Microstructure analysis of a V-cone steam flowmeter

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Abstract. The microstructure of a V-cone steam flowmeter made of 316L stainless steel was investigated by optical microscope and scanning electron microscope. The chemical composition of this flowmeter components were analyzed. The results show that the microstructure of every components is austenite. The chemical composition analysis shows that the flange and internals materials do not meet the relevant standard.

1. Introduction
Flowmeter is one of the most important instruments in process automation devices. It is widely used in metallurgy, power, coal, chemical industry, petroleum, medicine and people's daily life. V-cone flowmeter is one of differential pressure flowmeters. V-cone flowmeter overcomes some shortcomings of traditional throttling device, can better adjust flow and maintain flow stability, and achieve more accurate and effective measurement with a wider range. Microstructure has an important influence on the performance of steam flowmeters. Therefore, it is necessary to analyze the microstructure of the steam flowmeter.

In the past, some researchers investigated the microstructure of different alloys. Pan et al. [1] analyzed the microstructure of martensite white etching layers on the surface of treads of U71Mn rail. The result showed that the formation of white etching layers was caused by rapid temperature rises and the subsequent cooling down of rail surface. Jiao et al. [2] analyzed the microstructure of autoclaved ground dune sand-Portland cement paste. The result showed that the portlandite phase was consumed in GDS autoclaved mixtures. Chen et al. [3] investigated the critical effect of the morphology of feedstock carbide granules on the microstructure of selective laser melting processed carbides. The result showed that spherical pellets were more favorable than non-spherical pellets in obtaining a higher final density. Dong et al. [4] investigated the mechanism and the dependency between magnetostrictive composite performance and the orientation of the magnetic field. The results showed that the static and dynamic magnetostriction was increased as the orientation field increases. Anisimov et al. [5] performed electron microscopy analyses of electro-spark deposited IN 718 superalloy. Lv et al. [6] investigated the microstructural changes of biodegradable starch/wood power/polyactic acid composites. The results showed that the crystallinity of the composites increased at the initial stage of soil burial and decreased during degradation. Casalino et al. [7] investigated the metallurgical and mechanical behaviors of dissimilar 2 mm thickness AA6000 and Ti6Al4V butt joints.

In this paper, the microstructure of a V-cone steam flowmeter was analyzed. The chemical compositions of different components of this flowmeter were also measured to determine whether the materials used were qualified.
2. Macroscopic morphology
The V-cone steam flowmeter is shown in Fig. 1. It can be seen that this flowmeter has complete appearance and no obvious damage. The flowmeter is mainly composed of main pipeline, flange at both ends, internals and nozzle section. Both flanges and pipe sections are welded to the main pipeline. The flange outer diameter of this flowmeter is about 230 mm and the inner diameter is about 100 mm. The length of the main pipeline is 370 mm. The diameter of the two nozzles is about 15 mm and the height is about 100 mm. The distance between them is 30 mm. All components of the flowmeter are made of 316L stainless steel.

![Figure 1. Macroscopic morphology of V-cone steam flowmeter.](image)

3. Results and Discussions

3.1. Microstructure and chemical composition analysis of flange
The microstructure and chemical composition of one of the flowmeter flange are shown in Fig. 2. The sampling position of metallographic analysis is shown in Fig. 2(a). As shown in Fig. 2(b), the microstructure of flange is austenite. The chemical composition analysis of flange is shown in Fig. 2(c).

![Figure 2. SEM morphology and chemical composition of flowmeter flange.](image)
The chemical composition of flowmeter flange is shown in Table 1. From the table, it can be seen that both Ni and Mo contents are lower than 316L stainless steel standard according to GB/T 20878-2007 <Stainless and heat-resisting steels-Designation and chemical composition>.

| Element | C  | Si  | Mn  | P  | S  | Ni  | Cr  | Mo  |
|---------|----|-----|-----|----|----|-----|-----|-----|
| Flange  | 0.028 | 0.45 | 1.26 | 0.028 | 0.02 | 9.48 | 16.50 | 1.59 |
| 316L    | ≤  | ≤  | ≤  | ≤  | ≤  | 10.00- | 16.00- | 2.00- |
| (GB/T 20878-2007) | 0.030 | 1.00 | 2.00 | 0.045 | 0.030 | 14.00 | 18.00 | 3.00 |

The metallographic microstructures of V-cone flowmeter flange at different positions are shown in Fig. 3. It can be seen that there are similar metallographic microstructures in different locations, mainly austenite. The average grain size is about 30 μm.

3.2. Microstructure and chemical composition analysis of internals

The sampling position of metallographic analysis of internals is shown in Fig. 4(a). The SEM morphology of internals is shown in Fig. 4(b). The microstructure of internals is austenite.

| Element | C  | Si  | Mn  | P  | S  | Ni  | Cr  | Mo  |
|---------|----|-----|-----|----|----|-----|-----|-----|
| Flange  | 0.025 | 0.660 | 1.19 | 0.031 | 0.022 | 7.77 | 17.30 | 2.35 |
| 316L    | ≤  | ≤  | ≤  | ≤  | ≤  | 10.00- | 16.00- | 2.00- |
| (GB/T 20878-2007) | 0.030 | 1.00 | 2.00 | 0.045 | 0.030 | 14.00 | 18.00 | 3.00 |
The metallographic microstructures of V-cone flowmeter internals at different positions are shown in Fig. 5. It can be seen that the microstructure is austenite. The average grain size is about 60 μm.

![Figure 5. Metallographic microstructure of flowmeter internals.](image)

3.3. Microstructure analysis of flange welding position

The metallographic microstructures of different zones of flange welding position are shown in Fig. 6. It can be seen that the microstructure is austenite. The average grain size is about 20-30 μm.

![Figure 6. Microstructure analysis of flange welding position.](image)
4. Conclusion

Both Ni and Mo contents of flange and Ni content of internals are lower than 316L stainless steel standard according to GB/T 20878-2007. The microstructure is austenite and the grain size is relatively uniform.

References

[1] R. Pan, R.M. Ren, C.H. Chen, X.J. Zhao, The microstructure analysis of white etching layer on treads of rails, Eng. Fail. Anal. 82 (2017) 39-46.
[2] X.Y. Jiao, D.J. Wang, J.L. Yang, Z.Q. Liu, G. Liu, Microstructure analyses of autoclaved ground dune sand-Portland cement paste, Constr. Build. Mater. 789 (2019) 639-646.
[3] J. Chen, M.J. Huang, Z.Z. Fang, M. Koopman, W. Liu, X. Deng, Z. Zhao, S.H. Chen, S.H. Wu, J.Y. Liu, W.J. Qi, Z.P. Wang, Microstructure analysis of high density WC-Co composite prepared by one step selective laser melting, Int. J. Refract. Met. 84 (2019) 104980.
[4] X. Dong, M. Qi, X. Guan, J. Ou, Microstructure analysis of magnetostrictive composites, Polym. Test. 29 (2010) 369-374.
[5] E. Anisimov, A.K. Khan, O.A. Ojo, Analysis of microstructure in electro-spark deposited IN718 superalloy, Mater. Charact. 119 (2016) 233-240.
[6] S.S. Lv, X.J. Liu, J.Y. Gu, Y. Jiang, H.Y. Tan, Y.H. Zhang, Microstructure analysis of polylactic acid-based composites during degradation in soil, Int. Biodeter. Biodegr. 122 (2017) 53-60.
[7] G. Casalino, S. D'Ostuni, P. Guglielmi, P. Leo, M. Mortello, G. Palumbo, A. Piccininni, Mechanical and microstructure analysis of AA6061 and Ti6Al4V fiber laser butt weld, Optik. 148 (2017) 53-60.