threadedly connected tubular members. The method may include providing an automated pipe tripping apparatus. The automated pipe tripping apparatus may include an outer frame, the outer frame including one or more vertical supports; an inner frame, the inner frame slidingly coupled to the outer frame and positioned to be moved vertically by a lifting mechanism coupled between the inner and outer frames. The inner frame may include a tripping slips, the tripping slips positioned to receive a tubular member and selectively grip and support the tubular member; and an iron roughneck, the iron roughneck positioned above the tripping slips and positioned to receive the tubular member and make up or break out a threaded joint between a first and a second segment of the tubular member. The iron roughneck may be selectively movable in a vertical direction between a lower and an upper position by a roughneck lifting mechanism. The method may further include positioning the automated pipe tripping apparatus on a drilling floor of a drilling rig above the wellbore, the drilling rig including a ~~draw-works~~drawworks, an elevator, an automated pipe handling device, and a drilling floor slips, the tubular string extending through the automated pipe tripping apparatus; lifting the tubular string with the elevator at a relatively constant speed defining a tripping speed; moving the inner frame downward; moving the iron roughneck into the upper position; moving the inner frame upwards at the tripping speed so that the iron roughneck is aligned with the threaded joint between the uppermost tubular member and the next tubular member; actuating the tripping slips; transferring the weight of the tubular string to the tripping slips; breaking out the threaded joint with the iron roughneck; lifting the uppermost tubular member away from the iron roughneck; removing the uppermost tubular member from the elevator by the automated pipe handling system; moving the iron roughneck to the lower position; moving the elevator downward; moving the elevator upward at the tripping speed so that the elevator may attach to the tubular string; transferring the weight of the tubular string to the elevator; and releasing the tripping slips.

[0009] The present disclosure further provides for a method of ~~removing~~adding a tubular member ~~from~~to a tubular string being ~~removed~~inserted ~~from~~ into a wellbore. The tubular string may be made up of a

series of threadedly connected tubular members. The method may include providing an automated pipe tripping

apparatus. The automated pipe tripping apparatus may include an outer frame, the outer frame including one or more vertical supports; an inner frame, the inner frame slidingly coupled to the outer frame and positioned to be moved vertically by a lifting mechanism coupled between the inner and outer frames. The inner frame may include a tripping slips, the tripping slips positioned to receive a tubular member and selectively grip and support the tubular member; and an iron roughneck, the iron roughneck positioned above the tripping slips and positioned to receive the tubular member and make up or break out a threaded joint between a first and a second segment of the tubular member. The iron roughneck may be selectively movable in a vertical direction between a lower and an upper position by a roughneck lifting mechanism. The method may further include positioning the automated pipe tripping apparatus on a drilling floor of a drilling rig above the wellbore, the drilling rig including a ~~draw-works~~drawworks, an elevator, an automated pipe handling device, and a drilling floor slips, the tubular string extending through the automated pipe tripping apparatus, the tubular string gripped by the tripping slips; moving the inner frame downwards at a relatively constant speed defining a tripping speed; moving the elevator upward; attaching an additional tubular member to the elevator by the automated pipe handling system; moving the iron roughneck into the upper position; moving the elevator downward at a speed higher than the tripping speed until the lower threaded connector of the additional tubular member aligns with the upper threaded connector of the tubular string, then moving the elevator downward generally at the tripping speed; making up the threaded joint between the additional tubular member and the tubular string with the iron roughneck; transferring the weight of the tubular string to the elevator; releasing the tripping slips; moving the inner frame upwards; moving the iron roughneck into the lower position; moving the inner frame downwards at the tripping speed so that the iron roughneck is aligned with the upper threaded joint of the additional tubular member; actuating the tripping slips; transferring the weight of the tubular string to the tripping slips; and releasing the additional tubular from the elevator.

[0010] The present disclosure further provides for an automated control system. The automated control system may include first code instructions that vary the speed of a tubular member moving into or out of a

of inner frame 105. In some embodiments, outer frame 107 may be coupled to top drive rail as understood in the art to, for example, locate automated pipe tripping apparatus 101 over wellbore 15.

[0020] Inner frame 105 is driven vertically within outer frame 103 by a lifting mechanism. In some embodiments, such as depicted in FIG. 1, the lifting mechanism may be one or more hydraulic pistons 109 coupled between outer frame 103 and inner frame 105. Although depicted as connecting to a lower end of outer frame 103 and pushing vertically upward, one having ordinary skill in the art with the benefit of this disclosure will understand that other configurations of hydraulic pistons 109 could be substituted without deviating from the scope of this disclosure.

[0021] In other embodiments, the lifting mechanism may be a jackscrew mechanism. In such an embodiment, outer frame 103 may include one or more motors, each driving a corresponding leadscrew as understood in the art. Each leadscrew runs generally vertically and is coupled to a leadscrew nut coupled to inner frame 105. As understood in the art, as the leadscrews are rotated, inner frame 105 moves up or down depending on the direction the leadscrews are rotated. One having ordinary skill in the art with the benefit of this disclosure will understand that any number of other lifting mechanisms may be substituted without deviating from the scope of this disclosure, and may include without limitation cable and pulleys, rack and pinion, linear actuators, etc.

[0022] In some embodiments, inner frame 105 may include tripping slips 111. Tripping slips 111 may include forcing ring 113 and slips jaws 115. Tripping slips 111, like traditional power slips commonly used on drilling rigs, may releasably grasp and support a tubular string (not shown) during times that the tubular string is disconnected from the top drive or ~~draw-works~~drawworks. Tripping slips 111 may be actuated hydraulically, electrically, pneumatically, or any other suitable method used to actuate a traditional power slips. Tripping slips 111 are positioned to move vertically as inner frame 105 moves vertically within outer frame 103. The operation of tripping slips 111 will be described below.

[0029] In order to illustrate the operation of the components of automated pipe tripping apparatus 101, an exemplary tripping in operation and an exemplary tripping out operation will be described below.

[0030] In a tripping in operation consistent with embodiments of the present disclosure, as depicted in FIGS 3-8A, automated pipe tripping apparatus 101 is positioned on drilling floor 10 above wellbore 15 in drilling rig 1. Drilling rig 1 may include, as depicted in FIG. 3, drilling floor 10, rig floor slips 20 positioned in rotary table 25, drawworks 30, travelling block 35, top drive 40, elevator 45, automated pipe handling apparatus 50, and fingerboards 55. As understood in the art, drawworks 30 may be connected to top drive 40 via travelling block 35 and to move top drive 40 up and down within drilling rig 1. Elevator 45 may be coupled to top drive 40 and be positioned to connect to, suspend, and move a tubular segment within drilling rig 1. Elevator 45 may include one or more elevator links or bales which may be selectively actuatable to connect to the tubular segment. Automated pipe handling apparatus 50 serves to move pipe stands 60 between fingerboards 55 and elevator 45 during a tripping or drilling operation.

[0031] To begin the tripping in operation, automated pipe handling apparatus 50 may position a first tubular segment 151 to be supported by elevator 45. Elevator 45 supports first tubular segment 151 and lowers it toward wellbore 15. As elevator 45 lowers first tubular segment 151, inner frame 105 of automated pipe tripping apparatus 101 may move upward within outer frame 103 to an upper position. As inner frame 105 moves upward, iron roughneck 117 moves to the lower position to, for example, allow elevator 45 to properly position first tubular segment 151 within inner frame 105 as discussed below.

[0032] As depicted in FIGS. 4, 4A, as elevator 45 continues to move downward. At a certain point in the ~~decent~~descent of first tubular segment 151 through automated pipe tripping apparatus 101, tripping slips 111 engage with first tubular segment 151. In some embodiments, as tripping slips 111 are engaged, inner frame 105 is moving downward at a rate equal to that of first tubular segment 151, thus allowing tripping slips 111 to engage with first tubular segment 151 as first tubular segment moves continuously downward. The position along first tubular segment 151 at which tripping slips 111 are engaged may be

selected so that the upper threaded connector 153 of first tubular segment 151 is positioned at a height relative to inner frame 105 such that upper threaded connector 153 aligns to a point between fixed jaws 119 and makeup/breakout jaws 121 of iron roughneck 117 in its upper position.

[0033] Once tripping slips 111 have engaged first tubular segment 151, automated pipe tripping apparatus 101 is supporting first tubular segment 151, and elevator 45 may release it. Inner frame 105 continues to travel downward as elevator 45 releases first tubular segment 151, and lowers first tubular segment 151 into wellbore 15.

[0034] In some embodiments, a tubular filling apparatus may be included with automated pipe tripping apparatus 101. The tubular filling apparatus, as understood in the art, may be positioned to extend over the open end of a tubular segment to fill it with drilling fluid as it is added to the tubular string during a make up operation. In some embodiments, as depicted in FIG. 4B, the tubular filling apparatus may include gooseneck 135, which may extend over the open end of first tubular segment 151 and fill first tubular segment with drilling fluid. In some embodiments, gooseneck 135 may include a circulating packer, such as a TAM Casing Circulator (as produced by TAM International Inc.) connected to a drilling fluid supply pump on rig 1. In other embodiments, a tubular filling apparatus may be included as part of ~~top drive 35~~top drive 40.

[0035] Once first tubular segment 151 is released from elevator 45, elevator 45 moves upward within drilling rig 1 as depicted in FIG. 5. Pipe handling apparatus 50 retrieves second tubular segment 161 from fingerboards 55 and delivers it to elevator 45. In some embodiments, pipe handling apparatus 50 may retrieve second tubular segment 161 concurrently with one or more of the previous operations, and, as depicted in FIG. 4, hold second tubular segment 161 in a "ready position" until elevator 45 is positioned to receive it.

[0036] After elevator 45 has moved away from automated pipe tripping apparatus 101, iron roughneck 117 extends to its upper position about first tubular segment 151 as depicted in FIGS. 5, 5A. As

[0036] After elevator 45 has moved away from automated pipe tripping apparatus 101, iron roughneck 117 extends to its upper position about first tubular segment 151 as depicted in FIGS. 5, 5A. As

previously discussed, upper threaded connector 153 is aligned between fixed jaws 119 and makeup /breakout jaws 121. In some embodiments, the position of iron roughneck 117 may be fine-tuned by an upward or downward movement such that this positioning is achieved. As can be seen in FIG. 5, inner frame 105 has continued to move downward continuously during these operations.

[0037] As depicted in FIG. 6, once elevator 45 has received second tubular segment 161, elevator 45 lowers second tubular segment 161 within drilling rig 1 at a rate faster than the decent of inner frame 105 until the lower threaded connector 163 of second tubular segment 161 is aligned with upper threaded connector 153 of first tubular segment 151, at which time elevator 45 descends at the same speed as inner frame 105. As depicted in FIGS. 6A, 6B, threaded connectors 153, 163 are then made-up by iron roughneck 117. In some embodiments, pipe spinner 123 rapidly engages a majority of the threads of threaded connections 153, 163. In other embodiments, top drive 40 may rotate second tubular segment 161. ~~Makeup~~ Makeup/breakout jaws 121— in combination with fixed jaws 119— apply high torque to complete the makeup operation.

[0038] Once the connection is made, weight of tubular string 150 (now consisting of first and second tubular segments 151, 161) may be transferred entirely to elevator 45. Once elevator 45 supports tubular string 150, tripping slips 111 may disengage from tubular string 150 as depicted in FIGS. 7, 7A. Inner frame 105 may then travel upward within outer frame 103, while iron roughneck 117 moves back to its lower position as previously described as depicted in FIGS. 8, 8A, ready to receive the upper end of pipe string 150 as elevator 45 continues to descend. Pipe handling apparatus 50 may at the same time retrieve a third tubular segment 171 to be added to pipe string 150 in the next make-up operation.

[0039] The previously described process repeats for each tubular segment until tubular string 150 reaches the desired length in wellbore 15. At this point, rig floor slips 20 reengage tubular string 150. Inner frame 105 may move upward within outer frame 103 until it is higher than the uppermost end of tubular string 150. Automated pipe tripping apparatus 101 may then be moved away from the position

over wellbore 15, and other rig operations may be performed, including for example, drilling, casing cementing, completion, etc.

[0040] In a tripping out operation consistent with embodiments of the present disclosure, as depicted in FIGS 9-12A, automated pipe tripping apparatus 101 is positioned on drilling floor 10 above wellbore 15 in drilling rig 1. As depicted in FIGS. 9, 9A, tubular string 250, held by rig floor slips 20, extends above drill floor 10 far enough such that elevator 45 can connect to the upper end of tubular string 250 above iron roughneck 117 in its lower position as previously described.

[0041] In some embodiments, with inner frame 105 in a lower position within outer frame 103, tripping slips 111 engage with tubular string 250, and tubular string 250 is first lifted by automated pipe tripping apparatus 101 as inner frame 105 is moved upward within outer frame 103. In other embodiments, elevator 45 engages with tubular string 250 and begins moving it upward. As tubular string 250 begins to be lifted from wellbore 15, rig floor slips 20 disengage, allowing either tripping slips 111 or elevator 45 to support the weight of tubular string 250.

[0042] As depicted in FIGS 10, 10A, tubular string 250 is initially lifted by automated pipe tripping apparatus 101. As tubular string 250 moves upward, elevator 45, while moving upward at the same rate as inner frame 105, attaches to tubular string 250. The weight of tubular string 250 is transferred to elevator 45, and tripping slips 111 disengage.

[0043] As elevator 45 continues to lift tubular string 250, inner frame 105 moves downward within outer frame 103, and iron roughneck 117 moves to its upper position as depicted in FIG. 11.

[0044] As tool joint 253 corresponding to the bottom end of upper tubular segment 251 enters automated pipe tripping apparatus 101, when tool joint 253 is aligned with iron roughneck 117 as previously discussed, inner frame 105 moves upward at the same rate as elevator 45. As depicted in FIG. 11A, tripping slips

111 engage with tubular string 250, and a portion of the weight of pipe string 250 is taken by automated pipe tripping apparatus 101.

[0045] In embodiments which include them, upper and lower mud bucket seals 127, 129 are engaged at this point as depicted in FIG. 11B.

[0046] Iron roughneck 117 may then break out tool joint 253. Fixed jaws 119 and makeup/breakout jaws 121 engage tool joint 253, and apply high-torque to initially disconnect tool joint 253. In some embodiments, as depicted in FIG 11C, pipe spinner 123 then rapidly finishes disconnecting tool joint 253. In other embodiments, top drive 40 may rotate upper tubular segment 251. Any drilling ~~mud~~fluid 255 contained in upper tubular segment 251 is released as tool joint 253 is broken out, and may be captured by mud bucket 125. Drilling ~~mud~~fluid 255 may then flow through a drain line (not shown) to, for example, be recycled into the drilling ~~mud~~fluid supply.

[0047] Once tool joint 253 is broken out, as depicted in FIGS. 12, 12A, elevator 45 increases in speed, and hoists upper tubular segment 251 above automated ~~pipe handling apparatus~~pipe tripping apparatus 101. Automated pipe tripping apparatus 101 continues to lift tubular string 250 from wellbore 15. In some embodiments, automated pipe handler 50 then receives upper tubular segment 251 and delivers it to fingerboards 55. As inner frame 105 continues to lift tubular string 250, iron roughneck 117 moves to its lower position, as previously discussed.

[0048] The previously described process may then repeat for each tubular segment until tubular string 250 is entirely removed from wellbore 15. At this point, any procedure that necessitated the tripping out procedure may be undertaken, including without limitation replacing a bit, servicing a BHA, testing the well, perforating, etc. In some cases, automated pipe tripping apparatus 101 may be utilized in such a procedure, such as running casing, running a packer or other tool, or tripping back in a drill string with a replaced drill bit. In other cases, automated pipe tripping apparatus 101 may be removed from the drill floor directly above wellbore 15.

[0049] Because both elevator 45 and tripping slips 111 are capable of vertical movement, a tubular string being tripped in or out of a wellbore 15 may remain in continuous motion for the entire tripping process at a constant speed. Because the tubular string is in constant motion, the tubular string may be able to be tripped in the same amount as time as a traditional discontinuous tripping procedure while the tubular string remains at a slower speed than would be reached by a tubular string in a discontinuous tripping operation. In some circumstances, wellbore pressure may be rapidly increased or decreased by a rapid movement of a downhole tool. Commonly referred to as "surging" while tripping in, or "swabbing" while tripping out, these pressure fluctuations may cause, for example, reservoir fluids to flow into the wellbore or cause instability in a formation surrounding a wellbore. By allowing the same distance of tubular string to be tripped in the same amount of time but at a slower speed may, for example, reduce the chance of wellbore damage from swabbing. Additionally, the continuous motion may help to prevent, for example, hydraulic shocks caused by rapid starting and stopping of a tubular string in the wellbore.

[0050] In some embodiments, the tripping speed, defined as the speed of the tubular string within the wellbore during a continuous tripping operation, may be predetermined by an operator. In other embodiments, tripping speed may be controlled by a closed-loop feedback mechanism. For example, in some embodiments, the closed-loop controller may take into account a pressure measured by a pressure sensor at the bottom of the tool string. By measuring the pressure and monitoring, for example, absolute pressure changes, rate of pressure change, and acceleration of pressure change, the controller may increase or reduce tripping speed to, for example, prevent surging or swabbing in the wellbore. In other embodiments, pressure in the wellbore may be inferred by measuring a drive current used by top drive 40 or the lifting mechanism.

[0051] Additionally, as previously mentioned, in some embodiments, the control system of automated pipe tripping apparatus 101 may control one or more of drawworks 30, top drive 40, elevator 45, and pipe

handling apparatus 50. As such, the control system may additionally monitor the status of each of these systems and potentially modify tripping speed in response to, for example, environmental factors, system

9. The automated pipe tripping apparatus of claim 7, wherein the tubular filling apparatus comprises ~~TAM Casing Circulator~~circulating packer.

10. The automated pipe tripping apparatus of claim 1, further comprising a control system, the control system positioned to control the lifting mechanism, the iron roughneck, and the tripping slips.

11. The automated pipe tripping apparatus of claim 10, wherein the control system is positioned to further control at least one of a drawworks, top drive, elevator, elevator links, and automated pipe handling apparatus.

12. The automated pipe tripping apparatus of claim 10, wherein the control system further comprises a closed-loop controller positioned to control the speed of the tubular member during a tripping operation.

13. The automated pipe tripping apparatus of claim 12, wherein the closed-loop controller varies the speed of the tubular member in response to variations in pressure within a wellbore measured by a pressure sensor at the end of the tubular member positioned within the wellbore.

14. The automated pipe tripping apparatus of claim 1, wherein the outer frame is positioned to roll horizontally on one or more rollers along a track.

15. The automated pipe tripping apparatus of claim 1, wherein the iron roughneck further comprises a mud bucket, the mud bucket positioned to contain any drilling fluid contained within the upper of the first and second segments of the tubular member after a break-out operation.

16. The automated pipe tripping apparatus of claim 15, wherein the mud bucket further comprises at least one of a lower seal and an upper seal, the lower and upper seals positioned to seal the interior of the mud bucket to the tubular member.

17. The automated pipe tripping apparatus of claim 16, wherein the mud bucket further comprises a drain line positioned to permit drilling fluid to flow from the mud bucket to a drilling fluid reservoir.

18. A method of removing a tubular member from a tubular string being removed from a wellbore, the tubular string made up of a series of threadedly connected tubular members, the method comprising:

providing an automated pipe tripping apparatus, the automated pipe tripping apparatus including:

an outer frame, the outer frame including one or more vertical supports;

an inner frame, the inner frame slidingly coupled to the outer frame and positioned to be moved vertically by a lifting mechanism coupled between the inner and outer frames, the inner frame including:

a tripping slips, the tripping slips positioned to receive a tubular member and selectively grip and support the tubular member; and

an iron roughneck, the iron roughneck positioned above the tripping slips and positioned to receive the tubular member and make up or break out a threaded joint between a first and a second segment of the tubular member, the iron roughneck selectively movable in a vertical direction between a lower and an upper position by a roughneck lifting mechanism;

positioning the automated pipe tripping apparatus on a drilling floor of a drilling rig above the wellbore, the drilling rig including a ~~draw-works~~drawworks, an elevator, an automated pipe handling device, and a drilling floor slips, the tubular string extending through the automated pipe tripping apparatus;

lifting the tubular string with the elevator at a relatively constant speed defining a tripping speed;

moving the inner frame downward;

moving the iron roughneck into the upper position;

moving the inner frame upwards at the tripping speed so that the iron roughneck is aligned with the threaded joint between the uppermost tubular member and the next tubular member;

actuating the tripping slips;

transferring the weight of the tubular string to the tripping slips;

breaking out the threaded joint with the iron roughneck;

lifting the uppermost tubular member away from the iron roughneck;

removing the uppermost tubular member from the elevator by the automated pipe handling system;

moving the iron roughneck to the lower position;

moving the elevator downward;

moving the elevator upward at the tripping speed so that the elevator may attach to the tubular string;

transferring the weight of the tubular string to the elevator;

releasing the tripping slips.

19. A method of adding a tubular member to a tubular string being inserted into a wellbore, the tubular string made up of a series of threadedly connected tubular members, the method comprising:

providing an automated pipe tripping apparatus, the automated pipe tripping apparatus including:

an outer frame, the outer frame including one or more vertical supports;

an inner frame, the inner frame slidingly coupled to the outer frame and positioned to be moved vertically by a lifting mechanism coupled between the inner and outer frames, the inner frame including:

a tripping slips, the tripping slips positioned to receive a tubular member and selectively grip and support the tubular member; and

an iron roughneck, the iron roughneck positioned above the tripping slips and positioned to receive the tubular member and make up or break out a threaded joint between a first and a second segment of the tubular member, the iron roughneck selectively movable in a vertical direction between a lower and an upper position by a roughneck lifting mechanism;

positioning the automated pipe tripping apparatus on a drilling floor of a drilling rig above the wellbore, the drilling rig including a ~~draw-works~~drawworks, an elevator, an automated pipe handling device, and a drilling floor slips, the tubular string extending through the automated pipe tripping apparatus, the tubular string gripped by the tripping slips;

moving the inner frame downwards at a relatively constant speed defining a tripping speed;

moving the elevator upward;

attaching an additional tubular member to the elevator by the automated pipe handling system;

moving the iron roughneck into the upper position;

moving the elevator downward at a speed higher than the tripping speed until the lower threaded connector of the additional tubular member aligns with the upper threaded connector of the tubular string, then

moving the elevator downward generally at the tripping speed;

making up the threaded joint between the additional tubular member and the tubular string with the iron roughneck;

transferring the weight of the tubular string to the elevator;