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CONSIDERATIONS OVER THE DETERMINATION OF CARRYING CAPACITY FOR THE BAYONET DRILL PIPE CONNECTIONS

Adrian CREIȚARU
Petroleum-Gas University of Ploiesti, adriancreitaru@yahoo.com

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Abstract

The large diameter rotary blind drilling technology uses a special constructive drill stem, conformed to large pipe diametric dimensions and high level axial and torsion loads. Among pipe joint types, the bayonet (rapid) connection variant has significant advantages. This pipe joint solution is almost unknown and unusual in work but, in Romania, there is a design attempt (a few years ago), but not with applicative results.

This paper resume this favorable and interesting solution meaning to determinate the carrying capacity and, than, to propose some specific applicative cases.

1. General overview

In large diameter drill domain the most in use is the blind Rotary system. It means to permanently move downwards the drill stem, till the deepest (final) well depth. The deeper well the higher axial (heavy) load will be involved [1], [3]. That's why the drill stem dimensioning is proportional by the H_{max} quota.

The maximal depth (H_{max}) of the hole is, generally, in the 200…600 m domain (in seldom cases, up to 1000 m, or more) and the nominal drill diameter goes from 2.5 to 6 m. In any case, the drill pipe joints can use one of the following three forms:

- *thread shouldered* connections;
- *flanged* connections;
- *bayonet* connections.

All over the world, the most in use are threaded or flanged connections. In large diameter drill practice, only in a few countries (USSR, USA and China [3]) the bayonet connections were applied for the drill stem joins. This special connection brings some certain advantages [2], [4]:

- there are not necessary special tools for jointing;
- the rotary work torque can use both rotating sense;
- by comparison, it has medium (diametric and axial) overall dimensions;
- by own constructive details it holds a good joint locking;
- the bayonet solution brings the shortest joining time; as known, the surname of bayonet type is “rapid (fast) connection”.

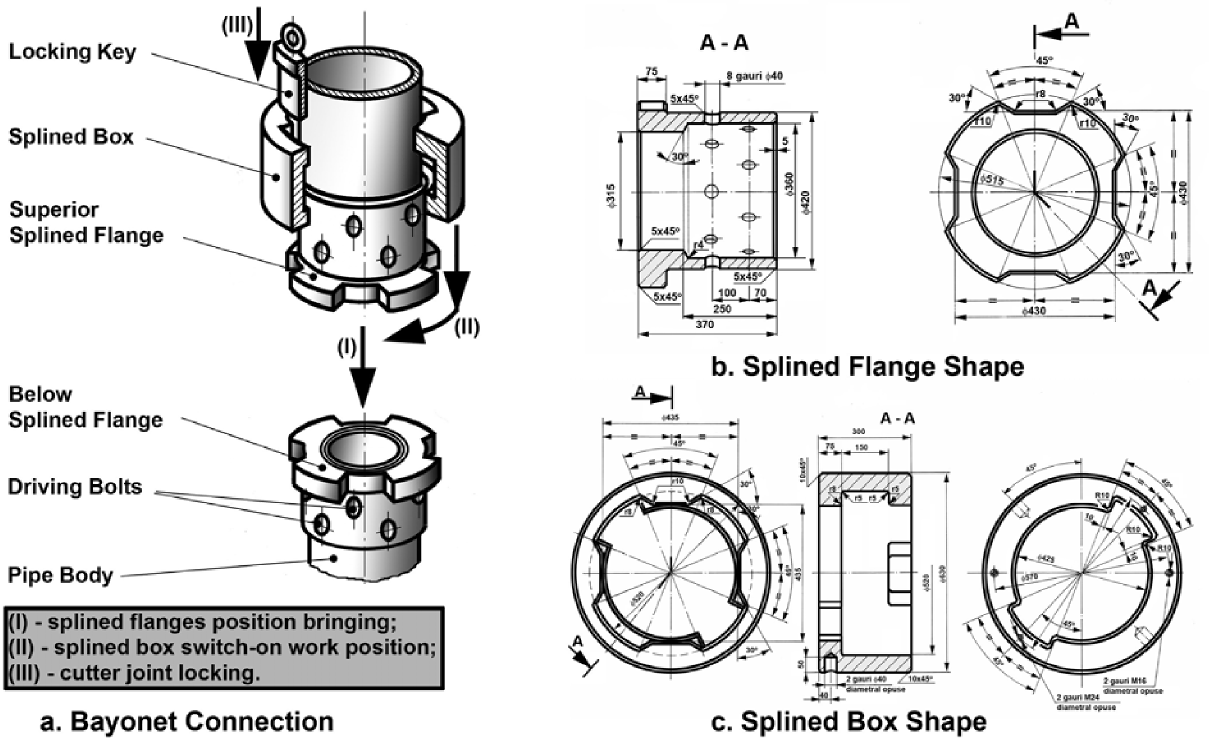
Same time, it must be mentioned some due shortcomings: its complexity deeds performing technology, difficulties concerning the fluid(s) circulation tackle, some unsolved sealing problems.

The only constructive variant designed (14 $^3/_8$ inch) had a theoretical good carrying capacity in both load conditions: high axial weight forces and hard drilling torsion terms. Anyway, the constructive and geometric parameters can be driven in the desired sense.

2. Constructive and dimensional parameters

The bayonet connection has a special shape; there is no similitude by the threaded or flanged pipe joints. The stem pipe assemblage is also faster than others; there are three steps to proceed (fig. 1., *a*): splined flanges position bringing (I), splined box switch-on work position (II) and cutter joint locking (III).

The joint main components, stem pipe assemblage procedure and designed geometrical parameters for the 14 $^{3}/_{8}$ inch variant – for both splined flanges and box are shown in figure 1., *b* and *c*.



a. Bayonet Connection

b. Splined Flange Shape

c. Splined Box Shape

Fig. 1. The main constructive, functional and geometric parameters of the bayonet connection

It's necessary to keep some of the following calculus decisive dimensions:

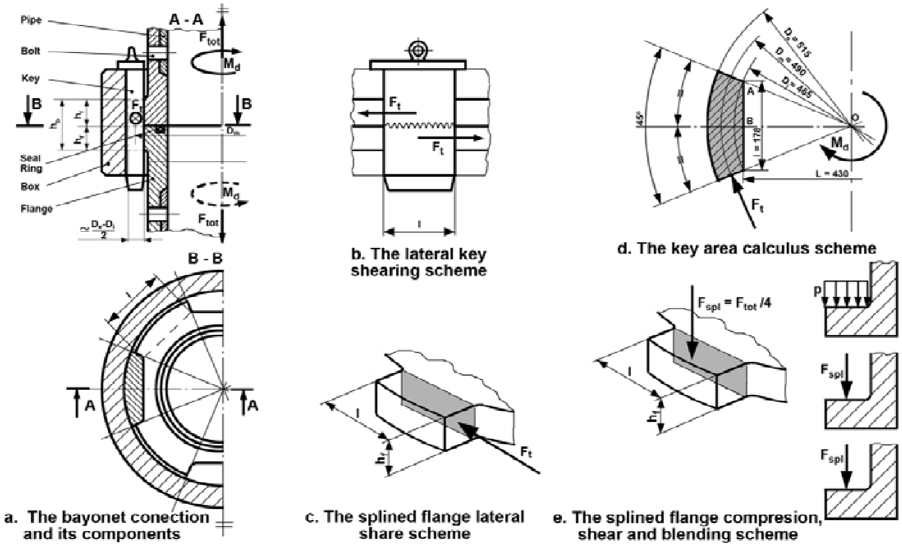
- At the splined flange: outer diameter (D_e = 515 mm), inner diameter (D_i = 465.5 mm), spline height (h_f = 75 mm), spline central angle ($\alpha = 45^{o}$);
- At the splined box: outer diameter (D_e = 520 mm), cavity height ($h_b = 2 \cdot h_f$ = 75 mm) and spline central angle ($\alpha = 45^{o}$);
- The locking keys: active length (L_a = 300 mm), box contact length ($L_b = 2 \cdot 75$ mm), flanges contact length ($L_f = 2 \cdot 75$ mm), key central angle ($\alpha = 45^{o}$).

For the following carrying capacity determination it's important to emphasis on a remark: the bayonet connection is a kind of joint by *load separation*. That means different load taking over, by its (different) components:

- The work drill torque (M_d) determines only key, box and flange lateral splines charging; as effect, the mentioned components are under *lateral shearing* and, also, under *direct local compression* (contact thrust);
- The drill stem trip in/out determines only axial loads, under the cumulative stem component weights (F_{tot}); this load determines different box and flange strain: axial spline *shearing*, *local compression* and *bending*.

3. The drill torque limit determination

The drill torque maximal limit determination operates by geometric characteristics, load specific cases and joint component materials. Key (41 MoCr 11), both Splined Box and Flanges (34 MoCrNi 15) brings, as requested, high resistance and mechanical behavior. The bayonet joint loading, detailed strain of its elements and specific calculus necessary schemes, are collated in figure 2.



a. The bayonet conection and its components

b. The lateral key shearing scheme

c. The splined flange lateral share scheme

d. The key area calculus scheme

e. The splined flange compresion, shear and blending scheme

Fig. 2. The constructive and load system, dimensional parameters and selected calculus schemes

From the very outset, maximal drill torque entails – on each of the two keys – a tangential (lateral) force (F_t), fig. 2., *a*:

$$M_{d,max} = F_t \cdot D_m \tag{1}$$

The active F_t position (D_m = 490 mm) can be found by relation:

$$D_m = \frac{D_e + D_i}{2} \tag{2}$$

An other preliminary step means the key cross-cut area ($A_{c,c}$) determination (Fig. 2., *d*). There are two tackle: the approximate calculus considers theoretical (*t*) convex-concave key shape:

$$A_{c,c}^{(t)} = \frac{A_{corona}}{8} = \frac{\frac{\pi}{4} \cdot \left(D_e^2 - D_i^2\right)}{8} = \frac{\pi \cdot \left(D_e^2 - D_i^2\right)}{32} \tag{3}$$

The accurate cross-cut key area determination – by considering a flat inner key shape, as designed case – is now possible by equation:

$$A_{c,c}^{(acc)} = \frac{1}{8} \cdot \frac{\pi \cdot D_e^2}{4} - 2 \cdot \frac{|AB| \cdot |OB|}{2} = \frac{\pi \cdot D_e^2}{32} - \frac{\left(\frac{D_i}{2} \cdot \sin\alpha\right)^2}{tg\alpha} \tag{4}$$

Considering constructive parameter $\alpha = 45^o/2$, there is a significant difference between these areas: $A_{c,c}^{(t)} = 5318.6\,\text{mm}^2$ and $A_{c,c}^{(acc)} = 7434.7\,\text{mm}^2$. The accurate cross-cut key area is by 35% larger. The maximal drill torque determination needs relation (1) development:

$$M_{d,max} = F_t \cdot D_m = \tau_{a,s} \cdot A_{c,c}^{(acc)} \cdot D_m \tag{5}$$

For shear admissible stress chousing, $\tau_{a,s}$, it can be use: for 41 MoCr 11, the keys material: $\tau_{a,s,k}$ = (0.2…0.4). τ_c = 145…300 N/mm^2; for 34 MoCrNi 15, for box an flange: $\tau_{a,s,fl}$ = (0.2…0.4). τ_c = 155…315 N/mm^2.

By considering the keys as critical elements, taking lateral shear as limit condition, the maximal drill torque becomes: $M_{d,max} = 728.6$ kN·m. Than, when lateral flange spline shearing as strength condition, the flange spline root area can be considered (fig. 2., *c*):

$$A_{f,sp} = l \cdot h_f = 13357.5 \text{ mm}^2 \tag{6}$$

This case, maximal drill torque becomes: $M_{d,max} = 1308.3$ kN·m; the strength condition for flange enclosure, is certainly less restrictive. At least, the drill torque can be determined by lateral spline contact thrust condition; the admissible contact, for 41 MoCr 11 – yield point in manufacturing is σ_c = 740 N/mm^2 –contact pressure range p_a = (0.2…0.25)· σ_c; for design practice could be used values between limits: p_a = 150…220 N/mm^2.

The maximal drill torque, determined by the key-spline contact thrust condition is:

$$M_{d,max} = F_t \cdot D_m = A_{contact} \cdot p_a \cdot D_m \tag{7}$$

when approximate key-spline contact area can be put as: $A_{contact} = h_f \cdot (D_e - D_i) / 2$.
This case, the limits for the drill torque are: $M_{d,max} = 137.8...202$ kN·m.

3. The axial loading capacity

The axial load capacity comes from the splined box-flange pair; the unitary split axial force – on each back flange – is $F_{spl} = F_{tot} / 4$ determines three kind of stress: shearing, local compression and bending. For local compression case [1], it can be written:

$$F_{tot} = 4 \cdot F_{spl} \cdot A_{spl,fl} \cdot p_{a,fl} \tag{8}$$

When axial spline-flange shear have to be imposed, the flange spline root area is done by formula (6); by consequence, the axial load capacity can be expressed by:

$$F_{tot} = 4 \cdot F_{spl} \cdot l \cdot h_f \cdot \tau_{a,fl} \tag{9}$$

Almost case, the splines bending is negligible; always, this situation gets low level stress.

4. Conclusions

The special bayonet connection analyze brings some conclusions over its capacity:

- The maximal drill torque for drill stem designed variant concords to drilling unit work parameters (F 400 4DH-M): $M_{d,max} \le M_{unit,max} = 200 \cdot 10^3$ N·m; otherwise, the usual drill torque in work is, rarely over 70…100 kN·m (hard drilling bottomset bed);
- Improving maximal drill torque level (for other new stem joint variants) can use a higher flange spline ($h_f \uparrow$);
- Axial load shows higher capacity forces: shear (>850 tf), contact (>1100 tf), banding (>1150 tf); all cases the unit maximal load is at $F_{max,unit}$ = 400 tf.

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