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Pipe-Handling Integration in Land Drilling Operations – Safety Review, Operational Drivers, and Field Performance Feedback

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Abstract

The value of safety is critical to our industry, and technology is adopted when all the stakeholders meet their needs. In drilling operations, the drilling contractor needs reliable systems with consistent performance that competes with current operations performance, in contrast the crew are looking for tools that they can understand and help them carry out their task better than before. The critical role of the derrickman is one that has a high standard to mechanize and meet the needs of the crew and contractor.

A fingerboard mounted pipe handling system has been introduced, which differs from previous attempts to eliminate the manual interaction of a derrickman in land drilling operations. The machine was the outcome of unique consensus between the designer and the drilling contractor and provides a solution equivalent to manual tripping speeds that is strongly accepted by the drill crew.

Critical to operational success was tripping speed, simplicity, and following the process that a manual operation is comfortable with. Eliminating the existing gripping devices and hoisting systems were one of many steps taken to improve the acceptance of a safety support tool on a working drilling rig.

This paper will examine a case study with Patterson UTI and an equipment manufacturer which will show the performance feedback from a field proven solution. This will address the barriers that hold this advancement back and has the possibility of greatly increasing safe land drilling operations.

Introduction

The Stand Transfer Vehicle (STV) is designed to get the derrickman out of harm's way on the rig floor or in the driller's house to provide an affordable and robust solution to address the derrickman's safety concerns. The main design parameters set for the tool were:

- Maintain or increase tripping efficiency as compared with manual operations
- Mirror the operations of the manual derrickman and not lift the stand during movement between the fingerboard and well center
- 3-1/2 in. to 10 in. drill pipe and drill collar without insert size changes
- Modular installation and removal of STV during rig up and rig down
- One man operation with the derrickman running the tool from the rig floor
- Visual feedback of STV position and operation without the use of feedback sensors or encoders
- Manual racking possible when tool is not operational

Iterative Design Approach

Vertical pipe handling systems have been utilized offshore for many years based on regulatory requirements, day rates, extreme environments, dynamics, increased sizes, and weight of drilling tubulars. The land market for vertical pipe handling machines has not yet required the derrickman to work out of the derrick and the products available for offshore do not meet the design requirements for land based on size, weight, complexity, and cost. With this in mind, we surveyed the current offshore product offerings and started prototype development of a machine that was based on a combination of existing product offerings. Following was the design basis for the first article machine:

- Installation above fingerboard with bridge and trolley system to move the guide arm and guide head within constraints of fingerboard slots, diving board alleyways, and well center
- Tubular guide head to work with existing 2 in. wide fingerboard slot tubes
- Guide head to quickly interface with tubular stand with self-latching fingers
- Quick release of guide head from tubular stand with instant opening of fingers to allow near immediate transfer of stand from guide head to elevator
- Fully hydraulic controls for all machine movements

The initial design was completed and the first article installed on a customer supplied 1500 HP rig during factory rig-up to prove the concept of the tubular guiding head and movement of the stand between the fingerboard slots and well center (Figure 1). The key to this full scale test was use of a unique tubular guide head with a variety of pipe sizes and document the dexterity of the head when moving stands between the fingerboard and the elevator at the well center. The guide head's operation needed to mimic the manual operations of a derrickman as the hand over between STV and the elevator at well center is critical to tripping speeds.

Testing also found a few design issues and those were addressed prior to moving forward as the initial design produced a heavy machine that adversely affected a rig's standard mast raising system. In addition, installing the machine above the fingerboard, although good for line of site while on the racking board, made control of the machine difficult from the ground as the fingerboard blocked the operator's line of site. Finally, integrating a STV and a fingerboard that was installed independent of the machine proved difficult as machine to fingerboard alignment and testing could only be realized during field installation. The STV's design needed to allow efficient installation and testing during an initial installation and repeated rig moves.

So in essence, it was back to the drawing board to address the above design issues. The weight was addressed by supporting the guide arm from the diving board which was integrated into the main fingerboard support structure. This alone reduced the installed weight by approximately 7,000 lbs. It also integrated the fingerboard and STV design and allowed the machine to be fully factory tested as a system prior to delivery to the field, which reduced the installation time on location. Another positive from the diving board mounted guide arm was the fingerboard slot alignment. As the machine does not utilize position encoders for control, the guide arm trolley utilizes a fingerboard index cam that aligns the guide arm and head with the fingerboard slots. This allows the operator to positively stop the machine at the required slot, which allows seamless movement of the stand between the diving board alleyway and fingerboards. Also, as the guide arm was supported below the diving board, the line of site to the machine from the drillfloor was greatly improved over the first article. See Fig. 2.

The final hurdle in the design was a simple and robust control and operating system that would allow manual hydraulic control from the fingerboard and remote control from the driller's cabin. The STV does not incorporate encoders for position control, so a dual camera and monitor system was utilized to provide visual feedback to the operator. One guide arm mounted camera follows the guide head along its path to and from well center and the other fixed well-center view camera monitors handover between the machine and the elevator. These cameras and their control-console mounted monitors allow the operator's joystick and switch commands to be immediately verified by the camera monitors. This greatly reduces the training time for efficient operation of the STV. See Fig. 3.

The prototype STV and fingerboard were delivered to Patterson-UTI for field trials on a 1500 AC rig after almost six months of factory testing and design verification. Thorough prototype field testing was considered the only method to properly launch a new product in this market as potentially selling many serial number one's to a variety of customers without a proper testing phase would be detrimental to the future success of the STV.

Prototype Testing Outcomes

The key to any product prototype testing is the crew taking ownership and having a stake in the success of the product. The trial period started in 2010 in the Barnett Shale area on Patterson-UTI 219 and was a collaborative effort between the contractor and OEM with efficient communication between the drilling crew and design engineering team. The crew and operator immediately sponsored the continued use of the tool, even as problems did arise, allowing this long two year test period to provide valuable feedback and design improvements to increase reliability and better suit the use and transportation of the tool where are described below:

- Breakaway Diving Board: During the trial the top drive elevator contacted the diving board on the way up, causing damage to divingboard and fingerboard support structure (Fig. 5 and 6). The prototype fully welded divingboard connection was updated with a breakaway design that clamps in place and uses replaceable shear pins to allow board rotation if contacted from above or below (Fig. 7). This clamp and shear pin system can be reset when contacted to allow the board to be reset and further prevent collateral damage to racking board system.
- Passive Fingerboard Stand Restraints: Each row of stands is securely held in place by a pneumatic latch that is remotely controlled from the operator's console to open and close. On a manual fingerboard each stand is typically tied back to each other by the derrickman to prevent the stands from moving within the slots, but as the operator was now on the ground, a variety of passive stand restraints were tested. These included rubber lined rows, rubber gated rows, and rows lined with inflatable air-bags on both sides of the fingerboard slot tubes to hold the rows of stands in place as the STV moved individual stands out and in pneumatic latches at each row. During the trial, the inflatable air-bags (Fig. 8 and 9) proved the most effective and could be adjusted as required based on pipe size, weight, and wind by changing the air pressure regulation on the bags. If manual racking is required the bags can be deflated, allowing a derrickman to move the stands in the fingerboard slots with normal manual force.
- Installation, Transport and Storage Frame: As mast and fingerboard raising is a function of the rig design, the STV was required to be installed in a variety of methods. A multi-use STV support frame

(Fig. 6) was designed to allow safe and efficient installation of the machine into the fingerboard prior to mast raising using a forklift or cherry picker, depending on mast orientation and heights. This frame also allows on-the-ground and in-the-mast testing and maintenance of the machine. Finally, when installed this frame provides a storage area where the machine can be parked away for the fingerboard for maintenance and troubleshooting, thus allowing manual racking of the fingerboard.

- Remote Operated Elevators: As the land rig market is new to mechanized or automated pipe handling systems, an offshore hydraulic elevator design was used for the trial. Its weight and package size created a few issues with the top drive link tilt system and tight torque tube envelope that will be addressed with a lightened design of 350 t hydraulic elevator for these tighter mast and smaller top drive applications.

Realized Features and Benefits

Table 1 below is based on the feedback from the Patterson-UTI crew and demonstrates that removing the derrickman from the derrick is more than about safety. Placing the derrickman near the driller on the floor adds a new dynamic to the drilling and tripping operation by allowing better communication and training amongst the crew. When breaks or tour changes are required, the floor hands, derrickman, driller, and tool pusher can all operate the tool. Finally as the crew soon realized the value of using the STV, they took complete ownership in the operation and uptime of the tool.

Features	Benefits
• Derrickman on Floor	• Safety • Communication • Interactive Training
• Efficiency	• HWDP and DC Manipulation • Consistency
• Intuitive and Ergonomic Controls	• Training Simplicity
• Continuous Operation	• Fatigue Reduction
• Installed Weight	• Choice of Installation Options
• Simple and Robust Design	• Troubleshooting and Maintenance

Table 1 – Features and Benefits

Conclusions

The STV's design is a result of a long iterative design process and prototype trial period that produced a unique, but simple tool that is slowly gaining momentum with drilling contractors and their operators as the tool does offer a combination of safety, reliability, and performance to this slow to adopt marketplace.

Fig. 1 – STV first article testing

Fig. 2 – STV prototype design testing

Fig. 3 – Control console

Fig. 4 – Prototype field testing

Fig. 5 – Welded Diving Board Design and Collision Damage

Fig. 6 – Welded Diving Board Design and Collision Damage

Fig. 7 – Updated Breakaway Diving Board

Fig. 8 – Passive Restraint System (deflated)

Fig. 9 – Passive Restraint System (inflated)

Fig. 10 – STV Installation Skid

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