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SUGGESTIONS ON PROPER CIRCULAR FREQUENCIES ESTABLISHING FOR THE SUCKER ROD PUMPING UNITS

There are comparatively analysed many methods of determining the fundamental circular frequency of a column of sucker rods with sectioned geometry, for a rod pumping unit and there are given utilisations recommendations.
Keywords: proper circular frequencies, rod pumping units

1. Theoretical Considerations

For a corect performance of a sucker rod pumping unit is necesary to have a very accurate knowledge of the fundamental circular frequency and there is choosen the pumping frequency avoiding the resonance ranges. The most used method implies a simple relation demonstrated by Drăgotescu N and corrected in [1] by Popovici Al.:

$$p = \frac{2\pi}{T} = \frac{2\pi \cdot c}{\lambda} = \frac{2\pi \cdot c}{4H} = \frac{\pi \cdot c}{2H} \cong \frac{8000}{H}, \qquad (1)$$

where: λ - length wave ; T - own oscilation period; H - depth of plunger;
c - speed of propagation of the sound in steel, $c=5100$ m/s, deduced by considerating of a steady wave system in the column of sucker rods with a node at the surface and a ventrum at the plunger.

The maximal force is the main characteristic of the pumping unit, according to which they are named and determining its right value is a fundamental condition of a good projecting and utilisation. Because of the complexity of the phenomenon during pumping process, the calculus formulas in the specialized literature offer different results. Some were theoretically deduced and they are affected by different simplifying hypothesis, other are empirically and other although theoretically deduced they have been introduced some correction terms for corresponding with experimental data, terms which refer to condition of work. No matter the criterion, at the upward stoke there is a moment when the force from the polished rod will have a maximum value F_M. In [2], it was created a comparative analyses between the experimental values of the maximal forces obtained by help of dynagraphs provided us with ecometrical experimental values from 40 wells of Moinesti area and the values resulted from the calculations done with the most commonly used formulas in the specialized literature, shown in a table and a graph, by giving directions for use. This way it was recommended the employment of (2) formulas, deduced by Al. Popovici.

$$F_M = G_b + G + 35 \cdot D \cdot 10^3 + \frac{1}{4} \cdot p \cdot s \cdot \omega \cdot \psi \cdot m \cdot \sin\phi_1 + \frac{1}{2} \cdot m \cdot s \cdot \omega^2 \cdot \cos\left(\varphi_1 + \frac{\pi \cdot \omega}{2p}\right) \qquad (2)$$

where: - G_b, column of fluid weight who acts on brute section of the sucker; G, weight of the sucker rod in the air; D, sucker diameter; p, fundamental circular frequency of a column of sucker rods; m , sucker rod mass; ω , angular velocity of the pumping unit cranks;

$$\psi = \frac{k_t}{k_t + k_p}; \qquad (3)$$

k_t, elasticity constant of tubing; k_p, elasticity constant of the rods;

$$\varphi_1 = \arccos\left(1 - \frac{\lambda}{r}\right); \qquad (4)$$

r, crank radius; φ_1 - crank angle where it finishes static deformation of the sucker rod and the tubing, at the taking over of weight of fluid column, calculated with elementary kinematical hipothesis (it may be calculated with much accuracy with exactly hipothesis).

$$\lambda = \lambda_p + \lambda_t \qquad (5)$$

λ , total elongation of the sucker rod and the tubing; λ_p (λ_t) - elastical elongation of the sucker rod (tubing) at taking over the weight of liquid column. Being the most appropriate formula for the experimental results, it will be used (2) for determining the fundamental circular frequency. The calculus is facilitated by Mathcad program.

2. Comparatively analysis between the calculus methods for fundamental circular frequency

Table 1 presents the values of fundamental circular frequencies of sucker rods for 40 wells, from Moinesti area. (results are systematized in [2]).

The dynamometratrion was performed using the dynamometer incorporate in the Echometer (fig.1).

Fig. 1 ECHOMETER equipment

Having the purpose of doing dynamometrations measures, the general assemblage schema from fig.2 was used and the necessary elements for dynamometrations measurements are:

- hard requirements:
    - power transducer;
    - current transducer;
    - connection cables;
    - computer;
- soft requirements:
    - DYN.EXE program - carries on measurements and dynamometrations analyses.
    - RODMASTER program - detail analysis.

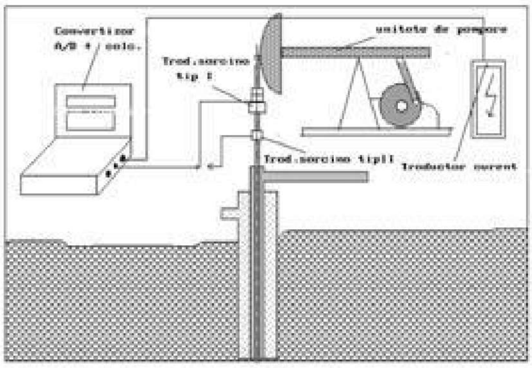

Fig. 2. Assemblage configuration for dynamometrations measurements

From the ecometrical obtained dynagraphs there were emphasized the experimental values of the maximal forces.

- The completion of wells with pumping units varying between:

- Maximal force: 5tf - 12tf (5000daN - 12000daN),
- Pumping frequency: 4,3strokes/min - 10,33strokes/min,
- Stroke length: 0,97m - 3,3m,
- Variety of pumps: TB, TLM, TLC, PCM, HHBC, THM, TH, RLAC, RLB,
- Dynamical level: 6m - 384m,
- Depth of plunger: 473m - 1907m,
- Diameter of the pump plunger: $1\,^{1/4}$ in - $2\,^{3/4}$ in (0,03175m-0,0698m).

- Measurements were done at wells where:

· The filling of the pump is varying in the domain 6% - 92%,

· The leakage at the travelling valve test:

- there are not
- there is small leakage 0,2 - 2,8 B/D (0,0318-0,4452m^3/zi),
- there is great leakage until 12,7B/D (2,019m^3/zi).

- 4 of the measured wells are new ones, with new projected equipment and extracting system, with proper dynagrafs and valve tests, the rest are old wells that don't work at optimum parameters. The comparative study is shown in table1.

The results due to column , method 1, refer to the circular frequency calculus with (1) formula.

The results due to column , method 2, are obtained using the finite elements method by help of COSMOS program [2].

Column, method 3, was completed determining the fundamental circular frequency from (2) relation, by help of Mathcad program, where the maximal force has an experimental value.

The graphic from fig.3 offers a comparison of the three methods obtained values.

It finds out:

- the results offered by finite elements method are very close with the experimental ones (the error reach the maximum value of 1,7%).
- the results obtained with relation (1) have a maximum error of 4% for rod lines with only one section, a maximum

error of 9% for 2 sectioned rod line and of maximum 12% for 3 sectioned rod line.

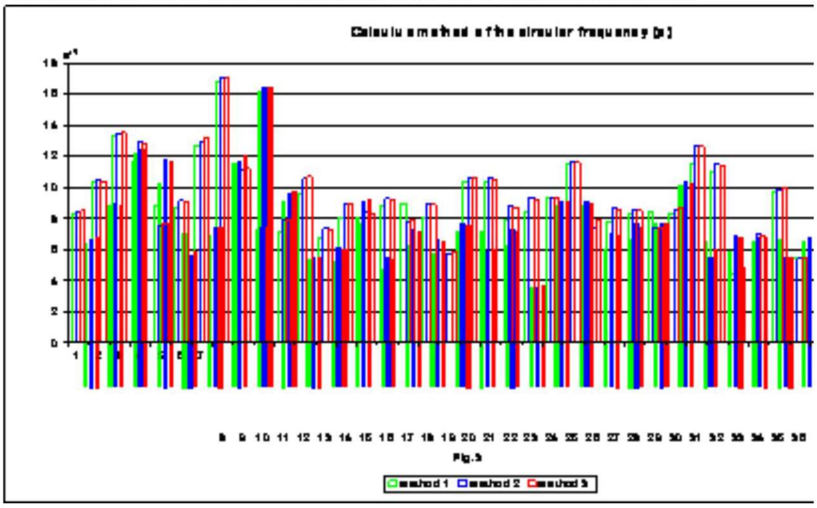

Fig. 3.

3. Recommendations for establishing fundamental circular frequency method

The fundamental circular frequency is an important characteristic of pumping units that allow the choosing of the optimal technological parameters in order to have a well function of the entire equipment, avoiding the resonance ranges.

Table 1

Nr. Experiment	Calculus method of the circular frequency (p)		
	method1	method 2	method 3
1	8.26	8.45	8.5
2	10.32	10.48	10.4
3	13.29	13.49	13.5
4	11.64	12.98	12.8
5	8.75	7.58	7.7
6	8.64	9.14	9.1
7	12.68	12.87	13.15
8	16.77	17.04	17
9	10.58	11.08	11.2
10	7.33	7.46	7.4
11	7.16	7.93	7.9
12	9.63	10.54	10.7
13	6.72	7.38	7.3
14	8.09	8.96	8.9
15	7.61	8.41	8.3
16	8.86	9.28	9.2
17	8.93	7.81	7.9
18	8.08	8.98	8.9
19	5.68	5.75	5.8
20	10.38	10.54	10.6
21	10.38	10.54	10.5
22	7.92	8.78	8.7
23	8.45	9.32	9.16
24	9.29	9.36	9.3
25	11.48	11.65	11.6
26	8.34	7.36	7.9
27	7.77	8.62	8.6
28	8.35	8.52	8.5
29	8.39	7.39	7.4
30	8.29	8.48	8.62
31	11.48	12.65	12.6
32	11.05	11.49	11.4
33	4.44	4.92	4.8
34	6.31	6.99	6.92
35	9.66	9.85	9.94
36	5.39	5.45	5.4
37	9.7	9.91	9.94
38	11.54	11.72	11.6
39	4.195	4.65	4.6
40	8.49	9.32	9.2

Because of its simplicity and the very close values due to experimental ones (maximum error of 12%), relation (1) is recommended to be used both for uniform and sectioned rod lines.

References: 1. *Popovici, Al.,* Utilaj pentru exploatarea sondelor de petrol, *Editura tehnică*, 1989.
2. *Rusu L.,* Studiul cinematicii şi dinamicii unităţilor de pompare cu balansier pentru extracţia petrolului, *teza de doctorat*, 2008.

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