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The Advantages of Underwater Multiphase Compressors in Marine Energy Development

Haoxian Wang*

Energy Power Engineering, Bauman Moscow State Technical University, Moscow, 105005, Russian
**Corresponding author*

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Abstract: Marine energy development is of great significance for the global energy pattern. As a key equipment, the underwater multiphase compressor plays a unique role in it. This paper deeply explores the advantages of underwater multiphase compressors in marine energy development. It begins with an elaboration of the challenges faced by marine energy development and the demand for efficient equipment. Then, it analyzes its advantages in multiple dimensions, such as reducing offshore platform facilities, reducing energy consumption, adapting to complex working conditions, and improving mining efficiency. At the same time, it analyzes its application status and future development trends, provides a theoretical basis for the rational selection of equipment in marine energy development, and the efficient and sustainable development of the marine energy industry.

1. Introduction

With the continuous growth of global energy demand and the gradual reduction of onshore energy resources, marine energy development has become the focus of attention of various countries. The ocean contains rich energy resources such as oil and natural gas. However, marine energy development faces many challenges, such as the harsh marine environment, complex mining conditions, and high development costs. In the process of marine energy mining, the transportation of oil and gas is a key link. The traditional mining method requires the separation of oil-gas-water mixtures first, and then the separate transportation, which not only increases the complexity and cost of equipment but also reduces the energy transportation efficiency. The emergence of underwater multiphase compressors has brought new solutions to marine energy development. It can directly pressurize and transport the unseparated oil-gas-water multiphase mixtures, simplifies the mining process, and has many advantages that traditional equipment cannot match. In-depth study of the advantages of underwater multiphase compressors in marine energy development is of great significance for promoting the development of the marine energy industry and improving energy utilization efficiency[1].

2. Technical Principles and Characteristics of Underwater Multiphase Compressors

2.1 Working Principle

The underwater multiphase compressor pressurizes the oil-gas-water multiphase mixture entering the compressor by using mechanical power through special impeller and volute designs.[2] During operation, the multiphase flow first enters the inlet section. Through a special flow-guiding device, the fluids of each phase are initially evenly distributed and then enter the impeller. The impeller rotates at high speed, applying centrifugal force to the mixture, enabling it to obtain kinetic energy and increase in pressure. In the volute, the velocity of the high-speed flowing mixture gradually decreases, and the kinetic energy is converted into pressure energy, ultimately achieving the pressurized output of the multiphase fluid. This unique working principle enables the compressor to adapt to the complex physical characteristics of multiphase flow, such as the density differences and flow-characteristic differences of different phases, and ensures a stable pressurization effect. The specific working principle is shown in Figure 1.

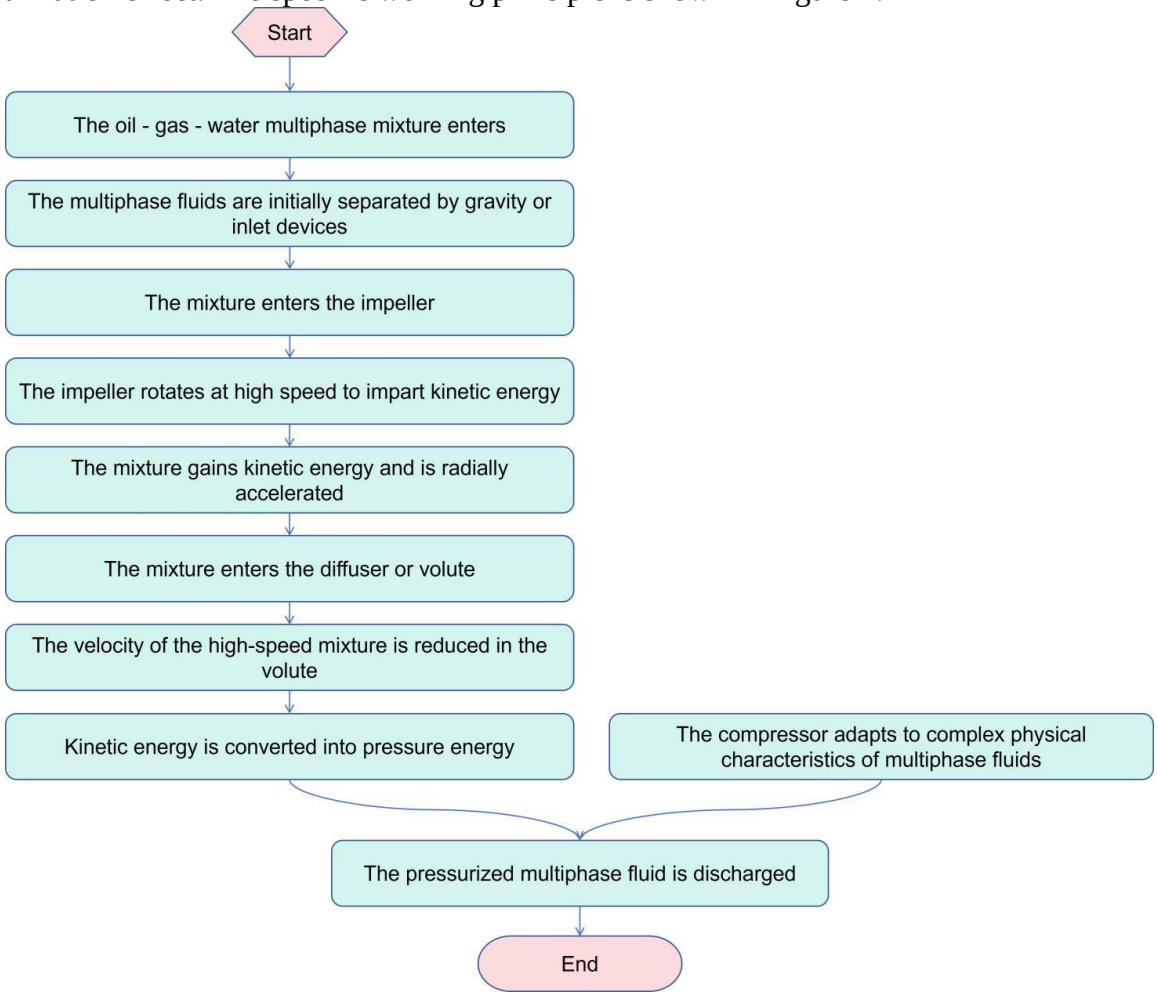

Figure 1: Working Principle Diagram of Underwater Multiphase Compressor

2.2 Structural Characteristics

It has a compact and sturdy structure and is made of high-strength and corrosion-resistant materials to adapt to the harsh high-pressure, high-salt, and humid marine environment. The key internal components of the compressor, such as the impeller and seals, have been processed through

special design and manufacturing processes. The impeller usually adopts a twisted-blade design to optimize the flow path of the multiphase flow, reduce flow losses and pressure pulsations. The seals are made of oil-resistant, water-resistant, and well-sealed materials to prevent the leakage of multiphase fluids. In addition, the compressor is equipped with an advanced intelligent monitoring system that real-time monitors the operating parameters of the equipment, such as pressure, temperature, and vibration. The data is transmitted to the control center through sensors to facilitate the timely detection of potential faults and maintenance, ensuring the long-term stable operation of the equipment[3].

2.3 Material Characteristics

To resist the corrosion and scouring of seawater, the shell of the underwater multiphase compressor is mostly made of materials such as nickel-based alloys and duplex stainless steels. These materials have excellent corrosion resistance and can effectively resist the erosion of chloride ions in seawater, extending the service life of the equipment. The internal components in contact with the multiphase fluid, such as the impeller and partitions, in addition to having corrosion resistance, also need to have good wear resistance. Alloy materials with surface hardening treatment, such as tungsten carbide-coated materials, are usually selected to enhance their surface hardness and reduce the wear caused by the scouring of solid particles in the multiphase flow, ensuring the reliable operation of the equipment under complex working conditions.

2.4 Control System

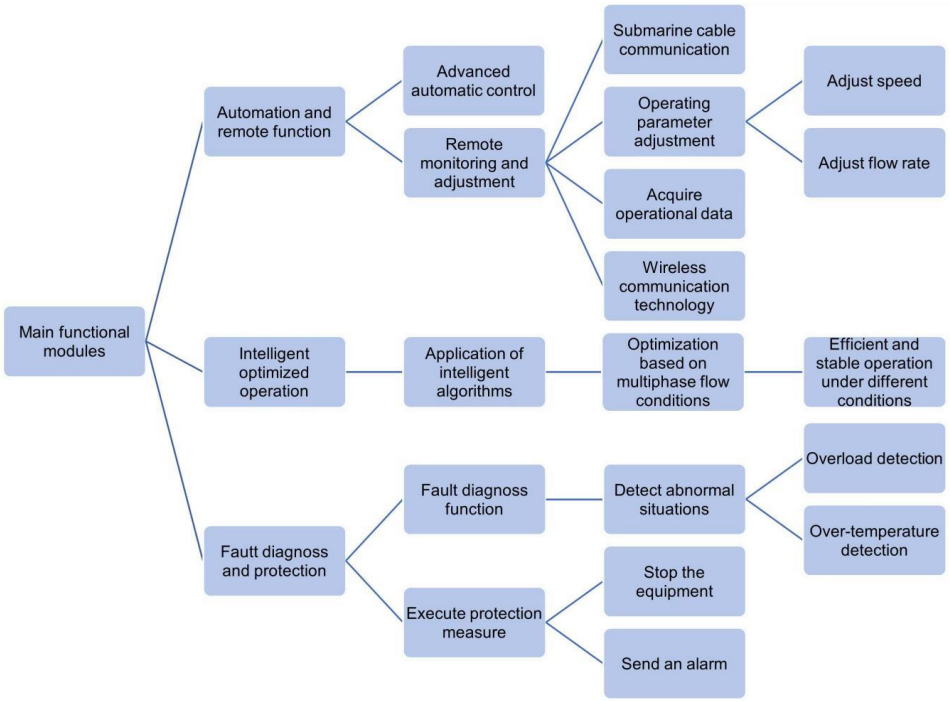

Figure 2: Main Functional Modules of the Underwater Multiphase Compressor Control System

The underwater multiphase compressor is equipped with an advanced automated control system with remote monitoring and adjustment functions(see Figure 2). Through underwater cables or wireless communication technologies, operators can real-time obtain the equipment operation data at the offshore platform or land-based control center and remotely adjust the operating parameters of the compressor, such as speed and flow rate, according to the changes in mining conditions. The

control system adopts intelligent algorithms and can automatically optimize the operation mode according to the real-time state of the multiphase flow to ensure efficient and stable operation under different working conditions. At the same time, the system also has fault diagnosis and protection functions. Once abnormal situations such as overload and over-temperature are detected, corresponding protection measures such as shutdown and alarm are immediately taken to avoid equipment damage.

3. Remarkable Advantages of Underwater Multiphase Compressors in Marine Energy Development

3.1 Reducing Offshore Platform Facilities

Traditional marine oil and gas mining requires the installation of large-scale oil-gas separation equipment, single-phase transfer pumps, and related supporting facilities on the offshore platform to achieve the separation and separate transportation of oil, gas, and water. However, the underwater multiphase compressor can directly pressurize and transport the multiphase mixture, omitting the complex separation process, greatly reducing the number of equipment and the occupied area on the offshore platform. This not only reduces the construction cost of the platform but also reduces the weight of the platform and the requirements for the structural strength of the platform, making the platform more flexible in design and construction, and allowing the selection of platform types with lower costs. At the same time, the reduced number of equipment also reduces the equipment maintenance workload and maintenance costs and improves the reliability of the offshore platform operation.

3.2 Reducing Energy Consumption

In the traditional mining process, a large amount of energy is consumed in the oil-gas separation and single-phase transportation processes. The underwater multiphase compressor directly pressurizes the multiphase mixture, avoiding the energy consumption required for oil-gas separation, and due to its optimized hydrodynamic design, the energy loss during transportation is small. By reducing unnecessary energy conversion links, the multiphase compressor can achieve efficient oil and gas transportation with lower energy consumption. In addition, its intelligent control system can adjust the operating parameters in real-time according to the actual mining conditions, further optimizing energy consumption. In the long-term marine energy development, it can save a large amount of energy costs for enterprises, improve energy utilization efficiency, and conform to the concept of sustainable development.

3.3 Adapting to Complex Working Conditions

The marine environment is complex and changeable, and factors such as sea conditions and reservoir characteristics always affect the mining operations. The underwater multiphase compressor can adapt to multiphase mixed flows with different proportions of oil, gas, and water. Whether it is a high-gas-content or high-water-content working condition, it can operate stably. Its special impeller and volute designs can effectively prevent phenomena such as gas locking and liquid hammer, ensuring normal operation under complex multiphase flow conditions. At the same time, since the equipment is installed underwater, it is less affected by factors such as sea waves and severe weather. Compared with the equipment installed on the offshore platform, it can continue to operate in a more severe marine environment, ensuring the continuity and stability of marine energy mining.

3.4 Improving Mining Efficiency

The complexity of the separation and transportation processes in the traditional mining method limits the oil and gas mining speed. The underwater multiphase compressor can directly and quickly pressurize and transport the multiphase mixture, simplifies the mining process, and greatly improves the oil and gas mining efficiency. Its high-efficiency pressurization capacity can make the oil and gas be transported from the seabed to the offshore platform or land-based terminal more quickly, shortens the mining cycle, and increases the oil and gas production per unit time. In addition, due to the reduction of equipment failures and maintenance time, the time utilization rate of the mining operation is further improved, bringing higher economic benefits to marine energy development.

3.5 Reducing the Risk of Environmental Pollution

The oil-gas separation equipment on traditional offshore platforms may cause pollution to the marine environment due to leakage and other reasons during operation. The underwater multiphase compressor reduces the number of equipment on the offshore platform, thus reducing the potential leakage risk points. At the same time, since it directly transports the multiphase mixture, it avoids the emission of volatile organic compounds(VOCs)that may occur during the oil-gas separation process, reducing the pollution to the marine atmospheric environment. In addition, if a leakage occurs, since the equipment is located underwater, the diffusion range of pollutants is relatively small, which is easier to control and handle, reducing the degree of damage to the marine ecosystem and being conducive to marine environmental protection.

3.6 Promoting Deep-Sea Energy Development

With the gradual reduction of shallow-sea energy resources, deep-sea energy development has become the future trend. However, the deep-sea environment has huge pressure, low temperature, and high mining difficulty, and traditional equipment is difficult to meet the requirements. The underwater multiphase compressor has a compact structure and is resistant to high pressure and can operate stably in the harsh deep-sea environment. Its characteristic of not relying on large-scale offshore platforms makes deep-sea energy mining more flexible and can achieve remote mining through the subsea production system. This provides the possibility for the effective development of deep-sea oil and gas resources, expands the scope of marine energy development, and is of great significance for ensuring the global energy supply.

3.7 Enhancing the Stability of Energy Supply

In marine energy development, the stability of equipment directly affects the stability of energy supply. The underwater multiphase compressor has high reliability and a long maintenance cycle. Its intelligent monitoring system and automated control system can timely detect and handle potential faults, ensuring the long-term stable operation of the equipment. Even when some equipment fails, through redundant design and backup systems, a certain production capacity can still be maintained, reducing the production-stop time caused by equipment failures, ensuring the continuous and stable transportation of marine energy to the user end, enhancing the stability of the global energy supply, and playing a positive role in the stable operation of the energy market.

3.8 Optimizing Resource Utilization

The underwater multiphase compressor can directly transport the multiphase mixture, enabling the development and utilization of low-grade oil and gas resources that may have been abandoned due to the high difficulty and cost of separation. Through efficient pressurization and transportation, these resources can be economically and effectively transported to the treatment facilities, improving the overall mining rate of marine energy resources. At the same time, its low energy consumption and small impact on the environment during the mining process also reflect the high-efficiency and sustainable utilization of resources, helping to achieve the maximum utilization of marine energy resources and providing a solid guarantee for the long-term development of the energy industry[1].

4. Application Status and Development Trends of Underwater Multiphase Compressors

4.1 Application Status

At present, underwater multiphase compressors have been applied in many marine energy development projects around the world, especially in the North Sea, the Gulf of Mexico, and other sea areas rich in oil and gas resources. In these projects, underwater multiphase compressors have successfully replaced some traditional mining equipment and achieved efficient oil and gas transportation. Some large-scale oil companies, such as Shell and BP, actively adopt underwater multiphase compressor technology to build subsea production systems, which improves the mining efficiency and reduces the cost. However, in the application process, some problems are also faced, such as the relatively high initial investment cost of the equipment and the high technical requirements for operators, which require professional training and maintenance teams[2].

4.2 Technical Innovation Directions

In order to further improve the performance of underwater multiphase compressors, technical innovation mainly focuses on material research and development, structural optimization, and intelligent control. In terms of materials, new high-strength, corrosion-resistant, and lightweight materials are constantly being explored to extend the service life of the equipment and reduce the weight of the equipment. In terms of structural design, through hydrodynamic simulation and experimental research, the impeller and volute structures are optimized to improve the efficiency and stability of the compressor. In the field of intelligent control, advanced technologies such as artificial intelligence and big data analysis are introduced to achieve adaptive control and predictive maintenance of the equipment, further improving the reliability and operation efficiency of the equipment.

4.3 Market Prospect Analysis

With the expansion of marine energy development to deep-sea and far-sea areas and the increasing demand for efficient and environmentally friendly energy mining, the market prospect of underwater multiphase compressors is broad. It is expected that in the next few years, the global market size of underwater multiphase compressors will continue to grow. Especially in emerging marine energy development areas, such as the deep-sea pre-salt oil fields in Brazil and the coastal areas of West Africa, the demand for underwater multiphase compressors will increase significantly. At the same time, with the continuous maturity of technology and the gradual reduction of costs, underwater multiphase compressors will be applied in more marine energy development projects,

promoting the rapid development of the marine energy industry[3].

4.4 Challenges and Countermeasures

Although underwater multiphase compressors have many advantages, they still face some challenges in the development process. In addition to the high initial investment cost, the maintenance and repair of the equipment are difficult. Once a failure occurs, professional underwater maintenance teams and equipment are required, and the maintenance cost is high and the time is long. In addition, the marine environment and reservoir characteristics of different sea areas vary greatly, which puts forward higher requirements for the adaptability of the equipment. In response to these challenges, on the one hand, enterprises and scientific research institutions should increase R&D investment and reduce equipment costs through technological innovation. On the other hand, a perfect equipment maintenance system should be established, and cooperation with professional underwater maintenance companies should be strengthened to improve the equipment maintenance efficiency. Simultaneously, we must enhance research into the working conditions of various sea areas and develop tailored underwater multiphase compressor products to meet the diverse market demands.

5. Conclusion

The underwater multiphase compressor, with its unique technical principles and structural characteristics, shows significant advantages in marine energy development. From reducing offshore platform facilities and energy consumption, to adapting to complex working conditions and improving mining efficiency, to reducing the risk of environmental pollution and promoting deep-sea energy development, it has brought transformative impacts on the marine energy industry. It not only optimizes resource utilization, enhances the stability of energy supply, but also promotes the development of marine energy development in a more efficient, environmentally friendly, and sustainable direction. Although underwater multiphase compressors currently face some challenges in the application process, such as high initial investment costs, difficult maintenance, and adaptability to different working conditions, with the continuous progress of technological innovation, the progress made in material research and development, structural optimization, and intelligent control will gradually overcome these obstacles. At the same time, the market prospect is also very broad. With the deepening and expansion of marine energy development, the demand for underwater multiphase compressors will continue to grow. In the future, underwater multiphase compressors are expected to play a more important role in marine energy development. The government, enterprises, and scientific research institutions should strengthen cooperation, increase R&D investment, improve technical standards and specifications, and promote the further development and wide application of underwater multiphase compressor technology, making greater contributions to the global marine energy development cause, helping to solve the global energy demand problem, and achieving the coordinated development of the energy industry and environmental protection.

References

[1] Liu Yongfei. "Current Status and Prospect of Underwater Pressurization Process Schemes. "Marine Engineering Equipment and Technology 7. 05(2020):317-322.
[2] Liu Yongfei. "Selection and Design of Underwater Compressors. "Marine Engineering Equipment and Technology 7. 05(2020):311-316.
[3] Liu Yongfei, Li Qingping, and Qin Rui. "The Latest Progress of Underwater Multiphase Pressurization Technology. "Marine Engineering Equipment and Technology 4. 04(2017):205-210.