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Improvement of Work-Hardening Behavior of Co-Cr-W-Ni Alloy by Adding Mn/Fe for Balloon-Expandable Stents

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Abstract. The Co-20Cr-15W-10Ni (CCWN, mass%) alloy, registered as American society of testing and materials (ASTM) F90, has been widely used as a balloon-expandable stent because of its excellent balance between its mechanical properties and corrosion resistance. To realize a less invasive stent placement, the stent diameter must be reduced, which implies that the stent strut thickness must be reduced. As such, the CCWN alloy must be high in strength and ductility while maintaining a low yield stress to facilitate the expansion and suppression of stent recoil. In this study, we focus on the effects of the adding Mn/Fe on the microstructure, mechanical properties, and corrosive properties of CCWN alloys. A 6 mass% Mn-added CCWN alloy with a grain size of approximately 20 μm prepared in this study exhibits excellent balance between tensile strength and ductility. In addition, it exhibits a lower yield stress while maintaining a high tensile strength compared with the ASTM F90 alloy. Meanwhile, a 6 mass% Fe-added CCWN alloy exhibits a higher ductility compared with the ASTM F90 alloy. The addition of Mn or Fe to the CCWN alloy increases the stacking fault energy of the alloy and suppresses strain-induced martensitic transformation during plastic deformation, thus improving the ductility of the alloy. Results of polarization tests show that the 6 mass% Mn- or Fe-added CCWN alloys exhibit the same corrosion current density as the ASTM F90 alloy. Mn-added Co-Cr-W-Ni alloys are suitable for use in balloon-expandable stents.

Introduction

Stent placement, which does not require open chest surgery, is widely used in the treatment of cardiovascular diseases. Two types of stents exist: self-expandable and balloon-expandable stents. Balloon-expandable stents were used to treat the Co-20Cr-15W-10Ni (CCWN, mass%) alloy, which exhibits excellent balance in terms of strength and ductility and is used for balloon-expandable stents[1-2]. In recent years, demand for more minimally invasive stent placement techniques to reduce physical and mental burden on patients has increased. To realize less intensive stent placement, the diameter of the stent must be reduced, which implies that the stent strut thickness must be reduced. Metallic materials used in small-diameter stent platforms must exhibit the following four properties: (1) Sufficient strength to maintain the expanded shape of the blood vessel; (2) ease of expansion and suppression of springback; (3) sufficient plastic deformability for processing into tube materials; and (4) sufficient corrosion resistance as a biomedical material. Therefore, to develop next-generation small-diameter stents, a material that possesses sufficient corrosion resistance and achieves high strength and ductility while maintaining low yield stress, i.e., an alloy with excellent work-hardening properties, is required. In our previous studies, we achieved both high strength and ductility in CCWN alloys by optimizing their thermomechanical treatment process[3-5]. We discovered that CCWN alloys with grain sizes of 10–20 μm demonstrate excellent strength–ductility balance upon heat treatment at a relatively low temperature of 873 K[3]. To apply this heat treatment process to practical stents, we optimized the heat treatment process for CCWN alloy tubes and successfully produced a