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Considerations on the Reliance of the Multiple Start Shouldered Threads for Large Diameter Drilling Pipe Joints

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Abstract

Multiple start thread is similar to standard thread, but lead of helix has, this case, bigger values. The "i" number of starts are here interfingering and, actually, the thread pitch is, an "i" times multiple of the circumferential pitch.

The case of multiple start threads some of dimensional characteristics are different enough and, by consequence, there are some functional characteristics also modified. Among these, the screw-on torque level increase brings here several advantages. Despite some certain benefits of multiple start thread use, in shouldered pipe connections domain these are not sufficiently extensive; the main drawback here appears the demanding manufacturing.

Constructive-technological restrictions – far less investigated – must be known, understood and optimally solved and overcome. Thus becomes possible wider use of such special thread.

One of the essential advantige of multiple start thread use for drilling stem connections refers to the torque moments. For drilling stem joints, the working torque moment, (M_w), must obvious be lesser than tightening torque (M_s) here applied – for necessarly avoid the under load re-clamping. This way, the multiple start thread becomes a relevant solution to increase the working torque level, when it is required.

Key words: *multiple start thread, pitch, shouldered connection, special thread, heavy duty thread*

Presentation and Introduction

The multiple start thread is generally less used in practice; this, because its execution is technologically difficult. Figure 1 shows the generation of multiple thread, compared to a normal thread (single start thread).

Among the arguments which recommend the use of multiple start threads can be listed [2, 3]:

- the screwing-in and off of the joint can be done faster;
- the re-screwing risk in charge state; some cases, it means raising the torque level;
- the contact pressure overload reducing risk, which may cause thread sticking;
- the screw-off torque reduction;
- widening range of the working torque values (M_w), because the screw-in torque of the assembly gets higher etc.

There are also certain limits which lead to restricted use:

- manufacturing technology is difficult and exacting;
- unequal loading on each thread start induce the local spire overloading;
- precision of start indexing is difficult to keep under control.

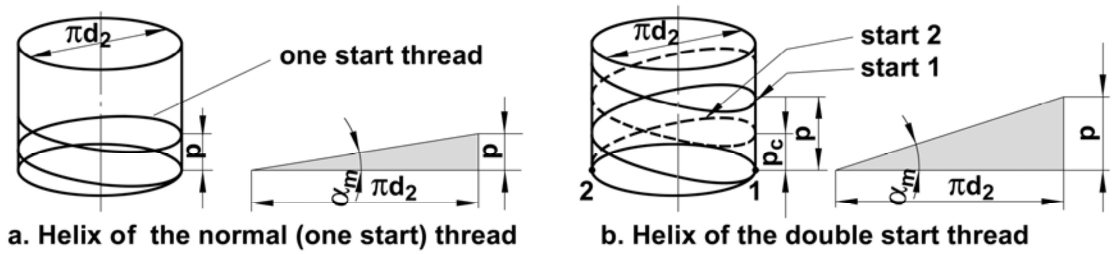

Fig. 1. The helix of the single and double start thread and the development of the helical curves

Theoretical Summary

If we consider "*i*" the thread start number – meaning the course of thread number – than, the frontal plane shows the indexing angle, θ, defined by equation:

$$\theta = \frac{360^o}{i} \tag{1}$$

Than, as Figure 1 shows, the case of multiple start case links two different outlines: thread pitch (p) and circumferential pitch (p_c):

$$p = i \cdot p_c \, . \tag{2}$$

Equation (2) suggests that multiple start threads operate by big-coarse pitch; it determines rapidity of screwing but, also, higher torque involved [4], [5].

In brief, there are also to be mentioned here:

- the lead of helix (angle of pitch) can be generally determined by:

$$\alpha_m = \text{arctg}\frac{p}{\pi \cdot d_2} \;; \tag{3}$$

- the lead of helix, in case of taper thread, by alter relation:

$$\alpha_m = \text{arctg}\frac{p}{\pi \cdot d_{2,m}} \;; \tag{3'}$$

  where $d_{2,m}$ is an average diameter; it can be chosen as a medium diameter or even a representative one (the value of the diameter in the measurement plane); by consequence, the case of taper thread brings this case a variable angular α_m value;

- considering the general formula for the self-locking condition:

$$\alpha_m \le \varphi' \;; \tag{4}$$

  it may be adjusted, for the case of multiple start (i) thread, as follows [2]:

$$(\alpha_m)^{(i)} \le (\varphi')^{(i)} \;; \tag{4'}$$

or the processed form of this condition:

$$\frac{p_c \cdot i}{\pi \cdot d_{2,m}} \leq \frac{\mu_t}{\cos\delta}. \tag{4''}$$

Relation (4″) comprises the notorious elements: i – starts number; p_c – circumferential (apparent) pitch; μ_t – frictional factor of the screw and δ – the angle of active flank of the thread.

Multiple Start Thread Suggested Application

The multiple start thread characteristics have to be lead in drill pipe joint domain. In the oil & gas branch, the drill stem uses standard shouldered thread, usually in common sizes. The large diameter drilling domain uses different connections: taper shouldered special asymmetric threads. Diametric size of the joints is always between 10 and 20 inch [2], [6].

Each of n joints of the drill stem is separately pre-loaded by axial force (F_o) and tightening torque ($M_{s,k}$), as Figure 2, *a* and *c* shows. Over them, the weight axial (F_t) and working torque moment (M_w) are pointed in same figure.

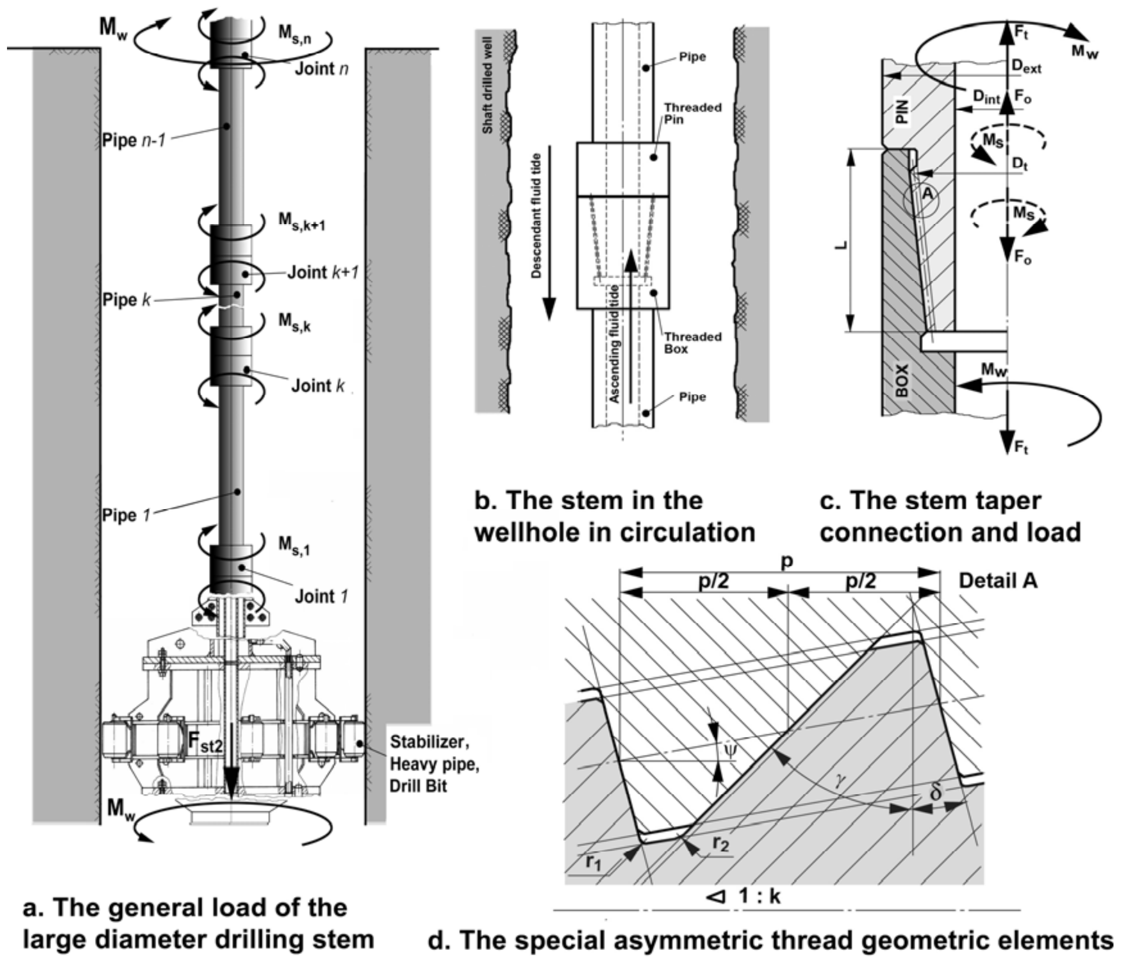

Fig. 2. The drill stem structure, its complex loading system and main geometric characteristics of the special taper shouldered thread

In Romania, the special taper thread, FM 200H (fig. 2 *c*, *d*), with asymmetric triangular profile, was used for several large diameter drill stems: D_n=10 in, 14 $^3/_8$ in and 20 in. As well, a few other dimensional versions remained in design stage since 80's [2, 3, 6].

Before 1990, when Romania extended efforts in large diameter drilling and equipment manufacturing, it became necessary, for specific cases, the use of multiple start threads. That time, the insufficient theoretical studies let this problem unsolved.

The need of multiple start thread use for large diameter drilling stems is extensive presented in [2, 3] (and also some other) works. Here are presented some specific detailed results.

The Necessary Torque Moments Correlation

The usual situation of a drill stem with shouldered thread joints (fig. 2,*a*), we suppose that each connection (single start thread) gets its *screw torque moment*, as joint *n*, meaning $M_{s,n}$. This torque level depends on many factors for each stem size, weight, drill depth, diameter and many more besides (fig. 3, *a*).

Intuitive graph can add chart of the *working* (drilling) *torque*, M_w. As well known, this moment has normal variations, induced by the technological drilling process. Anyway, the working torque field is always lower, to avoid the under load re-clamping risk (fig. 3,*a*).

In drilling process, can occur special operation, when bit, heavy assembly or stem sticking. This case there are stem run operations needed, such as rotation pulse. On same Figure 3,*a* is represented the *run torque*, M_r. This moment, such as a special case needs a higher value than working, but also lower than tightening level, to prevent re-clamping.

As graphic in brief, all three torque levels are overlap in Figure 3, *a*. To conclude, we leave here a question to debate: *if, some cases, a significant higher working torque (*$\mathbf{M'_w}$*) is needed, what to do?* When geological bottom strata imposes heavy working torque in drilling operation, the entire range of torque moments (M'_w, M'_r and $M'_{s,n}$) may have higher values. This will be posible if the shouldered stem connections are double ore triple start screwed (fig. 3,*b*).

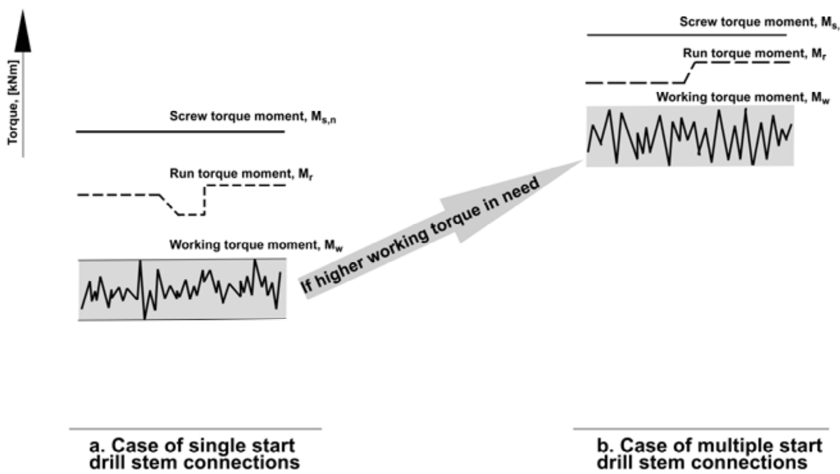

Fig. 3. The torque networking for two drill stem joints: *a* – single start thread, *b* – multiple start thread

The Machine Elements theory shows the way of screw-on torque calculus; the toque moment ($M_{s,n}$) can be considered by two fundamental parts: a part of torque (M_{tf}) is dedicated to frictional consumption in the threaded zone, the second part (M_{tf}) is dedicated to the shoulder.

Put in equation, this composite torque means:

$$M_{s,n} = M_{tf} + M_{sf} \tag{5}$$

In equation (5) both torque parts refers to frictional occurrence. If detailing the above equation, the following formulary can use:

$$M_{s,n} = F_{\text{o}} \cdot \left[\frac{d_{2,m}}{2} \cdot \text{tg}\left(\alpha_{m,m} + \varphi'\right) + \frac{\mu_{sh}}{3} \cdot \frac{d_{o,sh}^3 - d_{i,sh}^3}{d_{o,sh}^2 - d_{i,sh}^2} \right] = a_s^{(i)} \cdot F_{\text{o}} \tag{5'}$$

In relation (5′) the components have well known senses, but some specific features:

- $d_{2,m}$ is variable for the taper thread, the meaning value to consider is the average or those in the measuring plane;
- μ_{sh} is the friction factor of the joint shoulder; this area is within the limits outer shouldered diameter ($d_{o,sh}$) and inside shouldered diameter ($d_{i,sh}$);
- $\alpha_{m,m}$ is the angular value of helix angle; this case of taper thread the angle is variable and the recommended value to use is average or specific value of the measuring plane;
- φ' is is the frictional reported angle; the value is dependent of the friction factor of the pin-box thread reported to ψ function (active flank angle, fig. 2, *d*).

In the brief form of (5′) equation, the *specific preload factor,* $a_s^{(i)}$ is dependent on shape and dimensions of each connection size. It is more than obvious that preload factor $a_s^{(i)}$ gets higher values, when it comes to multiple start threads.

If we customize for a specific dimensional case of 14 $^3/_8$ in drill stem size, suggesting 2 other different subvariants (with 2 and 3 start threads), the calculated values of the preload factor and its modification is presented in table 1.

Table 1. The calculated values of the preload factor and screw-on torque modification on single and multiple thread starts, for 14 $^3/_8$ in drill stem size, 1:8 taper [2]

Frictional conditions \ Specific calculated characteristics	On shoulder, μ_{sh}	On thread, μ_t	Thread start number, *i*	Preload factor, $a_s^{(i)}$ [mm]	Percentage increase, [%]
Frictional factors considered on pin and box connection	0.07	0.06	1	**28.194**	-
			2	**31.363**	↑ 11.24
			3	**34.549**	↑ 22.54
		0.09	1	**30.039**	-
			2	**33.213**	↑ 10.56
			3	**36.400**	↑ 21.18
		0.13	1	**41.136**	-
			2	**44.329**	↑ 7.76
			3	**47.547**	↑ 15.58
	0.15	0.06	1	**44.122**	-
			2	**47.259**	↑ 7.19
			3	**50.479**	↑ 14.41
		0.09	1	**49.665**	-
			2	**52.843**	↑ 6.40
			3	**56.037**	↑ 12.83
		0.13	1	**57.067**	-
			2	**60.258**	↑ 5.59
			3	**63.477**	↑ 11.23

Considering for the mentioned stem connections ($14^3/_8$ in drill stem size), if maximal depth of the hole H= 300 m, an usual drill unit (F400-4DH-M, for example) can provide a rotary torsion moment of $M_{t,\ max}$=200 kN·m.

This case, if maximal axial preload (for every connection of the stem, if axial preload has choused uniform) is about 2000 kN [2], any frictional conditions determines the level of the screw-on torque $M_{s,n}$=56…114 kN·m.

Any level choused in this gap – let's say $M_{s,n}$= 80 kN·m – the working torque level must be lesser: such as M_w= 40…60 kN·m, to prevent any risk of unscrewing or re-screwing on load. Than, if the drilling plan system impose a higher schedule – let's say M_w= 80…100 kN·m (or more) – the entire set of torque moments must get higher.

This demand can be achieved by using multiple start thread, as Figure 3,*b* illustrates. The theoretic calculations made on this subject brought the values of the *specific preload factor,* $a_s^{(i)}$ and, implicitly the correspondent screw-on torque, $M_{s,n}$, when we should use double or triple start thread. The study refers on the usual following friction conditions:

- friction factor of the joint shoulder should be μ_{sh} =0.07, μ_{sh} =0.15 or μ_{sh} =0.21;
- friction factor of the thread should be μ_t =0,06, μ_t =0.09 or μ_t =0.13.

In these conditions, the values obtained for the preload factor were in the domain $a_s^{(i)} = 28.194...75.425$ mm.

We tried than, keeping the same dimensional characteristics of the assembly, to modify only the tapering value, from 1 : 8 to 1 : 6. Thus drove to a pretty similar gap.

When using a double start thread, the screw-on torque for the stem connections gets higher; if we chouse the percentage expressing, the increase is about 5…12%.

Certainly, the use of triple start thread determines higher values of the screw-on torque in the limits of 10…23%. Further start for these threads, reticently recommended.

This theoretical solution for drill stem threaded connections has to take account of other mechanical restriction: self-locking condition. It ensures the screwed-on operation against casual self screw-out in service.

It's well known that a higher start number of thread brings a grown screw-out risk. The basic self-locking condition to be valid here is:

$$\alpha_{m,m} \le \varphi' \tag{6}$$

The angular value of helix angle is – in the case of taper thread for these connections – variable along the element of the cone. It makes necessary here the average use of this angle. The table 2 gives the evaluated average $\alpha_{m,m}$ angles.

The results of self-locking analyze shows that in normal friction condition, this condition gets affirmative answer for any case of multiple i =1…4 start thread. If the frictional thread stage is too smooth, the i =3 or 4 start thread gets the risk of auto screw-out.

Conclusion

The analysis of functional thread characteristics, directed on multiple start thread use in drilling stem connection shows some relevant conclusions:

- ➢ The use of multiple start thread is possible even in the case of drilling stem shouldered connections. Practically, in Romania this purpose remains a simply project, a wish.

Table 2. The calculated $\alpha_{m,m}$ average angles, for cases of *i*=1.,.4 possible start of the thread

Joint characteristics \ Calculated values		The average value of the helix angle, $\alpha_{m,m}$ [deg]	Result of examination of the self-lock condition
Tapering 1 : 8	Single start thread	1.024	Always, YES
	2 start thread	2.055	Always, YES
	3 start thread	3.089	YES, except the case μ_t=0.06
	4 start thread	4.125	YES, except the case μ_t=0.06..0.08
Tapering 1 : 6	Single start thread	1.041	Always, YES
	2 start thread	2.090	Always, YES
	3 start thread	3.144	YES, except the case μ_t=0.06
	4 start thread	4.203	YES, except the case μ_t=0.06..0.08

- Multiple start thread brings here a lot of advantages; one of them refers to the complex management of the torque moments involved (screw, run and work torque).
- The specific preload factor gets enough different values for other that single start threads. It brings an obvious influence over the screw-on torque and, implicitly, over the working (or running) torque moments.
- The calculated torque increases were determined for usual friction conditions (μ_{sh} =0.07-0.21 and μ_t =0.06-0.13):
  - if using a double start thread, the screw-on torque increase is about 5…12% ;
  - if using a triple start thread, the screw-on torque increase is about 10…23%;
  - for other tapering values, results are almost the same.
- The basic self-locking condition is, on the other hand, an important condition to be verify; if use of multiple start thread is recommended, the risk of auto screw-out becomes obvious as the number of start is higher:
  - for 2 starts, this risk is till absent, any frictional conditions were chosen;
  - for 3 starts, this risk is rarely possible, only if frictional conditions are very fine;
  - for 4 starts, this risk is possible enough, if frictional conditions are fine.

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Recomandări în utilizarea filetelor cu mai multe începuturi pentru asamblările cu umăr ale prăjinilor de foraj cu diametre mari

Rezumat

Filetele cu mai multe începuturi sunt similare filetelor normale, dar ungiul de pantă al desfăşuratelor spirelor are valori mai mari. Cele "i" începuturi ale filetului se întrepătrund şi pasul filetului (p) este de fapt de "i" ori mai mare decât pasul aparent, (p_a).

O parte dintre caracteristicile geometrice ale filetului se modifică, atrăgând în consecință, modificare unora dintre caracteristicile funcționale. Între acestea, modificarea valorilor momentelor de înşurubare aduce pentru asamblare o serie de posibile avantaje.

În ciuda unor înlesniri certe ale utilizării acestor filete, asamblările cu umăr ale garniturilor de foraj nu au beneficiat de o extindere constructivă remarcabilă; principala oprelişte ținând încă de execuția pretențioasă a acestor filete. Restricțiile constructiv-tehnologice – mai puțin cercetate până în prezent – se impune a fi cunoscute, soluționate optim şi depăşite, făcând astfel posibilă utilizarea extinsă a acestui tip de filete speciale.

Unul dintre avantajele esențiale care recomanda folosirea filetelor cu mai multe începuturi la asamblările garniturii de foraj se referă la momentele de torsiune. Momentul de torsiune de lucru al garniturii de foraj, (M_w), trebuie sa fie evident mai mic decât momentul de strângere a asamblărilor (M_s) – pentru a se evita re-strângerea acestora sub sarcină. Astfel, un filet cu mai multe începuturi poate deveni o solutie pentru ridicarea plafonului momentelor de torsiune de lucru, atunci când acest lucru este necesar.