A scale removal and scale absorption method for circulating water system

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Abstract: In recent years, industrial water consumption keeps increasing, and industrial circulating cooling water accounts for the majority of industrial water consumption. Therefore, reducing the amount of circulating cooling water consumption can effectively save industrial water. Aiming at the high cost and low efficiency of circulating water treatment, this product is designed. The intelligent electronic scale removal and scale absorption device for circulating water mainly consists of two parts: one is the scale removal device, the other is the scale absorption device. Scale removal device does not require the use of chemical agents and salts, is a physical water treatment device, using the principle of capacitance to change the crystallization process of liquid calcium, so that scale loss adhesion, can protect pipes and mechanical equipment, to maximize their service life. Scale absorption device uses low voltage and high frequency current to act on the water through the scale suction device, change the physical structure and characteristics of the water, restore the free state of the scale, and be adsorbed by the scale suction device to achieve the purpose of scale removal. This product is an innovative clean, environmentally friendly water treatment device, in line with the concept of sustainable development.

1. Introduction

1.1. Background:
According to statistics, agricultural water consumption in China in 2017 was 376.64 billion m³, accounting for 62.32% of the total domestic water consumption in the same period; Water consumption in the industrial sector was 127.70 billion m³, accounting for 21.13% of the total domestic water use in the same period; Life water is 83.81 billion m³, accounted for 13.87% of the total domestic water during this period; Water consumption in the ecological sector was 16.19 billion m³, accounting for 2.68% of the total domestic water consumption in the same period. China's industrial water consumption increased from 52.3 billion m³ in 1978 to 127.7 billion m³ in 2017, and the proportion of water consumption increased from 11% to 21.6%, becoming the sector with the fastest growth rate of water consumption. Industrial recirculating cooling water accounts for about 70%–80% of industrial water consumption. Reducing the amount of recirculating cooling water can effectively save industrial water. However, most of the circulating water comes from tap water, especially the hard water in the north. As the operating time increases, it is easy to form scale, and the circulating water will be concentrated during operation, and the ion concentration will increase, which will further promote the production of scale. Other
suspended matter such as sludge and microbial colonies will be deposited on the surface of metal parts, causing corrosion and fouling of circulating equipment pipes, resulting in reduced heat exchange efficiency. In order to ensure the heat exchange efficiency and service life of the heat exchange unit, the circulating cooling water should be used to process.

At present, the treatment of industrial circulating water is mainly by chemical dosing. Traditionally, people use ion exchange method to remove calcium and magnesium ions in water to achieve scale prevention effect. Chemical cleaning method is used as scale prevention method or chemical treatment method is used, that is, chlorine is added to sterilize algae, and pharmaceutical is added to scale prevention treatment. However, these methods have the disadvantages of large equipment loss, such as poor management, which will corrode the pipeline and cause environmental pollution. Therefore, people have been exploring simple and effective physical methods (such as magnetic, electrical or mechanical methods for descaling, which will not cause secondary pollution to the water body) instead of high cost and polluting chemical methods.

1.2. Significance
Scale formation, which is common in industrial equipment, greatly reduces heat transfer efficiency and causes energy waste of 10%-40% in industrial production. This device can effectively remove scale and reduce energy waste. The device has the functions of descaling and absorbing scale, inhibiting scale and rust, sterilizing and killing algae, softening water quality, etc. Full physical type, completely replaces the traditional chemical treatment, and the effect is stable.

It can greatly reduce the amount of sewage and increase the concentration ratio of circulating water system. It also can effectively improve the comprehensive effect of 5-25% of the system and save 5-25% of energy consumption. The number of cooling towers can be reduced by more than 1/4 due to unscaling of pipelines. Service life of more than 10 years, no need to change water. The water quality of the system is clean, avoiding the failure and shutdown caused by scaling.

On the other hand, the installation method of the scale absorption device is simple, Place the scale absorption device in the circulating pool or the water tray of the cooling tower. There is no need to cut pipes or use chemical cleaning when installing electronic scale absorption device, so as to avoid corrosion damage of equipment caused by chemical cleaning.

The device is not only easy to install, but also has a good descaling effect, which is very practical.

2. Design scheme

2.1. Structural thinking
This design is composed of scale absorption device and scale removal device, making full use of the advantages of physical descaling, through this treatment method to reduce the corresponding disadvantages, make scale removal efficiency greatly improved. Scale removal device is installed at pipe inlet and scale absorption device at pipe outlet. First, the scale is peeled from the surface of the heat exchanger through the removal device, and the scale is converted into powder, so that it is free from the pipeline water[4].

Then, the scale absorption device sucks the powder form scale out of the circulating water.
2.2. **Principle of scale remover technology**

The electron scale remover technology uses the principle of capacitance to deflect charged particles in an electric field and change the crystal shape of the crystal.

The conductor is directly separated by a layer of insulation, which constitutes the capacitance. In the capacitance, the anions will move towards the anode, while the cations will move towards the cathode, turning the calcium carbonate crystals into smooth, rod-shaped crystals (Calcium carbonate changed from calcite structure to arachnite structure. The scale in this structure is very soft and does not adhere to the wall of the pipe). The electronic scale remover technique uses special capacitive electrical pulses to change the crystallization process of liquid calcium, thus causing scale to lose its adhesion[6].

Three main effects of electronic descaling:

- Prevent scaling on piping and equipment surfaces;
- Clean piping system;
- Rust remover and corrosion resistance.

Scale deposits occur when liquid calcium in water forms crystals that bond to each other (Untreated crystals). Physical water treatment creates another structure of calcium crystals that do not adhere to surfaces and form sediments. These harmless single crystals (CaCO3) play a key role in water treatment systems, and electronic descalers have a variety of ways to produce single crystals and clean pipes.

a) Separation of calcium bicarbonate by controlled electrophoresis.

The alternating frequency of the pulse field produces a potential gradient that represents the potential in the water and affects and dissolves the liquid $[Ca(HCO_3)_2]$.

The decomposition of $[Ca(HCO_3)_2]$:

$$ \text{Ca(HCO}_3\text{)}_2 \xrightarrow{\text{Electronic descalers}} \text{CaCO}_3 + \text{CO}_2 + \text{H}_2\text{O} \quad (1) $$

$$ \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3 \quad (2) $$

This is the production of calcium single crystals, and it can only grow in two opposite directions, so they will not gather together to form scale deposits. The two ends of a single calcium crystal are (+) and (-) rod-like structures. In this structure, they no longer bond to each other and form deposits. The longer it stays in the piping system, the larger its volume, and the longer the size of the single crystal, the better
the scale treatment.

The separation of water components by electrophoresis also changes the balance of calcium and carbonic acid, as in equation (2), leaving a small surplus of carbonic acid, which helps to remove the existing scale.

b) Decomposition of calcium bicarbonate through harmonic processing[3].

The electronic descalers controls the generation of harmonics. Harmonics are used to set the basic characteristics of water molecule clusters, which are basically the smallest entities of water. The extremely short wavelength of harmonics is parallel to the water molecule clusters to achieve the effect of resonance between the two sides, just as the resonance of high-pitched music with glass can make the wine cup burst, it can be compared with the wavelength of harmonics with the water molecule clusters, which has the same effect, namely, the water molecule clusters break.

When the water molecule clusters broke, the components of \(Ca(HCO_3)_2\) also decomposed, as in equation (1). The stronger the effect is, the more the single crystal grows, which eventually leads to the expected scale inhibition.

\[ \rightarrow \text{Single crystal and carbonic acid} \]

Controlled electrophoresis (a.) and harmonic processing (b.) both lead to the decomposition of liquid calcium into other substances. In this way, the electron descaling system produces a lot of single crystals and a lot of carbonic acid[5].

- A single crystal prevents surface scaling.
- Carbonic acid is a key component in the decomposition of existing scale deposits.

2.3. Principle of electronic scale suction device:

Under the action of the current, water in the scale absorber cathode electrolysis reaction produces \(OH^-\). \(OH^-\) ions generated by the cathode reaction break the balance between alkalinity and hardness in the solution near the cathode. The \(HCO_3^-\) ions in the solution are transformed into \(CO_3^{2-}\) ions. At the same time, \(Ca^{2+}, Mg^{2+}\) and other scale-forming ions in the water are in electrostatic attraction Migrate to the cathode area under the action of ions, and respectively generate \(CaCO_3\) and \(Mg(OH)_2\) precipitates. At the same time, under the action of electric field, the crystallization form of \(CaCO_3\) on the cathode plate surface changes from hard calcite structure to loose arachnite structure, which is more prone to flake off[1-2].

The electrochemical reaction between the cathode and water occurs as follows:

\[
2H_2O + 2e^- \rightarrow 2OH^- + H_2 \\
Mg^{2+} + 2OH^- \rightarrow Mg(OH)_2 \\
OH^- + HCO_3^- \rightarrow H_2O + CO_3^{2-} \\
Ca^{2+} + CO_3^{2-} \rightarrow CaCO_3
\]

Bactericidal algal killing principle(anode):

\[
4OH^- - 4e^- \rightarrow 2H_2O + 2[O] \\
H_2O \rightarrow OH^- + H^+ + e^- \\
O_2 + H^+ \rightarrow HO_2^- \\
O_2 + 2e^- \rightarrow O_2^2^- \\
2Cl^- \rightarrow Cl_2 + 2e^- \\
Cl_2 + H_2O \rightarrow HClO + HCl \\
HClO \rightarrow H^+ + ClO^-
\]

Strong oxidizing substances oxidize unsaturated fatty acids in the cell membrane, enhance the permeability of lysosomal membrane, release lysosomal enzymes, and lead to cell lysis and death, with the ability of continuous sterilization. Microorganisms generally have a negative charge in the water, and will migrate to the anode and accumulate, resulting in direct death of biological discharge.

3. Conclusion

The descaling method used in this device can greatly improve the descaling efficiency, reduce energy consumption and increase the safety of the working environment.

- Technology: The electronic scale removal technology does not require the use of chemical agents and salts, it is a physical water treatment device, using the principle of capacitance to change the crystallization process of liquid calcium, so that scale loses its adhesion, can protect pipes and mechanical equipment, to maximize their service life.
- Energy conservation and environmental protection: The heat exchange rate of the system
increases to avoid energy loss caused by temperature rise. The $\text{Ca}^{2+}$ and $\text{Mg}^{2+}$ ions in the water are adsorbed and eliminated, the concentration factor is reduced, and the sewage discharge is greatly reduced.

- System: This innovative design product can be installed without cutting pipes. Suitable for all kinds of pipe materials: iron, copper, stainless steel, galvanized iron, plastic, PVC, PE-X, composite pipe, etc. Therefore, this innovative design has great development potential[5].

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