

Research Concerning the Correlations Between Some Experimental Results in the Case of a Sucker Rod Pumping Installation

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In the paper are analyzed the correlations between the experimental results obtained for the instantaneous rotation speed of the cranks shaft of a conventional sucker rod pumping installation and the speed and the acceleration at the end of the polished rod. The correlations have been established by analyzing the kinematics of the mechanism of the sucker rod pumping unit. The experimental records have been processed with the program Total Well Management. A computer program for performing the simulations has been developed by the authors using Maple programming environment.

Keywords: pumping unit, kinematics, cranks shaft, polished rod

The data collected by the transducers (of load, position, pressure, power etc) with which are equipped the sucker rod pumping installations provides a lot of information concerning the pumping system's behavior during functioning [1-3]. The information from some of these transducers gives an overview of the operation of the pumping system, such as: the variation of the motor power, the variation of the gearbox torque and the variation of the instantaneous rotation speed of the cranks shaft, while other transducers provides information concerning the kinematics and the dynamics of the sucker rod column (for example: the variation of the position, speed and acceleration of the polished rod and the surface dynamograph) and the functioning of the depth pump, such as: the variation of the plunger position and of the instantaneous pump displacement. The correlations between the data acquired by these transducers are particularly useful for development or verification of different models concerning the kinematics and the dynamics of the pumping installations [4,5].

In this paper are analyzed the correlations between the experimental results obtained at a well serviced by a C-640D-305-120 pumping unit for the instantaneous rotation speed of the cranks shaft and the speed and the

acceleration at the end of the polished rod. For this purpose is analyzed the kinematics of the mechanism of the sucker rod pumping unit. The experimental records have been processed with the program *Total Well Management* [6]. For simulations a computer program has been developed by the authors using Maple programming environment [7].

Experimental part

The experimental records have been processed with the program *Total Well Management* [6]. It was analyzed a well serviced by a C-640D-305-120 pumping unit produced by *Lufkin* [8].

For establishing the variation on a cinematic cycle of the speed and of the acceleration at the end of the polished rod using the simulation program mentioned before were used the records concerning the variation of the instantaneous angular speed of the cranks shaft for two strokes: stroke 10 (fig.1) and stroke 25 (fig. 2). The instantaneous angular speed of the cranks shaft is expressed in strokes per minute (SPM) what it is equivalent to rotations per minute.

The simulation results have been compared with the records of the variation of the speed and of the acceleration

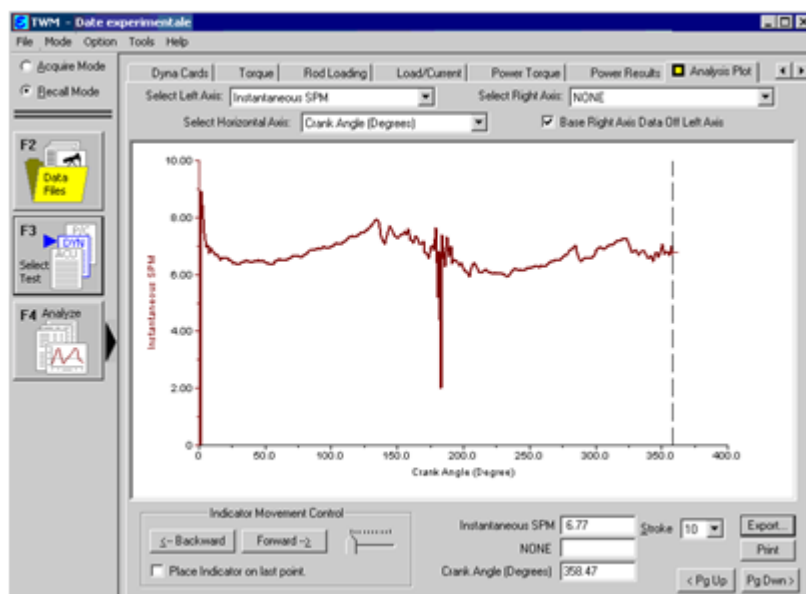


Fig. 1. The variation of the instantaneous rotation speed of the cranks shaft during the stroke 10

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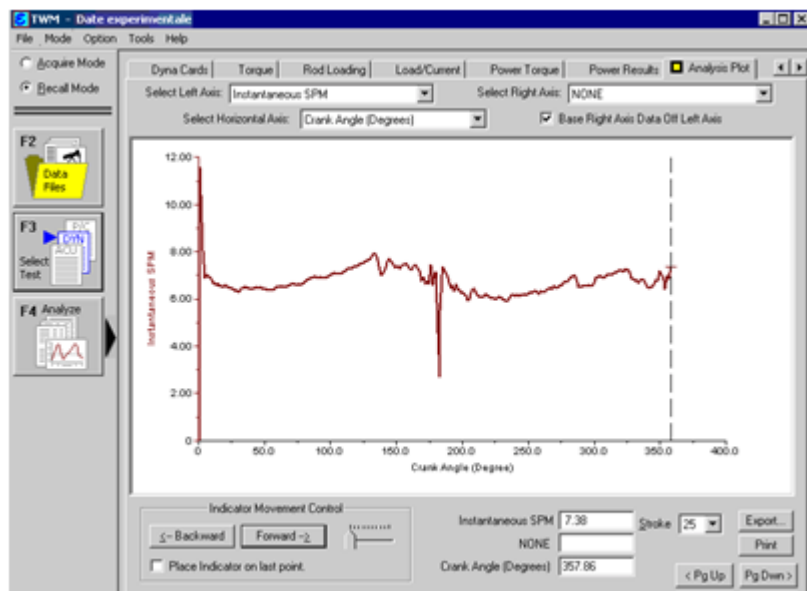


Fig. 2. The variation of the instantaneous rotation speed of the cranks shaft during the stroke 25

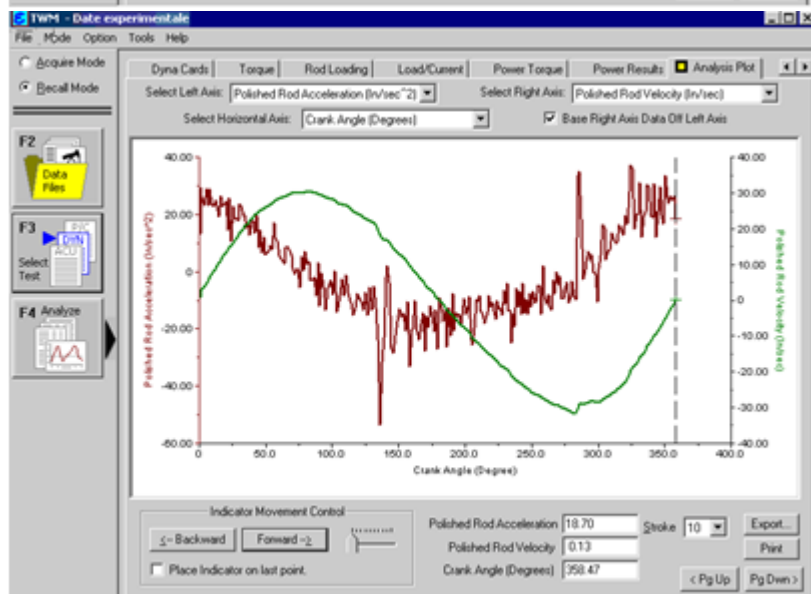


Fig. 3. The variation of the speed and of the acceleration at the end of the polished rod during the stroke 10

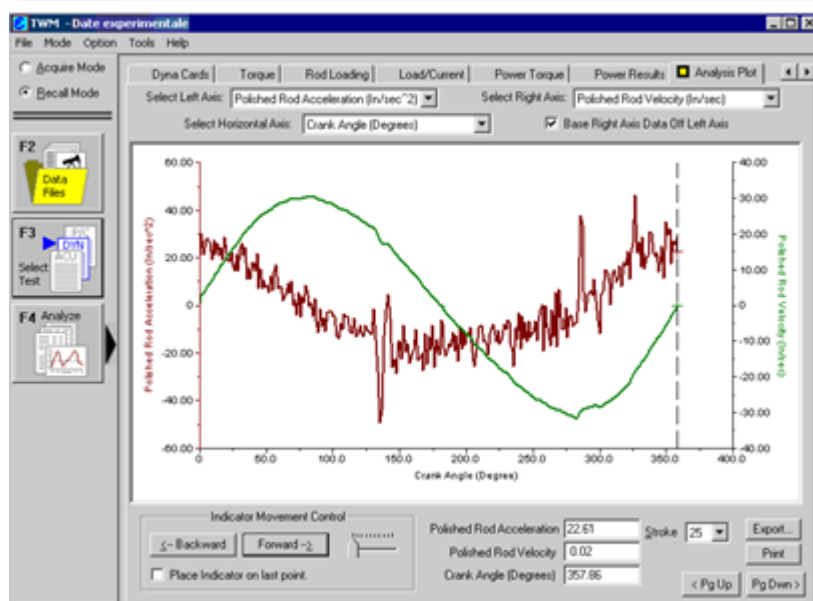


Fig. 4. The variation of the speed and of the acceleration at the end of the polished rod during the stroke 25

at the end of the polished rod for the two strokes (fig. 3 and fig. 4).

Cinematic analysis of the mechanism of the conventional sucker rod pumping units

The mechanism of the conventional pumping units is presented in figure 5. With 1 were noted the cranks of the

mechanism, with 2 the connecting rods and with 3 the mechanism's rocker. ω_1 is the angular speed of the cranks, expressed in rad/s.

The speed v_d at the end of the polished rod can be established with the relation [5]: $v_d = \omega_3 \cdot CD$, where ω_3 is the angular speed of the rocker that can be calculated with the following relation [9]:

$$\omega_3 = \dot{\varphi}_3 = \frac{d\varphi_3}{d\varphi_1} \cdot \frac{d\varphi_1}{dt} = \omega_1 \cdot \frac{d\varphi_3}{d\varphi_1} = \frac{\pi \cdot n_1}{30} \cdot \frac{d\varphi_3}{d\varphi_1} \quad (1)$$

where n_1 is the angular speed of the cranks expressed in rotations per minute.

The variation of the angle φ_3 (fig. 5) according to the angle φ_1 can be determined from the following system of equations obtained by projecting on Ox and Oy axes the vector equation $\vec{OA} + \vec{AB} + \vec{BC} = \vec{OC}$

$$\begin{cases} OA \cdot \cos \varphi_1 + AB \cdot \cos \varphi_2 + BC \cdot \cos \varphi_3 = x_C \\ OA \cdot \sin \varphi_1 + AB \cdot \sin \varphi_2 + BC \cdot \sin \varphi_3 = y_C \end{cases} \quad (2)$$

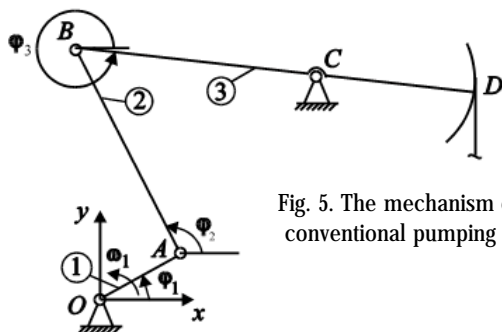


Fig. 5. The mechanism of the conventional pumping units

By rewriting the system of equations (2) into the form:

$$\begin{cases} OA \cdot \cos \varphi_1 + BC \cdot \cos \varphi_3 - x_C = -AB \cdot \cos \varphi_2 \\ OA \cdot \sin \varphi_1 + BC \cdot \sin \varphi_3 - y_C = -AB \cdot \sin \varphi_2 \end{cases} \quad (3)$$

and by squaring the two equations from (3) and then summing them, it results the following equation from which can be calculated the angle φ_3 :

$$A_3 \cdot \sin \varphi_3 + B_3 \cdot \cos \varphi_3 = C_3 \quad (4)$$

where:

$$\begin{cases} A_3 = 2 \cdot OA \cdot BC \cdot \sin \varphi_1 - 2 \cdot BC \cdot y_C \\ B_3 = 2 \cdot OA \cdot BC \cdot \cos \varphi_1 - 2 \cdot BC \cdot x_C \\ C_3 = AB^2 - OA^2 - BC^2 - x_C^2 - y_C^2 + 2 \cdot x_C \cdot OA \cdot \cos \varphi_1 + 2 \cdot y_C \cdot OA \cdot \sin \varphi_1 \end{cases} \quad (5)$$

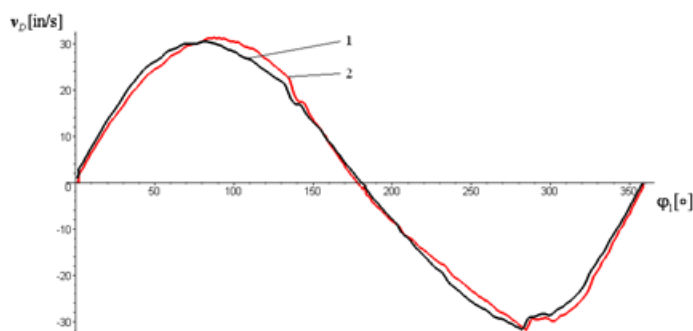


Fig. 6. The variation of the speed at the end of the polished rod for the stroke 10 (experimental - curve 1; simulation - curve 2)

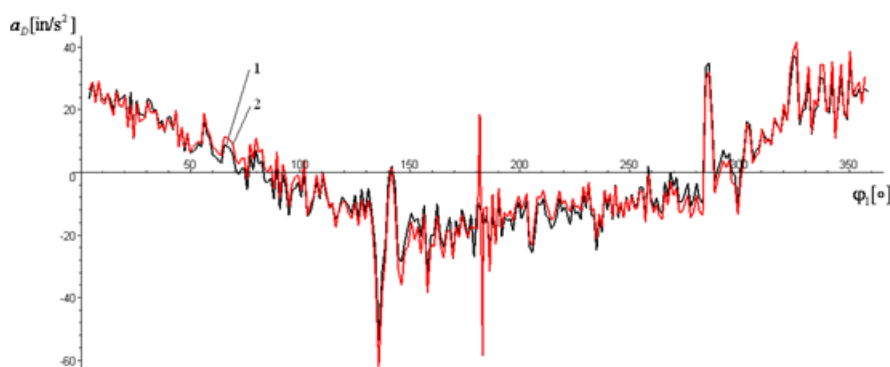


Fig. 8. The variation of the acceleration at the end of the polished rod for the stroke 10 (experimental - curve 1; simulation - curve 2)

The acceleration a_D at the end of the polished rod can be established by deriving with respect to time the speed v_D by taking into account the equation (1):

$$a_D = \dot{v}_D = CD \cdot \frac{d^2 \varphi_3}{d\varphi_1^2} \cdot \left(\frac{\pi \cdot n_1}{30} \right)^2 + CD \cdot \frac{d\varphi_3}{d\varphi_1} \cdot n_1 \cdot \frac{dn_1}{d\varphi_1} \cdot \left(\frac{\pi}{30} \right)^2 \quad (6)$$

Results and discussions

The cinematic analysis of the mechanism of the conventional sucker rod pumping units presented before has been transposed by the authors into a computer program using Maple programming environment [7]. The simulations have been performed in the case of a C-640D-305-120 pumping unit produced by *Lufkin* [8], whose component elements have the following dimensions: $OA = 30$ in. (0.762 m); $AB = 133.5$ in. (3.3909 m); $BC = 111.09$ in. (2.8217 m); $CD = 155$ in. (3.937 m). The coordinates of the point C (fig. 5) are [8]: (2.8194 m) and (3.5052 m).

In figures 6÷9 are presented the variations of the values of the speed v_D and of the acceleration a_D at the end of the polished rod for the strokes 10 and 25, respectively. The curves 1 represent the experimental results and the curves 2 correspond to the simulation results. For obtaining the simulation results have been used the records concerning the variation of the instantaneous angular speed of the cranks for the two strokes presented in figures 1 and 2.

Figures 6÷9 highlight a very good accordance between the experimental and simulation results, especially regarding the variation of the acceleration at the end of the polished rod. From figures 8 and 9 can be observed that the simulation results regarding the acceleration at the end of the polished rod practically track all the small variations of the experimental values of the acceleration.

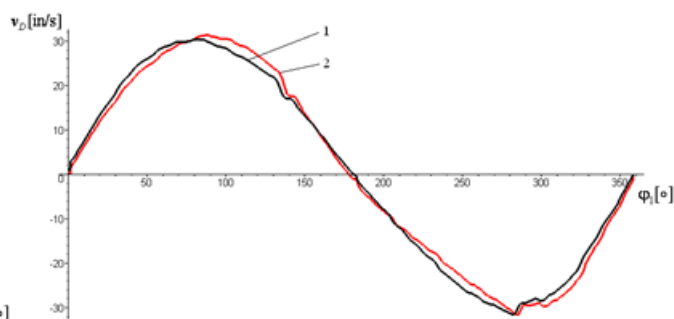


Fig. 7. The variation of the speed at the end of the polished rod for the stroke 25 (experimental - curve 1; simulation - curve 2)

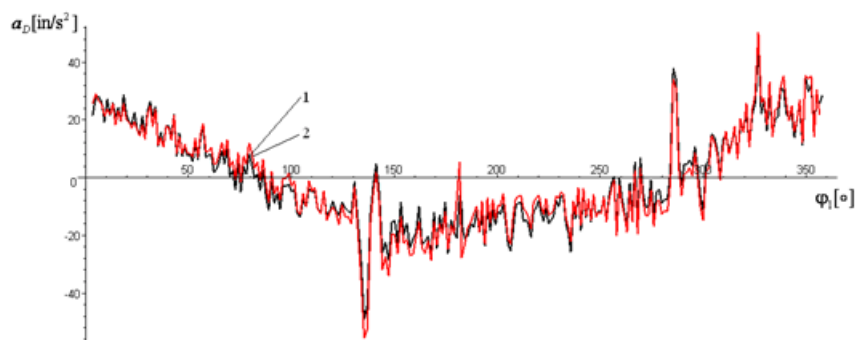


Fig. 9. The variation of the acceleration at the end of the polished rod for the stroke 25 (experimental - curve 1; simulation - curve 2)

Conclusions

In this paper has been presented some results concerning the cinematic analysis of the mechanism of the conventional sucker rod pumping units, highlighting the manner of determining the speed and the acceleration at the end of the polished rod. It has been analyzed in this way the correlations between the experimental results obtained at a well serviced by a C-640D-305-120 pumping unit for the instantaneous rotation speed of the cranks shaft and the speed and the acceleration at the end of the polished rod. For processing the experimental records has been used the program *Total Well Management* and for simulations has been developed a computer program using Maple programming environment. It has been obtained a very good accordance between the experimental and simulation results, especially regarding the variation of the acceleration at the end of the polished rod.

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