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Design and Research of Deep-Sea Hydrothermal Sampler with Multi-Cavity

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Abstract. In this paper, on the basis of the existing hydrothermal sampling equipment has devised a new hydrothermal sampler. Using Ansys Workbench software to analyze the valve core and valve seat sealing, the valve core half cone Angle is obtained on the influence law of sealing performance. Cavity of hot fluid into the sampling moment of impact piston is analyzed, the analysis shows that the strength of the piston to meet requirements and the impact piston vibration does not affect the o-rings seal performance.

Introduction

Deep-sea hydrothermal sampling is an important marine technology, The deep-sea hydrothermal fluid sampling widely used hydrothermal fidelity sampler, In order to achieve a sampling of deep-sea hydrothermal, The relevant units from all over the world have developed a series of hydrothermal sampler. Developed by the WHIO "Jeff" airtight packing pressure sampler can be used to obtain high-temperature hydrothermal and hydrothermal diffusion flow[1]. European marine science and technology program developed dwell sampler HPSS simultaneously carry up to eight sampling tube, and carries a seawater temperature, salinity and depth tester[2]. Japan developed a multi-bottle sampler can take six hydrothermal samples by one through a sampling[3]. The existing sampler mostly does not have airtight packing, but have complicated structure and large volume and weight, In order to fully understand the environmental characteristics and mechanism of hydrothermal vents, advanced and reliable sampling equipment is urgently needed.

Working conditions of the sampler is deep-sea, so the seal of the sampling valve is the key point of the whole equipment, need to simulate and in-depth study. This paper use FEA method to analyse the seal of sampling valve and the hot fluid percussion piston. Finally come to the conclusion that the Performance of the new type of hydrothermal sampler is safe.

The Structure Design of Hydrothermal Sampler Equipped with the Submarine

This paper designs a new type of submarine equipped with hydrothermal sampler, the sampler sampling valve can simultaneously connect six sample bottles. The main components of the sampling valve structure is shown in Figure 1.

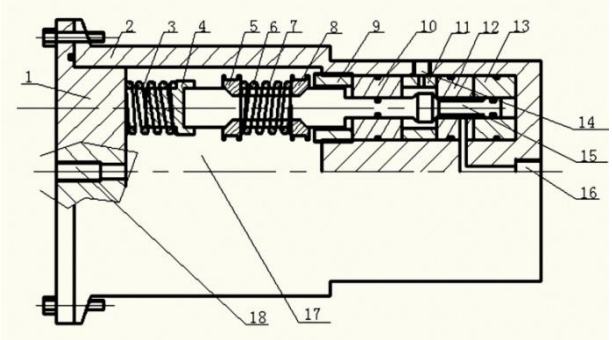


Figure 1. Diagram of sampling valve structure.

1 is the bottom end cover, 2 is the valve, 3 is reset spring, 4 is spring supporting rod, 5 is trigger ring 2, 6 is drive spring, 7 is the sleeve, 8 is trigger ring 1, 9 is support ring, 10, 11, 13 is valve sleeve, 12 is the seat, 14 is sampling bottle connector, 15 is the spool, 16 is Inlet hole, 17 is spring chamber, 18 is the interface.

Hydrothermal sampler equipped with manned submersibles reach the place of sampling, sandwiched by the manipulator, by opening the structure control of sampling valve opening and closing of the, using pressure differential to achieve the acquisition of hydrothermal, highest keep pressure of 70 MPa, comes with pressure compensator keep the pressure of the sample.

Research and Analysis of Valve Core Seal

Sealing is mainly used to prevent leakage, There are many reasons for the leakage of the seal, there are two fundamental reasons[4]:

Sealed on both sides exists pressure flow or diffusion leak.

Seal pairs allow leakage between the channels, that is, there is a gap.

When two different surface contact and cross cutting, said they are in the contact state, according to the conventional physical concept, has the following characteristics[5]:

The surfaces of different objects do not penetrate each other.

The positive pressure and tangential friction force can be transferred between different objects.

Normal tensile stress can not be transmitted.

The Valve Core and Valve Seat Contact Element Model Establishment

In this paper, the design of the valve core and valve seat seal using a conical seal. The valve core and the valve seat are in contact with each of the valve seat to form a closed sealing line. In order to analyze the valve cone angle of the angle of the valve seat is not the same time, draw the different cone angle of the valve head and valve seat contact model. Contact modeling of valve core and valve seat, First, geometric model was created by CAD software, second, 3-D model was imported into ANSYS WORKBENCH, then the grid division of model was done, completed some other steps and finally the result of tire's FEA was gotten.

The valve core material is titanium alloy TC4, the valve head made of pure titanium TA2, TA2 relative to TC4 as "soft" material, its good corrosion resistance and high temperature resistance.

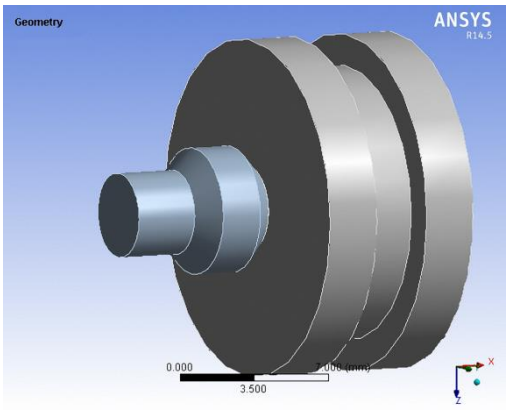


Figure 2. Valve head and valve seat sealing contact model diagram.

Analysis of Valve Core seal

The right end of the seat in the model are fixed, in the left end of the valve head is applied (50N, 100N, 150n, 200N, 250N, 300N) of different sizes and after solution obtained in applied under different conditions, the valve core and valve seat should stress nephogram and contact pressure contours, and according to the maximum contact pressure contact pressure curves are plotted.

As shown in Figure 3, Under the same applied force condition, with increasing cone half angle, contact pressure first increased and then becomes smaller, because the sampling valve sealing force provided by the drive spring, in order to achieve the requirements of the sampler and low energy

consumption, use of smaller driving force which can achieve the sealing effect, so the choice of appropriate spool half cone angle is helpful to the smaller force, so as to achieve the sealing effect.

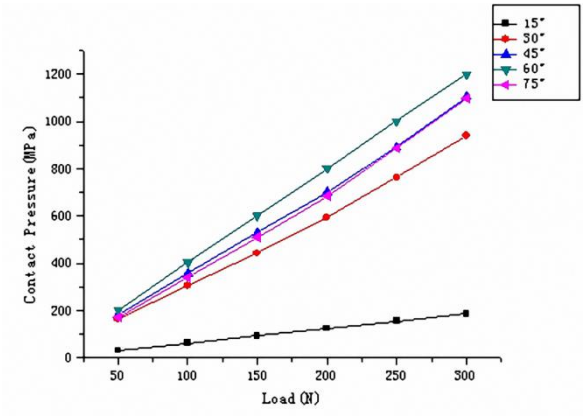
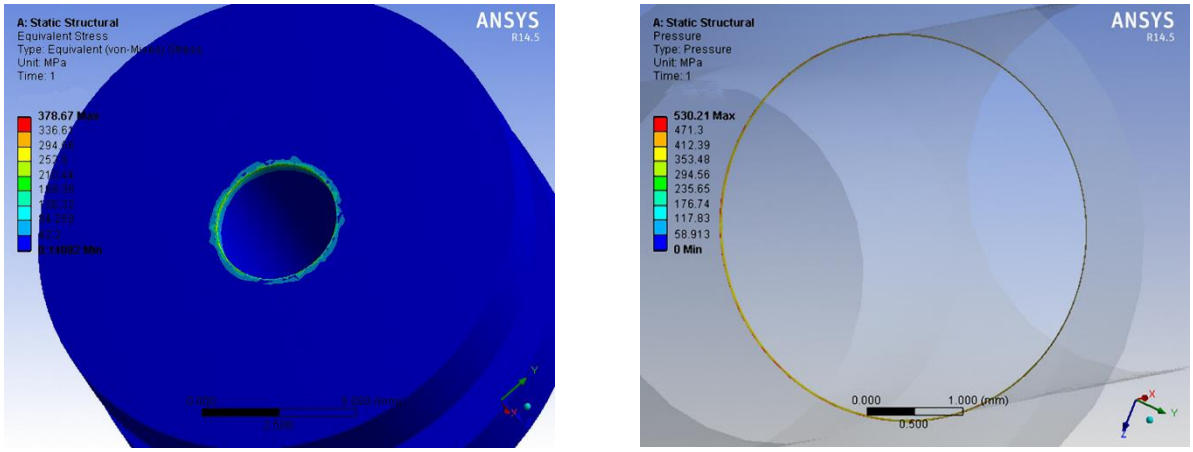


Figure 3. Contact pressure curve.

As shown in Figure 4, under the 150N load, the half cone angle is 45 degrees, the stress of the seat and the valve core and the valve seat contact pressure diagram is taken out.



(a) The seat part contact stress nephogram (b) Contact pressure curve under 150N

Figure 4. Valve seat stress and contact stress.

As shown in Figure 4, the seat in the contact area mostly in the elastic range, only in a marginal part of the stress exceeds the elastic limit, Plastic deformation occurs. Plastic deformation can increase the effective sealing width of the contact surface of the part, due to the metal surface is uneven, plastic deformation which can reduce or eliminate the gap between the contact surfaces, to improve sealing performance.

In the role of 150N force, the maximum contact pressure is 530Mpa, maximum contact pressure at the outer edge of the contact surface and contact surface forming a complete ring.

Finite Element Analysis of Hot Fluid Percussion Piston

Sampling the piston cavity is one of the important elements in the sampling bottle and force on the piston is complex, especially when start sampling and hot liquid under the condition of high pressure into sample bottles, into the speed of sampling bottle is large, it will cause certain impact and vibration of the piston. Therefore, it is necessary to analyze the impact of the piston.

Establishment of Impact Model

Sampler at 7,000 meters deep work, in the moment opens sampling valve, hydrothermal fluid into the sampling chamber at 70MPa pressure, since the sampling chamber pressure is much lower than the pressure of hydrothermal, hydrothermal therefore under 70MPa pressure in the pipeline the

formation of a high velocity jet impact on the sample chamber piston, piston sampling chamber will withstand a certain degree of fluid impact loads.

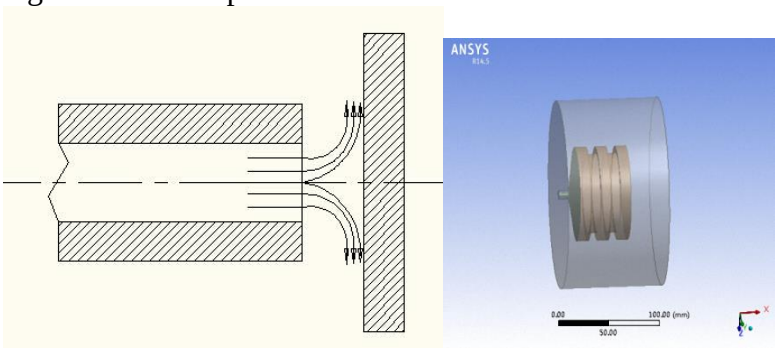


Figure 5. Hydrothermal impact piston model.

Sample chamber piston in the actual work process, the piston and cylinder wall sampling by O-ring seals, O-rings after assembly is squeezed, and the friction between the cylinder wall is very complicated, but also back to the O-ring buffer Water District the buffered water of obstruction of force complicated. Therefore, the model will be simplified to calculate piston fixed form, hydrothermal impact simplified model of the piston shown in Figure 5, when the hydrothermal fluid into the sampling chamber, hydrothermal will hit the center of the piston, In this case it can be considered the impact angle of 90 degrees.

Because of the viscous fluid in the practical work, the velocity distribution is not uniform, there is a velocity gradient in the vertical direction of the flow. In order to overcome the resistance, mechanical energy is consumed, and the energy loss can be divided into two types: Energy loss along the path and Local energy loss[6]. After calculating the energy loss, the load of the piston can be calculated.

Finite Element Analysis

The analysis model of the hot liquid impact piston is shown in Figure 6, 1 is pipe outlet, 2 is a symmetric centerline, 3 is a piston and hydrothermal contact surface, 4,5,6 are artificial boundaries. 7,8 are export pipelines. Hot liquid outflow from the outlet 1, impact piston face 3. After the impact, hot liquid flow to the surrounding. In the practical work, 4 is the sample cavity wall, but at the time of the analysis, the 4 is supposed to be the hot liquid outlet. After flowing into the sample chamber, the hot liquid will fill the gap between the piston and the bottom end, which will cause the pressure on the surface of the piston.

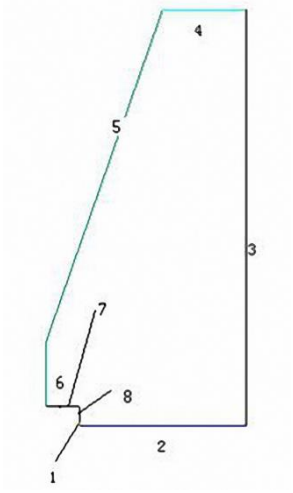


Figure 6. Computational domain model diagram.

The fluid is analyzed and solved, and the pressure diagram of the fluid on the piston surface is obtained, as shown in Figure 7.

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Forces - Direction Vector (1 0 0)
                          Forces (n)
Zone                      Pressure        Viscous         Total
wall-fluit                5802007.3       0               5802007.3
------------------------- --------------- --------------- ---------------
Net                       5802007.3       0               5802007.3
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Figure 7. Impact pressure diagram.

After the calculation is completed, exit the Fluent module, then simulate the force of the piston in the static analysis module. The piston stress nephogram is shown as Figure 8.

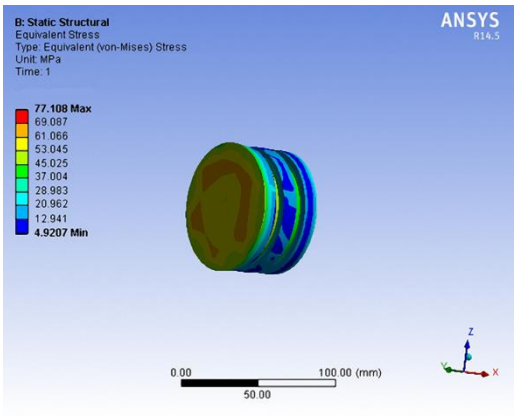

Figure 8. The piston stress nephogram.

When the hot liquid impact piston, the maximum stress of the piston and the hot liquid contact surface is about 69MPa, the maximum stress of the piston is about 77MPa, so the impact of the hot liquid has little effect on the piston. When taking into account the impact of the piston after hydrothermal, hydrothermal quickly filled the gap between the piston and the cylinder, the piston will produce hydrothermal pressure of 70MPa, when applying pressure 70MPa again on the piston, the piston stress cloud shown in Figure 9.

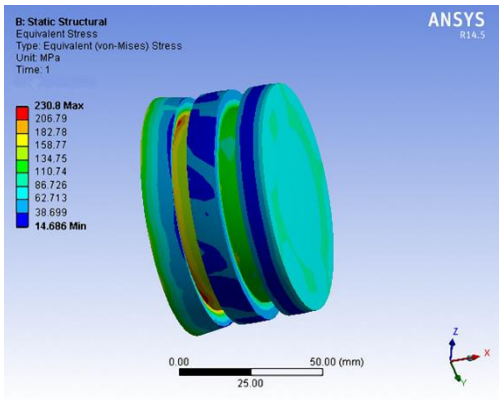

Figure 9. The piston stress nephogram.

Figure 9 shows that the maximum stress occurs at the O-ring groove, and the maximum stress 230.8MPa, less than the allowable stress, so when the piston is subjected to hydrothermal impact, the strength of the piston to meet the requirements.

Conclusion

In this paper, sealing performance of the sampling valve and heat fluid impact piston were analyzed. The half cone angle of the valve core has a certain effect on the sealing of the valve core and the valve seat, and the sealing force is different from the angle of the valve seat. When the hot liquid

impact piston, the piston strength satisfies the condition, and the piston vibration caused by the impact will not affect the normal operation of the O-ring.

Acknowledgement

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References

[1] Jeffrey, S. S., Kenneth, W. D. and Terence, R.H.A new gas-tight isobaric sampler for hydrothermal fluid[J]. Deep-sea Res. I, 2001,49:189-196.

[2] Malahoff, A., Gregory, T., Bossuyt, A., et al. A seamless system for the collection and cultivation of extremophiles from deep-ocean hydrothermal vents[J]. IEEE Journal of Oceanic Engineering, 2002,27:862-869.

[3] Ishibashi, J., Sano, Y., Wakita, H., Gamo, T., Tsutsumi, M. and Sakai, H. Helium and carbon geochemistry of hydrothermal fluids from the Mid-Okinawa Trough Back Arc Basin, southwest of Japan[J]. Chemical Geology,1995,123:1-15.

[4] Song Pengyun, Theoretical analysis of soft packing seal[J]. Lubrication and seal,2000:64-66.

[5] Deng Chunxiao, Pan Dilin. FEM analysis and optimization design for a hydraulic poppet valve[J]. Coal mining machinery,2004,6:33-36.

[6] Kong Long. Engineering Fluid Mechanics[M]. Beijing: China Electric Power Press,2008:95-97.