

Structural refinement of Cr-75Nb alloy subjected to air blast shot peening

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Abstract. In this paper, the air blast shot peening on Cr-75Nb alloy was carried out at the pressure of 0.6 MPa and processing duration of 13 min. The result showed that a severe plastic deformation layer was gained on the surface of Cr-75Nb alloy. The thickness of deformed layer was about 50 μm , and the structural scales of Nb-based solid solutions (Nbss) of top surface layer is refined to about 22 μm . The hardness of the surface layer is enhanced significantly in a narrow depth, which might be attributed to the structural refinement and/or work-hardening.

1. Introduction

In recent years, numerous investigations have been focused on the Laves phase NbCr₂ based intermetallic compounds due to their excellent mechanical performance such as high melting temperature (1730 °C), relatively low density (7.7 g/cm³) and appreciable creep resistance [1-3]. Therefore, these excellent properties project it as a promising candidate material for high-temperature structural applications. However, the oxidation resistance is in need of improvement for further application in the aeroengine hot end components in the aerospace industry.

The oxidation “pest” phenomenon has been observed in niobium alloys at 600°C, resulting in bad oxidation resistance of Cr-75Nb alloy in the temperature range of 950-1200°C [4]. Over the past decades, many researches [5,6] have been performed to develop a protective coating on NbCr₂ based alloys in order to improve the oxidation resistance above 1200°C. However, the pack cementation processes to prepare the coating are performed at high temperatures for a long duration, which may induce serious deterioration of the substrate. The problems may be solved by the occurrence of surface nanocrystallization (SNC) [7,8]. Nanocrystalline materials possess ultrafine grains with a large number of grain boundaries which may act as fast atomic diffusion channels [9,10].

Numerous investigations demonstrate that surface structural refinement can be achieved by severe straining of the material [11,12]. However, little has been investigated in the open literatures on the surface of Cr-75Nb. In this work, Cr-75Nb alloy was treated by air blast shot peening treatment (ABSP). The microstructural evolution and the hardness change were characterized by means of different analytical techniques. The microstructure of Cr-75Nb alloy was analyzed.

2. Experimental

The as-cast Cr-75Nb (at. pct) alloy plate used in this work was prepared by arc melting in the WK- II vacuum furnace. The arc melted ingot was remelted five times and annealed in vacuum at 1573 K for 10 hours and cooling to ambient temperature in the furnace for obtaining homogeneous structure, the structural scale of Nbss of Cr-75Nb alloy was about 90 μm , as shown in Fig.1. Sample of 10 × 10 × 10 mm³ was prepared for the ABSP treatment. Before the ABSP treatment, the Cr-75Nb alloy sample surface was polished with #1200 silicon carbide papers. Then, the surface of the sample was peened by the flying stainless shots (diameter of 1mm) with a high energy. The distance between the treated sample and the shot jet was 30 mm. The processing duration was 13

min.

The cross section of Cr-75Nb alloy sample was prepared for metallographic examination. The microstructure of Cr-75Nb alloy was characterized by scanning electron microscope (SEM). The phase constitutions in the treated surface layer were identified by using X-ray diffraction (XRD) instrument with Cu-K α radiation. And hardness measurements were performed by using Vickers indenter with 200 gf load and interior up to 500 μ m with 50 μ m intervals in order to investigate the hardness variations along the depth.

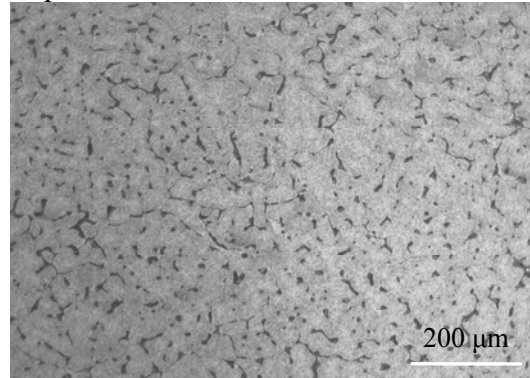


Fig.1 The optical micrograph of Cr-75Nb before ABSP

3. Results and discussion

3.1 Microstructure

The cross-sectional optical micrograph of the Cr-75Nb alloy treated for 13 min is shown in Fig.2. As in Fig.2, severe plastic deformation occurred in the surface layer of Cr-75Nb alloy. In the deformed layer, the near-equiaxed Nbss become streamlined. It is worth noting that the region A (shown in Fig.2) is obviously impacted by the balls at high speed and a small part of the material began to come off. The reason of the mass loss is that Laves phase NbCr₂ is an intermetallic compound with a topologically close packed (TCP) crystal structure. Due to its high brittleness attributed to the difficulty in moving dislocations by a process called synchroshear [13], repetitive and multidirectional loading on the Cr-75Nb alloy leads to the material loss.

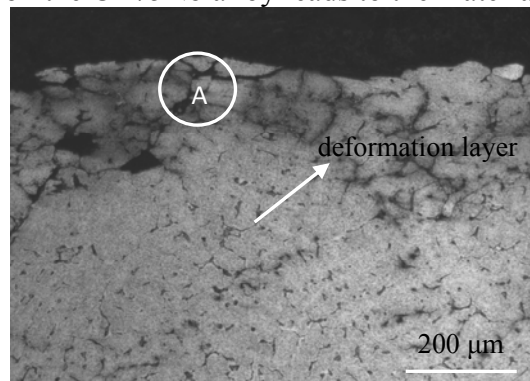


Fig.2 Optical observation on the deformation layer of the sample treated for 13min

Figure 3 shows that cross-sectional SEM observation of Cr-75Nb shot-peened with 13 min. As seen in Fig.3 a (low magnification), the Cr-75Nb alloy after the ABSP treatment shows a primary Nb-rich solid solution dendrites surrounded by a more or less continuous thin layer of Nb/NbCr₂ eutectic structure and the average structural scale of Nbss is about 90 μ m. In the Fig.3 b (high magnification), it occurs severe plastic deformation on the top surface of Cr-75Nb treated by ABSP. The thickness of the deformation layer is about 50 μ m. With treatment duration increasing to 13 min, the structural scale is refined to about 22 μ m.

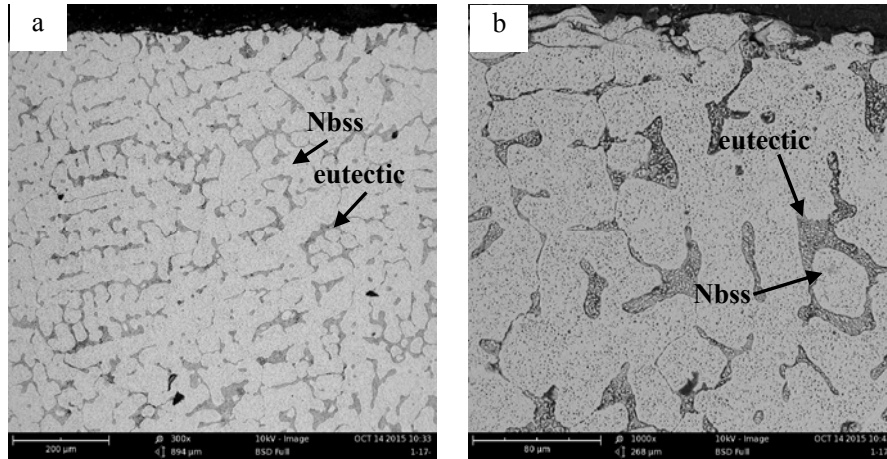


Fig.3 Cross-sectional SEM image of Cr-75Nb shot-peened with 13 min(a) low magnification; (b) high magnification

The X-ray diffraction of the top surface layer of untreated and treated sample are shown in Fig.4. It is noticed that the untreated and the ABSP treated Cr-75Nb alloy samples are consisted of Nb and NbCr₂ phase, without any evidence of a new phase. It differs from the Ni₃Al intermetallic of which the crystal structure changed during the SMAT [14]. It may be implied that the strains in the treated sample during ABSP are not large enough to induce a new phase transformation. The diffraction peaks of Nb and NbCr₂ shift to the high diffraction angle due to the solid solution of Cr. And there is evident broadening of the Bragg reflection profiles on the top surface layer of the shot-peened samples, which can be attributed to structural refinement and microstrain [15].

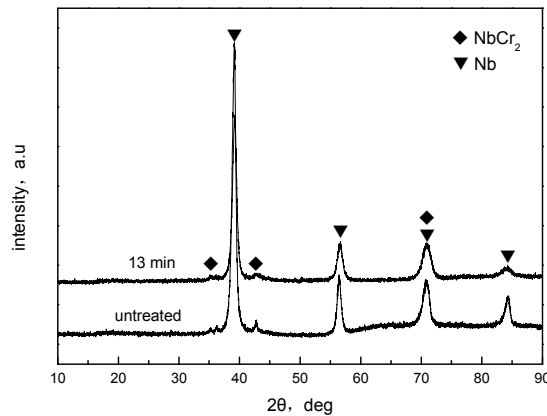


Fig. 4 XRD pattern of the untreated and shot peened Cr-75Nb alloy.

3.2 Hardness

Figure 5 shows the hardness variation along the depth of the sample treated for 13 min. It can be seen that the hardness of as-treated Cr-75Nb alloy increases significantly in the top surface layer. In the region of about 50 μm deep from the top surface layer, the hardness shows a sharp drop and then decreases till to a stable level with a further increase of the depth which means approaching the hardness of the matrix. For the sample treated for 13 min, the maximum hardness of the deformed layer is increased to 4.3 GPa, while the hardness of the matrix is 3.2 GPa. The present results show that the hardness of Cr-75Nb alloy can be significantly improved by ABSP, which might be owing to the structural refinement of Nbss and/or work-hardening.

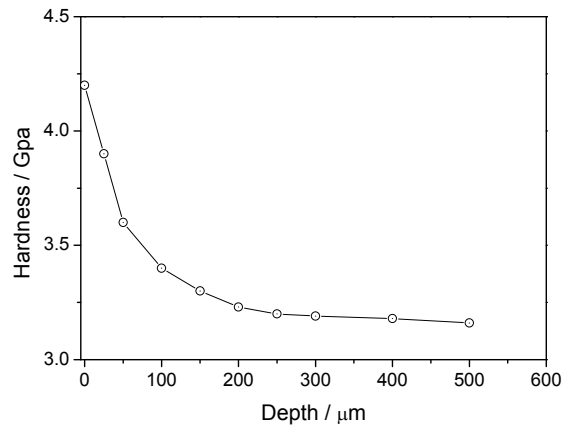


Fig. 5 Hardness variation along the depth of the sample treated for 13 min.

4. Conclusions

The ABSP treatment of Cr-75Nb alloy has been conducted at the air pressure of 0.6 MPa and the treatment duration of 13 min. A severe plastic deformation layer structure was fabricated on the surface layer of Cr-75Nb alloy subjected to the ABSP treatment. The thickness of the deformed layer of Cr-75Nb is about 50 μm . For the sample shot-peened for 13 min, the maximum hardness of the top surface layer is attached to 4.3 GPa, which is enhanced significantly compared with that of matrix. The structural scale of Nbss in the top surface layer of Cr-75Nb treated for 13 min could be refined to about 22 μm .

Acknowledgments:

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