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The Effect of Clamping Force and Friction Coefficient on The Clamping Clamp

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Abstract: In order to study the influence of clamping force and friction coefficient on the stress distribution of drill pipe joint during the buckling process, the nonlinear contact problem and elastoplastic mechanical properties of Φ139.7mm × 9.17mm drill pipe were simulated by finite element analysis method in this paper, and the stress distribution and size of drill pipe joint during the buckling process were obtained. And the effect of clamping force and friction coefficient on the joint of drill pipe. It is found that the stress of drill pipe joint is mainly concentrated in the contact position of drill pipe and the stress value of drill pipe joint shows a trend of increasing. When the friction coefficient is 0.15 and the clamping force is 600KN, although there is stress concentration in the contact position between the clamp teeth and the drill pipe joint, it does not exceed the yield limit of the drill pipe joint, and no plastic deformation occurs. Through the simulation calculation, it is found that the maximum clamping force and the maximum torque are 1200KN and 81.9KN.m respectively. When the torque is fixed, the change of friction coefficient has a great influence on the maximum clamping force of drill pipe joint. With the increase of friction coefficient, the maximum clamping force of drill pipe joint decreases continuously, and the friction coefficient is inversely proportional to the maximum clamping force. The research in this paper enriches the understanding of the buckling process of punching pliers and provides a reference for the rational buckling of pipe string.

Keywords: Punching pliers, Drill pipe joint, Clamping force, Winding torque, Friction coefficient, Stress.

1. Introduction

With the rapid development of oil drilling technology, iron driller technology came into being. It completely replaces the hydraulic power vise to realize the process of unloading buckle on the drilling tools, which has a high degree of automation, precise control and high safety coefficient. Iron driller on the buckle is divided into two stages, divided into spinning buckle clamp pre-tightening and punching buckle clamp tightening two processes, due to the spinning buckle clamp torque is insufficient, you need to use the punching buckle clamp for tightening, to realize the iron driller on the buckle operation. [1] When punching pliers fastening, the buckling torque mainly depends on the size of the clamping force and friction coefficient, however, too much clamping force will lead to the damage of the pipe column; too little clamping force will occur slipping phenomenon. Therefore, it is necessary to analyze the influence of clamping force and friction coefficient on the buckling torque. The continuous popularization of iron drilling technology makes more and more scholars at home and abroad to carry out in-depth research on the related problems in iron drilling technology.

Abd-Elhady, Amr A.[2] studied the effect of clamping force and friction coefficient on the elastic-plastic behavior of cracked bolt joints by using a three-dimensional elastic-plastic extended finite element method.Hashimura Shinji[3] and others, for the problem of bolted joints, investigated the variation of friction coefficients between the bearing surfaces under the target clamping force for M8 bolt/nut assemblies and the variation of friction coefficients from the middle to the end of the appropriate target clamping force for the bolt/nut assemblies. The rate of change of friction coefficient from the middle to the end of the target clamping force.Yan W, Xie D, Guo L[4] et al. for the problem of the contact between the clamping body and the outer wall of the pipe column during the buckling unloading operation on a punching clamp, established the relationship between the various influencing factors and the contact stresses, and simulated the contact stresses and deformations of the column with the Finite Element Method (FEM).

Yu Zhi,Zhang Le[5] used finite element to analyze the force of casing joint under different clamping force, and got the reasonable clamping force for the unbuckling test on this specification casing. Wu Xiangshi[6] and others analyzed the two-dimensional axisymmetric finite element model of drill pipe joints on the basis of elastic mechanics theory, and proposed a new calculation method of the upper buckling torque. Pei Junfeng [7] and others, in response to the chipping and wear phenomenon of the teeth of the iron driller's punching and buckling pliers in the process of unscrewing and unloading buckles, based on the Ansys Workbench finite element software, elasticity and plasticity analysis of the limit static working state of the teeth when they contact the drill pipe.

Yan Wenhui [8] and others take the relationship between the clamp tooth pattern and the equivalent friction coefficient as the entry point, based on the principles of contact mechanics and tribology, analyze the force analysis of the contact between the clamp teeth and the outer wall of the pipe column joint, and establish the relationship equations between the clamp tooth angle, the top chamfer radius of the teeth, the outer diameter of the pipe column and the depth of the bite mark and the equivalent friction coefficient. Ye Qiang [9] and others in the introduction of the punch buckle clamp structure principle, focusing on the design of the punch buckle clamp structure, to determine the punch buckle clamp clamp clamping structure, punch buckle structure, as well as the hydraulic control system and other key technologies. Liu Bailong [10] completed the design of rocker-type iron driller punching pliers and the simulation test of the process of upper unloading buckle on the basis of detailed research on the development of domestic and foreign iron driller technology.

Through reviewing the literature, it can be seen that domestic and foreign scholars have made many studies on iron driller technology. As the two actuators of the iron driller, the rotary buckling clamp and the punching buckling clamp complete the uploading and unloading operation of the pipe column. However, in the process of buckling, there are many factors affecting the effect of buckling, and to achieve the buckling torque and avoid the damage of the pipe column has become the biggest problem in the process of buckling. At present, although there are scholars to carry out research on related issues, but the impact of punching and buckling pliers on the buckle factors are less analyzed.

In this paper, the contact stress between the jaws and the joint of the drill pipe is analyzed in the process of punching and buckling pliers. It analyzes the contact mode and maximum clamping force between the jaws and the joint of the drill pipe, and analyzes the stress state of the joint of the drill pipe in the process of buckling. Punch-buckling pliers can solve the problem of insufficient torque of screw-buckling pliers, but the effect of punch-buckling pliers on buckling will be affected by the clamping force and friction coefficient, the clamping force is too small to meet the requirements of buckling, and too large to easily cause damage to the pipe column. Therefore, this paper adopts the finite element method to analyze the stress distribution of drill pipe joints under different clamping force, and the influence of friction coefficient on the contact stress of drill pipe joints under the same clamping force.

2. Finite Element Model

The working principle of TZG93/4-140S1 iron driller's punching clamp: the clamping cylinder pushes the left and right slider assemblies through the clamping mechanism, and the jaws installed on the slider act on the drilling tool, after the jaws of the upper and lower clamps are clamped on the drilling tool, the punching clamp cylinder transfers the thrusting force to the slider through the casing, and finally the clamping force drives the drilling tool to rotate, so as to carry out punching clamping operation, and the interaction force between the jaws of the punching clamp and drilling tool is shown in Fig. 1. The interaction between the jaws of the punching jaw and the drilling tool is shown in Fig. 1. The calculation formula for the buckling torque is:

$$T = 4Ff \cdot R \tag{1}$$

Formula: Ff ——force of friction;

R ——Radius of drilling tool joint;

However, the friction force is equal to the product of the positive pressure and the coefficient of friction, calculated as follows:

$$Ff = \mu F_N \tag{2}$$

Formula, μ ——coefficient of friction;

F_N ——positive pressure;

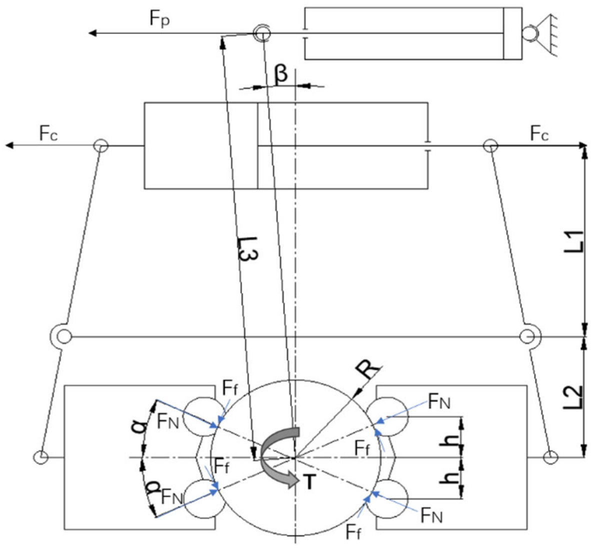


Figure 1. Schematic diagram of the force on the punch clamp

For the finite element model of the drill pipe, it is assumed that there is no ellipticity and wall thickness error, and the material is isotropic. This paper uses Solidworks three-dimensional drawing software to establish the punch button pliers on the buckle model in Figure 2.In the process of buckling, the interaction between the jaws and the drill pipe belongs to a highly complex nonlinear contact problem, and it is difficult to experimentally test the stress distribution of the drill pipe, and the use of the finite element method can be efficiently and clearly simulate the process of punching button pliers on the buckle. Therefore, this paper utilizes the static mechanics module of ABAQUS software for simulation. Considering the computational capacity of the computer for model simplification, only the joint clamping part of the drilling tool is retained in the simulation calculation, and the threaded part of the joint and the casing are omitted.

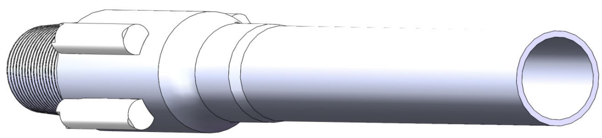


Figure 2. Punch and Buckle Pliers 3D Upper Buckle Model

The distribution of pincer teeth in the circumferential direction of the drilling tool joint is shown in Figure 3. The process of iron driller punching buckle is mainly driven by four clamping teeth to buckle the drill pipe, the clamping teeth are located on the outer wall of the drill pipe joint, and the edge line of the clamping teeth is coaxial with the drill pipe. Through the clamping force exerted by the clamping teeth to drive the drill pipe clockwise rotation to realize the upper buckle process. The diameter of the clamping teeth is D1=45mm, and the interval between the centers of the two clamping teeth is L=110mm; the outer diameter of the joint of the drill pipe is D2=177.8mm, and the inner diameter is d=101.6mm; the drill pipe selected for the simulation calculation is grade E steel, the drill pipe is inner and outer thickened, and the rotary shoulder connection type is 5 1/2FH.

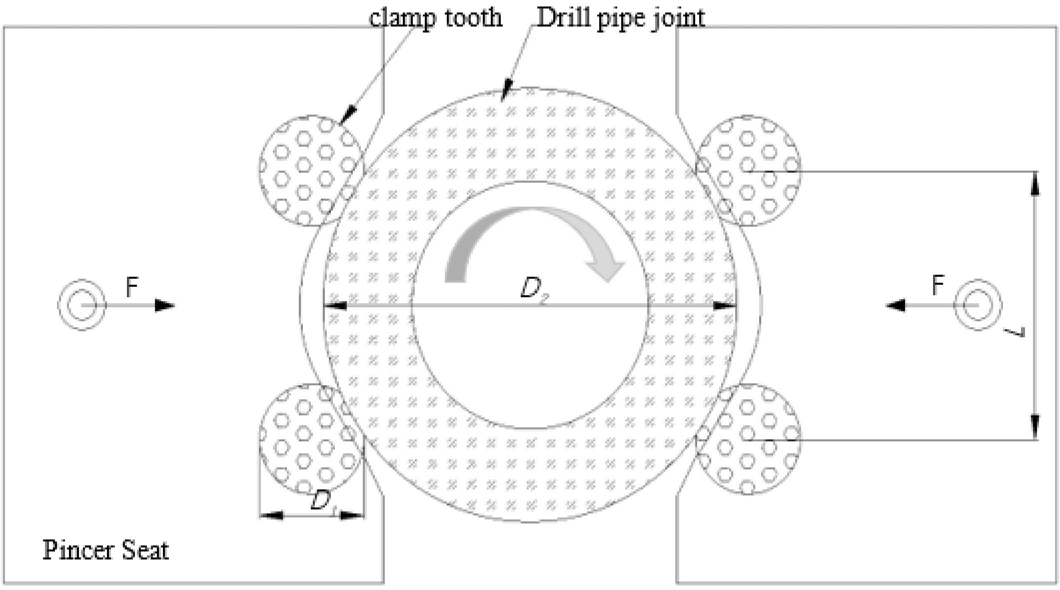


Figure 3. Schematic distribution of clamp tooth positions

The buckling process of the punch-buckling clamp belongs to the nonlinear contact problem, and the buckling is accomplished by the rotation of the jaws to drive the drill pipe. Because the jaws are much stiffer than the drill pipe, when the drill pipe is deformed, the jaws have almost no deformation. In the finite element model of this paper, the joint of the drill pipe is set to be a flexible body, the jaws are set to be a rigid body, and the contact mode is set to be the face-to-face contact between the rigid body and the flexible body. The material parameters of the drill pipe joint are shown in Table 1, and the material parameters of the clamp teeth are shown in Table 2. According to the actual production of this type of iron driller, the friction coefficient is 0.15, so the friction coefficient of the clamp teeth and the drill pipe joint is taken as 0.15 in this paper.

The material yield criterion is the von-Mises yield criterion, calculated as follows:

$$\sigma_s = \sqrt{\frac{1}{2}\left[\left(\sigma_1-\sigma_2\right)^2+\left(\sigma_2-\sigma_3\right)^2+\left(\sigma_3-\sigma_1\right)^2\right]} \tag{3}$$

formula: σ_1, σ_2, σ_3 represents the first, second and third principal stresses respectively, and is the yield strength limit of the material.

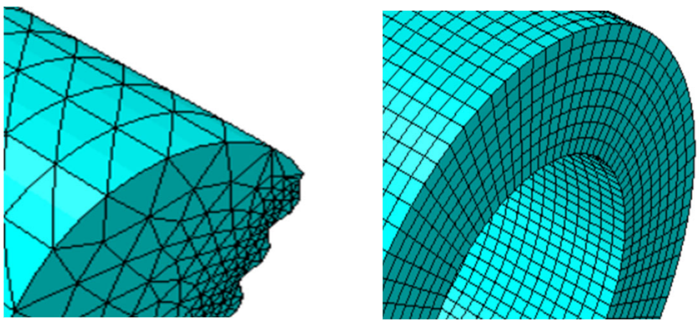
Table 1. Material parameters of drill pipe joints

parameters	yield strength /MPa	tensile strength /MPa	elastic modulus /MPa	Poisson's ratio	density /kg/m3
value	517	689	2E5	0.3	7850

Table 2. Parameters of clamping material

parameters	yield strength /MPa	tensile strength /MPa	elastic modulus /MPa	Poisson's ratio	density /kg/m3
value	835	980	2.08E5	0.3	7830

In the three-dimensional finite element model of the punch buckle clamp, the drill pipe joint is selected as C3D8R cell, hexahedral, with a total of 27880 cells; the clamp teeth are selected as C3D10 cell, tetrahedral, with a total of 9906 cells. The mesh of the 3D finite element model of the upper buckle of the punch clamp is shown in Figure 4. The boundary conditions of the punch buckle pliers are set as in Figure 5.



(a) pincer tooth mesh (b) Drill pipe joint grid

Figure 4. Mesh of the finite element model of the punching buckle clamp

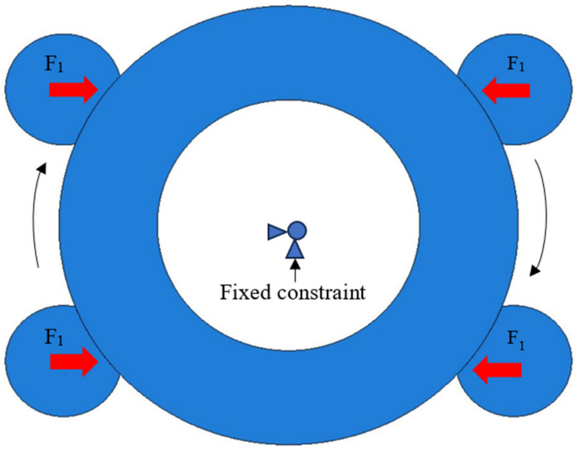


Figure 5. Schematic diagram of the boundary condition of the upper buckle of the punching buckle clamp

3. Stress Analysis of Drill Pipe Joints during Buckling of Punching Jaws

3.1. Stress distribution of drill pipe joint during loading of jaws

Through reviewing the literature, we know that TZG93/4-140S1 iron driller, the maximum torque of the upper buckle is 1000 000 N.m, the thrust of the clamping hydraulic cylinder is 659 400 N, the mechanical efficiency is generally 0.9 ∽ 0.95, according to the actual working conditions, this paper is taken as 0.91 for calculation. Therefore, the simulation is carried out when the clamping force is 600 KN, the clamp teeth are clamped and not rotated when the von-Mises stress is shown in Figure 6.

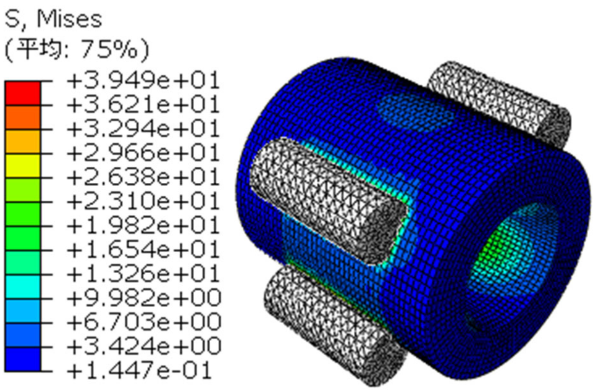


Figure 6. Clamping force of 600 KN clamp teeth loaded with von-Mises stress clouds

From Fig. 6, it can be seen that the von-Mises stress is centrally distributed in the contact position between the clamping teeth and the drill pipe joint, and the maximum value of the von-Mises stress in the drill pipe joint during the loading process of the clamping teeth is 39.49 MPa, which does not reach the yield strength value of the drill pipe, so the drill pipe joint will not be plastically deformed.

3.2. Clamp teeth rotation process drill pipe joint stress change rule

Punch buckle clamp on the buckle process is the clamp tooth rotation and thus drive the drill pipe on the buckle operation, clamp tooth rotation angle is generally between 40 ∽ 60 degrees, the type of iron driller punch buckle clamp teeth are generally 1 radian, so this paper clamp tooth rotation angle is set to 1 radian. After the clamp teeth loading is completed, the drill pipe is driven to rotate to carry out the process of upper buckle. The maximum von-Mises stress change curve of the drill pipe joint is shown in Fig. 7 when the jaws are rotated at different radian.

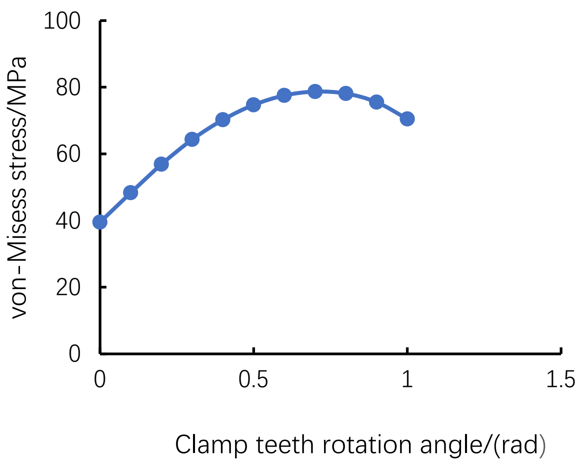


Figure 7. Maximum von-Mises stress variation curve during rotation of drill pipe joints

From Fig. 7, it can be seen that with the increase of the rotation angle of the drill pipe, the overall trend of the value of the von Mises stress increases, and the stress value increases from 34.49 MPa to 78.66 MPa. Compared with the maximum stress during the loading process of the jaws, the value of the maximum stress during the rotation process of the jaws increases by 2.28 times. The reason for this is that the upper buckling torque is the main influence factor for the stress change of the joint between the clamp teeth and the drill pipe. During the rotation process of the drill pipe driven by the jaws, the upper buckling torque changes continuously, because the upper buckling torque in the buckling process increases with the increase of the clamping force of the punching jaws, so the stress of the joint of the drill pipe increases gradually. The displacement of the punching clamp during the rotation of the drill pipe driven by the jaws is shown in Fig. 8.

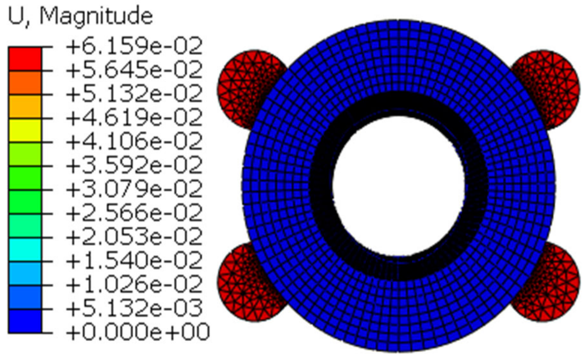


Figure 8. Displacement of the punching and buckling jaws during the rotation of the jaws.

As can be seen from Fig. 8, the maximum displacement of the jaws is 6.159x10-2 mm when the jaws are rotating, and the general depth of the bite mark is not more than 1 mm for the optimal working condition, and the depth of the bite mark is suitable for less damage to the joints of the drill pipe.

3.3. Analysis of maximum buckling torque of drill pipe

Punching clamp buckling is to make up for the lack of rotary buckling torque of the rotary buckling clamp and the buckling process, mainly through the thrust hydraulic cylinder and the punch hydraulic cylinder together to drive the jaws to drive the drill pipe for the buckling process. The size of the punching torque is mainly determined by the clamping force and friction coefficient. When the friction coefficient is certain, increasing the clamping force can effectively solve the problem of insufficient torque of rotary buckling. Take the friction coefficient as 0.15, increase the clamping force, that is, increase the torque, so as to draw the peak stress curve of punching buckle clamp punching process as shown in Figure 9.

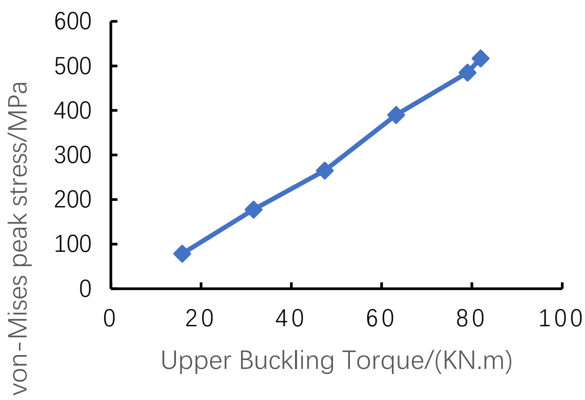


Figure 9. Peak stress curves of drill pipe joints at different buckling torques

As can be seen from Fig. 9, when the friction coefficient is constant, the maximum value of the von-Mises stress in the drill pipe joint during the buckling process of the buckling clamp increases with the increase of the upper buckling torque. When the upper buckling torque increases from 15.8 KN.m to 81.9 KN.m, the maximum von-Mises stress of the drill pipe joint increases from 78.6 MPa to 517 MPa, and the increase value is 83.1% of the yield strength of the material of the drill pipe joint; until the upper buckling torque increases to 81.9 KN.m, at which time, the clamping force of the drill pipe joint is 1200 KN, and the maximum value of von-Mises stress of the drill pipe joint is 517 MPa. Mises stress is 517 MPa, reaching the yield limit of the drill pipe material, the material begins to deform plastically, and does not exceed the maximum allowable upper buckling torque of this type of iron driller's punching pliers, i.e., this upper buckling torque is the maximum upper buckling torque of the punching pliers during the process of upper buckling and the maximum clamping force of the drill pipe joints is 1,200 KN. Therefore, for 139.7mm x 9.17mm drill pipe, the maximum buckling torque of the punching and buckling pliers is 81.9 KN.m. The finite element simulation of the drill pipe joint under the maximum buckling torque is as follows:

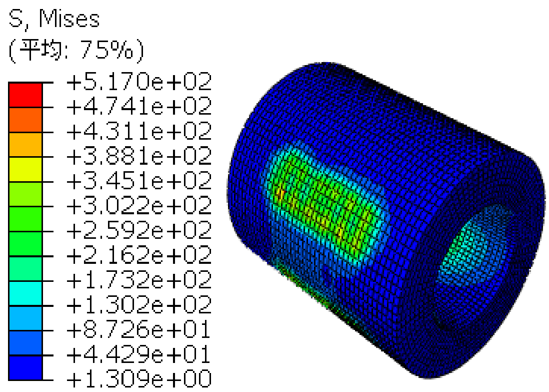


Figure 10. Stress cloud of drill pipe joint

3.4. Effect of friction coefficient on the maximum clamping force of drill pipe joints

In order to obtain a large buckling torque, the clamping force and friction coefficient can be increased. However, too large friction coefficient will easily lead to the surface damage of drill pipe joint, and in serious cases, it will cause the skin of drill pipe joint to peel off and accelerate the corrosion of drill pipe, therefore, it is especially important to study the influence of friction coefficient on the process of punching buckle clamp. When the upper buckling torque is certain, the friction coefficient is 0.15 ~ 0.3, and the maximum clamping force of the drill pipe joint under different friction coefficients is shown in Figure 11.

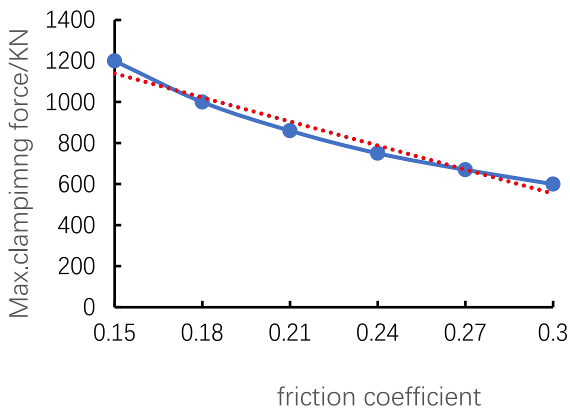


Figure 11. Variation curve of stress with friction coefficient for different clamping force

As can be seen from Fig. 11, when the upper buckling torque is a constant value, the maximum clamping force of the drill pipe joint decreases with the increase of the friction coefficient, and the red dotted line is the trend of the fitted curve, which is a linear relationship. The reason for this is that the upward buckling of the punching pliers needs to reach the rated torque, and the torque of the punching pliers is the sum of the friction between the four jaws and the drill pipe joint; when the torque is certain, the friction coefficient is inversely proportional to the maximum clamping force. Therefore, a suitable friction coefficient can reduce the output of clamping force, reduce the power cost and improve the buckling efficiency.

4. Conclusion

In this paper, the stress distribution law of drill pipe joints under the clamping teeth loading and rotation state is studied. The following understanding can be analyzed

(1) The stress of the drill pipe joint is mainly distributed in the contact position between the clamping teeth and the drill pipe joint, and in the process of rotation of the drill pipe joint driven by the clamping teeth, the maximum stress of the drill pipe joint von-Mises basically shows an increasing trend, which is due to the fact that, the upper button torque of the upper button process increases with the increase of the clamping force of the punch button pliers, and the stress of the joint of the drill pipe gradually increases.

(2) When the contact friction coefficient between the jaw teeth and the drill pipe joint is 0.15, the up-buckling operation is completed by increasing the up-buckling torque. when the up-buckling torque increases to 81.9KN.m, the drill pipe reaches the yield strength value, i.e., the maximum up-buckling torque of the drill pipe is 81.9KN.m. At this time, the maximum clamping force of the drill pipe joint is 1,200KN.

(3) When the upper buckling torque is a fixed value, the maximum clamping force of the drill pipe joint decreases with the increase of the friction coefficient, and the friction coefficient is inversely proportional to the maximum clamping force. Therefore, increasing the friction coefficient will reduce the size of clamping force and power cost, which can provide a reference basis for the actual operating conditions.

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