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Calculus Method for Optimizing the Balance in Rod Pumping Units

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Abstract

It is presented a calculus method for balancing optimization of rod pumping units. The computer program having this mathematic model as base, it is flexible and allows any input parameter and provides the exact weight values of counterbalance for pumping units with direct schema.

Key words: *rod pumping unit, balancing optimization*.

General Considerations

The rod pumping units are part of the most used equipment in oil operating activity. Their balancing is the most important problem in scaffoldig oil.

Considering the graphic of variation, during an operation cycle, of the action moment M_{a1}, according with constant angular velocity hypothesis of the motor drive, depending on the crank angle φ_1, it is clear that the operating system frequently change (from motor in generator and vice versa).

Neglecting balancing will lead to a inadequate operation which can reflect in both high energy consumption, and in rapid wearing out of the electric engine and the gear drive.

By balancing there are followed operating periods in minimal generator action system, and also obtaining a moment having as low as possible value, that is providing the uniformity of the moment M_{a1}.

Acoording to API method, a pumping unit is considered to be well balanced when the maximum values of the action moment in upward stroke and downward stroke are equal (fig.1).

$$M_{a1}^{1} = M_{a1}^{2} \tag{1}$$

These values are done for crank angels φ_{1M_1} and φ_{1M2}, difficult to determine, and that is why a calculus program provides approximate results.

This condition is imposed due to practical considerations. While operating, balancing is done using an ammeter, which measures the maximum current on a phase of the electric motor, both for upward and downward stroke of the pumping unit. The two values must be nearly equal.

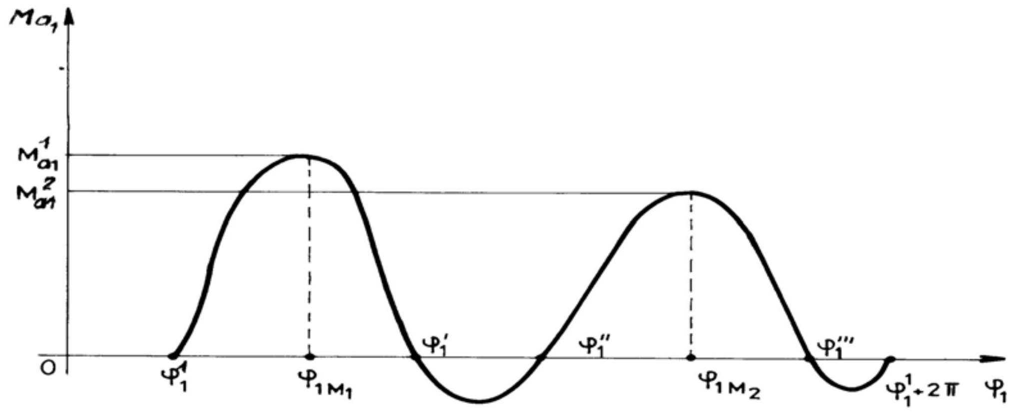

Fig. 1. Variation of the action moment

The proposed method implies knowledge of ungles $\varphi_1^1, \varphi_1^{''}$, where: φ_1^1 - cranck angle at the start of upstoke; $\varphi_1^{''}$ -cranck angle at the start of downstoke; and the unit is well balaced if upstroke mechanical work is equal with downstroke mechanical work:

$$L_u = L_c \tag{2}$$

This impose the condition:

$$\int_{\varphi_1^1}^{\varphi_1^{''}} M_{a_1} \cdot d\varphi_1 = \int_{\varphi_1^{''}}^{\varphi_1^1+2\pi} M_{a_1} \cdot d\varphi_1 \tag{3}$$

Calculus Examples

For a pumping unit with direct schema (fig.2), the next algorithm will follow, starting from the knowledge of the function M_{a1}=$M_{a1}(\varphi_1)$.

- Known values for the oscillating mass balance, CB_1 distance and the mass of rotating balance, are required;
- A value for OA_1 distance is chosen;
- A transcendental equation in OA_1 variable is solved.

$$f(OA_1) = \int_{\varphi_1^1}^{\varphi_1^{''}} M_{a_1} d\varphi_1 - \int_{\varphi_1^{''}}^{\varphi_1^1+2\pi} M_{a_1} d\varphi_1 = 0 \tag{4}$$

which represents exactly the required solution of balancing.

The program made in Mathcad offers the value of OA_1 which respects condition (4).

The results of the two methods will be compared, A.P.I and suggested method, considering the folowing units.

a) Maximum values of the action moment M_{a1}, obtained by the two methods $M_{a1M} = \max(M_{a1}^1, M_{a1}^2)$.

b) The operation period in generator system by calculating the areas:

$$A = A_1 + A_2 ,$$

$$A_1 = \int_{\varphi_1^{'}}^{\varphi_1^{''}} M_{a1} d\varphi_1 \quad \text{and} \quad A_2 = \int_{\varphi_1^{'''}}^{\varphi_1^{1}+2\pi} M_{a1} d\varphi_1 \; ; \tag{5}$$

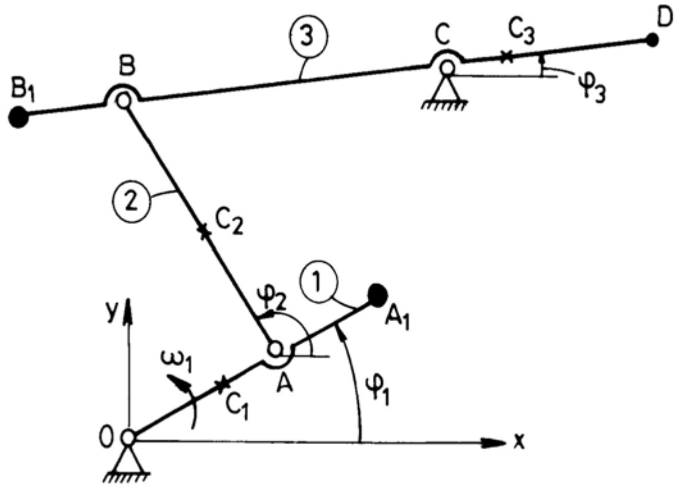

Fig. 2. Kinematic scheme for direct scheme pumping unit

c) The average motor moment to be minimum, implying:

$$M_{med} = \left(\int_{\varphi_1^{1}}^{\varphi_1^{1}+2\pi} M_{a1} d\varphi_1 \right) / 2\pi = \min \cdot \tag{6}$$

d) Maximum and minimum values, of the reactions from O and C joints (R_{OM}, R_{Om}, R_{CM}, R_{Cm}.).

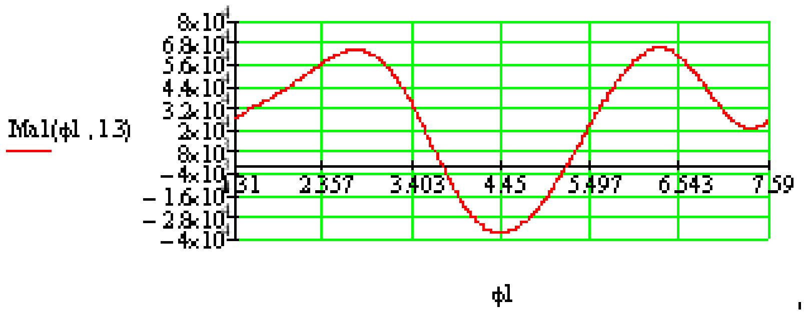

Fig. 3. Variation of action moment for a pumping unit with direct schema, balanced with OA_1=1,3m, as A.P.I method

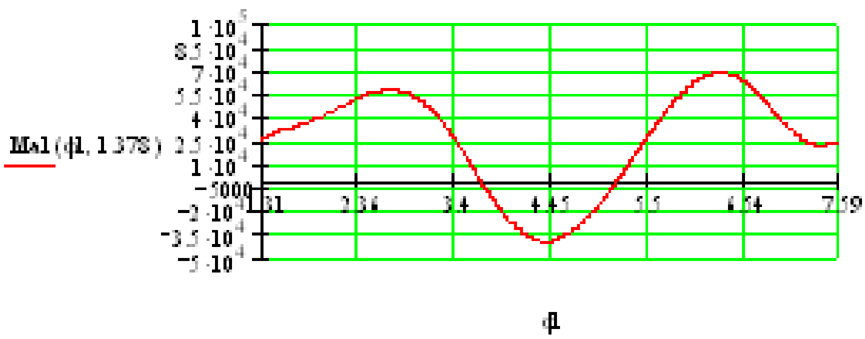

Fig. 4. Variation of action moment for a pumping unit with direct schema, balanced with OA_1=1,378m, as proposed method

Considering the variation of the action moment for a pumping unit with direct schema from Figures 3 and 4, where the unit is balanced with masses at OA_1=1.3m distance, as A.P.I. method and OA_1=1.378m distance, as proposed method, the above mentioned units are calculated in order to make certain comparisons.

The results can be found in Table1.

Table 1

METHOD	OA_1 [m]	A [N.m] $x10^4$	M_{a1M} [N.m] $x10^4$	M_{med} [N.m] $x10^4$	R_{OM} [N] $x10^5$	R_{Om} [N] $x10_4$	R_{CM} [N] $x10^5$	R_{Cm} [N] $x10^5$
Proposed method	1.378	3.59	7.05	2.7	1.271	8.55	3.463	1.3
A.P.I. Method	1.3	3.42	6.5	2.7	1.275	8.16	3.463	1.3

Conclusions

Analysis of Table 1 concludes on the two methods, proposed and A.P.I:

- the values of the balancing distances OA_1 are close, the difference is of centimeters;
- the operation in generator system is almost identical;
- the maximum balancing moment has a lower value in A.P.I. method, but the differences are little:

$$M_{a1M(\text{metoda propusă})} - M_{a1M(\text{metoda A.P.I})} = 5.44\text{kN.m}\ ;$$

- the average motor moment has the same value, whatever the method;
- the reactions in C joint are identical and the differences of reactions in O joint are very small, as seen in Table 1.

The suggested method gives results close to A.P.I method, and that is the reason it is recomanded to be used in order to achieve the above mentioned benefits.

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Metodă de calcul pentru optimizarea echilibrării la unităţile de pompare cu balansier

Rezumat

Este prezentată o metodă de calcul a echilibrării unităţilor de pompare cu balansier. Programul de calcul, având modelul matematic prezentat, este flexibil şi permite variaţia parametrilor de intrare şi obţinerea valorilor exacte ale maselor de echilibrare necesare unităţilor de pompare cu schemă directă.