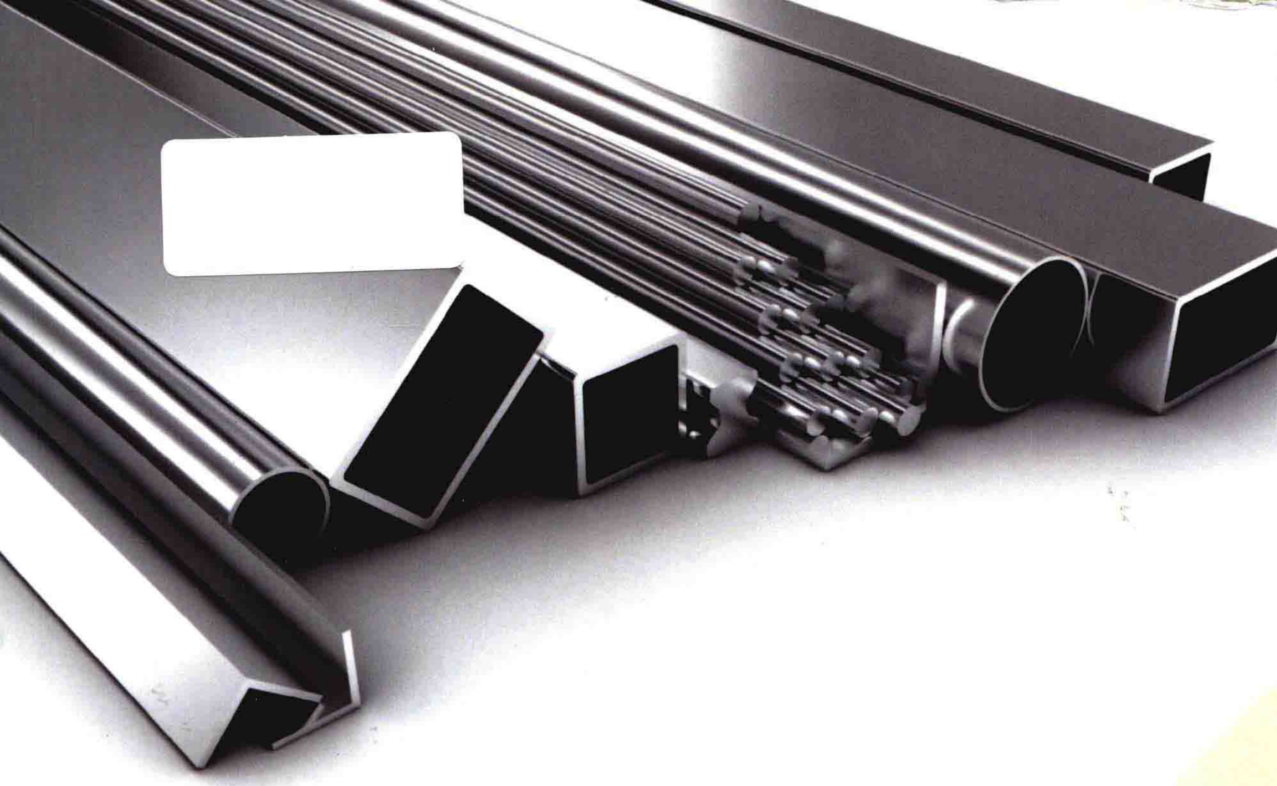

New Materials and Processing Technologies

Edited by

Tomasz Tokarski

TRANS TECH PUBLICATIONS

New Materials and Processing Technologies

Selected, peer reviewed papers from the
International Conference of
Non-Ferrous Metals - Processing and New Technologies,
June 4-6, 2014, Wisła, Poland

Edited by

Tomasz Tokarski

TTP

Trans Tech Publications Ltd
Churerstrasse 20
CH-8808 Pfaffikon
Switzerland
http://www.ttp.net

Volume 641 of
Key Engineering Materials
ISSN print 1013-9826
ISSN cd 1662-9809
ISSN web 1662-9795

Full text available online at *http://www.scientific.net*

***Distributed** worldwide by*

Trans Tech Publications Ltd
Churerstrasse 20
CH-8808 Pfaffikon
Switzerland

Fax: +41 (44) 922 10 33
e-mail: sales@ttp.net

and in the Americas by

Trans Tech Publications Inc.
PO Box 699, May Street
Enfield, NH 03748
USA

Phone: +1 (603) 632-7377
Fax: +1 (603) 632-5611
e-mail: sales-usa@ttp.net

printed in Germany

New Materials and Processing Technologies

Edited by
Tomasz Tokarski

Preface

International Conference of Non-Ferrous Metals - Processing and New Materials (ICNFM) was organized by the Faculty of Non-Ferrous Metals of AGH-University of Science and Technology in Cracow, Institute of Non-Ferrous Metals in Gliwice with support of the Foundation of Development and Promotion of Science. The aim of the conference was to establish an effective platform for institutions and industries to share ideas of innovative technology and knowledge. The conference covered wide range of topics in the area of materials engineering, metalworking, metal recycling, precious metals. Over 100 presentations and 30 posters were presented at the conference from witch 40% was selected to this issue of Key Engineering Materials. Beside with interesting presentations and discussions the during participant could enjoyed various relaxing options favoring personality and vitality development provided by Gołębiewski Hotel in the pearl of Beskidy Mountains, Wisła. I would like to express gratitude to the organizing and scientific committee, paper reviewers and especially to all participants for their great contribution to the conference success.

I believe that fruitful discussion of the topics presented during the conference will lead to the closer cooperation with respect to research, education and the industry.

On behalf of the organizing committee

Prof. Maria Richert

Dean of the Non-Ferrous Metals Faculty
Chairman of the 1st ICNFM, 4—6 June, 2013

Committees

Chairman

Prof. Maria Richert

Co-Chairmans

Prof. Joanna Karwan-Baczewska
Prof. Wacław Muzykiewicz
Prof. Stanisław Pietrzyk
Prof. Krzysztof Żaba

Organized by

Faculty of Non Ferrous Metals, AGH University of Science and Technology, Poland

Co-organized by

Institute of Non Ferrous Metals, Gliwice, Poland
Foundation of Development and Promotion of Science, Cracow, Poland

Scientific Committee

V. Agarwala, Indian Institute of Technology Roorkee, India
L. Blacha, Silesian University of Technology, Poland
J. Borowski, Metal Forming Institute, Poland
E. Cesari, University of the Balearic Islands, Spain
R. Chamer, Institute of Non-Ferrous Metals Gliwice, Poland
A. Chmielarz, Institute of Non-Ferrous Metals Gliwice, Poland
A. Ciaś, AGH University of Science and Technology, Poland
L. Ciura, Institute of Non-Ferrous Metals Gliwice, Poland
A. Czyrska-Filemonowicz, AGH University of Science and Technology, Poland
B. Dubiel, AGH University of Science and Technology, Poland
H. Dyja, Czestochowa University of Technology, Poland
R. M. Estrella, Michoacan State University, Mexico
K. Fitzner, AGH University of Science and Technology, Poland
W. Gąsior, Institute of Metallurgy and Materials Science, Poland
Z. Gronostajski, Wrocław University of Technology, Poland
F. Grosman, Silesian University of Technology, Poland
E. Guzik, AGH University of Science and Technology, Poland
M. Hardygóra, KGHM Cuprum, Poland
M. Hetmańczyk, Silesian University of Technology, Poland
A. Kalukiewicz, AGH University of Science and Technology, Poland
M. Karbowniczek, AGH University of Science and Technology, Poland
A. Kłyszewski, Institute of Non-Ferrous Metals Gliwice, Poland
R. Knosala, Opole University of Technology, Poland
T. Knych, AGH University of Science and Technology, Poland
M. Książek, Foundry Research Institute, Poland

Table of Contents

Chapter 1: Materials and Related Industrial Technologies

Chapter 2: Metalworking

CHAPTER 1:

Materials and Related Industrial Technologies

Key Engineering Materials Vol. 641 (2015) pp 3-9
© (2015) Trans Tech Publications, Switzerland
doi:10.4028/www.scientific.net/KEM.641.3

Submitted: 16.06.2014
Revised: 05.11.2014
Accepted: 19.12.2014

An analysis of the microstructure and mechanical properties of rapidly solidified Al-1Fe-1Ni-5Mg alloy

Anna Kula[1,a*], Ludwik Blaz[1,b] and Makoto Sugamata[2,b]

[1] Faculty of Non-Ferrous Metals, AGH – University of Science and Technology, 30-059 Cracow, Poland

[2] Department of Mechanical Engineering, College of Industrial Technology, Nihon University, 1-2-1 Izumi-cho, Narashino Chiba 275 – 8575, Japan

[a] kula@agh.edu.pl, [b] blaz@agh.edu.pl, [c] sugamata@cit.nihon-u.ac.jp,

Keywords: aluminum alloys, rapid solidification, plastic consolidation, TEM

Abstract. Experiments on Al-1Fe-1Ni-5Mg alloy were performed to determine the effect of rapid solidification (RS) on the material strengthening, which result from the refining of the grains and intermetallic compounds. Additionally, an enhancement of the material strengthening due to magnesium addition was also observed. RS procedure was performed using spray deposition of the molten alloy on the rotating water-cooled copper roll. As a result, highly refined structure of rapidly solidified flakes was obtained. Using common powder metallurgy (PM) techniques, i.e. cold pressing, vacuum degassing and hot extrusion, as received RS-flakes were consolidated to the bulk PM materials. For comparison purposes, the conventionally cast and hot extruded Al-1Fe-1Ni-5Mg alloy was studied as well. RS process combined with hot pressing and extrusion procedure was found to be very effective method for the manufacture of fine grained material and effective refinement of intermetallic compounds. However some inhomogenity of particles distribution was observed, which was ascribed to varied cooling rate dependent on the particular spray-drop size. Mechanical properties of as-extruded material were examined using compression test at 293-873K. High strength and ductility of as-extruded RS material with respect to conventionally produced alloy were observed. However, the effect of enhanced mechanical properties of RS material is observed only at low deformation temperatures. It was found that increasing deformation temperature above 400K results in negligible hardening of RS samples if compared to conventionally produced material.

Introduction

Several novel processing methods have been developed during the last decades to improve the performance of the materials produced by means of common industrial metallurgy (IM) methods. Among these methods rapid solidification (RS) techniques are of particular interest since the increase of the solid solubility, reduction of the alloying elements segregation and fined-grained microstructures can be achieved [1-2]. It has been already recognized that in many alloy systems, these effects result in improved mechanical, corrosion, physical and other properties [3-4].
Application of RS techniques has been extensively studied for Aluminum-Transition Metal (Al-*TM*) alloy systems due to its beneficial influence on the constituents phase morphology. In general, the hardening mechanism of Al-*TM* alloys is based on the high volume fraction of finely distributed primary intermetallic particles. Unfortunately, conventional ingot metallurgy processing routes cannot satisfy this requirement, primarily because of the formation of coarse intermetallic particles, which in turn deteriorate mechanical properties. Alternatively, application of the rapid solidification techniques enable significant improvement of mechanical properties, which result from the development of fine-scale particles evenly distributed in the aluminum matrix.
In the aluminum based materials produced by rapid solidification, transition metals such as Fe, Ni, Mn, V, Si, Cr [5-9] are usually selected as the alloying elements due to its slow diffusivity and low solubility limit in aluminum. Those factors are known to be beneficial for the materials, which are awaited to demonstrate a high thermal stability of their properties at elevated temperatures [6, 10].

In fact, it has been shown by e.g. Vojtěch et al. [6], Mitra [10] that high temperature treatment of Al-Cr [6] and Al-Fe-V-Si [10] alloys does not affect mechanical properties, which is related to high thermal stability of aluminide dispersoids morphology.
An advantage of rapid solidification based on structural modifications was found to be very promising for the development of high-strength Al-Fe-Ni alloys [9, 11]. Recent research results show that RS technique combined with plastic consolidation of RS-powders give a huge opportunity to produce materials with improved mechanical properties at ambient and elevated temperatures [11]. It has been also shown that the strengthening effect can be further enhanced by solid solution strengthening evoked by Mg additions [11].
While our previous researches on RS Al-Fe-Ni alloys have been dedicated to materials containing relatively high Fe and Ni additions [11], this work focuses on Al-Fe-Ni alloy with low Fe and Ni concentrations. In order to compensate reduced strengthening effect at relatively low alloyed Al-Fe-Ni alloy, an extra magnesium addition was used to increase the mechanical properties due to solid solution strengthening. In this paper the influence of rapid solidification on the microstructure and mechanical properties of the Al-1Fe-1Ni-5Mg alloy was analyzed. Microstructural features and its effect on the properties were discussed for both RS-material and samples produced by conventional, ingot metallurgy (IM) method.

Material and experimental procedure

Experiments were performed on aluminum alloy containing 1.31 wt.% Fe, 1.01 wt.% Ni and 4.77 wt.% Mg named hereafter Al-1Fe-1Ni-5Mg alloy. The alloy ingot was manufactured using a common metallurgy method from pure Al and pure alloying components. RS procedure was carried out using argon gas atomizing of melted alloy splat cooling on water-cooled and rotating cooper roll. The cooling rate during rapid solidification was estimated to be about $5 \cdot 10^5$ (K/s). Received RS-flakes were then consolidated to the bulk material using a cold pressing and vacuum degassing. Rods of 7 mm in diameter were extruded at ~670K from as-compressed material. For comparison purposes, conventionally cast and hot extruded IM Al-1Fe-1Ni-5Mg alloy was studied as well. Structural observations were performed using Hitachi SU-70 scanning electron microscope (SEM) equipped with back-scatter electron detector (BSE) and transmission electrons detector for STEM observations. Detailed analysis of fine structural components was performed using JEM 2010 transmission electron microscope (TEM) equipped with an Oxford Pentafet system for energy disperse X-ray analysis (EDX). Samples for SEM studies were prepared by means of standard metallography procedures, which included mechanical grinding and polishing with a 9, 3, 1 μm diamond suspensions and final polishing using 0.05 μm colloidal silica suspension. Thin foils for STEM and TEM observations were prepared using mechanical grinding of a sample to the thickness of ~100 μm and following electrochemical thinning by means of the twin-jet TENUPOL system and standard STRUERS procedures.
Samples for compression tests, 8 mm long and 6 mm in diameter, were machined from as extruded rods. Hot compression tests, within the temperature range 298–773K, were carried out at constant true strain rate $5 \cdot 10^{-3}$ s^{-1} using modified Instron testing machine. The hardness of hot deformed samples was measured using micro – Vickers testing machine and the load of 0,1kg (1N). Average hardness value was calculated for at least 10 measurement results.

Results and Discussion

In order to investigate the microstructures of as–extruded IM and RS Al-1Fe-1Ni-5Mg alloys SEM and TEM observations were performed. Relatively coarse-grained structure of IM sample is shown in Fig. 1a-b. The microstructure of RS Al-1Fe-1Ni-5Mg alloy was found to be effectively refined due to rapid solidification combined with hot extrusion as shown in Fig. 1c and Fig. 1d.