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Title: Influence of Thermomechanical Processing on Mechanical and Corrosion Properties of Titanium Alloys.

ABSTRACT

In this study, significant efforts in terms of extensive work and focus were dedicated for developing a novel Ti alloy for biomedical applications with low Young's modulus and superior mechanical and corrosion properties. The Ti-Nb-Zr based alloy containing small amounts of vanadium (V) was developed and investigated in order to evaluate its possible application as a biomedical material. Nb, Zr and V, having a β-phase stabilizing effect for Ti materials, were chosen to control the microstructure desirably. In spite of the fact V is associated with toxicity, the concentration used in this study was kept minimal.

The main aim of this research is to compile the effect of alloy composition, thermal and thermo-mechanical processing (TMP) on substantial properties (i.e. mechanical and electrochemical properties) related to the biocompatibility of a novel biomedical Ti alloy. This research concentrates its interest mainly on the evolution, evaluation and development of effective micro-structural features that can reduce Young's modulus, and improve major tensile properties, and corrosion behavior of bio-grade Ti alloy. The work presents the results on the influence of different TMP parameters on the mechanical properties and electrochemical behavior of metastable β alloy Ti-20.6Nb-13.6Zr-0.5V (TNZV). The TMP comprised of plastic deformation in β phase field (850 ^{o}C) and also in α + β (650 ^{o}C) field followed by solution heat treatments at same temperatures with cooling at various rates in addition to aging. The aging was done (500 ^{o}C/5h) for only water quenched (WQ) samples which were solution treated at both 850 ^{o}C and 650 ^{o}C. Factorial design of experiment was used to systematically collect data for mechanical properties. It appears from the reported literature that very few researchers have applied the statistical technique to investigate the effect of TMP parameters on the mechanical properties of biomedical Ti alloys. Therefore, the analysis of variance (ANOVA) was used to evaluate the effect of TMP parameters on the requisite properties of biomedical Ti alloys. Moreover, the optimization of the TMP process parameters was also performed to achieve the optimum values of different mechanical properties. The corrosion behavior of studied alloy was evaluated in a Ringer's solution at 37 ^{o}C via open circuit potential-time (OCP) and potentiodynamic polarization measurements.

Depending upon the TMP conditions, a wide range of microstructures with varying morphologies of α, β phases, or martensite phase were attained, allowing for a wide range of properties to be achieved. The martensitic structure was obtained only in the WQ samples which were deformed and solution treated at 850 ^{o}C, while the microstructure of other heat treated samples consisted of α and β phases only. Aging led to the increase in volume fraction of α phase through decomposition of β and/or martensite phase into the α phase. The morphology of α phase was modified in some cases of aging process.

It is found that the Young's modulus of TNZV alloy samples decreases with an increase in cooling rate from the solution treatment temperature. The martensitic transformations presented a leading cause in the reduction of Young's modulus. In contrast, the higher amount of α phase in the matrix was found to increase the Young's modulus. In all heat treatment conditions, WQ samples introduced lower Young's modulus compared to other heat treated samples due to less amount of α phase in the microstructure. The best value of Young's modulus was obtained in WQ samples which were deformed and solution treated at above β-transus temperature. With regard to mechanical properties, the martensitic transformations also played a key role of the reduction of the hardness but increasing largely the total elongation to failure. In all heat treatment conditions, air cooled (AC) samples show higher hardness and strength as compared to furnace cooled (FC) or WQ samples. In majority of heat treatment conditions, the WQ samples offered higher plasticity compared to other heat treated samples. The aging led to increase in the hardness, Young's modulus and strength and decrease in the ductility by decomposition of martensite and/or retained β into α phase. Corrosion tests indicated that TNZV alloy samples undergo spontaneous passivation owing to spontaneously formed oxide film in the human body environment. Depending upon the conditions of heat treatment, the AC and WQ samples showed lower corrosion rate owing to the less amount of less noble phase α in the microstructure compared to other samples. According to the presented results it could be considered that the mechanical and corrosion properties of investigated TNZV alloy suggest that the alloy is a potential candidate for biomedical applications.