

## E T S I + D + I

Este boletín informativo electrónico de periodicidad bimestral tiene como objetivo informar de las actividades de investigación desarrolladas en la ETS de Ingeniería y Diseño Industrial y recopilar los resúmenes de los artículos publicados en la Web of Science (WoS) de los que son autores o coautores investigadores de la Escuela.

## ACTIVIDADES

SEMANA DE LA CIENCIA Y LA INNOVACIÓN  
2019: "Por una Ciencia Inclusiva"

En el mes de noviembre de 2019, se ha desarrollado la "Semana de la Ciencia y la Innovación", un evento de divulgación científica que busca involucrar activamente a todos los ciudadanos en la ciencia, la tecnología y la innovación, y, de forma especial, a los más jóvenes.

El número de investigadores participantes, en toda la UPM, ha sido este año de 341, un 3% más que el año pasado.

Alrededor de cinco mil personas han disfrutado de las actividades ofrecidas en las distintas Escuelas de nuestra Universidad.

En nuestra Escuela, la ETSIDI, a lo largo de tres días laborales se ofertaron diversas actividades dirigidas a grupos escolares.

El viernes 8 de noviembre, los alumnos de la ESO tuvieron la oportunidad de participar en tres actividades de distinta índole científica. En primer lugar, asistir a una ponencia sobre la Tabla Periódica, presentada en el año en el que se conmemora el 150 aniversario de su creación.

También se realizaron dos talleres, para grupos más pequeños: "Visita al laboratorio de Fabricación Mecánica"; y "Aula Solar Fotovoltaica", en la cual pudieron conocer los paneles solares que tiene nuestra Escuela instalados en la azotea.



Fig. 1. "Aula Solar Fotovoltaica"

El martes 12 de noviembre, otro grupo de alumnos, también de la ESO, pudo participar en dos talleres diferentes: "Nuestro entorno en el infrarrojo", e "Ingeniería hidráulica para el desarrollo".



Fig. 2. "Nuestro entorno en el infrarrojo"

El miércoles 13 de noviembre se acogió en la escuela a un grupo de alumnos de Primaria, que, tras una charla denominada "Sonidos del Cielo", participaron en dos talleres diferentes. El primero de ellos, una actividad que permitió que los niños comprobaran lo que habían aprendido, mediante la herramienta del Kahoot,. El segundo, un taller, en el que se enseñó a los alumnos los robots que se han desarrollado en nuestra Escuela.



Fig. 3. Taller en el que se presentaron los robots desarrollados en la ETSIDI

Unido a todas estas actividades, durante la mañana del sábado 16 de noviembre tuvo lugar la Jornada de Puertas Abiertas "Ven y Descubre". En ella, niños de edades comprendidas entre los 7 y 14 años, junto con sus familiares, disfrutaron de un abanico de once talleres sobre diferentes temas relacionados con la ciencia y la tecnología. Se ofertaron actividades como "Adéntrate en la Química", "Aprendiendo a Medir", "Crea Tu Gadget Electrónico", "Energía Eléctrica a tu Alcance", "Diseño para crecer", "Nuestro Sol, Fuente de Energía", etc.



Fig. 4. "Hidráulica para el desarrollo"



Fig. 5. "Crea tu gadget electrónico"



Fig. 6. Las asociaciones también estuvieron en el hall, presentando sus diferentes proyectos

Con todas estas actividades, los profesores, personal, y alumnos voluntarios de la ETSIDI acogimos a más de cuatrocientos visitantes, en su mayoría "pequeños investigadores".



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## SEMINARIOS

Entre los meses de septiembre a noviembre de 2019, se han llevado a cabo en nuestra Escuela cuatro Seminarios, dirigidos a alumnos de Máster y Doctorado, e impartidos por ponentes de Universidades extranjeras que han sido invitados a la ETSIDI para exponer temas de actualidad, como son la contaminación, o el desarrollo de nuevos materiales.

SEMINARIO 23 DE SEPTIEMBRE DE 2019

Digital Image Correlation for shape and deformation measurements in solid mechanics: theory and practice

Impartido por: Profesora Katia Genovese, Università degli Studi della Basilicata (Italia)

SEMINARIO 14 DE NOVIEMBRE DE 2019

Contaminants of Emerging Concern in the Environment: Current situation and challenges

Impartido por: Profesor Jonathan Espindola, Universidade do Porto (Portugal)

SEMINARIO 25 DE NOVIEMBRE DE 2019

Overcoming limitations in photocatalytic/photochemical processes

Impartido por: Profesor Jonathan Espindola, Universidade do Porto (Portugal)

SEMINARIO 28 DE NOVIEMBRE DE 2019

Spectroscopic studies of dispersion and orientation of carbon nanotubes and graphene in aqueous inks and related nanomaterials

Impartido por: Profesor Eric Anglaret, Université de Montpellier (Francia)

**Nuestra ETSI+D+i**

**Seminario:**  
Contaminants of Emerging Concern (CECs) in the environment: Current situation and challenges  
*Jonathan Espindola*  
Faculdade de Engenharia, Universidade do Porto (Portugal)

**PORTO**  
FELP FACULDADE DE ENGENHARIA  
UNIVERSIDADE DO PORTO

Jueves, 14 de noviembre  
13:00 h

Sala roja

**Nuestra ETSI+D+i**

**Seminario:**  
Overcoming limitations in photocatalytic/photochemical processes  
*Prof. Jonathan Espindola\**  
\*Faculdade de Engenharia, Universidade do Porto (Portugal)

**PORTO**  
FELP FACULDADE DE ENGENHARIA  
UNIVERSIDADE DO PORTO

Lunes, 25 de noviembre  
15:30 h

Sala roja

**Nuestra ETSI+D+i**

**Seminario:**  
Spectroscopic studies of dispersion and orientation of carbon nanotubes and graphene in aqueous inks and related nanomaterials  
*Prof. Eric Anglaret\**  
\*Laboratoire Charles Coulomb, CNRS, Université de Montpellier (France)

**UNIVERSITÉ DE MONTPELLIER**

Jueves, 28 de noviembre  
12:30 h

Sala roja

## E T S I + D + I

Este boletín informativo electrónico de periodicidad bimestral tiene como objetivo informar de las actividades de investigación desarrolladas en la ETS de Ingeniería y Diseño Industrial y recopilar los resúmenes de los artículos publicados en la Web of Science (WoS) de los que son autores o coautores investigadores de la Escuela.

## PUBLICACIONES

**Takagi-Sugeno Fuzzy Incremental State Model For Optimal Control Of A Ball And Beam Nonlinear Model**

The optimal control of a ball and beam by an approach based on Takagi-Sugeno incremental state model is proposed. The advantages of incremental state model in comparison with the non incremental one are that the control action cancels steady state errors, the affine terms disappear and incremental state solves the problem of computing the target state, choosing zero as an objective. A generalized version of Takagi-Sugeno identification method is applied. For an optimal control, Linear Quadratic Regulator and optimal state observer are used in each fuzzy rule. Simulation results over the ball and beam nonlinear model show a stable closed loop in the full range, zero steady state error and good transient response.

## Autores:

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DOI: [10.1007/978-3-030-20055-8\\_51](https://doi.org/10.1007/978-3-030-20055-8_51)

## REFERENCIA:

*Al-Hadithi, BM; Adánez, JM; Jiménez, A. Takagi-Sugeno Fuzzy Incremental State Model For Optimal Control Of A Ball And Beam Nonlinear Model. International Workshop on Soft Computing Models in Industrial and Environmental Applications, 533-543 (SOCO 2019).*

## Culture, Society and Design ...As Usual As Sitting.

Design and culture are two concepts that have been advancing hand in hand throughout history; the design as that capacity that the human being has to devise and realize those objects that make life more pleasant and the culture as that place of encounter between human beings, perfect scenario to look for synergies and advance.

Society, a frame of reference where actions take shape, conditions and molds people, who, while yearning for their own identity, are continually conditioned by the Other, entering again and again into processes of imitation. And finally, the chair, an essential element of our culture, illustrates in each moment the speech making reference to our concerns, desires, actions in constant consonance with the daily actions of the human being.

The chair, that element that facilitates the attitude of stopping, resting and reflecting, also assumes a metaphorical dimension, socialization, loneliness, and work, in short, the main axis that brings together our past, present and future. And in this text the chair is the common thread that shows in images the relationship between Culture, Society and Design.

### Autores:

1. De Miguel Álvarez, L - Universidad Internacional de La Rioja (UNIR) Logroño, La Rioja, Spain.
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ISSN: [2254-6073](https://doi.org/10.2254-6073)

### REFERENCIA

De Miguel Álvarez, L; Nuere Menéndez-Pidal, S. *Cultura, sociedad y diseño...tan cotidiano como sentarse*. Revista Sonda: Investigación y Docencia en Artes y Letras, 139-152 (2018).

### Influence of Multiple Anchor Arrangement in the Behaviour of FRP-to-Concrete Anchored Joints

The effectiveness of fibre-reinforced polymers (FRP) external reinforcements is limited by premature delamination from concrete. In recent years, various anchoring systems were developed for FRP sheets.

Among these, FRP anchors stand out for their effectiveness. When the unit strength of a connector is insufficient, multiple anchors may be employed. This paper presents an experimental campaign consisting of single shear tests on CFRP anchored narrow (100 mm width) and wide (200 mm width) sheets in concrete substrates.

One anchor was installed in narrow sheets for comparison with wide sheets. Wide sheets were tested with one anchor and with two anchors transversally distributed to evaluate the influence of multiple anchors.

Results from both literature and tests show that an optimal arrangement of one anchor in narrow FRP sheets or two transversally distributed anchors in wide sheets can be equivalent, which allows the anchored joints to develop more than twice the bond strength.

#### Autores:

1. Cortez Flores, IA – School of Civil Engineering, UPM, Madrid, Spain.
2. Fernández Gómez, J – School of Civil Engineering, UPM, Madrid, Spain.
3. Villanueva Llaurado, P – School of Civil Engineering; Dept Mech, Chem & Ind Design Eng, ETSIDI UPM, Madrid, Spain.

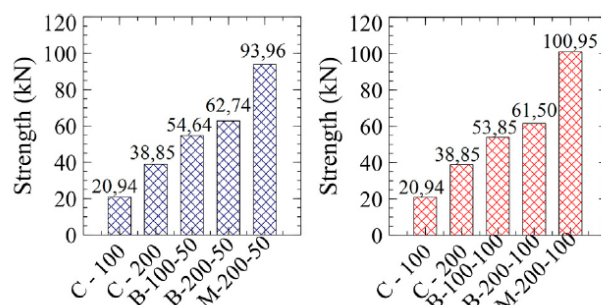


Fig. 15. Strength Comparison

DOI: [10.1016/j.compstruct.2019.111528](https://doi.org/10.1016/j.compstruct.2019.111528)

#### REFERENCIA

Cortez Flores, IA; Fernández Gómez, J; Villanueva Llaurado, P. Influence of Multiple Anchor Arrangement in the Behaviour of FRP-to-Concrete Anchored Joints. *Composite Structures*, V.230 (2019)



## Strengthening the Interaction of Art and Science Through Rubric-Based Evaluation Models: The Final Degree Project of the Dual Degree of Engineering in Industrial Design and Mechanical Engineering

Massachusetts Institute of Technology (MIT), one of the most prestigious institutions in technological innovation, incorporates art and creativity as a distinctive element of its research, technological degrees, humanities and creative subjects. Unfortunately, art and creativity do not have the same consideration.

This study intends to present a work line corresponding to the art-science integration, which is part of a renovation-didactic-project developed in the study-area of industrial design at the Higher Technical School of Engineering and Industrial Design (Escuela Técnica Superior de Ingeniería y Diseño Industrial, ETSIDI of the Polytechnic University of Madrid, Spain).

The benefits of rubric use in order to facilitate a creative-aspects-evaluation guide in the double degree of Engineering in Industrial Design and in Mechanical Engineering will be analysed precisely.

<b>1. MEMORY</b>		<b>70%</b>
<b>1.1. Index, introduction and study definition</b>	CG 8	15%
<b>1.2. Development</b>		<b>30%</b>
1.2.1. Concept, process and creativity	CG 2, CG 10	15%
1.2.2. Technical and scientific aspects	CG 1, CG 2, CG 7	15%
<b>1.3. Results and social, environmental and commercial impact</b>	CG 3, CG 4, CG 9	15%
<b>1.4. Conclusions and continuity</b>	CG 5	10%
<b>2. FORMAL ASPECTS AND COMMUNICATION</b>		<b>30%</b>
<b>2.1. Academic writing</b>	CG 5	10%
<b>2.2. Design and images</b>	CG 5	5%
<b>2.3. Presentation and oral defense (part in English)</b>	CG 5, CG 8	15%

Fig. 2. Sections of the rubric, degree competences and grading percentages

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DOI: [10.1007/978-3-030-00108-7\\_16](https://doi.org/10.1007/978-3-030-00108-7_16)

### REFERENCIA

Diaz-Obregon, R; Nuere Menéndez-Pidal, S; D'Amato, R; Islán, M. Strengthening the Interaction of Art and Science Through Rubric-Based Evaluation Models: The Final Degree Project of the Dual Degree of Engineering in Industrial Design and Mechanical Engineering. *New Trends in Educational Activity in the Field of Mechanism and Machine Theory*, 141-148 (2018)

## Didactic Methodologies Used in Industrial Design and Mechanical Engineering for the Implementation of the Marked Competencies and Their Professional Insertion

Since the academic year 2010-11 the Technical University of Madrid (UPM), University Carlos III of Madrid (UC3M) and the Salesianos Atocha College (CSA), have been steadily working on teaching their subjects through the Project-Oriented Learning (POL) methodology.

Later they also implemented more didactic methodologies in order to achieve a higher development in the competences of students. These schools incorporated Service-Learning (SL), and several other tools such as Dynamic Technical Documentation (DTD), Google Sites and Moodle.

Other teaching methodologies have been added since the academic year 2014-15 in order to further improve the training of students, which pay special attention to training units, which are particularly difficult to understand.

To this end, didactic methodologies such as Kounaikenshuu, Flipped Classroom, and tools such as Portfolio, Plickers and Kahoot! all aimed at improving the quality of the Bachelor Final Thesis.

The implementation of these new didactic methodologies not only improved students' academic training (32% improvement in UPM, 14% in theoretical training and 33% in practical training in CSA) but also achieved the competencies marked for the double Degree in Design and Mechanical Engineering at UPM and Industrial Mechatronics in the CSA.

These results were also confirmed by the satisfaction surveys carried out by the collaborating partners of the projects which showed improvements of between 19% and 43% in theoretical training and between 53% and 68% in practical training at UPM, whereas in CSA, the improvement in theoretical training was 22% and 85% in practical training according to the criterion of the partner-collaborators.

Professors and teachers from both institutions said that the implementation of these methodologies caused them to be overworked due to the excessive number of students but on the other hand, they also improved their teaching competencies.

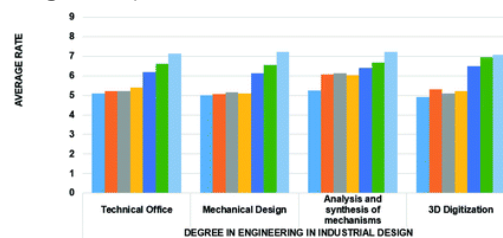


Fig. 1. Mean ratings UPM. Theoretical knowledge  
[Part of the image]

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DOI: [10.1007/978-3-030-00108-7\\_20](https://doi.org/10.1007/978-3-030-00108-7_20)

### REFERENCIA

García-Alonso, JM; Soriano-Heras, E; Blaya, F; Rubio, H. Didactic Methodologies Used in Industrial Design and Mechanical Engineering for the Implementation of the Marked Competencies and Their Professional Insertion. *New Trends in Educational Activity in the Field of Mechanism and Machine Theory*, 177-185 (2018)



## Floodplain Land Cover and Flow Hydrodynamic Control of Overbank Sedimentation in Compound Channel Flows

Overbank sedimentation is predominantly due to fine sediments transported under suspension that become trapped and settle in floodplains when high-flow conditions occur in rivers.

In a compound channel, the processes of exchanging water and fine sediments between the main channel and floodplains regulate the geomorphological evolution and are crucial for the maintenance of the ecosystem functions of the floodplains.

These hydrodynamic and morphodynamic processes depend on variables such as the flow-depth ratio between the water depth in the main channel and the water depth in the floodplain, the width ratio between the width of the main channel and the width of the floodplain, and the floodplain land cover characterized by the type of roughness.

This paper examines, by means of laboratory experiments, how these variables are interlinked and how the deposition of sediments in the compound channel is jointly determined by them.

The combination of these compound channel characteristics modulates the production of vertically axised large turbulent vortical structures in the mixing interface.

Such vortical structures determine the water mass exchange between the main channel and the floodplain, conditioning in turn the transport of sediment particles conveyed in the water, and, therefore, the resulting overbank sedimentation.

The existence and pattern of sedimentation are conditioned by both the hydrodynamic variables (the flow-depth ratio and the width ratio) and the floodplain land cover simulated in terms of smooth walls, meadow-type roughness, sparse-wood-type roughness, and dense-wood-type roughness.

### Autores:

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DOI: [10.1029/2019WR024989](https://doi.org/10.1029/2019WR024989)

### REFERENCIA

Juez, C; Scharer, C; Jenny, H; Schleiss, AJ; Franca, MJ. Floodplain Land Cover and Flow Hydrodynamic Control of Overbank Sedimentation in Compound Channel Flows. *Water Resources Research*, Volume 55, Issue 11 (2019)

### Theoretical transition probabilities, radiative lifetimes and Stark broadening parameters of singly ionized magnesium

The presence of spectral lines of singly ionized magnesium (Mg II) in stellar atmospheres has been reported in different stars. Recently, the low-resolution spectrum obtained from Supernova 2014 J in M82, in which Mg II absorption lines centred on 4400 Å as well as 7600 Å stand out, has been analysed. This is the motive for the atomic data calculations in this work, which are of much interest in the astrophysical area. In this article, ab initio relativistic Hartree-Fock calculations in an intermediate coupling formalism using Cowan's code allowed us to obtain the required transition probabilities to calculate the theoretical radiative lifetimes for excited  $nS-$ ,  $nP-$ ,  $nD-$  and  $nF-$  states of singly ionized magnesium. An asymptotic dependence of lifetime ( $\tau_{nl}$ ) on the effective principal quantum number ( $n^*$ ) has been determined. Also, the Griem semi-empirical approach was used to obtain the theoretical Stark parameters (width and shift) of spectral lines; these data are displayed for an electron density of  $10^{17} \text{ cm}^{-3}$  and temperatures  $T = 10-100 (\times 10^3 \text{ K})$ . We have compared the results of lifetimes for 16 levels and Stark parameters for seven spectral lines with previously reported experiments available in the literature.

Finally, we discuss the behaviour of the Stark parameters versus temperature for three relevant spectral lines (2802.70, 2797.99 and 7868.04 Å).

#### Autores:

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DOI: [10.1093/mnras/stz2744](https://doi.org/10.1093/mnras/stz2744)

#### REFERENCIA

Moreno Díaz, C; Alonso Medina, A. *Theoretical transition probabilities, radiative lifetimes and Stark broadening parameters of singly ionized magnesium*. *Monthly Notices of the Royal Astronomical Society*, Volume 490, Issue 2, Pages 1734–1737(2019)

## Integration of liquid air energy storage into the spanish power grid

The European energy transition implies a relevant increase of renewable energies in the electric power generation mix. Integrating additional renewables is becoming more challenging due to their variability. Spain's peninsular situation aggravates this problem because it is an electric island. Within this framework, Liquid Air Energy Storage (LAES) is a promising technology for balancing the power grid. This work proposes a transient thermodynamic modelling of a 100 MW LAES plant. The cycle incorporates a packed-bed cold-storage system to enhance the charge/discharge efficiency. The appearance of a thermocline in the cold-storage unit is relevant regarding the round-trip efficiency. An economic study based on the simulation results is performed considering different scenarios of renewables grid penetration (photovoltaic and wind power). Depending on the installed LAES capacity, the levelized cost of delivered energy is evaluated. The results suggest that it is more interesting to store photovoltaic energy in the daytime peak hours and release energy during the night-time valleys to maximize the use of storage plants. This allows the levelized cost of energy and storage to be reduced to values as low as 150 and 50 €/MWh respectively. These prices are competitive with compressed air energy storage and even with pumped-hydro storage.

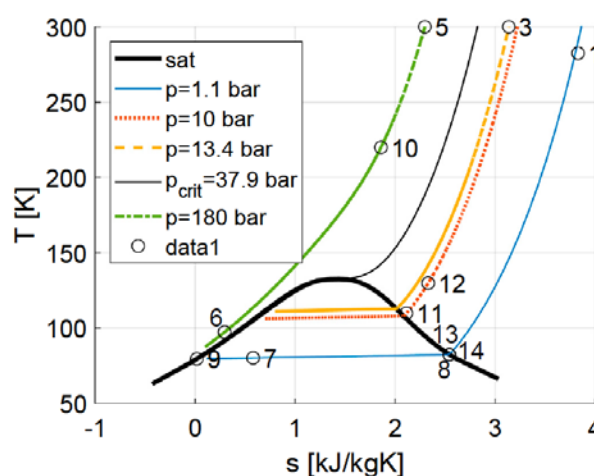


Fig. 3. Temperature entropy diagram of the liquefaction loop (charging mode).

### Autores:

1. Legrand, M – Dept Mech, Chem & Ind Design Eng, ETSIDI UPM, Madrid, Spain.
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1. Martínez Arévalo, C – Dept Mech, Chem & Ind Design Eng, ETSIDI UPM, Madrid, Spain.
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DOI: [10.1016/j.energy.2019.115965](https://doi.org/10.1016/j.energy.2019.115965)

### REFERENCIA

Legrand, M; Rodríguez Antón, LM; Martínez Arévalo, C; Gutiérrez Martín, F. Integration of liquid air energy storage into the spanish power grid. *Energy*, Volume 187(2019)

## Green Production of Glycerol Ketals with a Clay-Based Heterogeneous Acid Catalyst

Glycerol remains a bottleneck for the biodiesel industry as well as an opportunity from the biorefinery perspective, having a notable reactivity as a platform chemical. In particular, glycerol ketals can be envisaged as oxygenates for fuel formulation. In this study, we have focused on the green synthesis of glycerol ketals by reacting glycerol with acyclic (acetone, butanone) and cyclic (cyclohexanone) ketones in the presence of an acid activated clay Tunisian AC in homogeneous systems under quasi-solventless conditions. These reactions were followed by on-line Fourier Transform Infrared Spectroscopy (FTIR) (namely, ReactIR 10). Firstly, the contacting time was selected studying the activity, stability and chemical characteristics of a set of catalysts. The 1-h activated clay AC was further characterized by X-Ray diffraction (XRD), Fourier Transform Infrared Spectroscopy (FTIR) and Scanning Electronic Microscopy with Energy Dispersive Spectroscopy (SEM/EDS). Finally, the effect of the main operational variables (catalyst concentration, reagents molar ratio, time and temperature) were checked and we reflected on adequate second-order kinetic models with partial first-order deactivation.

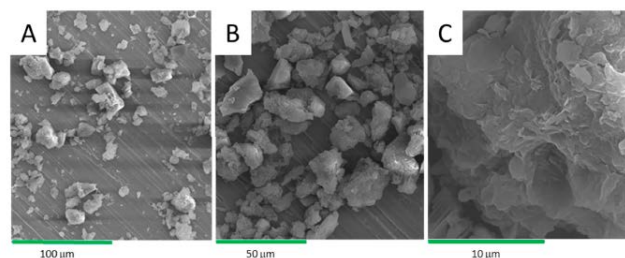


Fig. 8. SEM micrographs at several magnifications of the 1 h acid-activated clay (AC).

### Autores:

1. Amri, S – Tunis Manar Univ, Fac Sci Tunis, Natl Ctr Res Mat Sci, Lab Mat Composites & Clay Minerals, Grp Green & Appl Organ Chem, Tunisia. Univ Complutense Madrid, Chem Dept, Spain.
2. Gómez, J – Univ Complutense Madrid, Chem Dept, Spain.
3. Balea, A – Univ Complutense Madrid, Chem Dept, Spain.
4. Merayo, N – Univ Complutense Madrid, Chem Dept; Dept Mech, Chem & Ind Design Eng, ETSIDI UPM, Madrid, Spain.
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DOI: [10.3390/app9214488](https://doi.org/10.3390/app9214488)

### REFERENCIA

Amri, S; Gómez, J; Balea, A; Merayo, N; Srasra, E; Besbes, N; Ladero, M. Green Production of Glycerol Ketals with a Clay-Based Heterogeneous Acid Catalyst. *Applied Sciences-Basel*, Volume 9, Nº 21 (2019)



## Mechanical behaviour of vinylester adhesive joints used in laminated material for steel structures

One of the most important applications of adhesives in shipbuilding is the manufacturing of structural laminated materials. The application of these types of hybrid materials in a marine environment for extended periods of time and under adverse environmental conditions results in the accelerated degradation of the adhesive. Therefore, a specific experimental procedure is required to ensure the adequate performance of this adhesive bonded joint during its service life. In this study, an experimental method to analyse a vinylester adhesive in steel-adhesive-steel test specimens was applied ("mixed cantilever beam" specimens were used and mixed mode tests were carried out to obtain the fracture envelope). It was concluded that the energy release rate increased with the stress mode under dry conditions. In addition, the cohesive laws of vinylester showed that both the tangential stress and the strain are higher than the normal stress and strain. Finally, it was observed that adding distilled water to the adhesive joint for short periods of time improved its fracture strength.

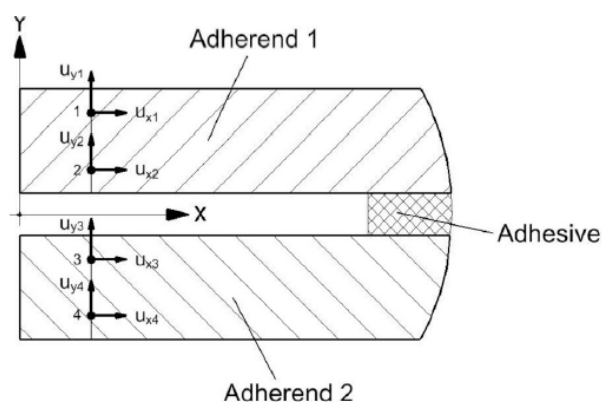


Fig. 4. Displacements at the control points and rotations of the adherends ( $u_{x,i}$  and  $u_{y,i}$  are the displacement in the x- and y-directions).

### Autores:

1. Alia, C – Dept Mech, Chem & Ind Design Eng, ETSIDI UPM, Madrid, Spain.
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DOI: [10.1016/j.marstruc.2019.102687](https://doi.org/10.1016/j.marstruc.2019.102687)

### REFERENCIA

Alia, C; Arenas, JM; Suárez, JC; Pinilla, P. Mechanical behaviour of vinylester adhesive joints used in laminated material for steel structures. *Marine Structures*, Volume 69 (2020)

### The impact of hydrograph variability and frequency on sediment transport dynamics in a gravel-bed flume

A laboratory study was undertaken to investigate how changes in flow regime and hydrograph shape (number of cycled hydrographs and duration of each hydrograph) together impact bedload transport and resulting bed morphology. Three hydrologic conditions (experiments) representing different levels of urbanization, or analogously different flow regimes, were derived from measured hydrometric field data. Each experiment consisted of a series of hydrographs with equal peak discharge and varying frequency, duration and flashiness. Bedload transport was measured throughout each hydrograph and measurements of bed topography and surface texture were recorded after each hydrograph. The results revealed hysteresis loops in both the total and fractional transport, with more pronounced loops for longer duration hydrographs, corresponding to lower rate of unsteadiness until reaching the peak discharge (pre-urbanization conditions). Shorter duration hydrographs (urban conditions) displayed more time above critical shear stress thresholds leading to higher bedload transport rates and ultimately to more variable hysteresis patterns.

Surface textures from photographic methods revealed surface armoring in all experiments, with larger armor ratios for longer duration hydrographs, speculated to be due to vertical sorting and more time for bed rearrangements to occur. The direction of bed surface adjustment was linked to bedload hysteresis, more precisely with clockwise hysteresis (longer hydrographs) typically resulting in bed coarsening. More frequent and shorter duration hydrographs result in greater relative channel adjustments in slope, topographic variability and surface texture.

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