TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, Mechanics, and Engineering
Vol. 64, Issues II, September, 2021

ON THE DESIGN OF THE PIPE CUTTING SYSTEM AT THE HORIZONTAL ERUPTION PREVENTION OF OIL RIG

Marius STAN, Costin Viorel VLĂȘCEANU

Abstract: *The eruption preventers have traditionally been developed using conventional construction methodologies. Today the needs of industry are changing very quickly, forcing some fundamental printing changes. In the present paper, the authors proposed to analyze the cutting operation of a horizontal eruption preventer using deformation energy theory and the finite element method, analyzing in the first phase a drilling specimen with minimal specifications followed by an analysis of behavior to the cutting operation of a drill rod with improved characteristics, resulting in a need to optimize the drive system by mounting a force amplifier.*

Keywords: *eruption prevention, sealing cutting jars, tensions, displacements, maps, MEF*

1. INTRODUCTION

Once the fluid in the layer begins to enter the well hole, different types of eruption preventer can be used to seal the annular space when the drilling rod is in the well, but only the etching bullet rash preventers have been designed to close (by cutting the drilling rod) and seal the wellbore in the event of an unexpected blowout.

Therefore, the last resort for the preventer assembly to close the probe is to activate the sealing slots. Therefore, the failure of sealing cutting bins can cause disasters, as happened in the Gulf of Mexico.

The disaster is a major explosion of crude oil, natural gas or the atmosphere or a productive layer after exceeding reasonable operating limits.

If the hydrostatic pressure given by the weight of the drilling mud is lower than the formation pressure, an explosion will occur. Control measures must be taken to prevent an explosion.

The main means of good control in drilling operations is achieved by the hydrostatic pressure, which is given by the weight of the drilling mud, which maintains the pressure in the formation and prevents the penetration of hydrocarbons into the well.

Explosion prevention devices (BOPs) are pressure regulating devices and are used as a good secondary means of control.

It acts as a safety barrier by controlling the molding pressures and the liquid that occurs in the well. The BOP consists of various sets of rams, of which the Blind Shear Rams (BSR) are used as the last line of defense for cutting the drill pipe and sealing the well.

The properties of the drill pipe have been dramatically improved to reduce the likelihood of damage to the drill pipe during the drilling operation.

These improvements increase material strength and ductility. As a result, large shear forces are required to cut a particular drill pipe.

This study aims to demonstrate that for the BOP skid bar, we need to optimize the operating system by adding a booster that will increase the shear force and help us close the well in an emergency, regardless of the conditions.

Explosion prevention devices (BOPs) are pressure regulating devices and are used as a good secondary means of control. It acts as a safety barrier by controlling the molding pressures and the liquid that occurs in the well. The BOP consists of various sets of rams, of which the Blind Shear Rams (BSR) are used as the last line of defense for cutting the drill pipe and sealing the well.

Drill pipe properties have been dramatically improved to reduce the likelihood of drill pipe failure during a drilling operation. These improvements increase material strength and ductility. As a result, large shear forces are required to cut a particular drill pipe.

This study aims to demonstrate that for shear BOP we need to optimize the operating system by adding a booster that will increase the shear force and help us close the well in an emergency, regardless of the conditions.

2. TUBULAR MATERIAL SHARING

Plus, even though we call them Shear Rams, rams don't cut themselves like they break a drill pipe. The vanes are cut into the tube at a short distance to form a tension riser, and then the tube is torn under tension according to the angle of the face of the vanes. See Figure 1.

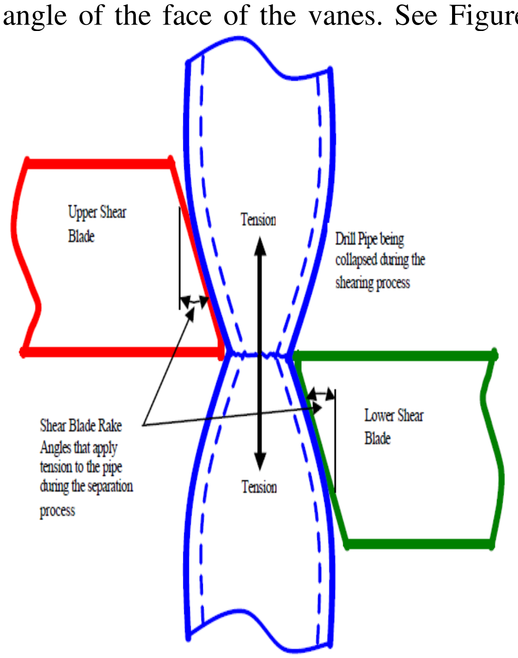

Figure 1 – Upper and lower cutting knives that crush the drill pipe and start cutting (or breaking)

1.1 Study of the adjustment process with the possibility of optimizing the operating system

In the first phase of the study according to API Standard Spec. 16A, for testing the shear operation performed by the 13B x 10k Shear Ram Blowout Preventer (SRBOP), the standard proposes that the test be performed using a 5-inch G-105 steel drill pipe.

The finite element shear operation study will take into account future observations:

• The test pressure will be generated by a hydraulic test unit capable of developing a pressure of 28 MPa;
• The pressure on the surface of the hole is 14 MPa;
• The drill pipe sample has a length of 1200 mm;
• the frictional forces between the parts that are in contact are negligible;
• good pressure equals atmospheric pressure;
• The tested drill pipe has no axial load.

2.1. The description of the geometrical and material characteristics of the drill pipe

The drill pipe characteristics are specified by the API 5DP standard.

Table 1 focuses on the parameters of size 5 in a drill pipe with a wall thickness s (g) of 9.19 mm and in Table 2 we found the properties of material class G-105.

Table 1 – Pipe dimensional data

Outer diameter	Inner diameter	Wall Thickness	Cross-sectional area
O.D	I.D	t	A_{dp}
[mm]	[mm]	[mm]	[mm2]
127	117,81	9,19	1767

Table 2 – Pipe mechanical data

Drill-pipe-body grade	Yield strength		Tensile (Ultimate) strength	Elongation
	σ_y		σ_{us}	E
	[N/mm2]		[N/mm2]	[%]
	Min.	Max.	Min.	Min.

G-105	724	931	793	15

2.2.Shearing process study for the 5in G-105 drill pipe

According to the principle in Figure 1, the geometric pattern of the drill pipe has two opposite notches which have a radial angle of 140 degrees formed by the V-shape of the rams and the vertical distance between the notches is 3 mm, which represents the distance between the upper and lower ram blades.

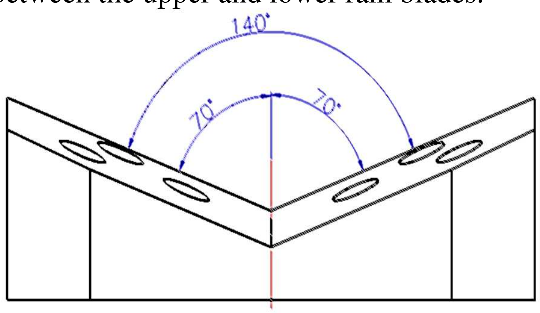

Figure 2 – The shear ram blade with V shape

In figure 3 is presenting the drill pipe sample tridimensional model that is fixed at the bottom part and in the placement area of the shearing forces. Simulation cuts with the MEF for data case in the next. A blowout will occur if the hydrostatic pressure imparted by the weight of the drilling mud is less than the pressure from the formation. Well, control measures have to be taken to prevent a blowout.

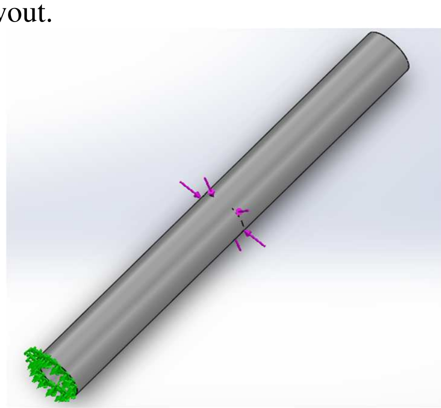

Figure 3 – Drill pipe sample 5in G-105 geometric model

We'll use the Distortion Energy Theory shear equation to estimate the required shear force for shearing operation: $F = 0{,}577 \cdot \sigma_y \cdot A_{dp}$ (1)

So for the 5 in G-105 drill pipe we have:

$$F = 0{,}577 \cdot 724 \cdot 176 = 738{,}160\ kN$$

The net effective shear force (i.e the maximum net force required to shear and seal, taking into account opening pressure/area and closing pressure/area) is specified by API 16 A standard and is determined by the next formula:

$$F_{eff} = (P_c \cdot A_c) - (P_o \cdot A_o) \qquad (2)$$

Where:

- F_{eff} is the net effective shear P_c is the closing pressure
- P_o is the opening pressure
- A_c is the closing area
- A_o is the opening area

$$A_c = \frac{\pi}{4} \cdot \left(D_p{}^2 - D_{t.i}{}^2\right) mm^2, \qquad (3)$$

where D_p is the operating piston diameter which is $D_p = 320\ mm$ and $D_{t.i}$ is the operating piston rod from the closing part which is $D_{t.i} = 90\ mm$

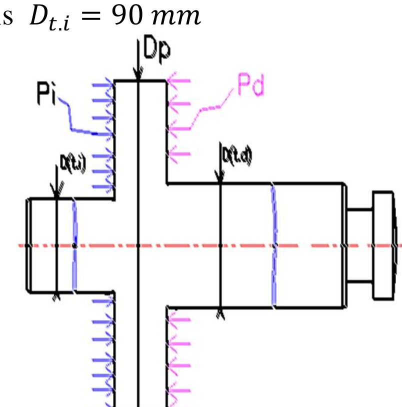

Figure 4 – Operating piston

In figure 4 are represented the formula's notations (2) for the operating piston cross-section.

$$A_i = \frac{\pi}{4} \cdot (320^2 - 90^2) = 74063\ mm^2$$

$$A_d = \frac{\pi}{4} \cdot \left(D_p{}^2 - D_{t.d}{}^2\right) mm^2, \qquad (4)$$

where $D_{t.d}$ is the operating piston rod from the opening part which is $D_{t.d} = 120\ mm$

$$A_d = \frac{\pi}{4} \cdot (320^2 - 120^2) = 69115\ mm^2 \quad (4')$$

$$P_c = 28\ N/mm^2 P_o = 14\ N/mm^2$$

It is calculated the characteristic effective shearing force of the operating system with the expression used above result: F_{eff}=1.106 MN

So by applying the effective shearing force (4',4'', *Feff*) on the tridimensional model of the drill pipe sample we will obtain the following results generated by the FEM program help.

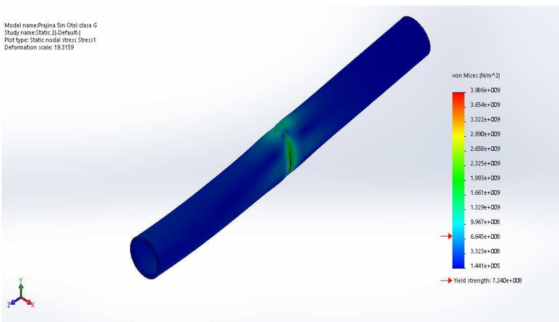

Figure 5 – Stress map for 5in G-105 drill pipe

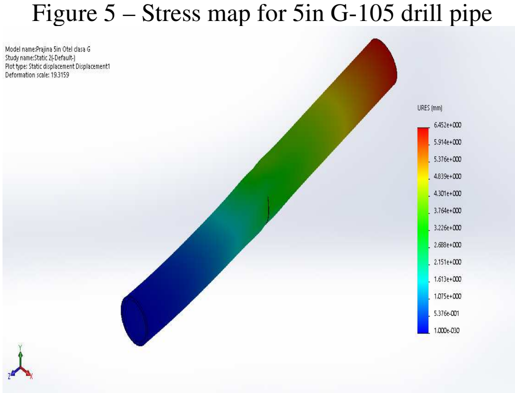

Figure 6 – Displacements map for 5in G-105 drill pip

As is it shown in figures 5 and 6, the maximum values of the tensions and displacements are:

- Maximum stress: 3987 Mpa;
- Maximum displacement : 6,45 mm.

In conclusion of the study performed above, it has shown that the yield strength of the drill pipe material is exceeded with a superior value which generates us that the shearing process of the drill pipe occurred. The improvements in drill pipe properties, particularly increased material strength and ductility, have also resulted in higher forces required to shear the drill pipe.

In table 3 is focused on the size parameters of the 5 in drill pipe, with a wall thickness, s(g), of 12,7 mm.

Table 3 – Pipe dimensional data

Outer diameter	Inner diameter	Wall Thickness	Cross-section al area
O.D	I.D	t	A_{dp}
[mm]	[mm]	[mm]	[mm2]
127	114,3	12,7	2407

In table 4 we found the mechanical characteristics of the S-135 material grade.

Table 4 – Pipe mechanical data

Drill-pipe-body grade	Yield strength		Tensile (Ultimate) strength	Elongation
	σ_y		σ_{us}	E
	[N/mm2]		[N/mm2]	[%]
	Min.	Max.	Min.	Min.
S-135	931	1138	100	13

The increased water depths, combined with the density of the drilling fluid and the shut-off pressure, contribute to the BOP having to create an additional force that affects the shear. In order to improve the strength of the drill pipe and dimensional changes, we will have to analyze test table 3, even for a top drill pipe, which has better properties than the first one. The booster is only available for a fan fuse that uses hydraulic operating systems. Due to the force required to cut the drill pipe 5in S-135 we can

In this situation, it is necessary to assemble a booster in the operating system to increase the shear force and the like to ensure good closing. The booster is only available for a blower fuse that uses hydraulic operating systems. twice as before and adjusting the effective shear force associated with the new operating system can confirm this improvement in shear capacity. Again, we use the shear equation Distortion Theory to estimate the required shear force for the shear operation, so for drill 5 in S-135 we have: F = 1300 kN

With an effective shear force for the booster operating system, the closing pressure (Pc) will act on both the surface of the main piston (Ac) and the booster piston (Ac. B). Formula (2) will therefore be:

$$F_{eff} = P_c \cdot (A_c + A_{c.B}) - (P_o \cdot A_o) \qquad (5)$$

observe that the BOP operating system cannot generate enough force to ensure the shearing function.

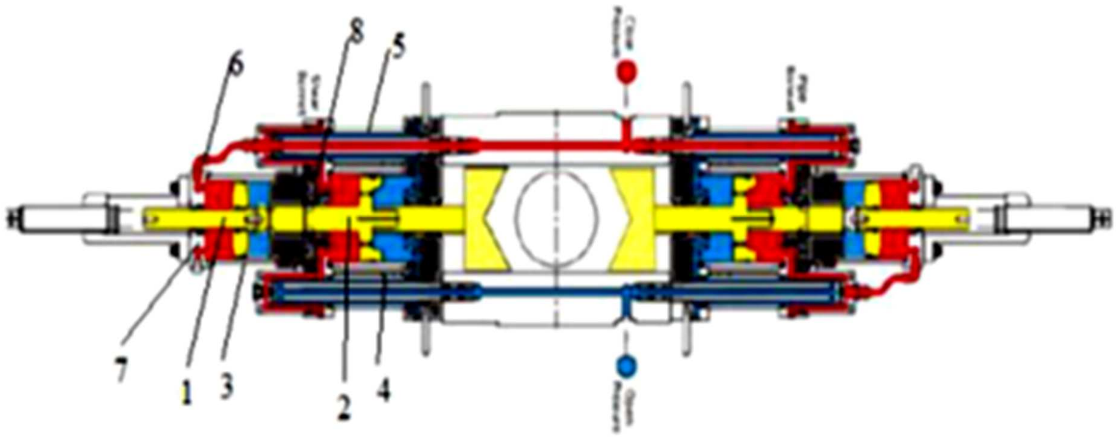

Figure 7 – The representation of the booster which shows hydraulic fluid line red for closing

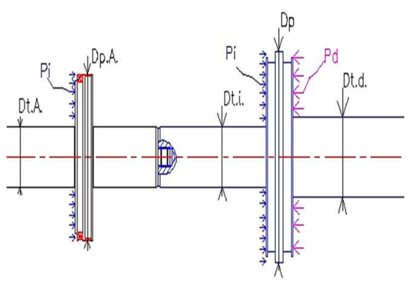

Figure 8 – The structure of the pistons which dual acts

Figure 8 are represented the notations that contribute to effective shear force determinations as a result of the simultaneous action of the two pistons.

$$A_{c.B} = \frac{\pi}{4} \cdot \left({D_{p.B}}^2 - {D_{r.B}}^2\right) mm^2, \qquad (6)$$

where:

$D_{p.B}$ is the booster piston diameter which is, and $D_{t.B}$ is the booster piston shaft diameter which is: $D_{p.B} = 250\ mm, D_{r.B} = D_{t.i} = 90\ mm$, and $A_{c.B} = 42725\ mm^2$

Using the data from the above, in the relation (6), result, $F_{eff} = 2.303$ MN

So by applying the effective shearing force on the tridimensional model of the drill pipe sample we will obtain the next results:

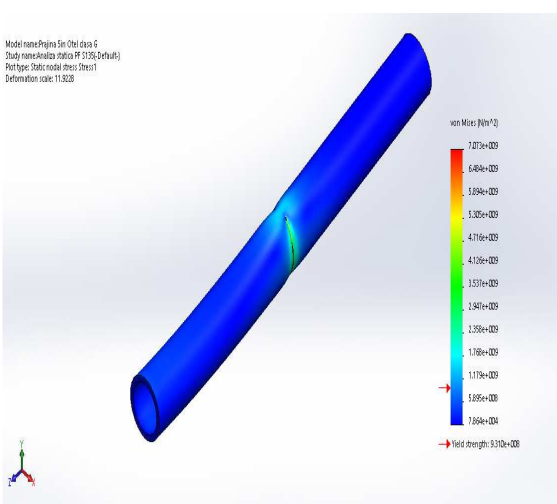

Figure 9 - Stress map for 5in S-135 drill pipe

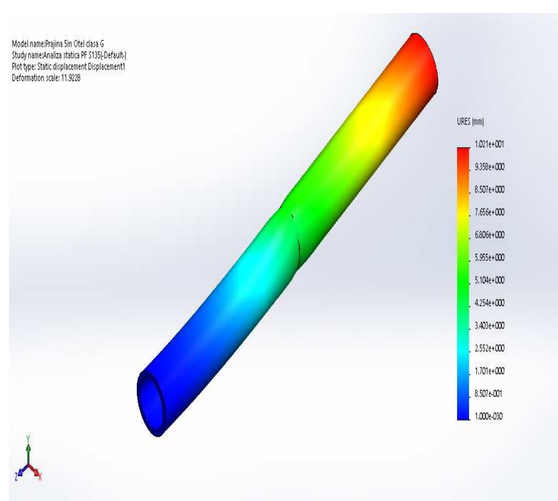

Figure 10 – Displacements map for 5in S-135 drill pipe

As is shown in figures 9 and 10, the maximum values of the tensions and displacements are: Maximum stress =7073 Mpa and Maximum displacement: 10,2 mm

3. CONCLUSION

The conclusion of the study came from the stress and displacement maps where we can notice that the drill pipe with improved characteristics will be cut, the maximum stress was reached which indicate the fact that the shearing operation will be accomplished even for the case of some additional factors which would lead to the necessity of a higher shear force, such as: well pressure; the drill string bending; acting pressure from the hydraulic control system.

4. REFERENCES

[1]Tekin, A., Choi, C., Altan, T., *Blind shear ram blowout preventers: estimation of shear force and optimization of ram geometry*, MSc Dissertation, The Ohio State University, Columbus, OH, US, 2010.

[2]Childs, G., Sattler, J., Williamson, R., *Evaluation of Shear Ram capabilities for the US Minerals and Management Service*, Requisition No. 3-4025-1001, West Engineering Service Inc., pp. 3-6, Texas, US

[3].***, *API Spec 16A Fourth Edition, Specification for Drill-through Equipment*, April 2017.

[4].***, *ANSI/API Spec 5DP First Edition, Specification for Drill Pipe*, august 2009.

Asupra proiectarii sistemului de taiere a tuburilor la prevenitorul de eruptie orizontal al instalatiilor petroliere

Lucrarea cuprinde studiul posibilitatilor de optimizare la proiectarea formei bacurilor de taiere ale materialului tubular de foraj la prevenitorul de eruptie a sondelor, corelat cu cerintele sistemului de actionare al acestuia din cadrul instalatiilor de foraj.

STAN Marius, Associate Professor Ph.D. Eng., Petroleum and Gas University of Ploiesti, Mechanical Engineering Faculty, Department of Mechanical and Electrical Engineering Email: mstan@upg-ploiesti.ro, (+40) 244.575.847.

VLĂȘCEANU Costin Viorel, Lecturer Ph.D. Eng. , Petroleum and Gas University of Ploiești Oil and Gas Engineering Faculty, Department of Petroleum Geology and Reservoir Engineering, Email: viorel.vlasceanu@upg-ploiesti.ro, (+40) 244.573.150