. Thus, the method of the present invention enables a lower string of casing 140 or other expandable tubular to be more effectively hung onto an upper string of
casing 110 by compressively expanding the lower string 140 into an overlapping portion of the upper string 110.

[0059] It is noted that a shoulder 480 is needed in order to pull the outer body 450 of the ram 400 from the hole. This is because the outer body 450 defines a separate body from the mandrel 420 of the ram 400. In the embodiment shown in FIG. 3, an enlarged collar 480 is used as the shoulder for lifting the outer body 450 from the wellbore 100. The collar 480 comes into contact with the bottom end or base 414 of the outer body 450 when the expander tool 300 is pulled.

[0060] While an enlarged collar 480 is used as the shoulder in the preferred embodiment, it is acceptable to utilize other "go-no-go" arrangements. For example, the body 350 of the expander tool 300 itself could serve as a shoulder for lifting the outer body 450. Alternatively, a shoulder could be added to a make-up joint 320 (arrangement not shown).

[0061] The preferred embodiment for the method of the present invention involves the expansion of a lower string of casing into an overlapping portion of an upper string of casing. However, it is within the scope of this invention to utilize compressive force to aid in the expansion of any expandable tubular. Other types of expandable tubulars include, but are not limited to, expandable sand screens, expandable seats for packers or whipstocks or for other tools, and expandable production tubing.

[0062] While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

1. A method for expanding a first tubular into a second tubular in a wellbore, comprising the steps of:
   positioning the first tubular within a wellbore;
   running the second tubular to a selected depth within the wellbore such that at least a portion of the second tubular overlaps with the first tubular;
   applying a compressive force to at least a portion of the second tubular, and
   expanding a portion of the second tubular which is in compression so that the outer surface of the expanded portion of the second tubular is in frictional contact with the inner surface of the first tubular.

2. The method for expanding a first tubular into a second tubular of claim 1, wherein the step of running the second tubular to a selected depth within the wellbore is accomplished by connecting the second tubular to a carrying mechanism on a working string.

3. The method for expanding a first tubular into a second tubular of claim 2, wherein the step of applying a compressive force to at least a portion of the second tubular is accomplished by positioning a compressive force apparatus on top of the second tubular, and activating the compressive force apparatus so as to impart a downward force from the top of the second tubular.

4. The method for expanding a first tubular into a second tubular of claim 3, wherein said compressive force apparatus is a hydraulically actuated ram; and said step of activating the compressive force apparatus so as to impart a downward force on the top of the second tubular is done by injecting fluid into an annular region within said hydraulically actuated ram.

5. The method for expanding a first tubular into a second tubular of claim 3, wherein the first tubular and the second tubular each define a string of casing.

6. The method for expanding a first tubular into a second tubular of claim 5, wherein said carrying mechanism is a collet; and said step of expanding a portion of the second tubular is accomplished by actuating a rotary expander tool having a plurality of rollers, said rotary expander tool being activated by hydraulic pressure.

7. The method for expanding a first tubular into a second tubular of claim 6, further comprising the step of placing a swivel between said collet and said rotary expander tool such that rotation of said rotary expander tool does not interfere with the connection between said collet and the second tubular.

8. The method for expanding a first tubular into a second tubular of claim 6, further comprising the steps of:
   releasing said collet from said second tubular after expansion of the second tubular has begun; and
   raising said expander tool within the wellbore so as to further expand the second tubular along a desired length.

9. The method for expanding a first tubular into a second tubular of claim 3, further comprising the step of biasing at least a portion of the second tubular to be expanded before said step of running the second tubular to a selected depth within the wellbore, so as to bias said portion of the second tubular to buckle outwardly upon said step of expanding a portion of the second tubular.

10. The method for expanding a first tubular into a second tubular of claim 9, wherein the step of biasing at least a portion of the second tubular to be expanded is accomplished by pre-stressing the portion of the second tubular to be expanded outwardly.

11. A method for expanding a first tubular into a second tubular in a wellbore, the first tubular and the second tubular each having a top portion and a bottom portion, comprising the steps of:
   positioning the first tubular within a wellbore;
   connecting the second tubular to a working string by a releasable carrying mechanism;
   connecting a rotary expander tool to said working string above said carrying mechanism;
   connecting a swivel to said working string between said carrying mechanism and said rotary expander tool;
   connecting a compressive force apparatus to said working string above said rotary expander tool, such that said compressive force apparatus is disposed on the top of the second tubular;
   running the second tubular to a selected depth within the wellbore on said working string such that the top portion of the second tubular overlaps with the bottom portion of the first tubular;
activating said compressive force apparatus to apply a compressive force to the top portion of the second tubular between the top of the second tubular and the point of connection of the second tubular with the releasable carrying mechanism; and

activating said rotary expander tool so as to expand at least a portion of the top portion of the second tubular into frictional engagement with the inner surface of the first tubular.

12. The method for expanding a first tubular into a second tubular of claim 11, wherein the first tubular and the second tubular each define a string of casing.

13. The method for expanding a first tubular into a second tubular of claim 12, wherein said compressive force apparatus is a hydraulically actuated ram comprising:

a tubular mandrel having a top end, a bottom end, and a bore therein, said hollow bore being in fluid communication with said working string;

an outer body having a top end, a bottom end, and an inner surface therebetween;

a through-opening within said mandrel;

an annular region between said mandrel and said inner surface of said body for receiving fluid from said through-opening in said mandrel, the annular region being configured such that the cross-sectional area of fluid above said through-opening is greater than the cross-sectional area of fluid below said through-opening;

an upper seal in said annular region, said upper seal being disposed between said mandrel and said inner surface of said body above said through-opening; and

a lower seal in said annular region, said lower seal being disposed between said mandrel and said inner surface of said body below said through-opening, thereby creating a fluidly sealed annular region around said through-opening.

14. The method for expanding a first tubular into a second tubular of claim 13, wherein

the top end of the mandrel is threadedly connected to the working string; and

the bottom end of the mandrel is in fluid communication with the expander tool.

15. The method for expanding a first tubular into a second tubular of claim 14, wherein said step of activating said compressive force apparatus and said step of activating said rotary expander tool are accomplished by injecting hydraulic fluid under pressure through said working string and into said fluidly sealed annular region.

16. The method for expanding a first tubular into a second tubular of claim 15, wherein said carrying mechanism is a collet.

17. The method for expanding a first tubular into a second tubular of claim 16, further comprising the steps of:

releasing said collet from said second tubular after expansion of the second tubular has begun; and

raising said rotary expander tool within the wellbore so as to expand the second tubular along a desired length.

18. The method for expanding a first tubular into a second tubular of claim 17, further comprising the step of biasing at least a portion of the second tubular to be expanded before said step of running the second tubular to a selected depth within the wellbore, so as to bias said portion of the second tubular to buckle outwardly upon said step of activating said rotary expander tool.

19. The method for expanding a first tubular into a second tubular of claim 18, wherein the step of biasing at least a portion of the second tubular to be expanded is accomplished by pre-stressing the portion of the second tubular to be expanded outwardly.

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