Characterization of SiC/Al Ceramic Matrix Composite produced by Directed Melt Oxidation (DIMOX)

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Abstract.
This research is to study the effect of firing temperature and holding time on production of SiC/Al Ceramic Matrix Composite (CMCs) and characterization of this materials produced by Directed Melt Oxidation (DIMOX). The firing temperature and holding time used are varied from 900°C to 1300°C with holding time for 10 and 20 hours respectively. The characterization of composites are examined such as density, porosity, hardness, and microstructure analysis. The results showed that SiC perform has been infiltrated by Al liquid occurred optimally on firing temperature of 1100°C with holding time for 20 hours. Ceramic Composite produced have highest density of 3.54 g/cm³ can be obtained at this condition, while porosity tends to increase with increasing firing temperature. Porosity within the channels is associated primarily with insufficient Al flow to fiend the solidification shrinkage. The highest hardness can be obtained on firing temperature 1300°C with holding time for 10 hours i.e. 1920 VHN. Distribution of SiC particles spread over SiC/Al composites product, and around SiC particles can be found Al, spinel (MgAl₂O₄), and Al₂O₃ and MgSi analyzed by EDS.

Key words : CMCs, firing temperature, holding time, DIMOX

1. INTRODUCTION

Ceramic Matrix Composite (CMCs) of SiC/Al which is one of the important candidate materials for use in airplanes, automobiles and the first wall of fusion reactors. Directed metal oxidation (DIMOX) One of the methods to produce the CMCs which have high toughness and good thermal shock resistance, as well as high stiffness, good wear resistance and high temperature stability. Further more, the method allows production of near net shape at a low cost. The process has been developed commercially by the Lanzaide Corporation. The process involves the oxidation of a bulk molten metal by a gas through a directed growth process to produce an interconnected ceramic reaction product, that may contain several percent of residual metal. This process mostly used for some space application.

Solid-liquid interface energy reduce by holding time for all of ceramic particle-Al alloy system. Some of the surface energy change and occurred faster interface reaction at higher temperature. Decomposition of oxide coating on the ceramic phase either physically or chemically has also been considered as one of influencing factor that affect the wetting kinetics.

Molten metal start to infiltrate when the solid-liquid interface energy decreasing.

In the many cases, the great improvement of wetting capability can be observed in the 900°C temperature for ceramic/Al-alloy system. This behavior has been explained by decomposition of thin coating of Oxide on the ceramic surface and also by the change of the Oxide coating on the liquid metal surface. Temperature will affect the viscosity, and the viscosity effect of molten Alloys to the infiltration is shown by intrinsic parameter (9) that is developed by Martin and expressed as:

\[ \phi = \frac{(\gamma \cos \theta)}{2 \mu} \tag{1} \]

For which: \( \gamma \) = Surface energy (mN/m), \( \theta \) = Liquid-Solid contact angle, \( \mu \) = molten viscosity

High intrinsic parameter value is used as the description of infiltration speed improvement for the lower viscosity of molten Alloys.

Although the stability of ceramic phase in the Metal-Ceramic system is usually only allowing a few solubilities, but the small amounts of solution can reduce solid-liquid interface energy. Adsorption is a surface reaction that is depend on concentrate, temperature and diffusivity. The relationship between the adsorption, temperature, surface energy, and concentrate is expressed by the Gibbs equation:

\[ \Gamma = -\frac{1}{RT} \frac{d\gamma}{dX} \tag{2} \]

For which:

\( \Gamma \) = Adsorbs (m²/mol)  
\( R \) = Gas constant (8.3144 joules /mol)  
\( \gamma \) = Surface energy (mN/m)  
\( X \) = Solute Mole faction

The greater the adsorption, the more the solute tends to lower the surface energy. The time dependence of wetting can be to explained in terms of reaction kinetic in ceramic-metal system, for a system of high reactivity interfacial reaction proceed quickly after physical contact between liquid and solid phases.

Generally, wetting ability is poor and wetting process is slow for less reactive system, so that needed by the longer time to reach the wetting. Analyzing of the oxide layer on the ceramic phase considered one of the factors affecting the kinetics of wetting. The liquid metal starts infiltration if decrease of the solid-liquid interfacial energy.