Study on Shear Performance of Shear Ram

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Abstract

The reliability of the shear rams is the key to the success of shut-in, so it is necessary to study the shear reliability of the shear rams. With the help of numerical simulation technology, the ABAQUS explicit dynamics analysis module is used to simulate and study the process of shearing the drill pipe. The results show that both the ISR and SBR shear rams can reliably shear S135 drill pipe of ϕ127. 0 mm (5 in) and below, and the shear stress and strain value of SBR shear ram are smaller. Therefore, the shearing performance is better than that of the ISR-type shearing ram; when the shearing rod has a larger diameter or a thicker wall thickness, the shearing slab has a larger shear stress peak, and the shear ϕ 127. 0 mm (5 In).The above S135 drill pipe has a large stress at the edge of the ram, which exceeds the yield strength of the ram material and has a high risk of failure; the optimal structural parameters of the ISR type shear ram are: chamfer 45°, The rake angle is 1° or 2°, and the V-shaped angle is 163°.

Keywords

Shear ram; ISR; SBR; stress peak; strain; chamfer; rake angle; V-shaped angle.

1. Introduction

The blowout preventer is the key well control equipment to prevent the occurrence of blowout accidents and balance the drilling pressure when exploring high-pressure oil and gas fields[1]. When an emergency situation occurs during drilling, workover or oil testing, the hydraulic blowout preventer shearing ram is closed, the well string can be cut off, and the well is sealed to ensure safe production[2]. Working reliability of shear rams.

It is the key to the success of shutting the well, so it is necessary to study the shear reliability of the shear rams.

Domestic scholars[3-5] have focused on the slab blowout preventer on the core and sealing system, but less on the shear performance of the shear ram. The author analyzes the mechanical behavior of the shearing ram by shearing the ram, and obtains the deformation law of the drill pipe. The fracture morphology of the drill pipe and the evolution of the stress field and strain field of the shear ram; the influence of the drill pipe specifications and the key structural parameters of the ram on the shear performance of the ram are analyzed, and the optimization method of the shear ram structure is given. . The research results provide a reference for the correct use and design of the shear rams.

2. Mechanical Behavior Analysis of Ram Shear Drill

The process of cutting the drill pipe by the shear rams is an extremely complex dynamic physical process involving multi-disciplinary theories such as elastic mechanics, plastic mechanics, fracture mechanics and tribology. It is difficult to use the traditional analytical method for the shear mechanism. Quantitative analysis and research. By using numerical simulation technology, the ABAQUS explicit dynamics analysis module is used to simulate the shearing process, which can effectively predict the shearing behavior of the drill pipe and the stress and strain of the shearing plate.

2.1 Finite Element Model

A three-dimensional model of ISR and SBR shear ram shear drills was established using Solidworks software. The shearing shutter is of integral type, the base material is 40CrNiMo, and the drill pipe material is 36CrNiMo4A. The mechanical properties of the materials are shown in Table 1.

Table 1. Mechanical property of materials

Category	Material	Yield strength/MPa	Tensile strength/ MPa	Elasticity modulus/ MPa	Poisson's ratio
Shear ram	40CrNiMo	960	1050	2.1x105	0.295
S135 drill pipe	36CrNiMo4A	937	976	2.02x105	0.3

The C3D4 tetrahedral unit is used to divide the overall mesh of the shearing rams, and the meshing of the cutting surface and the cutting edge position is performed to improve the calculation accuracy. The drill pipe unit mesh type uses the C3D8R hexahedral element. In order to reduce the calculation space, only the shear segment drill pipe is mesh refined. The finite element model of the shear rams and the drill pipe is shown in Figure 1.

a.ISR shear rams b. SBR shear rams

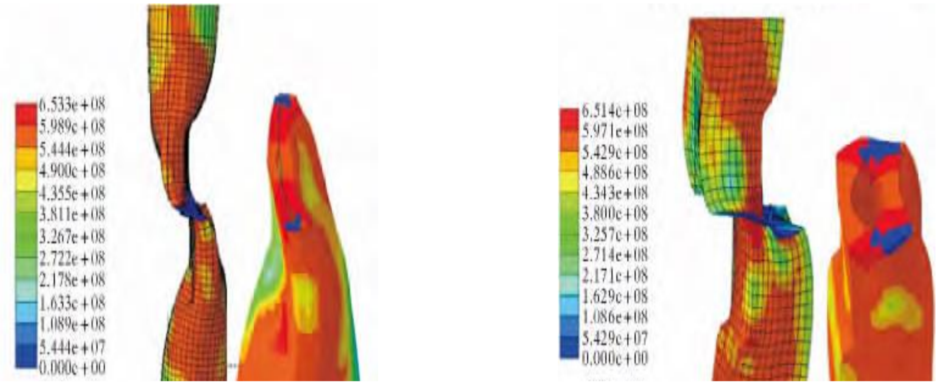
Fig 1. Finite element model

The shear ram in the ram blowout preventer is divided into two types: integral and insert type, including the upper ram and the lower ram[6]. When working, the two parts are closed to cut the drill pipe and continue to close. Seal[7], there is room for the shearing drill pipe on the ram and the bottom. During analysis, the degree of freedom of displacement in the y direction of the upper end of the drill pipe is constrained, the degree of freedom of displacement in the x and y directions of the rear surface of the seal rubber and the rotational freedom of the three directions are constrained, and 20 mm/s is applied to the rear end face of the shutter. The speed load simulates the process by which the rams moves the shear pipe.

2.2 Simulation Analysis Results

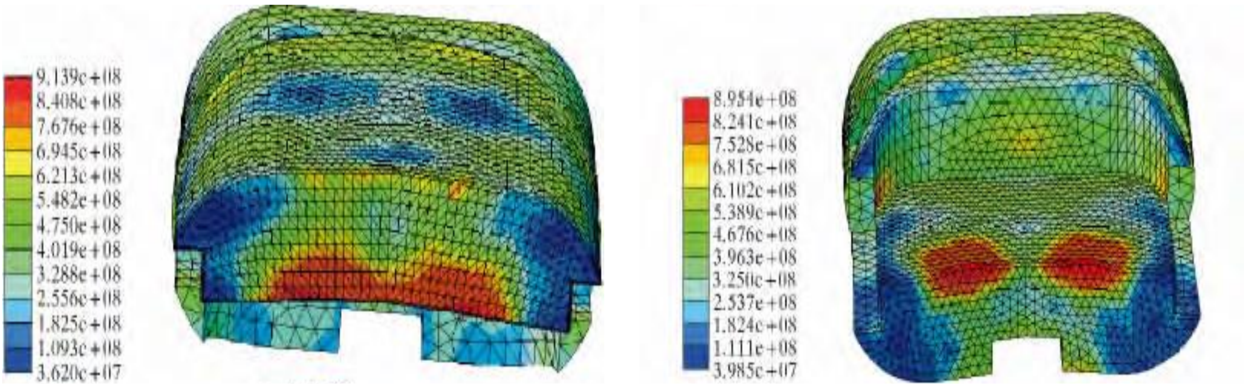
2.2.1 ISR Type Shear Rams Cutting Circle, Square Drill Pipe

The ISR type shear rams shear ϕ127. 0 mm (5 in) round drill pipe and 114 mm ($4\frac{1}{2}$ in) Square drill pipe were simulated and analyzed. The results are shown in Fig. 2 to Fig. 4. Show. As the shearing ram is closed, the shearing section of the drill pipe gradually enters the elastoplastic deformation stage until the failure is broken and the shearing is completed.



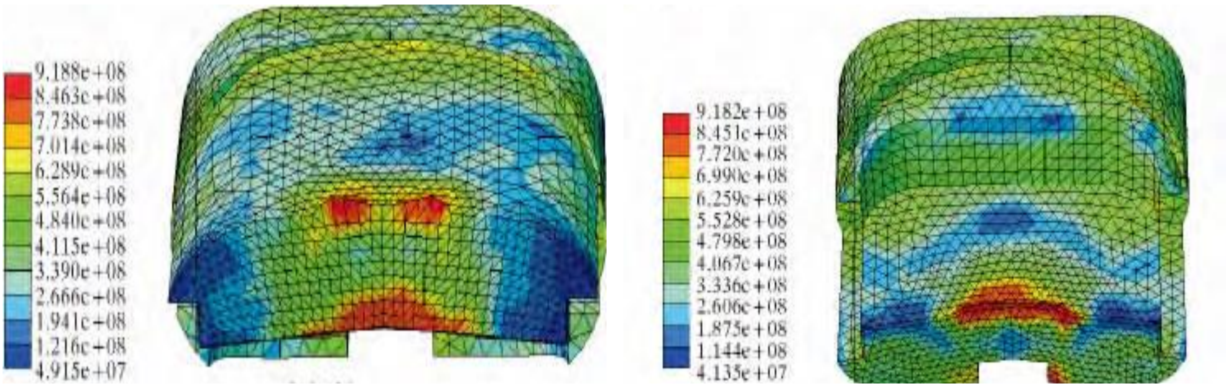
a. ϕ127mm(5 in Round drill pipe) b. 114 mm ($4\frac{1}{2}$ in) Square drill pipe

Fig 2. Drill pipe stress reprogram



a. upper shear ram b. lower shear ram

Fig 3. Misses stress reprogram of rams shearing ϕ127mm (5 in) round drill pipes



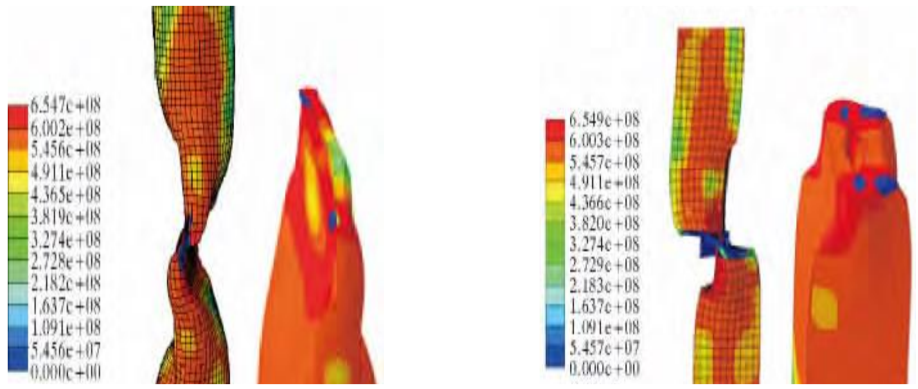
a. upper shear ram b. lower shear ram

Fig 4. Misses stress reprogram of rams shearing 114. 0 mm ($4\frac{1}{2}$ in) square Kelly

There are obvious high stress areas on the edge of the ISR type shear rams and they are symmetrically distributed. When the round drill pipe is sheared, the upper rams stress peak is 914 MPa, the lower rams stress peak is 895 MPa, the stress value is high, and the cutting edge has entered the yielding stage. The rams stress at the rear end of the cutting edge is low, about 450 MPa. Due to the larger wall thickness of the kelly, the peak stress of the ram is higher at the time of shearing, and the stress of the upper and lower rams is equivalent, which is 918 MPa.

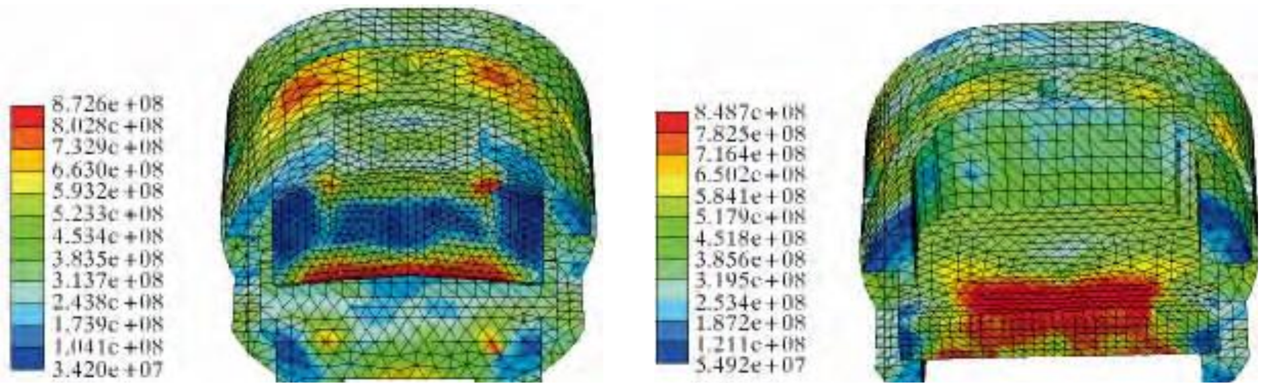
2.2.2 SBR Type Shear Rams Cutting Circle, Square Drill Pipe

The SBR type shear rams shear ϕ127. 0 mm (5 in) round drill pipe and 11.4 mm ($4\frac{1}{2}$ in) kelly were analyzed as an example. The analysis results are shown in Fig. 5 to Fig. 7.



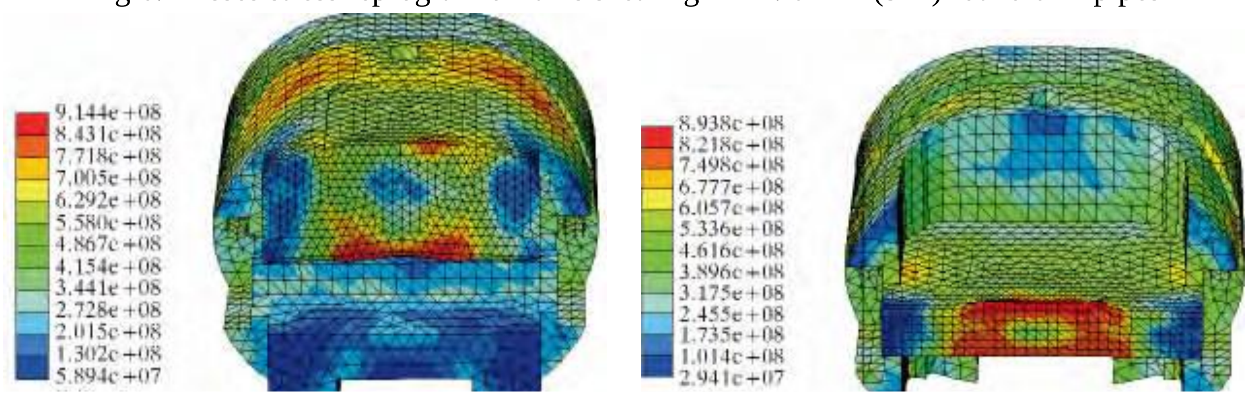
a. ϕ 127mm(5 in Round drill pipe) b. 114 mm ($4\frac{1}{2}$ in) Square drill pipe

Fig 5. Drill pipe stress reprogram



a. upper shear ram b. lower shear ram

Fig 6. Misses stress reprogram of rams shearing ϕ 127. 0 mm (5 in) round drill pipes



a. upper shear ram b. lower shear ram

Fig 7. Misses stress reprogram of rams shearing 114. 0 mm ($4\frac{1}{2}$ in) square Kelly

There is an obvious high stress area near the edge of the SBR type shear rams. When the round drill pipe is sheared, the upper rams stress peak is 873 MPa, and the lower rams stress peak is 849 MPa. Due to the thicker wall thickness of the kelly, the peak stress of the ram is higher during shearing, the peak stress of the upper ram is 914 MPa, and the peak stress of the lower ram is 894 MPa. The high stress zone is concentrated near the cutting edge, and the material has entered the yielding stage, but the deformation of the cutting edge is not obvious.

Comparing the shearing process of the two types of rams, it is known that the SBR-type shear rams have lower stress peaks and smaller cutting edge deformation, which is superior to the ISR-type shear rams.

3. Test Situation

Single-slide Cameron, double-brake letter-breaker side door direct-coupled supercharger, with SBR-type shear rams for ϕ127. 0 mm (5 in) S135 drill pipe for 3 shear tests ,Details are as follows.

(1) The first test was carried out with a Cameroon blowout preventer, and the hydraulic pressure was cut off by 15. 4 MPa. The cutting edge of the cutting ram is intact, the shearing process is slow, the upper end of the drill pipe is tidy, and the lower end is severely deformed and teared.

(2) The second test was carried out with a Cameroon blowout preventer and the hydraulic pressure was cut off by 15.6 MPa. The cutting edge of the cutting rams is intact, the cutting process is relatively slow, and the upper and lower fractures of the drill pipe are relatively neat. The slag generated by the tearing in the middle of the fracture is embedded in the sealing cavity of the ram rams on the shearing ram, and the effective sealing cannot be achieved after shearing.

(3) The third test was carried out with a letter breaker and cut off the oil pressure of 17. 0 MPa. The cutting edge of the cutting ram is intact, the shearing process is smooth, the upper and lower fractures of the drill pipe are relatively neat, and an effective gas seal of 105. 0 MPa is achieved after the shearing is completed.

It can be seen from the test results that the SBR type shear ram can smoothly cut the ϕ127. 0 mm (5 in) S135 drill pipe, the upper end of the drill pipe is neatly cut, and the lower end is extruded and torn. The fracture profile of the drill pipe is close to the simulation analysis results, which indicates that the calculation model of the shear rams is correct and feasible, and can be used for the subsequent shear performance study of the shear rams. A comparison of the shear simulation results with the test fracture morphology is shown in Figure 8.

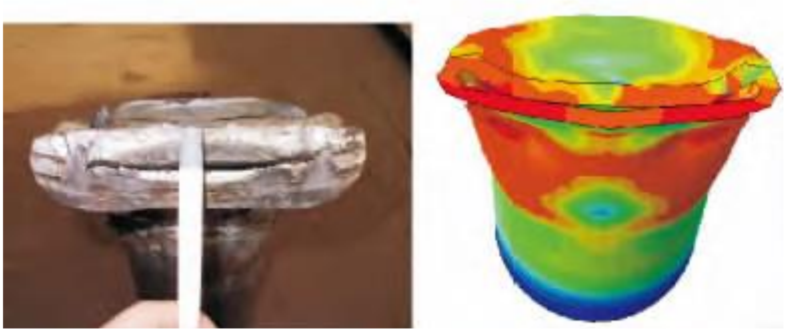


Fig 8. Fracture appearance comparison

4. Impact Analysis of Key Parameters of the Shearing Process

4.1 Influence of Different Drill Pipe Specifications on Shear Performance

Shear analysis was carried out on the round drill pipe and the square drill pipe of the oilfield's common specifications. The results are shown in Table 2 and Table 3. When ISR shear rams are sheared, the stress distribution on both sides of the ram is basically the same. The high stress areas are mainly concentrated near the V-shaped cutting edge and are symmetrically distributed. When cutting a drill pipe with a thicker wall thickness or a larger diameter, the peak stress of the ram is higher and the deformation of the cutting edge is more obvious. The shear stress and strain values of the SBR type shear rams when shearing ϕ127. 0 mm (5 in) and above are lower than the ISR type. When shearing ϕ127. 0 mm (5 in) and above, the stress values near the cutting edges of the two types of shear rams are all greater than 900 MPa, up to 980 MPa, and the ram material has completely yielded and the deformation is obvious. There is a high risk of failure.

Table 2. Results of analysis on shearing different specifications of round drill pipes

specification/ (mm x mm)	ISR				SBR			
	RU/MPa	εU	RL/MPa	εL	RU/MPa	εU	RL/MPa	εL
ϕ168.3X9.16	980	1.375	978	0.794	980	0.988	925	0.583
ϕ139.7X10.54	960	0.402	976	0.680	974	0.534	917	0.529
ϕ127.0X9.19	914	0.446	895	0.494	873	0.486	849	0.383
ϕ114.3X8.56	898	0.598	881	0.459	841	0.243	833	0.239
ϕ101.6X8.38	879	0.409	869	0.412	855	0.354	831	0.237
ϕ88.9X11.40	885	0.407	884	0.461	873	0.485	854	0.345

Table 3. Results of analysis on shearing different specifications of square Kelly

size/ mm	ISR		SBR	
	RU/MPa	RL/MPa	RU/MPa	RL/MPa
114.3	918	919	914	893
108.0	897	909	891	877
88.9	859	886	854	848
76.2	858	868	844	835
60.3	829	846	827	823

4.2 Influence of the Chamfering of the Ram Edge on the Shear Performance

Taking the shear ϕ127. 0 mm (5 in) round drill pipe as an example, the blade chamfering angles are 15°, 25°, 35°, 45°, 55°, 65° and 75°, respectively. The effect of different edge chamfers on the shear performance of ISR shear ramss was analyzed. The results are shown in Figure 9. It can be seen from the figure that the edge chamfering has a great influence on the stress peaks of the upper and lower ramss. When the upper rams edge chamfer is 45°, the rams stress peak is the smallest and the high stress zone range is the smallest, so the 45° chamfer of the upper rams is the optimal value. When the chamfering edge of the lower rams is 15°, the peak stress of the rams is the smallest and the range of the high stress zone is the smallest, so the 15° chamfer of the lower rams is the optimal value.

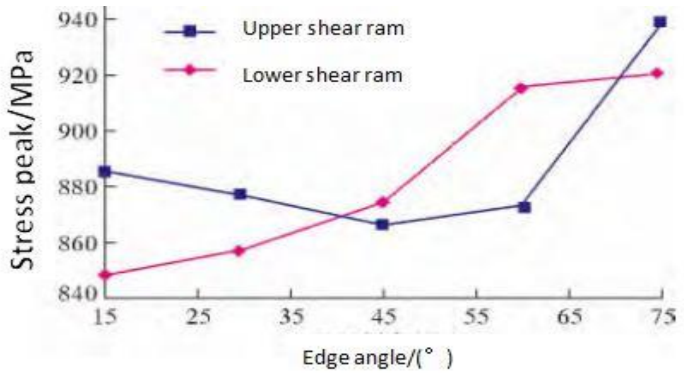


Fig 9. ram stress peak curve of rams under different edge chamfers

4.3 Influence of the Inclination of the Ram on the Shear Performance

Take the shear ϕ127. 0 mm (5 in) round drill pipe as an example, calculate the inclination angles of the knives by 0°, 2°, 4°, 6°, 8° and 10° respectively, and analyze the different rake angles. The effect on the shear performance of the ISR type shear rams is shown in Figure 10. It can be seen from the figure that the rake angle has a greater influence on the stress peak of the upper rams and less on the peak stress of the lower rams. When the rake angle is 2° or 1°, the rams stress peak is the smallest and the high stress region is the smallest.

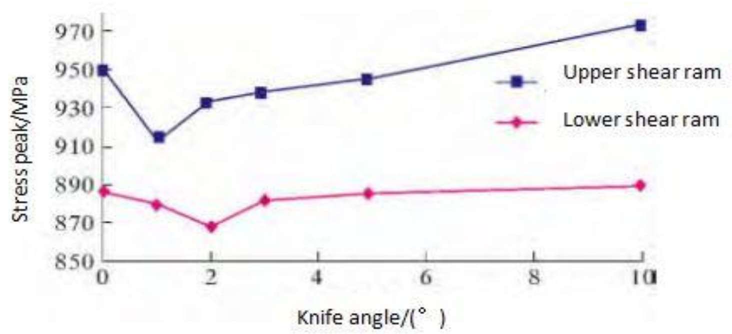


Fig 10. Ram stress peak curve of rams under different tool face inclinations

4.4 Influence of the Angle of the Knife Blade on the Shear Performance

Taking the shear ϕ 127. 0 mm (5 in) round drill pipe as an example, the V-shaped angles of the ram are taken as 155°, 159°, 163°, 167°, 171°, 175° and 179°, respectively. The influence of different V-angles on the shear performance of ISR shears was analyzed. The results are shown in Fig. 11.

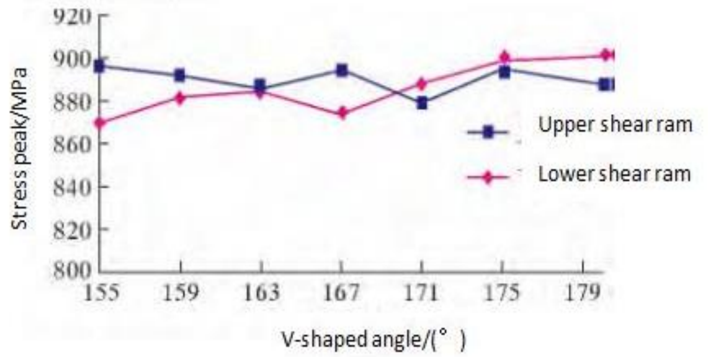


Fig 11. Ram stress peak curve of rams under different V-shaped included angles

It can be seen from the figure that as the angle of the V-shaped angle decreases, the range of the high stress region of the rams is reduced, and the stress peak is between 870 and 900 MPa. When the V-angle is 163° and 175°, the upper and lower shears are used. The peak stress of the ram is equivalent, but the 163° stress peak is slightly lower, so the comprehensive analysis can obtain 163° as the optimal value.

5. Conclusion

(1) Both the ISR type and SBR type shear rams can reliably shear the S135 drill pipe of ϕ127. 0 mm (5 in) and below. The shear stress and strain value of the SBR type shear ram are smaller, so Its shear performance is superior to ISR type shear ramss.

(2) When the shearing ram is used to cut a drill pipe with a larger diameter or a thicker wall thickness, the peak value of the shear stress is larger, and the slab edge of the S135 drill pipe is ϕ127. 0 mm (5 in) or more. The stress is large and has exceeded the yield strength of the ram material, so there is a high risk of failure.

(3) The optimal structural parameters of the ISR type shear rams are: chamfer 45°, rake angle 1° or 2°, V-shaped angle 163°.

Acknowledgements

Shandong University of Science and Technology.

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