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Abstract of Doctoral Thesis

Development of an Innovative Process to Fabricate Titanium Alloys Using Titanium Hydride

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Titanium (Ti) and their alloys have exceptional potential for expanded usage in key engineering applications, owing to their unique combination of outstanding mechanical and chemical properties. In spite of all the meritorious properties, the initial high cost of Ti and the complex fabrication process, often limit their wide range of applications. Therefore, it is necessary to develop an optimum fabrication strategy to offer commercially viable and good quality Ti based near-net shaped products. The powder metallurgy (PM) has near net-shape processing capabilities, and therefore, it can be a suitable process for the fabrication of cost effective Ti alloys.

Recently, few researches show that the use of extremely brittle titanium hydride (TiH_2) powder can overcome the sticking issues, generally exist, during mechanical alloying (MA) processes. Therefore, for preparing Ti-alloys, TiH_2 may be used as a precursor of Ti. Moreover, various researches also show that, a rapid sintering process such as “Spark Plasma Sintering (SPS)” can be a suitable method to maintain fine grained microstructure and high density.

To evaluate the feasibility of the TiH_2 powder as a precursor for Ti and Ti alloys, in the beginning of this project commercially pure Ti, Ti-40mass % Nb (Ti-40Nb) and Ti-25mass % Nb-11mass % Sn (Ti-25Nb-11Sn) was fabricated by mixing and MA of TiH_2 and elemental powders (Pure Nb and Sn) followed by their sintering via SPS method. Brittle TiH_2, unlike pure Ti powder, avoids agglomeration, and sticking to the balls and vials during MA process, leading to ~100% yield of MAed powders. Through this method, the Cp-Ti, Ti-40Nb and Ti-25Nb -11Sn alloys with fine grain microstructure was successfully prepared. Almost complete β-phase was achieved for Ti-40Nb and Ti-25Nb-11Sn alloys. However, the compacts prepared by such method suffer the poor mechanical properties i.e. brittle failure in the tensile loading. Such brittleness can possibly be due to the high amount of hydrogen retention. Therefore, to achieve good mechanical properties i.e. high strength and ductility, hydrogen content of the Ti alloys should be low. However, achieving good mechanical properties in the Ti alloys prepared by TiH_2 is still under research, and therefore, in this study, an initiative was taken to accomplish this objective. The prime novelty of this research was to develop a new PM process to fabricate Ti alloys, with good mechanical properties, by using TiH_2.

Therefore, the fabrication process was optimized from direct sintering (one-step sintering) of MAed powders, to dehydrogenation followed by sintering of MAed powder (two-step sintering). Moreover, to decrease the possibility of hydrogen content in the material, pure Ti powder was also mixed with the TiH_2 powder. The Ti-40Nb alloy and Ti-25mass% Nb-25mass% Zr (Ti-25Nb-25Zr) alloy was prepared via this novel PM process. The high density (i.e. without appreciable porosities) Ti-40Nb and Ti-25Nb-25Zr alloys with complete β phase were prepared. Moreover, under tensile test these alloys showed a good combination of high strength and ductility, which are comparable to the similar alloys prepared by other methods. Furthermore, the Ti-25Nb-25Zr alloy, with uniform and harmonic microstructure was also prepared by pre-alloyed PREP powders and results are compared with the similar alloy prepared by novel two-step PM method. The tensile strength of Ti alloy prepare by two-step sintering, using TiH_2, was much higher compared to the similar alloy prepared by PREP powders whereas strain to failure was comparable.