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Tool Joint Analysis to Reduce Errors in Hydraulic Calculations

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Abstract

The drilling industry cannot, without fail, match calculated and actual pump pressures. For example, pump pressure (p_p) calculations using API model with synthetic based mud (SBM) can be off as much as 35% [7].

Many experimental studies deal with the flow of fluids through pipes and annuli for pressure loss calculations. Most of these studies have concentrated on rheological models, pipe roughness, and geometrical parameters. However, the effects of tool joints had not been seriously investigated to estimate the pressure loss inside drill pipe and in the annulus. Optimization of hydraulic calculations for pressure loss corrections are the focus of this study.

Key words: *Drilling hydraulics, tool joint, internal taper.*

Introduction

Deep drilling and deviated wells need high-strength drill pipe, which often has adequate internal upset, or exact length of internal taper (m_{iu}), for tool joints. These internal upsets cause pressure losses that can be considerable. The pressure loss caused by entry into the tool joint is small compared with the exit losses.

On the other hand, the same problem can be experienced in the annulus between tool joint and casing due to the external upset of the tool joint. These pressure losses, in annulus, are ignorable but in narrow spaces they should be taken into consideration.

The results of this research, methods to estimate additional pressure loss from expansion and contraction of the fluid flowing through pipe and annuli, are of great importance in achieving correct results for pressure drop and hydraulics calculations.

Background Research

Denison [2] concluded that internally constricted drillstring elements can drastically affect the rig hydraulics. Also, the pressure loss caused by entry into the tool joint is small compared with the exit losses.

White and Zamora [7] established from a comparison between field and calculated data that one possible reason for discrepancies is increase in pressure caused by sudden contraction and expansion of the mud when passing through the tool joints, which is not taken into consideration in any published hydraulics calculation.

Mario Zamora, Sanjit Roy and Ken Slater [10] concluded that tool joints can increase pressure losses in the annulus and in the drillstring due to geometry effects and fluid contraction and expansion (fig. 1). Internally constricted tool joints can further increase drillstring losses because of the apparent inability of the fluid to recover from full turbulence (where $P \propto Q^2$) after entering the drill-pipe tube. This can dramatically increase the turbulent flow friction factor and pressures at high flow rates. One method to account for this behavior is to empirically adjust the Blasius constants (a) and (b) ($\lambda = \frac{4a}{Re^b}$ where $a = \frac{\log(n)+3.93}{50}$ and $b = \frac{1.75-\log(n)}{7}$).

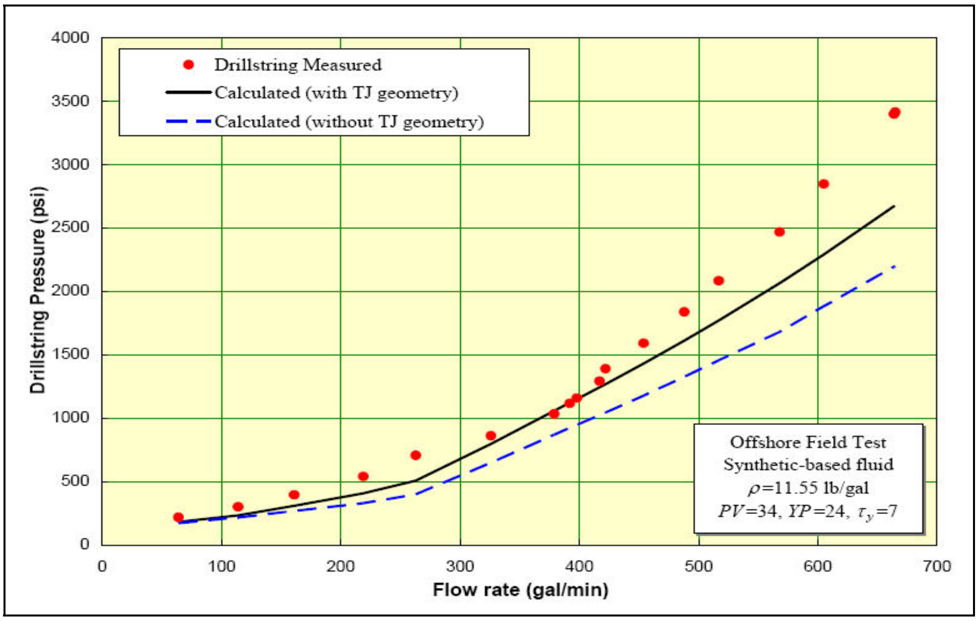


Fig.1. Comparison of measured and calculated drillstring pressure losses in an offshore well [7], including contribution of tool-joint geometry [10].

API RP13D [12] in their last edition, which was published in 2006, established that tool joints can affect frictional pressure losses in the drillstring and annulus for several reasons, the most obvious of which is the diameter difference that can be included as a lumped parameter. For internally constricted tool joints drillstring pressure loss can increase due to contraction and expansion effects as fluid enters and exits the tool joints. Also, if full turbulence is achieved in the tool joint, the drillpipe joint may be too short to allow complete fluid recovery. Field data support that this can result in the elevation in the turbulent flow friction factor.

In order to study geometry and dimensions of drillpipe upsets, there were studied 5 in (127 x 9,19 mm) drillpipes and thereby they were selected to cover internal and external suppliers [6].

The statistical distribution of the internal taper's length values (m_{iu}) is presented in figure 2, for both ends of drillpipe and also considering total measured values [6].

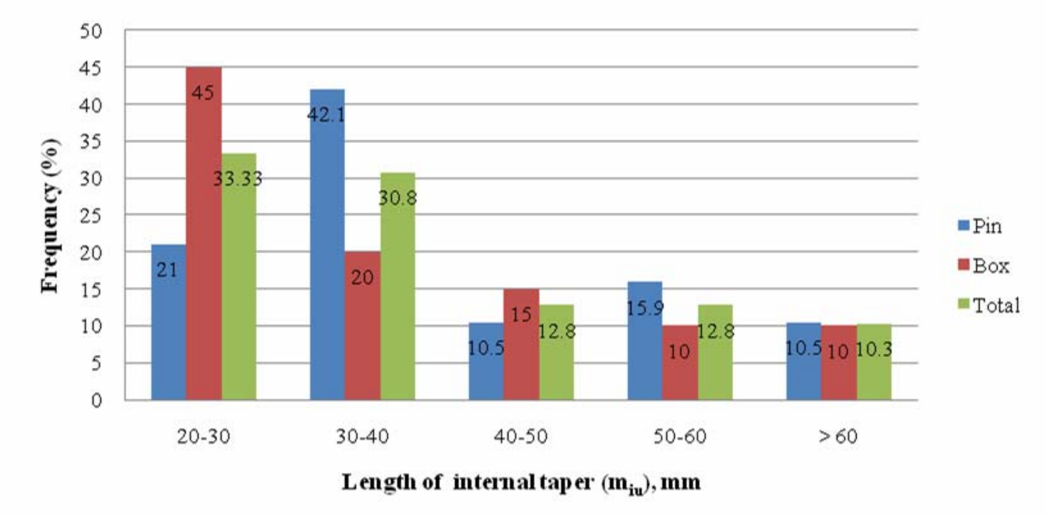
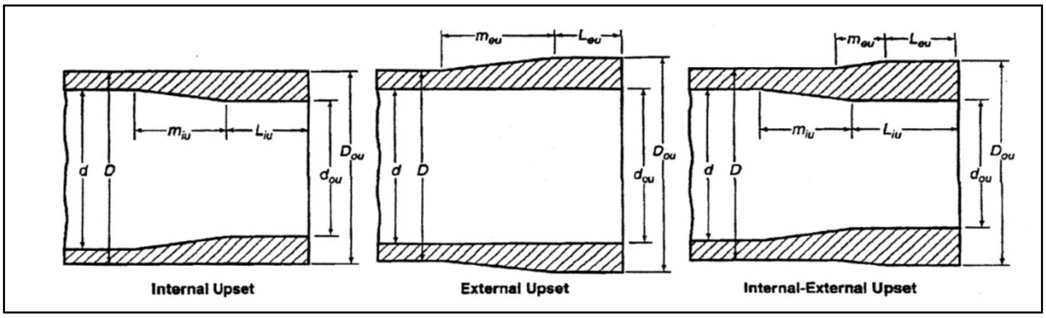


Fig.2. Statistical distribution of the internal taper's length values, m_{iu}, for investigated drillpipes [6].

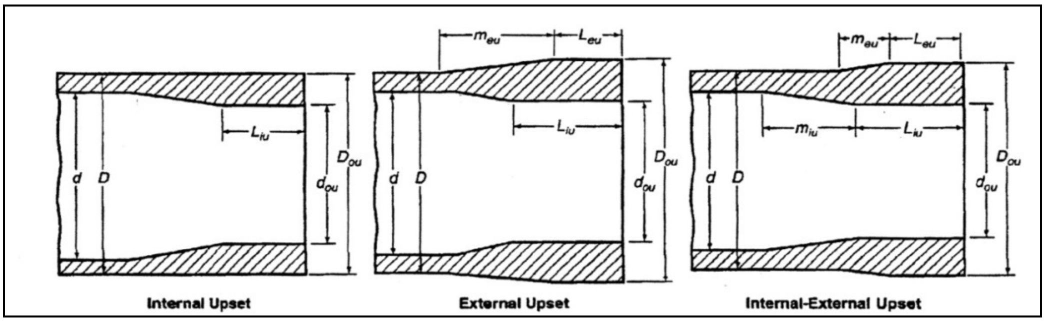
There is no significant difference between the values of internal taper's length (m_{iu}) at the same drill pipe.

There is not a clear trend regarding the value of (m_{iu}) at neither one of the manufactures (the investigated drillpipes were supplied by seven different manufactures) [6].



Group 1 (grade E)

a) **b)** **c)**



Group 3 (grade X, G and S)

Fig.3. Upset drill pipe for weld-on tool joints [14]:

a – internal upset; b – external upset; c – internal-external upset.

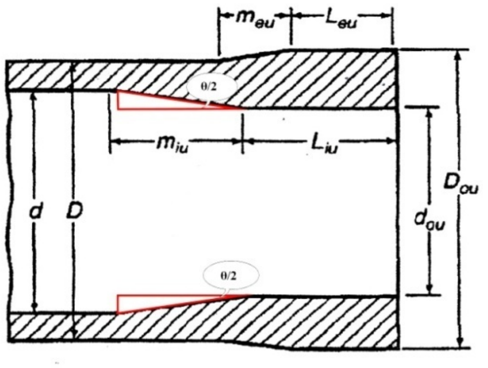


Fig.4. The angle θ is an important element in the enlargement and contraction equations

Results Analysis

We used three tool joint corrections for one set of data using seven different rheological models. The used data consisted of rheological and pressure loss in the drillstring and annulus, and pump pressure. We compared the calculated drillstring, annulus, and pump pressures, which were corrected, with the drillstring, annulus and pump pressure measured by White and Zamora [7].

Figure 5 shows the data of measured and calculated pump pressure vs. flow rates. Note that the calculated pump pressure is derived without any tool joint corrections.

For this case, with API (segmented Ostwald-de Waele) we have achieved a relative error of 32.97 % between the measured and calculated pump pressure. Also, the best approximation was for the Bingham plastic model with 23.44% (we consider that this model is not recommended for hydraulics calculations because of the existence of 24.26% relative error between measured and calculated shear stress).

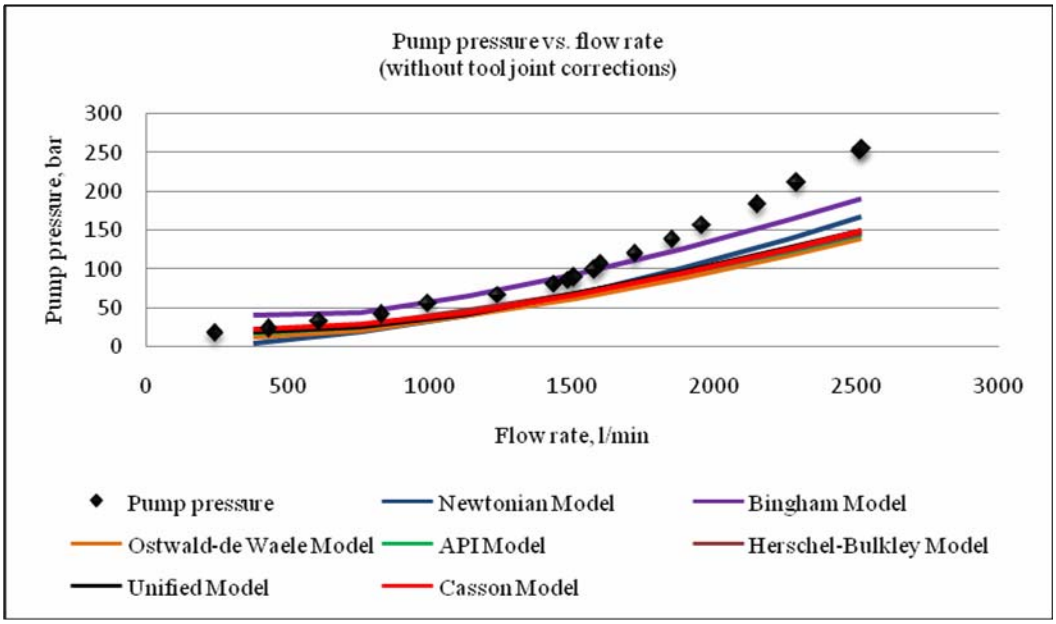


Fig.5. Pump pressure vs. flow rate (without tool joint corrections).

Considering the first approach, correction by contraction and enlargement effects in tool joints after Gibson's model, figure 6 shows the results:

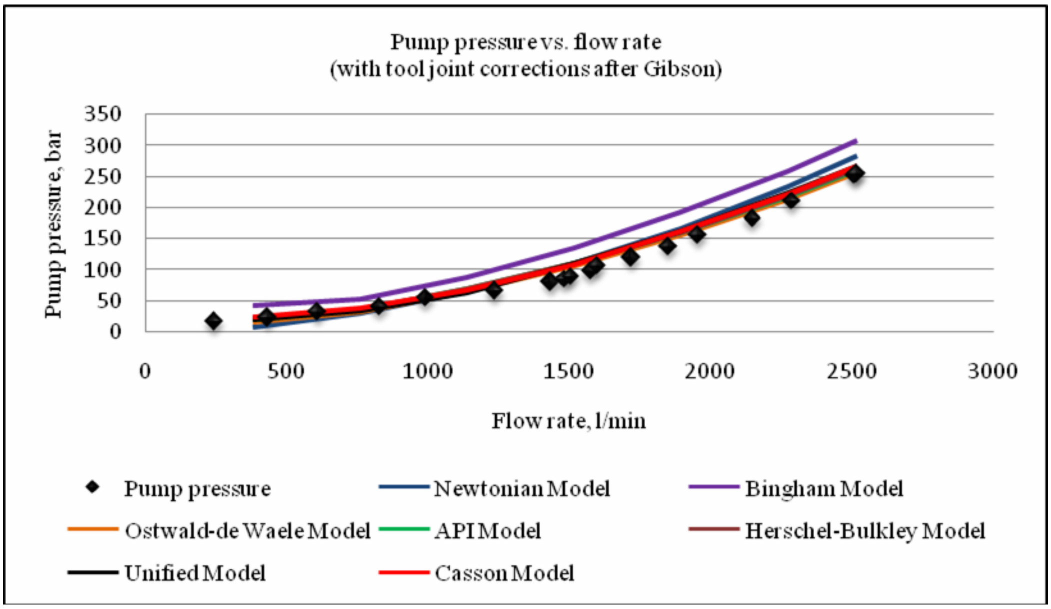


Fig.6. Pump pressure vs. flow rate (with tool joint corrections) after Gibson's model.

Figure 6 shows how the calculated pump pressure matches the measured data. API (segmented Ostwald-de Waele) presents a 9.883% relative error. However, the best match can be achieved with the Unified model (9.04%).

Considering the second approach, correction by contraction and enlargement effects in tool joints after Idelchik's model, figure 7 shows the results:

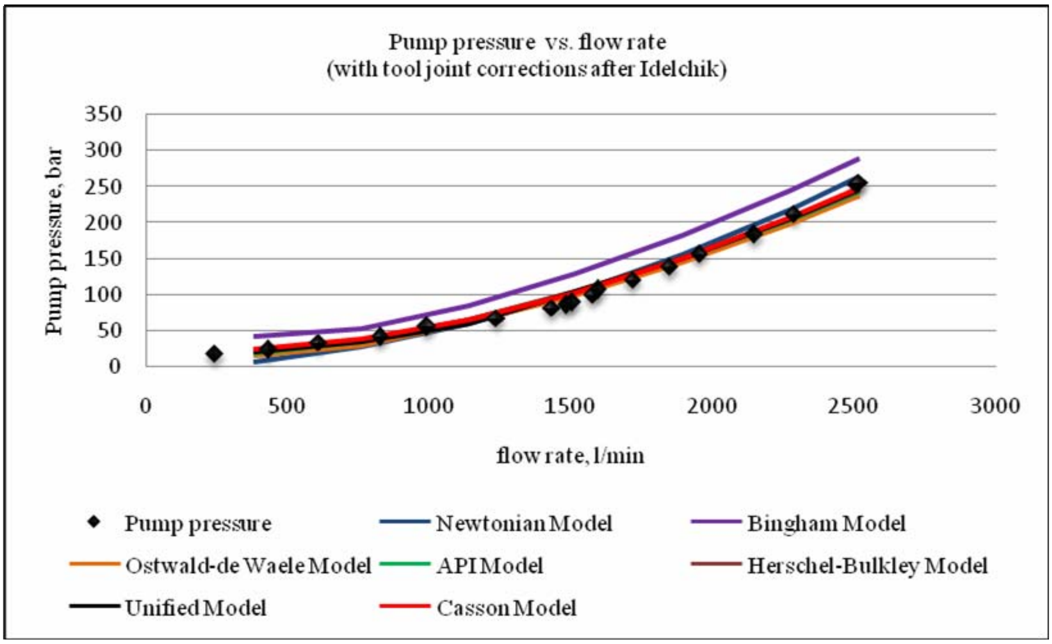


Fig.7. Pump pressure vs. flow rate (with tool joint corrections) after Idelchik's model.

Figure 7 shows how the calculated pump pressure matches the measured data. API (segmented Ostwald-de Waele) presents a good fit with 7.489% relative error. However, the best match can be achieved with the Unified model (5.616%).

Considering the third approach, correction by contraction and enlargement effects in tool joints after Borda-Carnot's model, figure 8 shows the results:

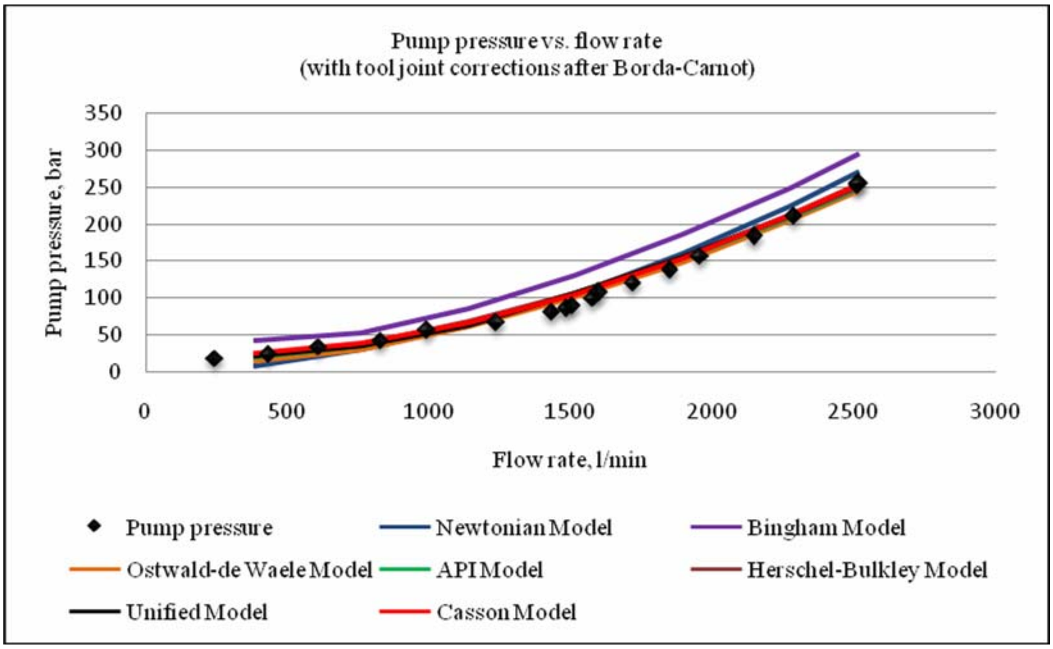


Fig.8. Pump pressure vs. flow rate (with tool joint corrections) after Borda-Carnot's model.

Figure 8 shows how the calculated pump pressure matches the measured data. API (segmented Ostwald-de Waele) presents a 7.791% relative error. However, the best match can be achieved with the Unified model (6.054%).

Table 2 presents, in synthesis, absolute average percent error (E_{AAP}) values for pressure loss calculations (Gulf of Mexico).

Table 1. Absolute average percent error (E_{AAP}) values for pressure loss calculations

Rheological Model	**Absolute average percent error (E_{AAP}) values for pressure loss calculations**			
	without tool joint corrections	Gibson Model	Idelchik Model	Borda-Carnot Model
Newtonian Model	41,023	21,775	18,051	19,064
Bingham Model	23,443	43,966	37,863	40,12
Ostwald-de Waele Model	40,54	11,36	11,056	10,3
API Model	32,97	9,883	7,489	7,791
Herschel-Bulkley Model	29,233	10,213	6,803	7,542
Unified Model	31,964	9,04	5,616	6,054
Casson Model	29,483	10,371	6,343	7,312

Conclusions

1. Tool joints can increase pressure losses in the annulus and in the drillstring due to geometry effects of contraction and expansion. Current API RP 13D does not include tool-joint pressure loss calculations.
2. Length of internal taper (m_{iu}) for upset drillpipes needs a special attention, because it has an important effect on pressure losses inside drillpipes.
3. Value of this length is not provided in API 5D (specification for drill pipe). This API recommends, only in some cases, a minimum length for internal taper, from strength point of view, for avoiding failure of drillpipes and for this reason, only by knowing the exact length of internal taper (m_{iu}) according to manufactures, we can calculate pressure losses in tool joints.
4. An article about researches concerning the frequency of the drill pipes failures [6] shows that there is not a clear trend regarding the value of (m_{iu}) at neither one of the manufactures (the investigated drillpipes were supplied by seven different manufactures). We have illustrated that these variations in length of internal taper result in very different variations of tool joint pressure loss calculations.
5. As we observed, the difference between measured and calculated pump pressure, without tool joint corrections, in our case study, exceeds 5-10%, margin which usually we add to calculated pressure losses inside drillstring and annulus, in purpose of correcting the difference between measured and calculated pump pressure.

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14. * * * API Spec. 5D, *Specification for Drill pipe*, 2000;

Analiza racordurilor speciale în scopul reducerii erorilor din calculele hidraulice

Rezumat

Industria de foraj nu poate să potrivească, fără eroare, presiunile calculate cu cele măsurate la pompă. De exemplu, calculul căderilor de presiune la pompă (pp), folosindu-se modelul API cu un fluid pe bază de hidrocarburi sintetice (SBM), poate să fie cu o eroare de 35% față de cea măsurată [7].

Foarte multe studii experimentale se ocupă de curgerea fluidelor în tuburi cilindrice circulare şi în spații inelare în scopul calculelor căderilor de presiune. Majoritatea acestor studii sunt concentrate asupra modelelor reologice, rugozității tuburilor şi parametrilor geometrici. Totuşi, efectele racordurilor nu au fost investigate în mod serios pentru a se estima căderile de presiune în prăjini şi totodată spațiile inelare. Scopul de bază al acestui studiu îl constituie optimizarea calculelor hidraulice în vederea corectării căderilor de presiune.