Petroleum and Coal

Article **Open Access**

Static Structural and CFD Simulation Analysis of Failures in Drill Pipes

Aslam Abdullah, Gautham Krishnan, Bandaru Kiran, Aruna Singh*

School of Chemical Engineering, VIT, Vellore, India

Received January 28, 202; Accepted September 5, 2023

Abstract

Drill pipe failures are common in the oil drilling and its advancement process, particularly in the transition zone of the pipe. Using ANSYS software, creating an analytical model based on the framework of the drill pipe and examined the stress concentration factor of the transition zone. According to the outcome of the analysis, the transition zone area is the vulnerable part of the drill pipe. Perforation in the transition zone area is another significant reason for the failure of the drill pipe FLUENT, a finite volume CFD solver was used to calculate the flow field of the fluid flowing through the transition zone area of drill pipe under various conditions. The distribution of velocity, pressure and shear stress in the transition zone area indicated the scouring of the pipe wall by the drilling fluid. The drilling fluid type and velocity, structural shape of pipe are significant impact on flow field.

***Keywords**: Transition zone area; Scouring; Failure; Fluid flow field; Drill pipe.*

1. Introduction

Drill pipe, which is located in the uppermost section of the drill column, is a significant tool in oil drilling and gas exploration [1]. Drill pipe is subjected to complicated loads such as wall shear stress, bending torque, torque, centrifugal force and vibrational load during the operating process [2, 21]. Drill pipe failures are common, and they result in a massive amount of human, material, and financial loss. As a result, determining the reason of failure and improving design is critical for the secure and effective operation of the drill pipe in the oil drilling and advancement process [3-7]. The failure location of the drill pipe was concentrated in the transition zone area. Chemical composition, mechanical characteristics, microscopic structure, and cross section shape of drill pipe were all investigated [8-10]. Drilling fluid's effect on drill pipe is also frequently overlooked [11-13]. However, due to the shift in flow channel, there is an abrupt change in the flow field of the drill pipe in the transition zone area [14]. The flow impact on drill pipe is aggravated by pressure fluctuations and the presence of low-pressure in areas [15]. As a result, it is critical to conduct the failure study of a drill pipe from the standpoint of scouring of pipe walls. The finite volume method was used to derive distributions of velocity, pressure and shear stress under various drilling fluid velocities, drilling techniques, and transition zone structures using computational fluid dynamics (CFD). The impact of each component was then examined in detail.

2. Modelling

Figure 1 shows a schematic illustration of the drill pipe. Subsequently, the variation in the size of the structure and the transition zone area becomes the drill pipe's fragile point; the transition zone's structure is indicated in Figure 2. Transition zone length should be kept to a minimum. Two key factors are transition length (M_{iu}) and the transition radius (R) [2]. Transition radius R is not properly standardized in current drill pipes [16-18]. To investigate the impact of both transition length (M_{iu}) and transition radius (R) on drill pipe's stress distribution, transition length (M_{iu}) and transition radius (R) are defined as factors that change variably, and their impact on the factor of stress concentration (K_t) is studied. The finite volume approach was used to derive distributions of velocity, pressure and shear stress under various drilling fluid velocities, drilling techniques, and transition zone area

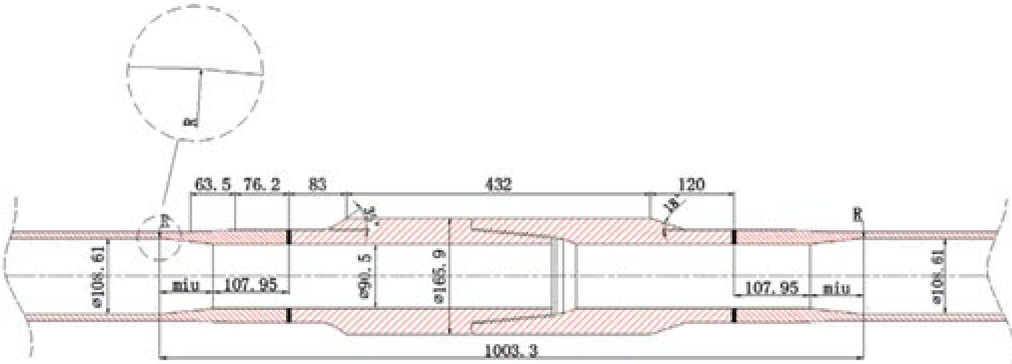

Figure 1. Drill pipe.

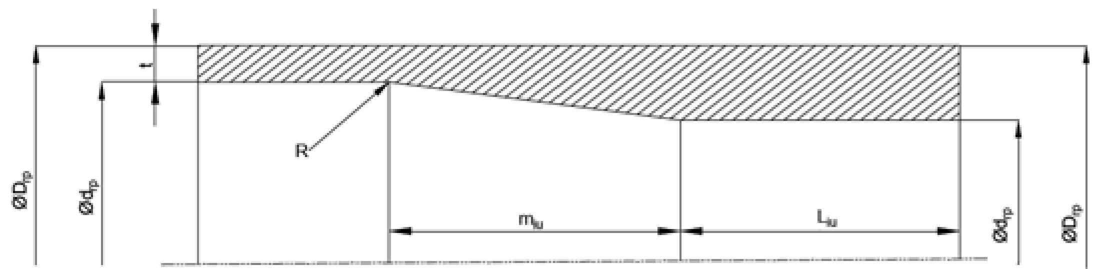

Figure 2. Transition zone.

3. Simulation study

3.1. Stress distribution

In the simulation, the axial tensile stress is the most essential consideration. The concentration of stress in transition zone areas is quite greater than in other portions of the tool joint and drill pipe, according to simulation study, with the transition radius between the transition zone area and tube pipe being the most problematic site. During the study process, the transition length (M_{iu}) varies from 40mm to 160mm, and the transition radius (R) varies from 0 to 300mm. With M_{iu} increasing, reduction of the factor of stress concentration (K_t) was observed. When transition radius (R) is increased, the K_t decreases in a predictable pattern as M_{iu} increases. R is taller, M_{iu} is longer, and K_t is shorter [2].

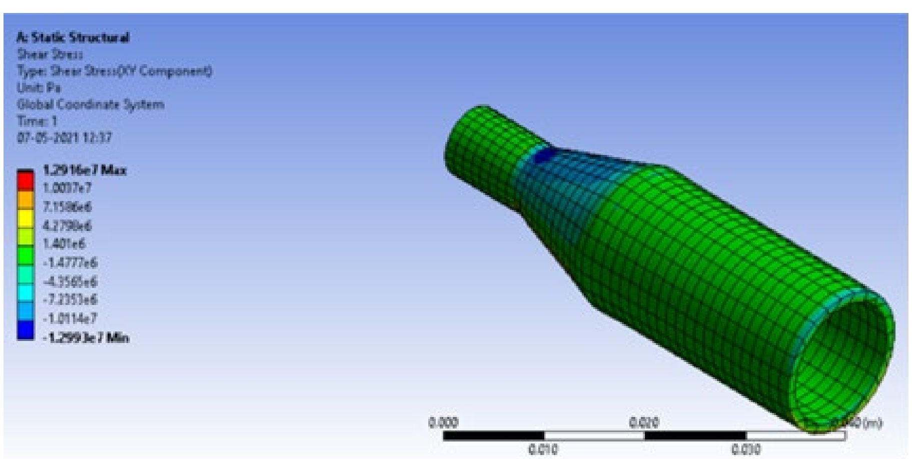

Figure 3. Stress distribution.

Table 1. Material properties of the drill pipe

Material	Density (kg/m^3)	Modul of elasticity E (MPa)	Poisson's Ratio	Unit weight (kN/m^3)
Structural Steel	7850	210000	0.3	78.5

3.2. Flow field simulation

The schematic illustration of the simulation using the drill pipe is shown in Figure 2. Transition zone area close to the pin thread flow channel differs from the transition zone area close to the box thread flow channel [15]. The contraction channel is one, and the expansion channel is the other. The boundary conditions for inlet velocity and pressure outflow were implemented for the realm of computation's inlet and outflow, consequently [2]. To reflect varying drilling fluid displacements, the inlet velocity was taken as 2 m/s, 3 m/s and 4 m/s. The pressure at the outflow was kept constant at 0 Pa to allow for a comparison study. In the simulation, air is a compressible gas, water is a volume component, and mud is a fluid with the power-law "s = 0.59(dv/dy)0.71" [15]. Table 2 shows the initial values for the material attributes. FLUENT 13.0, a commercial finite-volume CFD code, are used for all calculations.

Table 2. Material properties of the drill fluids

Drilling fluid	Viscosity (Pa s)	Density (kg/m^3)	Thermal conductivity (W/(m K))	Specific heat capacity (kJ/(kg K))
Mud	0.59	1200	1.731	1.675
Water	0.001	997	0.6	4.182
Air	1.788 x 10-5	1.226	0.242	1.006

4. Results and discussion

4.1. Stress distribution

Stress at the transition zone is greater than in other regions of the pipe and tool connection when subjected to axial tensile force [3]. The stress concentration factor (K_t) in the round corner of the transition zone is the most dangerous. If the radius is smaller than 100 mm, it is simple to produce oscillations in the K_t curves of the stress concentration factor. When the transition length is 150mm and the radius is 290mm, the factor of stress concentration (K_t) is at its lowest, and the optimal structure size is achieved.

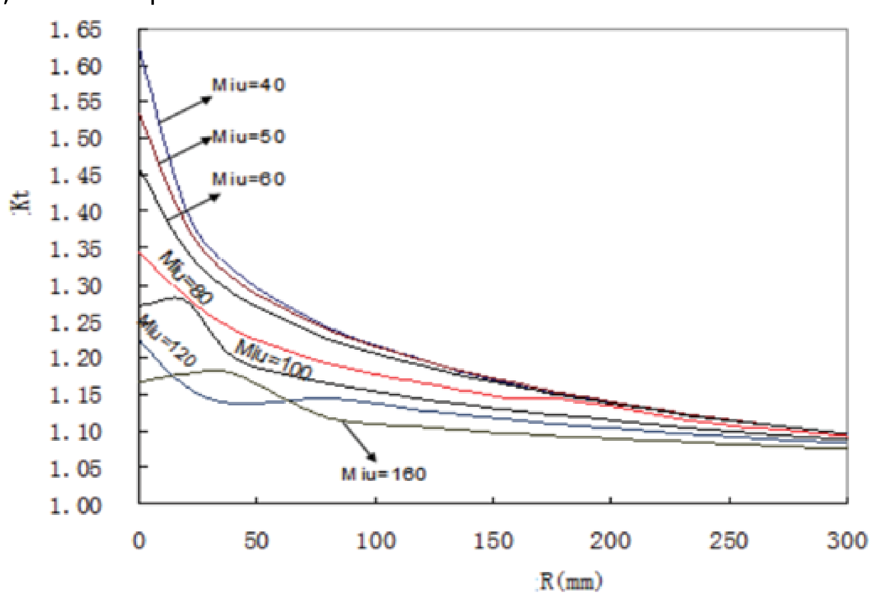

Figure 4. Stress concentration factor (K_t) and transition radius (R).

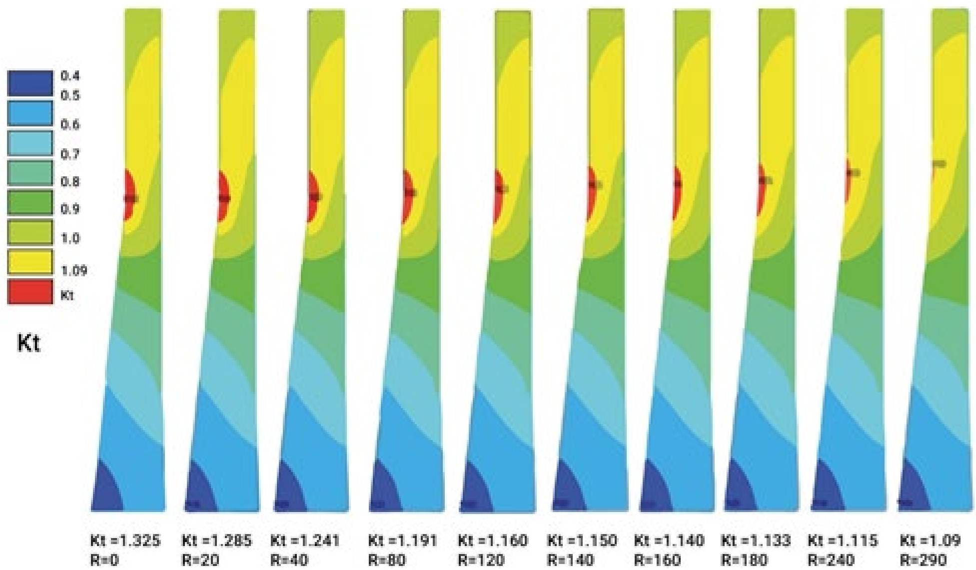

Figure 5. Changing of Kt with R when Miu is 70 mm.

4.2. Flow field simulation

The distribution of velocity and pressure in the transition zone area is given in Figure 7. In the transition zone at the pin thread, there is a large pressure reduction. The rule of conservation of energy can be used to comprehend this. In normal drilling operations, the drilling fluid flow rate remains constant, i.e., a steady flow is present in the drill pipe [19]. As a result, the cross-sectional area of the stream is reduced, the stream velocity increases [17]. Pressure is reduced as kinetic energy is increased to the detriment of pressure energy.

The pressure change trend is reversed in the transition zone area close to the box thread. The abrupt pressure change is specifically noticeable in the transition zone area link. The site stream channel is beginning to grow due to a local low-pressure condition. In addition, there is a local high-pressure connection between the transition zone area and the body of the drill pipe [20]. As a result, pressure variability is visible in the transition zone area close to the box thread. The pipe wall erodes repeatedly, as Eddy currents are formed. This is one of the causes for the presence of perforation in the transition zone area close to the box thread.

Out of the all the drilling fluids, Mud has the highest viscosity resulting in the most frictional loss. As a result, the mud drilling's pressure drop is the largest. The local low-pressure's maximum area is also the largest. Water is a fluid with a viscosity greater than air. As a result, in water drilling, the pressure deprivation and the local low-pressure area presumes second position and the pressure drop is minimum in air drilling.

Figure 6 shows, the dispersion of velocity affecting the distribution of shear stress in the pipe walls. The higher the shear stress in the pipe wall and lesser in the pipe diameter. Due to the alteration in the flow channel, abrupt changes are visible in the shear stress of the pipe wall at the transition zone's areas. In the middle of the transition zone area and the body of the pipe, the minimum value occurs. The maximum value is displayed in the link between the transition zone area and the joint of the drill pipe. Drill pipe walls are subjected to the most stress because the shear stress in the pipe walls is interconnected to the viscosity of drilling fluid. Second place goes to water and the bare minimum is air.

When the inlet velocity is kept constant, mud has extreme scouring effect on the pipe walls specifically near the transition zone area of the drill pipe, particularly at the box thread.

We've all learned that increasing drilling fluid displacement improves rock-cracking and cuttings-carrying capacity. Changes in displacement, on the other hand, impacts the drilling fluid flow field in the transition zone area. Three different input rates were selected to represent three different mud displacements.

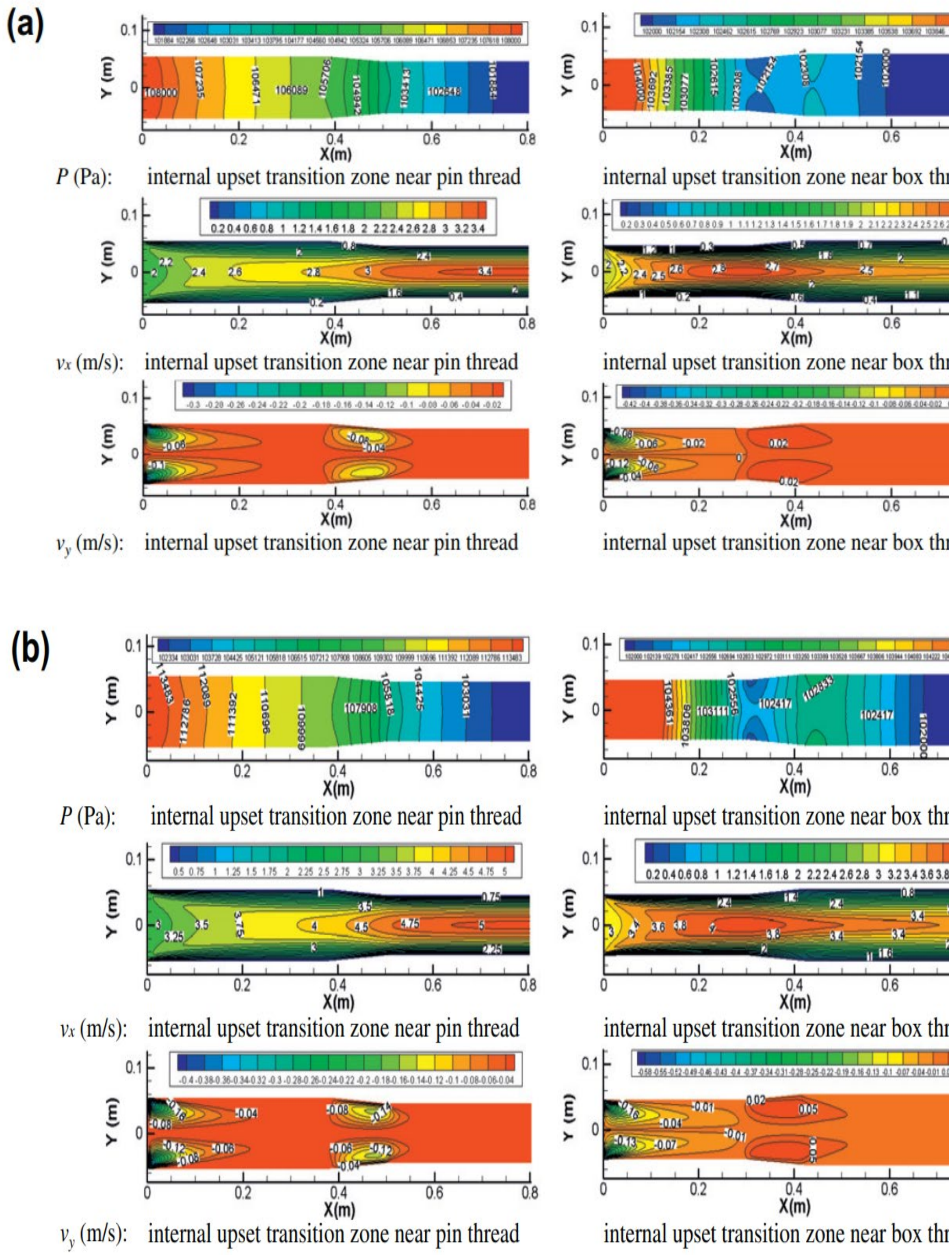

Figure 6. Pressure and velocity distribution under different inlet velocities in mud drilling: a) v=2m/s b) v=3m/s.

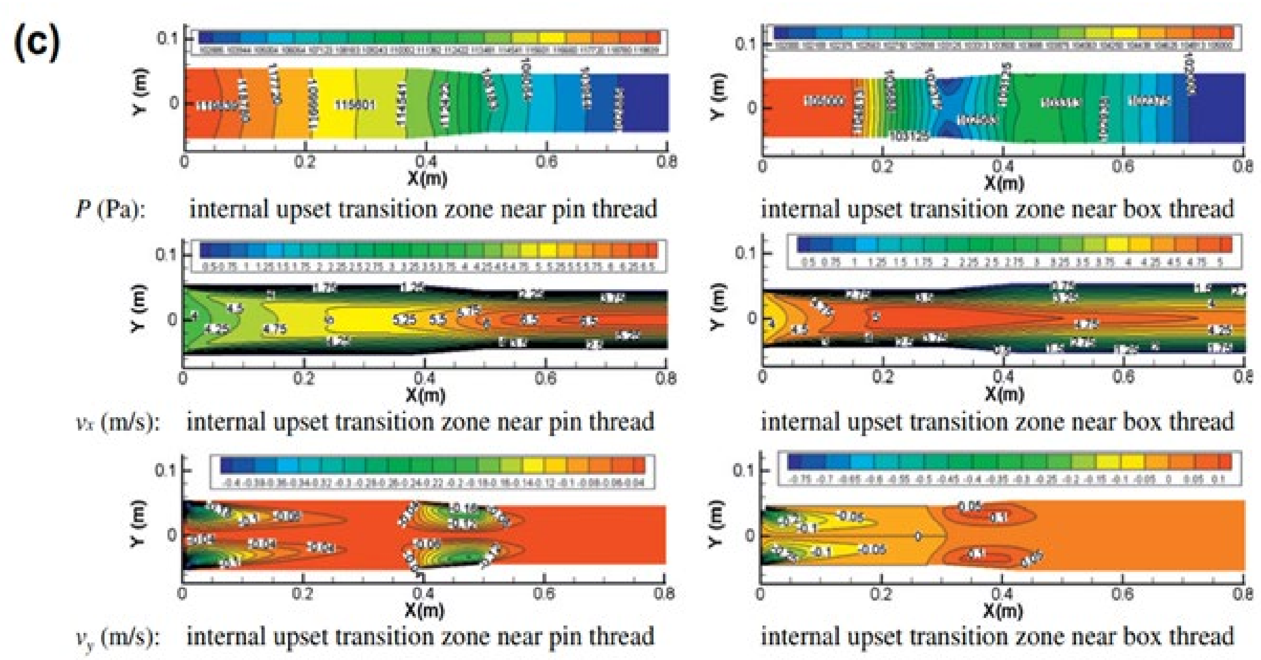

Figure 6. Pressure and velocity distribution under different inlet velocities in mud drilling c) v=4m/s.

In Figure 7, the pressure and velocity trend in the transition zone area in drilling with mud at three different inlet rates is portrayed. The larger the displacement for the greater the velocity at the inlet, result in a larger tangential velocity gradient. In addition, stream alterations in the transition zone area, particularly at the connection in the middle of the pipe and the transition zone, resulting in washout of the pipe by the flowing fluid. The erosion becomes more intense as the speed increases. Pressure builds up in the transitory fillet close to the box thread. When a fault occurs, the increase in pressure causes the defect to grow even larger.

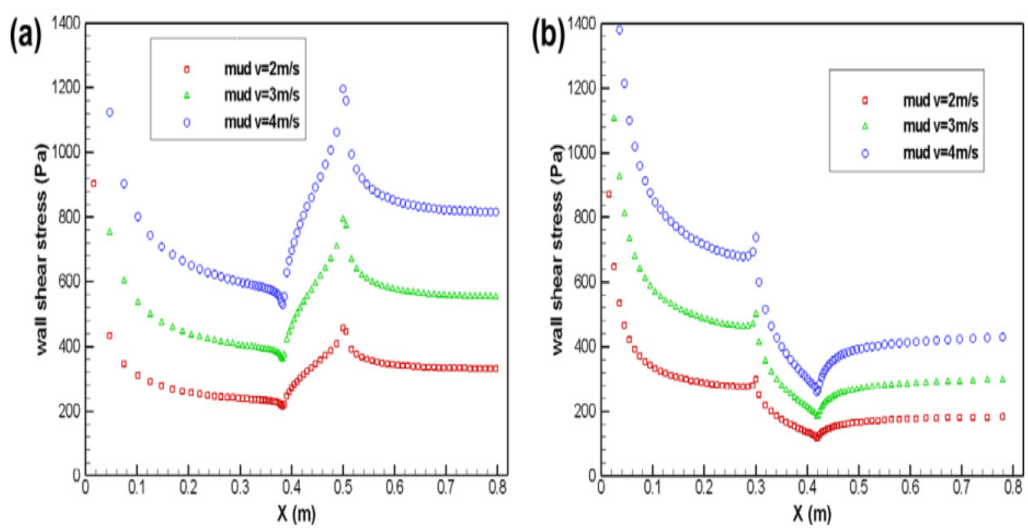

Figure 7. Wall shear stress distribution under different inlet velocities in mud drilling: a) Close to the pin thread, b) Close to the box thread.

Figure 7 depicts the shear stress distribution of the pipe wall at various flow rates. A higher drilling fluid flow rate results in a larger shear stress on the pipe wall at the transition zone area. The drilling fluid flow rate should be set so that the drilling rate is reasonably improvised, as well as the scouring of pipe walls is minimal.

5. Conclusions

Performed the drill pipe stress analysis and advancement of the oil drilling is addressed in this study. Stress at the transition zone is greater than in other regions of the pipe and tool connection when subjected to axial tensile force. The stress concentration factor (K_t) in the round corner of the transition zone is the most dangerous. If the radius is smaller than 100 mm; it is simple to produce oscillations in the K_t curves of the stress concentration factor. When the transition length is 150 mm and the radius is 290 mm, the stress concentration factor K_t is at its lowest, and the optimal structure size is achieved. The distribution of pressure and velocity in the internal upset transition zone is given in Figure 7. In the transition zone at the pin thread, there is a large pressure reduction. The rule of conservation of energy can be used to understand this phenomenon. The pressure change trend is reversed in the transition zone near the box thread. There is a local high-pressure connection between the transition zone and the drill pipe body. As a result, pressure variability is noticeable in the internal upset transition zone near the box thread. Eddy currents are formed which repeatedly erode the pipe wall. This is one of the causes for the presence of perforation in the transition zone near the box thread. Mud has the highest viscosity of the three drilling fluids, resulting in the most friction loss.

References

[1] Yonggang LU, Fangpo LI, Xin XU, Biyu YG, Caihong LU. Simulation Technology in Failure Analysis of Drill Pipe. Procedia Eng., 2011; 12: 236-241.

[2] Zhang YZ, Zhang JM, Shi ZJ. Application and development of numerical simulation for underground horizontal directional drilling. J. Coal Sci. Eng. 2012;18:101-107.

[3] Shaaban S. Design and optimization of a novel flowmeter for liquid hydrogen. Int. J. Hydrog. Energy., 2017; 42(21): 14621-14632.

[4] Zhu H, Lin Y, Zeng D, Zhou Y, Xie J. Simulation analysis of flow field and shear stress distribution in internal Upset transition zone of drill pipe. Eng. Fail Anal., 2012;21:67-77.

[5] Rahman MK, Hossain MM, Rahman SS. Survival assessment of die-marked drill pipes, integrated static and fatigue analysis. Eng. Fail. Anal. 1999;6:277-299.

[6] Horbeek JH, Birch W, McMahon MJ, Fearnley K. Successful reduction of North Sea drillstring failures. SPE Offshore Europe Conference. Aberdeen, UK, September 1995.

[7] Hill TH. Successful reduction of North Sea drillstring failures. World Oil, 1984; 18: 64–68.

[8] Albdiry MT, Almensory MF. Failure analysis of drillstring in petroleum industry: A review. Eng. Fail. Anal,. 2016; 65: 74-85.

[9] Li HL, Li PQ, Feng YR. Failure analysis and prevention of drill pipes. Pet. Ind. Pres. 1999; 4: 122-137.

[10] Luo FQ. Failure mechanism and countermeasures of drill string in Tarim Oilfield Southwest Petroleum University, Faculty of Petroleum Engineering, Chengdu 2006.

[11] Yuan GJ, Yao ZQ, Wang QH. Numerical and experimental distribution of temperature and stress fields in API round threaded connection. Eng Fail Anal., 2006;13:1275–84.

[12] LIU Hui. Failure Analysis of S135 Drill Pipe. Dril. Prod. Tech,. 2009; 04: 26-29.

[13] Jie Z, Qiang L, Shuanlu L. Investigation of Failure Causes for Drill Pipes Used in Tarim Oil Field and Relevant Preventative Actions. Steel Pipe, 2010; 04: 11-14.

[14] Kristoffersen S. Improved fatigue performance of threaded drill string connections by cold rolling. Ph.D. thesis, Norwegian University of Science and Technology, Norway. ISBN 82-421-5402-1, 2002.

[15] Shuan-lu L, Gian LF, Lin G. Cause analysis on drilling pipe wash out and preventive measure Oil Fld. Equip,. 2006; S1: 4-7.

[16] Fang-po L, Yong-gang L, Cai-hong L. Pieced Failure Analysis of ij127mm G105 Drilling Pipe Upse .' Oil Fld. Equip., 2010; 11: 10-13.

[17] Zhu H, Lin Y, Zeng D, Zhou Y, Xie J. Simulation analysis of flow field and shear stress distribution in internal upset transition zone of drill pipe. Eng. Fail. Anal., 2012; 21: 67-77.

[18] Fang-po L, Yong-gang L, Kai L. Failure analysis of G105 drilling pipe. Heat Treat. Met., 2009; 10: 27-29

[19] Yong-gang L, Jian-wen S, Kai L.' Failure Analysis on Fracture of a S135 Drilling Pipe Oil Fld. Equip., 2007; 05: 15-18.

[20] Baryshnikov A, Calderoni A, Ligrone A. A new approach to the analysis of drill string fatigue behavior. SPE Dril. Compl., 1997; 12: 77–83.

[21] Hicham F, Ahmed H, Titus N, Mohammad Aziz R, Ibrahim H, Ahmed H. CFD method for analysis on the effect of drill pipe orbital motion speed and eccentricity on the velocity profiles and pressure drop of drilling fluid in laminar regime. Pet. and Coal, 2019; 61(5): 1241-1251.

To whom correspondence should be addressed: Dr. Bandaru Kiran, School of Chemical Engineering, VIT, Vellore, India; e-mail: bandaru.kiran@vit.ac.in