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Research Progress of Erosion Wear Theory of Gathering and Transportation Pipes

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Abstract: The development process of erosion wear theory research in the past 60 years is reviewed, the content and limitations of various mainstream erosion wear theories are analyzed, and the research and discovery of the influencing factors of erosion wear in various stages are summarized. The conclusion is that erosion wear is affected by many factors, which is difficult to be explained by a universal theory. It is believed that the research direction of erosion wear theory should focus on the test of highly reduced erosion conditions, supplemented by numerical simulation analysis, and combined with the comprehensive research of macro and micro.

Keywords: Erosion wear mechanism; Plastic metal; Brittle metals; Influence factor.

1. Introduction

Erosion wear of gathering and transportation pipes is a surface damage phenomenon caused by the fluid carrying solid particles flowing through the pipe surface. The influencing factors of this phenomenon mainly include the metal properties of the pipe itself, such as hardness, ductility, etc; The viscosity of the fluid and the shape, size, hardness of the solid particles it carries, the speed and angle of impacting the metal surface, etc. In addition, studies have shown that the ambient temperature and pH are also important influencing factors[3-4]. Although there are many influencing factors for erosion wear, in general, the erosion wear of metal surface is mainly physical damage.



Fig.1 Erosion wear of metal pipes

2. Research Progress of Erosion Wear Theory

At the end of the 1990s, Levy proposed the "mechanism of micro-extrusion and forging" using the step-by-step erosion method and the single particle tracing method. His theory is the same as Evans'[5-17]. He believes that part of the kinetic energy of solid particles impacting metal materials will be converted into the thermal energy of metal materials, and the surface layer of softened heating area is more likely to produce pits and convex edges under the impact of solid particles, At the same time, the forging hardening zone formed under the surface layer of the softening area will promote the deformation of the surface layer. After the change of the metal material, the subsequent solid particles will continue to impact the area until the bulges formed on the material surface fall off. Different from Tilly's "secondary erosion theory", the "forging extrusion theory" roughly divides the erosion wear of metal materials into three stages. The first stage is that solid particles impact the metal surface to make it locally warm and soften; The second stage is the deformation of the softened metal surface under impact; The third stage is that the deformed bulge is knocked down by continuous impact [18-19]. Although Levy's research results did not consider the influence of various factors on the wear of metal materials, it explained the erosion wear process of most ductile materials in a more reasonable way.

3. Research progress on influencing factors of erosion wear

In 2013, Qu Wentao et al. evaluated the wear behavior of 20Cr steel under the impact of sand containing liquid by using a self-developed jet erosion test device. Their research showed that, within a certain range, with the increase of solid particle content in the fluid, the wear amount of 20Cr steel showed a trend of first increasing and then decreasing, and there was a critical value for the impact of sand content on the erosion wear of metal materials. They believe that the reason for this phenomenon is that before the content of solid particles exceeds the critical value, the interaction between particles is very small, and there is more energy when impacting the metal surface. When the content of solid particles exceeds the critical value, the interaction between particles is strengthened, and the energy directly acting on the metal surface is reduced.

In 2014, Sun Bingcai et al. analyzed the erosion wear of

40CrMo high-pressure manifold and found that the tensile stress generated when the elbow was under pressure was significantly greater than the axial stress. By comparing the erosion wear degree under different tensile stress conditions, they concluded that the greater the pressure inside the elbow was, the greater the tensile stress was, and the weaker the anti-erosion wear ability of the pipe was. The electron microscope scanning image also showed that when the material applied tensile stress, it is in a state of "easy fracture and erosion".

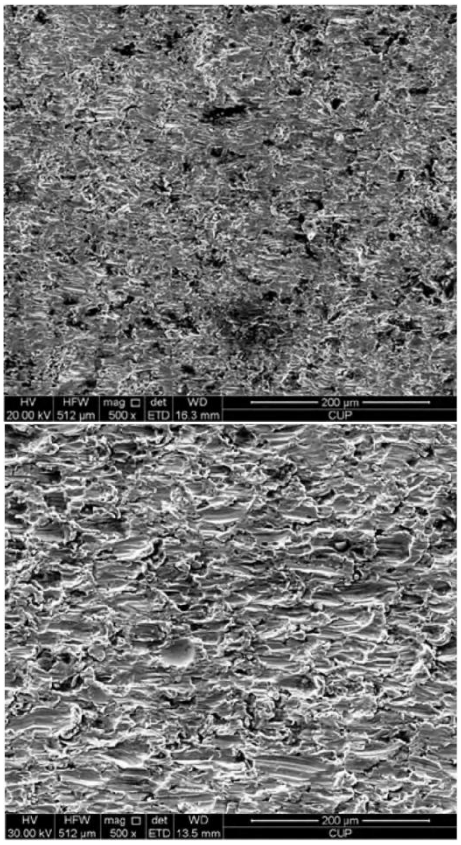


Fig.2 SEM image of material after stretching

(Left: no tensile stress; right: time 500MPa tensile stress)

In 2017, Khan et al. studied the influence of velocity, sand content and mud environment on mud wear behavior. In addition, this study also shows that the wear rate of the matrix alloy is smaller than that of the composite in alkaline medium, while the erosion wear resistance of the composite is better in acidic and saline medium. Khan's research shows that the impact of acid and alkali environment on erosion wear is not absolute, and the nature of the material itself is also one of the decisive factors.

In 2018, Chen Xiaochen et al. studied the mechanism and influence means of metal material erosion wear by combining experiment and mathematical model analysis. They obtained the morphology characteristics of material erosion wear through erosion test, and established a model to simulate the erosion process through SPE coupled FEM method. The results show that with the increase of erosion depth, the kinetic energy of solid particles gradually decreases, the impact angle gradually increases, and the wear of materials gradually changes from micro cutting to impact deformation. The research of Chen Xiaochen et al. shows that the erosion wear process of materials cannot be explained by a single theory. With the erosion process, the surface morphology of materials has been in a "changed" state, so the state of relative motion contact between solid particles and metal materials is also changing. At the same time, their research shows that different metal materials will have an impact on the erosion wear process due to their different properties, and the differences in erosion wear sections of different materials are controlled by the movement characteristics of solid particles. Therefore, they think that the improvement of material erosion wear should start from the perspective of changing the movement characteristics of erosion particles.

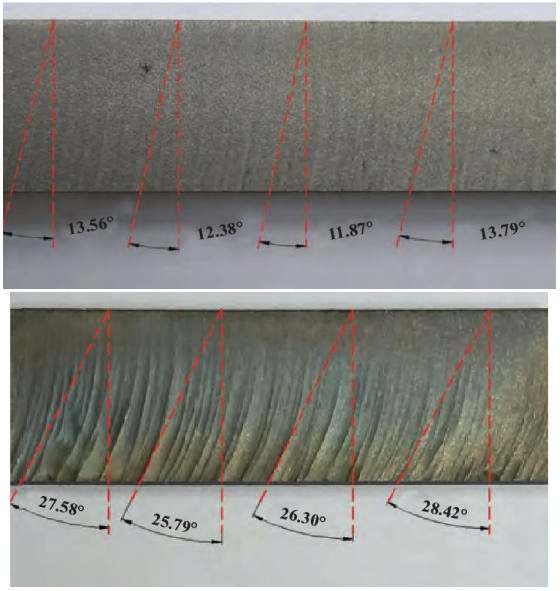


Fig. 3 Cross Section Shape of Different Steels after Erosion

(Left: 304L stainless steel; right: 45 steel)

4. Conclusion and prospect

(1) The erosion wear behavior of materials is complex and involves many influencing factors. At present, there is no universally accepted theory. In recent years, the achievements of a large number of researchers are mostly the verification of various mainstream theories. The experimental research on erosion wear is also limited to a small number of influencing factors, and few new theories have been born. At present, the focus of research should be on the development of a testing machine with more complete functions that can simulate more influencing factors. It is necessary to further strengthen researchers' understanding of erosion wear behavior.

(2) The process of erosion wear is the superposition of different types of materials in different stages, and the influencing factors are not uniform, so it is difficult to have a unified theory. The final interpretation of the erosion wear theory must be the integration of various theories of different materials and different erosion wear environments. It is a highly fitting development from phenomenon to mechanism, from single factor to erosion environment, and from macro phenomenon to micro change.

(3) At present, the method of numerical simulation of erosion is essentially a simplification of the actual erosion environment. Although it is convenient for the study of erosion wear theory, the setting of erosion environment is more inaccurate than the experimental study. The author believes that the research on numerical simulation of erosion must be combined with experiments. Experimental research is the data basis of numerical simulation, and numerical simulation is the theoretical supplement of experimental research.

(4) The weight-loss method as the only evaluation index of erosion wear degree is not accurate. Taking brittle materials

as an example, the weight loss measured by the erosion test may be very small, but there may be a lot of cracks on its microscopic surface morphology, which will greatly affect the stability of materials, and cannot be reflected only in terms of weight loss rate. Therefore, the test evaluation conclusion should be combined with the microscopic observation and analysis of the surface morphology after erosion wear.

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