JMEPEG
https://doi.org/10.1007/s11665-022-07535-4

1059-9495/$19.00

TECHNICAL ARTICLE

Application of Response Surface Methodology for Parameter Optimization of Aluminum 7075 Thixoforming Feedstock Billet Production

A. Megalingam, A.H. Ahmad, N.A. Alang, J. Alias, and N.A. Abd Razak

Submitted: 15 March 2022 / Revised: 24 September 2022 / Accepted: 1 October 2022

This paper aims to present the experimental work to formulate optimum processing parameters of the direct thermal method (DTM) using response surface methodology (RSM) for high-quality feedstock billet production. The DTM is one of the techniques which is used to produce aluminum 7075 alloy feedstock billets with globular microstructures for thixoforming operations. Based on the central composite design (CCD) techniques, 13 experiments were performed using two factors and levels. Pouring temperature parameters in CCD varied from 645 to 685 °C, with holding times ranging from 20 to 60 s. The size of the microstructures of the produced feedstock billets was measured, and the different parameter combinations were analyzed in detail by RSM. Moreover, the distribution of elements and the impact of primary and secondary phases on microstructures were examined by scanning electron microscopy (SEM)). Statistical analysis showed that R^2 values of circularity and aspect ratio were 0.96 and 0.97 and meanwhile probability values ($p < 0.05$), (F-value > p-value) at 95% confidence level, with an acceptable error percentage. RSM results showed that a pouring temperature of 665 °C and a holding time of 60 s produced the optimum globular microstructure. The grain diameter, circularity, and aspect ratio values were 61.12 μm, 0.707, and 1.44, respectively. Moreover, the predicted and experimental values are in good agreement. These experimental results that used the RSM explained the effects of the various combination parameters in detail using a limited number of experiments and have successfully identified the optimum parameters.

Keywords aluminum 7075, globular microstructure, optimization, response surface methodology, semisolid metal processing, thixoforming

1. Introduction

Semisolid metal processing (SSMP) is a modern technique used as an alternative to conventional metal castings, which provides a great possibility to produce near net-shaped metal components in a single forming operation (Ref 1-3). It follows the thixotropic behavior of non-dendritic globular microstructure alloys in the semisolid state. SSMP is useful for minimizing casting defects such as microporosity, microshrinkage, dendritic solidification in the fluid pool, hot tearing in the liquid phase, microseparation at the grain boundaries, and thermal shock effects (Ref 4-6).

A. Megalingam and **N.A. Abd Razak**, Department of Mechanical Engineering, College of Engineering, Universiti Malaysia Pahang, Lebuhraya Tun Razak, 25150 Kuantan, Pahang, Malaysia; **A.H. Ahmad** and **J. Alias**, Department of Mechanical Engineering, College of Engineering, Universiti Malaysia Pahang, Lebuhraya Tun Razak, 25150 Kuantan, Pahang, Malaysia; and Centre for Automotive Engineering, Universiti Malaysia Pahang, 26600 Pekan, Pahang, Malaysia; and **N.A. Alang**, Structural Performance and Materials Engineering (SUPREME), Faculty of Mechanical and Automotive Engineering Technology, Universiti Malaysia Pahang, 26600 Pekan, Pahang, Malaysia. Contact e-mail: asnul@ump.edu.my.

SSMP consists of two main categories, which are liquid and solid routes, based on the condition of the starting material. Several methods have been used to develop globular microstructures for feedstock billet production. The liquid route is performed in an agitated and non-agitated state. Agitated routes such as mechanical stirring, magneto hydrodynamic stirring (MHD), swirled enthalpy equilibrium device (SEED), and semisolid rheocasting (SSR) are only useful for small-scale laboratory experimentation, and it is not recommended for a large-scale industrial production. There are problems in implementing the insurgent action equally everywhere (Ref 2, 7). To achieve the uniform growth of the particles, it is necessary to reduce the heat of the molten metal within a limited time. New rheocasting (NRC) and cooling slope casting, as well as the solid routes such as strain-induced melt activated (SIMA), recrystallization and partial melting (RAP), and direct partial remelting (DPRM), are more expensive to operate. Deficiencies such as oxidation and gas porosity also occur (Ref 2). DTM is known to be an excellent method than other methods to produce a solid globular microstructure surrounded by a liquid matrix without distortion by a simple process (Ref 8).

DTM is a method for producing globular microstructure feedstock billets for the thixoforming process (Ref 9). Various studies have indicated that a significant number of high-quality billets were produced at a low cost in a simple method (Ref 8, 10). It has numerous advantages: ease of operation, rapid cooling system, immediate heat transfer between thin copper mold and molten metal, and low heat dissipation with the surroundings (Ref 11). Furthermore, rapid cooling in water at

Published online: 02 November 2022