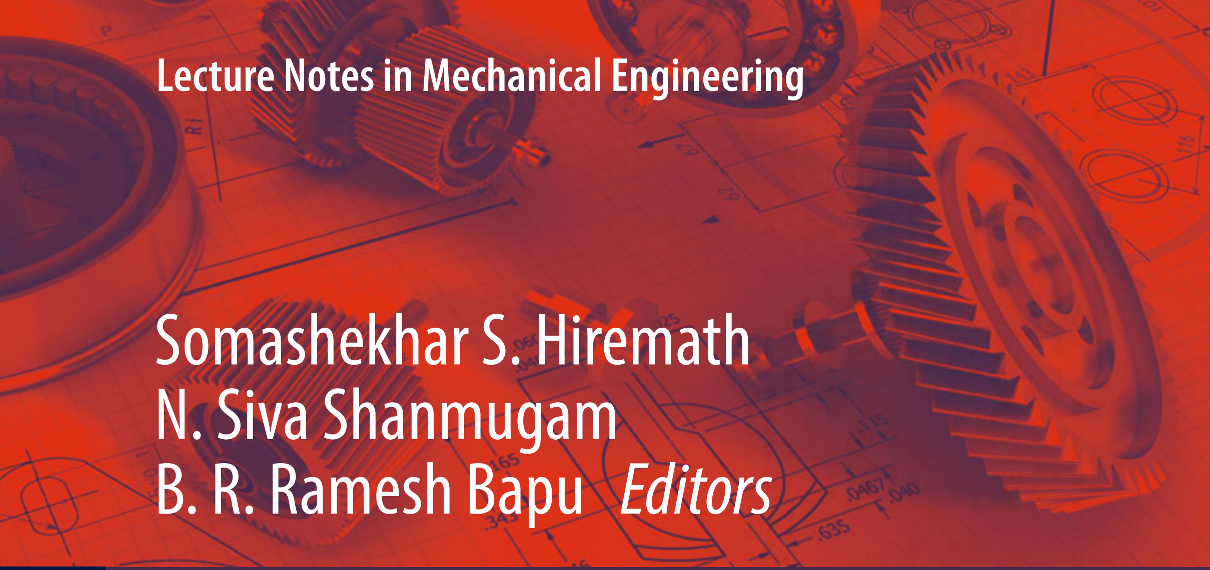


Lecture Notes in Mechanical Engineering

Somashekhar S. Hiremath
N. Siva Shanmugam
B. R. Ramesh Bapu *Editors*

Advances in Manufacturing Technology

Select Proceedings of ICAMT 2018

Springer

Lecture Notes in Mechanical Engineering

Lecture Notes in Mechanical Engineering (LNME) publishes the latest developments in Mechanical Engineering - quickly, informally and with high quality. Original research reported in proceedings and post-proceedings represents the core of LNME. Volumes published in LNME embrace all aspects, subfields and new challenges of mechanical engineering. Topics in the series include:

- Engineering Design
- Machinery and Machine Elements
- Mechanical Structures and Stress Analysis
- Automotive Engineering
- Engine Technology
- Aerospace Technology and Astronautics
- Nanotechnology and Microengineering
- Control, Robotics, Mechatronics
- MEMS
- Theoretical and Applied Mechanics
- Dynamical Systems, Control
- Fluid Mechanics
- Engineering Thermodynamics, Heat and Mass Transfer
- Manufacturing
- Precision Engineering, Instrumentation, Measurement
- Materials Engineering
- Tribology and Surface Technology

To submit a proposal or request further information, please contact the Springer Editor in your country:

China: Li Shen at li.shen@springer.com

India: Dr. Akash Chakraborty at akash.chakraborty@springernature.com

Rest of Asia, Australia, New Zealand: Swati Meherishi at swati.meherishi@springer.com

All other countries: Dr. Leontina Di Cecco at Leontina.dicecco@springer.com

To submit a proposal for a monograph, please check our Springer Tracts in Mechanical Engineering at http://www.springer.com/series/11693 or contact Leontina.dicecco@springer.com

Indexed by SCOPUS. The books of the series are submitted for indexing to Web of Science.

More information about this series at http://www.springer.com/series/11236

Somashekhar S. Hiremath ·
N. Siva Shanmugam · B. R. Ramesh Bapu
Editors

Advances in Manufacturing Technology

Select Proceedings of ICAMT 2018

Springer

Editors
Somashekhar S. Hiremath
Indian Institute of Technology Madras
Chennai, Tamil Nadu, India

N. Siva Shanmugam
National Institute of Technology
Tiruchirappalli, Tamil Nadu, India

B. R. Ramesh Bapu
Chennai Institute of Technology
Chennai, Tamil Nadu, India

ISSN 2195-4356 ISSN 2195-4364 (electronic)
Lecture Notes in Mechanical Engineering
ISBN 978-981-13-6373-3 ISBN 978-981-13-6374-0 (eBook)
https://doi.org/10.1007/978-981-13-6374-0

Library of Congress Control Number: 2019931857

© Springer Nature Singapore Pte Ltd. 2019
This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.
The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.
The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Organizing Committee

Chief Patron

Shri P. Sriram, Chairman, Chennai Institute of Technology, Chennai

Patrons

Shri P. Janakiraman, Vice Chairman, Chennai Institute of Technology, Chennai
Smt. S. Sridevi, Secretary, Chennai Institute of Technology, Chennai

Co-Patron

Prof. Dr. K. S. Srinivasan, Principal, Chennai Institute of Technology, Chennai

Conveners

Dr. B. R. Ramesh Bapu, Professor, Department of Mechanical Engineering
Dr. K. Vimalanathan, Professor, Department of Mechanical Engineering

Organizing Secretary

Dr. V. Dhinakaran, Professor, Department of Mechanical Engineering

Committee Members

Prof. M. D. Vijayakumar, Professor and Head, Mechanical Engineering
Dr. G. Gopalarama Subramaniyan, Professor, Mechanical Engineering
Dr. M. Ravichandram, Professor, Mechanical Engineering
Dr. K. Karthikeyan, Professor, Mechanical Engineering
Dr. S. Rajarasalnath, Professor, Mechanical Engineering
Prof. Prince Packiaraj, Professor, Mechanical Engineering
Dr. A. Dhanasekaran, Professor, Mechanical Engineering

International Advisory Committee

Dr. Angappa Gunasekaran, California State University, Bakersfield, USA
Dr. Moraru Roland, University of Petrosani, Romania
Dr. Joerg Niemann, University of Applied Sciences, Dusseldorf, Germany

Dr. Yuriy N. Saraev, Russian Academy of Sciences, Russia
Dr. Mikhail Slobodyan, Tomsk Polytechnic University, Russia
Dr. M. A. Rashid Sarkar, BUET, Dhaka, Bangladesh
Dr. Krishnaswami Srihari, Binghamton University, USA
Dr. Mohammad T. Khasawneh, Watson Institute for Systems Excellence (WISE), USA

National Advisory Committee

Chairman

Mr. P. Kaniappan, Managing Director, WABCO India Ltd

Advisory

Dr. K. Sanakaranarayanasasmy, NIT Tiruchirappalli
Dr. N. Siva Shanmugam, NIT Tiruchirappalli
Dr. S. Murugan, NIT Rourkela
Dr. N. Ramesh Babu, IIT Madras
Dr. Somashekhar S. Hiremath, IIT Madras
Dr. B. Muthukumar, IIT Guwahati
Dr. I. A. Palani, IIT Indore
Dr. L. Karunamoorthy, Anna University, Chennai
Dr. M. Kanthababu, Anna University, Chennai
Dr. N. Alagumurthi, Pondicherry Engineering College, Puducherry
Dr. V. Balasubramani, Annamalai University, Chidambaram
Dr. S. R. Devadasan, PSG College of Technology, Coimbatore
Dr. K. M. Paramasivam, MIT, Anna University, Chennai
Dr. K. Parthiban, NIT Tiruchirappalli
Dr. T. Ramesh, NIT Tiruchirappalli
Dr. V. Anandakrishnan, NIT Tiruchirappalli
Dr. S. Babu, PSG College of Technology, Coimbatore
Dr. K. Tamil Mannan, IGNOU, Delhi

List of Contributors and Reviewers

Dr. A. Arockiarajan, IIT Madras
Dr. Somashekhar S. Hiremath, IIT Madras
Dr. N. Siva Shanmugam, NIT Tiruchirappalli
Dr. B. Ravisankar, NIT Tiruchirappalli
Dr. V. Dhinakaran, Chennai Institute of Technology, Chennai
Dr. Jagadeesha, NIT Calicut
Dr. V. Pandu Ranga, IIT Bhubaneswar
Dr. Harpreet Singh, IIT Ropar
Dr. C. Sathiya Narayanan, NIT Tiruchirappalli
Dr. I. A. Palani, IIT Roorkee
Dr. P. Muthukumar, IIT Guwahati
Dr. V. P. Chandramohan, NIT Warangal

Dr. T. Radha Ramanan, NIT Calicut
Dr. T. Ramesh, NIT Tiruchirappalli
Dr. A. Krishnaveni, Government College of Engineering, Tirunelveli
Dr. Anathakrishnan, NIT Tiruchirappalli
Dr. S. Senthilkumaran, Anna University, Chennai
Dr. S. Periyasamy, Government College of Technology, Coimbatore
Dr. K. S. P. Rao, DMS SVH College of Engineering, Machilipatnam
Dr. S. Babu, PSG College of Technology, Coimbatore
Dr. N. M. Sivaraman, NIT Puducherry
Dr. A. John Rajan, VIT, Vellore
Dr. K. Jayaraman, IIT Madras
Dr. V. Raghuraman, VIT, Vellore
Dr. R. Bharanidaran, VIT, Vellore
Dr. J. Arunkumar, Auckland University of Technology, New Zealand
Dr. S. Sundar Pethaiah, Singapore Power, Singapore
Dr. V. Rajkumar, Singapore University of Technology and Design, Singapore

Foreword

This book published by Springer is an outcome of the International Conference on Advances in Manufacturing Technology—ICAMT 2018—that assimilates the research work of some prominent researchers in the extensive area of manufacturing technology.

This book presents an anthology of works presented at ICAMT 2018, covering subjects in the areas, such as material process, machine tools, cutting tools, manufacturing systems, optimization technologies, 3D scanning and re-engineering and 3D printing, and computer applications in design, as well as exciting subjects in contemporary manufacturing such as robotics and intelligent materials.

I am also grateful to Chairman Mr. P. Sriram and Principal Dr. K. S. Srinivasan, Chennai Institute of Technology; members of the ICAMT 2018 Committee; and the researchers who have actively participated in the elaboration of this book. A special thanks to Dr. Somashekhar S. Hiremath, Associate Professor, IIT Madras; Dr. N. Siva Shanmugam, Associate Professor, National Institute of Technology Tiruchirappalli; and Dr. B. R. Ramesh Bapu, Dean, Chennai Institute of Technology, who took the responsibility of being the editors of this book.

I would like to extend my sincere thanks to MK Autocomponents India Limited, ACMEE 2018, 13th International Machine Tool Exhibition (an initiative of AIEMA—Ambattur Industrial Estate Manufacturers' Association) for their support.

Chennai, India

Dr. V. Dhinakaran
Organizing Secretary-ICAMT 2018
Professor, Chennai Institute of Technology

Preface

Chennai Institute of Technology organized the International Conference on Advances in Manufacturing Technology—ICAMT 2018—in association with ACMEE on June 22–23, 2018. ICAMT 2018 was held for the third successive time in Chennai. The mission of ICAMT 2018 is to bridge the gap between academics and industry in the field of manufacturing technology. ICAMT 2018 includes oral, poster, and tutorial sessions given by experts in state-of-the-art topics.

ICAMT 2018 brings leading researchers from academia, R&D organizations, and industries from various countries together under one roof and at one time to discuss new opportunities, emerging trends of new technologies, machine tools, cutting tools, manufacturing systems, and simulation tools for solving manufacturing technology problems at various levels starting from material design to complex manufacturing system.

Sessions explore innovative as well as revered technologies, research, development and optimization, workforce efficiency, and productivity. Special emphasis is placed on expressing application trends, progress, and future course of manufacturing technology. ICAMT is planned to be held once in 2 years and will reflect the changing scenario in manufacturing and empower the future growth in a sustainable manner.

Chennai, India

Somashekhar S. Hiremath
N. Siva Shanmugam
B. R. Ramesh Bapu

About This Book

The present issue of Lecture Notes in Mechanical Engineering from Springer is the outcome of International Conference on Advances in Manufacturing Technology (ICAMT 2018) held at **Chennai Institute of Technology, Chennai, Tamil Nadu, India**, on June 22–23, 2018, as a parallel event with ACMEE, an international machine tool exhibition conducted in association with Ambattur Industrial Estate Manufacturers' Association (AIEMA). This edition of the ICAMT proceedings provides the in-depth work of different researchers and practicing engineers who are all working in the field of manufacturing industries and academic institutions throughout the globe. This book covers diversified topics of contemporary manufacturing technology such as:

Material process
Machine tools
Cutting tools
Robotics and automation
Manufacturing systems
Optimization technologies
3D scanning and re-engineering and 3D printing
Computer applications in design
Analysis and simulation tools for solving manufacturing technology problems at various levels starting from material designs to complex manufacturing systems.

Contents

About the Editors

Dr. Somashekhar S. Hiremath is Associate Professor at the Department of Mechanical Engineering, Indian Institute of Technology (IIT) Madras. He received his doctoral degree in 2004 from IIT Madras. He has published more than 150 papers in national and international journals. He has delivered more than 75 Invited talks on various topics of his research at engineering colleges, universities, research centers, industries, and conferences. Dr. Somashekhar also worked as a visiting Professor at Ecole Centrale de Nantes, France and Warsaw University of Technology, Poland. Currently, he is handling many consultancy and sponsored projects of various industries and R&D institutions of defense, Government of India. His current research areas are mechatronic system design, system simulation and modeling, robotics, finite element modeling, micromachining, fluid structure interactions, and fluid power systems.

Dr. N. Siva Shanmugam is affiliated to the Mechanical Engineering department, National Institute of Technology (NIT), Tiruchirappalli, India where he is currently working as Associate Professor. He received his doctoral degree in 2012 from NIT Tiruchirappalli. He has published numerous papers in reputed national and international peer-reviewed journals. He is actively associated with different national and international societies and academies. He has delivered several invited talks at various engineering institutions and industries located in different parts of India such as Tamil Nadu, Kerala and Andhra Pradesh. He has completed several research and consultancy projects, further he is handling multiple consultancy and sponsored projects for Bharat Heavy Electrical Limited (BHEL) and ISRO, Government of India. His research interests include FE simulation of welding processes, ergonomics study, and biomechanics.

Dr. B. R. Ramesh Bapu is currently working as Professor and Dean (R&D) at the Department of Mechanical Engineering at Chennai Institute of Technology, Chennai, Tamil Nadu, India. He received his bachelor's degree in Mechanical Engineering from Madurai Kamaraj University, in 1989, and his Master of Engineering Degree from the University of Madras and BITS (Pilani). He has 30 years of teaching experience and he has published 80 papers in reputed national and international journals, and conference proceedings. He is member of IE (I), SAE, IIPE and ISTE. He is also a Research Supervisor of Anna University, Chennai, JNTU Ananthapur, JNTU Kakinada, Sathyabama University and St. Peter's University. He has guided six doctoral scholars. His research areas of interest include thermal, renewable energy, high temperature coating, and alternate fuels.

Evaluation of Tensile Properties of Nanoclay-Filled Madar Fiber-Reinforced Polyester Hybrid Composites

Gunti Rajesh, M. V. Raghavendra Rao, K. Vijay and S. Gopinath

Abstract In the present work, an effort has been made to improve the mechanical properties of natural fiber-reinforced polyester composite using nanoclay. The composite specimens were prepared with varying weight proportions of short-madar fiber in the polyester matrix from 2.5 to 15% at an interval of 2.5% without and with nanoclay of 1%. The samples were then tested for tensile properties and the results were analyzed. The results showed that the tensile strength of composite was increased with increased fiber loading up to 10%, and with further addition of fibers, there was decrease in the tensile strength. The maximum value attained for 10% fiber loading was 23.33 MPa. The tensile strength of nanoclay-filled madar fiber-reinforced composite is increased to a value of 25.16 MPa up to 10% fiber loading and then with further addition of fibers along with nanoclay, the tensile strength is reduced. It is also observed that there increase in the modulus of madar fiber composite to a value of 520.2 MPa up to fiber loading of 15% and the tensile modulus of nanofilled fiber composites is increased to a value of 460.35 MPa up to fiber loading of 15% which is 11.5% less compared to that of composite without nanoclay. It is observed that there is reduction in the percentage elongation at break for madar fiber-reinforced polyester composite with and without nanoclay filler. The drop is 43.7% in madar fiber composite and it is much higher in composite filled with nanoclay.

Keywords Polyester · Madar fiber · Nanoclay · Tensile strength

1 Introduction

From several decades, lignocellulosic natural fibers have been widely used in the development and fabrication of partially degradable polymer composites. Environmental safety and use of renewable materials for making greener world have lead

---

G. Rajesh (✉) · M. V. Raghavendra Rao · K. Vijay · S. Gopinath
Department of Mechanical Engineering, DVR & Dr. HS MIC College of Technology,
Kanchikacherla 521180, Andhra Pradesh, India
e-mail: rajesh.mtech@gmail.com

S. S. Hiremath et al. (eds.), *Advances in Manufacturing Technology*,
Lecture Notes in Mechanical Engineering,
https://doi.org/10.1007/978-981-13-6374-0_1

industries to use natural fibers as reinforcing materials in composites [1]. Natural fibers have attractive and possible advantages, such as cheaper in cost, reduced tool wear, lower density, and reasonable specific strength, apart from their inbuilt features such as renewability and degradability. A huge number of natural fibers were available in the nature those are being used as reinforcements.

Nowadays, polymer nanocomposites reinforced with natural fibers are widely used for automobile, aerospace, sports, and military applications due to their multifunctional characteristics such as high specific strength, improved mechanical properties, flame retardancy, high corrosion resistance, and low cost when compared to synthetic fiber-reinforced polymer composites [2]. The hybridization is the practice that can eliminate the shortcomings of the present composites reinforced either by natural fibers or clay particles, like low durability and higher water absorption by natural fibers that make them unbalanced with non-polar polymer matrix and non-degradable characteristic of plastics based on clay particles [3].

The nanocomposites were fabricated with varying compositions (0, 0.5, 1, 1.5, and 2 wt%) of Cloisite15A as nanofiller along with glass fiber reinforcement in the polyester. The consequences of addition of nanoclay on the thermal, mechanical, and dynamic mechanical properties of nanocomposites were investigated [4]. The results of tensile and impact tests have obtained 1% as the best possible percentage of clay content in the composite for better mechanical properties. However, the storage modulus of composite was improved for 1% nanoclay fill. Thermogravimetric analysis indicated the initial degradation that starts at 200 °C for all the samples. The tensile fractured surfaces analyzed by SEM indicated brittle fracture for glass fiber-reinforced polyester without nanoclay, whereas by the addition of nanoclay the fracture has changed to ductile nature. Various categories of nanoclay along with natural fiber-based composites giving particular importance to their applications as food packaging and a summary of the most advanced and emerging characteristics of nano technology to develop eco-friendly hybrid composites compatible for food packaging were presented [5].

Wild cane grass fiber up to 40% volume fraction and organically modified montmorillonite (MMT) nanoclay of 4% were added to polyester resin to prepare hybrid composite, and their mechanical properties were investigated [6]. The results indicated that the use of nanoclay has shown noteworthy improvement in tensile, flexural, and impact properties of wild cane grass fiber-reinforced composites. The consequences in addition of nanoclay filler on mechanical and morphological properties of Napier/epoxy composites were examined [7]. The Napier/epoxy composites were fabricated with 2–5 wt% of montmorillonite (MMT) nanoclay by vacuum infusion technique and tested for flexural properties. The results depicted that flexural strength of composite was increased when 3% of nanoclay was added to it. However, there was an increase of 180% in flexural modulus of composite with 5% of nanoclay filler. The biocomposites from unsaturated polyester (UP) resin and chemically modified bamboo fibers were fabricated with hand layup method [8]. In this study, nanocomposite was prepared initially from UP and nanoclay by solution method. Then, that solution was poured on to the selective mat layers to prepare hybrid composite. Composites showed good properties at 90% of bamboo fibers modified by vinyl silane solution of 0.7 and 1% of nanoclay filler.

A relative study was made on the fracture toughness of woven glass fiber/polypropylene, chopped glass fiber/polypropylene, and nanoclay-filled polypropylene composites [9]. The technology of nano and microscale particle reinforcement in various polymeric fiber-reinforced composites with polyamides (PA), polyurethanes, polyesters, polypropylenes, and high-performance/temperature engineering polymers such as poly(ether-ether ketone) (PEEK), polyimide (PI), polyarylacetylene (PAA), and poly p-phenylene benzobisoxazole (PBO) was examined [10]. The effect of amount of nanoclay and alkali treatment of wood flour on physical and mechanical properties of low-density polyethylene (LDPE) composites with beech flour was studied [11]. In this study, 40% of wood flour chemically treated with 2% alkaline was added to LDPE. Cloisite15A nanoclay particles were added to the composite in different weight ratios. The results indicated a reduced water absorption rate by increasing the nanoclay content and alkaline treatment on flour. The tensile strength was also increased with increasing the nanoclay content, besides using the chemical treatments on flour. Also, the impact strength was improved by 3% with increased nanoclay content.

The effect of addition of nanoclay particles on the flame retarding properties of wood–fiber/plastic composites (WPC) were investigated [12]. This study indicated that the structure of nanocomposites and the clay content used had a great impact on the flame retardancy of WPC. Effect of addition of nanoclay on the fiber/matrix adhesion in epoxy/glass composites was investigated [13]. In this study, different organically modified clays were added at different weight fractions in the epoxy matrix. The results depicted that the formation of intercalated microstructures due to nanoclay led to considerable improvement in mechanical and thermal properties of the epoxy matrix.

Though several researchers have explored the advantages of addition of nanoclay in the natural fiber composites, there is still ample scope for the development of nanofilled composites reinforced with new natural fiber composites. In this study, a new mixture of natural fiber and matrix, i.e. madar fiber and polyester with 1% nanoclay were considered to fabricate hybrid composite. The short fibers with varying weight fraction in polyester were considered along with nanoclay, and tensile properties were evaluated.

2 Materials and Methods

2.1 Materials

The polyester resin of the grade ECMALON 4413 with viscosity of 500–600 cPs (Brookfield viscometer) and a specific gravity of 1334 kg/m^3 at 25 °C was purchased from Bindu Agencies Pvt. Ltd., Vijayawada, India. Methyl ethyl ketone per-

Table 1 Composite sample fabrication

S. no.	Fiber, wt%	Nanoclay, wt%	Polyester, wt%
1	2.5	1	96.5
2	5	1	94.0
3	7.5	1	91.5
4	10	1	89.0
5	12.5	1	86.5
6	15	1	84.0

oxide (MEKP) accelerator and cobalt octoate ($C_{16}H_{30}CoO_{4)}$ catalysts namely were obtained from local market. The organically modified montmorillonite (MMT) nanoclay used was supplied by sigma Aldrich, Hyderabad.

Extraction of Madar Fibers

Stem is collected from the madar (Calotropis Gigantea) plant and the fiber from the stem is extracted by water retting process. Here, the stalks of stems were submerged in water for 15 days. Then, the stems were taken out of water and were beaten gently using wooden mallet. The fibers were then extracted and dried in the sunlight for 48 h. The fibers were then chopped to a length of 3–4 mm.

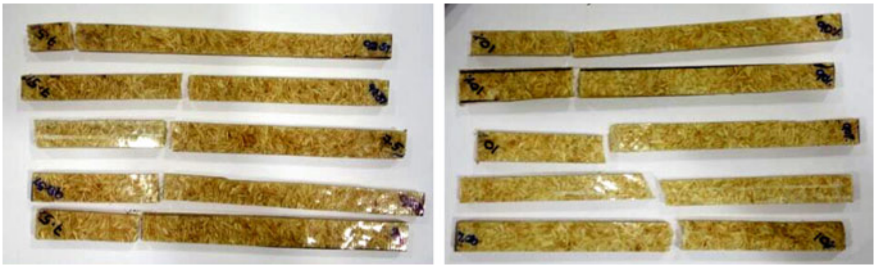
2.2 Fabrication of Composite

The modified nanoclay and polyester were dried in oven for about 2 h before use. The MMT particles have a fine particle-size distribution and exceptional dispersion in the matrix. An amount of 1% organically modified MMT nanoclay was mixed with the polyester resin by means of a sonicator for a period of 30 min at room temperature to obtain a homogenous mixture.

The madar fibers of size 3–4 mm were then added at various weight ratios from 2.5 to 15% to the mixture of polyester and nanoclay. The samples were prepared by filling the mixture in the mold prepared using rubber as per ASTM D638 for tensile properties using hand layup technique. For each weight ratio of fiber, five samples were prepared and an average of these was considered to calculate tensile strength. The detailed ratio of reinforcements and matrix to fabricate the composite was shown in Table 1.

2.3 Testing of Composite Samples

The samples were tested for tensile strength on a universal testing machine as per ASTM standard D638. The samples were loaded on the machine with maximum load set to 200 kg and the samples were tested at a crosshead speed of 0.5 mm/min



(a) 7.5% (b) 10%

Fig. 1 Tensile fractured samples of nanofilled polyester composites with 7.5 and 10% madar fibers

and the strain was measured with an extensometer of the machine. The elongation and their respective loads were noted (Fig. 1).

3 Results and Discussion

From the Fig. 2, it is observed that the tensile strength of untreated madar fiber-reinforced polyester composite was increased with increased fiber loading up to 10%, and with further addition of fibers, there was decrease in the tensile strength. The maximum value attained for 10% fiber loading was 23.33 MPa. The tensile strength of nanoclay-filled madar fiber-reinforced composite is increased to a value

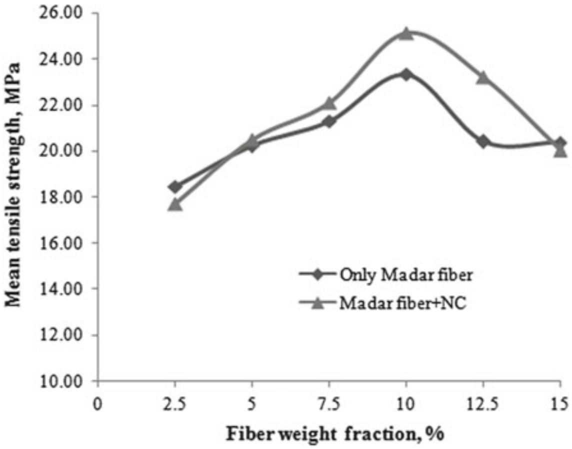


Fig. 2 Variation of tensile strength of nanoclay-filled and unfilled madar fiber-reinforced polyester composites with fiber loading

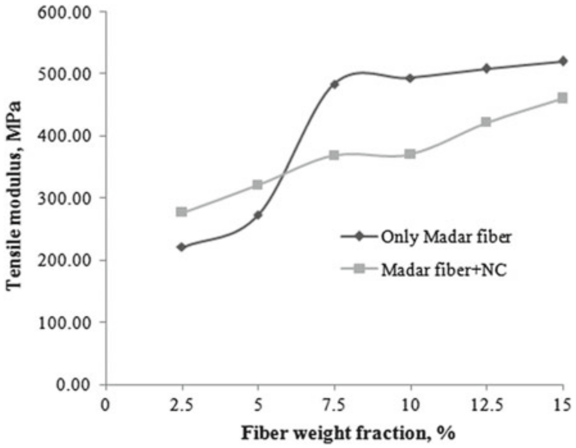


Fig. 3 Variation of tensile modulus of nanoclay-filled and normal madar fiber-reinforced polyester composites with fiber loading

of 25.16 MPa at 10% fiber loading which is 7.8% higher than madar fiber composite without nanoclay.

The increase in the tensile strength with increased fiber loading is due to better interaction between fiber and matrix and the drop in tensile strength with further addition of fiber beyond 10% is the fact that there is more fiber-fiber interaction than that of fiber–matrix interaction. It is observed that the addition of nanoclay in the madar fiber-reinforced composite has considerable effect on tensile strength of the composite.

From Fig. 3, it is observed that there was an increase in tensile modulus of madar fiber polyester composite without nanoclay to a value of 520.20 MPa at fiber loading of 15%. The tensile modulus of nanofilled fiber composites is increased to a value of 460.35 MPa at fiber loading of 15% which is 11.5% less compared to that of fiber-reinforced composite without nanoclay.

From Fig. 4, it is observed that there was reduction in the percentage elongation at break for madar fiber-reinforced polyester with and without nanoclay filler. The drop in the madar fiber-reinforced composite without nanoclay is 8.35–4.7%, i.e. the drop is 43.7%. The drop is much higher for nanofilled madar fiber-reinforced composite. The increase in the stiffness of the composite with the addition of nanoclay might be the reason for drop in elongation at break of the composite.

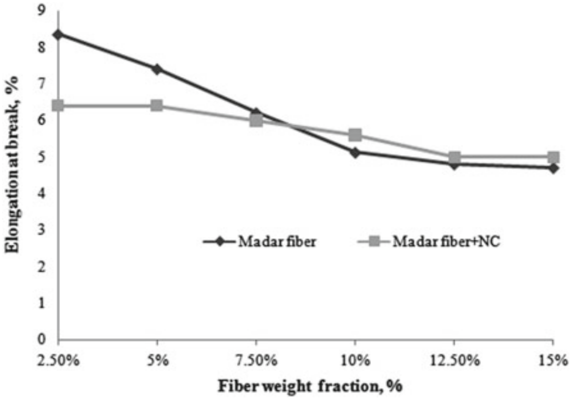


Fig. 4 Variation of % elongation of nanoclay-filled and normal madar fiber-reinforced polyester composites with fiber loading

4 Conclusions

With the results obtained from the experimental procedure, the following conclusions were made.

- The tensile strength of madar fiber-reinforced polyester composite with and without nanoclay was increased with increased fiber loading up to 10%, and with further addition of fibers, there was decrease in the tensile strength. The tensile strength of nanoclay-filled madar fiber-reinforced composite is increased to a value of 25.16 MPa at 10% fiber loading which is 7.8% higher than madar fiber composite without nanoclay.
- There was an increase in tensile modulus of madar fiber polyester composite without nanoclay to a value of 520.20 MPa at fiber loading of 15%. The tensile modulus of nanofilled fiber composites is increased to a value of 460.35 MPa at fiber loading of 15% which is 11.5% less compared to that of fiber-reinforced composite without nanoclay.
- It is observed that there is reduction in the percentage elongation at break for madar fiber-reinforced polyester with and without nanoclay filler. The drop in the madar fiber-reinforced composite without nanoclay is 8.35–4.7%, i.e. the drop is 43.7%. The drop is much higher for nanofilled madar fiber-reinforced composite.
- Finally, it is concluded that the fiber loading has influenced the properties of composite and also there is significant role of adding nanoclay of 1% in improving the strength of the composite.

References

1. Saba N, Tahir PM, Jawaid M (2014) A review on potentiality of nano filler/natural fiber filled polymer hybrid composites. Polymers 6(8):2247–2273
2. Arulmurugan S, Venkateshwaran NR (2016) Vibration analysis of nanoclay filled natural fiber composites. Polym Polym Compos 24(7):507–516
3. Essabir H, Raji M, Bouhfid R, Qaiss AEK (2016) Nanoclay and natural fibers based hybrid composites: mechanical, morphological, thermal and rheological properties. In: Engineering materials—nanoclay reinforced polymer composites. Springer Science, Singapore
4. Binu PP, George KE, Vinodkumar MN (2016) Effect of nanoclay, Cloisite15A on the mechanical properties and thermal behavior of glass fiber reinforced polyester. Procedia Technol 25(2016):846–853
5. Majeed K, Jawaid M, Hassan A, Abu Bakar A, Abdul Khalil HPS, Salema AA, Inuwa I (2013) Potential materials for food packaging from nanoclay/natural fibres filled hybrid composites. Mater Des 46(6):391–410
6. Ratna Prasad AV, Balakotesara Rao K, Mohana Rao K, Ramanaiah K, Kumar Gudapati SP (2015) Influence of nanoclay on the mechanical performance of wild cane grass fiber-reinforced polyester nanocomposites. Int J Polym Anal Charact 20(6):541–556
7. Lim KM, Majid MSA, Ridzuan MJM, Basaruddin KS, Afendi M (2017) Effect of nano-clay fillers on mechanical and morphological properties of Napier/epoxy composites. IOP Conf Ser J Phys Conf Ser 908:1–9
8. Thanh T, Mao N, Ngan N, Thanh N, Tai D (2011) Effect of nanoclay on properties of the biocomposite based on unsaturated polyester resin and bamboo fibers. VNU J Sci Math Phys 27(3):165–173
9. Ramsaroop A, Kanny K, Mohan TP (2010) Fracture toughness studies of polypropylene—-clay nanocomposites and glass fibre reinforced polypropylene composites. Mater Sci Appl 1:301–309
10. Njuguna J, Pielichowski K, Desai S (2008) Nanofiller fibre-reinforced polymer nanocomposites. Polym Adv Technol 19(8):947–959
11. Nozari O, Madanipour M, Farsi M, Tabei A (2013) Mechanical properties and water uptake of nanoclay/wood flour/LDPE composites after fiber surfacemercerization. Cellul Chem Technol 47(3–4):295–301
12. Guo G, Park C, Lee Y, Kim Y, Sain M (2007) Flame retarding effects of nanoclay on wood–fiber composites. Polym Eng Sci 47(3):330–336
13. Dorigato A, Morandi S, Pegoretti A (2011) Effect of nanoclay addition on the fiber/matrix adhesion in epoxy/glass composites. J Compos Mater 46(12):1439–1451

Characterization of Economical Aluminium MMC Reinforced with Weld Slag Particles

P. Paranthaman, P. M. Gopal and N. Sathiesh Kumar

Abstract Rapid advancement in technology forces the researchers to search for advanced materials with higher performance like composites. The composites are known for their better mechanical properties and less weight, but the cost is the major factor that hinders the wider application of these materials. In this study, welding slag is reused as reinforcement to produce economical metal matrix composites, because slag is produced in enormous amount during welding of materials which causes pollution. The aluminium alloy (Al 6063) is used as base material. Weld slag of different weight proportions (0, 5 10 and 15 wt%) is mixed with Al 6063 through stir casting process, and samples are taken for investigation. The mechanical properties of the composites like tensile strength, compression strength and its wear behaviour are analysed. And also, the microstructure of the MMC is analyzed through optical microscope (OM) to determine the weld slag distribution in aluminium matrix material. The observed result indicates that the addition of weld slag particles with aluminium increases the mechanical properties. The composite having 15% of welding slag exhibits the best tensile and wear resistance.

Keywords Composite · Weld slag · Stir casting · Tensile strength · Compressive strength

1 Introduction

Metal matrix composites (MMCs) gain significant importance worldwide due to their superior mechanical properties, because materials with better strength and less weight are well suitable and necessary for engineering applications [1]. Further, the development of sustainable and reusable materials from existing things has observed

---

P. Paranthaman (✉) · P. M. Gopal · N. Sathiesh Kumar
Department of Mechanical Engineering, Karpagam Academy of Higher Education,
Coimbatore 641021, India
e-mail: paranth.ponnusamy@gmail.com

S. S. Hiremath et al. (eds.), *Advances in Manufacturing Technology*,
Lecture Notes in Mechanical Engineering,
https://doi.org/10.1007/978-981-13-6374-0_2

an ideal global attention and importance from engineers as well as the wide-ranging community and government [2, 3].

Aluminium and its alloys have superior mechanical properties while adding reinforcements during metal matrix composite (MMC) development. The wide spectrum of unique properties can be attained with Al MMCs at comparatively low processing expenditure. The Al-based MMCs have superior specific stiffness and strength, enhanced elevated temperature properties (concerning its monolithic alloy) and thermal conductivity. The multi-functional characteristic of Al-based composites has seen its exploitation in aerospace technology, electronic heat sinks, antenna reflectors, automobile drive shafts fins and engine machineries, along with others [4]. Properties of these Al-based matrix composites majorly subject to (1) composition of the base alloy, (2) the character of material reinforced and (3) the techniques opted for MMC processing.

Thus, a large amount of research works reported in the literature have attempted to address how these facets influence the properties and behaviour of aluminium matrix composites. The majority of research works reported on the literature on Al composites has been committed frequently only on some of the aluminium alloys, such as A357, A359, 2618, 2254, 6061 and 7075. However, not much study has been reported on the exploitation of Al 6063 as matrix material for the Al MMC fabrication. Al 6063 alloy is the most readily obtainable aluminium alloy in the global metal markets. It is processed in soaring quantities at small price by the majority of aluminium processing industries for applications such as the production of glazing bars and window sections, wind screen and sliding roof sections for the automobile industry, pipes and tubing and for furniture also. The perspective for developing aluminium-based MMC with superior performance by using Al 6063 alloy as base material has created the thrust of this research exertion.

In recent past, an enormous amount of research works are carried on waste particle-reinforced MMCs. Currently, fly ash cenosphere [5], rock dust [6, 7] and CRT glass [7, 8] like waste particles are tried as reinforcement, and good results were obtained. Similar to these wastes, welding slag is noteworthy and is produced while joining metals which cause the pollution and leftover of resources. But, an effective recycling technique for this industrial waste is not yet discussed widely.

Hence, the current research intents to reuse welding slag as reinforcement to produce the composite materials. Further, among various MMC development methodologies, stir casting furnishes superior matrix particle attachment as a result of stirring action of particles into the metals. The studies in the literature described that the uniform mixing and wetting be able to obtain by choosing suitable parameters while MMC processing [9].

The present research investigation explores the mechanical and wear behaviour of welding slag-reinforced Al 6063 MMCs. The effect of reinforcement percentage on mechanical and wear behaviour of MMC has been investigated experimentally.