

Dr. Perumalla Janaki Ramulu  
A. Lavanya

# Design and Fabrication of Equal Channel Angular Extrusion Process Analysis for Non-Ferrous Materials



**Anchor Academic Publishing**

*disseminate knowledge*

**Janaki Ramulu, Perumalla, Lavanya, A.: Design and Fabrication of Equal Channel Angular Extrusion Process Analysis for Non-Ferrous Materials, Hamburg, Anchor Academic Publishing 2016**

PDF-eBook-ISBN: 978-3-96067-606-5

Druck/Herstellung: Anchor Academic Publishing, Hamburg, 2016

**Bibliografische Information der Deutschen Nationalbibliothek:**

Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über <http://dnb.d-nb.de> abrufbar.

**Bibliographical Information of the German National Library:**

The German National Library lists this publication in the German National Bibliography. Detailed bibliographic data can be found at: <http://dnb.d-nb.de>

**Dr. Perumalla Janaki Ramulu and A. Lavanya**

M.Tech (NIFFT), (PhD) (IITG)

MIE, IACSIT (MEG), IAENG, SCIEI, SMFRA, IDDRG, MASME, UAMAE, WASET, SAI Mech, ESME, ISAET

Associate Professor in the Programme of MDME, SoMCME

Adama Science and Technology University

Adama, Post Box: 1888, Ethiopia

All rights reserved. This publication may not be reproduced, stored in a retrieval system or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior permission of the publishers.

---

Das Werk einschließlich aller seiner Teile ist urheberrechtlich geschützt. Jede Verwertung außerhalb der Grenzen des Urheberrechtsgesetzes ist ohne Zustimmung des Verlages unzulässig und strafbar. Dies gilt insbesondere für Vervielfältigungen, Übersetzungen, Mikroverfilmungen und die Einspeicherung und Bearbeitung in elektronischen Systemen.

Die Wiedergabe von Gebrauchsnamen, Handelsnamen, Warenbezeichnungen usw. in diesem Werk berechtigt auch ohne besondere Kennzeichnung nicht zu der Annahme, dass solche Namen im Sinne der Warenzeichen- und Markenschutz-Gesetzgebung als frei zu betrachten wären und daher von jedermann benutzt werden dürften.

Die Informationen in diesem Werk wurden mit Sorgfalt erarbeitet. Dennoch können Fehler nicht vollständig ausgeschlossen werden und die Diplomica Verlag GmbH, die Autoren oder Übersetzer übernehmen keine juristische Verantwortung oder irgendeine Haftung für evtl. verbliebene fehlerhafte Angaben und deren Folgen.

Alle Rechte vorbehalten

© Anchor Academic Publishing, Imprint der Diplomica Verlag GmbH

Hermannstal 119k, 22119 Hamburg

<http://www.diplomica-verlag.de>, Hamburg 2016

Printed in Germany

## ABSTRACT

“Equal Channel Angular Extrusion (ECAE)” is a significant method in industrial forming applications, which is the most important method for production of ultrafine grained bulk samples, high plastic strains are introduced into the bulk material without any change in cross section. Equal channel angular extrusion has different die channel angles from which an optimum die channel angle should be identified. So that competent mechanical properties will be obtained from the extruder. This work is focused on the plastic deformation behavior of Al alloys by developing ECAE process and also studied the finite element analysis. For the simulation, the whole ECAE setup was modeled using CATIA and converted into STL file format. The STL files of ECAE imported into DEFORM-3D for simulations. The experiments are performed by fabricating the ECAE tools such as die, punch and billet. A series of experiments were carried out for the die angles of 115°, 125° and 135° and outer corner angle of 6°, billet diameter 9mm and height 70mm was used. A detailed analysis of the strains introduced by ECAP in a single passage through the die is noted. The experiments were conducted by attaching the ECAE tools to the Universal Testing Machine on aluminum alloy. From the experiment and simulation results, load, displacement, and punch force are evaluated and compared with each other.

# TABLE OF CONTENTS

<b>ABSTRACT</b> .....	<b>i</b>
<b>TABLE OF CONTENTS</b> .....	<b>ii</b>
<b>LIST OF FIGURES</b> .....	<b>iv</b>
<b>LIST OF TABLES</b> .....	<b>v</b>
<b>CHAPTER 1: INTRODUCTION</b> .....	<b>1</b>
1.1 History of Equal Channel Angular Extrusion Process .....	1
1.2 Aim and Scope of the Study .....	2
1.3 Equipment Used .....	3
1.3.1 Hydraulic Press .....	3
1.3.2 Mechanical Press .....	3
1.4 Tasks Involved.....	3
1.5 Organization of the Study.....	3
<b>CHAPTER 2: LITERATURE SURVEY</b> .....	<b>5</b>
2.1 Experimental Studies on Equal Channel Angular Extrusion Process .....	5
2.2 Numerical Analysis of Equal Channel Angular Extrusion Process .....	11
2.3 Finite Element Analysis of Equal Channel Angular Extrusion Process.....	13
2.4 Other Studies on Equal Channel Angular Extrusion Process.....	18
<b>CHAPTER 3: METHODOLOGY</b> .....	<b>19</b>
3.1 Experiment Setup .....	19
3.2 Equipment.....	20
3.2.1 Machine Frame or Loading Unit.....	20
3.2.2 Hydraulic System Unit.....	21
3.2.3 Electronic Control Unit.....	21
3.3 Die Design Details.....	21
3.4 Die Design Consideration.....	22
3.5 Different Parts of the Setup .....	22

3.6 Equal Channel Angular Extrusion Process Parameters .....	24
3.6.1 Channel Intersection Angle ( $\Phi$ ).....	24
3.6.2 Outer Corner Angle ( $\Psi_0$ ).....	24
3.6.3 Inner Corner Angle ( $\Psi_i$ ) .....	24
3.6.4 Inner Corner Radius ( $R_i$ ).....	24
3.6.5 Outer Corner Radius ( $R_o$ ).....	24
3.6.6 Temperature of Billet and Die .....	25
3.6.7 Friction.....	25
3.6.8 Force .....	25
3.6.9 Number of Passes.....	25
3.6.10 Deformation Route.....	25
3.7 Modeling of Equal Channel Angular Extrusion Setup.....	26
3.8 Raw Material Used For Experiment.....	27
3.9 Experimental Procedure For ECAE .....	28
3.10 Finite Element Analysis .....	29
3.11 Simulation Methodology .....	30
<b>CHAPTER 4: RESULTS AND DISCUSSION .....</b>	<b>31</b>
4.1 Experimental Investigation.....	31
4.2 Stress Evaluation at Different Steps .....	31
4.3 Punch Force Evaluation.....	34
<b>CHAPTER 5: CONCLUSIONS AND FUTURE SCOPE.....</b>	<b>38</b>
<b>REFERENCES.....</b>	<b>39</b>

## LIST OF FIGURES

3.1	Schematic representation of ECAE setup	19
3.2	Universal Testing Machine fixtures	20
3.3	UTM Hydraulic system unit	21
3.4	Punch and different channel angles of die	23
3.5	Modeling of punch	26
3.6	Modeling of die	26
3.7	Assembly of ECAE setup	27
3.8	ECAE setup on Universal Testing Machine	28
4.1	Before and after ECAP processing of the Al samples	31
4.2	Stress formations at different progressions for die channel angle of 105°	32
4.3	Stress formations at different progressions for die channel angle of 115°	32
4.4	Stress formations at different progressions for die channel angle of 125°	33
4.5	Stress formations at different progressions for die channel angle of 135°	34
4.6	Comparison of extrusion load with displacement with die channel angle of 105°	34
4.7	Comparison of extrusion load with displacement with die channel angle of 115°	35
4.8	Comparison of extrusion load with displacement with die channel angle of 125°	35
4.9	Comparison of extrusion load with displacement with die channel angle of 135°	36