

Development and Strength Verification of Hydraulic Power Tongs for Strongly Bonded Oil Tubing Makeup and Breakout

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Abstract

With the development of oil and gas fields extending to deep wells, ultra-deep wells and complex formations, the bonding phenomenon of tubing buckles is becoming more and more serious. The traditional hydraulic shackle pliers are difficult to meet the demand of high torque, and the knocking auxiliary shackle has high risk and high labor intensity. For this reason, this paper designs a release power tong that can squeeze the strong bonding tubing buckle. By squeezing the strong bonding tubing buckle, the bonding force of the tubing buckle is reduced to solve the difficult problem of strong bonding tubing buckle release. The correctness of the scheme is verified by the experiment of tubing extrusion and unloading, and the extrusion load is determined to be 25 t. The structure of the extrusion device was designed, and the strength verification and structural optimization were carried out by finite element method to verify its feasibility. This study not only improves the unloading speed and unloading efficiency of strongly bonded tubing buckles, but also is of great significance to ensure the safe production of oil and gas fields.

Keywords

Strongly Bond Tubing Buckle; Breakout; Hydraulic Power Tong; Strength Verification.

1. Introduction

With the development of oil and gas fields extending to deep wells, ultra-deep wells and complex formations, the bonding phenomenon of tubing buckles (caused by corrosion, high temperature and high pressure or chemical action) is becoming more and more serious, and traditional mechanical release tools are difficult to meet the high torque demand. With the advantages of high output torque and strong controllability, hydraulic power tongs have become the core equipment to solve the problem of strong bonding tubing buckle unloading [1-3]. Hydraulic power tongs are commonly known as hydraulic tongs. In oil drilling operations, they are mainly used to unload tubing threads and are important power equipment for operation [4]. Hydraulic power tongs have the characteristics of flexible operation, large torque, strong applicability, safety and reliability, convenient debugging and maintenance in operation. When the torque control system is selected, it can also accurately record and control the make-up torque, and provide reference for fine operation [5]. Compared with manual tubing tongs, hydraulic power tongs show obvious advantages and great potential.

Aiming at the research of tubing release tongs, Tang [6] of Lanzhou Petroleum Machinery Research Institute began to study the mechanical analysis of the jaws of hydraulic power tongs, tubing power tongs and casing power tongs when clamping the drill pipe; Yang(1977) [7] of Daqing Petroleum Institute theoretically analyzed and proved the correct installation conditions of the power tongs notch gear transmission system; Yang et al(2010). [8] of Daqing Oilfield developed the drill pipe casing

dual-purpose power tongs, which makes the traditional hydraulic power tongs have the function of casing tongs; Yu [9] of Northeast Petroleum University designed a D60-380 hydraulic power tong, the roller climbing and clamping mechanism is used to clamp and buckle the pipe string. Compared with the planetary structure, the space utilization rate of the power tong device is higher, and the clamping mechanism can provide greater force to clamp the pipe string; Zhu et al. [10] of Daqing Oilfield Drilling Engineering Company and Drilling Engineering Technology Research Institute developed a NTQ248-25Y toothless casing power tong. The casing power tong can complete the make-up operation of corrosion-resistant alloy casing with specifications of 114.3 ~ 177.8 mm, and the casing surface is completely free of tooth marks, and the casing is protected to the maximum extent; Huang et al. [11] from Drilling Engineering Technology Research Institute of Zhongyuan Petroleum Exploration Bureau successfully developed WTQ245-N micro-tooth mark casing clamp; Chen et al. [12] designed a telescopic automatic wellhead unloading device, which can achieve accurate centering and complete the unloading operation quickly and smoothly. Although China's hydraulic power tongs have made great progress and produced many new types of power tongs, there are still some problems affecting the performance of power tongs in China, and there are few studies on the power tongs for strong bonding tubing buckle release.

After a certain period of oil and gas well production, it is necessary to take out the tubing in order to carry out downhole operation and improve single well production. However, due to the influence of pressure, corrosion environment and underground debris in the process of oil and gas exploitation, the tubing string is deformed by extrusion and electrochemical corrosion bonding, which makes the conventional hydraulic clamp unable to unload [13-17]. In the field, the manual hammering of tubing buckle coupling is adopted, which has high labor intensity and high operation risk. There is an urgent need for an automatic shackle power tong that can adapt to the shackle of strongly bonded tubing to reduce labor intensity and improve operational safety. In this paper, through the development of the power tongs for the strong-bonded tubing buckle unloading, the problem that the torque applied to the tubing cannot be unloaded when the torque reaches the set value peak during the unloading process requires manual knocking and unloading is solved. At this time, the shock unloading mechanism can be started to unload the shock, and the outer wall of the pipe string can be protected to avoid damage due to excessive torque applied by the device. Improve the speed and efficiency of unloading, reduce the labor intensity of workers, and ensure the safety of personnel. At the same time, it reserves technology for workover operation and promotes the development of workover operation technology.

2. Tubing Extrusion Experiment and Pressurization Experiment

2.1 Tubing Extrusion Experiment

In the experiment, the loading force is used to test the tubing. By simulating the operation process of tubing unloading under actual working conditions, the effect of loading force on unloading torque is evaluated. In the tubing extrusion experiment, by applying the axial loading force, the contact pressure of the tubing thread connection surface can be increased, thereby changing the friction coefficient and reducing the torque required for unloading. The construction of the experimental site is shown in Fig. 1 (a).

The loading force was applied in stages to 25 t and kept stable, and the stress state under actual working conditions was simulated. Using the operator with the sensor to record the change of the torque, combined with the comprehensive logging instrument to monitor the pressure and deformation data, as shown in Fig. 1 (b). In order to reduce the experimental error, four groups of tubing extrusion experiments were carried out. The experimental results show that under the condition of loading force of 25 t, the tubing unloading torque is significantly reduced. When the loading force is determined to be 25 t, the unloading torque of 8000 N · m can be reduced to 4712 N · m, and the unloading torque is reduced by 58.9 %. It is verified that this scheme can effectively reduce the tubing unloading torque.

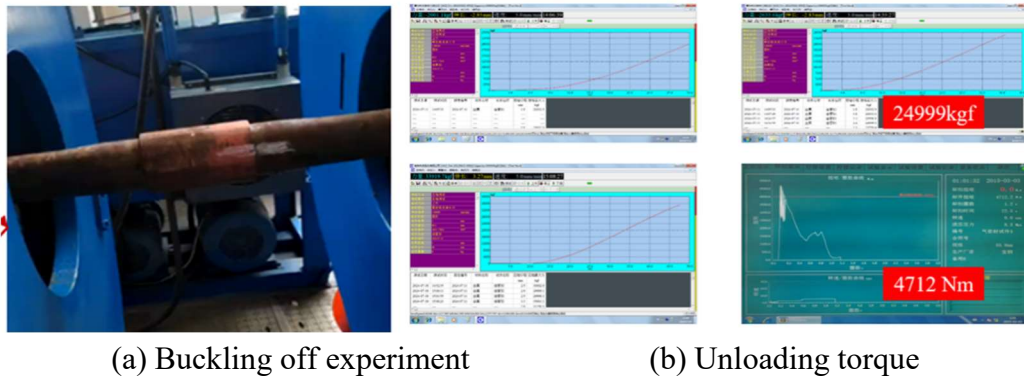


Fig. 1 Tubing buckle release experiment.

2.2 Pressurization Experiment

2.2.1 Causes and Principles of Pressurization

Due to the maximum operating pressure provided by the site is 5 MPa, and limited by the original hydraulic clamp, the diameter of the extrusion piston can only be in the range of 100 mm. According to this calculation, it is found that the required 25 t loading force cannot be achieved under this pressure condition. In order to ensure that the loading force can meet the standard in the tubing extrusion experiment, pressurization measures must be taken. Therefore, it is necessary to introduce additional pressurization equipment to increase the pressure level of the system, so that at least 25 t of loading force can be achieved in the experiment. Through pressurization, the tubing unloading operation closer to the actual working environment can be simulated, and the influence of higher loading force on the tubing unloading torque can be effectively evaluated to ensure the reliability and validity of the experimental data. This is very important for optimizing the tubing unloading process and improving the safety of field operations.

Based on the above reasons, choose to use the booster valve for pressurization. Inside the booster valve, there is an oil pressure sequence valve. When the preloading characteristic is operated, the actuator cylinder can be filled with oil to reach the preset pressure, the sequence valve acts, multiple pressurization can be obtained. Its structure is shown in Fig. 2, and the starting pressure adjustment of the oil pressure sequence valve is shown in Table 1.

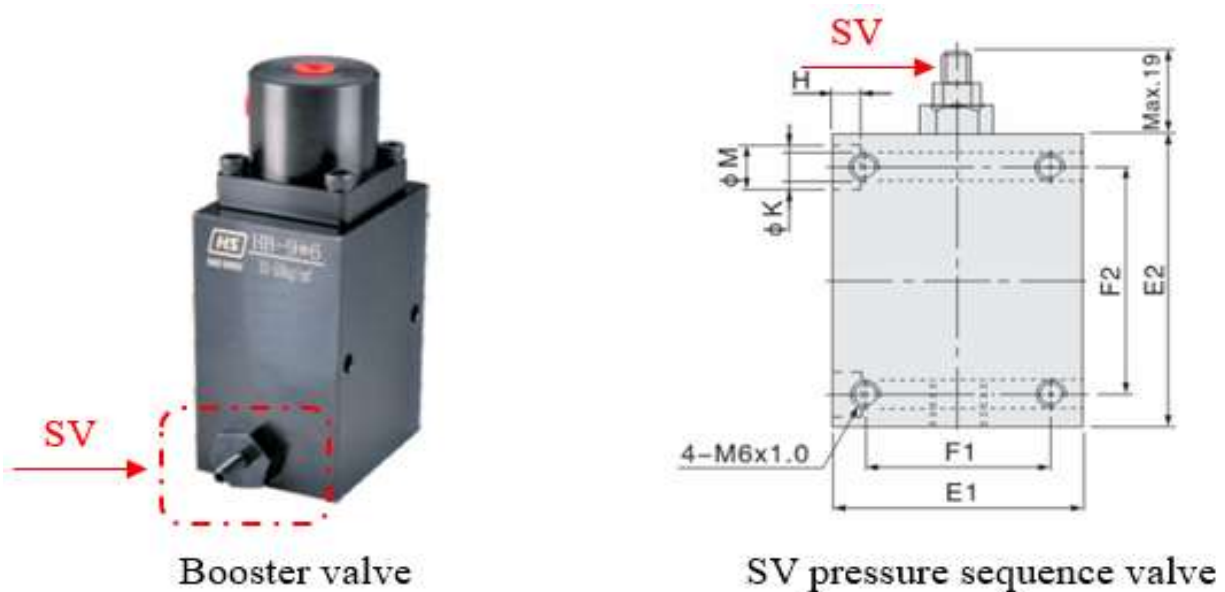


Fig. 2 Booster valve and oil pressure sequence valve.

Table 1. SV oil pressure sequence valve adjustment reference.

M6 length (mm)	7	6	5	4	3	2	1
Starting pressure (kg/cm²)	20	25	30	35	40	45	50

Through the selection of booster valve, the booster valve with M6 length of 3 mm, starting pressure of 4 MPa and booster ratio of 8 was adjusted. The specific clamping parameters are shown in Table 2.

Table 2. Clamping parameters.

Maximum pressure requirements	5	MPa
Target thrust	20	t
Pressure amplification factor	8	/
Pressurized volume	22	ml
Pressure after pressurization	40	MPa
Piston bore	100	mm
Pre-clamping thrust	4.005102	t
Maximum thrust after pressurization	32.04082	t

2.2.2 Pressurization Experimental Device and Results

In order to meet the experimental requirements and ensure that the loading force reaches 25 tons, a set of pressurization experimental device needs to be designed and completed. The device consists of a number of key components, including but not limited to hydraulic pumps, booster valves, hydraulic cylinders, pressure sensors, pressure gauges, experiment benches and hydraulic tubing.

In addition, in order to prevent the leakage of hydraulic oil under high pressure, special attention should be paid to the sealing performance of hydraulic cylinders. The whole device was strictly tested and calibrated before the formal experiment, which ensured the accuracy of the experimental data and the safety of the experimental process. The on-site experimental device is shown in Fig. 3.

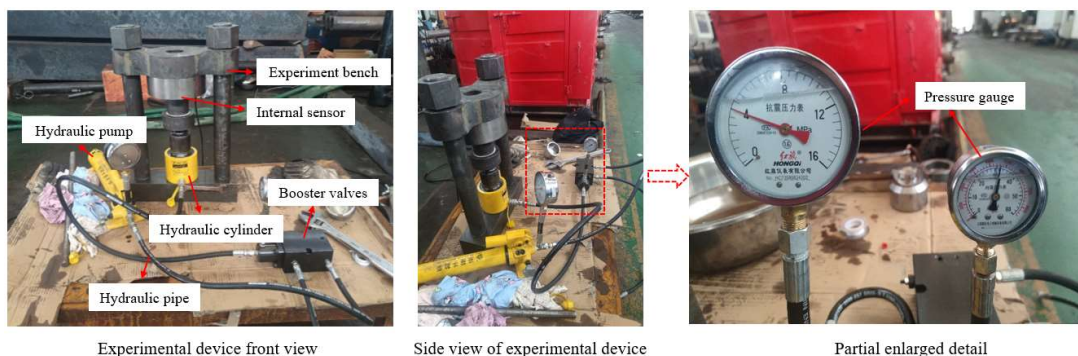


Fig. 3 Pressurization experimental device.

The pressure of 4 MPa was input by the hydraulic manual pump, and the pressure was increased to 32 MPa by the booster valve, which achieved 8 times of pressure increase. At this time, the thrust of the hydraulic cylinder measured by the force sensor is 24922 Kg, that is, 25 tons, which demonstrates that 25 tons of tubing extrusion pressure can be achieved by the booster equipment. This measurement result matches the expected loading force, as shown in Fig. 4.

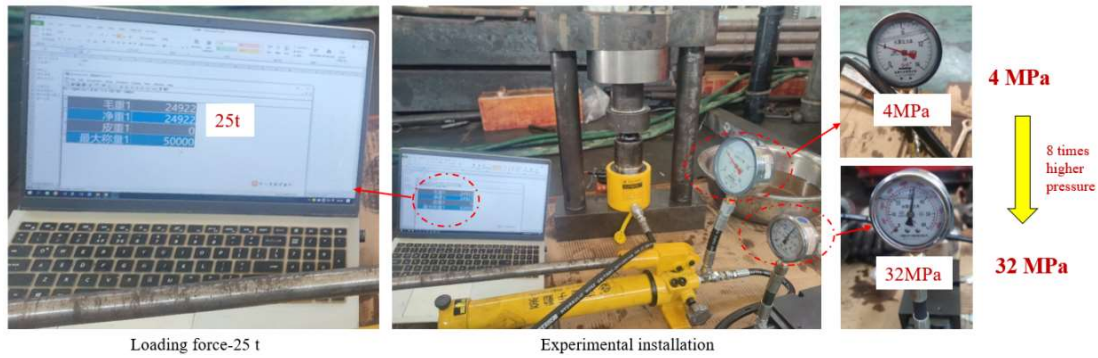


Fig. 4 Pressurization experimental results.

3. Structure Design of Extrusion Device

3.1 Selection of Hydraulic Pliers

The tubing extrusion device needs to be applied to the hydraulic pliers, and the hydraulic pliers is used to unload the shackle after the tubing extrusion is completed. In this experiment, XQ114/6B hydraulic power pliers is selected as the key tool to meet the specific test requirements. This type of hydraulic power tong is an open-type power tong used for quick shackle in oilfield workover operations. It has the characteristics of compact structure, light weight, high efficiency, large difference between two gear transmission stages, high speed and low torque. The technical parameters of the product are shown in Table 3.

Table 3. Hydraulic pliers part of the technical parameters.

Technical parameter	Reference value	Remark
Range of application	73 mm~114 mm	2 7/8"-4 1/2"
High-grade rated torque	1.5 kN•m	1106 lbf•ft
Low rated torque	6 kN•m	4425 lbf•ft
High-grade maximum speed	85 r/min	/
Low-grade maximum speed	20 r/min	/
Plier opening size	118 mm	/
Overall shape size	750×500×600 mm	/
Weight	220 kg	485 LBS
Rated system pressure	11 MPa	1595 Psi
Maximum delivery	100 L/min	26 GPM

3.2 Preliminary Design of Extrusion Structure

The extrusion device is a new design installed on the hydraulic tongs for the auxiliary unloading of the extrusion tubing buckle. Therefore, it is necessary to measure the size of the target hydraulic tongs first to obtain the approximate size of its key components, as shown in Fig. 5. The basic size model of the device can be constructed by measuring the various components of the hydraulic power clamp in detail, including the width of the jaw, the height of the clamp body, and the external size of the clamp body.



Fig. 5 Hydraulic power clamp size mapping.

In order to simplify the extrusion structure, a base is designed on the bottom of the hydraulic clamp body, which is connected with 9 bolts. A through hole is opened on the base to facilitate the external connection with the clamp body; the hydraulic shell is installed on the left and right ends of the base, and the hydraulic components are installed inside, and the extrusion of the tubing is completed by the piston push, as shown in Fig. 6.

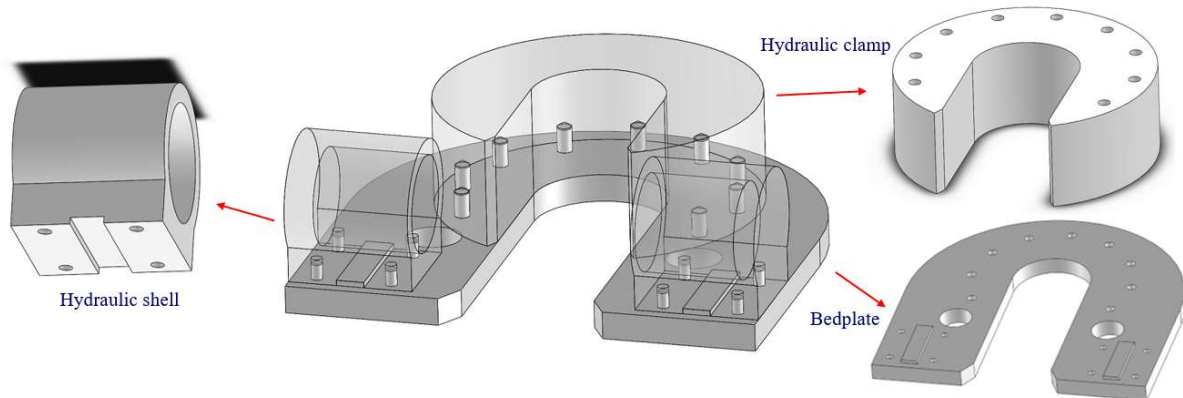


Fig. 6 Structure improvement of extrusion device.

4. Strength Verification and Structural Optimization

4.1 Strength Verification

4.1.1 Load Calculation of Hydraulic Shell

Firstly, the finite element stress analysis of the hydraulic components with extrusion load is carried out. As shown in Fig. 7, the maximum stress of the hydraulic shell does not exceed 507 MPa and the maximum strain does not exceed 0.0024 mm when subjected to a 25 t loading force; the bolts used to connect the base and the hydraulic shell are well stressed, the maximum stress does not exceed 329 MPa, and the maximum strain does not exceed 0.001 mm. Therefore, the hydraulic components meet the required carrying capacity.

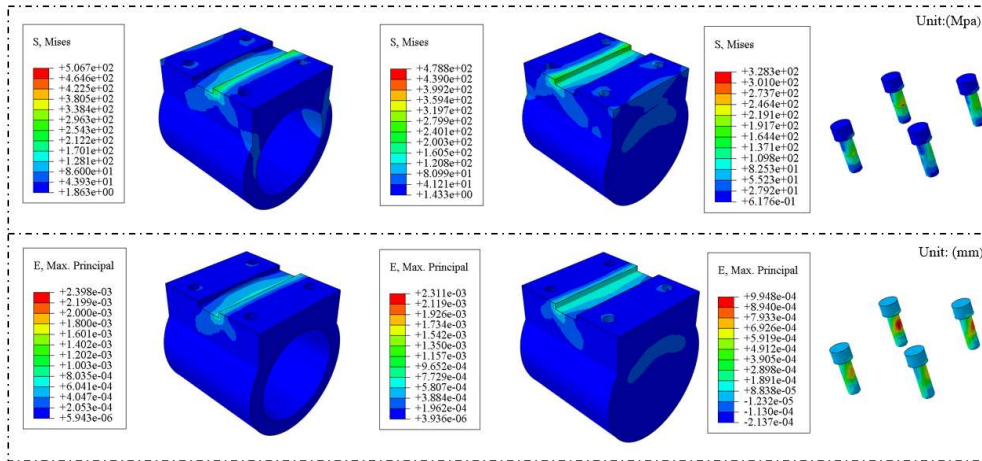


Fig. 7 Finite element analysis of hydraulic components.

4.1.2 Base Strength Verification

In order to verify the feasibility of the structure, the finite element stress analysis of the base and the tongs is needed. As shown in Fig. 8, after applying a 25 t loading force to the device, the stress values of the base countersunk hole, the tong thread hole and the bolt are very large, and plastic deformation occurs, and the maximum strain of the bolt is 0.25 mm, which has been damaged. Therefore, bolt connection alone cannot bear 25 t loading force.

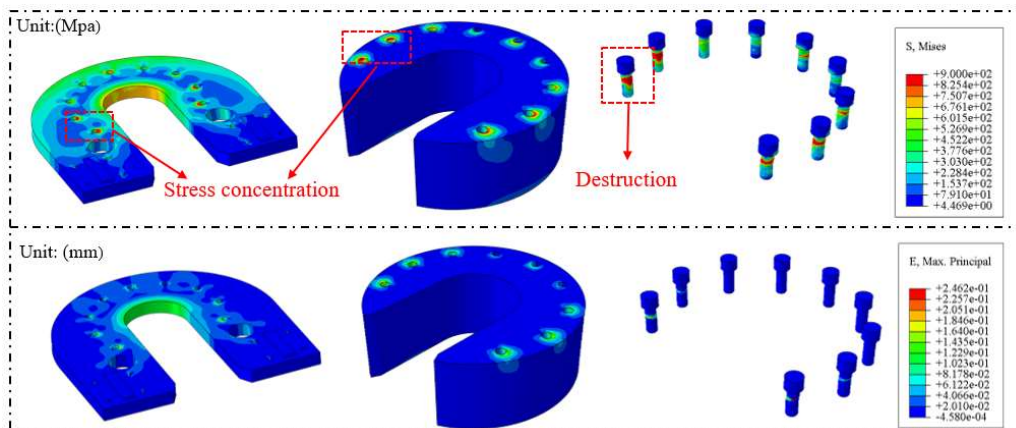


Fig. 8 Stress and strain cloud diagram of extrusion device.

4.2 Structural Optimization

In order to avoid damage caused by excessive bolt stress, a bearing stack is added to the base to resist the shear force together with the bolt, as shown in Fig. 9. The thickness of the bearing stack is set to 6 mm, 10 mm and 20 mm respectively, and the force on each component is analyzed.

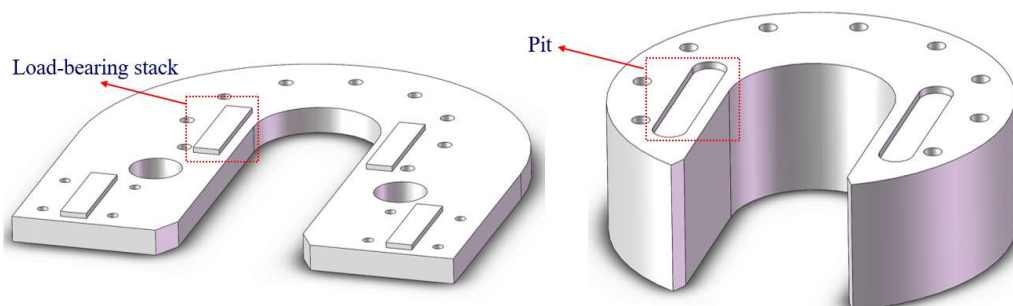


Fig. 9 Increase the load-bearing stack.

The stress and strain of each component are shown in Fig. 10, Fig. 11, Fig. 12. It can be seen that the stress value of the bolt after increasing the load-bearing stack is significantly reduced, and the force is better in the elastic range. When the load-bearing stack is 6 mm and 10 mm, the stress concentration occurs at the edge of the base load-bearing stack and the large tong slot, and plastic deformation occurs. The maximum loads that can be carried without plastic deformation are 10 t and 16 t, respectively. When the load-bearing stack is thickened to 20 mm, the stress on the bolt is reduced by 136 MPa and 30 MPa compared with 6 mm and 10 mm, respectively. No plastic deformation occurs on the base and the tongs, and the strain belongs to the normal category. It shows that the thickening of the load-bearing stack can effectively reduce the stress received by the bolt and increase the maximum load that can be borne. In summary, when the thickness of the load-bearing stack is 20 mm, the loading force that can be carried is at least 25 t.

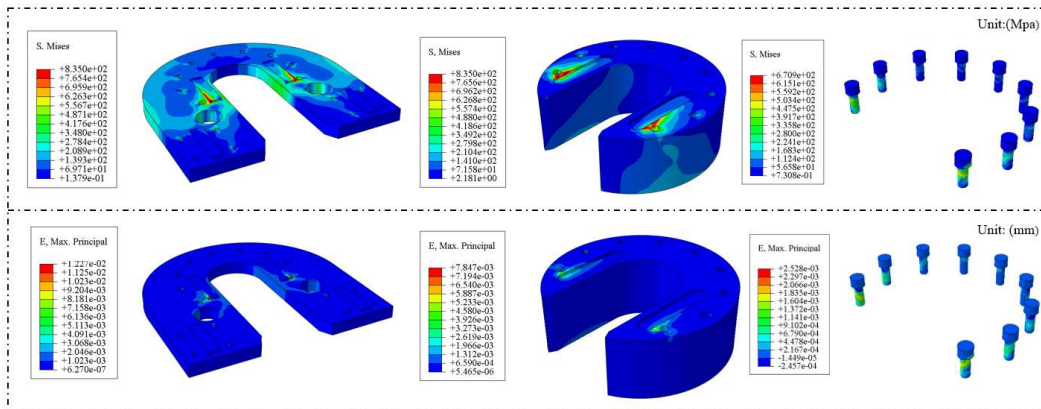


Fig. 10 The stress-strain cloud diagram after adding 6 mm bearing stack is increased.

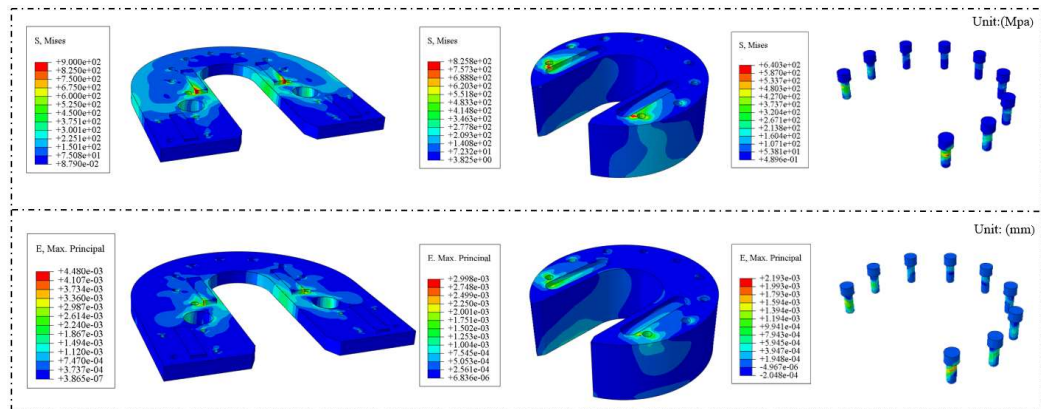


Fig. 11 The stress-strain cloud diagram after adding 10 mm bearing stack is increased.

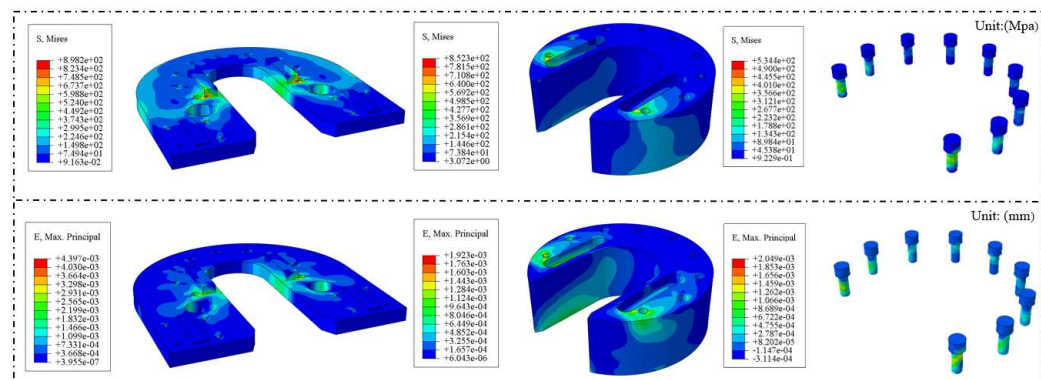


Fig. 12 The stress-strain cloud diagram after adding 20 mm bearing stack is increased.

5. Conclusion

- (1) Aiming at the phenomenon that the tubing buckle is prone to gluing when it is unloaded, a strong-gluing tubing buckle unloading device is developed. By squeezing the coupling during the unloading, the adhesion force of the tubing buckle is reduced to reduce the torque of the strong-gluing tubing buckle.
- (2) Through the tubing extrusion experiment, it is determined that when the loading force is 25 t, the make-up torque of 8000 Nm can be reduced to 4712 Nm of the release torque, and the release torque is reduced by 58.9 %, which verifies the feasibility of the scheme.
- (3) Through the design and development of pressurization experiments, an 8-fold increase in pressure from 4 MPa to 32 MPa was achieved, ensuring that 25 t tubing extrusion pressure can also be achieved in the low hydraulic environment on site.
- (4) Through the design optimization and strength verification of the extrusion device of the hydraulic power clamp, it is determined that the hydraulic power clamp of the strong bonding tubing buckle meets the strength requirements.

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