Hydraulic oscillator simulation analysis of structural performance of disc spring

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Abstract

In sliding during drilling, hydraulic oscillator to reduce the friction between the drill string and borehole wall rock to improve drilling conditions, structure of disc spring combinations are an important component of hydraulic oscillator. Paper main on hydraulic oscillator disc spring combination for work mechanical performance analysis, through theory calculation get meet hydraulic oscillator basic mechanical sex of combination parameter, last through limited Yuan simulation analysis, according to disc spring combination get of different delay back song area size determine meet hydraulic oscillation device of disc spring combination parameter, get Ø127 type hydraulic oscillator disc spring combination structure recommended used single disc 7 on collection combination way.

Keywords

hydraulic oscillator; disc spring composite structure and mechanical properties of finite element analysis.

1. Introduction

Level well, and big displacement well, and side to well process in the, due to well eye track complex, and drill column and wall rock between friction larger, often appeared stick card, and supporting pressure, and drilling efficiency low problem, currently both at home and abroad solution the class problem main method is in drilling process in the using hydraulic oscillation device, using hydraulic oscillator produced of pressure pulse led drill column low frequency, and small range axis to vibration, makes drill column and wall rock between friction State for moving friction State, to reduced drill column and wall rock between friction, Address the drill string and borehole wall caused by excessive friction between the rocks sticking, holding pressure, drilling efficiency is low [1-5]. Zhang Jianguo analysis has the tool of work principle and the composition structure, and for indoor simulation test, research has spray note type Sonic generator the parameter Zhijian of relationship [6]; Xu Hao in new sand 21-28 h well for has site test, used two trip drilling (first trip drilling not using hydraulic oscillation device, second trip drilling using Φ172mm hydraulic oscillation device) for compared [7]; Liu He will Jet type impact Rotary technology and vibration reduction motorcycle technology combined in with, development design has Jet type hydraulic oscillation device, On the hydraulic oscillator CFD numerical simulation of Jet flow and carried out two tests on the ground [8]; Tian Jialin developed a new drilling oscillator, oscillator analysis works, vibrator model is established, and oscillator experiment [9]; Muhanmmad h. Al-Buali, Alaa a. Dashash design axial oscillator (axial oscillation of e-line tools) this tool is integrated in the production test in the bottom of the tool and drilling equipment, makes coiled tubing axial vibration reduce of coiled tubing with the friction between the wall rock to improve drilling efficiency, and 12118ft field test of horizontal well total well depth [10]; J. Abdo, Al-Sharji on tool in different temperature, and different amplitude conditions Xia vibration frequency on level well in the drill column and wall rock between friction, and drill column axis force passed, and lock tight force effect law for research [11], integrated Shang by said both at home and abroad for hydraulic oscillator research main concentrated Yu power part research, for disc spring combination structure research less, while disc spring theory calculation contains more assumed, only for disc spring preliminary selection, for specific workers condition Xia of disc spring combination select needed further analysis calculation.

2. Disc Spring Force Analysis of Composite Structures

Hydraulic oscillator shaft a short section produced in conjunction with powered subs of periodic pulse pressure, part of the Drillstring axial reciprocating motion, part of the compression spring mix, store energy [12]. Hydraulic oscillator as part of disc spring composite structures, hydraulic oscillators working store and release elastic energy in the process.

2.1 Process Analysis of Disc Spring Combinations Stored Elastic Energy

Reducing hydraulic oscillator to elasticity coefficient k spring set hydraulic oscillator under the action of the relative speed of the drill string and borehole wall rock v_r, Spring arrangement are subject to periodic impulsive force $F_a \sin\omega t$, The hydraulic oscillator-drill-shaft as shown in the simplified model is shown in Figure 1.

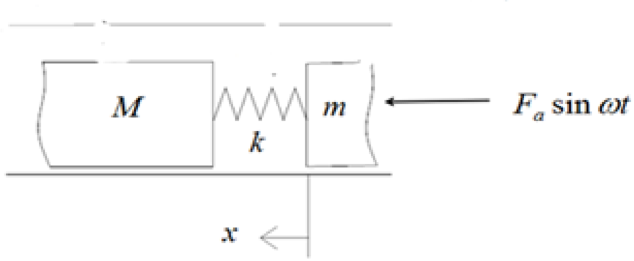


Figure 1. hydraulic oscillator, a simplified model of drill string and borehole wall

When $F_a \sin\omega t$ Is less than the between the drill string and borehole wall rock maximum static friction force f_s ,Drill at rest, that is:

$$F_a \sin\omega t \le f_s \tag{1}$$

Friction between the drill string and borehole wall:

$$F_f = F_a \sin\omega t \tag{2}$$

When $F_a \sin\omega t$ Is greater than the between the drill string and borehole wall rock maximum static friction force f_s, Drill start to slide, While compression spring combinations, spring combinations stored energy, friction between the drill string and borehole wall rock by static friction and sliding friction, which:

$$F_a \sin\omega t > f_s \tag{3}$$

When the spring is compressed to the maximum, the drill still pulsed power:

$$F_a \sin\omega t = F_f + \frac{1}{2}kx^2 \tag{4}$$

Friction between the drill string and borehole wall rock:

$$F_f = f_s \tag{5}$$

In formula Fɑ——power range, N; f_s ——Drill string and borehole wall rocks between the maximum static friction force, N; F_f ——Friction between drill string and borehole wall rock, N; ω——Hydraulic oscillator period, Hz; k——Disc spring coefficient of elasticity of composite structures; x ——vibrate range, mm;

2.2 Analysis of Composite Structure With Laminated Spring Release Elastic Energy

Hydraulic oscillator with pulse power $F_a \sin \omega t$ transformation, Spring combined to release energy, Between the drill string and borehole wall friction F_f changedirection, Vibration of drill string reverse pulse:

$$F_a \sin \omega t \le \frac{1}{2}kx^2 - F_f \tag{6}$$

As the spring combined to release stored energy, spring power $\frac{1}{2}kx^2$ decrease, wehn $\frac{1}{2}kx^2 = 0$, Back to the balance point of the drill in a static state.

In summary, on the hydraulic oscillator structure of disc spring combinations within a period, friction between the drill string and borehole wall rock changes as shown in Figure 2.

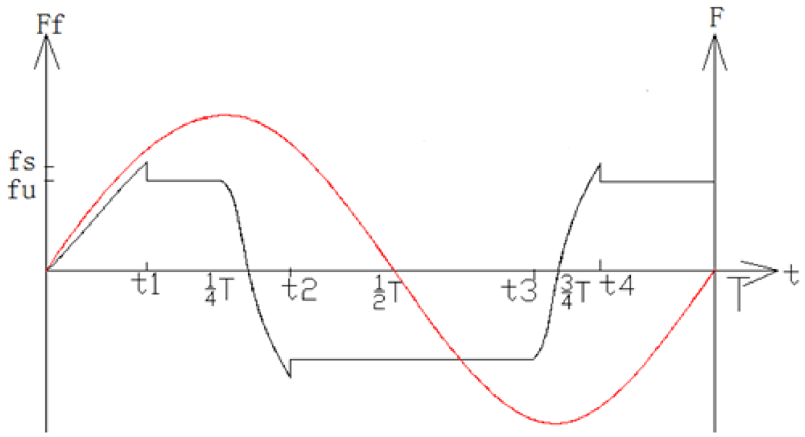


Figure 2. a friction between the drill string and borehole wall rocks within the oscillation cycle variations

3. Parameter Calculation of Hydraulic Oscillator Combined Disc Spring Structure Model

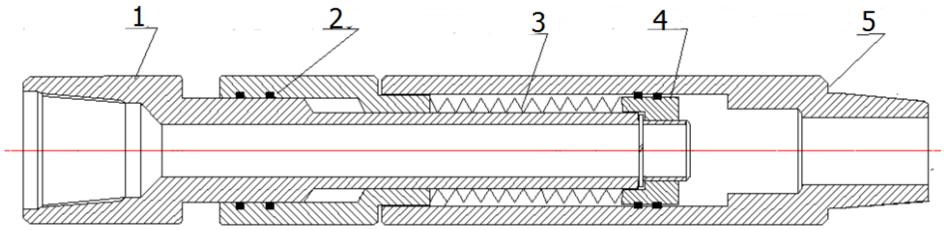
Hydraulic oscillator in periodic pressure pulse role Xia produced 3mm-10MM amplitude, and 6Hz-20Hz frequency of axis to vibration, for level well sliding drilling in the, landing motorcycle reduction resistance role, currently domestic wells Shang using of hydraulic oscillator more for abroad imports products, domestic on the tool main concentrated Yu analysis abroad oscillation tool of work principle, and structure composition, then on its for improved, and site experiment, research [13]. Therefore, composite structure analysis of disc spring on hydraulic oscillator reference literature in the process, select Φ 127 Study on the hydraulic oscillator, combine GB/T 1972-2005dish springselect D =100mm, d=51mm。

Table 1. Main technical parameters of hydraulic oscillator

specifications	external diameter /mm	working press /MPa	f/Hz	F/kN	vibrate displacement /mm
127	127	2.0~4.5	18	10~40	3.0~10.0

3.1 Disc Spring Combinations for Hydraulic Oscillator Structure Introduction

Slide the drilling process, installed hydraulic oscillator shown in distance ten drill bit as shown in Figure 3, is used to reduce excessive friction between the drill string and borehole wall rocks. Hydraulic oscillator main by valve axis short section, and power short section, and oscillation short section three part composition see Figure 3 by shows, power short section and valve axis short section tie role produced of periodic pulse pressure drive oscillation short section led drill column axis to vibration, makes drill column and wall rock between of friction State by static friction state change for moving friction State, to reduced drill column and wall rock between friction, improve drilling rate.



(1—oscillating tube, 2—O seal, 3—disc spring, 4—piston rod, 5—vibratemonoblock)

Figure 3. Hydraulic oscillator combined disc spring Assembly

3.2 Theoretical Calculation of Combined Disc Spring

Disc spring disc spring for short, by material into sheets of metal spring spring, is small in size, carrying capacity, uniform pressure, cushioning and shock absorption ability, according to users ' needs and design the appropriate disc spring geometry and combinations of advantages [14], the structure shown in Figure 4. Hydraulic oscillator oscillate in short sections of combined disc spring bear hydraulic oscillator shaft a short section produced in conjunction with powered subs periodic axial pressure, periodic change of disc spring combinations with axial pressure energy release and store conversion between two States.

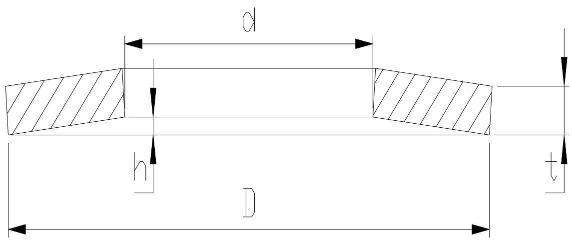


Figure 4.single disc spring size chart

Disc spring of by force calculation method has many species, but using most widely of is 1936 by Almen and Laszlo proposed of approximate calculation method [15], the calculation method ignored disc spring radial stress, and contact surface Shang friction, factors on disc spring by force of effect, is derived out has disc shaped spring in by outside pressure f role Xia of deformation relationship type, disc shaped spring combination load and deformation relationship can said for:

$$F = \frac{4E}{(1-\mu^2)} \cdot \frac{t^4}{D^2} \cdot K^4 \cdot \frac{f}{t} \cdot \left[K^4 \cdot (\frac{h_0}{t} - \frac{f}{t})(\frac{h_0}{t} - \frac{f}{2t}) + 1 \right] \quad (7)$$

$$F_z = nF \quad (8)$$

In formula F——load, N; D——disc spring exradius, mm; t——isc spring thickness, mm; E——elasticity, N/mm2; h0——Deformation of disc spring pressure usually, mm; f——Micro-deformation of disc spring, mm; K——enumerate coefficient; Fz——More pieces of laminated disc spring loaded; n——disc spring quantity;

Disc spring stiffness:

$$F' = \frac{dF}{df} = \frac{4E}{(1-u^2)} \cdot \frac{t^3}{K_1 D^2} \cdot K_4{}^2 \left\{ K_4{}^2 \left[(\frac{h_0}{t})^2 - 3 \cdot \frac{h_0}{t} \cdot \frac{f}{t} + \frac{3}{2} (\frac{f}{t})^2 \right] + 1 \right\} \tag{9}$$

transshape power:

$$U = \int_0^f F df = \frac{2E}{(1-u^2)} \cdot \frac{t^5}{K_1 D^2} \cdot (\frac{f}{t})^2 \left[K_4{}^2 \left(\frac{h_0}{t} - \frac{f}{2t} \right)^2 + 1 \right] \tag{10}$$

In formula d——Diameter of disc spring in the hole, mm; δ——Disc spring main stress, N/mm2; F'——rigidity of disc spring, N/mm; C——Diameter of disc spring; U——Disc spring deformation energy, N mm;

3.3 Determination of parameters of disc spring combinations

Hydraulic oscillator oscillate a short section of combined disc spring includes disc spring load, stiffness and stress calculations, load can be divided into static and variable loads, external load unchanged or changes over a long period of very hour static load, otherwise load [16]. Due to hydraulic oscillator oscillation short section disc spring combination in drilling process in the bear periodic pressure pulse role, belongs to by variable load role, so paper on oscillation short section disc spring combination for calculation Shi, according to by variable load conditions Xia of disc spring calculation method on different series of disc spring for calculation, through calculation get meet hydraulic oscillation device of disc spring combination parameter see Xia table 1 by shows:

Table 2. Parameters of disc spring combinations

numeral	A seriesdisc spring	B seriesdisc spring	compose
1	7	0	Single stack 7
2	0	18	6 on the Triassic
3	3	3	A series and B series single-stack 2-3 stack 4 of combined
4	4	2	A series of single-stacks of 3 and B series 3-3 combined

4. Analyse

Sliding during drilling, hydraulic oscillators where distance ten drill bit used to reduce excessive friction between the drill string and borehole wall rocks.

4.1 Basic Suppose

For hydraulic oscillation device of work features, due to drill column, and hydraulic oscillator oscillation short section of weight, led to disc spring combination by at location does not must is located in well eye middle, but paper only consider disc spring combination loaded and uninstall of mechanical characteristics, in not shadow Ah research oscillation short section disc spring combination normal work of situation Xia, on hydraulic oscillator disc spring combination structure for has following assumed: (1) ignored because drill column, and hydraulic oscillation device of itself gravity led to of location offset; (2) in the process of hydraulic oscillator, hydraulic oscillator structure model is symmetric to the bottom disc spring combinations; (3) the disc spring materials for linear elastic, isotropic.

4.2 Analysis of the a Series Disc Spring Combinations

Set A series disc Reed Zhijian friction factor for 0.3, on hydraulic oscillator end axis to loaded displacement maximum value 10MM Hou uninstall, its displacement-time curve as Figure 4 by shows, axis force-time curve as Figure 5 by shows, will displacement-time data and get of axis force-time data import EXCELL in the, get a, series single stack 7 on collection disc spring combination axis force-displacement curve as Figure 6 by shows,

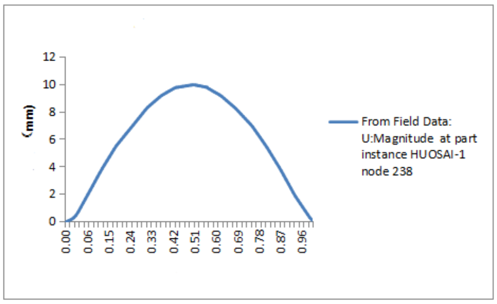


Figure 4. displacement-time

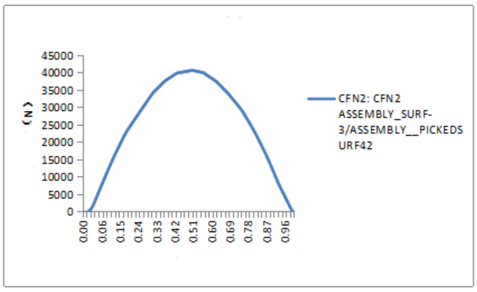


Figure 5. axis force-time curve

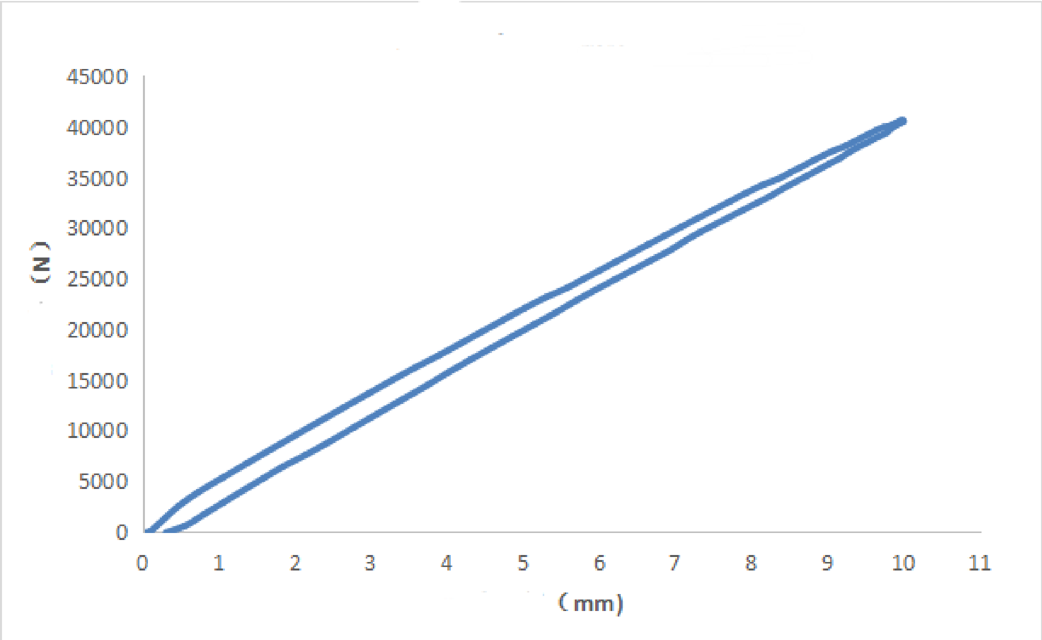


Figure 6. A series single stack 7 combined disc spring loading-unloading curve

4.3 B Series Analysis of the Disc Spring

Set b series disc Reed Zhijian friction factor for 0.3, to oscillation short section b series 3 stack 6 on collection disc spring combination, to hydraulic oscillator end imposed 10MM displacement load Hou uninstall, its displacement-time curve as Figure 7 by shows, axis force-time curve as Figure 8 by shows, will on b series 3 stack 6 on collection disc spring combination displacement-time and get of axis force-time data import EXCELL in the, get b series 3 stack 6 on collection disc spring combination load-displacement curve as Figure 9 by shows.

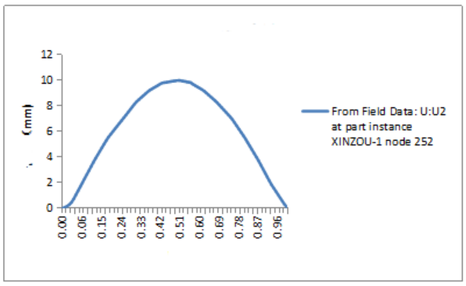


Figure 7-.time curve

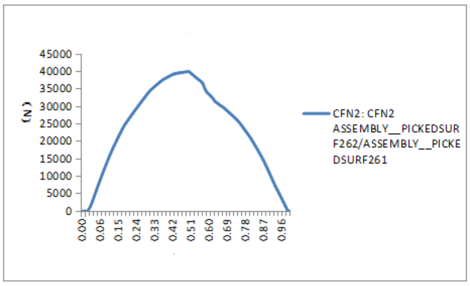


Figure 8. axial force-time curve

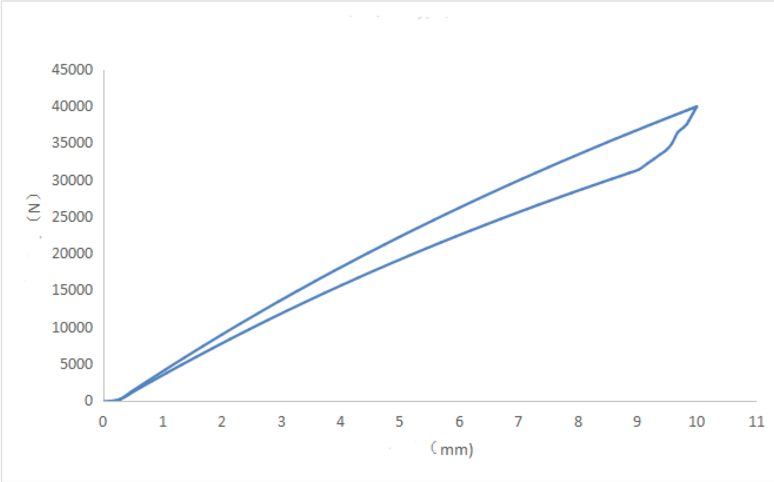
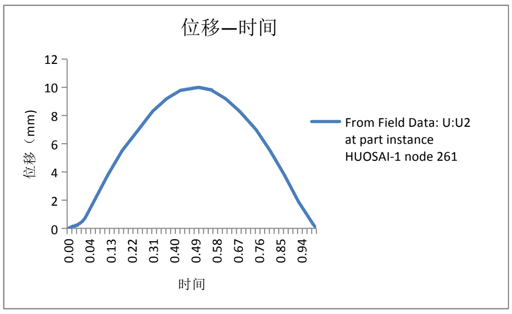


Figure 9. B series 3-stack 6 combined disc spring loading-unloading curve

4.4 Mixed Mode Disc Spring Combinations

(1)A series and B series single-stack 2-3 stack 4 of combined

Set oscillation short section a, series and b series the disc Reed Zhijian friction factor for 0.3, to hydraulic oscillator end imposed 10MM axis to displacement, displacement-time curve as Figure 10 by shows, axis force-time curve as Figure 11 by shows, will disc spring combination displacement-time data and limited Yuan analysis get of piston at axis force-time data import EXCELL in the, get hydraulic oscillation device 2 stack a, series and 4 stack b series disc spring combination load-displacement curve as Figure 12 by shows:



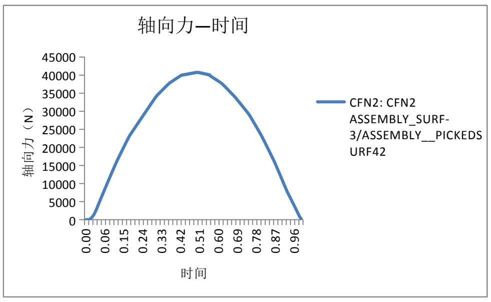


Figure 10.time curve Figure 11. axial force-time curve

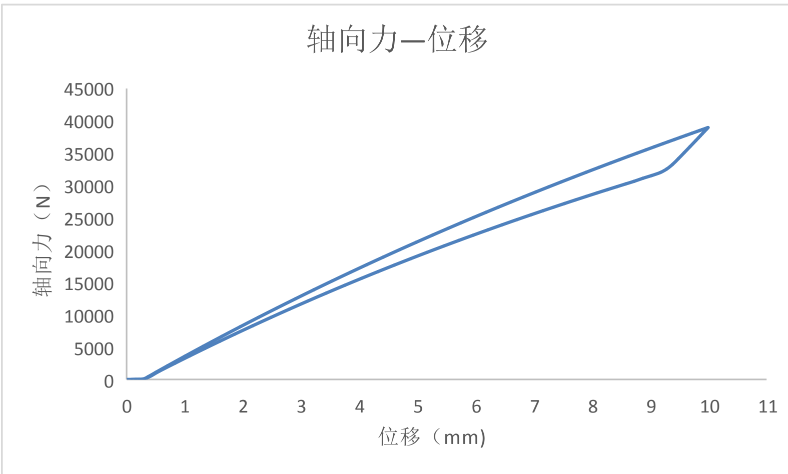
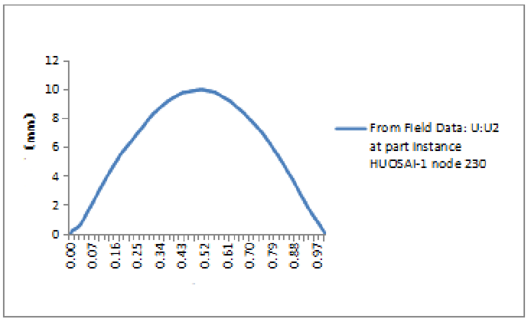


Figure 12. A series and B series single-stack 2-3 stack 4 of combined disc spring loading-unloading curve

(2)A series of single-stacks of 3 and B series 3-3 combined

Set oscillation short section a, series and b series the disc Reed Zhijian friction factor for 0.3, on piston end imposed axis to imposed 10MM displacement Hou uninstall, its displacement-time curve as Figure 13 by shows, through analysis get piston and disc spring combination contact at axis force-time curve as Figure 14 by shows, will on a, series single stack 3 on collection and b series 3 stack 3 on collection disc spring combination imposed of displacement-time data and limited Yuan analysis get of piston end axis force-time data import EXCELL in the, Get hydraulic oscillator oscillate a short section of a series of single-stacks of 3 and b series 3-3 on the disc spring combinations of load-displacement curve as shown in Figure 15.



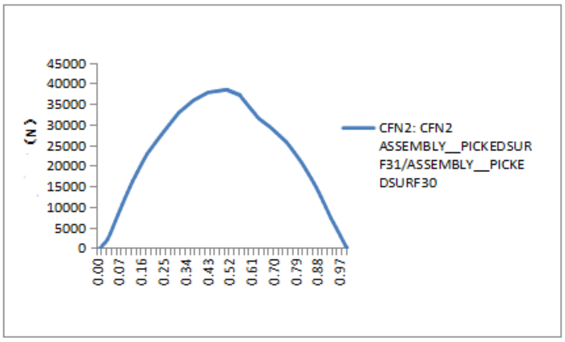


Figure 13.time curve Figure 14. axial force-time curve

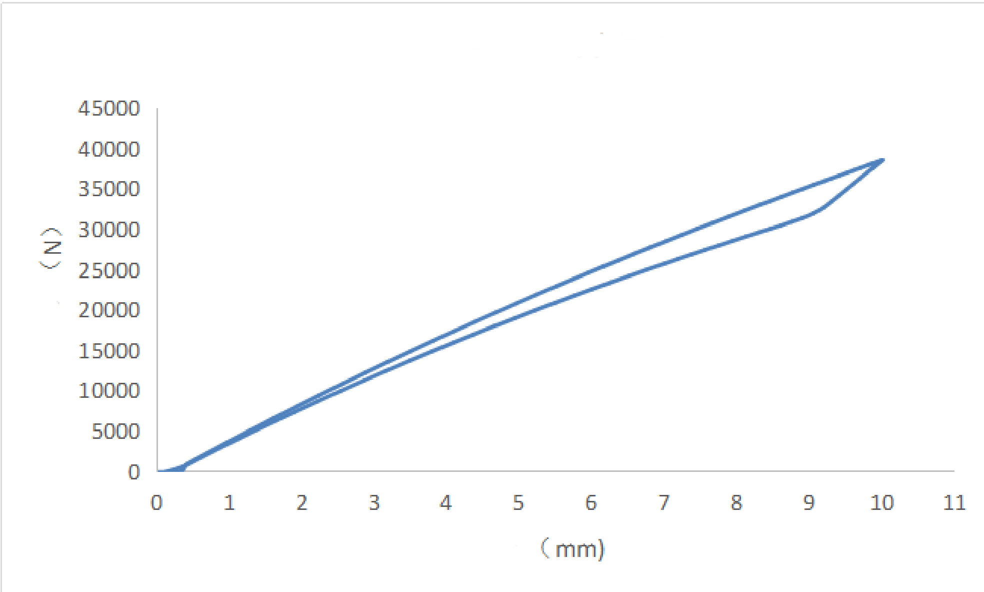


Figure 15. A series of single-stacks of 3 and B series 3-3 combined disc spring loading-unloading curve

4.5 Results Analysis

Axial vibration by hydraulic oscillator to meet conditions of the series of simulation analysis of disc spring combinations, the series of combined disc spring load-displacement curve obtained through load-displacement curve to calculate the spring stiffness and damping, rigidity of stiffness into loading and unloading stiffness, namely disc spring loaded the slope of the curve and unloaded the slope of the curve. Because the existence of friction between the disc springs, combined disc spring loading curves and the unloading curve do not coincide, load curves and the unloading curve surrounded by an area of disc spring in one loading and unloading in the process energy consumption, which is the series of combined disc spring damping. After calculations, are the series of combined disc spring loading-unloading area enclosed by a curve, concrete results are shown in table 2 below:

Table 2. Data simulation analysis of disc spring combinations

compose	Sluggish area/mm^2	add rigidity N/mm	unload rigidity N/mm	Max miss N/mm^2
Single stack 7	151	4176	4143	829
6 on the Triassic	263	4298	4065	809
A series and B series single-stack 2-3 stack 4 of combined	232	4245	4083	922
A series of single-stacks of 3 and B series 3-3 combined	189	4208	4124	842

By Shang table 2 known, the series meet Ø127 type hydraulic oscillator oscillation short section requirements of disc spring combination in the, a, series single disc 7 on collection combination for best combination way, its delay back area minimum for 151mm2, second for a, series single stack 3 on collection and b series 3 stack 3 on collection combination way, its delay back area minimum for 189mm2; single a, series and b series disc spring combination compared found, due to a, series stack collection number less, combination Hou disc Reed Zhijian friction on disc spring loaded stiffness and the uninstall stiffness effect smaller, Rigidity trend consistent with the actual situation.

5. Conclusion

Paper main reference Ø127 type hydraulic oscillator oscillation short section of basic size parameter, according to GB/T 1972-2005 disc shaped spring on oscillation short section disc spring parameter for calculation, and for corresponding of limited Yuan analysis, conclusion following:

(1) Same friction coefficient Xia a, series D=100mm disc spring single stack 7 on collection combination Shi, its delay back area minimum for 151mm2, second for a, series D=100mm disc spring single stack 3 on collection and b series D=100mm disc spring 3 stack 3 on collection combination , The hysteresis area for 189mm2, largest hysteresis area for b-series D=100mm 3 disc spring stack 6 involution, the hysteresis area for 263mm2.

(2) By the disc spring combination limited Yuan analysis known, disc spring combination compression Shi, the disc Reed by force uniform, disc Reed Shang surface by pressure role, Xia surface by pull role, disc Reed within circle contact stress is greater than outer ring stress, neutral layer stress minimum, disc spring combination compression volume for 10MM Shi, maximum Miss stress for 922N/mm2, meet disc spring strength requirements;

(3) After boundary condition on finite element model, the adjustment of parameters such as exposure to property, impose 10MM on disc spring combinations after displacement, get load of 40kN at the plate, with theoretical load is not very different, proves this finite element model in place of the actual test methods so as to improve the design of disc spring combinations.

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