MICROSTRUCTURE OF CAST Ni-Cr-Al-C ALLOY

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Nickel based alloys, especially nickel based superalloys have gained the advantage over other alloys in the field of high temperature applications, and thus become irreplaceable at high temperature creep and aggressive corrosion environments, such as jet engines and steam turbines. However, the wear resistance of these alloys is insufficient at high temperatures. This work describes a microstructure of a new cast alloy. The microstructure consists of γ matrix strengthened by γ′ fine precipitates (dendrites) improving the high temperature strength and of Chromium Cr₃C₂ primary carbides (in interdendritic eutectics) which are designed to improve wear resistance as well as the high temperature strength.

Keywords: Nickel based alloy, Chromium carbides, cast alloy, wear resistant alloy

The aim of the present study is to characterize the microstructure of the as-cast state quaternary Ni-Cr-Al-C alloy and to assess its ability to γ′ precipitation hardening.

2. Experimental procedure

The cross-sections of the investigated material ingot was polished and etched using modified Marbles reagent. The microstructure of the material was examined by Nikon LV150N light microscope and FEI VERSA 3D scanning electron microscope. The X-Ray diffraction (XRD) was performed by Pananalytical Empyrean diffractometer using CuKα1 radiation (λ = 1.5405 Å). Hardness tests were performed by TUKON 2500 hardness tester using the Vickers hardness test.
Chemical composition of investigated alloy (mass %)

| C  | Cr  | Al | Ni  |
|----|-----|----|-----|
| 0.85 | 20  | 3  | balance |

4. Results and discussion

The microstructure of the investigated alloy is presented in Figure 3 a) and b). It can be observed that the alloy consists of large grains with dendritic structure. Primary dendrites with secondary branches can also be visible. Chromium carbides are situated in primary eutectic in interdendritic zones (Figure 4) as well as in dendrites (Figure 5). The $\gamma'$ (Ni$_3$Al) phase is present after solidification in form of two morphologies: coarsed primary precipitates between carbides in interdendritic zones and fine secondary precipitates during cooling of the ingot (Figure 6). The X-Ray diffraction analysis revealed that chromium carbides are orthorhombic Cr$_7$C$_3$ and confirmed that the $\gamma'$ phase is present (Figure 7). It should be emphasized that the high purity alloy was successfully synthesized in the study. This alloy does not contain neither sulphides nor zones of the $\gamma/\gamma'$ eutectic which are characteristic for Ni-based superalloys in as-cast condition. The average hardness of the investigated alloy is 286±8 HV10.

3. Material

Investigated alloy was melted in vacuum furnace Balzers VSG-02 and then cast into metal chills. The chemical composition of the alloy is included in Table 1.
Fig. 4. Microstructure of investigated alloy a) SE image with EDS analysis area, b) c) d) e) show particular elements Aluminum, Carbon, Chromium and Nickel maps, respectively, f) EDS spectrum of the area.

Fig. 5. Microstructure of secondary carbides in dendrites in investigated alloy a) SE image, b), c), and d) EDS maps of carbon, chromium, and nickel, respectively.

Fig. 6. SEM-SE image showing microstructure of the investigated alloy.

Fig. 7. XRD analysis of the investigated alloy.
5. Conclusions

1. Microstructure of the investigated alloy consists of large grains with dendritic structure.
2. Dendrites mainly consists of γ solid solution with γ’ and Cr7C3 secondary precipitates.
3. Interdendritic zones contain eutectic chromium carbides (Cr7C3) and coarsed γ’ precipitates encircled with γ phase channels.
4. Neither graphite nor γ/γ’ eutectics are present in the alloy, what indicates proper balance between carbon and chromium content, as well as an adequate content of aluminum.
5. Results obtained during the study did not show any of solidification cracks and nonmetallic inclusions present in the alloy.
6. The investigated alloy in the as-cast state is precipitation hardened by γ’.

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