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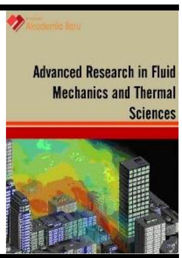

Conductance Study on The Effect of Torsion of Drilling Pipe on The Inside Pattern Fluid Flow

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ABSTRACT

The drilling pipe with convoyed water is commonly concentrated in the present day due to the internal and external complex forces exposed to it. Pumping fluid pressure, hydrostatic head and torsion forces are classified as internal forces, while the drilling wall of the pipe and the total deformation caused by these exposed forces are external forces. In this study, the total deformation generated was analysed. Two cases were examined as a standard operating Craft and Graves [1]. The drilling pipe is made of steel with dimensions length (1.5 m); outer diameter (4 in or 101.6 mm) and inner diameter (3.34 in or 84.836 mm). The parameters were modelled by using (INVENTOR PROF 2016 and ANSYS, V. 16.1 software). The results obtained showed that increasing the twisting force on the drilling pipe walls leads to increment in the radial water flow displacement.

Keywords:
Torsion; Drilling Pipe; Pattern Flow

1. Introduction

The machine member being subjected to the action of two equal and opposite couples acting (torque or twisting moment), is also subjected to both torsion and thrust forces. The stress of torsion is known as torsion shear stress. Its magnitude is zero on the censorial axis and the maximum on the outer surface. Main applications for mechanical creep of the projected torsion on the pipe with conveying flowing fluid inside, induces many forces transformed from the outer pipe-wall under the torsion to the fluid. Eco technological parameters such as, drilling wells, long pipelines, and others need accurate control to avoid impulsive outages for designed lifetime operation systems. The identified problem for the pipeline under tensional action is the fatigue failure in the pipe-wall structure in the complex industrial systems. While the fluid flowing inside pipeline plays an important role in pipeline fatigue pit distribution due to corrosion of the inside pipe-wall.

In their work, Modarres-Sadeghi and Païdoussis [2] indicated that the pit growth can be increased by fluid flow changes inside the pipe due to the torque transformed from pipe-wall to the fluid,

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especially with single-phase flow. In practical applications, most of the system a seem the friction between the liquid flowing inside the pipe with pipe wall, the velocity profile of moving liquid at the maximum value at the centreline of stream flow, while the minimum value may obtain near the wall pipe. The pipe connectors of wellbore are subjected into the compression and twisting loads. These effects cause the pipe under the curvature bending stress. In addition, Mitchell [3]; Łuczko and Czerwiński [4] presented the bending of the beam column of the wellbore pipe equations in 3D for helical buckled pipe. They concluded that the bending stresses becomes greater with used of connector standoff because of high generation of the inertia force. The pipe hydrodynamic transient with fluid structure interaction (FSI) of water hammer was presented by Richard Skalak and worthily introduced by Tijsseling and Lambert [5]. They considered the pressure waves are coupled in loads on radial and axial response of the pipe walls. The dissipated pressure waves provide for long distance pipelines. Skalak's model included the effects of radial inertia of liquids and pipe stress. The model one-time validated experimentally. They obtained that the axial vibration is low frequency with insignificant effect account.

Water hammer, capitation, structural dynamics, and fluid-structure interaction (FSI) effects on the significance of the liquid filled pipe system were studied by Tijsseling [6]. The results showed that the torsion motion of thin walls of liquid-filled pipe systems is satisfactory for most realistic applications. The flexibility and stress-intensification factors to allow for elbow vocalization effects for column separation and vaporous capitation. The model included whole applicable FSI mechanisms and is valid for low-frequency acoustical phenomena. Radial inertia forces were negligible in the long-wavelength pipe. The pipe conveying fluid and subjected to compressive loading was best reviewed by Paıdoussis and Li [7]. They considered focusing on the pipes with supported ends, cantilevered, and conveying compressible or incompressible fluid aspects as the major problems. The stability of vertical and horizontal supported pipe was studied with single end free.

The elastic and inelastic change of the convoying fluid is well reviewed Ibrahim [8]. The dynamic and stability of the flowing fluid inside the support pipe were discussed. His work also noticed the problem of which the pipe made materials. The transmitting loads from the pipe wall to the convoying fluid flowing was concluded as the significant changes on the fluid motion. Many parameters were analysed such as pipe damage by pressure, elastic fluid waves, the dynamic response and stability of long pipes...etc analysed the reflection of the fundamental torsion made to determine reflection coefficient for pipe at different shapes. Steel pipe of schedule 40 with ID (3in or 76.2 mm) was used to study the reflection of corrosion patches rate inside these pipes. They found that the reflection coefficient is at a maximum value located at the maximum depth. Many papers overviewed the dynamics of the filled-pipe fluid system. Li and Karney [9] presented various models to simulate the algorithms of fluid-structure interaction FSI. They listed important affecting parameters such as structure pipe properties, fluid-structure couplings and dynamic character of pipes when conveying fluids.

Their work confirmed that the FSI is correlated with fluid parameters due to the dynamic pipe changes. In addition, Wang and Jiang [10], used 3D models for non-linear flowing to study various kinds of systems for example: supported pipes placed in the vertical or inclined with motion constraints. While Peng and Xiong [11] confirmed that vibrations are additionally induced by external flow as Duan and Chen [12]; And Yang and Ai [13] stated. Furthermore, Guo and Xie [14] studied the cantilevered fluid-conveying micro-pipe.

The persistence of flowing velocity of fluids in the investigated systems respectively as a minor and the buckling effect does not take place yet at high flow velocities. Doll and Mote Jr [15] presented dynamical curved and twisted pipes to conclusion proved to be comparable. Wen and Yang

[16] and Morad [17] investigated the pipe included in a direct section associated to a curved section. The conservatory of the pipe axis was suitably accounted for and natural frequencies of the system which they found to be slightly responsive to fluid flow velocity variations.

The cantilevered pipes of an Eigen-frequency were calculated for metallic pipes. An indicated force of shear rigidity of pipe walls has been shown by Païdoussis and Price [18]. They obtained the shear deformation of drilling pipe walls compared with dynamical fluid flowing is minimal value. The stability of fluid flowing inside drilling pipes is predicated influences with the amount of twisting force which is received from the pipe walls. Many forces play as major roles of an interaction of pipe convoyed fluid as stability or instability form. The theory of linear pipe mechanics which convoyed fluid is studied by Ibrahim [8]. He cartridges as the centrifugal and combine forces acting upon the fluid flowing of drilling pipe convoyed fluid, while the elastic and inertia forces are combined of fluid flowing and pipe inertia. Doll and Mote Jr [15] noted that the centrifugal and combine forces were considered the no conservative property of the fluid flowing, due to the kinetic energy being affected directly by the boundary of the twisting force inside the drilling pipe. It is also noticed in other literature studies that the direction of drilling may induce fractures and borehole breakouts in the direction of, NE-SW for (maximum horizontal in-situ stress) and NW-SE for borehole breakouts (minimum horizontal in-situ stress). The results of this study showed that any hydraulic fracturing operation, EOR operations, drilling operations and the other operations in this field (Gachsaran field) can be planed more accurate. The super-giant Gachsaran field is the second largest oil field in Iran with 67 billion barrels of oil initially in place. It is located onshore in the prolific Zagros Basin, in southwest Iran, 220 kilometres from the city of Ahvaz and close to the town of Dogonbadan Alizadeh and Movahed [19].

From the literature discussed which examines many parameters that identify the combined dynamic motion interaction between the pipe walls and the fluid flowing inside the vertical drilling pipe and the convoyed fluid. This study presents and focuses on the fluid interaction between the convoyed fluid and the inside of the pipe walls. The drilling pipe walls are subjected to torsion and torsion deformation along the pipe. This deformation was transferred to the inside fluid flowing due to direct contact between this fluid and inner pipe walls.

2. Theory

The pipe-wall for the well-bore is subjected to the plastic deformation due to the slip occurring along with the crystallographic directions of the individual crystals, together with some flow of the pipe-wall boundary materials. Due to the fluid head, the pressure inside the drilling pipe increases by (66%) which showed by Rabia [20]. While, Peurifoy and Ledbetter [21] presented the torsion reflects directly with step relation by (50%) from the supply once through the drilling pipe wall. These two main assumptions will be considered to simulation the scenario of drilling pipe fluid behaviour with the amount of the pipe-wall creep material.

The following assumptions were summarized to achieve the simulation.

i. The parameters carryout of the drilling pipe wall achieved used INVINTOR Pro. 2016, while ANSYS 16.1 used for convoyed water, both are three-dimensional geometry.
ii. Two forces exposed on the drilling pipe, one is the inside pressure force from the convoyed water, and the other is from the torsion force of the drilling pipe wall.
iii. Steady state study flow fully developed flow of convoyed water.
iv. Isothermal flow and the fluid gravity effect through the vertical direction.
v. The convoyed fluid is suggested to use water properties to examine the test of the drilling pipe.

The transmitted torque through the drilling pipe-wall, supposed the r_1 and r_2 are the internal and external radii, respectively, as show in Figure 1.

The torsion shearing stress is represented by the total torque on the pipe is

$$T = \int_{r1}^{r2} 2\pi r^2 \tau dr \tag{1}$$

As the assumption of the constant pipe radii, the twist angle in implement to consider the material under elastic deformation as follows

$$\tau = \frac{G\theta r}{L} \tag{2}$$

Then Eq. (1) becomes

$$T = \int_{r1}^{r2} \left(\frac{G\theta}{L}\right) 2\pi r^2 dr = \frac{G\theta J}{L} \tag{3}$$

where

$$J = \int_{r1}^{r2} 2\pi r^2 dr \tag{4}$$

The mathematical relation for complex stresses for the pipe-rotate subjected to the torsion forces for yielding materials. The yielding material under a situation of combined stresses can be considered as a combination of principal stresses. The energy of criterion or (Distortion Energy) which presented by (Von Mises 1913) for yielding of the second stress deviator (J_2) for some critical value as

$$J_2 = k^2$$

where

$$J_2 = \frac{1}{6[(\sigma_2-\sigma_1)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2]}$$

The constant (k) represent the yield stress in torsion can be evaluated base on yielding of torsion forces for un-axial torsion of

$$\sigma_1 = \sigma_o, \sigma_{2=}\sigma_3 = 0 \quad \text{and} \quad \sigma_o^2 + \sigma_o^2 = 6k^2$$

Then

$$\sigma_o = \sqrt{3k} \tag{6}$$

By substituting Eq. (5) into Eq. (4) to obtain on the Von Mises as:

$$\boldsymbol{\sigma_o = \frac{1}{\sqrt{2}}[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2]^{\frac{1}{2}}} \tag{7}$$

by combining with shear stress, it can obtain on

$$\sigma_{\downarrow o} = \frac{1}{\sqrt{2}}[\left(\sigma_{\downarrow x} - \sigma_{\downarrow y}\right)^{\uparrow 2} + (\sigma_{\downarrow y} - \rho_{\downarrow z})^{\uparrow 2} + (\sigma_{\downarrow z} - \sigma_{\downarrow x})^{\uparrow 2} + 6(\tau_{\downarrow xy^{\uparrow 2}} + \tau_{\downarrow yz^{\uparrow 2}} + \tau_{\downarrow xz^{\uparrow 2}}]^{\uparrow\left(\frac{1}{2}\right)} \tag{8}$$

where σ_o represent the un-axial yielding torsion stress.

The torsion forcer's production at yielding stress show as

$\sigma_1 = -\sigma_2 = \tau$, when $\sigma_2 = 0$

Therefore,

$\sigma_1^2 + \sigma_1^2 + 4\sigma_1^2$=$6k^2$

$\therefore \sigma_1 = k$

Therefore, the Von Mises predicts the yield stress is less than torsion stress as show from below.

$$\boldsymbol{k = \frac{1}{\sqrt{3}}\sigma_o} \tag{9}$$

The Von Mises work theorem on the principal stresses of twisted pipe filled with water Case and Chilver [22]. The drilling pipe is subjected to thrust force with twisting. The direct stresses due to the compression load must be combined with the shearing stresses due to torsion in order to evaluate the principal stresses along with the drilling pipe. Suppose the drilling pipe is axially loaded in compression and torsion forces, there will be a stress (σ) at all points of the pipe. The principal stresses in this case as shown in Figure 1.

The following equation

$$\boldsymbol{\frac{1}{2}\sigma^2 \pm \frac{1}{2}\sqrt{(\sigma^2 + 4\tau^2)}} \tag{10}$$

And the maximum shearing stress, as

$$\tau_{max} = \frac{1}{2}\sqrt{(\sigma^2 + 4\tau^2)} \tag{11}$$

Particularly, the torsion forces are acting on the drilling pipe wall and transmitting to the water element as demonstrated Figure 2. The water exposed into two forces; the first is the flow and pressure forces due to pumping and the hydrostatic head of fluid accumulated inside pipe. The second force is the force of torsion transmitted due to the direct contact of moving water element contrarily with inside pipe-wall.

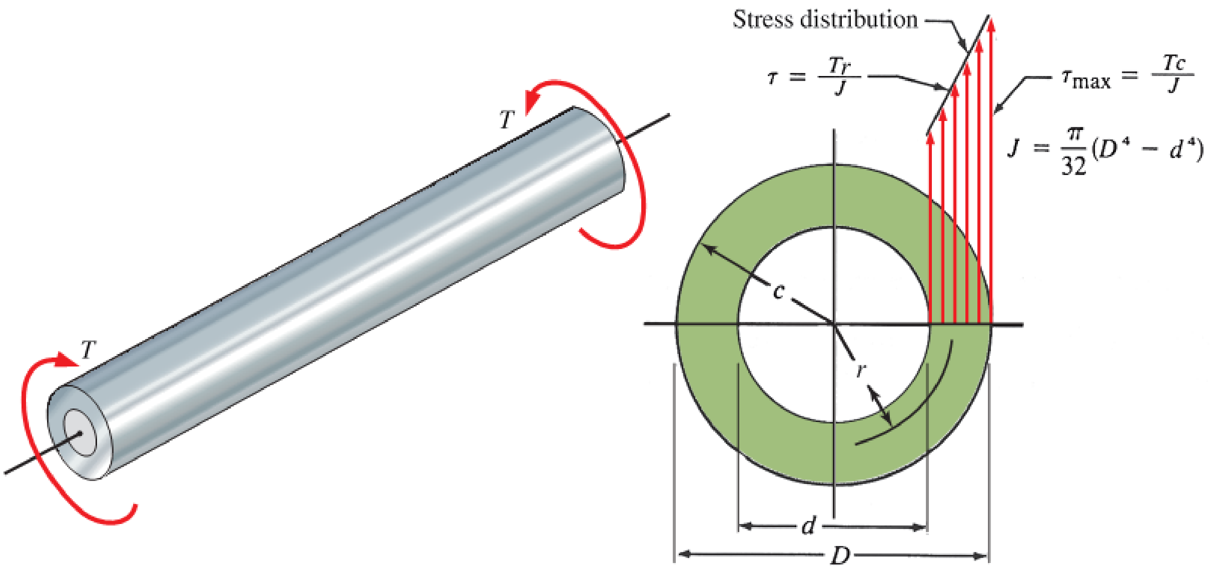


Fig. 1. Directional combined compression and torsion forces loaded on the drilling pipe wall Case and Chilver [22]

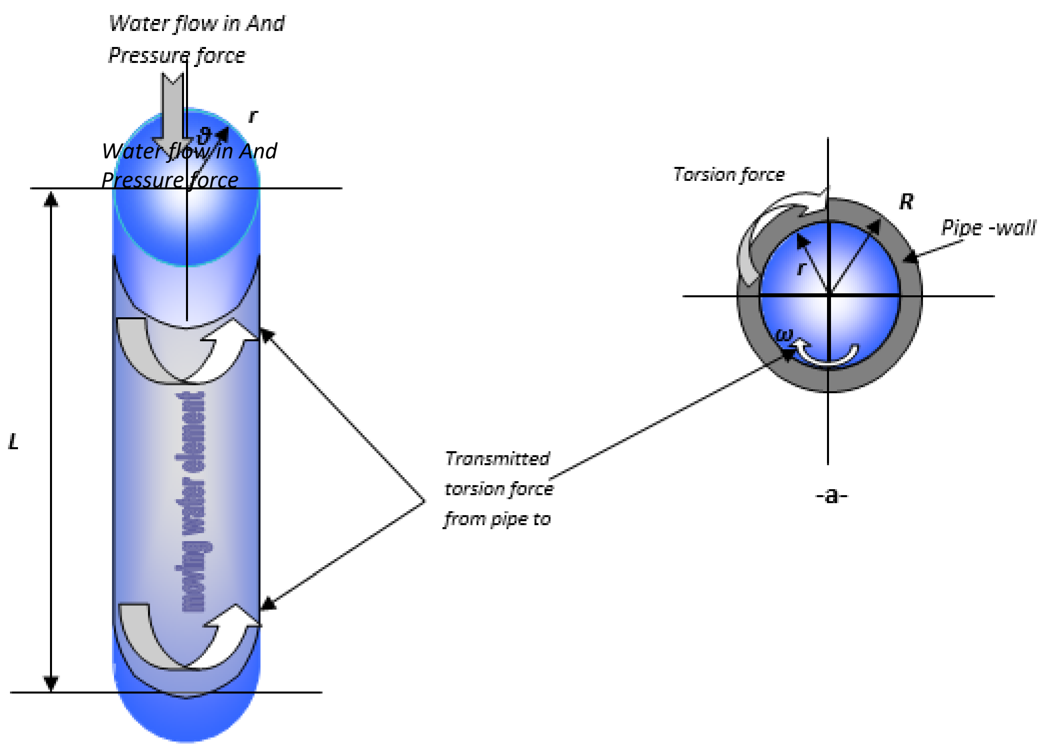


Fig. 2. Torsion force acting on, a) straight pipe exposed to torsion force, b) moving water element

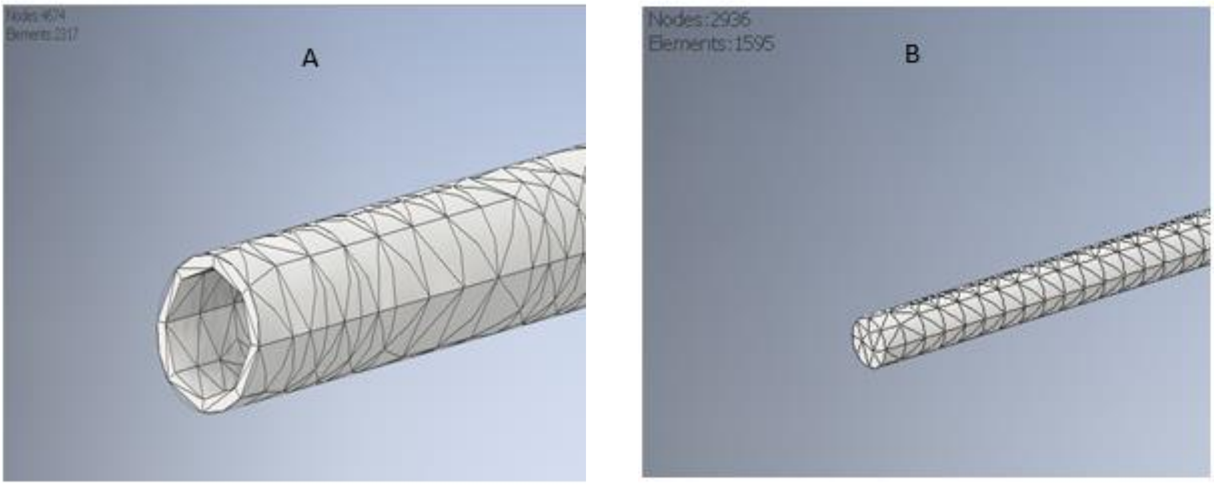
Form the opened literatures it can predicts on one of the important parameters which direct affecting of the flow of water inside drilling pipe it is radial displacement (RD), the formula presented by Tijsseling [6] as

$$RD = \frac{R^2}{tE} P_f \quad (12)$$

where, R=inner radius, t= pipe wall thickness, E= Young's modulus, and P_f =fluid pressure.

3. Computational Domain Test

Figure 2 clearly shows the model which to be tested of drilling pipe well with included water in downstream domain. The model was tested use the AUTODESCK INVENTOR Prof. 2016 to calculate the Von Mises solved with 3D drawing of the drilling pipe geometry. The pipe geometry of length (1.5 m) with outer diameter (4 in or 101.6 mm) and inner diameter (3.34 in or 84.836 mm) as applied in Craft and Holden [23]. The flow of water assumed turbulent flow. The geometry has been analysed for 3D-axis-symteric mashing of the drilling pipe wall (4674 nodes and 2317 elements) while for water domain is (2936 nodes with 1595 elements) as shown in Figure 3.



(a) (b)

Fig. 3. The nodes and elements of (a) drilling pipe wall, (b) water domain

4. Results and Discussions

The 3D drilling pipe wall was completely simulated using INVERTOR PROF. 2016, for the applied parameters. These parameters were obtained with characteristics of length (1.5 m) with outer diameter (4 in or 101.6 mm) and inner diameter (3.34 in or 84.836 mm). Two cases were tested for drilling pipe wall and water convoying inside this pipe as listed in Table 1.

Figure 4(a) shows the 3D applied torsion at the ends of the pipe with water pressure supplied of drilling pipe wall. The opposite direction of the torsion refers to the change in the direction of twisting load. While Figure (4)b shows the water convoyed inside the drilling pipe.

Table 1
The operating parameters

	Supply torsion (drilling pipe wall) N/m	Reflected torsion (drilling pipe wall) N/m	(supply water pressure (water inside drilling pipe) MPa	Hydrostatic water pressure MPa
Case 1	750	500	0.3	0.45
Case 2	1000	660	0.4	0.6

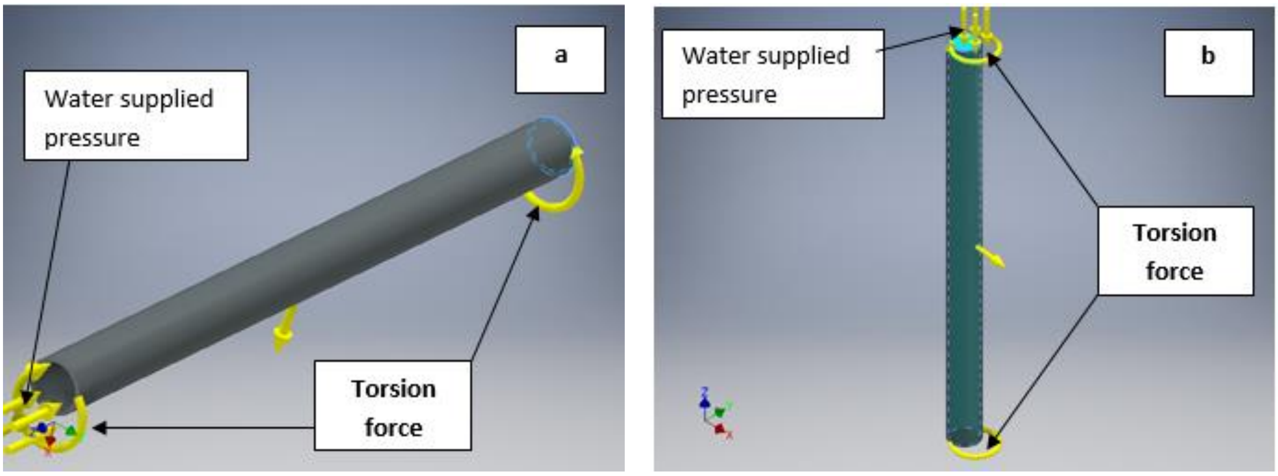


Fig. 4. The 3D of the applied loads of (a) the drilling pipe wall, (b) the water convoyed inside drilling pipe

To compute the Radial Displacement of the pipe wall, see Figure 5, which the best summary of flow algorithm work of INVENTOR Pro. 2016.

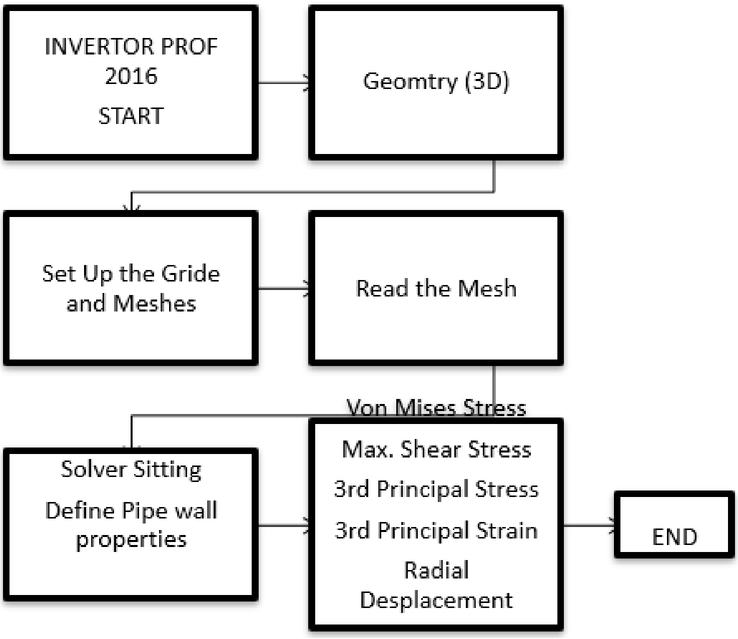


Fig. 5. Flow chart of the solution procedure

4.1 Case 1

Figure 6(a) shows the total displacement due to the applied torsion load from the supplied (A) end to the reflect end (B) of the drilling pipe wall. The elastic deformation observed slightly changed due to the stuffiness drilling pipe materials. While Figure 6(b) shows the total displacement of the water deformation inside the drilling pipe. The transmitted force from the pipe wall to the water is creeping the water direction inside drilling pipe.

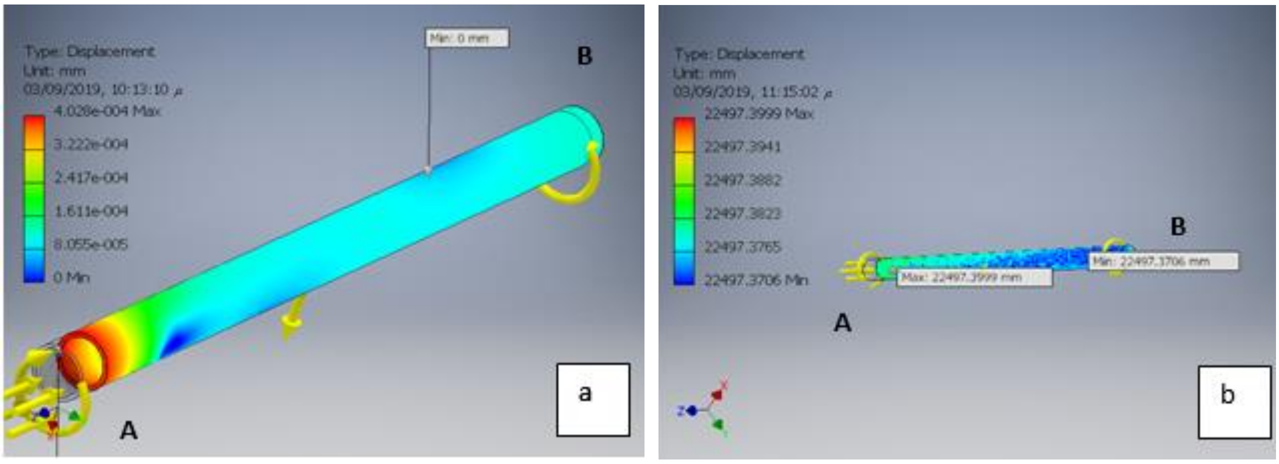


Fig. 6. The total displacement of (a) drilling pipe wall and (b) convoyed water inside drilling

The Von Mises theory based on the principal stresses of the third order, Figure 7(a) shows the active 3rd principal stresses of the drilling pipe wall. The figure clearly shows the changes in the stresses is limited of elastic deformation, that leads to the stuffiness of the drilling pipe wall materials which almost made from the carbon steel Craft and Graves [1]. The convoyed water directly affecting of the dynamical changed of stream flow due to the full developed flow with higher pressure developed at the end B of the drilling pipe. As show in Figure 7(b).

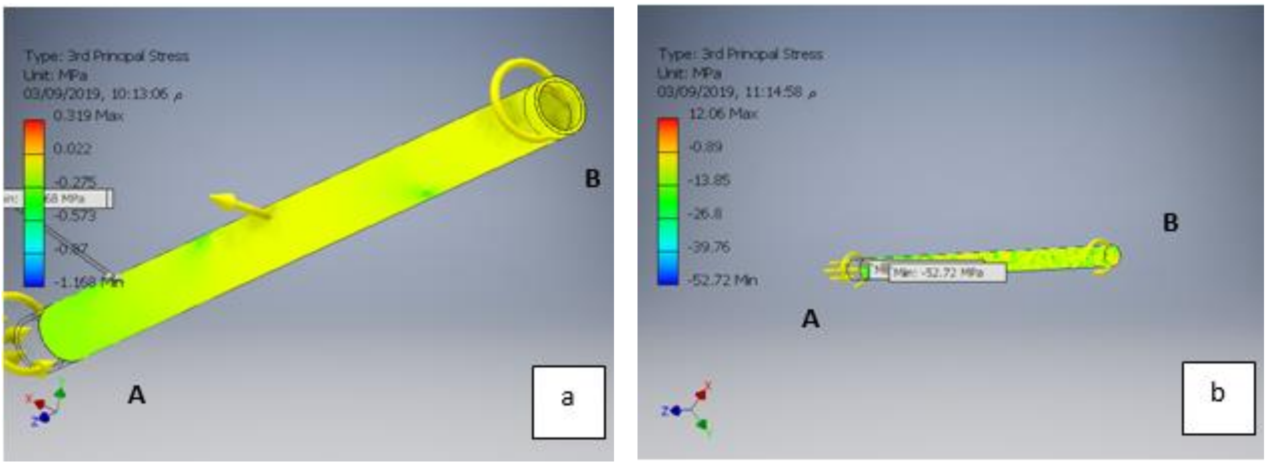


Fig. 7. The 3rd principal stresses of (a) drilling pipe wall, (b) convoyed water

The combined forces applied on the drilling pipe wall due to the loaded torsion force, the compression force, and the twisting force can be observed by 3rd principal strain (see In Figure 8(a)). High elastic change of the pipe wall material is represented by bulk modulus of elasticity. The water flow fibres of the provides more changes the existed strain which deformed by the transmitter the strain power to the convoyed water as clearly showed in Figure 8(b).

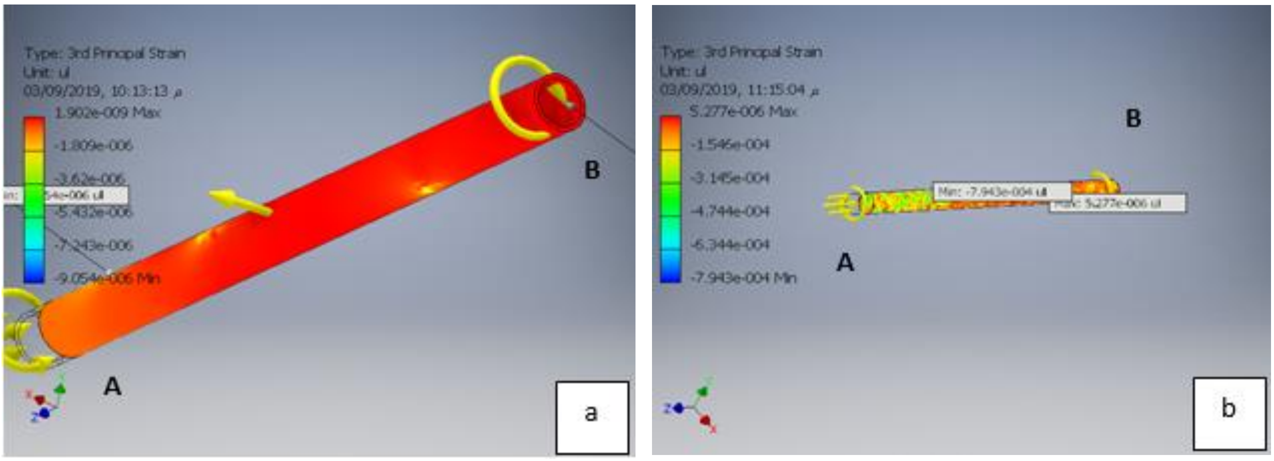


Fig. 8. Shows the 3rd principal strain of (a) drilling pipe wall, and (b) convoyed water

4.2 Case 2

According to Table 1, Case 2, the total displacement both of drilling pipe and convoyed water inside drilling pipe presented in Figure 8(a) and (b) respectively. In Figure 9(a), clearly shown the deformation displacement near the core drill bits is constant at end B of the drilling pipe, while it can see the large deformation displacement value at the end A of drilling pipe. The radial displacement of the water inside drilling pipe is shown in Figure 9(b). The enlargement deformation of flowing water inside drilling pipe is obtained.

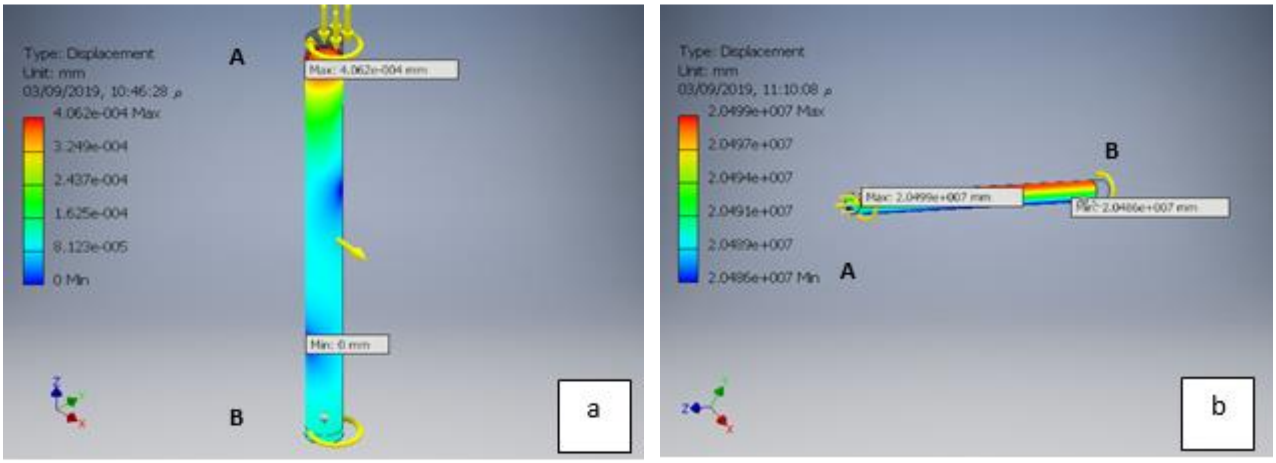


Fig. 9. The total displacement of (a) drilling pipe wall and (b) convoyed water inside drilling pipe

The third principal stress of Von Mises is presented in Figure 10(a) and b for drilling pipe and convoyed water inside drilling pipe, respectively. A third principal stress is stable at the end B. i.e. near the core drilling bit. At the comparison, this case with case (1) it is shows that the minor deformation creates in drilling pipe wall due to the pipe stuffiness material. On the other hand, the large change of third principal stress obtained of the convoyed water inside drilling pipe, which because of the more deformed water fibres due to flowing and exposed to the pumping pressure.

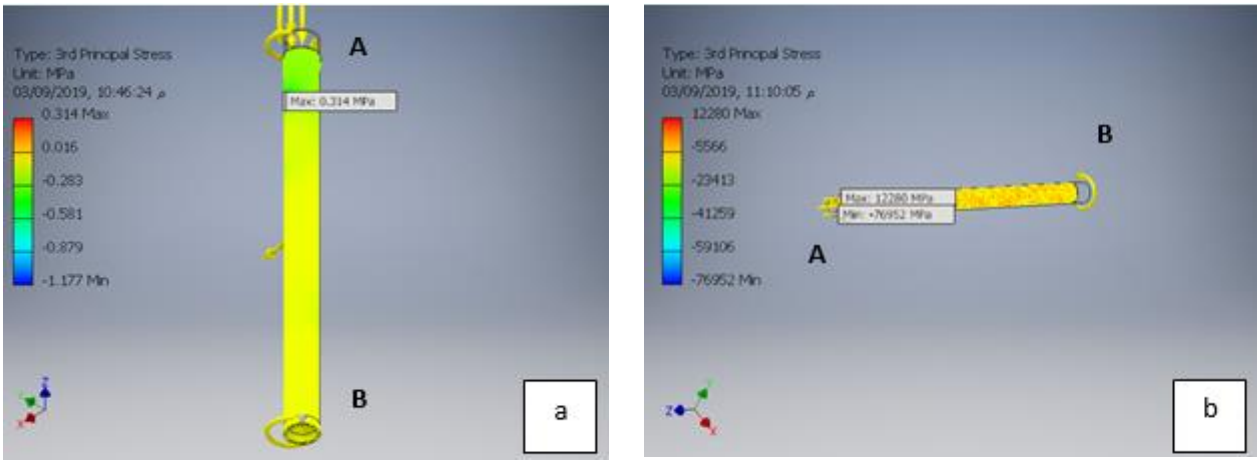


Fig. 10. The 3rd principal stresses of (a) drilling pipe wall, (b) convoyed water

The change in shape of both drilling pipe wall and convoyed water element inside drilling pipe is determined by the rate of strain deformation. Compared between case1 and case 2, in case 2 more strain deformation were occurred, in both drilling pipe wall and conveyed water, which because of the twisting force of the pipe wall may become high deformed near the core drill bits end B. While it became low deformed at end A, (see Figure 11(a)). Under the consideration in fact, the direct contact of conveyed water inside the drilling pipe with the drilling pipe wall, the strain deformation is transmitted to the water element. A gain, in case 2 the water element it will be under the more strain as compared with case 1 as shown in Figure 11(b).

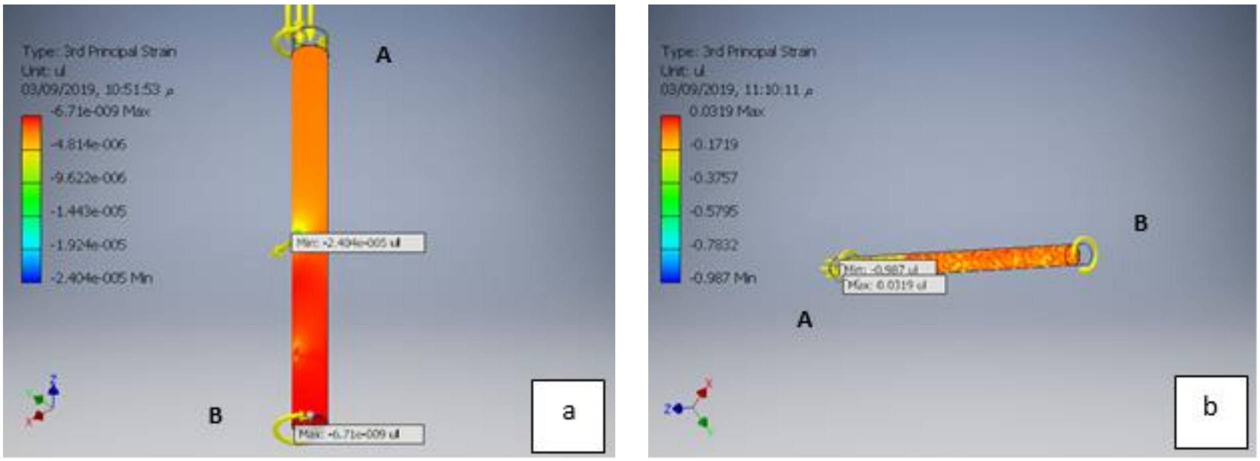


Fig. 11. Shows the 3rd principal strain of (a) drilling pipe wall, and (b) convoyed water

4.3 Radial Displacement of Water Element

The radial inertia displacement subjected to the water element is affected directly by the twisting force of the drilling pipe wall and results in the creep deformed of the water element. Both drilling pipe wall and conveyed water elements lead to wave deformed. These deformations are considered insignificant changes to the drilling pipe wall material because of high stiffness pipe material. While the radial deformation plays an important role in convoying water elements due to combining axial and radial variations. The present work is compared with Tijsseling [6] of water element as shown in Figure 12. This figure clearly shows the stability of the conveyed water element at total motion. The cumulative iteration steps ranged from (1 to 10) with time response ranged (0 to1 sec). A gain, this figure shows the radial displacement of convoyed water element increased by increasing the torsion load which transmitted from the drilling pipe wall, these increments of radial displacement will be matching with criteria of previous work.

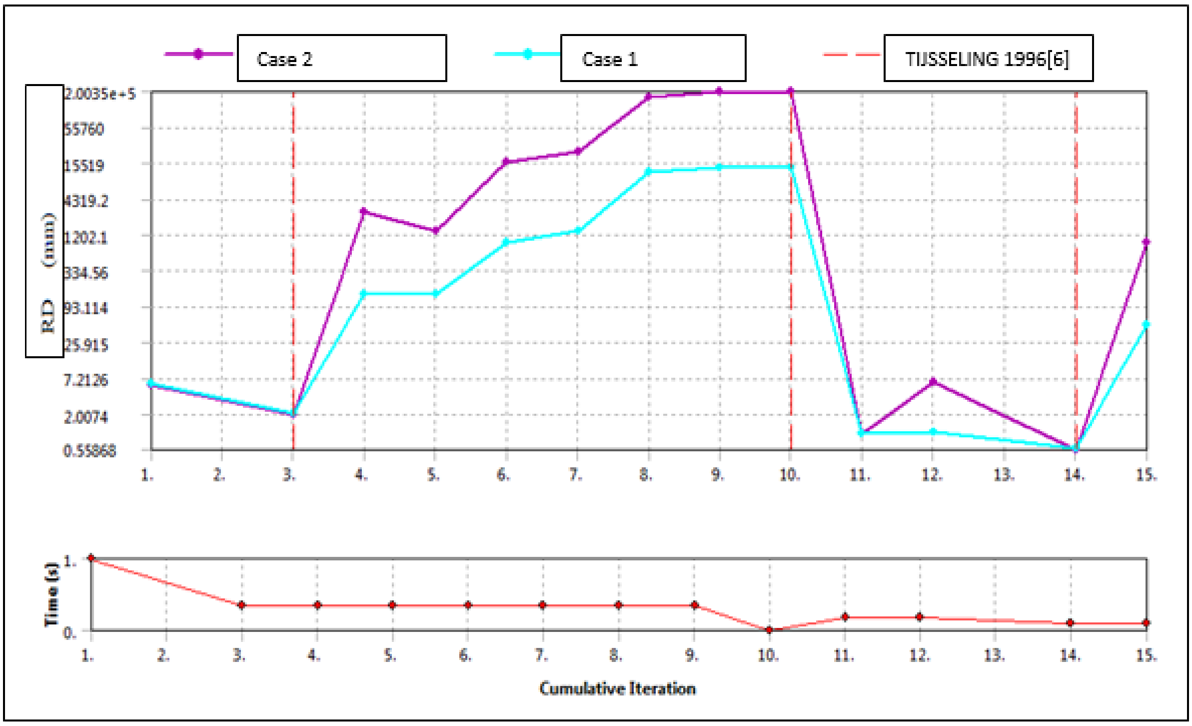


Fig. 12. The radial displacement of convoyed water

As the same mashing of a convoyed water element of 2936 nodes with 1595 elements, is simulated using ANSYS software 16.1. Figure 13 shows the total deformation of the water element plane inside the drilling pipe of case 2. The deformation decreases gradually form the boundary of the water element near the drilling pipe wall until it reaches to the centre of the water element flowing.

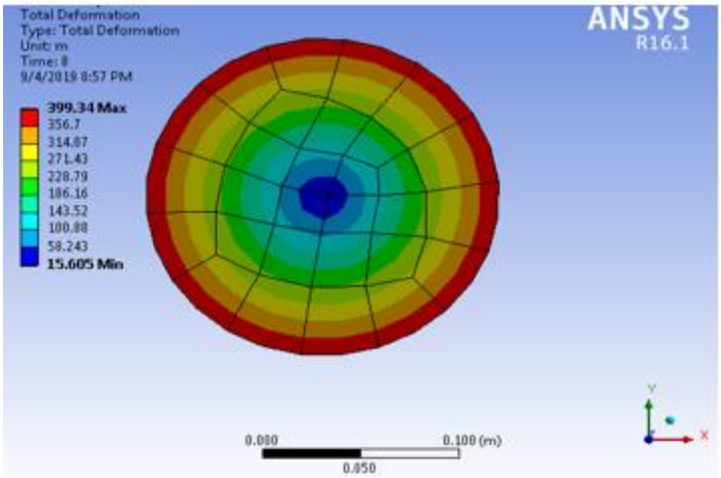


Fig. 13. The total deformation of water element

The rates of deformation continuously change it called the elastic strain. The conveyed water element exposed to the elastic strain due to the continued flow of water exerted to pumping pressure inside the drilling pipe. Figure 14 shows the plane of equivalent elastic strain of the water element diameter per unit length of drill pipe.

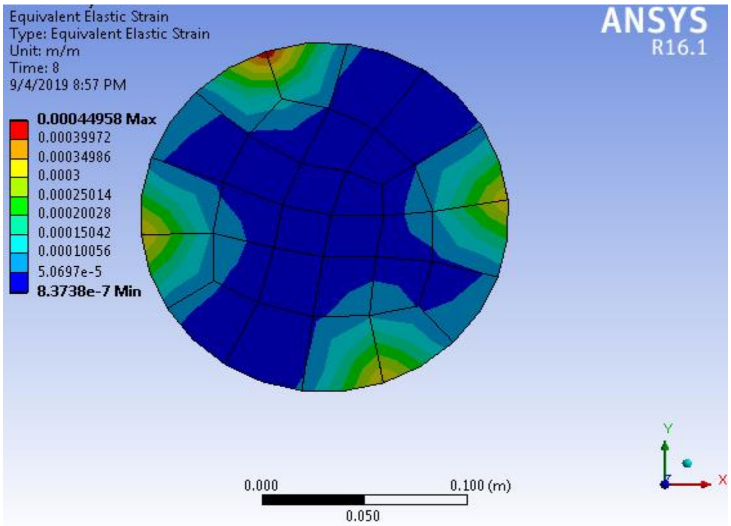


Fig. 14. Shows the equivalent elastic strain of water element

5. Conclusions

This study presents the effects on the convoyed water element of the torsional force of the drilli ng pipe wall. Two cases of operating parameters used to simulate the drilling pipe wall and the conv oyed water component inside the drilling pipe. This study presents the effects on the convoyed water element of the torsional force of the drilling pipe wall. Two cases of operating parameters used to simulate the drilling pipe wall and convoyed water element inside the drilling pipe. To acquire the ideal comprehension, two software were used to give the prediction of what is occurring and effect of the water element inside the drilling pipe. The INVERTOR PROF. 2016 to simulate 3D the drilling pipe wall and convoyed water element and ANSYS software 16.1 used to predict 2D the water element inside drilling pipe. For both this software modelled the convoyed water element at the same number of nodes and elements. Three parameters considered play important roles in the water element behaviour inside drilling pipe. Total displacement, principal stress and strain forces were investigated. The observation keys are as the following

i. The total displacement transmitted from the drilling pipe wall to the convoyed water element is directly affected at any increasing of the torsion force loaded by the drilling pipe wall.
ii. Principal stress and principal strain for both drilling pipe wall and water element is propositionally affected on the deformation of water element flowing.
iii. The radial displacement of the water element continuously changed with the equivalent of elastic strain.

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