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Classification and Application Development of Hedge Energy Dissipators

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Abstract: At present, most of China's oilfield mining using high-pressure fracturing and other methods, in the oilfield mining and subsequent pipeline transport are accompanied by a large amount of pressure and energy, the mining and pipeline transport equipment to produce a lot of wear and tear and hazards, so it is necessary to install pressure reduction and dissipation device. In the past, most of the sudden expansion and contraction of the energy loss generated by the pressure reduction and energy dissipation device. After continuous research by scholars, it is proposed to use the energy dissipation of the fluid between the pressure reduction and energy dissipation device, which has a higher stability, and can improve the efficiency of its energy dissipation. In this paper, the classification and research on the classification of the sudden expansion and contraction energy dissipation structure, the classification, optimal design and the application development of the hedge type energy dissipation structure in the field of petroleum industry are discussed, and some outlooks and suggestions are put forward for the research and development of the hedge type energy dissipation device in the future.

Keywords: Hedge-type pressure-relief energy dissipators; Structural studies; Tesla valves; Applied research.

1. Introduction

Oil and gas is an essential energy requirement in the continuous development of every country, and with the development of China's oil and gas demand, it is necessary to carry out relevant research in the petroleum industry. Through continuous theoretical and practical research, we can improve the recovery rate of oil and natural gas in China and maximise its use. At the same time, oil and gas resources as an important strategic reserve resources for all aspects of the country's development is very important, so for the oil and gas extraction and transport process of the actual problems need to be studied and solved. In the process of oil extraction and transport, high-pressure, high-head fluids can cause considerable damage to the extraction equipment and delivery pipelines, reducing the service life of the equipment, increasing the investment in production costs, and not conducive to safe and stable production operations. Therefore, in order to solve the above mentioned problems, it is necessary to carry out pressure reduction and energy dissipation for the production and pipeline equipment that generates high pressure and high head. In the following, the structures and devices of pressure-relief and energy dissipation are classified and described, and the current status of research on their application and improvement is described. The structure and devices of cyclone-type internal energy dissipation, sudden expansion and contraction type, and hedge-type internal energy dissipation are mainly described and analysed.

2. Classification of Energy Dissipative Structures and Current Research Status

2.1. High temperature corrosion

Cyclonic internal energy dissipation mainly through the structural design of the water flow to produce rotary motion, the turbulent motion inside the vortex will cause the water flow speed gradually reduced, and the kinetic energy into pressure energy. Through the dispersion and consumption of the vortex, the energy reduction and transformation is achieved. It mainly consists of a short inlet pipe, an inner pipe, a casing, a flange, an energy dissipation device and an orifice[1]. The structure through the pipe wall fluid from the orifice into the water, the formation of a certain intensity of vortex in the pipe, and with the superposition of the main stream of the incoming water, the formation of cyclonic characteristics of the flow field, so that the energy of the water flow through the energy-dissipating device is dissipated, the pressure is effectively reduced, and the equipment along the line is protected from impact wear and tear[2]. Cyclone type internal energy dissipation structure features: it is a simple structure, a wide range of applications, better energy dissipation efficiency, operation and installation is also more flexible and convenient. Horizontal cyclone type internal energy dissipation structure as a kind of energy dissipation structure, it has certain characteristics and advantages in the application, through the water high speed cyclone and air mixing effectively reduce cavitation and cavitation, at the same time, horizontal cyclone through the cavity formed by the cavity circulation can increase the shear effect between the turbulent flow, enhance the efficiency of energy dissipation. One of the side oblique inlet cyclone type internal energy dissipation structure shown in Figure 1[3].

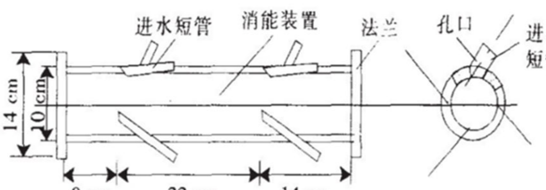

Figure1. Side-slope inlet cyclonic internal energy dissipation structure

Spiral internal energy dissipation structure is a kind of energy dissipation structure suitable for high head and high flow rate. It achieves energy loss through internal energy reduction to complete the pressure reduction and energy dissipation. Liu Daohua[4] and others proposed a combination of spiral and impulse energy dissipation structure, using the combination of the two methods to further improve the efficiency of energy dissipation. The structure through the lower end of the pipeline to increase the flow rate tester, real-time feedback data, the use of the data obtained on the pipeline water flow rate adjustment, so that it through the spiral energy dissipation and then after a hedge energy cancellation. The arrangement of the spiral hedge cancellation structure is shown in Figure 2.

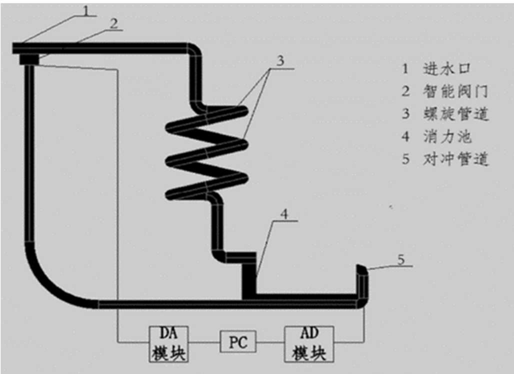

Figure 2. Arrangement of spiral counter-energy cancellation structure

2.2. Orifice plate type internal energy dissipation structure

Orifice plate type internal energy dissipation structure in the fluid flow through the hole hole will produce turbulence phenomenon, turbulence energy dissipation will make the water velocity decrease, so as to achieve energy consumption and reduction. The main principle is to form a huge head loss through the rapid contraction of the section of the pipeline through which the fluid flows, thus reducing the erosion loss of the fluid in the pipeline to the subsequent equipment, and achieving the purpose of pressure reduction and energy dissipation. Its features include wide range of application, simple structure, easy maintenance and so on. The orifice plate type internal energy dissipation structure achieves different degrees of effect by adjusting the arrangement of the orifice plate structure. The energy dissipation structure can be divided into single-stage and multi-stage energy dissipation structure, after a lot of research and practical application, we mostly use multi-stage orifice plate internal energy dissipation structure for application. Scholars at home and abroad after a large number of studies on the energy dissipation within the orifice plate and combined with the cavitation characteristics of the head loss formula calculated by the sudden expansion, and proposed that the Reynolds number and the contraction ratio is an important factor affecting the efficiency of energy dissipation of the orifice plate.

Wang Liqiang[5] constructed a variable aperture orifice plate energy dissipation device based on the traditional three-stage orifice plate energy dissipation device, and used a combination of numerical simulation and physical experimental validation to carry out systematic analysis and research on the pressure difference between adjacent sections, pressure drop ratio at the core position, pressure distribution along the course, cavitation number, flow velocity distribution, overflow capacity of the pipeline, and energy dissipation efficiency under different torsion angles, area contraction ratios and Reynolds numbers of the orifice plate. Analysis and research, and summed up the relevant laws. It is suggested to choose the combination of the orifice plate energy dissipation structure for the torsion angle of 6 °, area contraction ratio = 0.341. Zhang Changbing[6] for the first time in the accidental conditions of the establishment of experimental research to obtain the gas-liquid two-phase flow transient mathematical model, and successfully simulated the calculation of the orifice plate within the elimination of various hydraulic parameters, resulting in a three-stage orifice plate has a more efficient efficiency in the elimination of energy efficiency. The proposed direct distribution condition and energy dissipation of the dissipator in the orifice plate were calculated by a more direct physical conceptual model. Liu Qingzhao[7] et al. found that at small contraction ratios, the velocity distribution of the flow velocity field simulated by a standard model was analysed against the measured experimental data, and the error results were found to be relatively large. Therefore, it is proposed to use the two-dimensional LDA flow measurement instrument to measure the turbulent flow in the structure of the energy dissipation work in the orifice plate, and then use the standard model to numerically simulate and analyse the water flow in the orifice plate under different grid conditions, so as to derive the influence of the grid and the influence of the results of the calculations between the law. The schematic diagram of the orifice plate energy dissipator is shown in Figure 3.

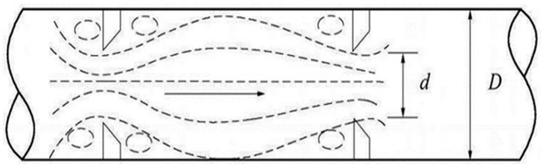

Figure 3. Schematic diagram of orifice plate energy dissipator

2.3. Cavity plug type internal energy dissipation structure

The hole-plug type of internal energy dissipation is a typical form of internal energy dissipation, which has the advantages of more stable flow, simpler structure, easier control of water flow parameters and so on. Its working principle is that when the water flows through the hole-plug type internal energy dissipation structure, the fluid forms a vortex wave on the hole-plug and releases it through the overflow channel. The existence of the hole plug causes the kinetic energy of the fluid to be converted into pressure energy, and the remaining pressure energy is released through the overflow channel to achieve energy consumption and dispersion. The hole plug type internal energy dissipation worker by making full use of the low position of the outlet of the flood relief hole is always in the submerged state, the hole plug position of the hydrostatic pressure will be very large, so it is possible to minimise the hole plug inlet area and the original diversion hole of the ratio of the area of the overflow, which obviously improves the efficiency of energy dissipation. At the same time also makes the hole plug has enough positive pressure to reduce the possibility of cavitation cavitation. The hole plug energy dissipation work as a new type of internal energy dissipation work, a large number of experts and scholars using the physical model test and the number of models of the method of its exploration and research and analysis, but also achieved a lot of results, and got a certain guiding conclusions. There are successful application examples of hole-plug energy dissipation work in foreign countries, such as the hole-plug type temporary relief holes of Glen Gap Dam in the United States and the hole-plug type energy dissipation of the relief bottom holes of Mecca Dam in Canada. They have been running since to meet the actual requirements of the project, the effect is also relatively good. In the petroleum industry, in the desander out of the oil sand mixture with high pressure or ultra-high pressure characteristics, the characteristics of the subsequent pipeline has brought a lot of erosion and damage, increasing the cost of equipment investment and maintenance. Some scholars have proposed the use of hole-plug type internal energy dissipation structure for its pressure reduction and energy dissipation, reduce the damage to the equipment and extend its service life. Regardless of what kind of hole plug structure of its energy dissipation mechanism is the same, the liquid flow through the sudden expansion and contraction of the surface of the shear, turbulence, friction and other roles will be converted into kinetic energy thermal energy consumption. The basic structure of the hole plug type internal energy dissipation sudden expansion and contraction section is shown in Figure 4.

Figure 4. Basic structure of a cave-plugged protruding and retracting segment

2.4. Toothed pier type internal energy dissipation structure

Toothed pier type internal energy dissipation structure consists of a series of fixed toothed pier, there is no complex mechanical or hydraulic components, its structure is relatively simple; it is usually composed of solid materials can withstand greater impact, has a long service life; through the friction and deformation of the toothed pier to produce a better damping effect, but in the process of dissipation of the energy there is a significant loss, the need for regular replacement; the structure in the dissipation of the energy will have a certain amount of deformation or plasticity The structure will have a certain deformation or plastic change in energy dissipation, can not be restored to its original state. Toothed pier type internal energy dissipation to ensure a larger overcurrent capacity at the same time energy dissipation rate is also a certain guarantee. Scholars at home and abroad on the number of tooth pier and area contraction ratio on its dissipation characteristics, pressure characteristics and flow characteristics of the impact of research. For example, You Zhiqiang [8]and others carried out a pressurised pipeline pier-type internal energy dissipation hydraulic properties in the area shrinkage ratio, the number of piers, the size of the main factors affecting the conditions of experimental research; Xue Dong[9] carried out the structure of the pressure and flow characteristics of the experimental study; Zhang Ting[10] and others to carry out the numerical simulation of the internal energy dissipation of the two different types of body. Domestic scholars carried out research on the efficiency of its energy dissipation by changing the structure of different tooth piers, as shown in Figure 5 for the cross-section of the tooth pier section.

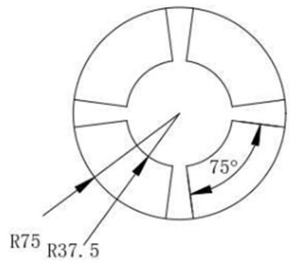

Figure 5. Cross-section of a toothed pier section

3. Classification and Optimisation of Hedge Energy Dissipators

Hedge-type energy dissipation devices achieve pressure reduction and energy dissipation by changing the direction of flow through the fluid, causing the fluids to hedge against each other to dissipate energy, and generating eddy currents at the hedge locations. It is optimised by improving key components of the core unit to increase the efficiency of the energy dissipation. One of the major advantages of hedonic energy dissipation is that it attenuates the energy through the self-consumption of the hedge between the fluids, which saves the power consumption in the production, avoids the loss and destruction of the production equipment, greatly improves the production efficiency, and ensures the safe production.

3.1. Classification of Hedge Energy Dissipators:

(1) Mechanical hedge energy dissipator

Mechanical impulse energy dissipator is a device used to absorb and disperse impact energy, its principle is mainly through the damping effect of shock-absorbing materials to absorb and disperse the impact energy, through the process of compression and release many times, the impact or vibration force through the constant movement of the spring and the damper is converted into other forms of energy, so as to reduce the impact on the object. It is usually composed of components such as springs, damping materials and dampers, and its main features are relatively simple structure, energy can be absorbed efficiently, has good durability can be reused, better regulation performance, adapt to a variety of environmental conditions.

(2) Hydraulic impulse energy dissipator

Hydraulic hedge type energy dissipator is a use of liquid flow and damping effect to absorb and disperse the impact energy device. The principle is to control the flow of liquid inside the device, pressure and damping effect, the energy into other forms of energy. Its main features are good regulation performance, efficient energy absorption, wide range of applications, high load capacity, durability and so on.

(3) Gas spring-type impulse energy canceller

Gas spring-type hedonic energy dissipator is mainly composed of gas spring and control valve. The gas spring is composed of a sealed container and an inflatable gas. When an external shock or impact force is applied to the gas spring, the gas is compressed and pressed internally, thus absorbing and consuming energy. A control valve is used to regulate the flow and pressure of the gas inside the gas spring. The behaviour of the energy dissipator can be precisely controlled by the opening and closing state of the control valve. Its main features are flexible adjustment, good stability and reliability, convenient maintenance and light volume.

(4) Electro-hydraulic hedge type energy dissipator

Electro-hydraulic hedge-type energy dissipator is composed of a piston connected to a liquid-filled chamber. When an external shock or impact force is applied to the piston, the liquid is squeezed and flows internally, thus absorbing and dissipating the energy. It has a control solenoid valve for regulating the liquid flow and pressure. By controlling its opening and closing status, the behaviour of the energy dissipator can be precisely controlled. Its main features are flexible regulation, high stability, relatively simple maintenance, and large size compared to other types of energy dissipation devices.

The optimal design of the hedge-type energy dissipator can be improved through the optimisation of nonlinear characteristics, but also through the method of numerical simulation to build the model, through the design of the initial simulation parameters, changing the structural parameters of the hedge-type energy dissipator, using ANSYS Fluent software, etc. to carry out simulation of the internal fluid after the change of the structure. The optimised structural parameters were obtained from the simulation results. The structural parameters of the hedonic dissipator include optimisation of the valve structure and optimisation of the damping material. The simulation software is used to build the structure of the studied energy dissipator, change the structural parameters of the valves, and compare and analyse the relatively better valve parameters with the simulation results to give a certain design range. We can choose the new shock absorbing material suitable for the selected energy dissipator to improve its energy dissipation efficiency and extend the use of the equipment time, improve the stability of the equipment.

3.2. Self-consuming new counter-energy cancelling structure

Based on other hedonic energy dissipation structures and devices, the newly proposed self-defeating structure, the Tesla valve, is more suitable in pipelines. The Tesla valve, called a flap conduit by its inventor, is a passive check valve with a fixed geometry. The valve allows the flow of fluid through its structure to proceed preferentially in one direction without moving parts. The valve structure is named after Nikola Tesla[11-16]. The structure is applied inside the pipe with protrusions, grooves or baffles, etc., which provide little resistance to the passage of fluid in any direction, although there is surface friction of the fluid, which creates a significant resistance to the flow of fluid in the opposite direction. It has no moving parts, so Tesla valves are more resistant to wear and fatigue. Tesla valves are used in microfluidic applications and offer the advantages of scalability, durability, and ease of manufacture for a wide range of materials. The flow principle of Tesla valves: the flow from right to left, the flow is divided into two streams. Obviously, the secondary flow will be very low because the fluid will have to make unnecessary turns to enter the area. This means that most of the flow will be attributed to the main flow, which is almost a straight line without many obstacles. As the fluid enters from the left, the flow splits into two streams again. At the bottom section the flow diverges and an unfavourable pressure gradient will make its life difficult. The second flow hits the barrel structure and loses momentum. After this loss of momentum, the flow needs to make a turn of approximately 180 degrees, which again results in a loss of flow. After all these obstacles, this stream flows with the first stream, coming from the opposite direction, leading to further energy loss. In short, when the flow goes from left to right, it goes through a large number of obstacles. The Tesla valve flow schematic is shown in Figure 6. The structure can be optimised by designing different pipe diameters, buffer lengths, pressures and multiple series-parallel combinations to improve the efficiency of pressure reduction and energy dissipation.

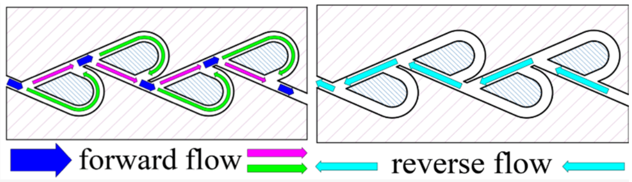

Figure 6. Tesla valve flow schematic

4. Application of Hedge Energy Dissipators in the Petroleum Industry

4.1. Application in drilling production

In the oil industry, we are in the drilling production process, in which the drilling fluid circulation system is an important part of it, improve the efficiency of the drilling fluid circulation system will greatly improve the production profit, reduce production costs. In the drilling fluid circulation system, the use of desander for the separation of some solid impurities, in which the equipment by separating the output from the well high-pressure mixed fluid, we propose to use the structure of the hedge-type pressure reduction and energy dissipation device, after the pressure reduction and dissipation of energy for the circulation of the drilling fluid. In the drilling process, the output fluid often carries large shocks and vibrations, which bring great wear and damage to the equipment in the drilling process, and the installation of the hedge-type pressure-relief and energy dissipation device can reduce and consume these energies to realise pressure-relief and energy dissipation, prolonging the service life of the equipment, reducing the risks in the production process, and improving the safety of the working process. At the same time, it can also reduce the noise generated by high-speed operation in the production process, providing a relatively comfortable working environment for the staff, which has a high practical application value.

4.2. Application in oil and gas pipelines

In the oil and gas pipeline transport, through the oil field transport and through the pumping station for the long-distance transport of oil and gas resources, in the process, it is essential to need to carry out pressure reduction and energy dissipation, in order to ensure the normal and safe operation of the pipeline, to extend the service life of the equipment, and to reduce the cost of maintenance. Different from the previous sudden expansion and contraction pressure reduction and energy dissipation structure, in recent years, domestic scholars have proposed the hedge-type pressure reduction and energy dissipation device using Tesla valve, which realises unidirectional pressure reduction and energy dissipation through the fluid inertia and the difference of flow resistance in different directions of flow. Hedge-type energy dissipation device can convert the collision energy into other forms of energy, using the energy between the collision of its own consumption to achieve high efficiency of energy dissipation. Secondly, the structure of the hedge type internal energy dissipation device has good stability, and the scope of application is relatively wide, can be used in machinery manufacturing, aviation vibration damping and so on. Limitations of the hedge type energy dissipation device, in its manufacturing process manufacturing complex precision, has a high manufacturing cost; its volume and weight is relatively large, in some areas of application has certain limitations. The equipment requires regular inspection and maintenance, the maintenance cost is relatively high.

In conclusion, in the face of complex oil development and transport conditions, according to the different conditions to consider a reasonable way of pressure reduction and energy dissipation, in order to improve the production efficiency, save production costs, protect the production equipment, and maintain long-term safe and stable operation has a certain theoretical and applied value.

5. Outlook for the Development of Hedge Energy Dissipators

With the research and application of hedonic energy dissipators in the oil and gas industry, various scholars have continuously developed the application of hedonic energy dissipators through simulation optimisation and experimental validation of energy dissipation devices, expanding the scope of application and improving production efficiency. For its future development direction, the following outlook is proposed:

(1) Combining numerical simulation and physical experimental verification to optimise the structure. The structure in the energy dissipator by using numerical simulation software such as ANSYS Fluent, such as improving the valve structure, optimising the inlet structure, etc. In order to improve the efficiency of energy dissipation. Meanwhile, it is improved by using new materials and precise process technology to ensure high production efficiency, save maintenance cost, facilitate long-term use, and apply to engineering conditions with complex conditions.

(2) Extend the application field by combining research and practical application experience. Extend the application field of hedge type energy dissipator, extend the different application occasions demand. In addition to the petroleum industry, it can be extended to machinery manufacturing, aerospace vibration damping systems and other fields.

(3) Combine AI technology with environmental protection and energy conservation awareness to continuously improve the energy dissipator. With the development of intelligence, the application of equipment in the petroleum industry also tends to be more intelligent and remote control. The use of sensors and artificial intelligence control technology to achieve remote safety operation and monitoring, reduce human input, reduce personal safety risks, increase work efficiency, and achieve accurate and efficient control. As the development of more energy-saving and environmentally friendly energy dissipators, such as the development of solar energy as the basis for energy supply and through the conversion of energy in the energy dissipator to achieve environmentally friendly and energy-saving production.

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