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Study on work performance of dual horsehead pumping units

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ABSTRACT

In order to understanding thoroughly the operating characteristics of dual horsehead pumping unit, with 8-type machine as the research object, we compared the conventional pumping unit and dual horsehead pumping unit about movement characteristics, loading characteristics and torque characteristics. The theory analysis results show that dual horsehead pumping unit have some good characteristics such as low impact, small dynamic load, small torque fluctuations, small balance weight and matching small motor power.

Keywords: dual horsehead pumping units(DHPU), conventional beam pumping units, energy conservation, polish rod load

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INTRODUCTION

Since dual horsehead pumping unit (DHPU) was invented and came into use in 1996, the practices of every oil field indicated it had notable energy-saving with 10%~30% saving ratio[1-2]. The structure of DHPU based on conventional beam pumping unit (CBPU), its conventional four bar mechanism was redesigned with flexibility reconfiguration. The back-arm of walking beam was connected a horsehead with a variational radius of curvature. Walking beam was connected linkage rod with flexible drive rope. Therefore the four-bar mechanism with fixed dimension of CBPU was changed into a four-bar mechanism with variational length. Because flexible drive rope always was tangent with cambered surface of rear-horsehead, its included angle was just 90°, the walking beam swung with wide-angle and the stroke was increased. This variational length four-bar mechanism decreased the amplitude of torque factor curve of pumping unit and the polished rod torque, so negative torque was avoided, and then motor efficiency was improved and fluctuate of power grid decreased[3-6].

Many mechanical oil extraction scholar and team studied the kinetic and dynamic characteristic of DHPU and then conducted mathematical modeling[7-9]. All these works provided technical guidance for extension and research of DHPU. However it was difficult to calculate the kinetic characteristic that was solution of transcendental equation, there were no related articles to elaborately comparative study of kinetic and dynamic characteristic of DHPU.

This paper conducted to study every performances of DHPU(CYJS8-3-37HB) comparing to CBPU(CYJ8-3-7HB), the performance parameters included displacement, velocity, acceleration, load of polished rod and output net torque of reduction gearbox. It provided qualitative and part quantitative understanding for oil well engineers and provided help for more extension DHPU.

II. GEOMETRY CONSTRUCTION AND KINEMATIC ANALYSIS OF DOUBLE HORSEHEAD PUMPING UNIT

Formula1~14 was geometry construction analysis of DHPU, the polished rod kinetic characteristic was referenced the paper[10].

$$K = \sqrt{I^2 + H^2} \tag{1}$$

$$\phi = \arctan(\frac{I}{H}) \tag{2}$$

$$\mu = \arctan(\xi) \tag{3}$$

$$\rho = e\xi \tag{4}$$

$$C = \sqrt{b^2 + \rho^2 - 2b\rho\cos(\xi + \varepsilon)} \tag{5}$$

$$P = L0 - \frac{e}{2}\{\frac{1}{2}[\xi\sqrt{\xi^2 + 1} + \ln(\xi + \sqrt{\xi^2 + 1})]\} \tag{6}$$

$$\gamma_1 = -\arcsin(\frac{b}{C}\sin(\xi + \varepsilon)) \tag{7}$$

$$\beta = \pi - (\mu + \gamma_1) \tag{8}$$

$$J = \sqrt{K^2 + R^2 - 2KR\cos(\theta - \varphi)} \tag{9}$$

$$\rho_1 = \arcsin(\frac{R\sin(\theta - \varphi)}{J}) \tag{10}$$

$$X = \arccos(\frac{C^2 + J^2 - P^2}{2CJ}) \tag{11}$$

$$\psi = X - \rho_1 \tag{12}$$

$$\alpha = \beta + \psi - (\theta - \phi) \tag{13}$$

$$\overline{TF} = \frac{A}{C}R\frac{\sin\alpha}{\sin\beta} \tag{14}$$

ρ ——radius vector of arbitrarily point of Achimedean spiral
ξ ——angle of Achimedean spiral
e ——coefficient of Achimedean spiral
C ——effective length of back-arm
μ ——angle between the arbitrarily point of Achimedean spiral and radius vector of curve
β ——driving angle
α ——angle between crank and connecting rod
θ ——crank angle
J ——distance from crank pin to centre of walking beam
R ——turning radius of crank
K ——length of primary rod
γ_1 ——angle between back-arm of walking beam and radius vector
ρ_1 ——angle between K and J
X ——angle between C and J
ψ ——angle between C and K
L_0 ——total length of flexible rod
$\overline{TF}$ ——torque factor

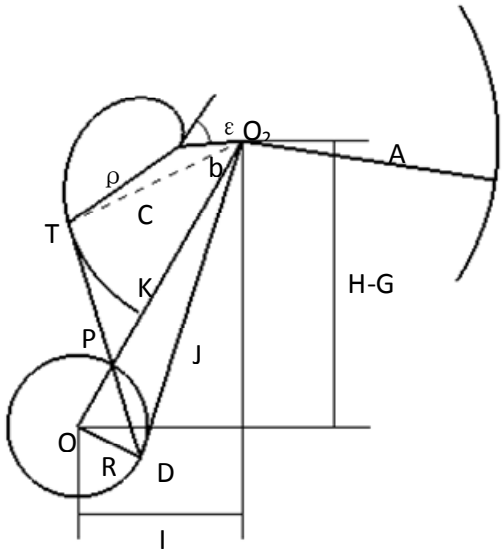

Figure 1. Structural Representation of Double Horsehead Pumping Unit

Ⅲ. BASIC CALCULATING PARAMETER

This paper selected CYJ8-3-37HB type CBPU and CYJS8-37HB type DHPU as study model to compare their working characteristic because the two type pumping unit had the same rated polished rod load, rated torque and similar structure size. So the two pumping unit working performance could be compared with high comparable worth. CBPU kinetic function could be found in reference [10]. The polished rod load calculation method was shown in the papers[11-14] that Gibbs proposed one-dimensional wave equation and its solution method for forecasting polished rod indicator diagram. The swabbing parameters and well condition was shown in Table 1.

TABLE 1. WELL CONDITION AND SWABBING PARAMETERS

Name	Value
Stroke (m)	3; 2.5; 2
Frequence of stroke (1/m)	3; 6; 9
Working liquid level (m)	600
Depth of plunger (m)	1000
Rod diameter (mm)	22
Pump diameter (mm)	57
Tube diameter (mm)	76
Water percentage (%)	90

IV. KINETIC CHARACTERISTIC

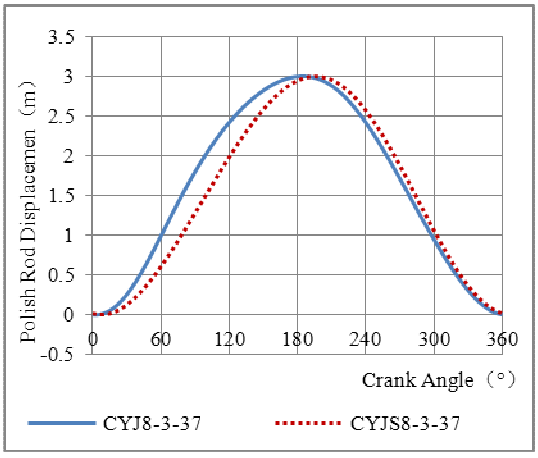

Figure 2. Polish Rod Displacement

Comparing to CBPU, the displacement maximum of DHPU moved to the right 14° along horizontal axis, that was from 178° to 192°. It obviously increased the turned angle in the upstroke. Because the crank motion of DHPU was approximately constant, it amounted to increase the run duration of up stroke and decrease the run duration of downstroke. It was swabbing process with slow upstroke and fast downstroke. The other characteristic of DHPU

was that the displacement was very little from initial period to 30°rotation angle, together with longer stroke time, therefore reciprocation pump valve was opened more slowly than before. As a whole, it was conducive to the liquid flowing into the pump chamber.

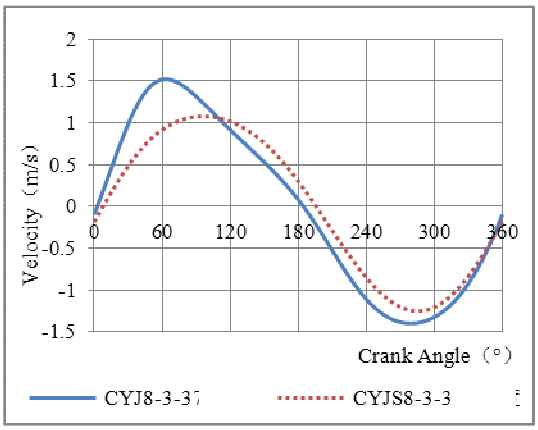

Figure 3. Polish Rod Velocity

Figure 3 indicated that the peak and valley value of polish rod velocity were all obviously decreased, especially in upstroke the reduction was even more nearly reaching 33%. The polish rod velocity of CBPU increased fast in the begin of cycle working period, but DHPU increased slowly and its curve was close to sine curve much more than CBPU.

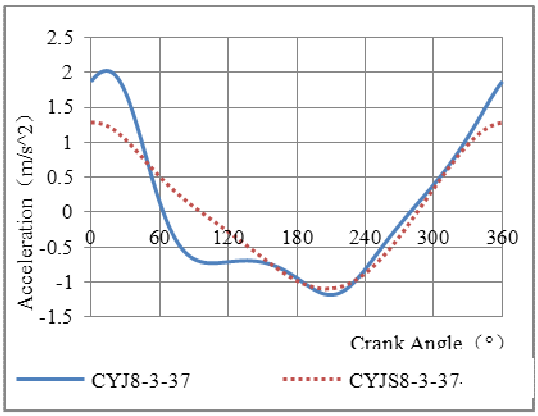

Figure 4. Polish Rod Acceleration

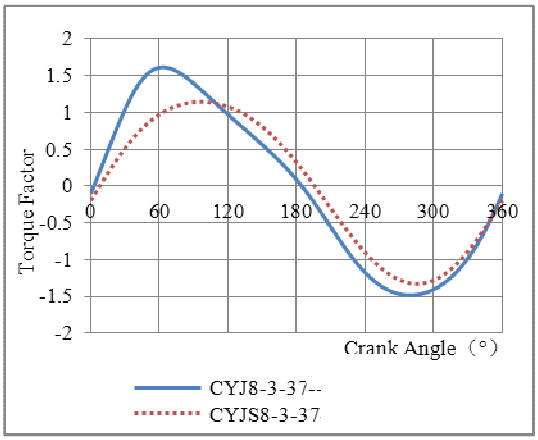

Figure 5. Torque Factor

As shown in Figure 4, the acceleration curve of DHPU was much gentler obviously than CBPU, it decreased about 36%. The fluctuate reduction of acceleration could decrease the polish rod load impact to whole grand pump unit system. Especially the alternating load of reduction gearbox was weakened that was good for improving its life.

Acceleration reduction could decreased the dynamic load of rod string, its indicate diagram was closer to static indicate diagram more than CBPU.

Figure 5 reflected difference tendency of torque factor curve between DHPU and CBPU. Maximum and valley value of torque factor of DHPU decreased respectively 29.2% and 11.5% so that it could effectively decrease the maximum polish rod torque acting on the reduction gearbox output axis. The characteristic of torque factor curve of DHPU indicated that the output net torque of reduction gearbox would be stable much more than CBPU. Zero point of torque factor of DHPU moved to right side along horizontal axis, therefore the range of negative torque decreased. Because generally, the negative torque of CBPU located in the scope of 90°~180°, but the DHPU polish rod torque curve was more full in this scope that was justly filled with balance torque. As Figure 8 shown, DHPU torque curve had not negative value, therefore its net torque curve volatility would be decreased greatly.

V. DYNAMIC CHARACTERISTICS OF DUAL HORSEHEAD PUMPING UNTI

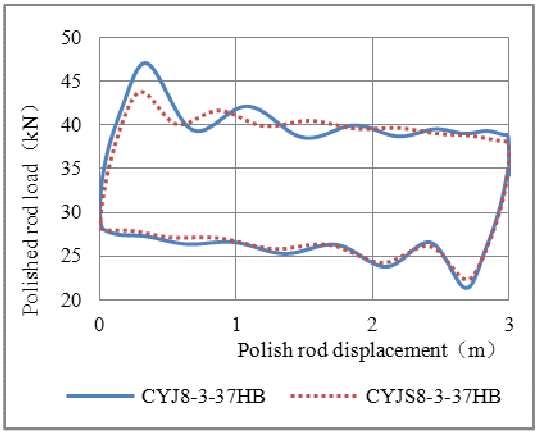

Figure 6. Indicator Diagram of Polish Rod

The maximum polish rod load of DHPU decreased much more about 7.01% than CBPU, the minimum polish rod load of DHPU decreased 4.52% as shown in Figure 6. it was mainly attributed to polished rod dynamic load inducing by the lower polished rod velocity and acceleration peak. But their two acting area were nearly equal to each other. Load fluctuating of DHPU was less than CBPU and much more approached the static pressure indicator diagram, DHPU had very excellent load shedding effect.

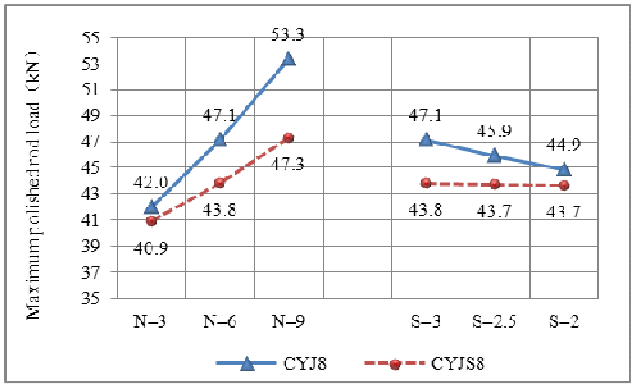

Figure 7. Stroke and Frequencies of Stroke Influence to Maximum Load Of Polish Rod

Influencing law to maximum polish rod load of DHPU by frequence of stroke was same as CBPU; maximum load of DHPU and CBPU all increased with frequence of stroke increasement. Maximum load of CBPU was 1.76 time bigger than DHPU, the difference of the two pump unit was nearly linear direct ratio relation. Influencing law to maximum load of DHPU by stroke were same as CBPU, but at the same stroke condition, the maximum load of DHPU decreased very less than CBPU, less than one percent point. It was indicated that polished rod load had low susceptibility to stroke variation. The rate of curve presented susceptibility of maximum load to independent variable in Figure 7, frequence of stroke had more important effect to polish rod load than stroke.

VI. TORQUE CHARACTERISTICS OF DUAL HORSEHEAD PUMPING UNIT

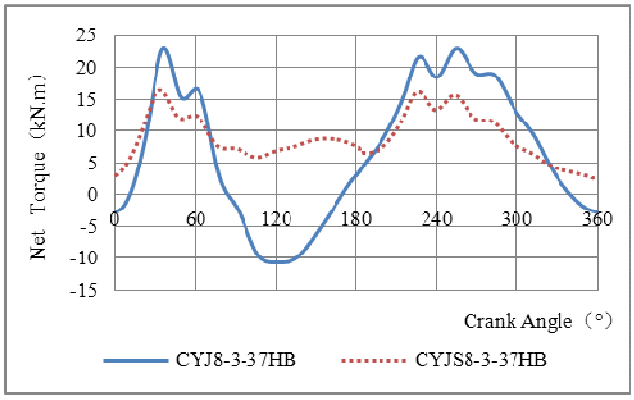

Figure 8. Net Torque Curve of Gearbox Output Axis

At swabbing condition of 3m stroke and 6 frequency stroke, torque peak of CYJS8 was decreased 40.23% less than CYJ8. The valley torque of CYJS8 changed from negative value to positive value, in other word, the negative value of whole torque curve of CYJS8 was completely eliminated. The fluctuate of alternating load was decreased so that the life of motor and reduction gearbox were all increased effectively. So the rated torque of reduction gearbox matching DHPU could be decreased.

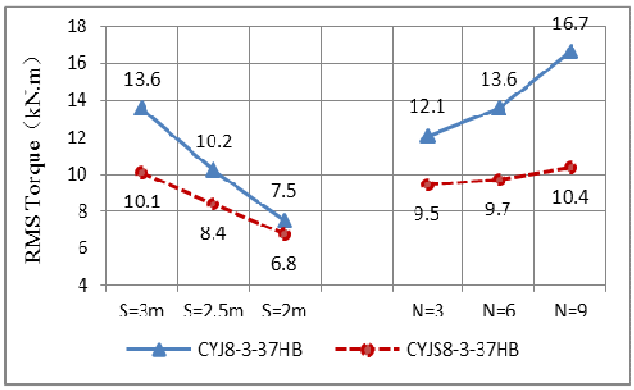

Figure 9. RMS Torque

Figure 9 indicated RMS torque of DHPU and CBPU at the 100% degree of balance condition. RMS torque was one of important parameters to select motor model. As Figure 8 shown, DHPU could decrease a motor model because RMS torque of DHPU was always less than CBPU at whatever stroke and frequency stroke working condition as shown in Figure.

CONCLUSION

At the same wording condition, the kinetic characteristic and dynamic characteristics of convention pumping unit and dual-horsehead pumping unit were calculated, including displacement, velocity, acceleration, torsion factor, indicator diagram and torque. Comparing to conventional pumping unit, the dual-horsehead pumping unit had the following characteristic;

1) DHPU had swabbing characteristic of slow-up-stroke and fast-down-stroke that was good for increasing the fullness of oil well pump.

2) DHPU decreased the maximums of polished rod velocity and acceleration. It was good for decreasing polished rod dynamic load and the indicator diagram approached static-indicator diagram much more than CBPU.

3）Torque factor curve of DHPU approached sinusoid curve much more than CBPU and its maximum of torque was decreased. It indicated that DHPU was good for balancing the polished rod torque with lighter counterbalance than before and decreasing, even eliminating negative torque,

4) RMS torque of DHPU reduction gearbox was decreased very much therefore the matching motor could be drop a model number.

NOMENCLATURE
DHPU- Dual Horsehead Pumping Unit
CBPU- Conventional Beam Pumping Unit
RMS - Root Mean Square

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