Hydrogen treatment of titanium based alloys

Marek Hartmann, Monika Losertová, Ivo Schindler, and Jaromír Drápala

VŠB-Technical University Ostrava, Faculty of Metallurgy and Materials Engineering, 17.listopadu 15, CZ-70833 Ostrava-Poruba, Czech Republic

The titanium alloys show high strength-to-weight ratio, good corrosion resistance and high biocompatibility, so they are of particular interest for use as biocompatible implants in biomedicine [1]. Nevertheless, workability of alpha + beta titanium alloys at room temperature is difficult and forming must be performed at elevated temperatures, thus improving hot deformation behavior by decreasing flow stress and working temperature is essential. The well-known reason of the difficulties with forming consists in relatively high temperature transformation of alpha + beta phases to beta phase, whereas beta phase with body centered cubic structure is more malleable then alpha phase with hexagonal close packed lattice. Although hydrogen deteriorates mechanical properties of many engineering metallic materials, titanium alloys included, and the brittleness of conventional alloys induced by the hydrogen is observed at room temperature as well as at elevated temperatures, in case of Ti alloys hydrogen can act as a temporary alloying element in special heat treatment technology, so-called the thermo-hydrogen treatment (THT) [2, 3] and shows beneficial effect in improving particular properties. Whereas the hydrogen works as beta stabilizer in Ti alloys, THT technology employs the reversible reaction of hydrogen with titanium in order to modify phase compositions, kinetics of phase transformations and evolution of metastable phases in titanium alloys [2-5].

The effect of heat treatment on the microstructure and hot deformation behavior of two biocompatible Ti alloys (Ti6Al4V and Ti24Nb) alloy was investigated. The thermal treatment of the specimens consisted of two-steps annealing at 600 °C and 850 °C and aging at 590 °C in flowing hydrogen or argon gases, the holding times differed for Ti6Al4V and Ti24Nb, respectively. The heat treated specimens were submitted to uniaxial compression tests at 750 °C and strain rate 0.05 s^{-1} on the Gleeble 3800 machine. The specimens were deformed to half of their initial height in each case. The amount of hydrogen in specimens was measured by means of an analyzer LECO RH600. The microstructure study was performed before and after isothermal compression test on the specimens in hydrogenated and non-hydrogenated conditions. Comparing the results obtained for the non-hydrogenated and hydrogenated specimens it was found that the deformation behavior of both alloys was different. While hydrogen content as high as 1325 wt. ppm had shown an obvious benefit effect on high temperature deformation behavior in the Ti6Al4V alloy by lowering the thermal deformation resistance, in case of Ti24Nb alloy the hydrogen in amount of 1663 wt. ppm affected supression of instabilities in true stress - true strain curves. However, the higher amount of hydrogen induced increasing flow stress and resulted in cracking of Ti24Nb specimens. The benefit effect of hydrogen on increasing formability of Ti24Nb at lower temperatures was not evident as it was observed in the case of Ti6Al4V alloy.

This article has been elaborated in the framework of the project No. LO1203 R̈egional Materials Science and Technology Centre - Feasibility Programf̈unded by Ministry of Education, Youth and Sports of the Czech Republic and co-financed by the European Social Fund and of the projects SGS SP2017/77 and SGS SP2017/58 supported by Ministry of Education, Youth and Sports of the Czech Republic.

[1] NIINOMI, M. Mechanical biocompatibilities of titanium alloys for biomedical applications. J. of the mechanical behavior of biomedical materials, 2008, 1, 1, 30-42.

[2] QAZI, J.I., et al. Phase Transformations in Ti-6Al-4V-xH Alloys. Metall. Mater. Trans. A, 2001, 32, 10, 2453-2463.

[3] ELIAZ, N., et al.. Hydrogen-assisted processing of materials. Materials Science and Engineering A, 2000, 289, 1-2, 41-53.

[4] MURZINOVA, M. A., et al. Application of reversible hydrogen alloying for formation of submicrocrystalline structure in (alpha + beta) titanium alloys. Proceedings of the Selected Papers of the First I

[5] ZONG, Y Y, et al. Strenghening versus softening mechanisms by hydrogen addition in beta-Ti40 alloy Int. J. of Hydrogen Energy, 39, 2014, 3498-3504.