Application of High Pressure Water Jet Technology in Cleaning Polymerization Vessel

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Abstract. In recent years, the demand for organic synthetic materials in chemical production process is increasing, in order to meet the growing demand for organic synthetic materials in various fields. As the core equipment, the efficient and orderly operation of polymerizer is very important to ensure safe production and improve production efficiency. Under normal working conditions, the deposition or adhesion of polymer plasticizers will inevitably occur as long as there are monomer contacts in the polymerization reaction of any process, and the adhesion of polymer products to the wall of the reactor will cause sticking problems, so regular cleaning of the reactor has become a necessary link. High-pressure water jet cleaning technology is a new type of cleaning technology emerging in the world in recent years. It has the advantages of low cost, high speed, high cleaning rate, no damage to the cleaned products, no pollution, etc. In this paper, the concept of cleaning polymerizer with high pressure water jet technology is briefly introduced. Through the study of the mechanism of the autoclave and the analysis of the characteristics of the autoclave, the cleaning of polymerizer with high pressure water jet technology is discussed.

Keywords: Polymerization Kettle, Sticky Kettle, High Pressure Water Jet Cleaning Technology

Introduction
The high-pressure water jet uses water as a carrier to convert mechanical energy into pressure energy through a specific nozzle or supercharging device through a liquid pressurization principle and to form a jet with higher energy through a nozzle orifice to convert pressure energy into kinetic energy [1-4]. The high-pressure water jet process is a multi-disciplinary problem combining elastoplastic mechanics, fluid mechanics, impact dynamics and fluid-solid coupling. High-pressure water jet technology is a kind of rapid advancement, wide-ranging and expanding new application fields. The technology, in the cleaning, derusting, cutting, drilling, rock breaking, coal breaking, etc., high-pressure water jets show strong adaptability and unique advantages [5-8]. In some developed countries, water jet cleaning has accounted for about 80% of industrial cleaning. Among many cleaning methods, it is a unique show [9-10]. In high-pressure water jet technology, pure water jets are usually used. Pure water jets need to raise the water pressure to a sufficient level to meet the working conditions, so the equipment itself is
more stringent [11-13]. Polymerization tank cleaning water jets are non-submerged continuous water jets. According to different pressures, water jets can be divided into low pressure, high pressure and ultra high pressure [14]. Water jets for industrial cleaning generally belong to high pressure water jets. Therefore, the cleaning polymerizer uses high pressure water jets [15]. This paper discusses the high pressure water jet cleaning polymerizer.

1. High-Pressure Water Jet Technology Cleaning Polymerization Kettle

1.1 Status of High Pressure Water Jet Cleaning

High-pressure water jet cleaning With the continuous improvement of high-pressure water jet cleaning mechanism and accessories, foreign developed countries have used special high-pressure water jet cleaning equipment for the cleaning of polymerizers, and many domestic enterprises are also using them. According to the user's usage and on-site investigation, the cleaning effect of the high-pressure water jet cleaning technology is good. Therefore, the cleaning of the polymerization reactor by this technology can avoid the shortcomings of the traditional cleaning, and is the development direction of the future polymerization cleaning. At present, a three-dimensional mechanical cleaning device for polymerizers with environmental protection and high efficiency has been developed in China. The main components of this device are high-pressure piston pump units, mechanical cleaning adjustment devices and three-dimensional rotary nozzles. In addition, the experimental research on the mechanical cleaning of the polymer water jet was carried out, and finally the parameters such as the optimal water jet pressure, water jet flow rate and nozzle speed range under the corresponding working conditions were explored.

1.2 Effective Method for Cleaning the Polymerization Kettle

In the physical cleaning method, the high-pressure water jet cleaning method is dominant, and the high-pressure water jet cleaning technology is an emerging technology that has developed most rapidly in recent years. The basic operation mode is to use the plunger pump to increase the water pressure, transform the huge water pressure into a high-speed water jet through the nozzle, and use the powerful impact force generated by the high-pressure water jet to remove the scale, thereby achieving the purpose of cleaning the polymerization tank. The operation mode is generally manual cleaning or mechanical device cleaning. The safety, economy and high efficiency of high-pressure water jet cleaning technology have been verified. Therefore, it has a very huge market application prospect and considerable economic benefits, which is the future development trend of polymerizer cleaning technology.

1.3 Advantages of High Pressure Water Jet Cleaning Machine Cleaning Polymerizer

The scale of the polymerizer is completely removed. The surface of the polymerizer is smooth and the cleaning rate can be above 90%. This avoids the scratches on the inner wall of the polymerizer during the manual cleaning process and prolongs the cleaning cycle of the polymerization kettle. It can be cleaned once in about 1 month, which can increase the production capacity and reduce the dosage of the viscosity reducing agent. The cleaning safety is good, the operator does not need to enter the polymerization kettle, and the cleaning operation is directly carried out in the manhole of the polymerization kettle, completely avoiding The chemical substances in the polymerizer are harmful to the human body and unsafe, eradicating safety hazards; the overall operation of the washing machine is relatively stable, the noise is relatively small, the operation is simple, easy to grasp, the cleaning medium is water, no chemical is added, No corrosion to equipment. In addition, the cleaning machine has a wide range of applications. It can not only clean the polymerization tank of 30m3, but also clean the polymerization tank of other specifications. It can also clean heat exchangers, boilers and pipelines after installing different working mechanisms. Cleaning equipment.

2. Mechanism Study of Sticking Kettle and Analysis of Characteristics of Sticking Kettle
2.1 Mechanism of Formation of Sticks
In industrial production, the polymerizer is prone to sticking to the kettle. The polymer is bonded to the agitator shaft of the polymerizer and the easy-to-attach areas such as the stirring blade, the inner wall, the nozzle and the condenser, and gradually increases with time, and finally becomes large. Piece. The formation process of the viscous kettle is: during the polymerization of propylene, monomers, dispersants and initiators in the liquid phase generate primary particles in the retention layer, and then condense in the kettle to form polymer particles, and the particles migrate to At the inner wall of the kettle, the stirring shaft and the stirring blade, the inner wall, the nozzle and the condenser, the particles continue to polymerize and firmly adhere to the wall to form an adherent. The formed primary sticks are crushed and ruptured after mechanical agitation and continue to polymerize, gradually forming massive scales, causing the surface liquid flow rate to slow down, and continuing to adsorb the polymer particles in the liquid, resulting in a longer and longer stick. The longer the reaction time, the greater the growth of the stick, and the sticking problem not only affects the production speed, but also reduces the product quality, and causes the heat transfer coefficient of the polymerizer to decrease and the production cost to increase. Through the experiments and summarization of the problem of the adsorption kettle of the polymerizer, it is found that the main influencing factors of the formation of the paste kettle are: the process conditions, the surface material of the kettle, the amount of the material in the stirred tank, and the like. The formation mechanism of the binder in the polymerization vessel is mostly experimental research.

2.2 Analysis of Mechanical Properties of the Viscous Kettle
Since the high-pressure water cleaning relies on the impact of high-pressure water to destroy the sticky material, it is extremely important to analyze the physical properties of the sticky material. From the analysis of chemical composition, it can be concluded that the viscous material belongs to the elastoplastic polymer material, and its physical and mechanical properties must be considered in consideration of stress, strain, time and temperature. Since the cleaning environment is generally normal temperature, temperature factors are not considered. In order to determine the basic physical properties of the sticking material, it is necessary to make the sample of the stick into a sample strip, and perform impact performance test to analyze the cleaning form of the stick. In principle, the polymer material is more susceptible to cracking when subjected to impact. The impact strength is the extent to which the spline is subjected to impact, that is, the energy absorbed before the spline breaks. The simply supported beam impact toughness test is the ratio of the impact energy to the cross-sectional area of the spline when the impact test is broken by the impact test. Generally, it is measured by a pendulum impact test. The spline is fixed on the support of the experimental machine, and the pendulum with a certain mass is raised to a certain height \( H_1 \) to obtain a certain potential energy, and the pendulum is broken and the pendulum is released. The remaining energy is \( mgH_2 \). From equation (1), the impact absorption work at the time of spline failure can be obtained, expressed in K, unit J.

\[
K = mg(H_1 - H_2) = 0.7J
\]  
(1)

And because the sample width \( b = 15 \text{mm} \), the effective thickness of the sample \( h = 7 \text{mm} \), and then the impact toughness of the sample is \( \alpha_k \), the unit J / m²:

\[
\alpha_k = \frac{K}{bh} = 6.66 kJ / \text{m}^2
\]  
(2)

The impact toughness index reflects the plasticity of the material under stress concentration and complex stress state. Compared with the impact absorption \( K \), \( \alpha_k \) can guide the parameter selection of the high pressure water cleaning experiment of this subject. The impact energy per unit area of high pressure water is greater than the value \( \alpha_k \). The crucible can be destroyed.

2.3 Clearing Process Design and Design
According to the analysis of mechanical properties, the best way of physical cleaning is impact sticking, so high-pressure water jet cleaning is a feasible method of removing the paste. According to the situation of on-site sticking, the most prone to the sticking chamber are: gas phase liquid phase transition zone, bottom of the kettle, thermometer sleeve and shaft paddle and accessories. According to the condition of the sticking pot, it is divided into 6 grades, as shown in Table 1. Therefore, the degree of sticking of the polymerizer should be evaluated before cleaning the polymerization tank at the cleaning site. Before the cleaning operation, the evaluation of the sticking pot will not only complete the cleaning operation faster, but also reduce the loss and improve the cleaning efficiency. It is of guiding significance to formulate the on-site cleaning process through the actual sticking situation.

Table 1. Viscous kettle case

| Viscosity tank level | Gas phase | liquid phase | Bottom of the kettle | Thermometer sleeve | Shaft and pulp |
|---------------------|-----------|--------------|----------------------|-------------------|---------------|
| 1                   | White frost | White frost  | Thin skin            | A few lumps       | Lump          |
| 2                   | Thin skin  | Thin skin    | Thin skin            | A few lumps       | Lump          |
| 3                   | Thin skin  | Thin skin    | Thick skin           | A few lumps       | Larger block  |
| 4                   | Thin skin  | Thick skin   | Thick skin           | Chunks            | Larger block  |
| 5                   | Thin skin  | Thick skin   | Thick skin           | Chunks            | Chunks        |
| 6                   | Thick skin | Thick skin   | Thick skin           | Chunks            | Chunks        |

3. Application of High Pressure Water Jet Technology in Cleaning Polymerizer

3.1 Three-Dimensional Rotating Nozzle Overall Design
The three-dimensional rotary nozzle is divided into five parts: the suspension inlet connection component, the nozzle assembly, the cross shaft core transmission component, the connecting device and the speed limiter. Firstly, the driving method is designed. The common driving method usually adopts external driving forced rotation and hydraulic driving automatic rotation. When using external power driving, the radial size of the nozzle must be increased, thus limiting the range of manholes through which the nozzle can pass. The polymerizer is filled with explosive and flammable hazardous gases, and the additional power source system creates unnecessary safety hazards. Therefore, the design uses a hydraulic drive. Common hydraulic drive is driven by hydraulic impeller drive and nozzle jet recoil drive. The hydraulic impeller drive is usually difficult to adjust the nozzle speed, and its applicable working pressure range is relatively low, so the design finally uses jet recoil drive. The driving device is located at the execution end of the nozzle assembly of the nozzle, and the actuator end adopts a double nozzle structure. The two nozzles are offset in anti-parallel installation, and the nozzle assembly is driven to rotate by the torque generated by the water jet recoil force.

3.2 Working Principle of High Pressure Cleaner
The high-pressure water jet polymerization tank cleaning machine utilizes the kinetic energy of the high-pressure water jet to crush and remove the hard scale on the inner wall of the polymerization vessel and the surface of the agitator. The three-dimensional rotating nozzle positioning mechanism is installed on the manhole of the polymerization kettle, the positioning rod extends into the polymerization kettle, and the positioning mechanism can be controlled by manual, electric, hydraulic, etc. (due to the slow movement speed, generally adopting manual control), the positioning rod is the telescope expands and contracts in the polymerization vessel and moves around the inner wall of the polymerization vessel, and the positioning rod can avoid the obstacles in the polymerization tank while moving. The front end of the positioning rod is provided with a three-dimensional rotating...
nozzle, which has two rotating nozzles, and a high-pressure water jet is ejected from the nozzle. When the cleaning nozzle rotates horizontally, the rotating torque formed by the two water jets drives the two nozzles to rotate in the vertical plane. The rotating nozzle can rotate 360° in the vertical plane, and can also rotate 360° in the horizontal plane. The positioning rod drives the three-dimensional rotating nozzle to move to the working point of the inner wall of the polymerization vessel and the surface of the agitator for cleaning. Due to the combined movement of the three-dimensional rotating nozzle and the positioning rod, the high-pressure water jet can cover any part of the polymerization tank to complete the cleaning of the polymerization tank.

3.3 High Pressure Water Jet Impact

When the high-pressure water jet impacts the surface of the dirt, the water droplets and air gaps in the jet will hit the surface of the sticking body in the form of force. When the jet impacts on the sticking body, an impact force is generated to break up the sticking material.

Let the jet exit velocity be $V_1$, m/s, and the final velocity be $V_2$, m/s, then the force $F$ of the jet acting on the dirt surface is (3):

$$F = \rho Q \sqrt{V_1^2 - V_2^2 \cos^2 \phi}$$

(3)

Where: $\rho$ is the density of water, kg/m$^3$; $Q$ is the jet flow rate, L/min; $\phi$ is the jet impact angle.

Since the jet velocity and the jet structure constantly change with the target distance, the force $F$ also changes as the target distance changes. When the water jet impacts on the dirt, the jet at the outlet of the nozzle is relatively tight, and the water flow at the impact flows along the surface of the dirt. When the target distance increases, the water jet spreads, causing a large amount of liquid to splash back when impacting the dirt, resulting in an increase in the impact on the object; but after increasing the target distance to a certain extreme value, the water jet velocity is reduced, resulting in a striking force. It is constantly decreasing. Therefore, the optimal target distance can improve the cleaning effect. Through the analysis of water jet characteristics, it can be analyzed how the target distance affects the cleaning effect. In addition, other factors affecting the cleaning effect are summarized in this chapter. In addition to this, this paper summarizes other factors that affect the cleaning effect, as shown in Figure 1.

![Fig 1. Factors affecting the cleaning effect](image)

**Conclusion**

The sticking material is a viscoelastic material, and its physical properties are different from those of brittle materials and elastoplastic materials. The external force of the sticking kettle is in the form of a
response between the elastic solid and the viscous liquid, and will be different after being loaded at different temperatures. Damage behavior, using this physical property can improve the cleaning process and method, and the research on the peeling mechanism of the sticking material and the critical value of the peeling stress are of great significance for accelerating the cleaning speed and improving the cleaning effect.

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