

Lecture Notes in Mechanical Engineering

Francisco Cavas-Martínez ·
Félix Sanz-Adan · Paz Morer Camo ·
Ruben Lostado Lorza ·
Jacinto Santamaría Peña *Editors*

Advances in Design Engineering

Proceedings of the XXIX International
Congress INGEGRAF, 20–21 June 2019,
Logroño, Spain

 Springer

Lecture Notes in Mechanical Engineering

Series Editors

Fakher Chaari, National School of Engineers, University of Sfax, Sfax, Tunisia

Mohamed Haddar, National School of Engineers of Sfax (ENIS), Sfax, Tunisia

Young W. Kwon, Department of Manufacturing Engineering and Aerospace Engineering, Graduate School of Engineering and Applied Science, Monterey, CA, USA

Francesco Gherardini  Dipartimento Di Ingegneria, Edificio 25, Università Di Modena E Reggio Emilia, Modena, Modena, Italy

Vitalii Ivanov, Department of Manufacturing Engineering Machine and tools, Sumy State University, Sumy, Ukraine

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>

Francisco Cavas-Martínez · Félix Sanz-Adan ·
Paz Morer Camo · Ruben Lostado Lorza ·
Jacinto Santamaría Peña
Editors

Advances in Design Engineering

Proceedings of the XXIX International
Congress INGEGRAF, 20–21 June 2019,
Logroño, Spain

Editors

Francisco Cavas-Martínez
Departamento de Estructuras,
Construcción y Expresión Gráfica
Universidad Politécnica de Cartagena
Cartagena, Murcia, Spain

Paz Morer Camo
Departamento de Mecánica
Tecnun - Universidad de Navarra
Donostia-San Sebastián, Guipúzcoa, Spain

Jacinto Santamaría Peña
Departamento de Ingeniería Mecánica
Universidad de la Rioja
Logroño, Spain

Félix Sanz-Adan
Departamento de Ingeniería Mecánica
Universidad de la Rioja
Logroño, La Rioja, Spain

Ruben Lostado Lorza
Departamento de Ingeniería Mecánica
Universidad de la Rioja
Logroño, La Rioja, Spain

ISSN 2195-4356 ISSN 2195-4364 (electronic)
Lecture Notes in Mechanical Engineering
ISBN 978-3-030-41199-2 ISBN 978-3-030-41200-5 (eBook)
<https://doi.org/10.1007/978-3-030-41200-5>

© Springer Nature Switzerland AG 2020, corrected publication 2020, 2024

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 Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface and Acknowledgements

The INGEGRAF 2019 Conference originates as the 29th International Conference on GRAPHICS ENGINEERING “The Digital Transformation in the Graphic Engineering”.

INGEGRAF 2019 has been organized by the area of graphical expression of the University of La Rioja. Cutting-edge topics in product design and manufacturing, innovative design and computer-aided design were especially encouraged.

The list of topics (and subtopics) covered in the present edition is the following:

- Product design and development: Green engineering and eco-design; User-centred design; Product lifecycle-based design; Robust design, reliability and maintenance; Modelling and simulation-based design; Ergonomics and human factors; Global product development.
- Computer-aided design and interactive design: Virtual approaches for interactive design; Virtual prototyping-based design; CAD, CAE, IFC and BIM; Image processing and analysis; Geometric modelling and analysis; Reverse engineering; Virtual and augmented reality.
- Manufacturing and industrial process design: Integrated/advanced manufacturing; Manufacturing process and production management; Rapid prototyping; Additive manufacturing; Flexible assemblies; Remanufacturing; Industry 4.0.
- Graphical bioengineering: Biomechanics; 3D modelling of biological structures; Computer-aided methods for pathologic diagnosis; Emotional engineering; Biomimicry for product design; Simulation and visualization of biological systems.
- Innovation in design: Creativity and innovation methods; Collaborative engineering; Intellectual and industrial property management; Design and research methods.
- Teaching/learning in graphic engineering: Teaching on graphic expression; Theoretical and applied geometry; Graphic design; New approaches in teaching/learning process; Project-based learning; Interactive 3D modelling.

- Engineering and construction: Sustainable building. Sustainable construction; Building information modelling; Photogrammetry and remote sensing; Geo-information. Data capture; Virtual environments. Augmented reality in AEC; Urban regeneration; Heritage and territory. Industrial heritage conservation.

We would like to thank our main organizers/institutions, High Technical School of Industrial Engineering from the University of La Rioja, and the rest of the sponsoring/collaborating companies and institutions for their support and grants.

We would also like to express our gratitude to the members of the different committees for their support, collaboration and good work. Thanks to all reviewers for their selfless effort reviewing contributions, which positively influenced the quality of the final papers presented at the conference.

Last, but not least, thanks to all the participants of INGEGRAF 2019.

November 2019

Francisco Cavas-Martínez
Félix Sanz-Adan
Paz Morer Camo
Jacinto Santamaría Peña
Ruben Lostado Lorza

Organization Committee

Conference Chair

Francisco Cavas-Martínez Universidad Politécnica de Cartagena, Spain

Conference Program Chairs

Rubén Lostado Lorza Universidad de La Rioja, Spain
Jacinto Santamaría Peña Universidad de La Rioja, Spain

Conference Advisory Chairmen

Paz Morer Universidad de Navarra—Tecnun, Spain

Scientific Committee

Fernando Aguilar Torres	Universidad de Almería, Spain
Rita Ambu	Università di Cagliari, Italy
Elidia Beatriz Bázquez Parra	Universidad de Málaga, Spain
Alain Bernard	Ecole Centrale Nantes, France
Francesca Campana	Università di Roma “La Sapienza”, Italy
Nicola Cappetti	Università degli Studi di Salerno, Italy
Vincent Cheutet	INSA Lyon, France
Marina Corral Bobadilla	Universidad de La Roja, Spain
Alain Daidié	INSA Toulouse, France
Luigi De Napoli	Università di Cagliari, Italy
Francisco Jose Fernández Cañavate	Universidad Politécnica de Cartagena, Spain
Francesco Ferrise	Politecnico di Milano, Italy
Xavier Fisher	ESTIA, France
Daniel G. Fernández-Pacheco	Universidad Politécnica de Cartagena, Spain
Cesar García Hernández	Universidad de Zaragoza, Spain

Valentín Gómez Jáuregui	Universidad de Cantabria, Spain
Tommaso Ingrassia	Università degli Studi di Palermo, Italy
Julien Le Duigou	Université de technologie de Compiègne, France
Francesco Leali	Università degli Studi di Modena e Reggio Emilia, Italy
Carlos León Robles	Universidad de Granada, Spain
Muriel Lombard	Université de Lorraine, France
Cristina Manchado del Val	Universidad de Cantabria, Spain
Cristina Martín Doñate	Univesidad de Jaén, Spain
Marian Martínez-Calvo	Universidad de La Rioja, Spain
Maria Luisa Martínez Muneta	Universidad Politécnica de Madrid, Spain
Massimo Martorelli	Università degli Studi di Napoli “Federico II”, Italy
Rikardo Minguez Gabiña	Universidad del País Vasco, Spain
Ramón Mirálbes Buil	Universidad de Zaragoza, Spain
Anna Eva Morabito	Università del Salento, Italy
Alessandro Naddeo	Università degli Studi di Salerno, Italy
Manuel Paredes	INSA Toulouse, France
Marcello Pellicciari	Università degli Studi di Modena e Reggio Emilia, Italy
Guillermo Peris	Universidad Politécnica de Valencia, Spain
Eugenio Pezzuti	Università di Roma “Tor Vergata”, Italy
Roberto Raffaeli	Università eCampus, Italy
David Ranz	Universidad de Zaragoza, Spain
Roberto Razzoli	Università degli Studi di Genova, Italy
José Ignacio Rojas Sola	Universidad de Jaén, Spain
Bertrand Rose	Université de Strasbourg, France
Félix Sanz-Adan	Universidad de La Rioja, Spain
Irene Sentana Gadea	Universidad de Alicante, Spain
Egoitz Sierra	Universidad del País Vasco, Spain
Eneko Solaberrieta	Universidad del País Vasco, Spain
Domenico Speranza	Università degli Studi di Cassino e del Lazio Meridionale, Italy
Miguel Suffo Pino	Universidad de Cádiz, Spain
Davide Tumino	Università degli Studi di Enna “Kore”, Italy

Organizing Committee

President

Félix Sanz-Adan	Universidad de La Rioja, Spain
-----------------	--------------------------------

Secretary

Marian Martínez-Calvo	Universidad de La Rioja, Spain
-----------------------	--------------------------------

Members

David Arancón	Universidad de La Rioja, Spain
Marina Corral	Universidad de La Rioja, Spain
Rubén Lostado Lorza	Universidad de La Rioja, Spain
Jacinto Santamaría Peña	Universidad de La Rioja, Spain
Íñigo Sanz-Pena	Universidad de La Rioja, Spain
Fátima Somovilla	Universidad de La Rioja, Spain
Efrén Tarancón	Universidad de La Rioja, Spain

Contents

Product Design and Development

Use of Composite Materials in the Design of a Ventilation Grille Attending to Eco-Sustainability Factors 3
F. Xavier Espinach Orús, Fernando Julián Pérez, Manel Alcalà Vilavella, Marc Delgado Aguilar, and Quim Tarrés Farrés

Improvement in the Design of a Front Hub for the BMX Bicycle 13
Rafael M. Pinilla-Gutiérrez, Laia Miravet-Garret, Juan Franquelo-Soler, Fernando Gómez-Hermosa, and Francisco J. Ortiz-Zamora

Prosumer and Product Design Through Digital Tools 23
L. Asión-Suñer and I. López-Forniés

Sustainability Assessment in the Implementation Phase of a Retail Space 31
Natalia Muñoz López, José Luis Santolaya Saénz, Anna Biedermann, and Javier Molina Sánchez-Migallón

Comparative Analysis of Ecodesign in the Design and Manufacturing Methods for Mechanical Parts Made of Nylon PA6 40
José M. Paricio-Sánchez, Ramón Miralbés-Buil, Juan A. Peña-Baquedano, and Alfonso Casas-Albiñana

Co-creative Experiences for the Achievement of the Sustainable Development Goals 49
Jorge Sierra-Pérez and Ignacio López-Forniés

A Swift Clench-and-Release Device for Bicycles’ Wheels with Disk Brakes 58
Giovanni Berselli, Matteo Bonomi, and Roberto Razzoli

Design of Urban Furniture for the Rehabilitation of Spaces	68
Silvia Doblas Expósito, Óscar D. de-Cózar-Macías, Francisca J. Castillo-Rueda, and Patricia Mora-Segado	
Application of New Systems for Positioning the Steering Wheel in Vehicles for the Improvement of Ergonomics in Autonomous Driving	77
Cristina Martín-Doñate, Antonio Gines-Alcaide, Jorge Manuel Mercado-Colmenero, Annalisa Di Roma, and Fermin Lucena-Muñoz	
Conceptual Design of Foldable and Stackable Furniture for Preschool Classrooms	86
J. S. Velázquez-Blázquez, R. G. Silva-Quituisaca, J. Nieto-Martínez, F. L. Sáez-Gutiérrez, D. Parras-Burgos, and F. J. F. Cañavate	
Computer-Aided Design and Interactive Design	
The Inclined Plane Rosary Pump of Benito Bails’ ‘Elements of Mathematics’ (1790): Geometric Modeling and Virtual Reconstruction	97
José Ignacio Rojas-Sola, María de las Mercedes Catena-Ibáñez, and Eduardo De la Morena-De la Fuente	
The Model Based Definition Features - MBD Applied to the Technical Computer Aid Design and Drawing	105
Ramón Miralbes-Buil, Juan Antonio Peña-Baquedano, Jose Manuel Paricio-Sánchez, and David Ranz Angulo	
Geometrical Study of the Barrel as an Element of the Wine-Making Productive Process. Parameterization and Modelling	115
Adriana Conde-Fernández, Eduardo Zurita-De La Vega, Pablo Vila-Lameiro, and Patricia Eva Tato-Sánchez del Valle	
Walking Mechanisms: Study and Design for Use in Sandy Environments	123
Gregorio Romero Rey, M. Luisa Mtz. Muneta, Antonio Carretero Díaz, Juan de Dios Sanz Bobi, and Jorge Gonzalez-Onieva	
A Proposed Methodology for Calculating the Rigid Body Natural Frequencies of EPDM Rubber Fixed Supports with the Finite Element Method (FEM)	132
Eduardo Jiménez-Ruiz, Fátima Somovilla-Gómez, Saúl Iñiguez-Macedo, Carlos Berlanga-Labari, Marina Corral-Bobadilla, and Rubén Lostado-Lorza	

The Importance of 3D Scanned Mesh Processing in FEM Simulation Results	142
Saúl Iñiguez-Macedo, Eduardo Jiménez-Ruiz, Fátima Somovilla-Gómez, José Manuel Valle-Melón, Marina Corral-Bobadilla, María Ángeles Martínez-Calvo, and Rubén Lostado-Lorza	
Manufacturing and Industrial Process Design	
Inspection of 3D Printing and Advanced Manufacturing Processes Using Hybrid 3D Metrological Technologies	153
L. Barrenetxea, R. Minguez, O. Etxaniz, N. Ortega, and S. Plaza	
Conformal Cooling Systems Design and Dimensioning for Injection Molds	166
Abelardo Torres-Alba, Daniel Díaz - Perete, Cristina Martín-Doñate, and Jorge Manuel Mercado-Colmenero	
Custom Elasticity Materials Through Mixing Thermoplastics with Extrusion 3D Printers	175
Ane Eguiazabal-Galán, Aitor Cazón-Martín, María Isabel Rodríguez-Ferradas, Leire Frances-Morcillo, Paz Morer-Camo, and Luis Matey-Muñoz	
Wheelchair Mobility Aid Through the Adaptation of Electric Scooters	184
Bernardo Pajares Moreno, Guillermo Peris-Fajarnés, Ismael Lengua, and María Moncho-Santonja	
Graphical Bioengineering	
A Custom-Made Photogrammetry Scanner to Support Paediatric Surgery	193
Harkaitz Eguiraun, Lander Barrenetxea, Xabier Amezua, Oskar Casquero, Ruben I. Garcia-Fernandez, and Iñigo Tuduri	
Best-Fit Alignment in the Digital Dental Workflow	202
Xabier Amezua-Lasuen, Mikel Iturrate-Mendieta, José Antonio Oriozabala-Brit, Xabier Garikano-Osinaga, Iñaki Martín-Amundarain, and Eneko Solaberrieta-Mendez	
Digitization of the Mechanical Articulator: Virtual Articulator	212
José Antonio Oriozabala-Brit, Xabier Amezua-Lasuen, Xabier Garikano-Osinaga, Mikel Iturrate-Mendieta, Iñaki Martín-Amundarain, and Eneko Solaberrieta-Mendez	
Medical Play Therapy: Development of the JUNIOR-MRI Role Play	219
Diego Paderno, Edoardo Alessio Piana, Ileana Bodini, and Valerio Villa	

Infrared Thermography as a Visualization Technique for Light Muscle Pathologies 227
Francisco-Javier Soto-Lara and Manuel Damián Marín Granados

Development of a Methodology of 3D Modeling of Heads for Their Application in the Design of Customized Sports Helmets 234
David Ranz Angulo, Ramón Miralbes-Buil, and Luis Vidal-Piña

Comparative Analysis of the Adhesion of Metallic Inserts on Dental Implants-Prosthetic Assembly Generated by Polymeric Materials Used for Additive Manufacturing 245
M. Suffo, J. I. Vilches-Pérez, and M. Salido-Peracaula

3D-Printed Canine Tibia Model from Clinical Computed Tomography Data 254
Fátima Somovilla-Gómez, Saúl Iñiguez-Macedo, Eduardo Jiménez-Ruiz, Laura Muro-Fraguas, Gonzalo Gañán-Catalina, Álvaro Leciñana-Soldevilla, Marina Corral-Bobadilla, Carmen Díaz-Bertrana-Sánchez, and Rubén Lostado-Lorza

Efficacy of Morpho-Geometrical Analysis of the Corneal Surfaces in Keratoconus Disease According to Moderate Visual Limitation 263
J. S. Velázquez-Blázquez, D. G. Fernández-Pacheco, J. Alió del Barrio, J. L. Alió, and F. Cavas-Martínez

Innovation in Design

Experimental and Analytical Approaches for Determining the Axial Behavior of Cylindrical Extension Springs 275
Manuel Paredes, Thomas Stephan, and Hervé Orcière

Design Guidelines for Light and Noise Management in the Neonatal Intensive Care Unit 284
Rosana Sanz-Segura, Eduardo Manchado-Perez, Maria Pilar Ferrer-Duce, Delia Gonzalez de la Cuesta, and Elif Özcan

Inspiration in Elements of Nature for the Promotion of Creativity in the Conceptual Design of Products 294
D. Parras-Burgos, D. G. Fernández-Pacheco, F. J. F. Cañavate, F. Cavas-Martínez, F. L. Sáez-Gutiérrez, and J. Nieto

Teaching – Learning in Graphic Engineering

Objective Evaluation of Geometrical Product Specification/ Geometrical Dimensioning and Tolerancing Basic Skills 305
Gabriele Baronio, Ileana Bodini, Diego Paderno, Stefano Uberti, and Valerio Villa

How to Assess the Impact of ICT Contribution in the Graphic Expression Subjects for Engineering Degrees?	313
Triviño-Tarradas Paula, Carranza-Cañadas Pilar, Burgos-Ladrón de Guevara Enrique, and Hidalgo-Fernández Rafael Enrique	
Industrial Design as a Tool for Enhancing Entrepreneurship	320
Cristina Martín-Doñate, Fermin Lucena-Muñoz, Lina García-Cabrera, Elisabeth Estevez, and Jorge Manuel Mercado-Colmenero	
On the Internationalization of CAD Learning Through an English Glossary	330
Raquel Plumed, Victoria Pérez-Belis, Anna Agustín-Claramonte, Néstor Jarque-Bou, Carmen González-Lluch, and Ana Piquer	
Analysis of Spatial Comprehension Through a Retrospective Study of Its Effects Among First Year Electrical Engineering Students	339
Manuel-Damián Marín-Granados, Fernando Gómez-Hermosa, María-del-Carmen Ladrón-de-Guevara-López, Laia Miravet-Garret, and Francisco-Javier Soto-Lara	
Self-assessment in Industrial Engineering. Pilot Test in Graphic Engineering at the Polytechnic University of Catalunya-BarcelonaTech	347
Anna Pujol-Ferran and Oscar Farrerons-Vidal	
About BIM in Civil Engineering	356
José Ángel Aranda Domingo and Miguel Ángel Gil Saurí	
Where is Descriptive Geometry Heading?	365
Rafael Ortiz-Marín, Gloria Del Río-Cidoncha, and Juan Martínez-Palacios	
Active Learning, Improvement of Spatial Abilities and Understanding of Technical Drawing in the Graphic Expression Course	374
Laura Diago Ferrer, Verónica Zubiaurre Eizaguirre, and Enrique Tardio Monreal	
Experience in the Implementation of a Product Lifecycle Management System (PLM) for the Management of Projects in the Subject of Technical Office	386
Pedro Ubieto-Artur, Cristina Royo-Sánchez, and César García-Hernández	
From Y to Z Generation, an Engineering Students' Spatial Skill Analysis	395
Vicente A. López Chao and Jorge Martín-Gutiérrez	

Fostering Outcomes; INGENIA Subjects and Digital Prototyping Laboratories	403
M. Luisa Mtz. Muneta, Gregorio Romero Rey, Juan de Dios Sanz Bobi, and Antonio Carretero Díaz	
Introducing Parametric CAD in a First Year Course in Engineering Degree: A Case Study	411
Alba Roda-Sales, Verónica Gracia-Ibáñez, Maria-Jesús Agost, Miquel Gómez-Fabra Gómez, and Mariana Núñez-García	
Augmented Reality and Mobile Devices as Tools to Enhance Spatial Vision in Graphic Representations	420
T. Polhmann, D. Parras-Burgos, F. Cavas-Martínez, F. J. F. Cañavate, J. Nieto, and D. G. Fernández-Pacheco	
Comparison and Analysis of Graphic Engineering in the Degree in Engineering in Industrial Technologies	428
Elidia Beatriz Blázquez-Parra, Isidro Ladrón de Guevara-López, and Manuel Damián Marín-Granados	
Validation of the Use of Concept Maps as a Tool for the Teaching and Learning of Industrial Drawing	438
Eduarne Iriondo-Plaza, Fernando Veiga-Suárez, Urko Eslava-Adot, and Alain Gil-Del-Val	
Interactive and Lightweight Step-by-Step-Based Environment for Self-learning in Basic Graphic Expression Skills	446
Francisco L. Sáez-Gutiérrez, Laura S. C. Albaladejo, J. S. Velázquez-Blázquez, Dolores Parras-Burgos, Francisco J. F. Cañavate, Daniel G. Fernández-Pacheco, and Francisco Cavas-Martinez	
TDT-L0 a Test-Based Method for Assessing Students' Prior Knowledge in Engineering Graphic Courses	454
Barbara Motyl, Gabriele Baronio, Domenico Speranza, and Stefano Filippi	
Design of Emergency Vehicle Lighting Integrated in Fire Fighting Trucks	464
María Alonso-García, Aída Solís-Mellado, Cristina Gómez-Vázquez, Manuel Fernández-Rubio, Óscar D. de-Cózar-Macías, and Elidia Beatriz Blázquez-Parra	
Engineering and Construction	
3D Semantic-Rich Modelling of Underground Utility Networks	475
Adrian Preciados Royano, José Andrés Díaz Severiano, Valentín Gómez-Jáuregui, Cristina Manchado del Val, Julen López Iglesias, Olmo Fernández García, and César Otero González	

Revision of Automation Methods for Scan to BIM	482
Julen López Iglesias, Jose Andrés Díaz Severiano, Piedad Eliana Lizcano Amoroch, Cristina Manchado del Val, Valentín Gómez-Jáuregui, Olmo Fernández García, Adrian Preciados Royano, and César Otero González	
Modelling As-Built MEP Facilities in a BIM Environment	491
Olmo Fernández García, Jose Andrés Díaz-Severiano, Valentín Gómez-Jáuregui, Cristina Manchado del Val, Julen López Iglesias, Adrian Preciados Royano, and César Otero González	
Geometric Analysis of the Windows of Cordoba's Minarets (Spain) Contribution Title	499
Rafael E. Hidalgo Fernández, Rafael Ortiz-Cordero, Jerónimo Sanz Cabrera, Pilar Carranza Cañadas, Enrique Burgos Ladrón De Guevara, and Paula Triviño Tarradas	
The Analysis of Pathologies in the Church of San Ildefonso in Salorino (Cáceres) Using Geomatic Techniques	507
José Juan de Sanjosé Blasco, Manuel Sánchez-Fernández, Alan D. J. Atkinson, and Angel M. Marra Recuero	
HBIM. Parametric Families from Point Clouds in Heritage Elements	518
María José Marín Miranda, Francisco Javier Chorro Domínguez, Manuel Sánchez-Fernández, and Juan Pedro Cortés-Pérez	
Data Management in "Scan to HBIM" Projects	527
Manuel Sánchez-Fernández, Francisco Javier Chorro, María-José Marín, José Juan de Sanjosé-Blasco, and Luis Francisco Martínez	
Plates Pre-dimensioning for Injection Molds by Using Computational Design and Inclusion of the Parts in BIM Methodology	535
Daniel Diaz-Perete, Abelardo Torres-Alba, Jorge Manuel Mercado-Colmenero, and Cristina Martin-Doñate	
Analysis of the Application of the Superblocks Model in the Context of the PEMUS in the City of Málaga	544
Francisco J. Ortiz-Zamora, E. Beatriz Blázquez-Parra, Francisca Castillo-Rueda, Patricia Mora-Segado, and Francisco Benítez-Villaespesa	
An Accurate Structural Reconstruction in 3D of the Hypostyle Hall at the Ancient Egyptian Temple Complex of Karnak	554
I. A. Liarte Fernando, M. C. Juárez Castelló, and F. J. Marrodán Esparza	

Automatic Detection of High-Voltage Power Lines in LiDAR Surveys Using Data Mining Techniques	568
Daniel Chasco-Hernández, José A. Sanz-Delgado, Víctor García-Morales, and Jesús Álvarez-Mozos	
Comparison of Digital Terrain Models Obtained with LiDAR and Photogrammetry	576
Martínez-Agirre Alex, García-Morales Víctor, and Álvarez-Mozos Jesús	
3D Digitization of the Archaeological and Palaeontological Heritage Through Non-contact Low-Cost Scanners. Comparative Analysis	586
N. Santamaría-Hoyos, J. Santamaría-Peña, J. M. Valle, and F. Sanz-Adán	
Optimization of the Management and Maintenance of Urban Elements Through Geolocation and Linking of Interactive Database to the Construction Information Model	597
M. J. García-Granja, Óscar D. de-Cózar-Macías, E. B. Blázquez-Parra, and A. B. Gutiérrez-Sánchez	
From Opportunity Identification to Concept Generation of Sustainable Modular Buildings	605
Guido Bruni, Luigi De Napoli, Vincenzo Maria Mattanò, and Antonino Morabito	
Correction to: TDT-L0 a Test-Based Method for Assessing Students' Prior Knowledge in Engineering Graphic Courses	C1
Barbara Motyl, Gabriele Baronio, Domenico Speranza, and Stefano Filippi	
Correction to: Digitization of the Mechanical Articulator: Virtual Articulator	C2
José Antonio Oriozabala-Brit, Xabier Amezua-Lasuen, Xabier Garikano-Osinaga, Mikel Iturrate-Mendieta, Iñaki Martin-Amundarain, and Eneko Solaberrieta-Mendez	
Author Index	615

Product Design and Development



Use of Composite Materials in the Design of a Ventilation Grille Attending to Eco-Sustainability Factors

F. Xavier Espinach Orús¹, Fernando Julián Pérez¹(✉),
Manel Alcalà Vilavella¹, Marc Delgado Aguilar²,
and Quim Tarrés Farrés²

¹ Organització Gestió Empresarial i Disseny de Producte, Universitat de Girona,
c/ Maria Aurelis Capmany i Farnés 61, 17003 Girona, Spain
fernando.julian@udg.edu

² Enginyeria Química, Agrària i Tecnologia Agroalimentària,
Universitat de Girona, c/ Maria Aurelis Capmany i Farnés 61,
17003 Girona, Spain

Abstract. This work deals with the design, the engineering of products and the selection of materials destined to the manufacture of a ventilation grille. Additionally, simulates a process of identification and use of agricultural waste for the formulation of composite materials. These materials, once characterized, can be used for the manufacture of new products.

The final product is expected to combine design attributes, technical and legal feasibility, along with the implementation of new biologically based materials that ensure a reduction in the environmental impact.

Taking into account the industrial design, a final concept is proposed and modeled. The product geometry, production technology and legal specifications will be the input data for the product engineering.

The selection of material will be based on the technical and environmental impact requirements. Thermo-mechanical fibers from corn stalks reinforced high-density polyethylene composite was prepared and characterized. These properties are used, together with the boundary conditions, to model and test a virtual model. The final product will be obtained by injection. The new product must be able to deploy under the expected use conditions. The new materials present an economically attractive opportunity to replace other materials, metallic, composite or virgin.

Keywords: Product design · Sustainability eco-design · Composite materials · Use of waste

1 Introduction

Both in the process of designing or redesigning a new product intervene a large number of experts in different fields. The experience of the different actors is devoted to industrial design, product engineering and materials science, among others [1].

The redesign process includes all the necessary activities and knowledge of the actors previously indicated to adapt an existing design to other requirements, which may be legal, technical or economic. In the case of the study, a ventilation grille is redesigned for its manufacture using another material and another technology. The redesign implies that the resulting product must retain the technical and use [2, 3].

The process of redesigning a ventilation grille is presented taking into account a factor that we consider important, such as sustainability. The original appearance and size have been maintained. The innovation that allows generating value is mainly the change of material.

In order to obtain the reinforcements, an agroforestry waste was used. The fibers were obtained by steam treatment of corn stems. Subsequently, a defibration was carried out and then the fibers were mixed with a high density polyethylene (HDPE). Such composite materials, based on thermo-mechanical fibers of corn and HDPE are recyclable and can save up to 50% or more of the volume of the polymeric matrix, in this case HDPE. At the end of their life cycle, the products manufactured with these materials can be incinerated without the generation of waste. In the construction sector, in the case of the grid, the useful life of the materials is especially long, and it is for this reason that the recycling of its components must be promoted.

In terms of materials selection, the current tendency is to look after natural-based composites in order to take into account the sustainability of the final product [4, 5]. Natural fibers or cellulosic fillers/fibers can be classified under four categories depending on their performance when incorporated in a plastic matrix: (i) wood flour or agroforestry waste flour in general, (ii) wood fibers (iii) natural strands or bundles of strands and (iv) fibers from agroforestry residues [6, 7]. The agricultural residues can be considered as particle fillings that improve the tensile and flexural modulus of the compounds with little effect on the composite resistances [8, 9].

Agroforestry residues, made up of stalks and leaves, use to be chipped and buried, or incinerated in land. The overall exploitation of corn stalks and leaves results in different products suitable for their use as filler or reinforcement of composite materials. Hence, the milling process brings to a corn flour with small aspect ratio (L/d), able for the production of wood plastic composites. However, if corn residues are submitted to a defibering process under aqueous conditions, a fibrous material with higher aspect ratio is obtained, suitable for somewhat better product requirements [10]. Both types of processes show almost 100% of yield, with respect to the initial corn residue. Furthermore, the use of thermo-mechanical processes (vaporization followed to defibering) results in a fibrous matter with intrinsic properties, at a very competitive yield [11]. Finally, the utilization of more aggressive treatments such as organosolv processes or sosa-antraquinone treatments (semi-chemical processes) bring to fibers with better mechanical properties [12, 13].

This work focus on then use of agroforestry reinforced polyolefin. Product design and innovation researchers have worked together with experts in materials science in the development of an ecological ventilation grid. The development of the new product presents innovative objectives in the application of new materials to meet the final requirements of the market sub-sector.

2 Methodology

In order to create value, a process divided by knowledge areas is proposed, converting agricultural waste into product proposals. To get from the starting point to the goal, follow the steps proposed in Fig. 1.

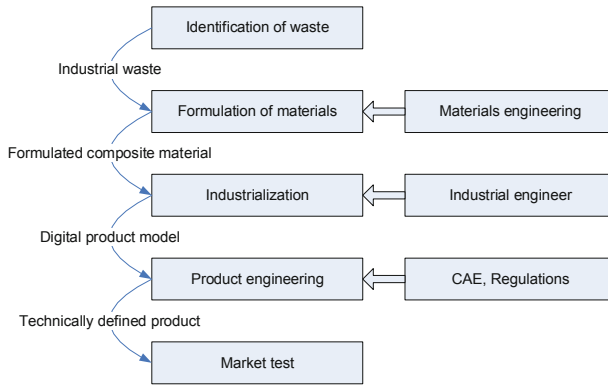


Fig. 1. Research framework for product development.

In the first stage, those materials capable of being recovered are identified. This stage can be the result of an investigation or the proposal of a company that wants to value its waste. It is important the participation of experts in materials science to establish the suitability of the proposed materials.

The second stage comprises the formulation of the composite materials. It is a typically experimental stage. Material science experts have to establish the matrices upon which the composite material will be based. In this way, the uses of the elements to be inertized as loads or reinforcements will be established. All laboratory tests are carried out to establish the physical and chemical characteristics of the formulated materials. At the end of the stage all the graphs and tables characteristic of the composite materials and their variations will be provided to the engineers and designers responsible for the industrialization stage.

The third stage of industrialization combines knowledge in engineering with those of industrial design. Throughout the stage, the product to be designed or industrialized is established, taking into account the production processes. You can start from an existing product or redesign one again. This stage is applied research. At the end of the stage, a digital model of the product is obtained. This model includes all the geometric specifications that must allow adaptation to the use and manufacturability of the product.

The fourth stage has to establish if the design is able to respond positively to the boundary conditions to which it will be subjected. In this way, the loads, pressures, limitations of the degrees of freedom that are either defined in homologation norms or deduced from their use will be applied to the digital model. The stage is typically applied. Computer-aided engineering (CAE) programs are used to reach the results.

During this stage, optimization loops are established with the previous ones since it is typically necessary to make modifications in the geometry or in the specifications of the materials to ensure a correct result. At the end of the stage, a feasible product is obtained from a technical point of view [1].

The next stage includes all market studies and economic analyzes that must ensure economic and market feasibility. This stage is beyond the scope of this investigation.

3 Formulation of the Material

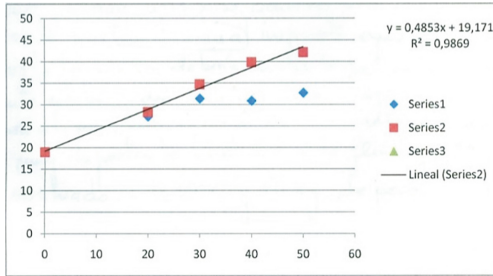
Fibers from corn are identified as the result of agricultural activity. The stems of corn are subjected to a treatment with steam to extract the fibers. For the matrix of the composite material, the use of HDPE is proposed.

Table 1 shows the flexural properties of the materials with the coupling agent (2% de Maleated Polyethylene - MAPE) for formulations at 20, 30, 40 and 50% (w/w).

Table 1. Flexural properties with and without coupling agents for % w/w formulations.

%w/w	Flexural modulus: E_f^c		Flexural strength: σ_f^c	
	2% MAPE	0% MAPE	2% MAPE	0% MAPE
0	0.520 (0.03)	0.52 (0.03)	18.92 (0.35)	18.92 (0.35)
20	1.55 (0.12)	0.51 (0.06)	27.24 (0.56)	28.24 (0.34)
30	1.98 (0.07)	1.92 (0.17)	31.36 (0.4)	34.7 (0.81)
40	2.53 (0.06)	2.61 (0.04)	30.85 (0.34)	39.81 (0.43)
50	2.86 (0.13)	2.78 (0.1)	32.69 (0.66)	42.13 (0.24)

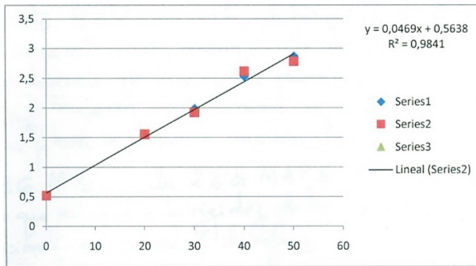
Regarding the σ_f^c , two situations can be verified that refer to its evolution with the reinforcement percentage (Fig. 2). In the case of the formulation without coupling agent, the resistance to bending (σ_f^c) increases linearly up to 30% (w/w) to then inflect. Probably in the first part the increase in σ_f^c is due to the mechanical anchoring of the HDPE on the surface of the fibers. This capacity of diffusion and anchoring of the HDPE on the fibers stabilizes when increasing the percentage of reinforcement, because of the absence of chemical interactions between the fibers and the matrix. On the other hand, it is verified that using only 2% of MAPE the σ_f^c increases linearly with the reinforcement percentage. This is a consequence of the creation of hydrogen bonds between the hydroxyl groups of the surface of the fibers and the maleic anhydride phase of the MAPE. Thus, the interphase of the coupled composites is stronger than uncoupled ones. The highest tensile strength was obtained for the composite with 50% w/w reinforcement content. This composite showed a strength 133% higher than the matrix.



% w/w	0% MAPE	2% MAPE
0	18.92 (0.35)	18.92 (0.35)
20	27.24 (0.56)	28.24 (0.34)
30	31.36 (0.4)	34.7 (0.81)
40	30.85 (0.34)	39.81 (0.43)
50	32.69 (0.66)	42.13 (0.24)

Fig. 2. Flexural strength: σ_f^c .

On the other hand, it was observed that the flexural modulus evolves linearly with the reinforcement percentage and that this evolution is independent of the coupling agent (Fig. 3). Therefore, for this type of application the composite material without coupling agent could be used.



% w/w	2% MAPE	0% MAPE
0	0.520 (0.03)	0.52 (0.03)
20	1.55 (0.12)	0.51 (0.06)
30	1.98 (0.07)	1.92 (0.17)
40	2.53 (0.06)	2.61 (0.04)
50	2.86 (0.13)	2.78 (0.1)

Fig. 3. Module strength: E_f^c .

Figure 4 shows the holes generated by the fibers during the tensile test and can be compared to the interface of a fiber that generates a tensile strength of 20.36 MPa with 2% MAPE (40% w/w)).

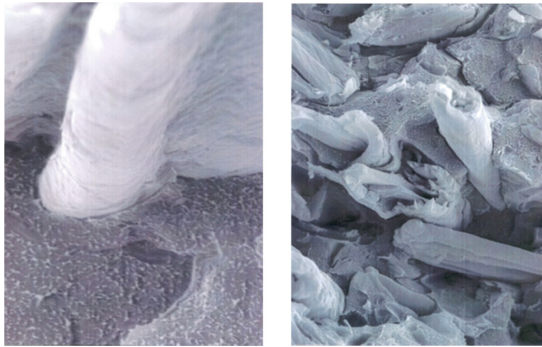


Fig. 4. Gaps that generate fibers, without MAPE and with MAPE.

Regarding the rigidity of the materials, a linear evolution is observed with the reinforcement percentage, typical of this type of materials.

Facing the industrialization of these composites, a very important parameter is the flow index (Melt Flow Index - MFI). In this case, it was evaluated at 210° and 10 kg of weight (Fig. 5). In the case of materials at 50% (w/w) it is observed that at 210 °C and 10 kg. The pellets do not flow. This would indicate that between 2 and 3% of lubricating agent should be used in this case to drive the MFS to values to 8 ÷ 10 g 10 min.

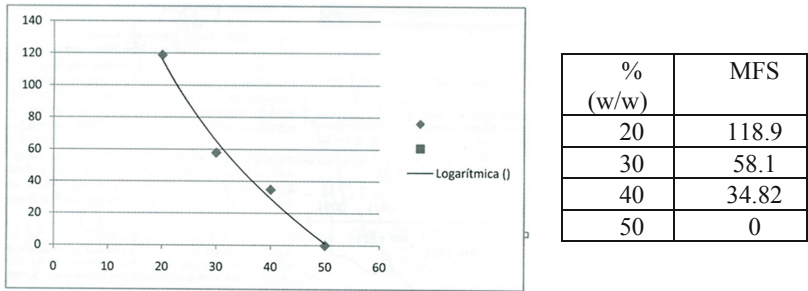


Fig. 5. MFS fluency index.

From the results analyzed and according to economic and sustainability technical criteria, it can be inferred that a good option would be the use of the 40% (w/w) formulation that allows compliance with the required requirements, saving on the consumption of a product like HDPE and inert a significant amount of agricultural waste. From an economic point of view, although the manufacture of the composite material involves an additional transformation operation, the balance is positive.

4 Results and Discussion

The starting points for the choice of the product to be industrialized are, on the one hand, the formulation of the investigated material, the market to which it is addressed, elements and materials for the construction and on the other the manufacturing technology chosen, in this case the injection. These conditions establish that the product to be designed must be of small or medium dimensions, high production, and not subject to great stress or strain. The number of construction elements that respond to these requirements is very high; boxes for meters or electrical connections, mailboxes, answering machines, IP switches, luminaires, cladding...

The choice of the product responds to a search for references and a creativity session with the entire research team. The techniques used were the Synectics and Metaplan to obtain a list of ideas and then an evaluation of them [14–16]. The criteria of choice have been; technical feasibility, market possibilities, and potential improvements in the aspects of industrial design. Under these conditions, the chosen product has been a ventilation grid (Fig. 6).



Fig. 6. Ventilation grid 400×400 . Reference element and aluminum grid.

The starting product is an aeration grid of 400×400 mm. This element is built in concrete. The current product has a mass of 4.5 kg. In the market there are similar products made of aluminum, plastic, steel ... but we have not identified any manufacturer that uses composite materials with characteristics similar to the one formulated in this article.

The boundary conditions are established in the Technical Building Code (CTE). The main loads to which it will be subjected are those of the wind. The calculation hypothesis will be an installation in a type building of 25 m in height, located in a C zone and with a degree of roughness V (CTE, Formula 1). For these requirements, the final request is approximately 1000 N/m^2 .

$$q_e = q_b \cdot c_e \cdot c_p \quad (1)$$

For the calculations and the redesign we add a coefficient of maximization of loads of 1.5, with which the design solicitation becomes 1500 N/m^2 .

Following the steps proposed in the methodology, we modeled the current product, obtaining a 3D model and subjected it to the boundary conditions. The characteristics of the test material are those corresponding to a standard concrete, E : 2.1 GPa. The model is subjected to a load of 1500 N/m^2 perpendicular to the outer face and all its embedded sides are considered (restriction of all degrees of freedom). The most interesting results are an equivalent safety coefficient of 317 and a maximum deformation in the 0.02 mm model (Fig. 7a). The oversized is due to the sections of material used, due to the parameters of manufacturing parts molded with concrete. This type of manufacturing requires large sections to ensure the filling of the molds. The design is acceptable due to the low cost of the material.

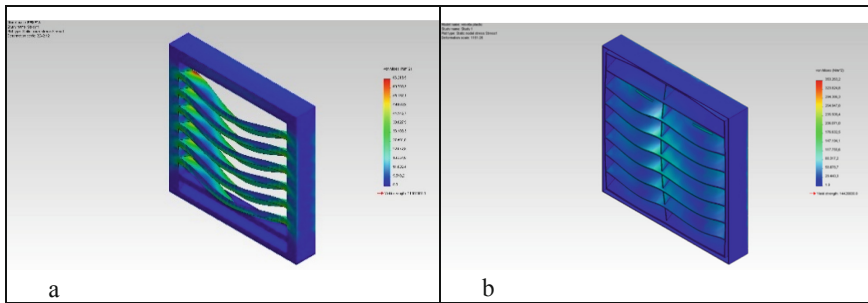


Fig. 7. A: Resulting stresses in the grid subjected to the boundary conditions (def. scale x2242). B: Resulting stresses in the grid subjected to the boundary conditions (def. scale x1151).

To ensure that the product can be manufactured by injection it is important that the thickness of the piece is constant and that there are no barriers to unmold. For the piece to be economical, the mold must be of two pieces, without sliders or inserts. The redesigned product shares the appearance with the starting one, with the inclusion of a central rib that acts as a reinforcement and as a filling channel. The thickness of the wall is 2.5 mm and the final mass of the piece is 1.2 kg. For the realization of the calculations, the small rounding in the edges or the angles of demolding of the piece are not contemplated.

The model is subjected to the same boundary conditions as the original part and the most outstanding results are an equivalent safety coefficient of 41 and a maximum deformation of 0.04 mm (Fig. 7b).

The cost attributable to the material would be, for HDPE virgin 2.04 €, and for HDPE + 40% w/w 1.32 €. In this way, a saving of 35% is established. The final cost of the product would be € 1.62.

With the economic data and the geometric proposal (Fig. 8) it is possible to start the market study stage to verify if the product is totally feasible and can go into production.

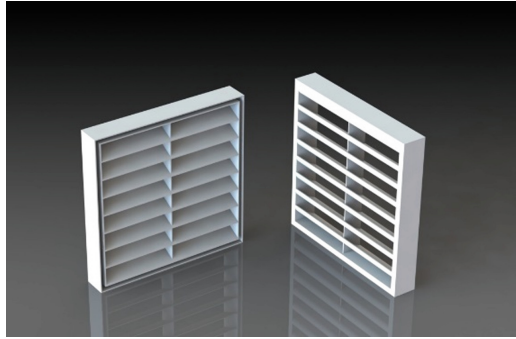


Fig. 8. Final proposal

5 Conclusions

A methodology for the design and development of products based on the reuse of waste materials is proposed, which is able to establish a new composite material and a new technically viable product. The application to building materials, regardless of the final product (ventilation grille) opens a wide range of possibilities. The creation of opportunities establishes the need for collaboration between different areas of knowledge. In this case the collaboration between materials science, design and engineering is able to develop a new material and turn it into a product proposal.

The agricultural residues of corn stem are susceptible to be used as reinforcement load of composite materials with an HDPE matrix. With the same and depending on the percentage of reinforcement with and without coupling agent, products capable of satisfying the requirements of a certain gamma of market products can be obtained. This constitutes a clear contribution to sustainability, reducing the consumption of a petroleum product and inerting an agricultural waste that is usually incinerated.

Nonetheless, to establish clearly the environmental advantages of the proposed composite materials, a life cycle analysis is needed. The use of natural fibers hinders recycling the materials.






References

1. Serrano, A., et al.: Study on the technical feasibility of replacing glass fibers by old newspaper recycled fibers as polypropylene reinforcement. *J. Clean. Prod.* **65**, 489–496 (2014)
2. Julian, F., et al.: Design and development of fully biodegradable products from starch biopolymer and corn stalk fibres. *J. Biobased Mater. Bioenergy* **6**(4), 410–417 (2012)
3. Julian, F., et al.: Bio-based composites from stone groundwood applied to new product development. *BioResources* **7**(4), 5829–5842 (2012)
4. Galan-Marin, C., Rivera-Gomez, C., Garcia-Martinez, A.: Use of natural-fiber bio-composites in construction versus traditional solutions: operational and embodied energy assessment. *Materials* **9**(6), 465 (2016)

5. Kozłowski, R., Władyka-Przybylak, M.: Uses of natural fiber reinforced plastics. In: Wallenberger, F.T., Weston, N.E. (eds.) *Natural Fibers, Plastics and Composites*, pp. 249–274. Springer, Boston (2004)
6. Vallejos, M.E., et al.: Micromechanics of hemp strands in polypropylene composites. *Compos. Sci. Technol.* **72**(10), 1209–1213 (2012)
7. Espinach, F.X., et al.: Analysis of tensile and flexural modulus in hemp strands/polypropylene composites. *Compos. Part B Eng.* **47**, 339–343 (2013)
8. Rowell, R.M., et al.: Utilization of natural fibres in plastic composites: problems and opportunities. In: Leao, A.L., Carvalho, F.X., Frollini, E. (eds.) *Lignocellulosic-Plastics Composites*. Universidade Estadual Paulista, Universidade Estadual Paulista, Sao Paulo (1997)
9. Flandez, J., et al.: Management of corn stalk waste as reinforcement for polypropylene injection moulded composites. *BioResources* **2**(7), 1836–1849 (2012)
10. Jiménez, A.M., et al.: Tensile strength assessment of injection-molded high yield sugarcane bagasse-reinforced polypropylene. *BioResources* **11**(3), 6346–6361 (2016)
11. Reixach, R., et al.: Tensile properties of polypropylene composites reinforced with mechanical, thermomechanical, and chemi-thermomechanical pulps from orange pruning. *BioResources* **10**(3), 4544–4556 (2015)
12. El Mansouri, N.-E., et al.: Research on the suitability of organosolv semi-chemical triticale fibers as reinforcement for recycled HDPE composites. *BioResources* **7**(4), 5032–5047 (2012)
13. Jimenez, L., et al.: Organosolv ethanolamine pulping of olive wood - Influence of the process variables on the strength properties. *Biochem. Eng. J.* **39**(2), 230–235 (2008)
14. Ferrer, J.B., et al.: Eco-innovative design method for process engineering. *Comput. Chem. Eng.* **45**, 137–151 (2012)
15. Howard, T.J., Dekoninck, E.A., Culley, S.J.: The use of creative stimuli at early stages of industrial product innovation. *Res. Eng. Des.* **21**(4), 263–274 (2010)
16. Julian, F., et al.: Study of the creative tension in students of engineering of two Spanish universities. *Interciencia* **36**(7), 524–530 (2011)



Improvement in the Design of a Front Hub for the BMX Bicycle

Rafael M. Pinilla-Gutiérrez¹ , Laia Miravet-Garret² ,
Juan Franquelo-Soler² , Fernando Gómez-Hermosa² ,
and Francisco J. Ortiz-Zamora² 

¹ Universidad de Málaga, c/ Doctor Ortiz Ramos s/n, 29071 Málaga, Spain

² Dpto. de Expresión Gráfica, Diseño y Proyectos,
Escuela de Ingenierías Industriales, Universidad de Málaga,
c/ Doctor Ortiz Ramos s/n, 29071 Málaga, Spain
laiamiravet@uma.es

Abstract. Bicycle wheels for BMX (Bicycle Moto Cross) are subjected to considerable stresses during the practice of this sport, particularly in the Free-style mode where the execution of stunts and large jumps often causes the breakage of certain components.

This study describes the improved design of a front hub for this type of bicycle, which presents two essential advantages in comparison with the existing hubs according to a market survey. Its shell has been optimized to reduce the risk of broken spokes by redesigning the flanges to avoid stress concentration points while increasing their support surface. Moreover, the protection of the spokes is also improved by a new hub cover and the creation of a subdivision of the cone whose assembly provides greater fixation, which allows for maintaining the assembly of all the hub components either with or without the hub cover.

Other aspects of the design have been considered based on several investigations and surveys regarding both aesthetic concepts and other demands of this extreme sport.

Keywords: Bicycle Moto Cross · BMX · Hub · Spokes

1 Introduction

The BMX (Bicycle Moto Cross) emerged in California (USA) in the 60's as teenagers imitated motorcycle racing with their bicycles, which, little by little, increased in popularity until it became a cycling discipline that was recognized by the International Cycling Union in 1993 [1], although there are video references that date back to 1955 in the Netherlands [2, 3].

The “Racing” modality consists of racing at the highest possible speed through bumpy or obstacle-laden courses while the “Freestyle” mode entails the difficulty of performing jumps and acrobatic sequences in the different environments that define its various modes (“park”, “Street”, “flat”, “vertical” and “dirt”), and on different structural elements (benches, stairs, railings, and vertical walls) [1]. Bicycles of a relatively smaller size (frames between 950 and 1025 mm with 20-in. wheels) are used, and these