BULETINUL Universităţii Petrol – Gaze din Ploieşti	Vol. LXVI No. 2/2014	27 – 30	Seria Tehnică

Aspects of Crank Design in Case of Rod Pumping Units with Reverse Scheme

Liliana Rusu

Universitatea Petrol-Gaze din Ploiesti, Bd. Bucuresti 39, Ploiesti
e-mail: lianarusu57@yahoo.com

Abstract

This paper presents a calculus method for balancing optimization of rod pumping units with reverse scheme. The method establishes the constructive shape of the crank by imposing conditions that lead to a minimal motor moment, minimal reactions in the crank joints and minimum run time in a generator regime.

Key words: *rod pumping units with reverse scheme, balancing optimization, constructive shape of the crank.*

Theoretical Considerations

Balancing aims not only to minimize the operating time in a generator regime, but to obtain a reduced and uniform driving moment.

In case of rod pumping units with reverse scheme, balancing is done by introducing on the crank, in point A_1, a rotative counterweight, offset by an angle α, from the crank (fig.1).

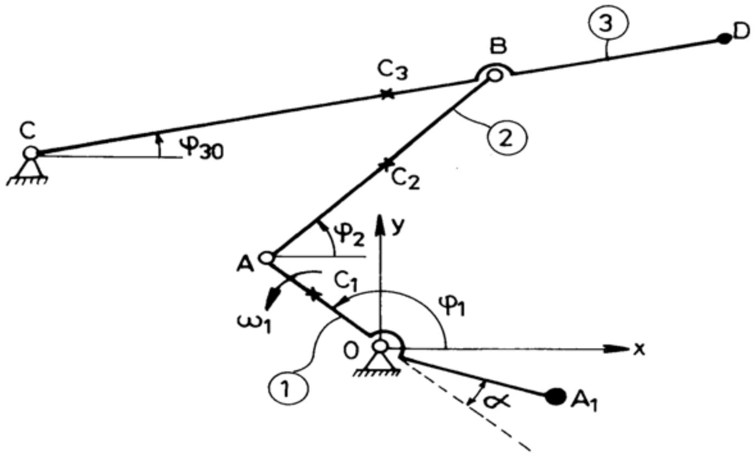

Fig. 1. Kinematic scheme for reverse scheme pumping unit

Current practical balancing calculations do not take into consideration the moments caused by other categories of forces (forces and moments of inertia) but only the one produced by the force at horsehead.

As the counterweight is offset by an angle α from the crank, this results that the curve of the counterbalancing moment will be offset from the curve of the moment produced by the well load, with $\Delta\varphi$ angle.

Figure 2 shows the two overlapped variation curves, for an ideal case of balancing. This implies that counterbalancing effect is delayed at the begining of the upstroke with angle $\Delta\phi$ and before the begining of the downstroke with the same angle $\Delta\phi$.

The resultant curve is the one which represents the torque output of the reducer gear, noted further, M_{a1}.

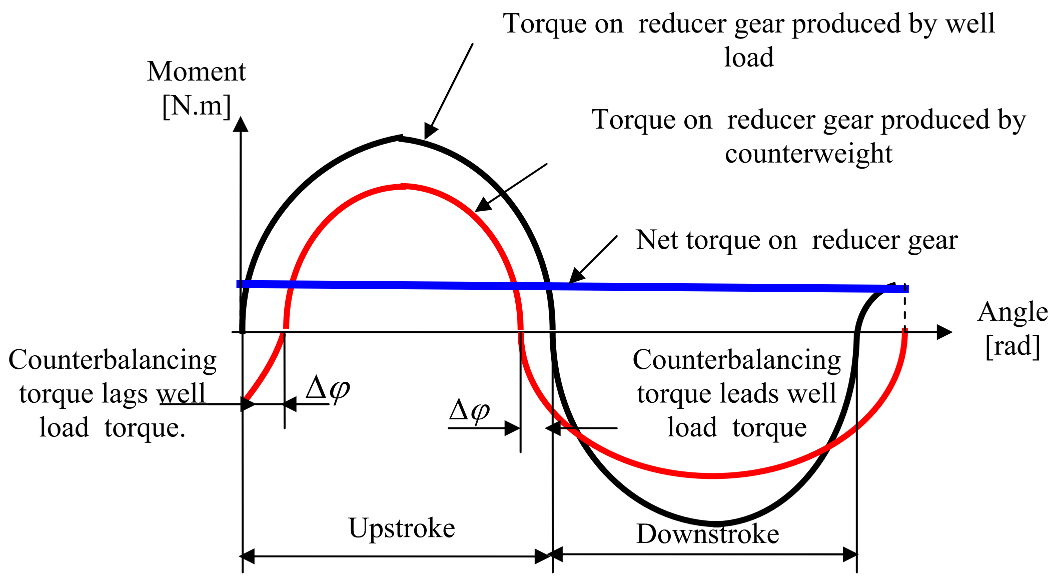

Fig. 2. Ideal curve of the torque on reducer gear for the unit with reverse scheme

In real operating conditions, we must consider the driving moment, noted M_a and calculated by means of all categories of forces and torques which act on the driving mechanism of the rod string and also consider its exact kinematics [2, 3].

The counterbalancing moment is:

$$M_{G_r} = G_r \cdot OA_1 \cdot \cos(\varphi_1 + \alpha) \tag{1}$$

It results:

$$M_{a1} = M_a - M_{G_r} \tag{2}$$

In real operating conditions, the curve obtained by subtraction of the two moments must be positive throughout the duration of one stroke. This situation is ideal, reason for which it is allowed to study the condition that the resultant graphic area below the axis, should be minimum.

Obviously, a value for angle α must be found leading not only to a minimal motor moment, but also to minimal reactions from the crank joint O. Therefore the conditions to be imposed for establishing the offset angle are:

a) Minimum operating time in generator regime (the resulting graph area located under the axis, noted A, to be minimal).

b) The average motor moment to be minimal, which implies:

$$M_{\text{med}} = \left(\int_{\varphi_1^{\text{i}}}^{\varphi_1^{\text{i}}+2\pi} M_{\text{a}1} \text{d}\varphi_1 \right) / 2\pi = \min$$

where φ_1^{i} is the initial angle measured in radians (angle at the begining of upstroke).

c) The extreme values of the reactions from the crank joint O (R_{OM}, $R_{\text{Om.}}$), to be minimal.

Calculus example

It is presented an example for a rod pumping unit with reverse scheme (API Spec. 11E, class III - VULCAN), having the following design features:

- *OA* = 1.381m, *AB* = 4.2m, *BC* = 6.57m, *CD* = 7.92m, *OC* = 6.27m, ω_1 = 0.94 s^{-1}.
- Pump P 2 7/8 x 1 ¾ (piston diameter *D* = 0.044m);
- Stroke length: *s* = 3,66m;
- Depth of plunger: *H* = 2100m;
- Specific weight of extracted fluid: γ_l = 9000 N/m^3;
- The rods string components is indicated in table 1.

Table 1

Rod size [in]	Rod diameter d_{i} [mm]	Cross-section area A_{i} [cm^2]	Weight of length q_{i} [N/m]	String Length l_{i} [m]
1	25	4,9	44	504
7/8	22	3,8	33	567
3/4	19	2,83	25	1029

Balancing was carried out with a rotative counterweight G_{r} = 70000N, at distance $OA_1 = R$ = 2,57m, offset by an angle α = 0.4 rad from the crank. The following overlapped graphics (fig. 3) were obtained:

- with continuous line, the driving moment variation for unbalanced unit with reverse scheme, [M_{a}]=*N m*.
- with dotted line, the counterbalancing moment variation, [M_{G_r}]=*N m*.
- with dashed line, the curve of the torque on reducer gear for the balanced unit with reverse scheme, [$M_{\text{a}1}$]=*N m*.

Using Mathcad software, Table 2 was prepared in order to show the values of the rezultant graph area, situated under the axis, the average motor moment and the maximum, respectively the minimum values of the reactions from the crank joint O, at different counterweight offset angles α , from the crank.

Analizing Table 2, it is found that the angle that meets conditions a), b) and c) is α = 0.4 rad = 23°.

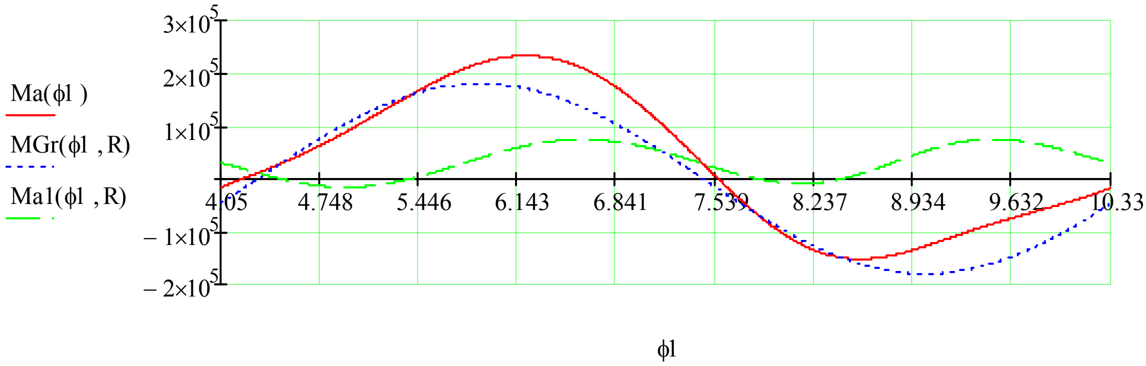

Fig. 3. Overlapped graphics of the presented moments

Table 2

$\alpha[rad]$	$A[N \cdot m] \times 10^4$	$M_{a1}^{max}[N \cdot m] \times 10^4$	$R_{OM}[N] \times 10^5$	$R_{Om}[N] \times 10^5$
0.25	- 2.35	8.69	2.567	1.47
0.3	- 1.54	8.29	2.57	1.47
0.35	- 1.26	7.89	2.58	1.46
0.4	- 1.34	7.48	2.58	1.455
0.45	- 1.73	8.05	2.59	1.45
0.5	- 2.487	8.72	2.596	1.446
0.55	- 3.378	9.45	2.6	1.442
0.6	- 4.35	10.22	2.64	1.438

The angle can be chosen depending on which condition is intended to be more important.

References

1. Popovici, Al. – *Utilaj pentru exploatarea sondelor de petrol*, Ed. Tehnică, 1989.
2. Rusu, L., Eparu, I. – Analiza cinematică exactă pentru o unitate de pompare cu schemă inversă, *Buletinul Universității Petrol-Gaze din Ploiesti, Seria Tehnică*, Vol. LVII, Nr.4/2006.
3. Rusu, L. – Calculul cinetostatic al unităților de pompare cu schemă inversă, *Annals of the the Oradea University, fascicle of management and technological engineering*, Vol. VI(XVI), 2007.
4. Rusu, L., Eparu, I. – Metodă de calcul pentru optimizarea echilibrării la unitățile de pompare cu balansier, *Buletinul Universității Petrol-Gaze din Ploiesti, Seria Tehnică*, Vol. LXIV, Nr.3/2012.

Aspecte privind forma constructivă a manivelei în cazul unității de pompare cu balansier cu schemă inversă

Rezumat

Este prezentată o metodă de calcul pentru optimizarea echilibrării uniătaților de pompare cu schemă inversă. Metoda stabileşte forma constructivă a manivelei impunand condiții care sa conducă la un moment motor minim, reacțiuni minime in articulația manivelei şi un timp de funcționare minim in regim de generator.