Journal of Physics
Conference Series

The 11th Biennial Conference on Classical and Quantum Relativistic Dynamics of Particles and Fields

1239

The open access journal for conference proceedings
iopscience.org/jpcs

IOP Publishing

ISSN: 1742-6596

Table of contents for issue 1, volume 3103, Journal of Physics: Conference Series

Volume 3103

2025

Previous issue Next issue

International Symposium on Advances and Innovation in Mechanical Engineering 2024 (ISAIME 2024) 01/10/2024 - 02/10/2024 North Maluku, Indonesia

Accepted papers received: 27 August 2025
Published online: 08 October 2025

Open all abstracts

Preface

Energy

Design and Applied Mechanics

Advanced Material

Manufacture

JOURNAL LINKS

Journal home
Journal Scope
Information for organizers
Information for authors
Contact us
Reprint services from Curran Associates

Journal of Physics:
Conference Series

Preface

To cite this article: 2025 *J. Phys.: Conf. Ser.* **3103** 011001

The 5th ISAIME 2024 Committe

Patron:	Dr. M. Ridah Adiam, M.Hum	
Advisory:	Prof. Dr. Ir. Ario Sunar Baskoro, S.T., M.T., M.Eng	BKS-TM Indonesia
Co Advisory:	Prof. Dr. -Ing Mulyadi Bur	Universitas Andalas
	Prof. Dr. Ir. Triyogi Yuwono, DEA	Institut Teknologi Sepuluh November
	Prof. Dr. Ir. Yanuar, M.Sc., M.Eng	Universitas Indonesia
	Prof. Dr. Ir. Indarto, DEA	Universitas Gajah Mada
	Prof. Dr. Bambang Sudarmanta, S.T., M.T.	Institut Teknologi Sepuluh November
	Ir. Endah Harisun, S.T., M.T.	Universitas Khairun
	Ir. Kifli Umar, S.T., M.T.	Universitas Khairun
Chairman:	Ir. Lita Asyriati Latif, S.T., M.TM	Universitas Khairun
Vice Chair	Dr. Ir. Muchlis N, S.T., M.T.	Universitas Khairun
	Dr. Ir. Trisuyono, S.T., MS.Ren	Universitas Khairun
	Ir. Sandi Rais, S.T., M.T.	Universitas Khairun
Program Chair	Dr. Kadri Daud, S.T., M.T.	Universitas Khairun
	Dr. Ir. Iis Hamsir A. Wahab, S.T., M.Eng	Universitas Khairun
	Ir. M. Muzni Herbelubun, S.T., M.T.	Universitas Khairun
	Ir. Ahmad Seng, S.T., M.T.	Universitas Khairun
	Ir. Muhammad Jamil, S.T., M.T., ASEAN Eng.	Universitas Khairun
Scientific Advisory:	Prof. Dominique PERREUX	Université de Franche Comté, France
	Prof. Dr. Eng. Muhammad Aziz	The University of Tokyo, Japan
	Prof. Dr. Kulacthe Piantong	Ubon Ratchathani University, Thailand
	Prof. T. M. Indra Mahlia	University of Technology Sydney
	Prof. R. W. (Bill) Carter, Ph.D.	University of The Sunshine Coast, Australia
	Prof. Dr. Eng. Ir. Jalaluddin	Universitas Hasanuddin
	Prof. A. P. Bayuseno	Universitas Diponegoro
	Prof. Dr. Ing. Ir. Harwin Saptoadji	Universitas Gajah Mada
	Prof. Dr.-Ing. Nasruddin	Universitas Indonesia
	Dr. Ir. Sri Raharno S.T., M.T.	Institut Teknologi Bandung
	Ir. Berlin Paripurna, Ph.D.	Universitas Muhammadiyah Yogyakarta
Secretariat:	Maulana Ibrahim, S.T., M.T., Ph.D.	Universitas Khairun
	Ir. Bambang Tjiroso, S.T., M.Eng	Universitas Khairun
	Salkin Lutfi, S.Kom., M.Kom	Universitas Khairun
	Mochammad Apriayadi Hadi Sirad, S.T., M.T.	Universitas Khairun
	Amat Umron, S.T., M.T.	Universitas Khairun
	Fasril Samil S.T.	
	Safran Safrudin, S.T.	
Treasury and Marketing:	Yulinda Sakinah Munim, S.T., M.Sc	Universitas Khairun
	Sunarti Ibrahum, SE., M.Si	Universitas Khairun
	Ratni Ismail, SH	Universitas Khairun
Logistic:	Ir. Ivan Junaidy A. Karsim S.T., M.Eng	Universitas Khairun
	Ir. Witono Hardi, S.T., M.T.	Universitas Khairun
	Ir. Ishak Usman, S.T., M.T.	Universitas Khairun
	Ahmad P. Sarju, S.T., M.T.	Universitas Khairun
	Yunus Hi. Abbas, S.T., M.T.	Universitas Khairun
	Rudi Hartono, S.T., M.Ling	Universitas Khairun
	Iwan Gunawan, S.T., M.T.	Universitas Khairun
	Sahdar Radjak, S.T., M.T.	Universitas Khairun
	Syafrin Al Fajrin, S.T., M.Sc	Universitas Khairun
	Sukirman B, S.T., M.T.	Universitas Khairun

Journal of Physics: Conference Series **3103** (2025) 011001 doi:10.1088/1742-6596/3103/1/011001

The Indonesian Consortium of Mechanical Engineering Higher Education

PREFACE

The Indonesian Consortium of Mechanical Engineering Higher Education (BKS-TM Indonesia) has established the International Symposium on Advances and Innovation in Mechanical Engineering (ISAIME) as an annual scientific forum for academics, researchers, and practitioners in the field of mechanical engineering. The 5th ISAIME was convened on October 2, 2024, organized by the Mechanical Engineering Study Program, Faculty of Engineering, Universitas Khairun, Ternate, Indonesia, with the theme "Innovation in Science and Technology in Mechanical Engineering Toward Industry 4.0."

This symposium served as a platform to present and discuss recent advances, research findings, and innovations across a wide range of topics, including mechanical application design, energy conversion, manufacturing processes, materials engineering, and mechanical engineering education. Distinguished experts delivered a total of two keynote lectures from Universität Duisburg-Essen, Germany, and the University of Groningen, the Netherlands, while 52 technical papers were presented and grouped into four thematic areas: mechanical application design, energy conversion, manufacturing processes, and materials engineering. These contributions reflect the growing role of mechanical engineering in supporting technological innovation, environmental sustainability, and human resource development in the context of Industry 4.0.

The Organizing Committee gratefully acknowledges the sponsorship and support of various companies and partner institutions, as well as the commitment of all speakers, authors, and participants who contributed to the success of this event. The knowledge and insights shared during the 5th ISAIME are expected to foster academic collaboration, strengthen networks between academia and industry, and contribute to the advancement of science and technology in mechanical engineering.

Depok, August 16, 2025
Sekretarus Jenderal BKS-TM Indonesia

BADAN KERJA SAMA TEKNIK MESIN INDONESIA

Prof. Dr. Ir. Ario Sunar Baskoro, S.T., M.T., M.Eng

Journal of Physics: Conference Series **3103** (2025) 011001 doi:10.1088/1742-6596/3103/1/011001

Preface from the Organizing Committee

On behalf of the Organizing Committee, We would like to express our deepest gratitude and appreciation to all parties which have enabled the successful convening of the 5th International Symposium on Advanced and Innovation in Mechanical Engineering (ISAIME 2024) in conjunction with the 22nd Annual National Mechanical Engineering Seminar. This event is being held on October 2, 2024, at the Bela International Hotel, Ternate, Indonesia. Over the years, this symposium and seminar have served as an esteemed platform for the exchange of ideas, the dissemination of knowledge, and the strengthening of collaboration among academics, researchers, practitioners, and industry professionals in the field of mechanical engineering.

The theme of this year's symposium, "Innovation in Scientific and Technological in Mechanical Engineering Toward the Era of Industry 4.0", reflects the commitment to addressing current challenges while embracing opportunities brought forth by the digital transformation of industry. We expect that this event will provide participants with valuable insights into recent technological advancements, foster scholarly discussions, and inspire innovative contributions that can support industrial development and deliver meaningful benefits to society.

The Organizing Committee would like to acknowledge and thank all keynote speakers and invited speakers for their invaluable contributions, the participants for their active engagement, and the committee members for their dedication and effort in ensuring the successful preparation and implementation of this event.

We hope that the symposium and seminar will proceed smoothly and achieve their intended objectives, contributing significantly to the advancement of mechanical engineering knowledge and practice. We wish all participants a productive and rewarding experience at the 5th ISAIME 2024 and the 22nd Annual National Mechanical Engineering Seminar.

Sincerely,

Ir. Lita Asyriati Latif, S.T., M.TM, IPM
Chair of the Organizing Committee

Journal of Physics: Conference Series **3103** (2025) 011001 doi:10.1088/1742-6596/3103/1/011001

Three-dimensional tomographic imaging of flows in energy and process technology

Prof. Khadijeh Mohri

Tomography
Chair of Fluid Dynamics
Institute for Energy and Material Processes
Universitat Duisburg, Germany

Abstract

Three-dimensional tomographic imaging is applied to investigate transient and turbulent flows in energy and process technologies. Techniques, including Filtered Back Projection, Algebraic Reconstruction, Bayesian methods, and Evolutionary Reconstruction, are used in conjunction with optical diagnostics such as chemiluminescence and background-oriented schlieren tomography. Multi-simultaneous modality setups (up to 32 cameras) enable high-resolution, non-intrusive measurements of species concentration, temperature, and refractive index in flames and reactive flows. Applications range from laboratory-scale combustion studies to industrial gas-firing systems, supporting the validation of numerical models and process optimization. Results demonstrate the potential of tomography for low-cost, real-time 3D diagnostics in both research and industrial environments.

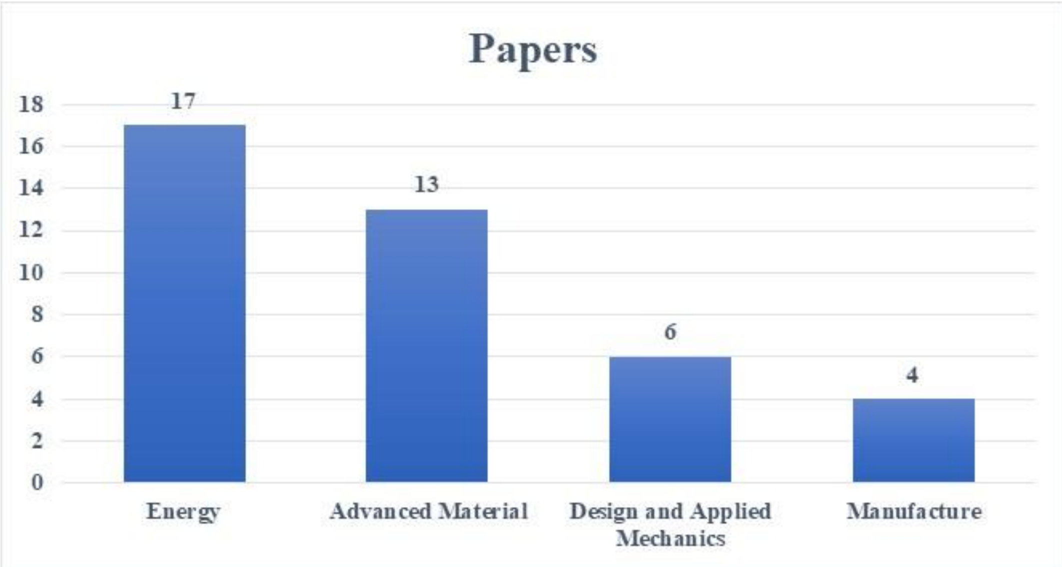
Journal of Physics: Conference Series **3103** (2025) 011001 doi:10.1088/1742-6596/3103/1/011001

Wednesday October 2nd, 2024
Mechanical Engineering Study Program, Universitas Khairun

08:00 – 08:30	**R E G I S T R A T I O N**
08:30 – 09:00	**Opening and Welcome Speech**
09:00 – 12:15	**Parallel Session I (Presentation):** - **ISAIME** - **SNTTM**
12:15 – 13:15	**ISHOMA**
13:15 – 14:00	**Parallel Session II (Presentation):** - **ISAIME** - **SNTTM**
14:00 – 15:30	**Keynote Speaker Session:** - **Prof. Khadijeh Mohri – Univ. Duisburg, Germany** - **Prof. Bayu Jauawardhana – Univ. of Groningen, Netherlands**
15:30 – 16:00	**COFFE BREAK**
16:00 – 18:00	**Parallel Session II (Presentation):** - **ISAIME** - **SNTTM**
18:00 – 20:00	**Closing Ceremony**

Topic Papers

Topic	Papers
Energy	17
Advanced Material	13
Design and Applied Mechanics	6
Manufacture	4



Journal of Physics: Conference Series **3103** (2025) 011001 doi:10.1088/1742-6596/3103/1/011001

First Author and Title list

No.	First Author	Title	Affiliation
1	Aditya Rio Prabowo	The impact of Trapezoidal Counter-rotating Vortex Generator on the H-Darrieus Turbine Performance: CFD Model	Sebelas Maret University
2	Aditya Rio Prabowo	The Implementation of Used Food Cans and Polyurethane Foam to Increase Energy Absorption in Impact Attenuators of Formula Student Racing Cars	Sebelas Maret University
3	Adjar Pratoto	Mechanical Properties of Coco Peat Briquettes Produced through Mechanical Thermal Expression	Universitas Andalas
4	Agung Setyo Darmawan	Enhancing White Cast Iron: The Role of Normalizing on Microstructure and Hardness	Universitas Muhammadiyah Surakarta
5	Ahmad Indra Siswantara	Review of turbulence and vortex stress on submerged pico hydropower cross-flow Banki turbine internal flow	Universitas Indonesia
6	Ahmad Kholil	Analysis and Optimization of Interlocks Joining Parts in Design for Additive Manufacturing	Universitas Negeri Jakarta
7	Ahmad Syihan Auzani	High-Concentration Palm Biodiesel Fuel Filtration: A Comparative Analysis of Existing Filtration Systems and Design of a Cross-Flow Ceramic Membrane Filter Rig for Marine Diesel Engines	Universitas Indonesia
8	Ario Sunar Baskoro	Effect of Micro Friction Stir Spot Welding (mFSSW) Parameters on Temperature, Weld Geometry, and Joint Strength of AA1100 and AZ31B Dissimilar Materials.	Universitas Indonesia
9	Bambang Arip Dwiyantoro	Performance analysis of Dual Mixed Refrigerant System in Cryogenic Distillation Column as carbon capture at Acid Gas Removal Unit	Institut Teknologi Sepuluh Nopember
10	Bambang Arip Dwiyantoro	The effect of number and dimension in economizer hopper on fly ash capture capabilities and flue gas characteristics	Institut Teknologi Sepuluh Nopember
11	Benny Dwika Leonanda	Refractory Sealpot Replacement: Advancements at Teluk Sirih PLTU	Universitas Andalas
12	Berli Kamiel	Dynamic Characterization of SS400 Steel Using the Oberst Method	Persyarikatan Muhammadiyah
13	Dedikarni Panuh	Effect of palm frond fiber and aluminium powder with a polyester resin binder on the brake pads composite	Universitas Islam Riau
14	Dian Pamuji	Modelling and Simulation of the Effect of a Sparrow Bird-Leg-Inspired Vibration Isolator Parameters on Dynamic Responses	Institut Teknologi Sepuluh Nopember
15	Didi Widya Utama	Effect of velocity and angle of attack on the aerodynamic characteristics of a 3-D printed fixed-wing plane	Universitas Tarumanagara
16	Eddy Elfiano	Viscous Dissipation Effect for Al2O3-Ag/Water Hybrid Nanofluid in Mixed Convection: A Numerical Analysis	Universitas Islam Riau
17	Eko Prasetya Budiana	Comparative Analysis Between Conventional Single Slope Solar Still with Inserted Paraffin on Less Leakage Fin	Universitas Sebelas Maret

No.	First Author	Title	Affiliation
18	Eko Prasetya Budiana	Experimental Comparison Between a Conventional Solar Still and an Additional Inserted Horizontal Solid Circular Fin	Universitas Sebelas Maret
19	Firman Ridwan	The Effect Of Cement Ash On The Ionic Conductivity And Tensile Strength Of PVA/Salt/Gelatin Solid Electrolyte Membrane	Universitas Andalas
20	Friddya Nabila	A Numerical Study on Flow Characteristics of Discrete Double Inclined Ribs V-Type Effect on Microbubble Generator Performance	Institut Teknologi Sepuluh Nopember
21	Friddya Nabila	Numerical Study of Cabin Cooling on Electric Airport Apron Bus for Tropical Climate	Institut Teknologi Sepuluh Nopember
22	Harinaldi Harinaldi	Implementation of a fluidic oscillator as an active flow control device to improve the aerodynamic performance of an airfoil	Universitas Indonesia
23	Hendrix Noviyanto Firmansyah	The Influence of Flex Banner Types on the Impact and Flexural Strength of Hybrid Composite Materials	Universitas Negeri Semarang
24	I Gusti Ketut Puja	The role of nanocarbon from coconut shell charcoal on the tensile and impact strength of epoxy matrix composites	Universitas Sanata Dharma
25	Lydia Anggraini	Development and Validation of a Thermocouple for a Thermodynamics Experiment	President University
26	Mahros Darsin	Impact Strength, Microstructure, and Fractography of Titanium-PLA Filament in FDM 3D Printing	Universitas Jember
27	Muhammad Arif Budiyanto	Redesigning the MMA Welding Machine for Reducing Assembly Time and Cost with the DFMA Approach	Universitas Indonesia
28	Muhammad Burhanuddin Fauzi	Coffee Drying Using a Combination of Solar and Electric Heaters, Utilizing PCM as a Thermal Energy Storage	Universitas Indonesia
29	Muhammad Khairul Afdhol	Effect of variations in the composition of silica sand and recycled thermoplastics on microstructure, compressive strength, and hardness as a composite material	Universitas Islam Riau
30	Mulya Juarsa	Effect of gap size and coolant temperature on CCFL in a semi-spherical narrow gap for IVR simulation	BRIN Republik Indonesia
31	Mulya Juarsa	PID Control Simulation for Heating Power Control to Maintain Temperature Stability in Passive Cooling System Simulation Facility	BRIN Republik Indonesia
32	Mustasyar Perkasa	Numerical Analysis of the Use of Natural Composite Prepreg Material Ramie-PLA in the Development of Universal Chassis Profile Shapes for City Car Electric Vehicles	BRIN Republik Indonesia
33	Nandar Abdurahman	Analysis of N19 product quality control in the PTED process using the Six Sigma DMAIC method (Case Study: X Ltd)	Universitas Nusa Putra
34	Oknovia Susanti	Comparison of Mechanical Properties and Microstructure of Hot-Rolled Mg-Gd Alloys Between 95% Reduction and 80% Reduction as Degradable Implants	Universitas Andalas

Journal of Physics: Conference Series **3103** (2025) 011001 doi:10.1088/1742-6596/3103/1/011001

No.	First Author	Title	Affiliation
35	Oknovia Susanti	Mg-1.6Gd alloys hot rolled at a reduction of 80% through the Cytotoxicity test for implant material.	Universitas Andalas
36	Ridho Irwansyah	Modification of Wingtip Devices Configuration to Increase Aerodynamic Efficiency of Aircraft	Universitas Indonesia
37	Rudi Amme	Effect of SMAW Dissimilar Welding Current on Mechanical Properties of Low Carbon Steel AISI 1010 and Stainless Steel SUS304	Universitas Hasanuddin
38	Sri Raharno	The Development of an Overall Equipment Effectiveness Computation System on Metal Inert Gas Welding Machine	Institut Teknologi Bandung
39	Wahyu dwi lestari	The Role of Octane Hyper-boosting Phenomenon in Orange Peel Additive on Exhaust Emissions	Universitas Pembangunan Nasional Veteran Jawa Timur
40	Zulkifli Djafar	Effect of Pigment Pastes on the Tensile Strength of Woven Ramie Fiber Composite in Seawater	Universitas Hasanuddin

Title List

No.	First Author	Title	Affiliation
1	Friddya Nabila	A Numerical Study on Flow Characteristics of Discrete Double Inclined Ribs V-Type Effect on Microbubble Generator Performance	Institut Teknologi Sepuluh Nopember
2	Ahmad Kholil	Analysis and Optimization of Interlocks Joining Parts in Design for Additive Manufacturing	Universitas Negeri Jakarta
3	Nandar Abdurahman	Analysis of N19 product quality control in the PTED process using the Six Sigma DMAIC method (Case Study: X Ltd)	Universitas Nusa Putra
4	Muhammad Burhanuddin Fauzi	Coffee Drying Using a Combination of Solar and Electric Heaters, Utilizing PCM as a Thermal Energy Storage	Universitas Indonesia
5	Eko Prasetya Budiana	Comparative Analysis Between Conventional Single Slope Solar Still with Inserted Paraffin on Less Leakage Fin	Universitas Sebelas Maret
6	Oknovia Susanti	Comparison of Mechanical Properties and Microstructure of Hot-Rolled Mg-Gd Alloys Between 95% Reduction and 80% Reduction as Degradable Implants	Universitas Andalas
7	Lydia Anggraini	Development and Validation of a Thermocouple for a Thermodynamics Experiment	President University
8	Berli Kamiel	Dynamic Characterization of SS400 Steel Using the Oberst Method	Persyarikatan Muhammadiyah
9	Mulya Juarsa	Effect of gap size and coolant temperature on CCFL in a semi-spherical narrow gap for IVR simulation	BRIN Republik Indonesia
10	Ario Sunar Baskoro	Effect of Micro Friction Stir Spot Welding (mFSSW) Parameters on Temperature, Weld Geometry, and Joint Strength of AA1100 and AZ31B Dissimilar Materials.	Universitas Indonesia
11	Dedikarni Panuh	Effect of palm frond fiber and aluminium powder with a polyester resin binder on the brake pads composite	Universitas Islam Riau
12	Zulkifli Djafar	Effect of Pigment Pastes on the Tensile Strength of Woven Ramie Fiber Composite in Seawater	Universitas Hasanuddin
13	Rudi Amme	Effect of SMAW Dissimilar Welding Current on Mechanical Properties of Low Carbon Steel AISI 1010 and Stainless Steel SUS304	Universitas Hasanuddin
14	Muhammad Khairul Afdhol	Effect of variations in the composition of silica sand and recycled thermoplastics on microstructure, compressive strength, and hardness as a composite material	Universitas Islam Riau
15	Didi Widya Utama	Effect of velocity and angle of attack on the aerodynamic characteristics of a 3-D printed fixed-wing plane	Universitas Tarumanagara
16	Agung Setyo Darmawan	Enhancing White Cast Iron: The Role of Normalizing on Microstructure and Hardness	Universitas Muhammadiyah Surakarta

No.	First Author	Title	Affiliation
17	Eko Prasetya Budiana	Experimental Comparison Between a Conventional Solar Still and an Additional Inserted Horizontal Solid Circular Fin	Universitas Sebelas Maret
18	Ahmad Syihan Auzani	High-Concentration Palm Biodiesel Fuel Filtration: A Comparative Analysis of Existing Filtration Systems and Design of a Cross-Flow Ceramic Membrane Filter Rig for Marine Diesel Engines	Universitas Indonesia
19	Mahros Darsin	Impact Strength, Microstructure, and Fractography of Titanium-PLA Filament in FDM 3D Printing	Universitas Jember
20	Harinaldi Harinaldi	Implementation of a fluidic oscillator as an active flow control device to improve the aerodynamic performance of an airfoil	Universitas Indonesia
21	Adjar Pratoto	Mechanical Properties of Coco Peat Briquettes Produced through Mechanical Thermal Expression	Universitas Andalas
22	Oknovia Susanti	Mg-1.6Gd alloys hot rolled at a reduction of 80% through the Cytotoxicity test for implant material.	Universitas Andalas
23	Dian Pamuji	Modelling and Simulation of the Effect of a Sparrow Bird-Leg-Inspired Vibration Isolator Parameters on Dynamic Responses	Institut Teknologi Sepuluh Nopember
24	Ridho Irwansyah	Modification of Wingtip Devices Configuration to Increase Aerodynamic Efficiency of Aircraft	Universitas Indonesia
25	Mustasyar Perkasa	Numerical Analysis of the Use of Natural Composite Prepreg Material Ramie-PLA in the Development of Universal Chassis Profile Shapes for City Car Electric Vehicles	BRIN Republik Indonesia
26	Friddya Nabila	Numerical Study of Cabin Cooling on Electric Airport Apron Bus for Tropical Climate	Institut Teknologi Sepuluh Nopember
27	Bambang Arip Dwiyantoro	Performance analysis of Dual Mixed Refrigerant System in Cryogenic Distillation Column as carbon capture at Acid Gas Removal Unit	Institut Teknologi Sepuluh Nopember
28	Mulya Juarsa	PID Control Simulation for Heating Power Control to Maintain Temperature Stability in Passive Cooling System Simulation Facility	Republik Indonesia
29	Muhammad Arif Budiyanto	Redesigning of MMA Welding Machine for Reducing Assembly Time and Cost with DFMA Approach	Universitas Indonesia
30	Benny Dwika Leonanda	Refractory Sealpot Replacement: Advancements at Teluk Sirih PLTU	Universitas Andalas
31	Ahmad Indra Siswantara	Review of turbulence and vortex stress on submerged pico hydropower cross-flow Banki turbine internal flow	Universitas Indonesia
32	Sri Raharno	The Development of an Overall Equipment Effectiveness Computation System on Metal Inert Gas Welding Machine	Institut Teknologi Bandung
33	Firman Ridwan	The Effect Of Cement Ash On The Ionic Conductivity And Tensile Strength Of PVA/Salt/Gelatin Solid Electrolyte Membrane	Universitas Andalas

Journal of Physics: Conference Series **3103** (2025) 011001 doi:10.1088/1742-6596/3103/1/011001

No.	First Author	Title	Affiliation
34	Bambang Arip Dwiyantoro	The effect of number and dimension in economizer hopper on fly ash capture capabilities and flue gas characteristics	Institut Teknologi Sepuluh Nopember
35	Aditya Rio Prabowo	The impact of Trapezoidal Counter-rotating Vortex Generator on the H-Darrieus Turbine Performance: CFD Model	Sebelas Maret University
36	Aditya Rio Prabowo	The Implementation of Used Food Cans and Polyurethane Foam to Increase Energy Absorption in Impact Attenuators of Formula Student Racing Cars	Sebelas Maret University
37	Hendrix Noviyanto Firmansyah	The Influence of Flex Banner Types on the Impact and Flexural Strength of Hybrid Composite Materials	Universitas Negeri Semarang
38	I Gusti Ketut Puja	The role of nanocarbon from coconut shell charcoal on the tensile and impact strength of epoxy matrix composites	Universitas Sanata Dharma
39	Wahyu dwi lestari	The Role of Octane Hyper-boosting Phenomenon in Orange Peel Additive on Exhaust Emissions	Universitas Pembangunan Nasional Veteran Jawa Timur
40	Eddy Elfiano	Viscous Dissipation Effect for Al2O3-Ag/Water Hybrid Nanofluid in Mixed Convection: A Numerical Analysis	Universitas Islam Riau

Author List

No.	First Author Name	First Author Affiliation	First Author Email
1	Aditya Rio Prabowo	Sebelas Maret University	aditya@ft.uns.ac.id
2	Adjar Pratoto	Universitas Andalas	adjar.pratoto@eng.unand.ac.id
3	Agung Setyo Darmawan	Universitas Muhammadiyah Surakarta	agung.darmawan@ums.ac.id
4	Ahmad Indra Siswantara	Universitas Indonesia	a_indra@eng.ui.ac.id
5	Ahmad Kholil	Universitas Negeri Jakarta	ahmadkholil@unj.ac.id
6	Ahmad Syihan Auzani	Universitas Indonesia	auzani@ui.ac.id
7	Ario Sunar Baskoro	Universitas Indonesia	ario@eng.ui.ac.id
8	Bambang Arip Dwiyantoro	Institut Teknologi Sepuluh Nopember	bambangads@me.its.ac.id
9	Benny Dwika Leonanda	Universitas Andalas	benny@eng.unand.ac.id
10	Berli Kamiel	Persyarikatan Muhammadiyah	berlikamiel@umy.ac.id
11	Dedikarni Panuh	Universitas Islam Riau	dedikarni@eng.uir.ac.id
12	Dian Pamuji	Institut Teknologi Sepuluh Nopember	ridlodian@poliwangi.ac.id
13	Didi Widya Utama	Universitas Tarumanagara	didiu@ft.untar.ac.id
14	Eddy Elfiano	Universitas Islam Riau	eddy_elfiano@eng.uir.ac.id
15	Eko Prasetya Budiana	Universitas Sebelas Maret	ekoprasetya@staff.uns.ac.id
16	Firman Ridwan	Universitas Andalas	firmanridwan@eng.unand.ac.id
17	Friddya Nabila	Institut Teknologi Sepuluh Nopember	friddyabella06@gmail.com
18	Harinaldi	Universitas Indonesia	harinald@eng.ui.ac.id
19	Hendrix Noviyanto F.	Universitas Negeri Semarang	hendrix@mail.unnes.ac.id
20	I Gusti Ketut Puja	Universitas Sanata Dharma	ketut@usd.ac.id
21	Irwansyah	Universitas Syiah Kuala	irwansyah@usk.ac.id
22	Lydia Anggraini	President University	lydia.anggra@president.ac.id
23	Mahros Darsin	Universitas Jember	mahrosdarsin@gmail.com
24	Muhammad Arif Budiyanto	Universitas Indonesia	arif@eng.ui.ac.id
25	Muhammad Burhanuddin F.	Universitas Indonesia	kosri@eng.ui.ac.id
26	Muhammad Khairul Afdhol	Universitas Islam Riau	afdhol@eng.uir.ac.id
27	Mulya Juarsa	BRIN Republik Indonesia	mulya.juarsa@brin.go.id
28	Musa B. Palungan	Universitas Kristen Indonesia Paulus	musa_ukip@yahoo.com
29	Mustasyar Perkasa	BRIN Republik Indonesia	must011@brin.go.id
30	Nandar Abdurahman	Universitas Nusa Putra	nandar.abdurahman_tm20@nusaputra.ac.id
31	Oknovia Susanti	Universitas Andalas	oknovia.s@eng.unand.ac.id
32	Ridho Irwansyah	Universitas Indonesia	ridho@eng.ui.ac.id
33	Risdiyono	Universitas Islam Indonesia	risdiyono@uii.ac.id
34	Rudi Amme	Universitas Hasanuddin	rudyamme@gmail.com
35	Rustan Tarakka	Universitas Hasanuddin	rustan_tarakka@yahoo.com
36	Sri Raharno	Institut Teknologi Bandung	harnos@itb.ac.id
37	Triyono	Universitas Sebelas Maret	triyono74@staff.uns.ac.id
38	Wahyu dwi lestari	Universitas Pembangunan Nasional Veteran	wahyu.dwi.tm@upnjatim.ac.id
39	Zulkifli Djafar	Universitas Hasanuddin	zulkiflidjafar3065@gmail.com

Journal of Physics:
Conference Series

PAPER • OPEN ACCESS

The role of nanocarbon from coconut shell charcoal on the tensile and impact strength of epoxy matrix composites

To cite this article: I Gusti Ketut Puja and Emanuel Talenta Blessa 2025 *J. Phys.: Conf. Ser.* **3103** 012036

The role of nanocarbon from coconut shell charcoal on the tensile and impact strength of epoxy matrix composites

I Gusti Ketut Puja[1*] and Emanuel Talenta Blessa[2]

[1,2] Department of Mechanical Engineering, Universitas Sanata Dharma, Yogyakarta, Indonesia

*E-mail: ketut@usd.ac.id

[1]0000-0002-6025-3865

Abstract. This study, which examines the tensile and impact strength of nanocarbon composites from coconut shell charcoal with an epoxy matrix. This study involved five variations in the weight of nanocarbon added to epoxy resin, namely 200, 300, 400, 700, and 1000 ppm. All specimens were produced using molds made of silicone rubber with shapes that follow the ASTM D638-01 tensile test standard and the ASTM D 6110-02 impact test standard. The results showed that adding 400 ppm increased the tensile strength of pure epoxy resin by 6.5% from 45.1 MPa to around 48 MPa, while its elastic modulus increased by around 13% from 2.92 GPa to 3.3 GPa. On the other hand, the most optimal average impact strength that can be absorbed occurs at a variation of 700 ppm, around 6.3 kJ/m^2, an increase of 19.5% compared to pure epoxy resin, which is around 5.28 kJ/m^2. These findings suggest that the mechanical properties of the composite's resin may be enhanced through the incorporation of nanocarbon derived from coconut shell charcoal. These findings have the potential to influence the application of the composite by rendering it more customizable to the needs of various industries.

Keywords : nanocarbon, composite, coconut shell charcoal, tensile strength

1. Introduction

Material is an important component in the manufacture of a product. One type of material that continues to be developed is composites. One type of material that is the subject of ongoing development is composites. Composites are a combination of several materials that exhibit superior properties to those of their constituent materials [1]. In general, composites are composed of two main elements: the matrix and the filler. The matrix fulfils the roles of transferring loads and acting as a binder in the composite. One frequently employed matrix is the thermoset type of epoxy resin. Due to its chemical resistance, epoxy resin is extensively utilized in the production of high-quality goods [2]. The filler, conversely, is a material utilized for the purpose of filling voids within the composite and providing reinforcement. The forms that filler assumes in composites include fibers, whiskers and particles [3].

Fillers in composites can be derived from natural sources or synthesised. In parallel with the advancement of material science, the use of synthetic fillers is being superseded. The production of advanced materials has increasingly embraced the use of natural fillers. One such natural filler is coconut shell charcoal. Coconut is also referred to as the 'plant of life'. The term is derived from the fact that a multitude of components within the coconut plant can be put to use, with the coconut fruit representing one such example. In general, coconut fruit is widely processed as an ingredient in processed foods and beverages. The processing of the fruit has an impact on the amount of waste produced in the form of coconut shells. These shells have a variety of beneficial uses, including as an organic fertiliser, charcoal, and in the production of handicrafts. Additionally, coconut shells have a high calorific value, with the average calorific value of coconut shell charcoal being 23.68 MJ/kg. [4]. Consequently, coconut shell is frequently employed as a fuel source. Additionally, coconut shell is composed of cellulose (26.6%), hemicellulose (21%), lignin (29.4%), and pentosan (27.7%), indicating that it has a relatively high carbon content (49.86%) [5]. The combination of a considerable carbon content and the accessibility of the materials involved make coconut shell charcoal frequently utilised as an ingredient in material development.

Research related to composites with coconut shell charcoal fillers has been conducted on multiple occasions. One such study is the research conducted by Chandra et al. (2022) regarding the tensile testing of epoxy resin with the addition of 5% coconut shell charcoal filler. [6]. In the study, coconut shell charcoal of a particle size of 1000 mesh (14 microns) was utilised. Subsequently, the coconut shell charcoal particles were combined with a matrix of epoxy resin to form a composite. The composite was subjected to tensile testing using a universal testing machine (UTM). The tensile tests performed on the epoxy resin yielded an average ultimate tensile strength of 44.82 MPa. The maximum tensile strength of epoxy resin with a filler is observed to be inferior to that of epoxy resin without a filler, which reaches 51.32 MPa. The observed decline in tensile strength can be attributed to the weakening effect of the molecular bonds between the epoxy resins, induced by the presence of the coconut shell charcoal particles. Conversely, the introduction of filler has been shown to enhance the elastic modulus of the composite. The findings of this study indicate that while the incorporation of coconut shell charcoal filler may elevate the elastic modulus of epoxy resin, it does not necessarily guarantee an increase in its ultimate tensile strength.

In a recent study, Raza et al. (2021) examined the influence of multi-walled carbon nanotube (MWCNT) fillers on the mechanical properties of epoxy resin composites [7]. In this study, two types of multi-walled carbon nanotubes (MWCNTs) are employed: pristine multi-walled carbon nanotubes (p-MWCNTs) and functionalised multi-walled carbon nanotubes (f-MWCNTs). The synthesis of f-MWCNTs entails the addition of carboxylic groups to p-MWCNTs, a process referred to as functionalisation. Epoxy resin specimens were prepared by the addition of p-MWCNTs and f-MWCNTs at varying mass fractions. The mass fractions utilised in this study were 0.1%, 0.5% and 1%. The tensile testing results demonstrated that the specimens containing p-MWCNT and f-MWCNT fillers exhibited a notable enhancement in tensile strength and elastic modulus, with increases of 24% and 64%, respectively, in comparison to the specimens lacking fillers. Additionally, the increase in tensile strength and elastic modulus was accompanied by a reduction in strain at fracture. Furthermore, the test results demonstrated the impact of functionalisation. The tensile strength and elastic modulus of the samples with f-MWCNT fillers were found to be higher than those of the samples with p-MWCNT fillers. This is due to the fact that MWCNTs are more brittle than epoxy resin. The brittle nature of MWCNTs suppresses the elasticity of epoxy resin by initiating cracks, resulting in a higher propensity for failure at low strains in MWCNT composites compared to pure epoxy resin samples. The observed increase in tensile strength and elastic modulus was not evident in samples with high filler mass fractions. This can be attributed to the occurrence of agglomeration or precipitation in the epoxy matrix at high filler concentrations, which effectively negates the enhanced tensile strength imparted by the addition of MWCNTs.

The effect of filler addition on the mechanical properties of epoxy has been a topic of considerable investigation in numerous studies. Nevertheless, there is a paucity of research examining the mechanical properties of epoxy and nanocarbon composites with a nanocarbon mass fraction below 1000 ppm (or 0.1%). The aim of this research is to examine the influence of nanocarbon derived from coconut shell on the mechanical properties of epoxy resin, with specific focus on the effect of filler mass fractions below 1000 ppm (or 0.1%) Coconut shell was selected as the fundamental source of nanocarbon for this study given its prevalence and competitive pricing in tropical regions, including Indonesia. The utilisation of nanosized filler particles in this research was motivated by the recognition that nano-structured materials exhibit distinctive characteristics and functionality that diverge from their macro-structured counterparts [8]. The epoxy resin and carbon composite samples were subsequently moulded with varying mass proportions of nanocarbon. The samples were then tested by tensile and impact analysis. Additionally, an examination of tensile test failures was conducted using macro photography. The findings from the tensile and impact analysis, along with the observations from the tensile test faults using macro photography, were discussed and compared with existing literature to ascertain the behaviour of the composite material.

2. Materials and Methods

2.1 Materials

The composite samples included in this study were manufactured using a variety of techniques and materials. The materials utilised in the experiment include epoxy resin and nanocarbon. The

(a) (b) (c)

Figure 1. (a) Catalyst, (b) Epoxy, dan (c) Nanocarbon from coconut shell charcoal.

epoxy resin employed is an Eposchön brand product comprising bisphenol A and epichlorohydrin. Epoxy resin requires a catalyst for the hardening process. The catalyst used in this research is of the cycloaliphatic amine type (EPH 55). The nanocarbon used in this research is derived from coconut shell charcoal. The coconut shell charcoal was procured from commercial sources in the Sleman, Yogyakarta area. The charcoal was then processed to nanosized particles. Figure 1 depicts the epoxy resin, catalyst, and nanocarbon utilized in this study.

2.2 Nanocarbon synthesis

In this study, nanocarbon was produced from coconut shell charcoal. The charcoal was first crushed, then ground until it formed a powder, and finally filled to one-thirds of a tube's volume. This tube was subsequently filled with metal balls, reaching two-thirds of its total volume, before being subjected to high energy milling (HEM) using a shaker mill [9]. The shaker mill was operated until the size of the coconut shell charcoal carbon was reduced to the nanoscale. Figure 1 (c) illustrates the resulting nanocarbon produced by this synthesis process.

2.3 Composite manufacturing

The composite is manufactured using the hand lay-up technique. The production of composite specimens commences with the fabrication of molds in accordance with the tensile test standard, ASTM D638-01, and the impact test standard, ASTM D6110-02 [10], [11]. Geometric dimensions

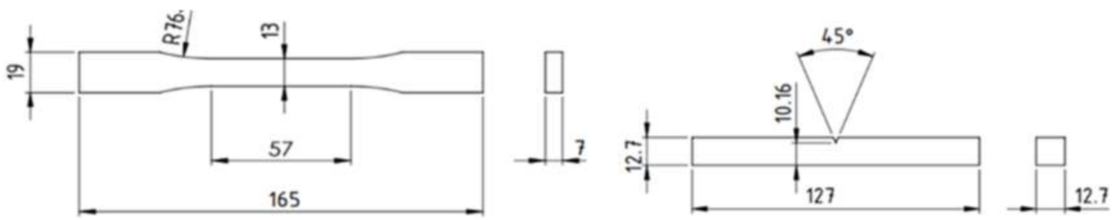


Figure 2. Dimension of tensile testing specimen (left), Dimension of impact testing specimen (right).

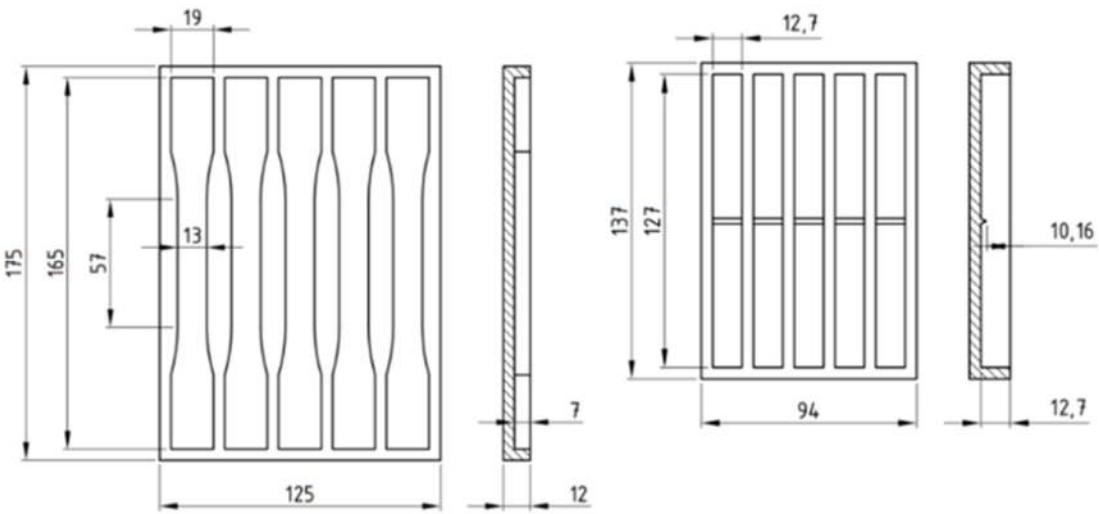


Figure 3. Dimensions of silicone molds of tensile testing and impact testing test specimens.

for ASTM D638-01 and ASTM D6110-02 shown in the picture 1. A composite mould was fabricated utilising silicone rubber. The dimensions of the mould were calibrated to the geometry depicted in Figure 2, with the objective of minimising the machining process. This approach is intended to diminish the occurrence of defects in the specimen. The configuration and dimensions of the mould can be observed in Figure 3.

The subsequent phase entails the preparation of epoxy resin mixtures, both with and without filler. In the absence of filler, the epoxy resin and catalyst were combined in a 2:1 ratio. Subsequently, the mixture was stirred with a stirrer for a period of 10 minutes at a rotation speed of 500-800 rpm, until a homogeneous mixture was achieved. In the case of epoxy resins with filler, calculations are required in order to determine the quantity of filler that must be incorporated into the resin and hardener mixture for each variation in the amount of filler. Once the requisite calculations have been completed, the nanocarbon is incorporated into the epoxy resin, which is then stirred for a period of 10 minutes using a stirrer until a homogeneous mixture is achieved. Subsequently, the epoxy resin and nanocarbon mixture is stirred for a further 5 minutes with the catalyst (hardener) to ensure a homogeneous blend. The epoxy resin mixture, both with and without filler, is then poured into the prepared mould and left to dry for a period of 24 hours at room temperature.

2.4 Tensile test

Tensile testing was conducted using a 2017 JTM-UTC 220 serial 6604 tensile testing machine. Tests were conducted on each composite filler mass fraction on five occasions, with five different specimens being used on each occasion. Prior to the commencement of testing, the dimensions of each specimen were duly noted. These dimensions were then entered into the tensile testing machine. The displacement rate for each specimen was selected, and the machine was then activated. The resulting test data was processed to obtain the tensile strength, strain, and modulus of elasticity. The tensile strength, strain, and elastic modulus can be determined using equations 1, 2, and 3, respectively [3], [12].

$$\sigma = \frac{F}{A} \tag{1}$$

$$\varepsilon = \frac{\Delta l}{l_0} \tag{2}$$

$$E = \frac{\sigma}{\varepsilon} \tag{3}$$

Where σ is tensile strength (N/mm^2), F is load (N), A is test specimen cross-sectional area (mm^2), ε is strain, Δl is displacement (mm), l_0 is initial length (mm), and E is modulus of elasticity (N/mm^2). The cross-section of the specimen fracture was also analyzed using macro photography. This analysis was carried out to determine the type of fracture that occurred and to study the characteristics of the specimen from the shape of the fracture.

2.4 Impact test

Impact testing is a test employed to ascertain the degree to which a test object absorbs energy in response to a shock load. The impact test process employs the 1995 GT-7045 impact testing machine, series 8401159. The impact test specimen features a notch angle of 45°, which is evaluated through the Charpy method. Each specimen was subjected to five replicates, with five distinct specimens, at a specified filler mass fraction. The specimen was positioned with the notch in the centre and aligned with the pendulum. Subsequently, the pendulum was elevated to an angle α and then released to strike the specimen. Following the impact, the pendulum moved to an angle β. The angle obtained is employed to calculate the ductility value of the specimen. The calculation of impact energy and ductility value can be performed using equations 4 and 5 [3].

$$W = mgl(\cos\beta - \cos\alpha) \quad (4)$$

$$K = \frac{W}{A} \quad (5)$$

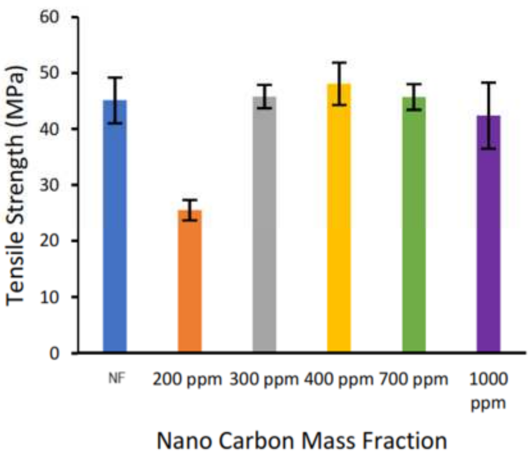
Where, W is energy absorbed (Joule), m is the mass of the pendulum (kg), g is gravitational acceleration (m/s^2), l is the length of the pendulum (m), β the final angle of the striking process, α is the initial angle of the striking process, K is the ductility value (kJ/m^2), dan A is the cross-sectional area of the broken specimen (m^2).

3. Result and Discussion

3.1 Result and Discussion of Tensile Testing

Tensile testing was conducted on composite materials with and without the addition of fillers. The fillers were nanocarbon derived from coconut shell charcoal and varied in mass at 200 ppm, 300 ppm, 400 ppm, 700 ppm and 1000 ppm. Tests were conducted in accordance with the ASTM D638-01 standard. The resulting data was plotted in a graph to illustrate the relationship between load and strain. This data was then processed to obtain the tensile strength and elastic modulus. The tensile strength and elastic modulus for each tested filler mass variation are presented in Figure 4. Additionally, the tensile strength and elastic modulus of all specimens are shown in Table 1.

The data indicate that the average tensile strength of specimens with a filler mass fraction of 200 ppm to 400 ppm has increased. These findings are consistent with the results of the study conducted by Raza, et al. (2021), which indicated that the incorporation of fillers into composites led to an enhancement in their tensile strength and elastic modulus. This phenomenon is attributed to an elevated solubility and dispersion of epoxy resin resulting from the addition of coconut shell charcoal nanocarbon, thereby facilitating a notable increase in the strong adhesion forces between epoxy resin and coconut shell charcoal nanocarbon [7].



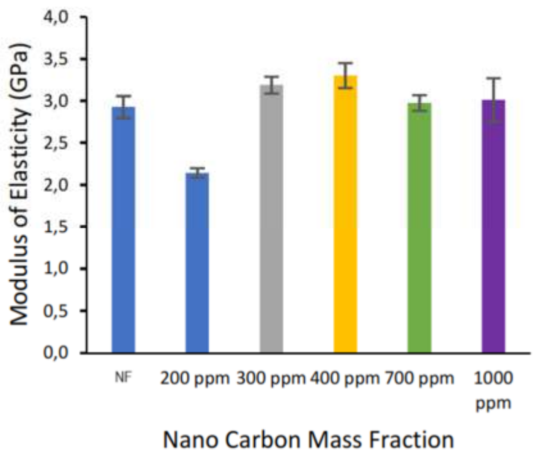


Figure 4. Graph of the relationship between average tensile strength and filler mass fraction (left), Graph of the relationship between average elastic modulus and filler mass fraction (right).

Table 1. Tensile testing data of all specimens.

Mass Fraction	Specimen	Tensile Strength (MPa)	Modulus of Elasticity (GPa)
Without Filler (NF)	1	48.51	1.76
	2	39.57	2.16
	3	42.93	2.08
	4	49.54	2.06
Average		45.14	2.01
200 ppm	1	23.19	1.27
	2	27.01	1.08
	3	24.32	1.43
	4	27.57	1.33
Average		25.52	1.28
300 ppm	1	48.66	2.11
	2	43.88	2.31
	3	44.82	2.23
Average		45.79	2.22
400 ppm	1	52.98	2.29
	2	42.39	2.41
	3	48.68	2.28
	4	48.24	2.14
Average		48.07	2.28
700 ppm	1	45.96	1.91
	2	43.65	1.85
	3	49.41	1.36
	4	43.94	1.42
Average		45.74	1.64
1000 ppm	1	48.49	1.42
	2	48.10	1.31
	3	35.84	1.27
	4	37.18	1.28
Average		42.40	1.32

The tensile strength and elastic modulus of epoxy resin containing a mass fraction of 200 parts per million (ppm) of filler are observed to be lower than those of epoxy resin without a filler present. This may be attributed to the introduction of low-mass-fraction nanocarbon, which may act as an impurity. The addition of 200 ppm nanocarbon impurities to the epoxy resin weakens the molecular bonds between the resin molecules. This negatively impacts the composite's overall strength and performance.

Furthermore, the data indicates a downward trend in tensile strength and elastic modulus at 700 ppm filler mass fraction. A similar pattern is evident in the 1000 ppm filler mass fraction. This reduction is attributed to the formation of agglomerations of coconut shell charcoal nanocarbon, resulting in impeded load transfer from epoxy resin to coconut shell charcoal nanocarbon [13]. The results obtained are in line with the results of research conducted by Ervina et al. (2016) [14].

The modulus of elasticity obtained at each filler mass fraction exhibits variability. At mass fractions of 300 and 400 ppm, the elastic modulus is notably elevated in comparison to other mass fractions. The increased solubility and uniform dispersion of the filler particles result in a stronger adhesion force, which is the cause of the elevated elastic modulus observed in composites with 300 and 400 ppm filler mass fractions. Meanwhile, composites without filler and composites with 700 and 1000 ppm filler mass fraction exhibit a nearly identical elastic modulus. This phenomenon can be attributed to the agglomeration process of nanocarbon [7], [12]. Nanocarbon possesses brittle properties. In composites with a high mass fraction, agglomeration intensifies this brittle nature, thereby reducing the elastic modulus of the composite.

3.2 Result and Discussion of Impact Testing

The impact test was conducted to determine the amount of energy absorbed by the composite material per unit area of the specimen. The results of the impact test are processed using equation 4 and equation 5. The impact test uses the ASTM D 6110-02 impact test standard with the Charpy impact testing method. The impact tester used has an α angle of 150°, a pendulum weight of 1.375 kg, and an arm length of 38.48 cm. Figure 5 and Table 2 show the processed results of the data obtained from the impact tests that have been carried out.

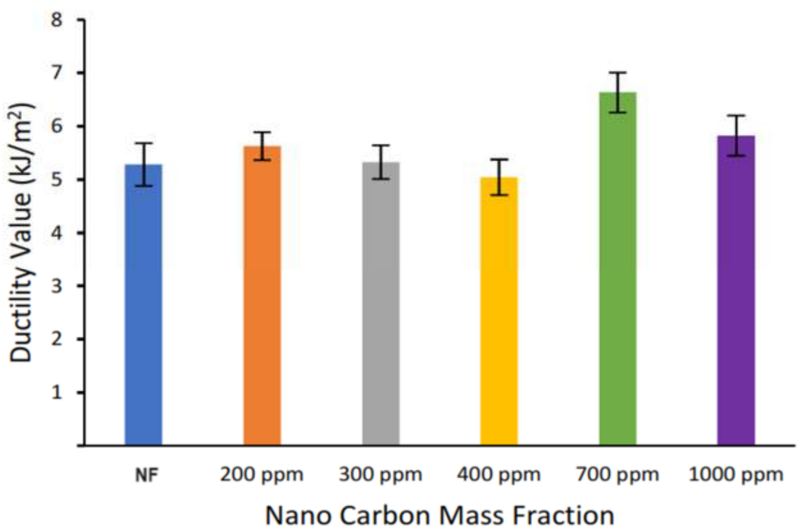


Figure 5. Graph of the relationship between ductility value and nanocarbon mass fraction.

Table 2. Impact testing data of all specimens.

Mass Fraction	Specimen	Energy absorbed (Joule)	Ductility value (kJ/m²)
Without Filler (NF)	1	0.597	4.87
	2	0.646	5.23
	3	0.683	5.70
	4	0.708	5.77
	5	0.634	4.82
Average		0.653	5.28
200 ppm	1	0.829	6.38
	4	0.771	5.79
	5	0.708	5.25
Average		0.769	5.81
300 ppm	3	0.609	4.39
	4	0.752	5.45
	5	0.720	5.14
Average		0.694	4.99
400 ppm	1	0.585	4.48
	2	0.585	4.59
	3	0.585	4.64
	5	0.658	4.88
Average		0.603	4.65
700 ppm	1	0.771	5.74
	3	1.035	7.04
	4	0.784	6.14
Average		0.863	6.31
1000 ppm	2	0.634	4.92
	3	0.784	5.93
	4	0.708	5.74
Average		0.708	5.53

The mean value of ductility obtained at filler mass fractions of 200, 300, and 400 is nearly identical to the variation observed in the absence of filler addition. This is due to the fact that the incorporation of fillers with an insufficient mass fraction can result in the epoxy resin becoming the dominant component within the composite. Consequently, the ductility of the composite is predominantly influenced by the epoxy resin. Furthermore, the transfer of impact energy between the epoxy resin and the filler has not occurred efficiently due to the limited quantity of filler present. The discrepancy in the ductility values obtained from this test may be attributed to the formation of voids during the composite moulding process. The formation of voids may facilitate the propagation of cracks when subjected to a shock load. The random positioning of the voids results in a slight variation in the impact test results.

At a filler mass fraction of 700 ppm, the composite exhibits enhanced ductility compared to composites lacking filler and those with filler mass fractions of 200 ppm, 300 ppm, and 400 ppm. This result is consistent with the findings of Amer Hameed Majeed's research, which demonstrated that the ductility value of a composite with filler is higher than that of a composite without filler. This is due to the substantial addition of nanocarbon derived from coconut shell charcoal, which results in an expansion of the contact point between the epoxy resin and the nanocarbon. This enables the epoxy resin to transfer a greater quantity of impact energy to the nanocarbon, while simultaneously absorbing a greater quantity of impact energy [15]. Furthermore, an optimal bond between the matrix and filler can mitigate the formation of defects in the composite, thereby enhancing the composite's ductility. However, the ductility value obtained for the composite with a mass fraction of 1000 ppm was found to be lower than that of the other composites. This phenomenon can be attributed to the agglomeration of coconut shell charcoal nanocarbon, which is challenging to disperse with epoxy resin. This results in the formation of weak interfacial forces between the particles and the epoxy matrix, as observed in previous studies [7], [14]. The weakening of these forces ultimately leads to a reduction in the ductility value.

3.3 Results and Discussion of Macro Photos of Tensile Testing Fractures

Macroscopic structure observation is employed to ascertain the configuration of the specimen's fractured surface based on the outcomes of tensile testing. This process entails the utilisation of macro photography, which captures images of the composite specimens with disparate filler mass fractions. Illustrative examples of these macro images can be observed in Figure 6.

The macro photography reveals a radial development of the fault shape that can be described as a fan shape comprising different sections. The initiation of a fault is preceded by a defect that arises during the loading process, which subsequently evolves into a crack. Subsequently, the cracks are linked to other cracks resulting from additional defects, such as voids or scratches in the composite material. The initial point of fracture initiation is predominantly concentrated at the lower edge. Subsequently, the fracture propagates in a direction from the lower side towards the surrounding surface.

In accordance with the findings of Bandyopadhyay's research, the fracture failure of epoxy materials occurs via a crazing fracture mechanism and can be divided into three to four stages [12], [16]–[18]. This is in accordance with the results of the macro photography, which revealed four stages of fracture. The initial fracture, caused by a cavity, represents the starting point for the fracture. The formation of a cavity results in a smooth fracture. In the second stage, the crack extends, marking the onset of a rough fault. As the applied stress increases, the cracks on the fracture surface grow, leading to a rougher fracture surface in the third stage. Finally, the test specimen undergoes a cleavage process, which occurs so rapidly that the composite experiences slight plastic deformation at the crack tip.

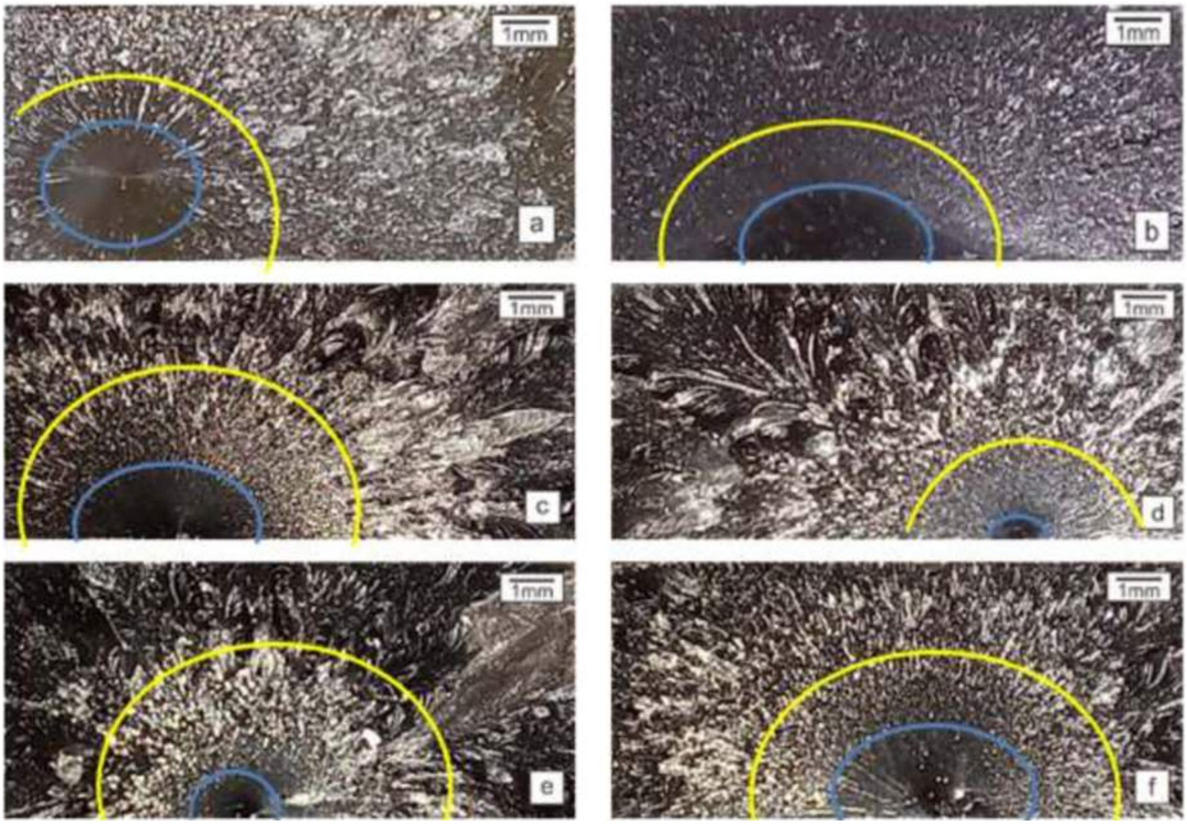


Figure 1. Macro photo results of composite materials with nanocarbon mass fraction of a) 0 ppm, b) 200 ppm, c) 300 ppm, d) 400 ppm, e) 700 ppm, and f) 1000 ppm.

The region delineated by the blue circle is predominantly characterised by the presence of black region. The black colouration indicates that the fault occurred with great rapidity, resulting in the formation of shiny black sides. Furthermore, this area represents the initial propagation of fissures prior to the fault. The areas delineated by the yellow circle and those situated outside the blue circle exhibit disparate conditions. In these areas, some of the surfaces of the test specimens display a white hue with small, elongated dots. This suggests that the area in question was the point of origin for the formation of tears during the fault. The tear is clearly visible in the subsequent area, specifically the region exterior to the yellow demarcation. In composites with filler mass fractions of 300 ppm and 400 ppm, there is a prevalence of white regions. This suggests that a considerable number of tears occur in composites with filler mass fractions of 300 and 400 ppm. This observation aligns with the findings of the tensile test, which demonstrated that composites with filler mass fractions of 300 and 400 ppm exhibited higher tensile strength than composites without filler and those with 200 ppm filler. Consequently, the composite displays minimal plastic deformation at the end of the crack.

4. Conclusion

The incorporation of nanocarbon filler derived from coconut shell charcoal into epoxy resin composites has been demonstrated to enhance the tensile strength and ductility values of the resulting composites. The composite exhibited the optimal tensile strength (48.07 MPa) when the mass fraction of the filler was 400 ppm. The optimal ductility value was observed in the composite with a filler mass fraction of 700 ppm, exhibiting a value of 6.31 kJ/m^2. Nevertheless, an increase in filler content above 700 ppm in the composite results in a decline in tensile strength and ductility values. This reduction in tensile strength and ductility is attributed to the formation of agglomerations of coconut shell charcoal nanocarbon, which impedes load transfer from the epoxy resin to the filler and reduces the adhesion forces between filler and resin. Consequently, the composite exhibits slight plastic deformation at the crack tip.

Acknowledgment

The authors would like to thank the "Laboratory of Materials and Manufacture" at Universitas Sanata Dharma Yogyakarta Indonesia for supporting the experimental works.

Author Contribution

I Gusti Ketut Puja contributed to: Conceptualization, Methodology, Investigation, Formal analysis, Writing–review & editing. Meanwhile, **Emanuel Talenta Blessa** contributed in terms of**:** Investigation, Data curation, Validation, Visualization, Writing–original draft.

References

[1] S.-J. Park and M.-K. Seo, "Composite Characterization," in *Interface Science and Technology*, vol. 18, Elsevier, 2011, pp. 631–738.

[2] C. Shi, S. Jin, K. Jin, Y. Yang, and L. Xu, "Improving bonding behavior between basalt fiber-reinforced polymer sheets and concrete using multi-wall carbon nanotubes modified epoxy composites," *Case Stud. Constr. Mater.*, vol. 18, p. e02216, Jul. 2023, doi: 10.1016/j.cscm.2023.e02216.

[3] J. William D. Callister and D. G. Rethwisch, *Materials Science and Engineering : An Introduction 9th Edition*, 9th Editio. New York, NY: WIiley, 2014.

[4] T. Rout, D. Pradhan, R. K. Singh, and N. Kumari, "Exhaustive study of products obtained from coconut shell pyrolysis," *J. Environ. Chem. Eng.*, vol. 4, no. 3, pp. 3696–3705, Sep. 2016, doi: 10.1016/J.JECE.2016.02.024.

[5] C. O. Umerah, D. Kodali, S. Head, S. Jeelani, and V. K. Rangari, "Synthesis of carbon from waste coconutshell and their application as filler in bioplast polymer filaments for 3D printing," *Compos. Part B Eng.*, vol. 202, p. 108428, Dec. 2020, doi: 10.1016/J.COMPOSITESB.2020.108428.

[6] T. O. Chandra *et al.*, "Tensile properties of epoxy resin filled with activated carbon derived from coconut shell," *Mater. Today Proc.*, vol. 66, pp. 2967–2971, Jan. 2022, doi: 10.1016/J.MATPR.2022.06.568.

[7] I. Raza, M. Hussain, A. N. Khan, T. Katzwinkel, and J. Feldhusen, "Properties of light weight multi walled carbon nano tubes (MWCNTs) nano-composites," *Int. J. Light. Mater. Manuf.*, vol. 4, no. 2, pp. 195–202, Jun. 2021, doi: 10.1016/J.IJLMM.2020.09.003.

[8] I. Khan, K. Saeed, and I. Khan, "Nanoparticles: Properties, applications and toxicities," *Arab. J. Chem.*, vol. 12, no. 7, pp. 908–931, Nov. 2019, doi: 10.1016/J.ARABJC.2017.05.011.

[9] N. Ngafwan, M. Effendy, G. Supangkat Samidjo, I. Gusti Ketut Puja, and I. N. G. Wardana, "The role of Carica papaya latex bio-catalyst and thermal shock in water on synthesizing rice husk," *Arab. J. Chem.*, vol. 16, no. 4, p. 104568, Apr. 2023, doi: 10.1016/J.ARABJC.2023.104568.

[10] ASTM International, *ASTM D638-01 Standard Test Method for Tensile Properties of Plastics*, 08.01. ASTM International, 2017.

[11] ASTM International, *ASTM D6110-02 Standard Test Methods for Determining the Charpy Impact Resistance of Notched Specimens of Plastics*, 08.03. ASTM International, 2017.

[12] A. International, *ASM Handbook: Volume 21, Composites*. 2001.

[13] A. H. Majeed, M. S. Hamza, and H. R. Kareem, "Effect of Ading Nanocarbon Black on the Mechanical Properties of Epoxy," *Diyala J. Eng. Sci.* , vol. 7, no. 1, pp. 94–108, Mar. 2014, doi: 10.24237/DJES.2014.07107.
[14] J. Ervina, M. Mariatti, and S. Hamdan, "Effect of Filler Loading on the Tensile Properties of Multi-walled Carbon Nanotube and Graphene Nanopowder filled Epoxy Composites," *Procedia Chem.*, vol. 19, pp. 897–905, Jan. 2016, doi: 10.1016/j.proche.2016.03.132.
[15] H. He, K. Li, J. Wang, G. Sun, Y. Li, and J. Wang, "Study on thermal and mechanical properties of nano-calcium carbonate/epoxy composites," *Mater. Des.*, vol. 32, no. 8–9, pp. 4521–4527, Sep. 2011, doi: 10.1016/J.MATDES.2011.03.026.
[16] ASM International, *ASM Handbook: Volume 19, Fatigue and Fracture*. United States of America, 1996.
[17] S. Bandyopadhyay, "Review of the microscopic and macroscopic aspects of fracture of unmodified and modified epoxy resins," *Mater. Sci. Eng. A*, vol. 125, no. 2, pp. 157–184, Jun. 1990, doi: 10.1016/0921-5093(90)90167-2.
[18] ASM International, *ASM Handbook : Volume 12, Fractography*. United States of America: ASM International, 1987.