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NON-CONTACT MAGNETIC MECHANICAL SEAL

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Abstract
In view of the non-contact mechanical seal's problems that the seal clearance and fluid film are unstable at low speed state, and the seal clearance cannot initiative adjust, analyze the structures of traditional mechanical seal, use the TRIZ theory, choose the "stability of object's structure", "adaptability and versatility" as the improve elements, the "difficulty of monitoring and testing", "component complexity" as the deteriorate elements. Some inventive principles were obtained from the contradiction matrix, select the "feedback principle" and "replacement of mechanical systems principle", creative design non-contact magnetic mechanical seal, get open and closing forces by electromagnetic force, achieve the mechanical seal clearance active control by electronic control system, improving the non-contact mechanical seal working stability and reliability, extending service life.

Keywords: seals; mechanical seals; TRIZ theory; Magnetic force.

Introduction
Mechanical seal is a kind of sealing device that at least has a pair of end surfaces perpendicular to the rotational axis, under the action of the compensation element and the dielectric pressure to prevent leakage of fluid, also known as end face seal. It is indispensable part in fluid machinery and power machinery [1]. Mechanical seal has good sealing performance, low leakage, long service life, less power consumption and other characteristics, was widely used in rotating equipment of chemical production. Mechanical seal can be divided into contact and non-contact mechanical seal, this paper focuses on non-contact mechanical seal research. The principle of non-contact mechanical seal is the stationary ring and rotating ring relatively rotating with a certain speed, forming a small clearance between seal faces, to form a very thin liquid film when the media through the clearance, resulting in resistance to prevent leaks[2]. Non-contact mechanical seal includes hydrostatic pressure gas sealing and fluid dynamic pressure seal, the former has the characteristics of low leakage, energy saving and environmental protection, long life, but the operation stability requirements to provide an external gas source and a complex control system, increase the cost [2, 3]; the latter rely on hydrodynamic seal, seal unit shaft must reach a certain speed to form the dynamic pressure effect. From the development of sealing technology at home and abroad, fluid dynamic pressure mechanical seal can better meet the high PV value, widely used in nuclear power, aerospace and other industries [4]. But the spindle rotational speed of the reaction kettle, blender and other important equipment is too low to form enough fluid film opening force and stiffness, unable to guarantee the normal operation of the sealing. This is the major problems of long plagued researchers, although made a lot of research and improvement, but the main research and improvement of the traditional mechanical seal design focus on friction, the material, and the structure of dynamic and static ring, the lack of structural changes on the entire sealing device innovation [5]. This paper analyzes the mechanical seal problems existing in the present research stage, with TRIZ theory as the instruction, in order to realize the non-contact mechanical seal end clearance can control as the goal, conducting innovative design.

The Introduction of TRIZ theory
TRIZ is the meaning of the resolve theory of inventive problem, which is spelled by the "theory of inventive problem solving" Russian word meaning replacement into a section of English words. This theory is the former Soviet Union G.S.Altshuler and its lead a group of researchers, based on the analysis and research on 2.5 million patents around the world, proposed integrated theoretical system that consisted of various methods and algorithm to solve the technical problems and achieve innovation. TRIZ is a kind of knowledge-based, people-oriented, systematic theory to solve the problem of the invention [6, 7]. Use of TRIZ principle, can break the existing mindset, stimulate creative thinking. Furthermore, the use of TRIZ can accurately predict the evolution of the law of technical systems, the development direction of the prediction system evolution, provides design direction for the structural design [8].
The problem solving flow chart of TRIZ [9], shown in Figure 1. First, turn the problems into TRIZ standard problems by applying 39 elements; then, apply the 40 TRIZ principles to get TRIZ standard solution; finally, in view of the

practical problems, application of professional knowledge, through the analogical thinking standard solution can be converted to field solution of solving practical problems. Due to the advancement of TRIZ method, reduces the deviation problem-solving ideas and the final ideal solution, makes it easy to innovation, and is more efficient than directly using professional knowledge to solve, and the quality of the final solution is also higher [10].
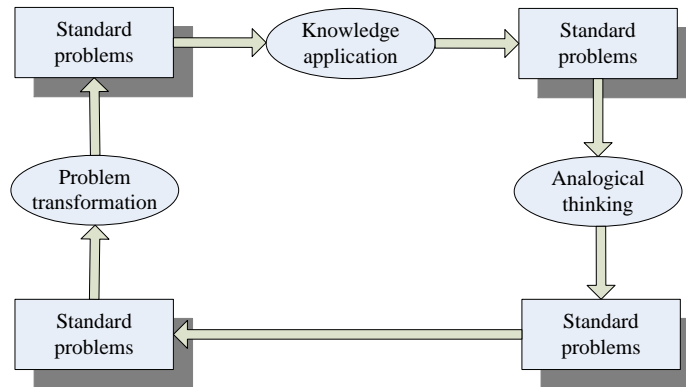

Fig.1 The process of TRIZ

TRIZ principles of conflict resolution

Altshuller divides the conflict into "conflict management", "technical conflict" and "physical conflict", TRIZ mainly solves the technology conflict and physical conflict. Physical conflict is to point to: in order to the realization of the function of some, opposite to the performance index requirements, or of the system or components opposite requirements are put forward [8]. For physical contradictions, TRIZ provides four separation principles to solve, namely spatial separation principle, time separation principle, whole and part separation principle, and separation principle based on conditions. Technology conflict refers to a system which exists multiple evaluation parameters, and technical conflicts always involves two basic parameters, when trying to improve one of the parameters, the performance of another parameter will be deteriorated.

TRIZ tools "Contradiction Matrix" can solve the technology conflict, which is established by the correspondence between the technical conflicts expressed with 39 elements and the 40 inventive principles. The process of resolve technology conflict using "Contradiction Matrix" is: determine the technology conflicts existed in the design process, describing the technical conflict by 39 elements, and then find the contradiction matrix table, get the corresponding invention principle, and apply to the specific issues, get the specific solutions.

Mechanical seal innovation design process
Problem analysis

Traditional non-contact mechanical seal structure as shown in figure 2, it exists two problems: one is the seal clearance between the seal surface cannot initiative adjust. Due to the sealing system itself and external interference, such as sealing ring face scratches, axial movement, force (hot) distortion, face wear, pressure fluctuations, improper operation lead to working condition fluctuate, due to the seal clearance cannot be initiative adjust, the sealing stability may be affected. The second is the sealing clearance size and fluid film stability is heavily depending on the operating conditions and medium conditions, especially the unit speed. The sealing surface of the high relative speed helpful to gain greater fluid film bearing capacity and stiffness, but the given unit speed is often cannot be changed or varied within a certain range, which greatly restrict the formation of high-performance fluid film, lead to mechanical seal performance and using range is limited. And now creative design of a mechanical seal, achieve initiative adjust of the mechanical seal clearance, to make the stability of the seal is no longer directly related to the unit speed and be bound by them, so that can be applied more widely.
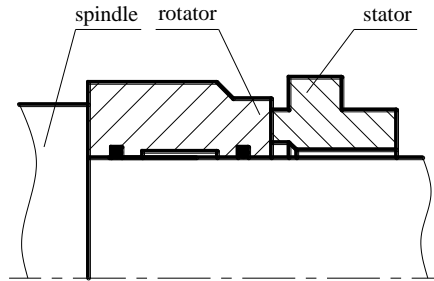
Fig. 2 traditional mechanical seal

Applied TRIZ to solve technical conflict

First, the mechanical seal problems abstracted into 39 elements in TRIZ. By analyzing the result of the problem, the parameter "stability of object's structure" and "Adaptability and versatility" were chosen as for improvement, and the parameter "difficulty of monitoring and testing" and "component complexity" as for deterioration. Obtain the inventive principle No. 35,22,39,23 and 15,29,37,28 by the TRIZ contradiction matrix. After analysis, select 23 (feedback principle), 28 (replacement of mechanical systems principle).

Table 1 Technical conflict matrix

General engineering parameters			deterioration parameter			
			…	36	…	37
				component complexity		difficulty of monitoring and testing
Improvement parameter	…					
	13	stability of object's structure				35, 22, 39, 23
	…					
	35	Adaptability and versatility		15,29 37,28		
	…					

Use of the feedback principle and replacement of mechanical systems principle, improve the traditional non-contact mechanical seal structure, add a sensor in the traditional non-contact mechanical seals, real-time detect the seal clearance changes, achieve initiative adjust of the mechanical seal clearance. Replace the mechanical system by an electromagnetic drive system, and use the electromagnetic force instead of the dynamic and static force of the traditional non-contact mechanical seal fluid film to obtain the opening force and the closing force, so that the seal clearance size and fluid film stability is no longer depend on the operating conditions. The improved non-contact mechanical seal structure is shown in figure 3. Coaxially set rotating seal ring and stationary seal ring to achieve its axial end face seal, the rotating ring is the ferromagnetic material or magnetic material structure. Rotating ring directly circumferentially fixed in the rotation axis unit by a pin and slot that design allows axial displacement gap, so it can make with the axis of rotation at work, can also be achieved axial movement between the two stationary rings, and both its axial end faces are sealing faces. The two stationary rings set respectively in the rotating ring on both sides of its axial, and the end faces opposed to rotating ring are sealing faces. There is a certain clearance between the rotating ring and the two stationary rings, respectively is h_1 and h_2. Two stationary rings respectively have a same size annular groove, groove wound coil set equal area. At the edge of the two stationary rings is respectively equipped with a sensor, in order to detect the offset signal of the rotating ring.
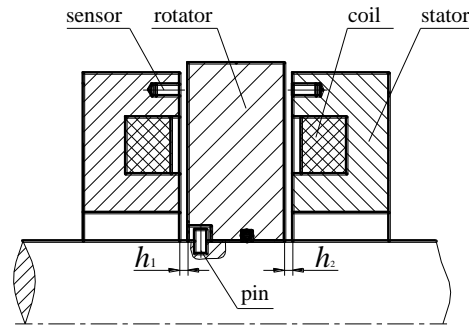
Fig. 3 The structure of non-contacting mechanical seal

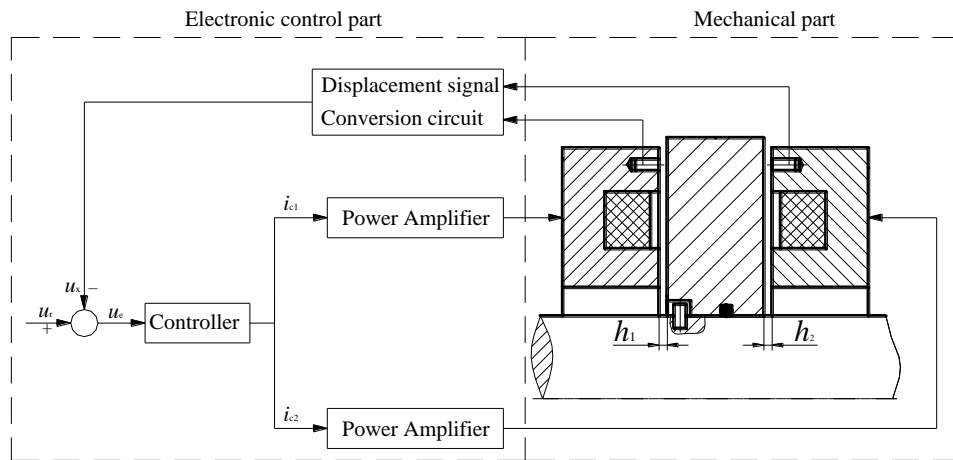**Working principle of non-contact magnetic mechanical seal**

Fig. 4 control system

When non-contact magnetic mechanical seals work, rotating ring rotates with the shaft, the two stationary ring coil is energized by the electricity control structure, the two stationary ring respectively generate the opposite direction electromagnetic attractive force in the rotating ring, the electromagnetic force integrated with the medium fluid pressure between the seal faces formed two equal and opposite attractive forces on the rotating ring, so that the rotating ring suspended in the equilibrium position between the two stationary rings, both sides clearances of the seal faces are in design condition, realize non-contact mechanical seal. During operation, when the disturbance occurs, cause the rotating ring axial displacement deviation from the equilibrium position, the seal clearances on both sides of the rotating ring occur increase/decrease changes, the sensors set in the seal clearances can feed back the position offset signal to the electricity control structure, after a comparison operation with the preset range and the enlargement processing, converted to a corresponding increase or decrease control current and loaded onto the corresponding electromagnetic coil of the two stationary rings, change the magnetic force acting on both sides of the rotating ring, through the composition of forces of the both sides magnetic forces to restore rotating ring to the equilibrium position.

This is the creative design of non-contact magnetic mechanical seal based on TRIZ theory, embodies the high efficiency of TRIZ theory in innovation design. The device improves the operation stability of the non-contact mechanical seal, so it can apply more widely.

Conclusions
In this paper, creative design of non-contact mechanical seal by using TRIZ theory, on the basis of the analysis of practical problems, determine the areas of conflicts of stability of object's structure and difficulty of monitoring and testing, adaptability and versatility and component complexity, using TRIZ standard parameters to describe the conflict, find the contradiction matrix, determine the invention principles, design a non-contact magnetic mechanical seal.

This design solves the problems exist in the traditional non-contact mechanical seal: the seal clearance between the seal surface cannot initiative adjust and the sealing clearance size and fluid film stability is heavily depending on the operating. Using magnetic levitation technology principle, through controllable electromagnetic force, the stationary ring and rotating ring will always formed seal by the form of non-contact relatively rotating. And the seal clearance can be determined by the control system according to design requirements, realized the real-time active control according to running status, makes the stability of the seal is no longer directly related to the unit speed and be bound by them, therefore applicable to a wider range of speed situations and have a good dynamic performance, enhance the reliability and stability of the non-contact mechanical seal operation, has the good implement ability.

Because of the invention described above can be achieved completely no friction, no wear effects, adapt to a wide range of speed, high accuracy, low power consumption, and thus more suitable for mechanical seals at special circumstances, such as vacuum technology, clean, corrosion and acid alkaline medium and high temperature, low temperature seals.

References

1. Gu Yongquan. Mechanical seal practical technology [M]. Beijing: China Machine Press, 2001.
2. Che Xiaogang. Principles and applications of mechanical seal [J]. Science and Technology Innovation Herald, 2008(31): 231.
3. Sun Zegang, Huang Wenquan. Simulation of flow field and temperature field for mechanical seal cavity [J]. Drainage and Irrigation Machinery, 2009(03): 200-203.
4. Zhang Jinfeng, Yuan Shouqi, Cao Wuling. Present research status and prospect on mechanical face seal [J]. Fluid Machinery, 2004(10): 26-31.
5. Wang Heshun, Dong Lin, Huang Zepei. Numerical simulation on flow field of aerostatic dry gas seal [J]. Journal of Drainage and Irrigation Machinery Engineering, 2011, 29(2): 165-169.
6. Liu Shangming, Liu Dongliang, Liu Hengyi. TRIZ and its application in creative design of mechanical product [J]. Modern Manufacturing Technology and Equipment, 2007(03): 43-44, 84.
7. Niu Zhanwen, Xu Yanshen, Lin Yue. Inventive scientific methodology-TRIZ [J]. China Mechanical Engineering, 1999(01): 92-97.
8. Xia Shenglai, He Jingwu. Applying research of TRIZ theory in airplane structural design [J]. Machinery Design & Manufacture, 2008(12): 57-59.
9. Shen Menghong. Innovative approach - TRIZ theory overview [M]. Peking University Press, 2011.
10. Pan Chengyi, Zhang Jianyi, Xiang Jingzhong, et al. Creative design of multi-functional special-shaped shelf-chair based on TRIZ theory [J]. Forestry Machinery & Woodworking Equipment, 2008(10): 29-31.