Aluminum Nano-Composites for Elevated Temperature Applications

Research Team:
Cecilia Borgonovo
Makhlouf M. Makhlouf

Introduction

Particulate reinforced metal matrix composites have been used in many industries for many years and with the advent of nanotechnology, the size of the reinforcing particles progressively scaled down to the nano-level. Aluminum matrix nano-particle composite materials have shown promising mechanical and thermal properties; e.g., high strength, hardness, stiffness, as well as resistance to thermal degradation and creep. Unfortunately, manufacturing aluminum matrix nano-composites is not easy and numerous attempts have been made to overcome the manufacturing issues such as mechanical alloying, powder metallurgy, infiltration techniques and spray deposition. However, these processes are expensive and have their own limitations. Manufacturing methods based on mechanical agitation are cost-effective but the particles tend to agglomerate because of Van der Waals forces. The agglomerated particles can be dispersed by ultrasonic vibrations, but the use of ultrasonic devices on the foundry floor is not practical and has scalability issues. In-situ fabrication of the particles within the metal matrix could be the answer to the manufacturing challenges. In this case, the nano-sized particles are formed directly in the melt by reacting with a gas. For example, the reaction of a nitrogen-containing gas with a molten aluminum alloy leads to formation of AlN particles that are well dispersed in the matrix alloy and are characterized by a clean particle/matrix interface. Therefore, the objective of this work is to investigate and optimize a scalable economical process for manufacturing Al alloy-AlN nano-particle composite material and to characterize the microstructure and properties of the resulting material.

Methodology

The project is divided into 3 major tasks:

Task 1: Determine the feasibility of the gas-liquid method experimentally

Task 2: Develop a mathematical model that is able to determine the critical parameters involved in the formation of the reinforcing particles and in their distribution. The following variables will be considered in the model:

- *Liquid temperature*
- *Gas flow rate*
- *Ambient pressure*

– *Nozzle diameter*

– *Interfacial energy of the system*

Task 3: Use the mathematical model as a guide to construct and apparatus and to design experiments geared towards obtaining the optimum parameters for processing Al-AlN nano-composite material with optimum microstructure and properties.

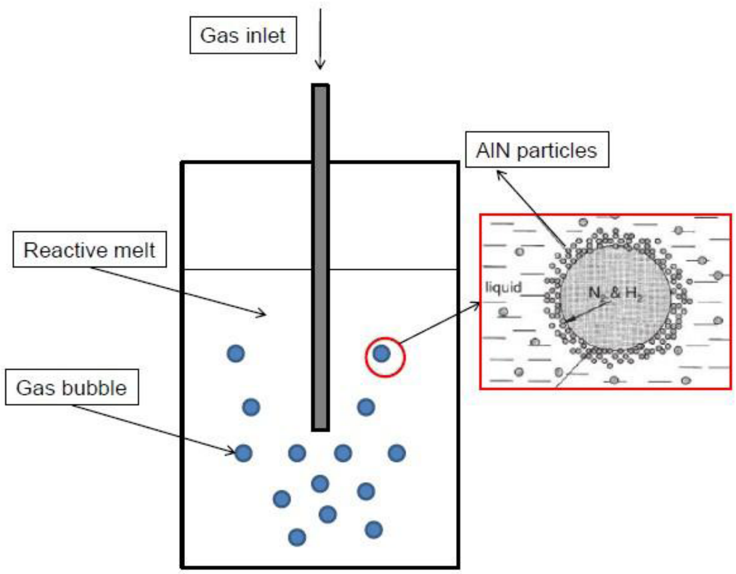

Fig. 1: Schematic representation of the in-situ gas/liquid process.

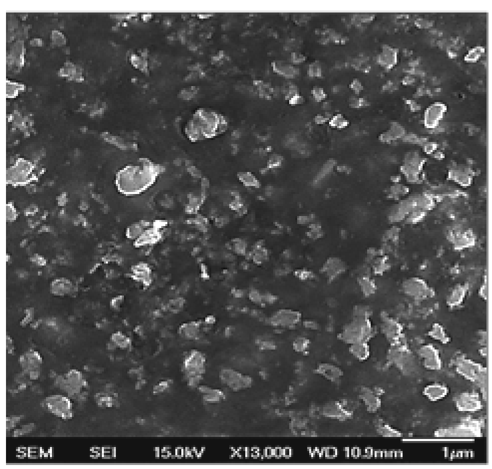

Fig. 2: SEM image showing AlN particles in an Al-Li alloy formed by reacting the molten alloy with anhydrous ammonia gas.