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Study on Pumping Unit Well Flow Fluctuation Coupling

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Abstract: In the oil production, mostly production by pumping unit driven rod pumping reciprocating motion. The oil collecting pipeline parallel crude oil production to delivery to the metering station collects transfer. Pumping unit motion can be simplified as a crank link motion, so the flow of crude oil rod pump production regularly surges. Different working parameters of the oil well, production time, conveying distance may be different, the pipe flow with flow instability, pressure fluctuation big shortcoming, the back pressure fluctuation of the pumping unit working imbalance. through the analysis of several pumping coupling rules of flow fluctuation, pumping parameters influence on the flow fluctuation, can be set up, to provide reference wells and ground pipeline design for pumping parameters.

Keywords Luctuation; Velocity; Pressure drop; Parameter

INTRODUCTION

Currently, the energy saving measures for rod pumped well mainly focus on the optimization and renovation of the rod pumped well itself while neglecting the influence of back pressure caused by flow fluctuation of crude oil inside the gathering line on the well. The fluctuation of back pressure of gathering line leads to consequences like the operation imbalance of the pumping unit, increase of energy consumption, reduction of service life of pumping rod. The increase of back pressure at the wellhead will reduce the well production and increase the electricity consumption of pumping unit [1-2]. Due to the characteristics of oil pumped well, the single well production fluctuates. When crude oil of several wells gathers together, the back pressure caused by flow of crude oil after coupling of different flow fluctuation varies largely. The selection of optimal flow fluctuation approach will help improve the production and efficiency of the oil field. The effect of flow coupling approach on production of rod pumped well is discussed through production characteristics of rod pumped well and calculation of back pressure of gathering network.

FLOW COUPLING OF GATHERING LINE

Flow diagram of transportation of crude oil produced by several wells through pipeline to metering station.

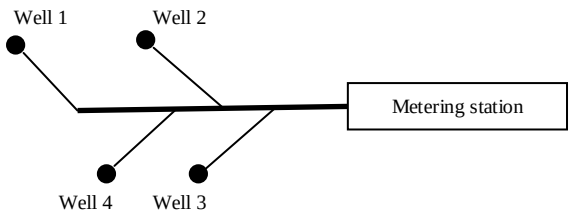

Fig 1 Diagram of oil transportation through gathering line

Since the movement of pumping unit can be simplified as simple harmonic movement and the flow of each well is changing periodically, to simplify the calculation and neglect the influence of error and stroke loss, the flow during upward and downward stroke of pumping unit is calculated based on speed of suspension center. The calculation formula for suspension center is as follows:

Upward stroke:

$$v = \frac{S}{2}\omega \sin \emptyset \quad 2k\pi \le \emptyset \le 2k\pi + \pi \tag{1}$$

Downward stroke:

$$v = \frac{S}{2}\omega \sin \emptyset \quad 2k\pi + \pi \le \emptyset \le 2\ (k+1)\ \pi \tag{2}$$

Among which, k is integral number, $\emptyset = \omega t$, v is suspension center speed, m/s; s is stroke length, m; ω is angular speed of crank, rad/s; $\emptyset$ is turn angle of crank, rad; t is time, s.

Formula for calculation of well production based on suspension center speed is as follows:

Upward stroke flow: $q = vA$ (3)

Downward stroke flow: $q = vA_P$ (4)

Among which q is production, m^3/s. A is the annulus area between oil pipe and pumping rod, m^2; A_P is the section area of pumping rod, m^2.

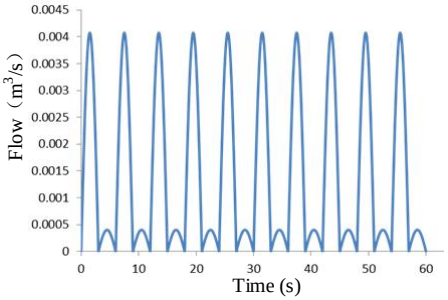

Fig 2 Relationship between single well fluctuation and time

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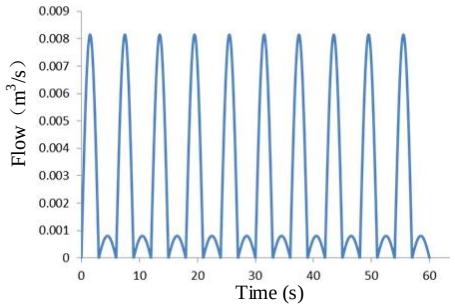

Fig 3 Superposition of flow when the phase difference of two wells is 0

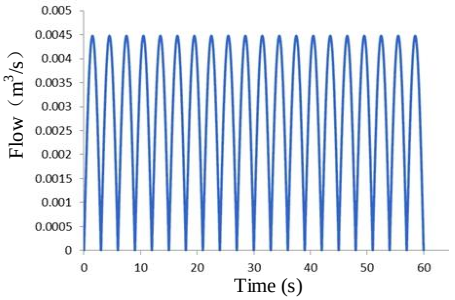

Fig 4 Superposition of flow when the phase difference of two wells is π

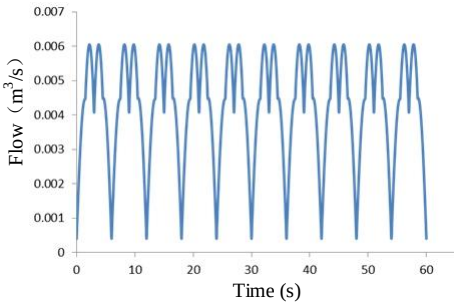

Fig 5 Superposition of three well flow

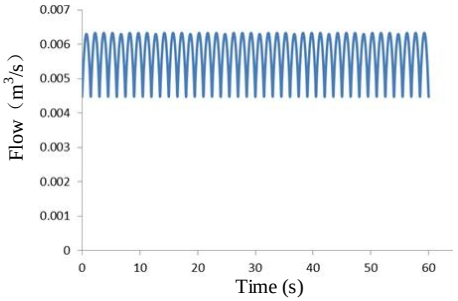

Fig 6 Superposition of four well flow

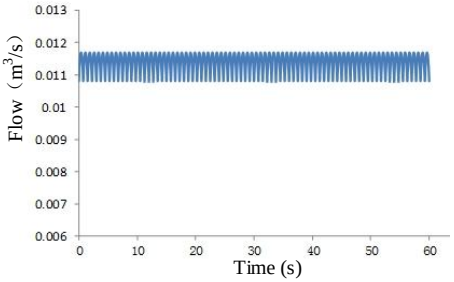

Fig 7 Superposition of eight well flow

Figure 3 shows the flow coupling when the phase difference of two wells is 0, which produces the fluctuation amplitude twice of the flow coupling when the phase difference of two wells in figure 4. Figure 4-figure 7 are the optimal flow coupling inside the gathering line with different number of wells.

The analysis suggests that selection of optimal flow coupling approach is able to reduce the flow fluctuation amplitude and make the flow of gathering line more stable. The relationship between the increase of number of wells and the flow fluctuation of gathering line is non-linear, and the number increase may enlarge the flow fluctuation. Due to the complexity of actual production of well, the law of flow fluctuation at each entry node of gathering line has to be monitored in real time and the optimal coupling method has to found through data analysis.

ANALYSIS OF FLOW FLUCTUATION ON OPERATION OF PUMPING UNIT

The flow of crude oil of several pumping units entering the gathering pipeline can be represented with movement equation and continuity equation[3]:

$$g\frac{\partial H}{\partial x}+V\frac{\partial V}{\partial x}+\frac{\partial V}{\partial t}+\frac{4}{\rho D}\tau_w=0 \tag{5}$$

$$V\frac{\partial V}{\partial x}+\frac{\partial V}{\partial t}-V\sin\alpha+\frac{a^2}{g}\frac{\partial V}{\partial x}=0 \tag{6}$$

Among which H is the water head of certain section of relevant reference surface at the moment of t, m; g is the gravity acceleration, m/s^2;V is the fluid flow of certain section at the moment of t, m/s; D is the diameter of pipeline, m; α is the included angle between the pipeline and horizontal position; a is the transmission speed of the pressure wave, m/s; τ_w is the shear stress between flow and wall surface, Pa; ρ is the fluid density, kg/m^3.

When the flow in the pipeline fluctuates periodically, the pressure drop is the sum of pressure drop produced by friction force and pressure drop produced by fluctuation. The sum of fluctuation pressure drop within one cycle is zero and the pressure drop at certain moment can be represented by the formula as follows:

$$\Delta p=\rho\frac{32}{Re}\frac{lV^2}{D}+\rho l\frac{\mathrm{d}V}{\mathrm{d}t} \tag{7}$$

Among which Δp is pressure drop, Pa;l is the pipeline length, m; Re is Reynolds number.

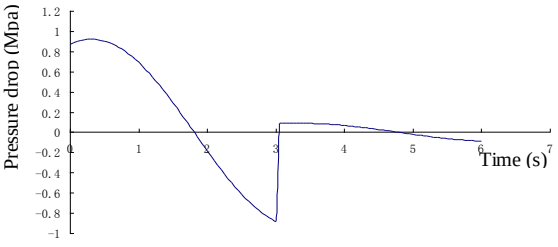

Fig8 Single well pressure drop

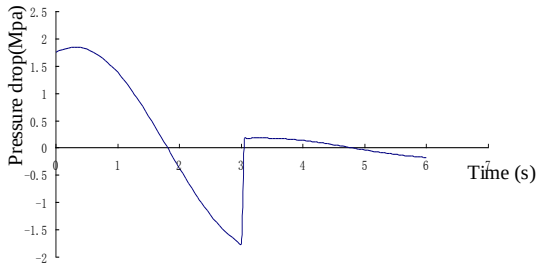

Fig 9 Pressure drop when the two well phase position is 0

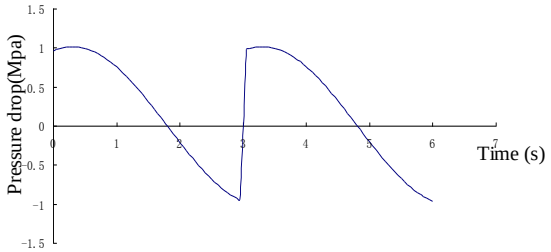

Fig 10 Pressure drop when the phase position of two wells is π

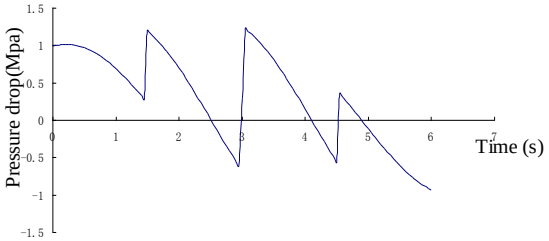

Fig 11 Pressure drop of three well flow coupling

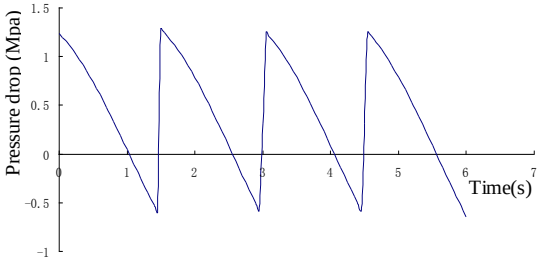

Fig 12 Pressure drop of four well flow coupling

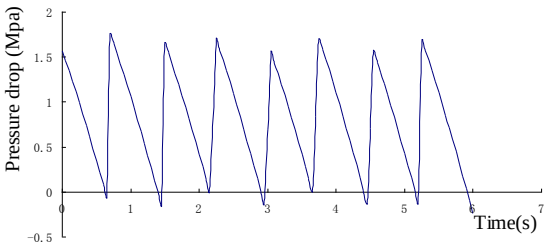

Fig 13 Pressure drop of eight well flow coupling

Figure 8-figure 13 is the relationship between pressure drop and time under different conditions obtained through analysis of loss of gathering pipeline.

The flow coupling suggests that the selection of optimal coupling approach is able to reduce the maximum pressure drop, i.e. the back pressure on the rod pumped well acted by gathering pipeline. Figure 10-figure 13 are the relationship between pressure drop and time during optimal coupling for two wells, three wells, four wells and eight wells respectively. Two rod pumped wells are taken as examples to analyze the influence of flow coupling on pumping unit. Figure 3 and figure 9 are the change of production and pressure drop of two wells when the phase difference is 0. When two pumping units are moving upward at the same time from bottom dead center , the crude oil produced also enter the gathering line, enlarging the flow of gathering line by several times and producing large maximum pressure drop so that the maximum back pressure produced for well is increased and the maximum load of pumping unit is also improved. Figure 4 and figure 10 show the change of production and pressure drop of two wells when the phase difference is π. When one pumping unit moves upward from the bottom dead center and the other pumping unit moves downward from the top dead center, compared with when the phase difference is 0, the flow fluctuation and the maximum pressure drop are smaller so that the maximum back pressure produced for the well is small and the maximum pumping unit is small.

CONCLUSION

The flow fluctuation of oil pipeline has large influence on the stability of pipeline flow and back pressure of well. The coupling of flow fluctuation of pumping unit is able to reduce the amplitude of flow fluctuation and make the flow more stable; able to reduce the maximum back pressure and amplitude of back pressure so that the pumping unit works more stably. The actual flow of pumping unit is very complicated. The optimal flow coupling approach for several wells by monitoring of flow change law is able to save the energy, reduce the exhaust of pumping unit and extend its service life.

ACKNOWLEDGEMENT

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