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Research and Structure Optimization on the Performance of KZ-28 Type Vibrator Plate

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Abstract: ***Because of the characteristics of safety, environmental protection and high efficiency, the traditional explosion source has been gradually replaced by the non-explosive source in some areas, and the vibroseis has become the main equipment for petroleum exploration. It adopts the finite element dynamics method to study on the KZ-28 type vibrator plate, and find that the original vibration device exists large contact force and uneven distribution problem in the plate center. After optimizing the original vibrator plate structure, the analysis results indicates that the maximum deformation of the plate center position is 5.6% less than the original, respectively. Through optimization, the plate deformation is reduced and the uniformity of the contact force is improved, which can improving the signal quality, improve the survey quality.***

Keywords: Vibrator; Vibrator plate; Structural Optimization; Finite Element; Performance Study

1. Introduction

Vibroseis is a non-explosive seismic source, and can overcome many disadvantages of explosive seismic sources. It also has the features of efficient, safe, environmentally friendly, in the most parts of the world, the vibroseis has gradually replaced the traditional position of explosion source, become the main equipment of oil and gas exploration. Vibroseis vibrator is a kind of excitation device for continuous exploration signal, it is the core component of vibroseis, which installed in the middle of vibrator. The KZ-28 vibroseis vibrator is belong to hydraulic vibrator, it converts liquid pressure into mechanical vibration of vibrator, as is shown in Fig. 1.[1]

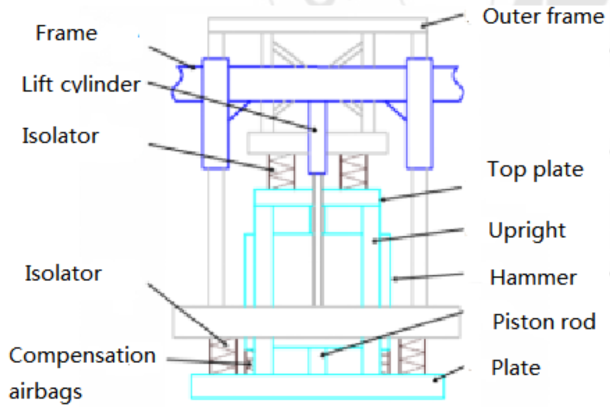


Figure 1: The Force Model of the Vibrator

In the working process of the vibrator, the vibrator plate was directly contacted with the ground. Therefore, the vibrator plate is the important device that connected to the vibrator and the ground, is the key of seismic signals, the quality of the vibrator plate affects the quality of the vibrator's output signal, by using the method of finite element analysis, the KZ-28 vibroseis is analyzed with mechanics, and calculates the vibrator plate deformation and the law of contact force distribution, according it, to optimize the vibrator plate, so as to achieve the aim of improve the vibroseis plate performance.[2-3]

2. The analysis of working process of KZ-28 vibroseis

The amplitude of rated hydraulic exciting force is 20Mpa in the frequency range of 5Hz to 125Hz for 12 seconds. In normal condition, in order to guarantee the output signals to not be distorted,we select the 70%-85% of the rated fluid pressure amplitude in the working process of vibroseis, vibroseis is a signal source excitation device the Let the frequency has certain regular changes over time, the output force can be adjusted according to the design requirements.

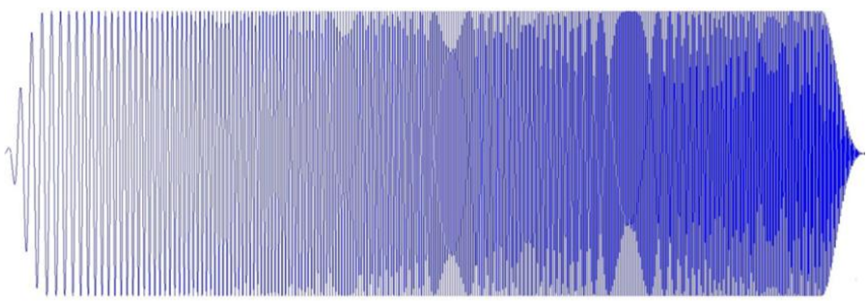


Figure 2: Vibroseis's scanning signal of 5-125 hz in 12 seconds

Model of vibrator and the earth system is shown in Fig 3, according to Sallas model[4],the dynamic equation of the system was established. It is assumed that the vibrator plate is rigid body, the vertical acceleration is equal in all parts of the plate, and the plate is completely coupled with the ground .It is assumed that vibrator for quality-spring-damper system,the reference points on the ground, the kinetic equation of vibrator hammer and plate will be as below:

$$-F = M_r \frac{d^2 X_r}{dt^2} + D\left(\frac{dX_r}{dt} - \frac{dX_b}{dt}\right) + K\left(X_r - X_b\right) \quad (1)$$

$$F - F_g = M_b \frac{d^2 X_b}{dt^2} - D\left(\frac{dX_r}{dt} - \frac{dX_b}{dt}\right) - K\left(X_r - X_b\right) \quad (2)$$

Both of above formulas can be simplified:

$$-F_g = M_r \frac{d^2 X_r}{dt^2} + M_b \frac{d^2 X_b}{dt^2} \quad (3)$$

K—The elastic coefficient of hydraulic oil;
M_r—quality of the vibrator hammer;
M_b—The quality of the vibrator plate;
D—The damping of hydraulic oil;
F—the force of hydraulic oil that effect on hammer;
F_g—The ground force that effect on the plate;
X_r—The downward displacement of heavy hammer;
X_b—The downward displacement of plate.

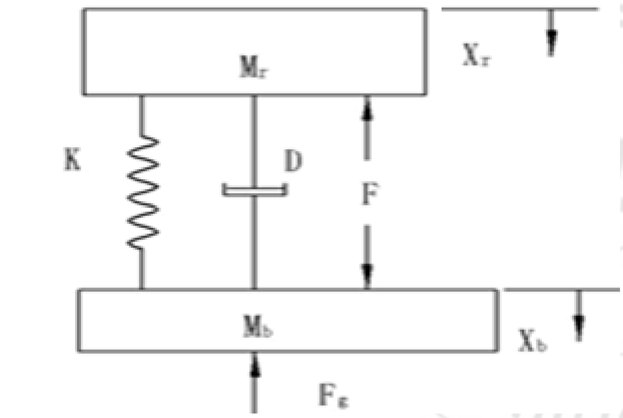


Figure 3: The dynamical model of vibrator

According to (3), the force of the vibroseis effects on the earth's surface which depends on the quality of vibration hammer and tablet, and acceleration. It is assumed that if weight of heavy hammer be increased under the condition that the output,the acceleration of hammer and plate are unchanged,if decrease the weight of plate, the signal of hammer will greatly affect the output of vibroseis, that means ground nonlinear characteristics little effect on vibroseis ground force. Therefore, the harmonic distortion of signal of vibroseis is smaller, if increase the weight of plate, the signal of plate will greatly affect the output of vibroseis, the harmonic distortion of ground force signal will be bigger.[5-7]

3. Simulation study of KZ-28 type vibrator

3.1 Set up the simulation models

By analyzing the structure and the working characteristics of the KZ-28 type vibrator, the heavy hammer, affiliated parts, and the i-steel tablet piston plate are been simplified. The completely geometric model of vibrator is shown in Fig 4.

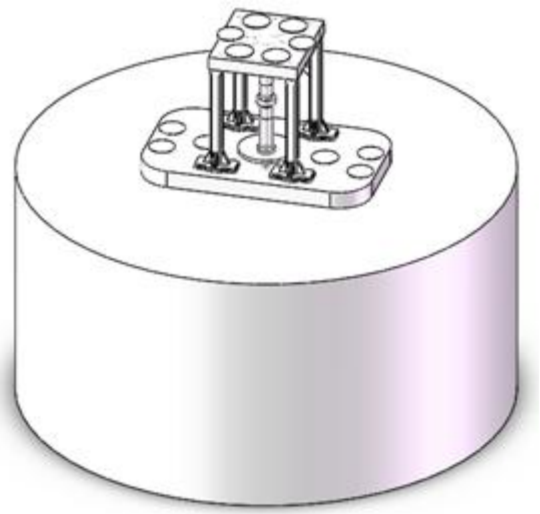


Figure 4: Geometric model of vibrator

Table 1: Material parameters of vibrator model

Component	Material	Density (kg/m^3)	Modulus of Elasticity(Pa)	Poisson's ratio	Yield strength (MPa)
Structure above the plate	45steel	7890	2.09×1011	0.269	355
Plate	16Mn	7850	2.12×1011	0.310	345
Ground	stone	2600	5.5×1010	0.270	--

3.2 Deformation analysis of KZ-28 type plate

Through the simulation, the deformation diagrams of in half cycle plate are shown in Fig.5 and Fig.6. Under the action of fluid pressure in the first half of the cycle, bend deformation occurs downwards, the deformation of plate near the piston is maximum, the deformation of plate near four pillar and weights is small. Therefore, the plate occurs "bend in the centre downwards", maximum deformation is 18.9μm. Under the action of fluid pressure in the second half of the cycle, bend deformation occurs upwards, the deformation of plate near four pillar and weights is few. Therefore, the plate occurs "bend in the centre upwards", maximum deformation is 126μm.

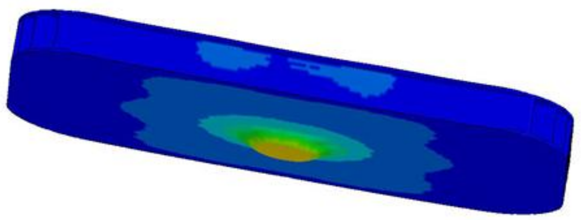


Figure 5: Deformation diagrams of plate in first half cycle

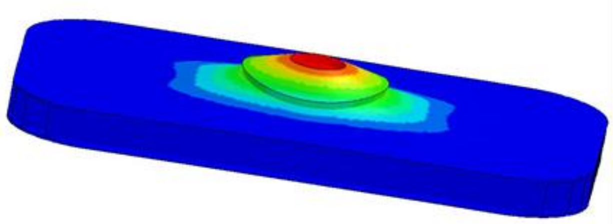


Figure 6: Deformation diagrams of plate in second half cycle

3.3 Contact force analysis of KZ-28 type plate

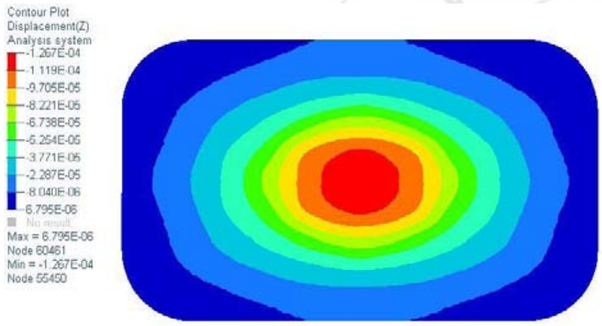


Figure 7: Contact force analysis of KZ-28 type plate

Isoline chart of contact force in the bottom of plate in condition of maximum contact force is shown in Fig.7, it can be seen in the figure, the contact force at the centre of plate is large, at the four corners of plate is small. At the same time, distribution pattern of contact force presents elliptical shape, suggesting that the contact force between plate and ground exist differential in the direction of the distribution. By analysizing the problem, results obtained from this study are as follows:

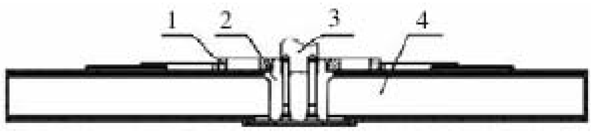
(1) In one cycle of hydraulic load, presents elliptical shape, the isoline of deformation in the bottom of plate presents elliptical shape, especially in the centre of the plate. This shows that plate's deformation exists difference in the direction of width and length, deformation in width significantly greater than the deformation in length.

(2) The contact force between plate and ground are mainly concentrated in centre of plate which result in seismic signal maldistribution,the vibrating forces at the bottom of the center position are larger, and the vibrating forces at the bottom of the four corners are smaller, result in the distortion of output signal.[8]

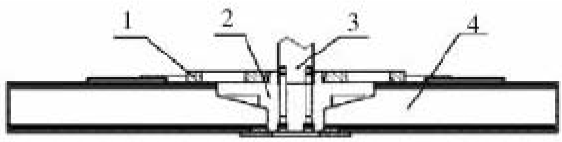
4. Study on Structure and Properties of Optimized Plate

4.1 Structure optimization of plate

KZ-28 type plate structure determines the stress state of it, accordance with the existing problems, the following improvements for the piston base are made: (1) Increase the flange (2)Design the pocket for the flange, as shown in Fig 8 and Fig 9.



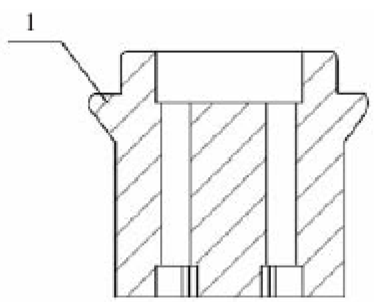
（a）The structure of the plate before optimization



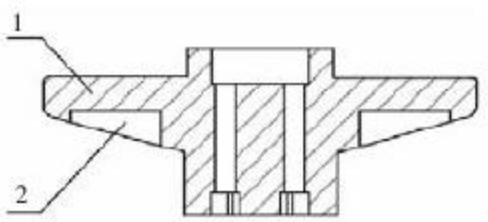
(b) The structure of the plate after optimization

1. Reinforcement plate 2.The piston base 3.The piston 4.Plate

Figure 8: The Structure of the plate before and after optimization



（a）The structure of the plate before optimization



（b）The structure of the plate after optimization

1.Flange 2.Pocket

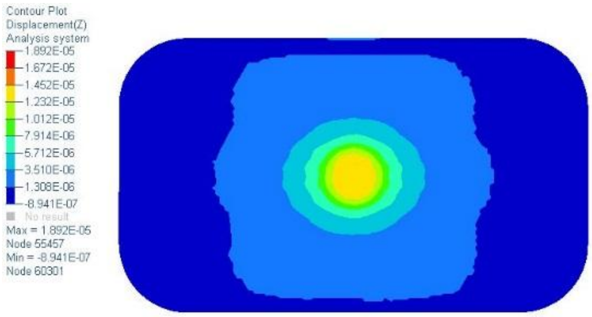
Figure 9: The comparison of the piston rod base structure before and after optimization

Through this kind of structure improvement scheme, in order to transmit the force from the piston to ground,to reduce the deformation of plate and the distribution of contact force.

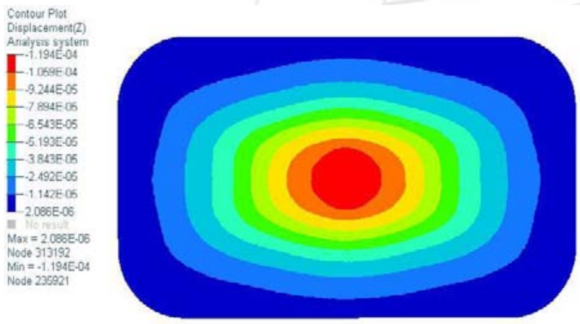
4.2 Deformation analysis of plate after optimization

As shown in figure 10, according to the results of simulation analysis, conclusion obtained from this study are as follows: (1) In the first half of the cycle, the deformation in the bottom. is reduced from 19.3μm to 18.9μm,it reduces 2%, in the second half of the cycle, the deformation in the bottom is reduced from 126μm to 119μm, it reduces 5.6%, the deformation of new structure is smaller.

(2) After the optimization, isoline of deformation at the centre of plate also presents elliptical shape, but deformation difference in the direction of width and length are also has been significantly reduced.



（a） The deformation isoline cloud of the vibrator in the first half cycle



（b）The deformation isoline cloud of the vibrator in the second half cycle

Figure 10: The deformation isoline cloud of the vibrator in a cycle after optimization

The deformation isoline cloud of the vibrator in a cycle after optimization suggest that:
(1) After optimization, the stress nephogram of large contact force at the centre of plate and at the bottom of pillar have significantly increased, it is shown that new structure transmits the force from the piston to plate, significantly improves the uniformity of contact force, lows down the output signal distortion.

(2) After the optimization, isoline of deformation at the centre of plate also presents elliptical shape, but deformation difference in the direction of width and length are also has been significantly reduced, it significantly improves the uniformity of contact force, reduces the difficulty of the processing of seismic signal.

5. Conclusion

1) Simulation analysis of KZ-28 type vibrator plate shows that: The deformation at the centre of plate is large, the deformation at the four corners of plate is small, it exists different deformation in the direction of the distribution, the contact force between plate and ground exist big differential in the direction of the distribution, which is the main causes of plate deformation, output signal distortion,and the decrease of exploration precision.
2) After the structure optimization for the KZ-28 type vibrator plate, increase the flange and design the pocket for the flange.
3) The simulation result after the structure optimization shows that: The biggest deformation is decreased by 5.6%; Plate deformation difference is also got obvious improvement the uniformity of contact force is improved; plate's performance result in a dramatic improvement to improve the precision exploration.

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