Abstract

[Research Title]

Development and Application of Cost-effective High strength Titanium Alloys Using In-process Wastes

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In this project, a new recycling process was developed to convert off-grade titanium sponge waste with excess iron and oxygen impurities into cost-effective titanium alloys with high strength and ductility. These wastes have never previously been used as raw materials in the production of Ti alloys because high Fe and O content significantly decreases the ductility of conventionally cast materials. This limitation is overcome by the employment of a novel powder metallurgy (PM) approach. In this process, the in-situ formation of brittle TiH_2 compounds was promoted to improve the milling ability of bulk wastes into fine powders for re-consolidation by PM. The hydrogen atoms from these TiH_2 compounds were also found to be beneficial for accelerating the sintering of the milled powders due to their high diffusivity in Ti crystals. Additionally, a quantitative analysis on the strengthening of Ti alloys by Fe and O solutes was performed using theoretical models and the rule of mixtures. This analysis produced highly accurate predictions for the tensile yield stresses of the PM Ti-Fe-O ternary alloys. Furthermore, a machine learning approach was also applied to estimate the stress-strain curves of alloys with different Fe content and microstructures. In combination, the results of these analyses proved very useful in the alloy design of Ti-Fe-O materials prepared from off-grade Ti sponge waste of varying Fe and O contents. Upscaled Ti-Fe-O alloys prepared by rolling showed a good balance between high strength and satisfactory elongation, superior to existing Ti alloys which rely on rare and expensive elements. The recycled materials were subsequently used to produce knives for the outdoor activities market. In evaluations conducted with the customers, knives produced from the recycled Ti alloys were found to exhibit excellent cutting performance and superior durability to existing Ti materials. In conclusion, off-grade Ti sponge wastes containing Fe and O impurities were successfully recycled into low-cost and high-performance Ti-alloys by utilizing a powder metallurgy process. This newly established presents an effective means in reducing energy consumption and CO_2 emissions by the recovery of these waste products for use in high-value applications.

[References]

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