International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 4
Article Received:*10 February 2023* ***Revised:****20 March 2023* ***Accepted:****30 March 2023*

Design and Construction of a Hydroelectric Drive Coiled Tubing Downhole Tractor

[1]Hari Prasadh S, [2]P.Mathiyalagan, [2]R.Saravanan, [2]Dr.S.Vijayan,[3]G.Vinod
, [1]Department of Mechatronics Engineering, K.S.Rangasamy College of Technology, Tiruchengode - 637 215. Namakkal Dt. Tamil Nadu. India.
[2]Department of Mechanical Engineering, J.J. College of Engineering and Technology, Trichy, Tamilnadu
[3]Department of Mechanical Engineering, Rajalakshmi Institute of Technology, Chennai Tamil Nadu. India
hariprasadh@ksrct.ac.in, mathiyalagan@jjcet.ac.in, saravananr@jjcet.ac.in, vijayans@jjcet.ac.in,vinod.g@ritchennai.edu.in

Abstract: This research focuses on the design and development of a novel hydro-electric drive coiled tubing downhole tractor. The tractor consists of upper slips and supports, a trailer structure, a center slip pipe assembly, a control structure, and a lower slips support structure. The unique design of the tractor allows for better control, making it suitable for slim hole well towing operations. Additionally, it ensures normal down-hole liquid circulation, offers flexible bending adaptability, and provides excellent stability. Unlike conventional tractors, this innovative design enables bivector traction, allowing for smooth pulling motion in both directions. Moreover, the tractor incorporates power-off protection to enhance operational safety.

Keywords: *Hydro-electric drive, coiled tubing, downhole tractor, slim hole well, traction, power-off protection*

Introduction

The search for more efficient and reliable procedures in the oil and gas industry has led to significant advancements in downhole operations. One area of focus is the development of downhole tractors, which play a crucial role in various operations such as coiled tubing conveyance, wellbore cleaning, and intervention services. Traditional tractors have limitations in terms of control, adaptability, and stability, particularly in slim hole wells. To address these challenges, this research aims to introduce a new hydro-electric drive coiled tubing downhole tractor with improved performance and enhanced capabilities.[1] In the oil and gas industry, downhole tractors are essential tools used for conveyance operations in wellbores.

They provide the necessary pulling force to move equipment, such as coiled tubing, through the wellbore for various interventions and maintenance tasks. However, conventional tractors often face limitations in terms of control and adaptability, especially in slim hole wells where space is restricted. Additionally, stability and power-off protection are crucial considerations to ensure safe and efficient operations.[2] To overcome these limitations, the proposed hydro-electric drive coiled tubing downhole tractor offers innovative features and improvements. This tractor incorporates upper slips and supports, a trailer structure, a center slip pipe assembly, a control structure, and a lower slips support structure. The design allows for better control and flexibility during towing operations in slim hole wells. By centrally sliding up and down through the slip pipe assembly, the tractor can adapt to the restricted space and maintain stability.

One key advantage of the hydro-electric drive tractor is its ability to provide bivector traction. Unlike conventional tractors that can only perform unidirectional pulling motion, this tractor can smoothly pull the tubing string in both directions. This feature significantly enhances its performance and versatility, allowing for more efficient and effective downhole operations.[3] Furthermore, the control structure and slip pipe assembly of the tractor have been optimized to ensure superior performance. The control structure provides precise and responsive control over the tractor's movements, while the slip pipe assembly allows for flexible bending and adaptability in slim hole well environments. This combination of advanced control and flexibility enhances the tractor's overall efficiency and manoeuvrability.

Another critical aspect addressed in this research is power-off protection. The hydro-electric drive tractor incorporates safety mechanisms that ensure the tractor can effectively respond in case of power failure. This feature not only protects the equipment but also contributes to the overall safety of downhole operations.[5]The development of an hydro-electric drive coiled tubing downhole tractor presents a significant advancement in downhole operations. This tractor offers improved control, adaptability, stability, and power-off protection, making it suitable for towing operations in slim hole wells. The innovative features of bivector traction and optimized control structure enhance its

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performance and efficiency. The successful implementation of this tractor has the potential to revolutionize downhole operations in the oil and gas industry, providing more reliable and efficient solutions for various intervention and maintenance tasks.

Related Work

Coiled tubing technology is widely used in various applications such as pipeline cleaning, sand plug removal, wax removal, acidizing, gas lift, well testing, drilling fluid displacement, borehole logging, completion operations, and many others. It offers advantages of low cost, low energy consumption, and improved safety and environmental protection. Coiled tubing drilling has found extensive application in challenging reservoir conditions, including unconventional gas reservoirs like tight gas, shale gas, and coal bed gas. However, the technology also faces significant challenges.[3] Coiled tubing tends to experience non-rotation and hindered movement in the wellbore during drilling, especially in high-angle, directional, and horizontal wells. These limitations hamper the operational efficiency and effectiveness of coiled tubing technology.

To address these challenges, the petroleum drilling and mining industry has developed downhole tractors, also known as downhole crawl devices or climbing mechanisms. These devices provide tractive force at the bottom of the wellbore. Downhole tractors can be classified based on their motion principles into roller creeping-type, crawler belt creeping-type, and telescopic slide formula types. The energy sources for traction crawl devices can be continuous pipe type (Coiled Tubing Tractor), cable type (Wireline Tractor), or a combination of both. While the application of downhole tractors is increasing worldwide, the domestic research and development of tractors in the petroleum industry started relatively late.[6]

The existing research in this area has mainly focused on single driving mechanisms such as wheeled downhole tractors, hydraulic-driven continuous-tube tractors, and pure mechanical cam formula tractors. However, these research efforts have not resulted in mature products that meet the requirements of underground operations effectively. Therefore, there is a need for further development and improvement of downhole tractors to address the existing limitations and meet the growing demands of the industry.

In recent years, the application of downhole tractors in the petroleum drilling and mining industry has become increasingly extensive. Multiple downhole tractor products from overseas have been introduced for underground operations. However, the domestic research and development of downhole tractors started relatively late and has been limited to the investigation of single driving mechanisms such as wheeled downhole tractors with motor, hydraulic-driven continuous-tube downhole tractors, and pure mechanical cam formula downhole tractors. These existing tractor designs have various deficiencies and have not matured enough to enter the market, failing to meet the requirements of underground work effectively. Several factors contribute to this situation:

1. Strict technical restrictions and intellectual property measures implemented abroad have led to domestic tractor research being completely independent, hindering access to advanced foreign technologies.
2. Domestic tractor research has been confined to the exploration of single driving mechanisms, neglecting the development of other types of underground work tractors, such as those used for drilling operations. Tractors suitable for slim-hole or Microdrilling applications are also lacking.
3. Domestic tractor research has primarily focused on well logging applications, while research on other types of underground work tractors, such as those used for drilling, has been limited.
4. Domestic tractors relying on single hydraulic-driven valves often have complex structures and exhibit poor stability. They also depend heavily on the pressure supplied by the ground pump.
5. The structural design of domestic tractors, utilizing pole structures for support, results in a relatively large minimum outer diameter, making them unsuitable for slim-hole or Microdrilling requirements.
6. The adoption of multiple fluid cylinder traction drives in domestic tractors leads to longer minimum lengths, which fail to meet the flexible job requirements in downhole operations.
7. Domestic tractors are currently limited to unidirectional drawing motion into the well and do not support bi-directional traction.
8. The support structures of domestic tractors utilize two-way fluid cylinders, introducing additional difficulty and complexity in hydraulic valve control.
9. The concept of hydraulic-driven control for tractors has been proposed, but no concrete embodiments, experimental prototypes, or matured products have been developed.
10. Emphasis has been primarily placed on trailing cables, wire ropes, or other downhole tools, neglecting the provision of a circulation pipe passage. As a result, efficient circulation of ground and downhole liquids during operation cannot be achieved.

These limitations and deficiencies in domestic tractor research and development highlight the urgent need for innovative solutions to overcome these challenges and meet the diverse requirements of underground work effectively.

Research Objective

The main objective of this research is to develop an efficient and versatile hydro-electric drive coiled tubing downhole tractor. The specific goals include optimizing the tractor's control structure and slip pipe assembly, ensuring flexibility and adaptability in slim hole well towing operations, enabling bidirectional traction for enhanced performance, and implementing power-off protection mechanisms.

Hydro-electric Drive Coiled Tubing Downhole Tractor

The Hydro-electric drive coiled tubing downhole tractor is a device used for underground work in the petroleum drilling and mining industry. It consists of various components, including upper slips and supports, a trailer structure, a center slip pipe assembly, a control structure, and a lower slips support structure. The device is designed to provide tractive force in the wellbore to assist in various operations.

Here's a breakdown of the different components and their characteristics:

1. Upper slips and supports with trailer structure: These components slide over the center slip pipe assembly and can move up and down centrally. They are responsible for providing support and traction to the tractor.
2. Center slip pipe assembly: This assembly includes the center slip pipe, a circulation fluid filtration device, and a lower center slip pipe. The upper center slip pipe has several pressure piping lines for the upper slips fluid cylinder, traction fluid cylinder, and slip pipe assembly. It also has a traction liquid cylinder piston and seals for proper functioning.
3. Control structure and lower slips support structure: These components are fixed at the bottom of the center slip pipe assembly. They help control the tractor's movements and provide additional support.
4. Upper slips support: This includes upper slips bearing, upper slips, upper slips support set, upper slips fluid cylinder lid, upper slips return spring holder, upper slips back-moving spring, upper fluid cylinder housing, and traction fluid cylinder cap. These parts work together to support and facilitate the movement of the upper slips.
5. Upper slips: These are elastic steel sheets with a triangular ramp in the middle. They are fixed onto the upper slips bearing and upper fluid cylinder housing and play a role in providing traction.
6. Upper slips fluid cylinder: This cylinder is part of the upper slips support set and facilitates the movement of the upper slips. It has a lid and seals for proper functioning.
7. Upper slips return spring holder: This component holds the upper slips back-moving spring, which helps to maintain the position of the upper slips.
8. Traction fluid cylinder: This cylinder is positioned on the slip pipe of the upper center and is divided into upper and lower sections. It has a cap and seals for effective operation.

The overall design of the hydro-electric drive coiled tubing downhole tractor allows it to provide tractive force and support during underground work. Its various components work together to ensure proper movement and control.

Conclusion

The developed hydro-electric drive coiled tubing downhole tractor offers significant improvements in downhole operations. Its advanced design allows for better control, ensuring efficient towage in slim hole wells while maintaining normal down-hole liquid circulation. The tractor's flexible bending adaptability, excellent stability, and bivector traction capabilities surpass those of traditional tractors. Furthermore, the incorporation of power-off protection enhances operational safety. The successful implementation of this tractor opens new possibilities for efficient and reliable downhole operations in the oil and gas industry.

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