Electronically Controlled Deep Sea Sampling Tube Pressure Maintaining Cutting Device Capable of Long-term Use

Hai Zhu, Jiawang Chen, Yuan Lin, Peihao Zhang, Ziqang Ren, Xiaoling Le, Jing Xiao, Ziang Feng
Ocean College, Zhejiang University, Zhoushan, 316021,China
**Corresponding author: simaizhu @icloud.com*

I. INTRODUCTION

A kind of sample tube pressure-keeping cutting device is designed, which is feasible from the perspective of manufacturing and assembly, and the relevant Ansys simulation is carried out to verify the rationality of the structure. The biggest breakthrough is that one installation can realize multiple cutting of sampling pipes, eliminating the step of cleaning sea mud in the pipes. In addition, the redesign of the cutting knife and the re-selection of the outer cylinder material reduced the overall size to 71.9% and the mass to 22.3%.Anti- sludge blocking design was carried out, thus realizing long- term use design.

II. DEVICE DESIGH

A. Design indicators

As an important part of the pressure maintaining transfer device, the cutting device requires a smooth, undisturbed rapid cutting of the sampling tube at an in-situ pressure of 30 MPa. The design purpose and design indicators of this equipment were proposed[1、2]:

- Working pressure: 30Mpa;
- Operating temperature: 2-4 °C;
- Pressure change during transfer: ≤20%;
- Cause no secondary pollution to the sample;
- Controllable cutting process;
- Shorten the cutting time as soon as possible.

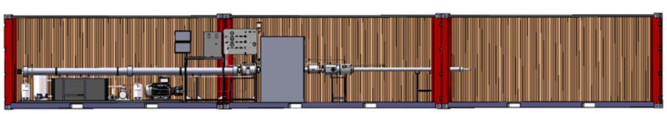

Fig. 1 Overall drawing of pressure maintaining transfer device

B. Institutional composition

The cutting device requires a smooth, undisturbed rapid cutting of the sampling tube at an in-situ pressure of 30 MPa. The sampling tube high pressure cutting device mainly comprises a clamping mechanism and a cutting mechanism. The subsea sampling tube is transported to the operating vessel for pressure-holding cutting to obtain small samples for laboratory research.

The clamping mechanism is intended to assist other mechanisms on the pressure maintaining transfer device to further secure the sampling tube for smoother cutting. It is shown in the left half of Figure 2.

The cutting mechanism aims to achieve a smooth and controllable cutting effect without the sampling tube rotating. The mechanism adopts a knife-rotating method to meet the requirements. It is shown in the right half of Figure 2.

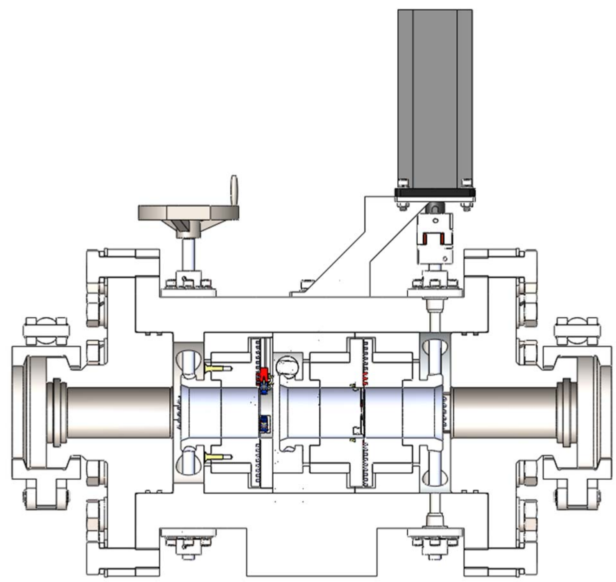

Fig. 2 The whole half section of the high pressure cutting device.

The cutting device not only requires good cutting results, but also needs to be simple and feasible in both assembly and manufacturing. The previous sampling tube high pressure cutting device was optimized, and many previous unreasonable designs including the clamping mechanism, the cutting mechanism and the cylinder were solved.

C. Working principle

The sampling tube high pressure cutting device mainly comprises a clamping jaw, a spiral groove disk and a fixed disk, wherein the fixed disk is kept motionless, and the spiral groove disk is operated by a manual spoke, and the sample tube can be

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finally clamped by controlling the number of rotation turns after feeding 5mm per rotation turn.

The basic principle of the cutting mechanism is similar to that of the clamping mechanism, except that a fixed disk is replaced by a freely rotatable disk. This makes the cutter have a certain cutting speed while feeding. The rotating speed is determined by the cutting disc (i.e. the free rotating disc), and the advancing and retreating speed and advancing and retreating speed of the cutter are determined by the differential speed between the spiral groove disc and the spiral groove disc.

Fig. 3 Test piece for cutting mechanism

III. ELECTRONIC CONTROL AND CURVE DESIGN

The movement of the cutter is controlled by two servo motors, model number DELTA ECMA-J10807SS, equipped with DELTA ASD-A2-0743-M. The control mode of servo motor selects the speed control mode, and the laboratory engineer is responsible for designing the upper computer for interface control. Combined with the characteristics of the Archimedes spiral, it can precisely control the advance and retraction speed of the cutter and the rotational speed of the circumferential cutting.

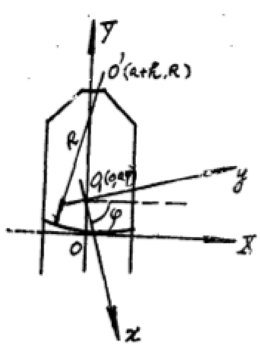

Fig. 4 Round involute meshing

As a flat thread type three-jaw chuck disk curve, the following conditions must be met: when the wire is rotated at any angle, the displacement of the three jaws in the groove of the disk body should be equal (the three-claw movement is equal). Thus, after the disk is rotated for one revolution, the claw arc is moved to the adjacent one of the coils, and the displacement of the jaws in the slot is just the pitch of the coil. Therefore, if the arc is an equidistantly distributed jaw, not only can the disc be embedded in any position, but also the teeth arc between the discs and the coils can be meshed at the same time, so the coil The pitch of the flat two threads must remain constant.

In order to solve such problems, the wire curve is intended to adopt an involute curve. Considering that the claw arc is easy to process under the existing equipment conditions, the arc curve is selected as a semi-circular arc of the equidistant distribution, and the distance between the core and the claw width is a+h, and the arc is half. R, the distance between the two adjacent arcs is $2\pi a$.

On the wire, take the core of the wire as the coordinate origin, and establish the coordinate system XOY (Fig. 4), so that the initial position of the core O' in the claw arc is (a+h, R), and the core of the claw width is in OY. On the shaft. The wire curve is the moving coordinate system XO_1Y after the coordinate system XOY passes the positive translation distance $a\varphi$ to the OY axis and then rotates the angle φ clockwise around the new coordinate origin O_1. Let h = 0, then the curve equation of the wire curve:

$$x=a\cos\varphi+a\varphi\sin\varphi$$

$$y=a\sin\varphi-a\varphi\cos\varphi$$

IV. OPTIMIZATION OF DESIGN

A. Cutting knife redesign

The length of the cutting knife is related to the depth of precession, that is, to the diameter of the sampling tube. In addition, it is necessary to ensure the engagement of the three teeth, so the length of the cutting knife is related to the diameter of the sampling tube and the number of teeth engaged.The length of the cutting knife has been reduced from 79mm to 43 mm.The cutter head of the cutting knife has also been redesigned. The cutter head needs to be able to be retracted repeatedly so as not to affect the movement of the sampling tube inside the cutting device and at the same time to reach the center of the circle of the sampling tube.

Because the wall of the sampling tube is very thin, it becomes more reasonable and reliable to design the cutter head as a blade-like sheet. As shown in the Figure 6, it can be seen that the cutting section is flat.

Fig.5 Version comparison of cutting Knife

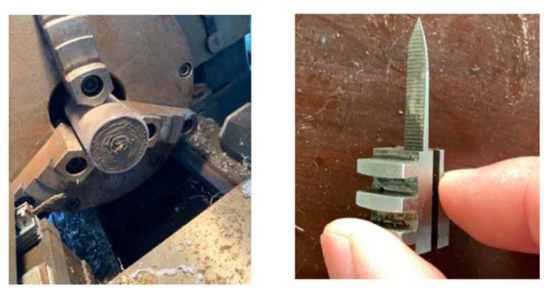

Fig.6 Experimental cutting

B. Optimizationofoverallsizeandweight

The redesign of the cutter and the re-selection of the outer cylinder material reduced the overall size to 71.9% and the mass to 22.3%.Thanks to the material selection of the outer cylinder changed from the original 17-4PH to 7075 aluminum alloy, the overall quality has been greatly reduced. A test device was made to test the principle and feasibility in practice. As shown in the figure 6, the device successfully cut the thick sampling tube with smooth and flat cutting surface. By controlling the two servo motors, the circumferential rotation speed and the radial feed speed can be controlled.

Fig.7 Cutting experimental device and cutting section

V. LONG-TERM USE DESIGN

Since the sampling tube is mainly composed of seabed silt, it will enter the groove of the spiral groove disc through the gap during cutting, affecting the precession of the cutting knife. Therefore, a cutter plug is designed to prevent silt from entering. Due to this design, it is not necessary to disassemble the sludge for cleaning after each cutting is completed. Therefore, the long-term use design is realized. Because the new type of cutting knife produces little chips, which is important for cutting in enclosed space. Because if the amount of chips is too large, it needs to be removed frequently to remove the chips, which affects the multiple uses of the cutting device.

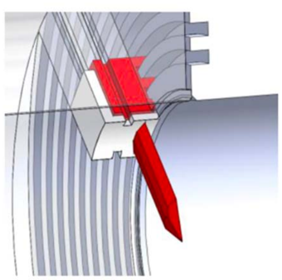

Fig.8 Anti-sludge blocking design

VI. CUTTING EFFECT EVALUATION

For the description of the quality of the cutting surface, some indicators are often involved, such as surface roughness, cutting disturbance zone scale, slit width, slit perpendicularity, slit surface finish, brittle fracture rate, slag loading rate, heat affected zone width. Different cutting parameter settings correspond to different cutting surface features. The description of the cutting surface and how to link the cutting parameters with the cutting surface features are the focus of research. A set of cutting specification manuals is proposed to give corresponding ideal cutting parameter settings for different samples.

Seabed sampling objects are generally seabed sediments and drilling cores. The rheological properties of the samples affect the quality of the cut surface of the sample. Good cutting surfaces are more advantageous for subsequent laboratory studies. It is important to study how to ensure the quality of the cut surface for different samples. There is a strong relationship between the mechanical properties of seabed sediments and their concentrations, so it is necessary to explore the effect of concentration on the rheological properties of bentonite suspensions.

The clay suspension system is more complex, and the clay mineral particles are charged sheet-like nanoscale particles. The surface of the particle has a permanent negative charge. The charge on the edge changes significantly with pH: positive in acidic environments and negative in alkaline conditions. Therefore, in the clay suspension, the clay particles are subjected to a complex electric double layer electrostatic force, and the interaction force mainly has an electrostatic attraction between the face and the edge and an electrostatic repulsion between the faces. In order to achieve the balance between electrostatic force and van der Waals force (collectively referred to as DLVO force), a structure such as face-to-face and face-edge can be formed between the particles to make the clay suspension into a gel state[3、4].

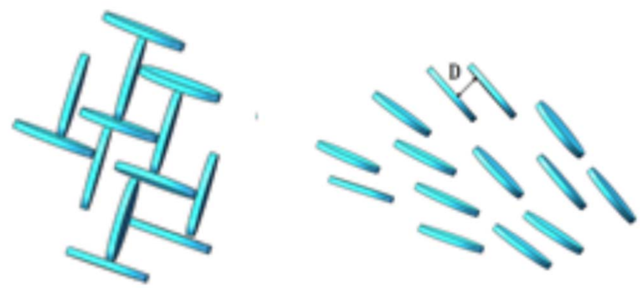

Fig.9 Microstructure diagram of bentonite clay particles

Seabed sediments of different depths have different compositions. Typically, the main components of the seabed core are clay and terrigenous debris. In terms of the depth and location of the gas hydrate, its storage environment is shale deposits and the main component is a clay suspension.

In the past, the cutting of the core does not consider the mechanical properties of the sample, which may cause some unsatisfactory cutting effects, such as disturbance, brittle fracture, and slag. How to reduce such undesired conditions requires exploration of the mechanical properties of the sample.

The combination of engineering practical problems and theoretical research complements each other. The core cutting device can be used for cutting most cores. The introduction of rheology provides a reference for the scientific setting of cutting parameters.

VII. REAL EFFECT

This high pressure pressure cutting device has not been made into real material, which is used for the actual gas hydrate sampling pipe cutting. We believe that with this design, better cutting effects will be presented. The new device will be produced by the end of 2019 and put into use. The current state is that the processing drawings have been produced, and the actual cutting effect cannot be provided in this paper at the current stage of processing.

Fig.10 The previous version of the cutting device

The follow-up work will continue, and the use effect of relevant devices will be further reflected in the subsequent work. The cutting device will be processed in the following period of time, and there is reason to believe that better cutting effect will be shown.

VIII. CONCLUSION

Compared with the existing technology, the main benefits of this work are:

1. New material selection and cutting knife design have greatly reduced the weight and size of the cutting device.

2. The newly adopted cutter plug makes it difficult for cuttings and sludge to enter the spiral groove disc, which makes multiple cuts possible.

3. The use of servo motor allows the cutting process to be controlled by the upper computer, which is accurate and convenient.

4. The new cutting knife can be used for cutting thin pipe walls, expanding the application range of the device.

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