A high pressure holding and cutting device for sampling tube of natural gas hydrate

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A high pressure maintaining cutting device for natural gas hydrate sampling tubes is designed, which is mainly used for pressure maintaining cutting of deep sea sampling tubes. The main mechanism is designed in detail, some advantages of this design are expounded, and the operation sequence of the cutting mechanism is introduced. Since the design and processing have not been completely completed, ANSYS simulation of some related parts has been carried out. The advantages of current design over previous generation products are summarized, and the existing problems are also explained.

Keywords—cutting; simulation; design

I. INTRODUCTION

The natural gas hydrate sampler is a powerful tool for studying the characteristics of hydrate in different regions. The gas hydrate sample pipe is transported to the operation ship for pressure maintaining cutting to obtain small samples for laboratory research. The cutting device requires minimal possible cutting disturbance while being able to maintain the same pressure and temperature as the sampling point. A new high pressure cutting device for gas hydrate sampling tube is designed, which includes clamping mechanism, cutting mechanism, high pressure inner cylinder, high pressure cylinder, end cover, temperature control system, pressure maintenance system and motor control board.

II. DESIGH

A. Main body design

The cutting device requires a smooth, undisturbed rapid cutting of the sample tube at an in-situ pressure of 25 MPa, which puts forward the following requirements for the cutting device:

1. The cutting device must be resistant to high internal pressure;
2. Simple structure, avoid redundancy;
3. Each part of that cut device connected with the transfer device require higher sealing performance;
4. The sample cutting device does not cause secondary pollution to the sample;
5. Minimize the disturbance of the sample during the cutting process;
6. The cutting process is controllable and the cutting depth is accurately controlled;
7. Shorten the cutting time as soon as possible.

The following is the design chart of high pressure preservation cutting device for gas hydrate sampling tube.

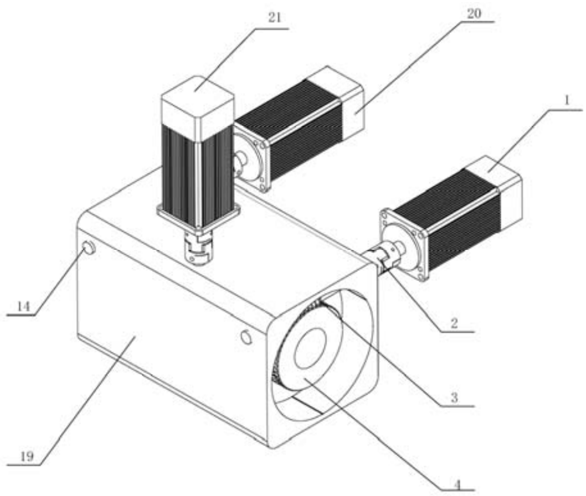

Fig. 1. The overall appearance of the high pressure cutting device

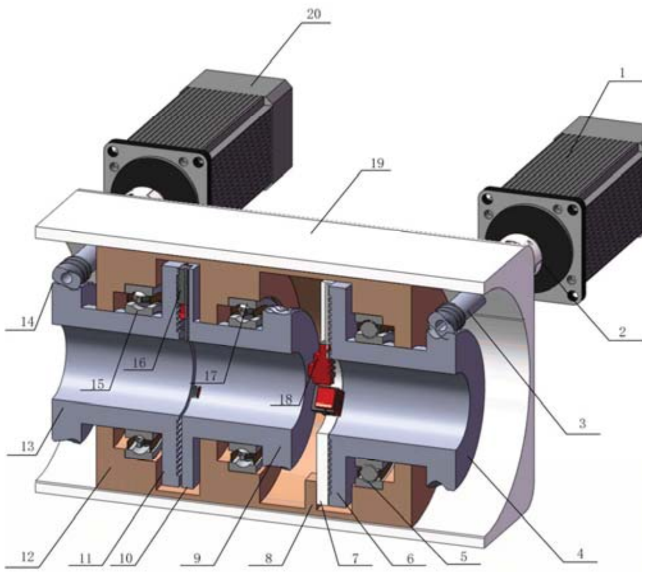

Fig. 2. The whole half section of the high pressure cutting device.

1. Clamping motor, 2. Coupling, 3. Clamping worm, 4. Clamping worm wheel, 5. Clamping mechanism bearing, 6. Clamping spiral groove plate, 7. Fixed disk, 8. High pressure cylinder, 9. Cutting worm wheel, 10. Cutting disc, 11. Cutting spiral groove plate, 12. High pressure inner cylinder, 13. Feed worm wheel, 14. Feed and back worm,15 、 17. Cutting mechanism bearing, 16. Cutting head, 18. Claw, 19. High

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pressure outer cylinder, 20. Feed motor, 21. Circumferential cutting motor.

The working process of the high pressure cutting device for deep sea sediment pressure sampling and transferring is as follows:

1) When the sample tube reaches the specified position, start the clamping motor, fast radial movement, until is about to clamp through the control panel switch to slow clamping.

2) Wait until the clamp clamping, turn off the clamping motor, complete clamping.

3) Start the feed motor so that the cutter head is fed quickly. After reaching the surface of the sample tube, the motor switches to low speed.

4) Slow feed, fast circumferential cutting at the same time, wait for cutting is completed, stop feeding.

5) Adjust that rotating speed of the feed motor, and returning the cutter head.

6) Rotate the clamping motor in the opposite direction so that the clamp releases the sample tube

7) Cutting is completed, pushed to the designated position again, repeated cutting operation.

B. Design of main movement mechanism

A new high-pressure cutting device for natural gas hydrate sampling tube is designed, which mainly includes clamping mechanism and cutting mechanism.

- The clamping mechanism comprises a claw, a clamping spiral groove plate, a fixed disk, a clamping bearing and a clamping motor. The clamping spiral groove plate and the clamping worm wheel are integrally connected, and the clamping bearing supports the high pressure inner cylinder, and the bearing is a deep groove ball bearing and oil lubrication. The guide groove is mounted on the fixing plate so that the jaws are directly loaded into the fixing plate. Three plate-like bodies are formed inside the high-pressure inner cylinder, and holes are formed therein for fixed connection with the fixing plate by bolts. Archimedes spiral fit between the jaws and the spiral grooved disk. The relative rotation of the jaws is determined by the Archimedes spiral.

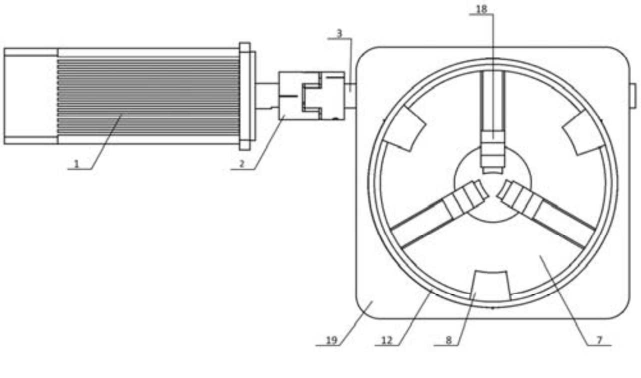


Fig. 3. Schematic diagram of clamping mechanism

- The cutting mechanism comprises a cutting disc, a cutting spiral groove plate, a cutter head, a cutting bearing, a circumferential rotating motor, and a front and rear knife motor; the guiding groove is located on the cutting disc, the spiral groove on the cutter head cooperates with the spiral groove plate, and the bearing supports the high pressure inner cylinder. The spiral groove plate and the cutting disk cut the forward and reverse worm wheels by a circumferentially rotating worm wheel, and the cutting spiral groove is made of an Archimedes screw; the worm gear mechanism is included in the cutting mechanism. In the clamping mechanism, the worm is connected to the high pressure outer cylinder by a contact dynamic seal, and the worm gear mechanism is driven by an external motor. The high-pressure outer cylinder and the end cover are bolted, and the internal structure of the high-pressure cylinder is consistent with the spiral groove plate. In the design, the high pressure cylinder is sufficient to withstand a design pressure of 25 MPa; the motor control panel controls the rotational speeds of the forward and reverse motors and the circumferential rotating motor to determine the peripheral speed and radial feed rate of the cutting mechanism, and an electric motor can also be used. The control panel controls the clamping speed of the clamping mechanism.

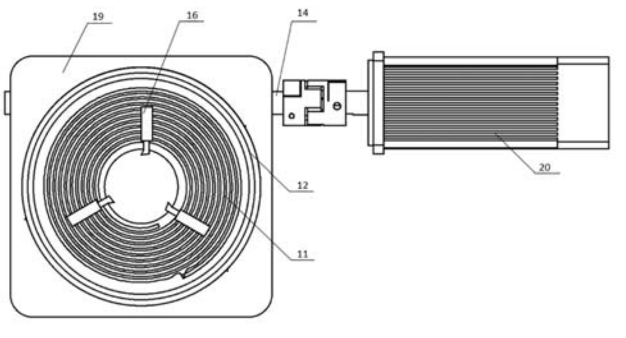


Fig. 4. Schematic diagram of left half of cutting mechanism

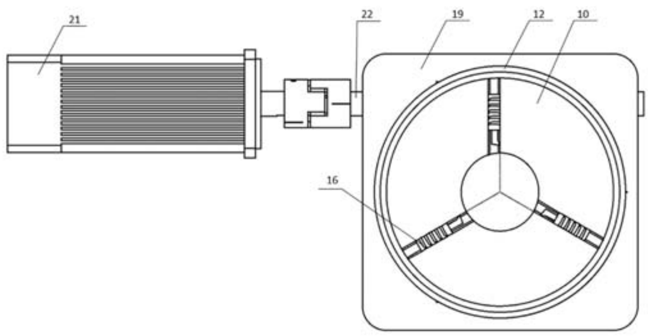


Fig. 5. Schematic diagram of right half of cutting mechanism

III. ANSYS SIMULATION

Since the design took a long time, it is currently in the testing and processing stage and has not yet been formally worked. In order to make up for the shortage of physical objects, the design team carried out ANSYS simulation analysis. It mainly includes the simulation of cutter head and turbine. the simulation results show that the material selection and design are reasonable.

A. Modeling

Solidworks is used to establish a three-dimensional model and is imported into ANSYS for simulation analysis. The material properties of the cutter bar include elastic modulus e = 210 GPA, poisson's ratio v = 0.3, yield strength y = 1350 MPa, and density p = 7850 kg / m3. The material properties of the cutter head are as follows: elastic modulus e = 520 GPA, poisson's ratio v = 0.22, and density p = 12,000 kg / m3.

B. Finite element mesh generation

In ANSYS, meshing can be said to be a crucial step. because the quality of meshing directly affects the accuracy and speed of solution, we often need to modify the meshing. meshing is a very practical modification method. The grid division of the blade is refined in the cutter head part. The tooth part of the worm is also refined.

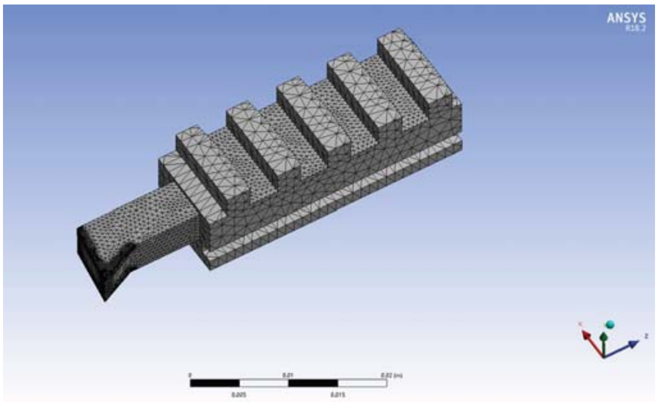


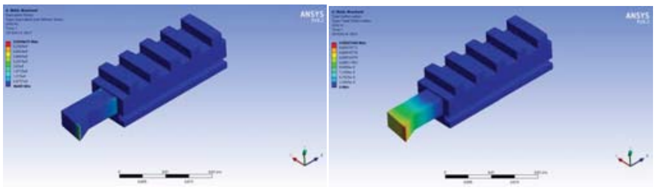
Fig. 6. Ansys mesh division of cutting head

The main purpose of finite element analysis is to check the structural response to certain load conditions. Therefore, it is also a key step to specify suitable load conditions in the analysis. Proper loading will be able to better simulate the actual situation and correctly reflect the mechanical characteristics of the actual structure.

C. Results

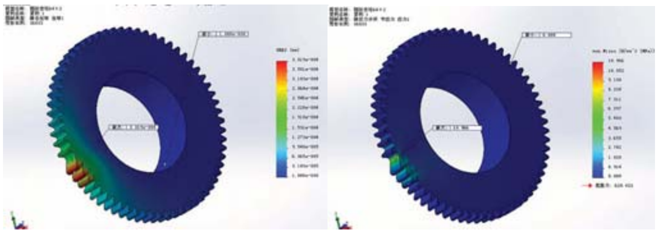
It can be seen from the above stress and displacement distribution map that the maximum stress and strain experienced by the cutter head appear at the position of the cutting edge. The maximum deformation of the cutter head is 0.2mm and the maximum stress is 2.8×10^9Pa..

At the same time, some relevant analysis is also carried out on the turbine. Based on SolidWorks solid model of large gear, the material is set as alloy steel. The load is applied to the tooth profile surface of the worm wheel in the form of normal force, wherein the normal force direction is perpendicular to the tooth profile surface and the normal force is uniform load of 100 n.. An axial constraint and a radial constraint are applied to the outer surface of the protruding shaft of the worm wheel. The solid model of the worm wheel is meshed by finite element method and the displacement diagram of the worm wheel is obtained by simulation calculation as shown in figure 66, and the worm wheel should try to be as shown in figure 67. The deformation result of the worm wheel in the figure is enlarged 36033 times in proportion. Analysis of the data in fig. 4.3 and fig. 4.4 shows that the maximum deformation of the worm wheel is 0.00038 mm and the maximum stress is 10.97 MPa .



(a) (b)

Fig. 7. Deformation diagram(a) and stress diagram of cutter head (b)



(a) (b)

Fig. 8. The overall appearance of the high pressure cutting device

IV. Results And Discussion

This previous version of the cutting device was designed to cut gas hydrate sampling tubes acquired in shenhu sea, south China sea. Good results have been obtained in practical operation.

Fig. 9. The previous version of the cutting device

Fig. 10. Test piece for cutting mechanism

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.

V. Conclusion

Compared with the existing technology, the beneficial effect of the invention is:

A. The cutting device has pressure balance at the same time of resisting high pressure, and avoids installation difficulty caused by different internal and external pressure.

B. The structure is simple, the structure is basically symmetrical, and the installation is convenient and simple.

C. The cutting is uniform, the disturbance of the cutting process to the sample is reduced, the sample cutting device does not generate secondary pollution to the sample, and the cutting is carried out under the conditions of pressure maintaining and temperature control.

D. The cutting process is controllable, and the cutting depth can be accurately controlled according to the lead of the Archimedes spiral line.

E. By adjusting the speed of the motor, the cutting and cutting speed and cutting speed can be controlled, both high cutting speed and low feed speed can be met at the same time, and the cutting speed can be fast when needed.

F. By adjusting the speed and rotation direction of the clamping motor, we can clamp and release the sample tube, and also control the clamping and loosening speed.

The difficulty lies in the design and control of the cutter head and jaw. The cutter head must be fed at the same time and the sampling tube must be cut at the same time. Requirements for the concentricity of the spiral groove disc and the limit disc are put forward. 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.

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.

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