BULETINUL Universităţii Petrol – Gaze din Ploieşti	Vol. LVIII No. 3/2006	67 - 72	Seria Tehnică

Computation Method for the Contact Pressure Developed upon Make-Up of Round Thread

Marius Bădicioiu, Vlad Ulmanu

Universitatea Petrol-Gaze din Ploieşti, Bd. Bucureşti, 39, Ploieşti
e-mail: mbadicioiu@upg-ploiesti.ro

Abstract

The paper presents a new computation method for the contact pressure developed on the flank of round thread upon make-up that takes into account the shape of contact surface between the two components of the connection. The proposed method is general and it may be used for all types of conical threads employed in the construction of oil tubular goods.

Key words: *contact pressure, make-up, thread.*

Introduction

The mounting of the threaded connections of oil tubular goods is carried out applying a make-up moment whose value is mainly determined by the tightness condition of the connection. Standardized threaded connnections are characterized by the fact that casing pin and coupling have the same taper angle, and therefore upon manual make-up by a given moment, the pin and coupling spires get in touch simultaneously. By the (mechanical) application of a make-up moment, a contact pressure which provides the tightness of the connection is developed between the sides of the thread.

For the analytical determination of the state of stress and deformation in a conical threaded connection under individual or simultaneous pressure of servicing strengths (make-up, traction, internal and external pressure, etc.), the literature uses a series of relationships. Many of these relationships are empirical and do not take into account a series of factors such as: shape of contact surface, state of contact surface, slope angle of sides etc.

This paper presents a new computation method for the contact pressure developed upon make-up that takes into account the shape of the contact surface between the two components of the connection [1].

Contact Pressure Developed on the Conical Contact Surface

Due to the fact that the connection is conical, the make-up leads to the development of a radial contact pressure between the pin and coupling; this pressure is usually determined using the theory of elasticity. The common expression employed for the determination of the contact pressure between the two elements of the threaded connection, obtained by considering the pin and coupling as thick-wall tubes subjected to internal and external pressure [2,4] (fig. 1) is:

$$p_c = \frac{\delta E\left(r_m^2 - r_n^2\right)\left(r_n^2 - r_c^2\right)}{2r_n^2\left(r_m^2 - r_c^2\right)}. \tag{1}$$

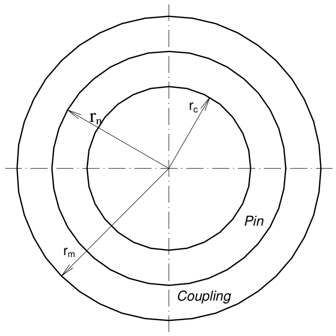

Fig. 1. Pin and coupling

where r_m represents the exterior radius of the coupling;
r_c – interior radius of the pin;
r_n – (nominal) mean radius of the thread;
E – elasticity modulus;
δ – radial accumulation ($\delta = 0.5 n_r \Delta p$);
n_r – number of rotations upon make-up;
Δ – thread taper angle;
p – thread pitch.

Although equation (1) has been developed for cylindrical contact surfaces, it is also used for the computation of conical contact surfaces of threaded connections of oil tubular goods, either by adopting a radius of the contact surface equal to the mean radius of the thread (which would lead to a linear distribution of contact pressure along the thread) or by introducing a radius of the conical contact surface that is variable along the length of the thread.

The equation of the make-up moment given by the requirement of defeating the friction forces developed on the contact surface of spires [5] is as follows:

$$M_t = \mu\, p_c A_c r_m , \tag{2}$$

where μ represents the friction coefficient; p_c – contact pressure between pin and coupling; A_c – area of contact pressure; r_m – mean radius of thread.

Contact Pressure Developed on the Sides of Conical Thread Spires

The contact between the pin and coupling upon make-up occurs on the load flanks of the thread spires, which are conical spiraled surfaces. Two contact surfaces are represented: a contact surface located on the load flank and the other on the stab flank, angled in relation to the axis of the spire with the sides' angle α. (for round thread $\alpha = 30°$).

In order to determine the computation method of the contact pressure developed on the sides of conical thread we have considered the round thread connection (fig. 2). The contact pressure applied on a thread spire develops perpendicularly on its sides.

The determination of the contact area for each side separately is achieved by considering the contact surface composed of a family of curves on the width of the load flank, whose curve radius is given by the equation (fig. 3) [3]:

$$\rho_f\left(\phi, b_f\right) = R - \frac{\phi}{4\pi} p\Delta - b_f \cdot \cos(\alpha) , \tag{3}$$

where R represents the maximum theoretical radius on top of the thread; ϕ – the angle between the radius of the spire in a given point and R; p – spire (thread) pitch; Δ – thread taper angle; b_f – width of contact surface (b_{fa} for load flank and b_{fp} for stab flank), and α – angle of slope of the thread side (for round thread $\alpha = 30°$).

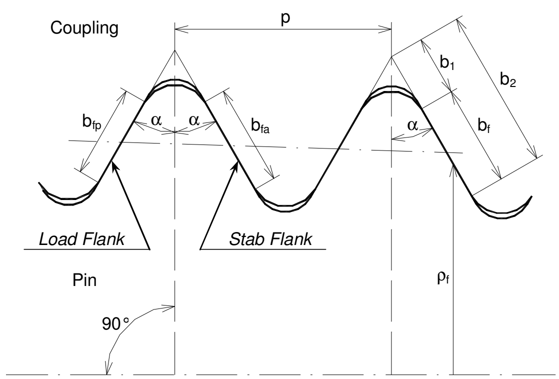

Fig. 2. Thread Geometry

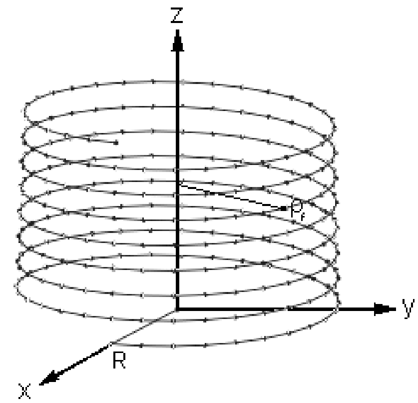

Fig. 3. Conical Spire Axis

The parametric equations of the contact surface on a thread side are:

$$x(\phi, b_f) = \rho_f(\phi, b_f) \cdot \cos(\phi);$$
$$y(\phi, b_f) = \rho_f(\phi, b_f) \cdot \sin(\phi); \quad (4)$$
$$z(\phi, b_f) = \frac{\phi}{2\pi} p \pm b_f \cdot \sin(\alpha).$$

For z coordinate, "+" sign shall be considered for the load flank, and "–" sign for the stab flank.

The area of the contact surface shall be calculated using the area integral as follows:

$$A_c = \int_{b_1}^{b_2} \int_0^{2\pi n} \sqrt{A^2 + B^2 + C^2}\, d\phi\, db_f \ , \quad (5)$$

where A, B and C are functional determinants:

$$A = \frac{D(x, y)}{D(\phi, b_f)};\ B = \frac{D(y, z)}{D(\phi, b_f)};\ C = \frac{D(z, x)}{D(\phi, b_f)}, \quad (6)$$

b_1 and b_2 – distances from the theoretical top of the thread at the beginning and, respectively, the end of the contact surface, measured on the side surface.

Solving the functional determinants (6) and introducing them in equation (5), it results:

$$A_c = \int_{b_1}^{b_2} \int_0^{2\pi n} \sqrt{\left(\frac{p}{2\pi}\right)^2 \left(\frac{\Delta}{2}\sin(\alpha) \mp \cos(\alpha)\right)^2 + \left(\frac{p\Delta}{4\pi}\phi + b_f \cdot \cos(\alpha) - R\right)^2}\, d\phi\, db_f \ , \quad (7)$$

where "–" sign shall be considered for the load flank, and "+" sign for the stab flank.

Considering the nominal radius of the contact surface $r_n = \rho_f$, by introducing equation (3) in equation (1) it results the expression of the contact pressure developed by make-up on any surface element of the side:

$$p_{cf} = E\delta \frac{\left[\left(R - \frac{\phi}{4\pi} p\Delta - b_f \cdot \cos(\alpha)\right)^2 - r_c^2\right]\left[r_m^2 - \left(R - \frac{\phi}{4\pi} p\Delta - b_f \cdot \cos(\alpha)\right)^2\right]}{2\left(R - \frac{\phi}{4\pi} p\Delta - b_f \cdot \cos(\alpha)\right)^3 (r_m^2 - r_c^2)}. \quad (8)$$

The total strength developed by pressure on the contact surface of the side shall be determined by integrating contact in relation to area. Thus, its expression becomes:

$$F_{cf} = E\delta\int_{b_1}^{b_2}\int_{0}^{2\pi n}\frac{\left[\left(R-\frac{\phi}{4\pi}p\Delta-b\cdot\cos(\alpha)\right)^2-r_c^2\right]\left[r_m^2-\left(R-\frac{\phi}{4\pi}p\Delta-b\cdot\cos(\alpha)\right)^2\right]}{2\left(R-\frac{\phi}{4\pi}p\Delta-b\cdot\cos(\alpha)\right)^3(r_m^2-r_c^2)}\times$$

$$\times\sqrt{\left(\frac{p}{2\pi}\right)^2\left(\frac{\Delta}{2}\sin(\alpha)\,\mu\cos(\alpha)\right)^2+\left(\frac{p\Delta}{4\pi}\phi+b\cdot\cos(\alpha)-R\right)^2}\,d\phi db. \tag{9}$$

Equation (9) is extremely difficult to integrate due to its complexity. For this reason, a mathematical computation program may be used to solve it.

The make-up moment may be determined using the relationship:

$$M_t = \mu r_n F_c = \mu r_n\left(F_{cfa}+F_{cfp}\right)\sin(\alpha)\,, \tag{10}$$

where F_c represents the total contact force developed on the two sides of the thread:

$$F_c = \left(F_{cfa}+F_{cfp}\right)\sin(\alpha)\,, \tag{11}$$

F_{cfa} – contact force on the load flank;

F_{cfp} – contact force on the stab flank.

Numerical Application for the Threaded Connection of Casing of 5½ in Diameter with Round Thread

To determine the contact pressure and corresponding make-up moment by the proposed method, we have considered the case of a threaded connection with long round thread for casing of 5½ in diameter, with the following characteristics:

- internal diameter of the casing: d_c = 124.3 mm;
- external diameter of the coupling: d_m = 153.7 mm;
- maximum theoretical radius at the top of the thread: R = 68.35 mm;
- thread pitch: p = 3.175 mm;
- taper angle: Δ = 0.0625;
- thread length on z axis: l_z = 63.5 mm;
- longitudinal elasticity modulus: $E = 2.1\cdot10^5$ N/mm^2;
- angle of slope of thread sides: $\alpha = 30°$.

For this numerical application, it was considered a χ rotation angle of the pin in relation to the coupling of 480°.

The number of rotations on make-up is determined according to the χ rotation angle of the pin in relation to the coupling, measured from the completion of the manual make-up. This number is $n_r = \frac{\chi}{360}$.

To determine the values of contact pressure and make-up moment a mathematical computation program was created using MathCAD.

Table 1 shows the values of the contact pressure on the thread sides, determined by the analytical method for a rotation angle of 480°, using equation (8).

Table 1. Analytical determination of contact pressure values on load flanks of thread

l_z , [mm]	p_{cfa} , [N/mm^2]			p_{cfp} , [N/mm^2]		
	$b = 0$	$b = b/2$	$b = b$	$b = 0$	$b = b/2$	$b = b$
0	20.781	19.985	18.805	20.781	20.060	19.015
12.7	20.330	19.298	17.869	20.330	19.392	18.118
25.4	19.733	18.457	16.769	19.733	18.570	17.060
38.1	18.986	17.457	15.501	18.986	17.591	15.834
50.8	18.083	16.292	14.059	18.083	16.447	14.436
63.5	17.019	14.956	12.436	17.019	15.133	12.859

Figure 4 shows the variations of the contact pressures on the load flank (fig. 4.a) and stab flank (fig. 4.b) on the length of the considered thread, at the beginning, middle and end of the contact surface width.

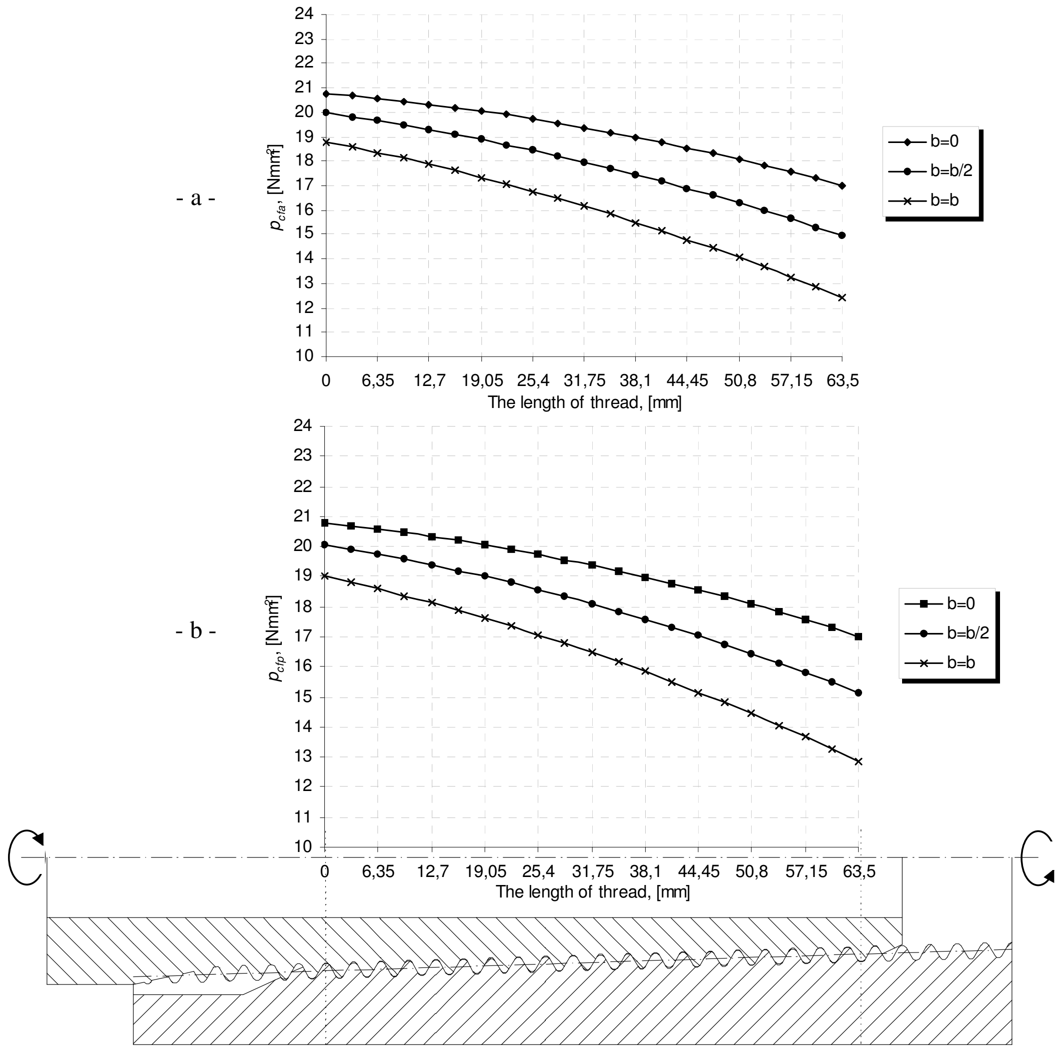

Fig. 4. Variation of contact pressure on the length of considered thread:
a) on the load flank; b) on the stab flank.

For the chosen rotation angle of the pin in relation to the coupling, a make-up moment M_t of 4228 Nm was determined using equation (10).

Conclusions

1. The paper proposes a computation method for the determination of the contact pressure developed on the sides of complete spires of the thread corresponding to a given value of the make-up moment.
2. The proposed method allows for the determination of contact pressure variation on both sides of the thread spire, both on the length of the considered thread and on the width of the contact surface.
3. The proposed method is general and may be used for all types of conical threads employed in the construction of oil tubular goods.

References

1. Bădicioiu, M. – *Cercetări privind rezistenţa şi etanşeitatea îmbinărilor filetate, cu aplicaţii la materialului tubular pentru foraj-extracţie – Teză de doctorat,* Universitatea Petrol-Gaze din Ploieşti, 2005.
2. Bes de Berg, F., Retail, P. – Fuites dans les filetages des tubages: Influence de la température et du passage dans le domaine plastique, *Revue de L'Institut Francais du Petrole*, Vol.37, No.1, , pg. 99-111, 1982.
3. Roşculeţ, M. – *Analiză matematică*, Editura Didactică şi Pedagogică, Bucureşti, 1974.
4. Schwind, B.E. – Equations for Leak Resistance of API 8-Round Connectors in Tension, *SPE Drilling Engineering*, pg. 63-70, March, 1990.
5. Ulmanu, V. – *Material Tubular Petrolier*, Editura Tehnică, Bucureşti, 1992.

Metodă de calcul a presiunii de contact dezvoltate la înşurubare între flancurile filetului rotund

Rezumat

Articolul de faţă prezintă o nouă metodă de calcul a presiunii de contact dintre flancurile filetului rotund, dezvoltată la înşurubare, care ia în consideraţie forma suprafeţei de contact dintre cele două componente ale îmbinării. Metoda propusă are caracter de generalitate şi poate fi utilizată pentru toate tipurile de filete conice utilizate în construcţia materialului tubular petrolier.