Simulation and Design of Multistage Unlimited Packers in Horizontal Wells

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Abstract. The staged fracturing technology for horizontal wells has successfully promoted the development of unconventional oil and gas, but it faces the challenges of rapid production decline in oil and gas wells. Studies on the multistage unlimited fracturing technology, that is, the existing fracturing tools are redesigned, the fully bored wellbore can be modified, any number of stages can be designed, and the technical advantages such as maximizing reservoir reconstruction can be achieved. The conventional packers cannot achieve the multistage unlimited fracturing, the packers are redesigned in this study. Through the Solid works software, the single use pin is transformed into a one-way internal tooth and a locking mechanism of the cardboard. The structure can be hydraulically applied to the piston, and the piston drives the internal teeth of the sealing sleeve to perform locking and adduction, so as to achieve repeated setting and unsealing of the packer. By means of ANSYS software and finite element calculation method, it is verified that the designed packer meets the third strength theory and safety requirements.

1.Introduction
Packer refers to a downhole tool with an elastic sealing element that can seal the annulus of the oil jacket, control the liquid production and injection through the separated layer, and protect the casing[1]. Packers mainly rely on sealing elements to achieve their various functions. The sealing effect of the packer is inseparable for the normal daily production of oil and gas wells, and the smooth completion of various downhole measures. Therefore, the packer is a significant weapon for the rational development and production of oil and gas fields. According to the working principle, packers can be divided into the following types: Self-sealing, compression, Wedge type, expansion type[2].

The packer system is not only affected by temperature, pressure, media and other factors when working downhole, but also affected by changes in working conditions. Under the influence of these various factors, the packer system and the string system are very easy to change, which leads to the packer's early unsealing or missealing[3]. In severe cases, it will cause more serious faults and accidents. happened. Therefore, in view of these influencing factors, it is very important to analyze the working environment of the packer. A packer usually includes a sealing mechanism, an anchoring structure, a centralizing mechanism, a setting mechanism, a locking structure, and an unsealing structure, but the above structures do not necessarily include all packer mechanisms. The following is a brief introduction of each institution[4].

In response to this problem, many researches have begun on the multistage unlimited fracturing technology, that is, the existing fracturing tools are redesigned, the fully bored wellbore can be modified, any number of stages can be designed, and the technical advantages such as maximizing reservoir
transformation can be achieved. It is an important means to increase the production and ultimate recoverable reserves of unconventional production wells.

2. Materials and methods

The working principle of the traditional compression packer is mainly through lifting and releasing the pipe string, rotating the pipe string, adding hydraulic pressure, etc., so that the setting pin of the packer is broken by shearing force, thereby compressing the sealing element and passing. The one-way locking effect of the locking mechanism makes the sealing element maintain the sealing working state.

When unsealing is required, the unsealing pin on the packer is sheared due to greater shearing force by lifting the string, rotating the string, adding hydraulic pressure, etc., and finally releases the elastic sealing element to allow the packer is unblocked. This packer breaks the traditional packer which relies on shearing pins to realize setting and unsealing. Through a new type of locking mechanism and unsealing mechanism, the packer can realize repeated setting and unsealing, realizing infinite compression. It not only effectively reduces the risk of construction operations, but also improves operation efficiency and reduces production costs. Applied Solidworks to draw a three-dimensional diagram of the new packer, as shown in Figure 1.

![Figure 1. Packers perspective view](image1)

The designed horizontal well infinite-stage packer model is Y341-115, Y represents the compressive type of the packer, 3 represents that the packer is a suspended packer, 4 represents that the setting method of this packer is hydraulic Setting, 1 indicates that the unpacking method of this packer is to unpack the pipe string, and 115 indicates that the maximum outer diameter of the packer steel body is 115mm.

3. Results and discussions

The inner teeth of the locking mechanism are located at the inner circumference of the cylinder, that is, on the inner wall of the sealing sleeve. The material used is the same as that of the sealing sleeve, which is 35CrMo. According to the role of the inner teeth, the surface is quenched to improve its strength and make it sufficient to meet the requirements. The test algorithm is used to design the inner teeth.

The inner tooth width of each ring is 5mm and the tooth tip height is 3mm. There are six inner teeth in each ring with a total width of 30mm. The purpose is to ensure that after the compression of the rubber barrel is completed, the inner teeth can be stuck by the clamping plate of the locking mechanism, so that the rubber barrel keeps the setting state. It is calculated that: $\sigma = 166.32 \text{MPa} < 359.33 \text{MPa}$, Therefore, the internal tooth structure design is reasonable.

The inner teeth of the locking mechanism drawn with SolidWorks are shown in Figure 2.

![Figure 2. Internal locking mechanism](image2)
The ring sleeve of the locking mechanism is connected to the liner by thread, \( R_{TN} = R_{CW} = 38\text{mm}, \) \( R_{TW} = 41\text{mm}. \) The outer circumference of the ring sleeve is uniformly connected with four boards, whose function is to jam the inner teeth of the sealing sleeve indirectly to prevent the rubber barrel from being unsealed under the action of the rubber's own restoring force after the completion of setting and removal of the hydraulic pressure. Each card plate is 2\text{mm} in thickness and 5\text{mm} in width. The initial state is about 45\(^\circ\) from the axis direction of the ring sleeve, and the length is just enough to jam the inner teeth on the sealing sleeve, about 12.5\text{mm}.

A return spring is installed in the connection between the card plate and the ring sleeve to ensure that the card plate can return to the initial state after removing the force acting on the card plate. The locking ring sleeve and the card board drawn with SolidWorks are shown in Figure 3.

![Figure 3. Locking mechanism collar and pallet](image)

The internal teeth of the locking mechanism and the clamping plate play a locking role after setting to prevent the rubber cylinder from unsealing, as shown in Figure 4.

![Figure 4. Internal teeth and pallet locking effect](image)

Figure 4. Internal teeth and pallet locking effect

When the packer is used, the tubing string is connected to the packer through the upper joint 1 and the lower joint 18. The liner 11 is in clearance fit with the central pipe 12 with an inner diameter of \( \Phi 50\text{mm} \) and an outer diameter of \( \Phi 66\text{mm} \), in order to prevent the central pipe from moving with the liner when the central pipe moves in the axial direction. The main sealing elements are the long rubber cylinders 4 and 8 and the short rubber cylinder 6. The piston 10 and the sealing sleeve 17 are connected by threads, and the ring sleeve 13 of the locking mechanism and the liner 11 are connected by threads to unseal the ring sleeve. 16 and the central tube 12 are also connected by threads. There are six internal teeth 15 on the inner wall of the sealing sleeve 17. The diagram is shown in Figure 6.

![Figure 6. Multistage unlimited fracturing packer assembly drawing](image)

1- Upper joint, 2- Adjustment ring, 3- Retaining ring, 4, 8- Long rubber tube, 5, 7, 9- Spacer ring, 6- Short cartridge, 10- piston, 11- Liner, 12- Central tube, 13- Locking mechanism ring sleeve, 14- Locking mechanism card board, 15- Internal teeth, 16- Unblock ring sleeve, 17- Gland, 18- Lower joint, 19- Short connector

Figure 6. Multistage unlimited fracturing packer assembly drawing
The packer structure is composed of multiple parts, and the sealing part includes a rubber cylinder, an outer center tube, a spacer ring, and a casing tube. Model analysis can be used to study the sealability. The packer is axisymmetric as a whole, and its constituent elements are also axisymmetric parts. The finite element model can be simplified as a cross-axial section.

The loads applied to the rubber cylinder were 4 MPa, 8 MPa and 10 MPa in sequence. The deformation clouds of a plastic cylinder shown in Figure 7. It can be analyzed from Figure 7 that the sleeve first contacts the upper part of the rubber cylinder, then the middle part contacts, and the bottom part finally contacts; when the top pressure load changes, the contact pressure between the sleeve and the rubber cylinder changes accordingly. The maximum contact pressure appears at the upper part, and the pressure decreases from top to bottom. It can be concluded that the change of pressure load causes corresponding changes in pressure load and compression distance. And the contact length increases as the load increases, the upper rubber cylinder has the largest variable shape, and the lower rubber cylinder has the smallest variable.

4. Conclusion
The traditional packer needs to cut off the pins to realize the setting process. The Solidworks software is used to transform the "single use" pins into a one-way internal tooth and card plate locking mechanism. This structure can act on the piston by hydraulic pressure, and the piston drives the internal teeth of the sealing sleeve to lock and retract, so as to realize the repeated setting and unsealing of the packer. The application of ANSYS software and finite element method verifies that the designed packer meets the third strength theory and safety requirements; the analysis shows that under different pressure loads, the top stress of the upper rubber cylinder is the largest, so in the design Increase the wall thickness of the glue cylinder.

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