Microstructure and tensile properties analysis of a long-diameter nozzle flowmeter

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Abstract. The tensile properties of materials used in flowmeters at room temperature and high temperature were studied. The tensile tests were conducted in the range of 23°C to 600°C and strain rate 0.1s⁻¹. The fracture morphology was analyzed by scanning electron microscope. The results show that the microstructures are ferrite and pearlite. The content of each element meets with the corresponding standard.

1. Introduction

Long-diameter nozzle flowmeter is mainly used in high temperature and high pressure occasions in power industry. Main steam, main feed water or desuperheated water all adopt this typical design. It has the characteristics of wide range ratio, shock resistance, long service life and large measurement range. The safety of steam flowmeter is very important for the safe operation of power plant.

In the past, the microstructure and mechanical properties of different metals were investigated by many researchers. Ahmed et al. [1] studied Fe doping in CuGaTe₂ and its influence on structural and thermal transport properties. The results showed that the thermoelectric properties of composite materials could be greatly improved by controlling its microstructure. Meftah et al. [2] investigated the effect of the starting material type and the Si/Al ratio in the hydrothermal synthesis process. The results showed that the final product microstructure depended on the aluminosilicate sources and the Si/Al ratio. Zhang et al. [3] investigated the microstructure and low-cycle fatigue behavior of spray-formed Al-Li alloy 2195 extruded plate. The results showed that the cyclic hardening and stability were closely associated with the interaction between moving dislocations and obstacles. Jiao et al. [4] investigated the effect of airflow pressure on microstructure and mechanical properties. The result showed that the volume fraction and geometrical morphology of O phase were crucial to the mechanical properties. Chamanfar et al. [5] investigated the hot deformation behavior and microstructure of a newly developed AA6099 alloy after homogenization. The results showed that the main flow softening mechanism for homogenized AA6099 was dynamic recovery. Li et al. [6] studied the microstructural response and tensile properties on 2024-T351 aluminum alloy specimens. The results showed that the low temperature laser shock could make the microstructure of the material evolve more favourably and make the material have better tensile properties.

In this paper, the tensile properties of materials used in flowmeters at different temperatures were studied. The chemical composition was analyzed.
2. Macroscopic morphology
As shown in Fig. 1, the long-diameter nozzle flowmeter mainly consists of short pipe, pressure-taking pipe, supporting ring, long-diameter nozzle and positioning pin. The outer diameter of the pipeline is about 190 mm and the inner diameter is about 150 mm. The diameter and height of the pressure-taking pipe are about 20 mm and 80 mm, respectively. The distance between the two pressure-taking pipes is 230 mm. The pressure-taking pipes are connected with the pipeline by welding. The quality assurance certificate indicates that the material is 12Cr1MoVG alloy structure steel.

![Macroscopic morphology of long-diameter nozzle flowmeter](image1)

Figure 1. Macroscopic morphology of long-diameter nozzle flowmeter.

Tensile specimens were taken from the pipeline. The size of the tensile specimens is shown in Fig. 2. The metallographic examination was carried out in different areas of the long-diameter nozzle flowmeter.

![Size of tensile specimen](image2)

Figure 2. Size of tensile specimen.

3. Results and Discussions

3.1. Tensile properties
The stress-strain curves at different temperatures including room temperature and high temperatures are shown in Fig. 3. It can be seen that the fracture strain increases slightly with the increase of test temperature. Temperature has a great influence on fracture strength. With the increase of temperature, the fracture strength decreases obviously. At room temperature, the fracture strength is about 750 MPa. When the temperature rises to 550 ℃, the fracture strength is about 500 MPa.

![Stress-strain curves](image3)

(a) $T=23^\circ\text{C}$, Strain rate=0.1%  
(b) $T=550^\circ\text{C}$, Strain rate=0.1%
Figure 3. Stress-strain curves at different temperatures.

The high temperature tensile fracture morphology is shown in Fig. 4. It can be seen from the graph that the fracture presents a classic cup-cone shape. Fracture area reduction increases with the increase of temperature. With the increase of test temperature, the depth and the relative area of fracture dimple both increase.
3.2. Microstructure and chemical composition analysis

The microstructure and chemical composition of the long-diameter nozzle flowmeter is shown in Fig. 5. As shown in Fig. 5(a), the microstructures are ferrite and pearlite. Fig. 5(b) is the SEM morphology. The chemical composition results are shown in Fig. 5(c). It can be seen that the content of each element meets with the corresponding element content standard of 12Cr1MoVG steel according to GB/T 3077-2015 < Alloy structure steels >.
4. Conclusion
The content of each element meets with the standard of 12Cr1MoVG steel according to GB/T 3077-2015. The results show that the microstructures are ferrite and pearlite.

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