Microstructure and chemical composition analysis of a vortex steam flowmeter

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Abstract. The microstructure and chemical composition of a vortex steam flowmeter made of 304 austenitic stainless steel were investigated based on the optical microscope and scanning electron microscope analysis. The results show that the microstructures of flange and weld between the flange and main channel are austenite. The chemical composition analysis shows that the contents of Ni and Cr of flange and weld between the flange and main channel do not meet the relevant standard.

1. Introduction
At present, there are many kinds of flowmeters used in industry. Vortex flowmeter is widely used in the measurement of steam flow under high temperature because of its high temperature resistance and low pressure loss. Vortex flowmeter is widely used in petroleum, electric power, chemical industry and other fields. The measuring principle of vortex flowmeter is based on the principle of Carmen vortex street. The physical structure of the vortex flowmeter is to install a vorticity generator in the fluid. The vortices on both sides of the flowmeter are generated by the flow of the fluid. This phenomenon is called Carmen vortices.

In the past, the microstructure of different materials was investigated by researchers all over the world. Hou et al. [1] analyzed the microstructure of IrO2 thin films. The results showed that the strain relaxation leaded to stacking faults at grain boundaries. Arora et al. [2] investigated the microstructure-corrosion property correlation of NiCo-carbon nanotube composite coatings. The results showed that the optimum carbon nanotube concentration could produce a microstructure with largest fraction of low energy low angle grain boundaries. Nosrati et al. [3] used a non-destructive micro-tomography analysis to study nickel laterite ore agglomeration behaviour and agglomerate microstructure. Rad et al. [4] investigated the microstructural evolutions of binary Mg-xCa alloys with various Ca contents. The results showed that the Mg-0.5Ca alloy was a promising alloy to be used as biodegradable implants. Ivashchenko et al. [5] discovered the hierarchical character and high ordering of microstructure. The results showed that the microstructure was responsible for fluorescence emittance of ultrasmall magnetic iron oxide multimodal nanoparticles hydrocolloids. Li et al. [6] analyzed the surface asperity evolution and microstructure of Al 6061T5 alloy. The results showed that the lubrication could accelerate the crystallization in CUPC process. Bi et al. [7] investigated the relationship between rolling contact fatigue cracking and plastic deformation of the pearlitic microstructure.

In this paper, the microstructure and chemical composition of a vortex steam flowmeter were analyzed.
2. Macroscopic morphology

As shown in Fig. 1, the vortex flowmeter is mainly composed of main channel, flange, internal components and nozzle section. The flowmeter has complete appearance and no obvious damage. The outer diameter of the flange of this vortex flowmeter is about 230 mm, the inner diameter is about 100 mm, and the length of the main channel is 160 mm. The flanges at both ends are welded to the main channel. According to the data attached to the flowmeter, each component material is 304 austenitic stainless steel. Microstructure and chemical composition of the samples were analyzed in different areas of the flowmeter.

![Image of vortex flowmeter](image)

Figure 1. Macroscopic morphology of vortex steam flowmeter.

3. Results and Discussions

3.1. Microstructure and chemical composition analysis of the flowmeter flange

SEM morphology and chemical composition of the flowmeter flange is shown in Fig. 2. The sampling position of SEM is shown in Fig. 2(a). The SEM morphology is shown in Fig. 2(b). It can be seen that the microstructure of the flowmeter flange is austenite. The results of chemical analysis are shown in Fig. 2(c). From the test results, the contents of Ni (7.78%) and Cr (17.65%) are slightly lower than those of 304 austenitic stainless steel in GB/T 20878-2007 < Stainless and heat-resisting steels-Designation and chemical composition > standard.
Figure 2. SEM morphology and chemical composition of flowmeter flange.

The metallographic microstructure of different positions of flowmeter flange is shown in Fig. 3. It can be seen that the grain size of flowmeter flange at different positions is relatively uniform, which is about 50-60 μm.

| Element | wt% |
|---------|-----|
| Si      | 0.39|
| Cr      | 17.65|
| Mn      | 1.39|
| Fe      | 72.79|
| Ni      | 7.78|

Figure 3. Metallographic microstructure of flowmeter flange.

3.2. Microstructure and chemical composition analysis of flange welding position

SEM morphology and chemical composition of the weld between the flange and the main channel of the vortex flowmeter is shown in Fig. 4. The sampling position of SEM is shown in Fig. 4(a). The SEM morphology of the weld between the flange and the main channel is shown in Fig. 4(b). It can be seen that the microstructure of the weld is austenite. The chemical analysis results are shown in Fig. 4(c). From the test results, the contents of Ni (7.07%) and Cr (17.65%) are lower than those of 304 austenitic stainless steel in GB/T 20878-2007 < Stainless and heat-resisting steels-Designation and chemical composition > standard.
Figure 4. SEM morphology and chemical composition of flange welding position.

The metallographic microstructure of different positions of the weld between the flange and the main channel is shown in Fig. 5. It can be seen that the grain size at different positions of the weld is not uniform. The average grain size in Fig. 5(a) is about 25 μm. The average grain size in Fig. 5(b) and Fig. 5(c) is about 45–50 μm. The average grain size in Fig. 5(d) is about 55–60 μm. It is obvious that inhomogeneous grain structure will lead to slightly different mechanical properties of welds.

![SEM morphology and chemical composition](image)

| Element | wt% |
|---------|-----|
| Si      | 0.35|
| Cr      | 17.65|
| Mn      | 1.48|
| Fe      | 73.46|
| Ni      | 7.07|

Figure 5. Metallographic microstructure of flange welding position.

4. Conclusion
The contents of Ni and Cr of flange and weld between the flange and main channel are lower than 304 austenitic stainless steel standard according to GB/T 20878-2007. The grain size at different positions of the weld between the flange and main channel is not uniform.

References
[1] X.Y. Hou, R. Takahashi, T. Yamamoto, M. Lippmaa, Microstructure analysis of IrO₂ thin films, J. Cryst. Growth. 462 (2017) 24-28.
[2] S. Arora, N. Kumari, C. Srivastava, Microstructure and corrosion behaviour of NiCo-Carbon nanotube composite coatings, J. Alloy. Compd. 801 (2019) 449-459.
[3] A. Nosrati, W. Skinner, D.J. Robinson, J. Addai-Mensah, Microstructure analysis of Ni laterite agglomerates for enhanced heap leaching, Powder. Technol. 232 (2012) 106-112.

[4] H.R.B. Rad, M.Ha. Idris, M.R.A.Kadir, S. Farahany, Microstructure analysis and corrosion behavior of biodegradable Mg-Ca implant alloys, Mater. Design. 33 (2012) 88-97.

[5] O. Ivaschenko, J. Gapiński, B. Peplińska, Ł. Przysiecka, T. Zalewski, G. Nowaczyk, M. Jarek, A. Marcinkowska-Gapińska, S. Jurga, Self-organizing silver and ultrasmall iron oxide nanoparticles prepared with ginger rhizome extract: Characterization, biomedical potential and microstructure analysis of hydrocolloids, Mater. Design. 133 (2017) 307-324.

[6] H.J. Li, Z.Y. Jiang, D.B. Wei, X.J. Gao, J.Z. Xu, X.M. Zhang, Surface asperity evolution and microstructure analysis of Al 6061T5 alloy in a quasi-static cold uniaxial planar compression (CUPC), Appl. Surf. Sci. 347 (2015) 193-201.

[7] G.L. Bi, Y.X. Han, J. Jiang, Y.D. Li, D.Y. Zhang, D. Qiu, M. Easton, Microstructure and mechanical properties of an extruded Mg-Dy-Ni alloy, Appl. Surf. Sci. 347 (2015) 193-201.

[8] D. Benoît, B. Salima, R. Marion, Multiscale characterization of head check initiation on rails under rolling contact fatigue: Mechanical and microstructure analysis, Appl. Surf. Sci. 366-367 (2016) 383-391.