LARGE SCALE PROCESSING AND CONSOLIDATION OF NANOCRYSTALLINE $FE_{91}NI_8ZR_1$ ALLOY

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ABSTRACT

Nanocrystalline $Fe_{91}Ni_8Zr_1$ (at. %) powder is being produced in bulk quantities with the same microstructure and thermodynamic stability as powder produced in small batches. Previously, 10 gram batches were produced by high-energy ball-milling in SPEX mills at cryogenic temperatures and then consolidated by equal-channel angular extrusion (ECAE). Producing the powder quantities in a SPEX mill required for the manufacture of bulk parts is a difficult and labor intensive process. Consequently, a ZOZ CM08 rotary mill was purchased and is now being used to scale powder production to much larger (e.g., kilogram) quantities, thereby enabling research to focus on industrial consolidation methods such as hot isostatic pressing (HIP), cold isostatic pressing (CIP) extrusion and final machining. This paper will report the processing parameters used for these consolidation methods that enable the retention of mechanical and thermodynamic characteristics first observed in the laboratory scale SPEX mill version of the powder.

INTRODUCTION

With an ever increasing demand for performance, the U.S. Army is seeking new Fe-based alloys with improved characteristics for use across a wide range of operating conditions. Materials of interest should have increased tactical and logistical performance to include 1) light-weighting the soldier/vehicle while increasing their protection and 2) increasing the lethality for munitions and weapons platforms. One class of material that has the potential to meet these challenges is nanocrystalline oxide-dispersion-strengthened (ODS) alloys. Fe-based ODS alloys have been in development for use in generation IV nuclear reactors, mainly because of their superior strength, creep and fatigue properties at high temperatures as well as high radiation damage tolerance. [1]

With grain sizes below 100 nm, nanocrystalline metals and alloys have garnered significant interest primarily due to their superior mechanical properties as compared to their coarse grained counterparts. For example, the Hall-Petch relationship describes the dramatic increase in yield strength with decrease in grain size down to about 20 nm for most metals. At grain sized below 100 nm, nanocrystalline metals possess a significant volume fraction of grain boundaries to which this increase of strength is related. However, this same factor also makes them thermally unstable and prone to rapid and progressive grain growth at moderate and sometimes low temperatures. For instance, nanocrystalline Al and Cu, are well known to undergo growth at room temperature. Such microstructural instability makes nanocrystalline