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PIPELINE OFFLINE TROUGH CLEANING TECHNOLOGY

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In the process of contemporary industrial pipeline installation, most pipelines must be cleaned before being put into use due to production and operation process requirements. This paper takes the offline trough cleaning of pipelines as the research object, and explores the evolution process of the metal microstructure under this cleaning method and the best cleaning conditions under the influence of the three factors of concentration, temperature and time.

Keywords: steel pipeline; corrosion; offline trough cleaning; pickling experiment; microscopic research

INTRODUCTION

With the development of human society, the rapidly growing demand for industrial transportation has promoted pipeline transportation to become the fifth largest transportation system after railway, highway, water transportation and air transportation. [1] Taking the petrochemical industry as an example, as of the end of 2018, the world's natural gas pipelines have exceeded 1 400 000 km. [2] However, pipeline corrosion, scaling, impurities and other factors seriously threaten the life of the pipeline and weaken the advantages of pipeline transportation. Therefore, most of the medium require that the must pipeline be pickled before the metal pipeline is applied. [3,4] The current pipeline pickling methods mainly include offline trough cleaning and online cycle cleaning. [5] The current pipeline pickling methods mainly include offline trough cleaning and online circulating cleaning. The offline trough cleaning studied in this paper is mainly to remove the installed pipelines. After being decomposed, put it into the pickling trough to soak, and then install the pipeline after complete cleaning. It is widely used because it has the advantages of easy inspection of the cleaning effect and easy control of the cleaning quality. [6,7] However, the existing technology has disadvantages. For example, the cleaning speed is not easy to control, and the cleaning speed is slow. Therefore, actively research the pipeline offline trough cleaning technology, explore the best cleaning conditions under this technology and the changes in the microstructure of the metal pipeline during the pickling process, which has a great reality for achieving high-efficiency and high-quality cleaning of the pipeline and reducing cleaning costs. [8]

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EXPERIMENTAL PROCESSES

The most representative metal pipes are stainless steel pipes and carbon steel pipes. Taking carbon steel pipes as an example, they are widely used because of their excellent processing technology, outstanding shock and compression performance and low cost. Common types are Q195 and Q235. [9] However, because carbon steel mainly contains two elements, Fe and C, it has low corrosion resistance so that it is more prone to pipeline corrosion. [10]

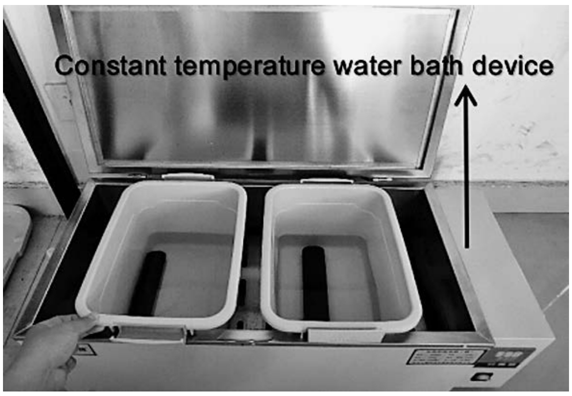

Figure 1 Experimental equipment

Select low-carbon steel pipelines to study offline trough cleaning, as shown in Figure 1 for the simplified experimental equipment. The three factors of pickling temperature, pickling time, and pickling solution concentration are respectively controlled and the pickling orthogonal experiment is carried out. The specific experimental process is as follows: three kinds of pickling liquids with mass fractions of 10 %, 15 %, 20 % are separately configured, and the pickling liquid is maintained at three temperature conditions of 40°C , 45°C and 50°C by using a constant temperature water bath heating box. Lift the numbered carbon steel pipes with the same corrosion degree into the pickling solution.

The concentration of the pickling solution is checked every hour, and the effect of the pipe pickling is observed with an electron microscope. When the pipe achieves the requirements of the pickling, stop the experiment and record. At the same time, cut pipe samples before, during and after pickling with the wire cutting machine and put them into electron microscope to observe the changes of metal microstructure morphology.

RESULTS AND DISCUSSION

The effect of the pickling experiment is shown in Figure 2. It is not difficult to find that the pipe after pickling has no traces of rust, the inner and outer walls are smooth, burr-free and metallic grayish white.

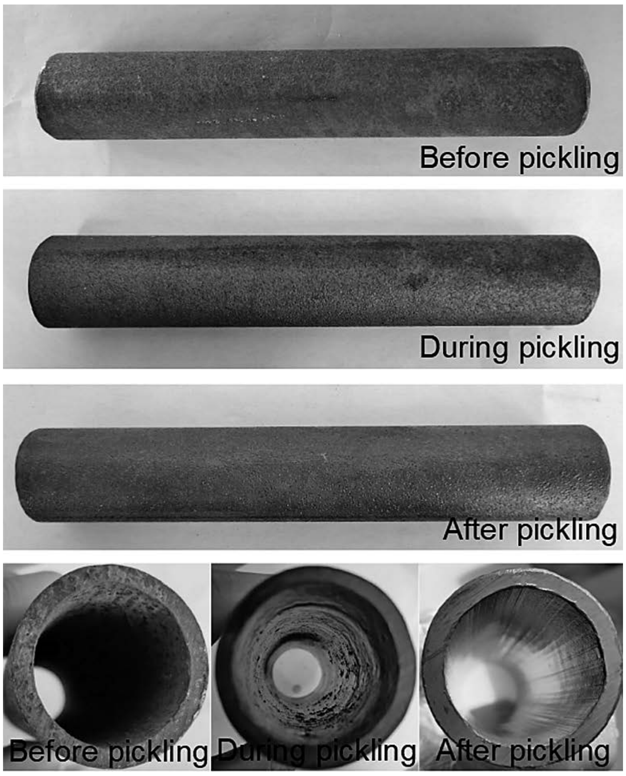

Figure 2 Pickling effect

From the microscopic morphology point of view, corrosion products of crystal form, crystal cluster form and film form are distributed on the pipe wall before pickling, they are scattered and distributed with the uneven degree of corrosion, as shown in Figures 3 - 5.

When the sample is placed into the pickling solution with a concentration of 10 % and a constant temperature of 45°C for pickling for two hours, the severely rusted areas, such as burrs and dents on the inner wall of the pipe, begin to form a relatively flat corrosion layer on the surface of the pipe wall, and some areas begin to show the original form of carbon steel. Although the metal burr on the wall is reducing, but it still exists. The corrosion at the bulge or depression is uneven, which affects the pickling effect to a certain extent, as shown in Figures 6,7.

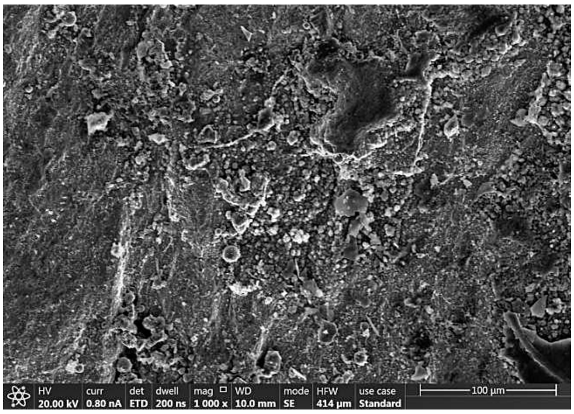

Figure 3 Cluster morphology of corrosion products

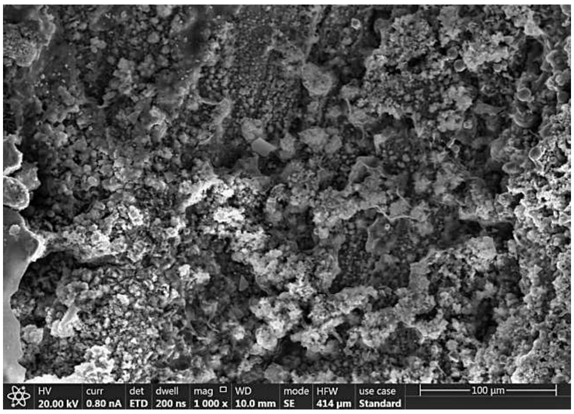

Figure 4 Crystal morphology of corrosion products

Figure 5 Corrosion product film-like morphology

Figure 6 Metal burrs and impurities

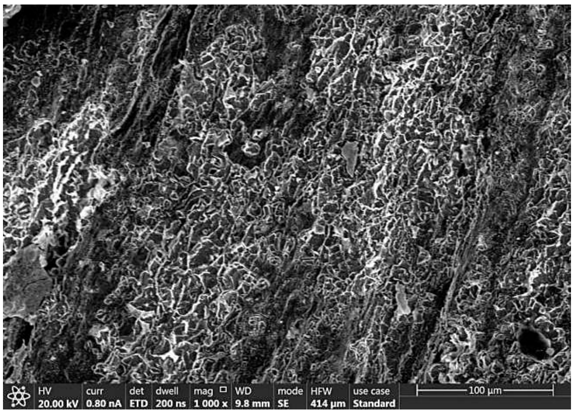

Figure 7 Metal burrs and impurities

Continue the experiment under these conditions. After 4 hours, although some small defects appeared in some areas, the defects may be caused by impurities on the pipeline wall or severe rust residues. However, a large area of flat and regular carbon steel structure appeared on the inner and outer walls of the pipeline, it indicates that the expected pickling effect has been achieved, as shown in Figures 8,9.

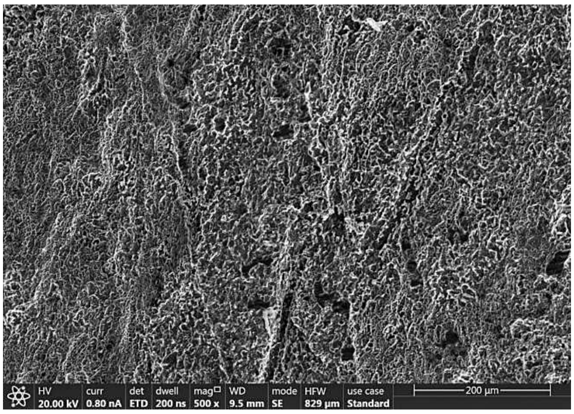

Figure 8 Tiny defects on pipe wall

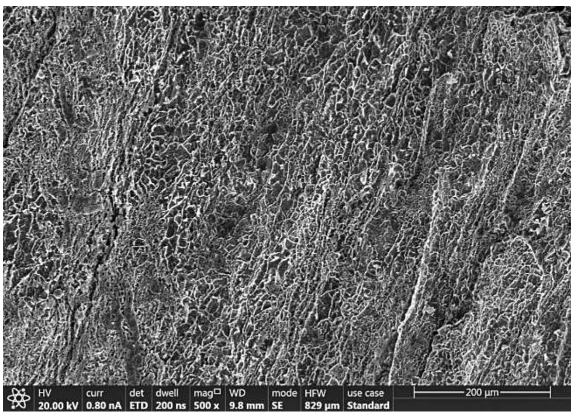

Figure 9 Better corrosion layer surface

Since carbon steel pickling generally has a corrosion layer depth of about 8 - 12 um, it takes 10 um as the target value. The corresponding pickling time under different concentrations and temperature conditions is also different. It is worth noting that, in the pickling solution with a mass fraction of 20 % at a constant temperature of 50°C, the outer wall of the pipe that is in contact with the bottom of the trough has pickling agent crystals. After removing the crystals, it is found that the crystallized areas are corroded severely. The phenomenon of uneven corrosion appeared, which will seriously affect the pickling effect, as shown in Figure 10.

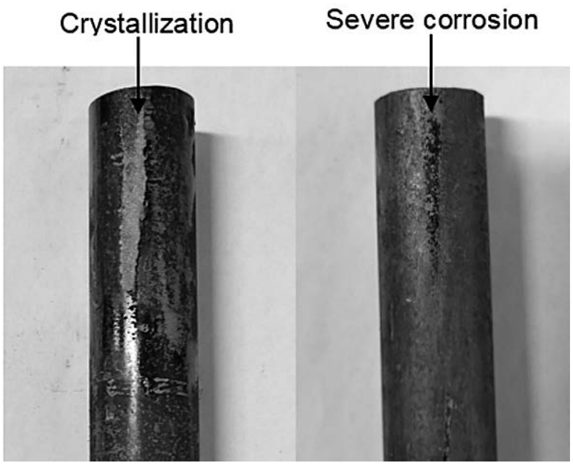

Figure 10 Pickling agent crystallization

In order to reduce the number of experiments, a three-factor three-level orthogonal test was designed to explore the best pickling conditions from a multi-factor perspective. It chose the Box-Behnken Design model to conduct a response surface analysis on the experimental results. The influencing factors (concentration, time, temperature) were taken as the independent variables, and the corrosion depth was taken as the evaluation index. From the P value of concentration, temperature and time, it can be judged that the three test factors have a very significant impact on the corrosion depth. When the corrosion depth regression model $P < 0{,}05$, it shows that the three regression terms have significant interaction in the regression model. According to the analysis results of the regression model, the multivariate quadratic regression equation is used to fit the functional re-

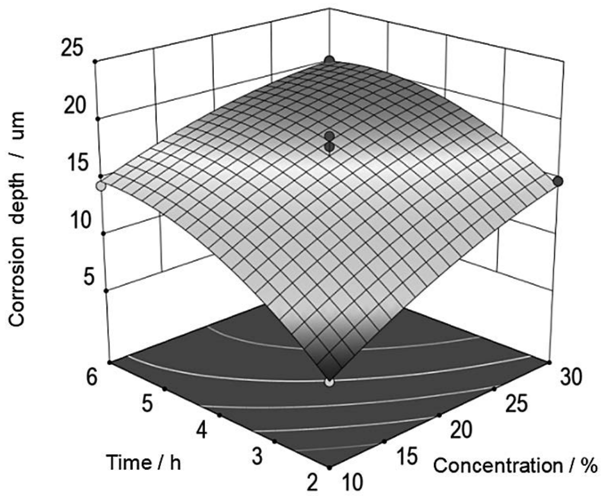

Figure 11 Time-concentration 3D response graph

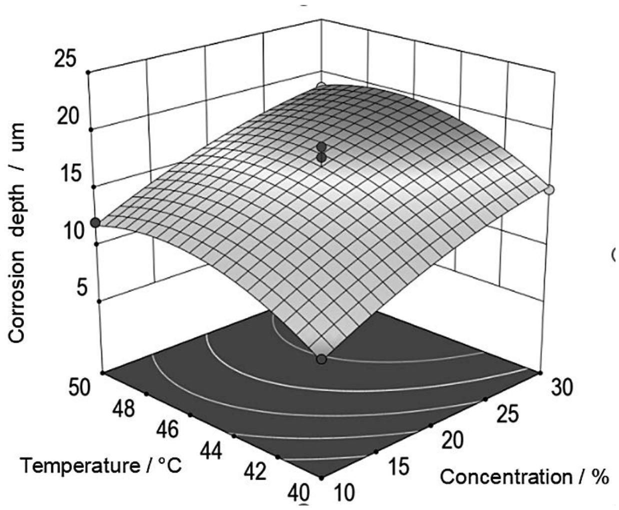

Figure 12 Temperature-concentration 3D response graph

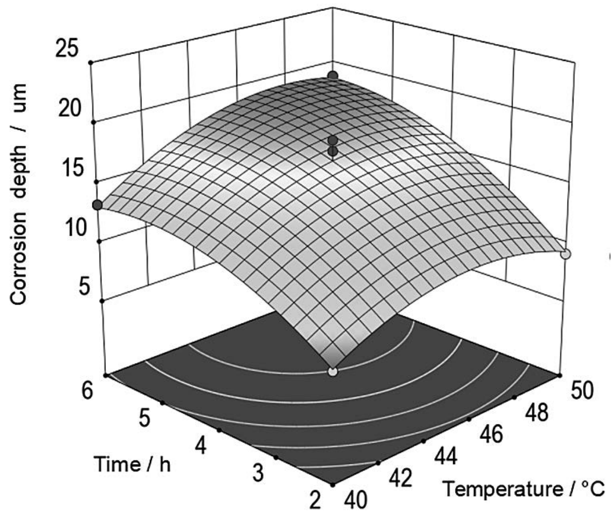

Figure 13 Time-temperature 3D response graph

lationship between the factors and the response value to draw the 3D response surface diagram of the interaction effect of each factor, as shown in Figures 11 - 13.

It is not difficult to find that in the process of increasing the corrosion depth from 5 - 20um, both time and concentration increase at a certain rate. In contrast, the interactive response of temperature and concentration, temperature and time does not tend to be linear. There is a relatively flat area between 40°C and 45°C and 3 to 5 hours. It is speculated that the optimal solution should be In this area. Set the target expectation to 10um. According to the 72 results given by Design-Expert, the optimal experimental condition is to pickle for 3,8 hours in a 10 % pickling solution at a constant temperature of 42°C. The result is consistent with the experimental conclusion and the prediction of response change.

CONCLUSION

The off-line trough pickling technology of pipeline is studied in this paper. Through pickling orthogonal experiment, metal microstructure analysis and response variation analysis, it is determined that the influencing factors of the pickling effect under this kind of technical conditions are concentration, temperature, and time in descending order. At the same time, it was determined that the best pickling conditions were: placing the pipes in a constant temperature of 42°C and pickling with a 10 % mass fraction of pickling solution for 3,8 hours.

Acknowledgments

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Note: The responsible translator for English language is Y. BIAN
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