CLBA2024

6.ª CONFERÊNCIA LUSO-BRASILEIRA DE ADESÃO E ADESIVOS

12-13 DEZEMBRO 2024 - PORTO - PORTUGAL

BOOK OF ABSTRACTS

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PREFÁCIO

A conferência Luso-Brasileira de Adesão e Adesivos é realizada bianualmente, alternadamente no Brasil e em Portugal, e tem como objectivo reunir os trabalhos das diversas áreas que envolvem o estudo do fenómeno da adesão e dos materiais adesivos. A organização do evento é partilhada pela Associação Brasileira de Adesão e Adesivos e pela Associação Portuguesa de Adesão e Adesivos.

A conferência será exclusivamente online.

Todas as áreas relacionadas com adesão e adesivos são bem-vindas: Aspectos fundamentais da adesão, ciência e tecnologia de superfícies; avanços em materiais adesivos; propriedades mecânicas de juntas coladas; projectos inovadores; aplicações (aeronáutica, automóvel, naval, civil, petróleo, odontologia, etc.); testes e normalização; aspectos industriais; procedimentos de qualidade, aspectos ambientais e ecológicos; bio-adesão.

Os trabalhos completos em inglês serão publicados numa edição especial da revista internacional *The Journal of Adhesion* (Taylor & Francis) e na *SN Applied Sciences - Collection Applied Adhesion Science* (Springer).

A melhor apresentação oral será premiada com um certificado e uma cópia da obra E A S Marques, R J C Carbas, A F G Tenreiro, Lucas F M da Silva, 'Introdução às ligações adesivas estruturais', Publindústria, Porto, 2021.

O melhor póster será premiado com um certificado e uma cópia da obra: Lucas F M da Silva, R Carbas, E Marques, 'Problemas e trabalhos práticos de juntas adesivas estruturais', Publindústria, Porto, 2017.

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PROGRAMA DA CONFERÊNCIA CLBA24 (CONFERÊNCIA ONLINE, HORÁRIO DE PORTUGAL)

Autor sublinhado → Autor que apresenta

Quinta-feira 12 de dezembro de 2024	
10:00	***Abertura da CLBA24***
	Sessão 1 – Adesão e tratamentos superficiais Chair: LFM da Silva (FEUP, Portugal) e S de Barros (CEFET/RJ, Brasil)
10:20	Influence of injection conditions on adhesion interface in sandwich panels **(CLBA24_8)** A Guimarães, T Costa (Purever Industrial Solutions, Portugal), A Trindade, RJC Carbas, LFM da Silva
10:40	Unveiling the failure complexities of acrylic PSAs: A comprehensive study of peel test behaviour and cohesive zone modelling **(CLBA24_3)** BD Simões (INEGI, Portugal), HC Sousa, EAS Marques, RJC Carbas, S Maul, P Stihler, P Weißgraeber, LFM da Silva
11:00	Uso do ensaio TDCB na avaliaçao da energia critica de propagação em modo I (GIC) entre camadas de PLA impresso 3D **(CLBA24_7)** AN Silva (Universidade Federal Rural do Semi-árido, Brasil), Y Wu, R Grangeat, P Casari, S de Barros
11:20	Utilização de lignina kraft modificada para aumento da energia livre superficial de polipropileno **(CLBA24_26)** MPS Bisneto, RR de Sousa Junior, GES Garcia, LG Freitas (Universidade Federal do ABC (UFABC), Brazil), DJ dos Santos
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	Sessão 2 – Propriedades de adesivos I Chair: EAS Marques (FEUP, Portugal) e V Tita (Universidade de São Paulo, Brasil)
12:00	Repair and end of life strategies for ecofriendly adhesive bonded joints **(CLBA24_34)** R Soares (INEGI, Portugal), S Jalali, EAS Marques, RJC Carbas, D Paiva, F Magalhães, LFM da Silva
12:20	Análise comparativa do desempenho mecânico de juntas de cisalhamento ensaiadas em temperaturas elevadas com as curvas de HDT e Tg (DSC e DMA) **(CLBA24_32)** NFR Rohem (CEFET/RJ Brasil), S de Barros, EM Sampaio, VJ Cortines, RM Carneiro Neto
12:40	Development of a unified specimen for direct generation of cohesive zone law data of adhesives – Strength components **(CLBA24_6)** DS Correia (INEGI, Portugal), EAS Marques, RJC Carbas, LFM da Silva
13:00	Fracture energy of a polyurethane adhesive in vehicle body applications: investigating the interaction of strain rate, loading mode, and temperature **(CLBA24_9)** M Ribas, A Akhavan-Safar (INEGI, Portugal), RJC Carbas, EAS Marques, S Wenig, LFM da Silva
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14:30	Curved single lap joints: Enhancing strength by mitigating stress concentrations **(CLBA24_14)** RCJ Carbas (INEGI, Portugal), VDC Pires, EAS Marques, LFM da Silva
14:50	Mechanical performance of aluminum-carbon fiber laminated joints at different strain rates **(CLBA24_15)** RCJ Carbas (INEGI, Portugal), EAS Marques, LFM da Silva
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15:30	Joint design and mechanical characterization processes for high performance bonded structures **(CLBA24_30)** EAS Marques (University of Porto, Portugal), A Akhavan-Safar, RJC Carbas, BD Simões, FC Sousa, AF Tenreiro, AM Lopes, LFM da Silva
15:50	Lap shear and T-peel properties of acrylic and epoxy structural adhesives joints **(CLBA24_13)** MDM Martins (SENAI CIMATEC, Brasil), TCP Macedo, MVBO Ribeiro, YTB Santos, DM Souza, JDV Barbosa
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	Sessão 4 – Aplicações Chair: RJC Carbas (INEGI, Portugal) e V Tita (Universidade de São Paulo, Brasil)
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17:10	Adhesive bonding technology in automotive battery pack manufacturing and dismantling: An overview **(CLBA24_12)** VC Rodrigues (INEGI, Portugal), M Kasaei, R Beygi, EAS Marques, RJC Carbas, LFM da Silva
17:30	Characterization of mechanical properties of a commercial adhesive applied in the equestrian sector **(CLBA24_2)** CMC Ferreira (INEGI, Portugal), BD Simões, EAS Marques, RJC Carbas, LFM da Silva

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	Sessão 5 – Propriedades de adesivos II Chair: EAS Marques (FEUP, Portugal) e S de Barros (CEFET/RJ, Brasil)
10:00	J Integral vs CBBM in fracture analysis of highly deformable adhesives **(CLBA24_10)** M Ribas, A Akhavan-Safar (INEGI, Portugal), RJC Carbas, EAS Marques, S Wenig, LFM da Silva
10:20	Cyclo-olefin polymer multi-material hotmelt adhesive - Mechanical characterization, joint testing and numerical modelling **(CLBA24_11)** VCMB Rodrigues (INEGI, Portugal), RJC Carbas, EAS Marques, K Ejiri, A Klein, B Nelson, LFM da Silva
10:40	Effect of double double laminates on the fracture energy in mode I of adhesive joints **(CLBA24_18)** A Bezerra, LL Vignoli, RM Carneiro Neto (Universidade Federal do Rio de Janeiro, Brasil), EM Sampaio
11:00	Numerical analysis of the bonded composite joints under mixed-mode using design of experiments and CBBM method **(CLBA24_22)** R Beck, JAP da Silva, LFM da Silva, V Tita, R De Medeiros (Santa Catarina State University, Brazil)
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11:40	Virtual testing of single lap joint bonded composite structures using 2D and 3D finite element models **(CLBA24_23)** D Dametto, R Beck, LFM da Silva, V Tita, R De Medeiros (Santa Catarina State University, Brazil)
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14:40	A design and validation process for structural bonded joints exposed to harsh service conditions **(CLBA24_31)** EAS Marques (University of Porto, Portugal), BD Simões, A Akhavan-Safar, RJC Carbas, LFM da Silva
15:00	Development of a cohesive zone model for characterizing the fracture behavior of pressure-sensitive adhesives **(CLBA24_4)** BD Simões (INEGI, Portugal), HC Sousa, EAS Marques, RJC Carbas, S Maul, P Stihler, P Weißgraeber, LFM da Silva
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16:00	Melhoria da propriedade anticorrosiva de vernizes com nanopartículas de alumina e sílica **(CLBA24_27)** A Vinagre Neto, RR de Sousa Junior, TM Coutinho (Universidade Federal do ABC (UFABC), Brasil), DJ dos Santos
16:20	Lignina kraft hidroxipropilada como resina taquificante em adesivo hot melt **(CLBA24_28)** LP Freitas (Universidade Federal do ABC (UFABC), Brasil), RR de Sousa Junior, LG de Freitas, DJ dos Santos
16:40	An experimental and numerical study of the reinforcement of steel plates with hybrid carbon/flax composite patches under flexural loading **(CLBA24_33)** MA Tazi, M Jebli, S Teixeira de Freitas, P Casari, S de Barros (CEFET/RJ, Brasil)
17:00	***Encerramento CLBA24***

SESSÃO 1 – ADESÃO E TRATAMENTOS SUPERFICIAIS

CHAIR: LFM DA SILVA (FEUP, PORTUGAL) E S DE BARROS (CEFET/RJ, BRASIL)

Influence of injection conditions on adhesion interface in sandwich panels

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Composites are materials combining a strong reinforcement with a lighter matrix for enhanced mechanical and thermal properties. A typical example is the sandwich panel, comprising sturdy outer layers and a lightweight core, such as rock wool, enclosed between them. The outer layers can be metal, wood, or plastic. In panels with polyurethane (PUR) cores, the bond between the PUR and metal sheets can weaken over time due to stress and fatigue, potentially causing structural failure. Researchers are actively exploring methods to enhance PUR and metal sheet adhesion. Their studies encompass surface treatments, optimizing injection conditions, refining PUR composition, and computer modeling of the material interface [1, 2]. Studies by Pereira et al. [1] highlighted that primers significantly enhance adhesion, whereas Naik et al. [2] explored optimizing the production process through tests to ensure robust and long-lasting adhesion.

This study investigated the adhesion of PUR adhesives to metal sheets under real-world production conditions. The panels were produced in a factory environment using all the parameters and procedures to create a fundamental part. The study aimed to identify and categorize common adhesion defects (e.g., voids, weak adhesion) that may occur during production, additionally, it aimed to develop corrective actions to prevent these defects. The study involved performing pull-out tests on specimens taken from different positions on a large board and comparing the results with reference specimens without defects.

[1] Pereira, M., Ramezani, M., Pasang, T., & Withy, B. (2017). Investigation of polyurethane bonding to steel in sandwich panels. In Materials Science Forum (Vol. 890, pp. 401-405). Trans Tech Publications Ltd.

[2] Naik, R. K., Panda, S. K., & Racherla, V. (2020). A new method for joining metal and polymer sheets in sandwich panels for highly improved interface strength. Composite Structures, 251, 112661.

Unveiling the failure complexities of acrylic PSAs: a comprehensive study of peel test behaviour and cohesive zone modelling

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Pressure-sensitive adhesives (PSAs) are vital in modern manufacturing due to their ease of application and strong adhesive properties, making them indispensable in industries like electronics, automotive, and packaging. In the context of this work, understanding the failure mechanisms of PSAs under various peel test conditions is crucial for optimizing their performance and reliability in high-stress applications. This study delves into the failure mechanisms of two acrylic pressure-sensitive adhesives (PSAs) under various peel test conditions. By conducting peel tests across a comprehensive range of angles (30° to 180°), we constructed detailed load failure envelopes for each adhesive, revealing their behavior under different loading conditions. The experimental data highlighted the consistency of adhesion energy across varying peel angles, confirming it as an intrinsic material property when accounting for energy dissipation from the steel backing's bending. Integrating experimental findings with numerical simulations, we applied cohesive zone modeling (CZM) to peel tests. Cohesive laws derived from experiments accurately predicted the behavior of peel specimens at different angles, with numerical predictions closely matching experimental outcomes. This work presents a robust methodology for extracting cohesive laws of joints, enabling precise behavior predictions. Additionally, extensive stress analysis along the adhesive layer provided deeper insights into the failure modes of the acrylic PSAs studied

Uso do ensaio TDCB na avaliaçao da energia critica de propagação em modo I (G_{IC}) entre camadas de PLA impresso 3D

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A Manufatura Aditiva (AM) tem vivenciado grande desenvolvimento, tanto no que diz respeito ao aperfeiçoamento de máquinas quanto a utilização de novas matérias-primas. Esse desenvolvimento da AM tem sido impulsionado por fatores como, grande versatilidade que permite a produção de componentes com geometria complexa, rapidez de produção e redução de defeitos[1]. Atualmente, esta área de produção apresenta várias técnicas, como exemplo tem-se a *Inkjet Printing and Contour Crafting*, *Powder Bed Fusion* e *Fused Deposition Modelling* (FDM). A técnica FDM tem se destacado pelo baixo custo, facilidade de manuseio, além do baixo desperdício[2]. Quando comparada a outras técnicas de fabricação como por exemplo a estereolitografia, essa técnica apresenta limitações quanto ao desempenho mecânico, devido a menor adesão entre as camadas[3]. Com o intuito de contornar essas limitações vários estudos têm analisado a relação entre parâmetros e materiais. Nesse sentido o presente trabalho considerou o emprego do ensaio tipo *Tapered Double Cantilever Beam* (TDCB) para avaliar a energia crítica de propagação em modo I (G_{IC}) entre as camadas de peças impressas por FDM. O estudo foi realizado com PLA e considerou a preenchimento do tipo Gyroid nas proporções 20, 40, 60 e 80%. O ensaio TDCB mostrou-se viável, pois apresenta um comprimento significativo para avaliação do comportamento da trinca, e, nos testes realizados observou-se que a trinca se propagou conforme os princípios da mecânica da fratura linear elástica (MFLE), para todos os percentuais de preenchimento e espessuras considerados.

[1] T.D. Ngo, A. Kashani, G. Imbalzano, K.T.Q. Nguyen and D. Hui, Compos part b-eng, 143, 172 (2018).
[2] H. Cheng, M. Tang, J. Zhang, H. Wang, J. Zhou, Q. Wang and Z. Qian, Compos part b-eng, 270 (2024).
[3] M.A. Caminero, J.M. Chacón, I. García-Moreno, J.M. Reverte. Polym. Test., 68, 415 (2018).

Utilização de lignina kraft modificada para aumento da energia livre superficial de polipropileno

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O polipropileno (PP), um polímero não polar amplamente utilizado no setor de embalagens devido às suas excelentes propriedades mecânicas e facilidade de processamento, possui uma baixa energia livre de superfície, resultando em pobres propriedades de adesão [1]. Isso dificulta processos de impressão em superfície e ligação com outras camadas de filmes poliméricos. Uma estratégia para contornar essa limitação é a mistura de PP com polímeros polares, que aumentam a energia livre superficial do material [1,2]. A lignina, um dos biopolímeros mais abundantes da Terra, rica em grupos funcionais fenólicos e alifáticos, oferece uma interessante possibilidade de modificação do PP, especialmente a lignina técnica, um subproduto do processo kraft, obtido em grandes quantidades anualmente. No entanto, devido ao caráter parcialmente polar da lignina, há dificuldades na interação entre PP e lignina. Este estudo investiga a acetilação direta da lignina kraft (KL) para melhorar sua dispersão na matriz de PP e aumentar a molhabilidade e adesão do material. O PP e a KL acetilada (AKL) foram combinados e processados por extrusão. Foram avaliadas as propriedades térmicas e mecânicas dos compostos, a dispersão da lignina e a molhabilidade. Além disso, filmes de PP e PP-lignina foram colados a polipropileno orientado biaxialmente aluminizado (BOPP) para testes de adesão prática. Os resultados mostraram aumento na energia livre de superfície e adesão melhorada, especialmente em amostras com AKL devido à melhor dispersão. Assim, AKL aumentou a energia livre de superfície do PP e melhorou a adesão prática. Isso apresenta a lignina, um polímero renovável e de baixo custo, como uma alternativa sustentável para melhorar as propriedades de adesão de polímeros como o PP.

[1] R.R. Sousa Jr., J.R. Gouveia, A.M. Nacas, L.B. Tavares, N.M. Ito, E.N. de Moura, F.A. Gaia, R.F. Pereira and D.J. Santos, Mater. Res., 22, e20180123 (2019).
[2] M.P. da Silva Bisneto, J.R. Gouveia, L.D. Antonino, L.B. Tavares, N.M. Ito and D.J. dos Santos, Polymers, 14, 999 (2022).

SESSÃO 2 – PROPRIEDADES DE ADESIVOS I

CHAIR: EAS MARQUES (FEUP, PORTUGAL) E V TITA (UNIVERSIDADE DE SÃO PAULO, BRASIL)

Repair and end of life strategies for ecofriendly adhesive bonded joints

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Adhesives have become essential in various industries, with increasing demand for sustainability while retaining high-performance properties. Vitrimers offer a promising solution, combining the robust mechanical characteristics of thermosets with the reusability of thermoplastics. Through reversible exchange reactions, such as transesterification, vitrimers enable dynamic covalent bonding, allowing for topological rearrangements without affecting the overall cross-link density [1].

In this study, a vitrimer was synthesized using DGEBA (epoxy), sebacic acid, and zinc acetylacetonate. Three samples were prepared, each containing the same quantities of these materials, with the only variable being the solvent used. The first sample had no solvent, the second used acetone, and the third contained ethanol and water to dissolve Zn and SA. Using the third sample, test specimens were fabricated to conduct differential scanning calorimetry (DSC) and tensile tests. However, the adhesive performance was low compared to other adhesives. Another test involved heating two specimens to the reaction temperature to assess whether they would retain adhesion after cooling. The outcome was a rigid vitrimer that could not be separated, demonstrating its recyclability. To enhance performance, future work will focus on optimizing the vitrimer production process to develop a more practical adhesive, with adjustments to solvent concentrations and reaction temperature for improved properties.

[1] Surós M., Santiago D., Verdugo P., Pedrola M., De la Flor S., Polymer, (2024).

Análise comparativa do desempenho mecânico de juntas de cisalhamento ensaiadas em temperaturas elevadas com as curvas de HDT e Tg (DSC e DMA)

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A utilização de materiais compósitos e adesivos estruturais na indústria de óleo e gás tem apresentado um crescimento exponencial. Como referência, apenas uma das empresas brasileiras do setor de manutenção offshore realizou, no ano de 2023, mais de 3000 aplicações utilizando esse tipo de tecnologia. Um ponto de atenção consideravelmente limitante é a temperatura máxima de utilização dos materiais de matriz polimérica. O limite superior de temperatura é definido através da Temperatura de Transição Vítrea (Tg) ou Temperatura de Deflexão Térmica (HDT). Porém, existem técnicas diferentes para a obtenção da Tg, seja através de DSC ou DMA. Este último, inclusive, pode apresentar três curvas: Tangente de Delta, Módulo de Armazenamento e Módulo de Perda. No entanto, não é indicado nas normas de projeto qual curva deve ser utilizada como referência.

O presente trabalho busca apresentar a análise do comportamento térmico de um adesivo epoxídico em equipamentos de HDT, DSC e DMA, juntamente com a realização de ensaios de tração e single lap joint (metal-metal) em máquina de ensaio universal com forno. Serão executados ensaios em patamares de temperatura distintos. O objetivo é apresentar uma análise comparativa entre a temperatura na qual haverá uma queda significativa do desempenho do adesivo e os limites de temperatura definidos nos ensaios térmicos supracitados.

Development of a unified specimen for direct generation of cohesive zone law data of adhesives – Strength components

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In the current industrial panorama, many key players are dissatisfied with the current adhesive characterisation technics, them being extremely time-consuming, complex, and expensive procedures. As such, developing faster mechanical characterisation approaches is a necessity given the rapidly expanding use of adhesive bonding in industrial applications. Due to this, the development of a more unified and agile method has the potential to be a disruptive technology for a wide range of users, including adhesive manufacturers and the automotive, aerospace, and electronic industries, among many others. It can also significantly reduce development times and costs.

The construction and experimental validation of this completely integrated adhesive characterisation tool, able to greatly reduce the time required to characterize an adhesive, are demonstrated in the current work.

To this extent the strength components of the unified specimen, for tensile (modified butt joint) and shear (modified TAST) loading, were studied recurring to two different adhesives, to validate it on a wider spectrum. The results from the numerical and experimental tests were then compared against the standardised methods to access their validity and the specimen's capability to properly characterise an adhesive.

Fracture energy of a polyurethane adhesive in vehicle body applications: investigating the interaction of strain rate, loading mode, and temperature

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Polyurethane adhesives play a critical role in joining various components of vehicle structures, ensuring their overall integrity and safety. While increasing the strain rate improves their strength and fracture response, however, at elevated temperatures these adhesives may experience property degradation, compromising their performance. In the context of vehicle body engineering, it is crucial to comprehend how loading mode and strain rate influence the mechanical response of structural adhesives at high temperatures. This understanding can aid in the design of more reliable and durable adhesive systems that withstand the multiple stresses encountered in vehicle applications. This study aims to analyze the impact of loading mode and strain rate on the property degradation of a polyurethane adhesive. Experimental tests were conducted at both 23 ºC and 60 ºC, simulating the temperature conditions experienced in automotive environments. Various loading rates were applied to the adhesive specimens, allowing for an examination of the corresponding strain rates. To assess crack size, two different methods were employed: a compliance-based approach during experimental testing and a digital image correlation and tracking method, which improved the understanding of strain rate characteristics.

SESSÃO 3 – JUNTAS ADESIVAS ESTRUTURAIS I

CHAIR: LFM DA SILVA (FEUP, PORTUGAL) E EM SAMPAIO (UNIVERSIDADE DE SÃO PAULO, BRASIL)

Curved single lap joints: Enhancing strength by mitigating stress concentrations

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Adhesively bonded joints have become increasingly popular across various industries due to their clear advantages over traditional mechanical fastening methods. The single lap joint, known for its simplicity and robustness, remains the most widely used type of adhesive joint. However, a major challenge associated with this joint is stress concentration at the overlap ends, particularly for low-ductility adhesives [1].

This study proposes a novel concept: a curved single lap joint with a non-uniform adhesive thickness. This design aims to mitigate stress concentrations near the overlap edges. The joints were evaluated experimentally and numerically to investigate the performance of this joint using two adhesives: Araldite® 2015-1 and AV138. Finite element models were developed using ABAQUS software. This study demonstrates that the curved single lap joint (SLJ) can effectively reduce stress concentrations. However, the effectiveness of this concept in enhancing joint performance is highly dependent on the ductility of the chosen adhesive.

[1] L.F.M. da Silva, A. Öchsner, and R.D. Adams. Handbook of Adhesion Technology, Second Edition, (Springer-Verlag, Berlin, 2018).

Mechanical performance of aluminum-carbon fiber laminated joints at different strain rates

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The use of composite materials in industry is growing due to various technological advances in composite materials, the main disadvantage is the delamination that can lead to premature failure [1]. This study explores a method to address this issue. Inspired by fibre metal laminates (FMLs), carbon fibre reinforced polymer (CFRP) composites were modified by including one and two aluminium sheets during the laminate manufacture to enhance the composite through-thickness properties. The objective was to identify the joint configuration that gives the best joint strength improvement in relation to the CFRP-only reference joint. The configuration of the joint that provided the optimal balance of joint strength and delamination prevention was tested under impact loading conditions. A numerical model using finite element analysis is developed in ABAQUS to study the performance of the best configuration. Experimental and numerical results are compared.

[1] L.F.M. da Silva, A. Öchsner, and R.D. Adams. Handbook of Adhesion Technology, Second Edition, (Springer-Verlag, Berlin, 2018).

Adhesively bonded joints of hybrid flax/jute/glass fibre reinforced composites: An experimental study

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In several industrial sectors the demand for more environmentally sustainable materials with reduced carbon footprint and more recyclability has grown increased interest over the last decades [1,2]. This work investigates the effect of material on the performance of adhesively bonded joints made from flax, jute and hybrid flax/jute/glass fiber-reinforced composites. The primary objective is to evaluate how different fiber architectures and material combinations influence the mechanical performance of single-lap joints (SLJs). Pure and hybrid composites were fabricated by using unidirectional and twill flax and jute and glass bidirectional fabric reinforcements. SLJs bonded with two adhesive types (a structural ductile bi-component epoxy adhesive and a brittle one) were fabricated and tested. It was found that the hybridization of jute fibre reinforced composites with flax and glass fibres significantly improved the bonded joint performance for all tested specimens, when compared to the neat jute fibre reinforced composites. A jute/flax/glass fibre hybrid composite bonded structure presents a potentially cost-effective and efficient alternative for reducing the structural carbon footprint, without a significant compromise in mechanical properties.

[1] H.F.M. de Queiroz, V. Pastor, A.C. de Mendonça, J.S.S. Neto, D.K.K. Cavalcanti, M.D Banea (2024, Int. J. Adhes. and Adhes., 133, 1037452024.

[2] J.S.S. Neto, H.F.M. de Queiroz, R.A.A. Aguiar, R.A.A. Lima, D.K.K. Cavalcanti, M.D. Banea (2022), Journal of Renewable Materials, 10, 3, pp.561-589.

Joint design and mechanical characterization processes for high performance bonded structures

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Adhesive bonding is a key joining process that offers a wide range of advantages for high-performance vehicle applications, including unparalleled versatility, material compatibility, excellent mechanical performance, and unmatched cost-effectiveness. However, despite its growing use in high-performance vehicle structures, adhesive bonding is still seen as a challenging process in many sectors, limiting its widespread adoption and potential. This paper shares and discusses key findings and lessons learned from multiple studies on joint design, joint and material characterization conducted within the Advanced Joining Processes Unit of INEGI. First, the development of mechanical characterization processes for structural adhesives is described, including bespoke testing equipment design and associated data reduction methods. Secondly, the evaluation of adhesive and joint performance under extreme environmental and loading conditions, such as fatigue, aging, creep, and impact loads, is highlighted. Next, the development of advanced numerical models to support design activities is discussed, with a focus on custom continuum and damage mechanics models that can simulate the failure of bonded joints and adhesives under complex conditions. Finally, manufacturing-relevant aspects and research activities are addressed, mainly related to the implementation of advanced non-destructive testing methods to identify serious defects in bonded joints.

Lap shear and T-peel properties of acrylic and epoxy structural adhesives joints

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Adhesive is a substance capable of holding at least two surfaces together in a strong and permanent manner [1]. They perform the function of joining two materials together by certain interfacial interactions [2]. Applications related to adhesive bonding are today very diverse and can be found in virtually all types of industry, such as the aeronautical industry, rail and automotive industry, civil construction, shoes, electronics, and emerging fields such as biology and medicine [3]. The materials most used in industry to make structural adhesives are epoxy, methacrylates and polyurethanes. They are increasingly being used as alternatives to replace processes such as welding, or mechanical fastenings with rivets and screws.

Considering this, the objective of this study was to evaluate the mechanical properties of shear and T-peel strength of adhesively bonded steel joints, prepared with epoxy and acrylic adhesives. Shear and T-peel tests were performed using overlapping joints bonded by epoxy or acrylic adhesives with low-carbon steel (SAE 1020). Based on the T-peel results, greater resistance was observed for acrylic adhesives when compared to epoxy adhesives. The results of the Lap shear tests indicated that the shear strength with the epoxy adhesive is greater than that of the joints bonded with acrylic adhesives. In both tests, cohesive and adhesive failures were observed, regardless of the chemical base of the structural adhesive, indicating that the material used is not the main determinant with regard to fracture of bonded joints, and it is necessary to evaluate other aspects, such as the need for mechanical or even chemical preparation, increasing the adhesion of the adhesive to the substrate.

[1] E. M. Petrie, Handbook of Adhesives and Sealants. New York: McGraw-Hill Companies, 2000.
[2] Shybi, Siby Varghese, Hanna J. Maria, and S. T. A.A. Handbook of Adhesive Technology, Ed. Boca Raton: CRC Press, 2018.
[3] Lucas F. M. da Silva, Andreas Öchsner, and R. D. A. Handbook of Adhesion Technology. Switzerland: Springer International Publishing, 2018.

SESSÃO 4 – APLICAÇÕES

CHAIR: RJC CARBAS (INEGI, PORTUGAL) E V TITA (UNIVERSIDADE DE SÃO PAULO, BRASIL)

Adhesives in veterinary medicine: a review

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Adhesive bonding is a versatile tool used in medicine due to its applicability in a wide range of clinical scenarios and its better biocompatibility. Its effectiveness is associated with its adaptability to either soft tissue or orthopedic applications. Recognizing these benefits has led to the extension of adhesive bonding from human medicine to veterinary surgical procedures. This review highlights the adhesives used in animal care which are categorized and discussed based on their type and application within veterinary practice. Cyanoacrylate adhesives are known for their quick-setting properties and result in strong bonds when applied to skin. Therefore, these wound closure adhesives are a good substitute to conventional fixation methods such as sutures resulting in less tissue trauma. In orthopedic applications, polymethylmethacrylate (PMMA) has been extensively used as an acrylic bone cement working as an alternative for screw connections. This biomaterial contributes to a faster bone healing procedure since it improves the implant stability by holding it against the bone. Methyl methacrylate-based resin cements, used in animal dentistry, serve as an adhesive between the restoration material and the tooth. Its main goal is to keep the restoration in place for long periods of time. Resin-based cements are greatly valued because of their high strength, wear resistance and lower solubility. Over the years, alternative methods have also emerged to replace horse nails when assembling shoes to horse hoofs using composite adhesives such as polymethylmethacrylates and urethanes. These 2-part adhesives can in a matter of minutes form a strong bond between the hoof wall and the shoe without compromising the integrity of the horse hoof. Tissue sealants can also perform other functions that other traditional methods cannot which is the case of bleeding conttol. These are usually employed in surgical procedures in order to ensure tissue regeneration, to promote hemostasis and accelerate the healing process.

Geopolymer as a fire protection for laminates composites materials: an adhesion preliminary study

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Due mainly its mechanical properties and high resistance of aggressive environments the composites materials have been objective of many studies [1]. As an important application of laminates composites in petroleum and gas industries is the repair of steel pipes with not through-wall (type A) and through-wall defect (type B). The composite repair can restore the integrity of the pipeline in a short time if compared with the substitution of the damaged pipeline. However, the use of composite repair sometimes is limited by its temperature low resistance. With the aim of expanding the application of laminates composites and reduce dependence on national industry of imported materials the use of geopolymer as a fire protection of laminates composites is object of this study. As a preliminary step of this research the adhesion of the geopolymer in steel and laminate composites substrates were evaluated. Pull off tests were conducted in treated and untreated substrates and compared with the reference material (imported material). Three geopolymers were evaluated. This research is begin developed by Fine Composites in partner of industry and university with the insertion of Brazilian researchers in the national industry by funding from the National Council for Scientific and Technological Development (CNPq) and Ministry of Science, Technology and Innovation (MCTI).

[1] A. Passos, R. de Aguiar, H. Costa, E. Sampaio and S. de Barros, J. Adhes. Sci. Technol., 35, 1723 (2021).

Adhesive bonding technology in automotive battery pack manufacturing and dismantling: An overview

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The integration of electric vehicles (EVs) powered by lithium-ion (Li-ion) batteries marks a pivotal phase towards achieving a net-zero environment. Thus, the anticipated surge in EVs adoption in the coming decade is expected to yield a substantial influx of battery waste. Despite the manifold advancements in optimizing Li-ion battery packs, ensuring a sustainable end-of-life strategy remains an engineer and economical challenge. In addition, the existence of diverse pack configurations poses an obstacle to the efficient disassembly process. This paper provides an overview of the multiple cell and battery pack bonding solutions being used in the current market. In a more detailed investigation towards the feasibility of dismantlable adhesives, this paper scrutinizes the use of adhesives to bond battery pack components with prismatic cells, strongly taking the emerging debonding-on-demand trend into consideration. Studies assessing adhesive debonding have demonstrated that some formulations are responsive to external stimuli, capable of weakening the interface bond. For battery applications, these modified adhesives must neither show property degradation nor experience such trigger mechanics during service. This would also enable the intentional weakening of the adhesive layer as needed. In addition, the article presents brief and concise solutions for adhesive selection in battery packs with prismatic cells, drawing from an in-deep analysis of battery assembly, adhesive bonding and dismantling fields.

Characterization of mechanical properties of a commercial adhesive applied in the equestrian sector

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Despite the technological development in many industries, the equine sector is still employing the same procedures since Middle Ages, such as the horseshoe application method. Typically, this entails heating and shaping the horseshoe before assembling it with horse nails. Although traditional in some its methods, the equine industry receives extensive investment and can be considered a dynamic and competitive industry, representing a billion euros market in Europe. Hence, it was time to modernize the methods employed in this field with reliable and less-invasive solutions for applying the horseshoe to the hoof.

There are currently several commercial adhesive solutions in the market specifically tailored for this application. In this work, the mechanical properties of an acrylic adhesive developed for horseshoe bonding were characterized under quasi-static conditions. In the characterization process, tensile bulk testing was performed to determine Young's modulus, tensile strength and tensile strain to failure. Double Cantilever Beam (DCB) tests were conducted to achieve the fracture toughness in Mode I, using the J-integral approach to measure the critical energy release rate, J_{IC}. Afterwards, a numerical simulation/validation of the adhesive behaviour was performed considering a triangular-shaped cohesive zone model (CZM) which compared the load-displacement experimental results with the numerical data obtained from Abaqus software.

SESSÃO 5 – PROPRIEDADES DE ADESIVOS II

CHAIR: EAS MARQUES (FEUP, PORTUGAL) E S DE BARROS (CEFET/RJ, BRASIL)

J Integral vs CBBM in fracture analysis of highly deformable adhesives

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The fracture analysis of highly deformable adhesives in pure mode I loading conditions is of paramount importance for ensuring structural integrity and safety in various engineering applications. This paper presents a comparative study between two widely used data reduction schemes, the J integral and Compliance Beam Based Method (CBBM), in assessing the fracture behaviour of such adhesives. Experimental investigations on different highly deformable adhesive specimens reveal a notable discrepancy between the results obtained from the J integral and CBBM approaches, with the former generally yielding more conservative outcomes. The objective of this study is to elucidate the underlying reasons for this disparity through a detailed analysis of the fracture mechanisms involved. Insights gained from this research will not only enhance our understanding of fracture behaviour in highly deformable adhesives but also provide valuable guidance for refining fracture analysis techniques to ensure accurate and reliable assessment of structural integrity.

Cyclo-olefin polymer multi-material hotmelt adhesive - Mechanical characterization, joint testing and numerical modelling

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Zeon's Cyclo-Olefin Polymer multi-material adhesive (MMA) comprises a transparent and non-tacky sheet-based amorphous thermoplastic is characterized by a distinctive polymer microstructure, demonstrating resilience to heat, moisture, and impact. Its amalgamation of robustness and malleability renders it an optimal selection for scenarios necessitating the joint of disparate materials. The curing stage obliges for pressure and a temperature higher than the fusion point of the adhesive, allowing it to flow. The film adhesive was provided with 0.1 [mm] of thickness. Bulk specimens were manufactured and tested at different temperatures at a quasi-static rate. The effect of cold drawing and reorientation of the molecular chains can be observed before strain hardening effect. Double cantilever beam (DCB) tests were conducted to study the critical energy release rate in mode I, using the J-integral method as a data reduction scheme. Aluminium and CFRP single lap joints (SLJ) were manufactured to analyse the in-joint behaviour. Results showed always a non sudden interfacial failure after adhesive plasticization, allowing the adhesive to deform prior to failure. The tensile, shear and in-joint test results served as input to a numerical model. Due to the interfacial failure, the adhesive layer was separated in two types of elements: a thin cohesive with the interface properties and two-dimensional elements with the adhesive properties. The model was validated by comparing it with experimental results for two overlap lengths.

Effect of double double laminates on the fracture energy in mode I of adhesive joints

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Os Laminados Double – Double (DD) são uma nova configuração de laminados que tem potencial para revolucionar o design de estruturas compostas. Além de serems mais eficientes e versáteis que os clássicos laminados QUAD, os laminados DD também otimizam métodos de produção e melhoram a eficiência econômica. O objetivo desse trabalho é avaliar a força máxima e a energia de fratura em juntas adesivas carregadas em modo normal, sendo utilizados substratos compósitos nas configurações QUAD e DD. Para essa análise, será utilizado o ensaio DCB (*double cantilever beam*). O método CBBM (*compliance based beam method*) será utilizado no tratamento dos dados do ensaio DCB, o qual não exige a medição direta da propagação da trinca ao longo do ensaio. Além disso, os campos de deslocamento vertical e horizontal serão medidos através da análise de correlação de imagens digitais (DIC). Os ensaios estão andamento.

Numerical analysis of the bonded composite joints under mixed-mode using design of experiments and CBBM method

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Composite aircraft structures have been extensively studied under various loading conditions, which can induce different failure modes. The failure modes, particularly the failure modes I and II with the fracture energies associated to each one, are influenced by geometric and material variations, leading to uncertainties related to the obtained fracture energies. This work introduces a methodology to simulate the Mixed-Mode Bending test (MMB) standardized by ASTM D6671. The specimens are constructed with carbon/epoxy adherents and a ductile-based epoxy adhesive. The methodology employs a 2D finite element model within Abaqus® software, supported by a Python™ routine. The design of experiments (DoE) technique, specifically the Plackett-Burman Design (PBD) method, is applied to reduce the number of required simulations. To assess the impact of geometric and material variables on fracture strength responses under various mixed-mode ratios were obtained. The Compliance-Based Beam Method (CBBM) adapted for the MMB test is used, following the ASTM D6671 recommendation. The numerical model is constructed using 4-node cohesive type elements (COH2D4) for the adhesive and 4-node plane strain elements (CPE4R) for the composite adherents. The test apparatus, is modeled using a 2-node, two-dimensional, linear rigid link (R2D2). The adhesive response is evaluated using a triangular traction-separation law (TSL). The model was validated against experimental results available in the literature. The mixed-mode total fracture energy derived from CBBM for various mixed-modes ratios is used to obtain the Main Effect (ME), making it possible to identify the parameters that most significantly influence the joint's mechanical resistance. In conclusion, this study provides a combination of finite element modeling, experimental validation, and statistical analysis to identify key factors influencing fracture behavior. This approach offers valuable insights for the design and optimization of composite joints, ensuring enhanced performance and reliability in aeronautical and aerospace industry applications.

SESSÃO 6 – JUNTAS ADESIVAS ESTRUTURAIS II

CHAIR: RM CARNEIRO NETO (UNIVERSIDADE FEDERAL DO RIO DE JANEIRO, BRASIL) E V TITA (UNIVERSIDADE DE SÃO PAULO, BRASIL)

Virtual testing of single lap joint bonded composite structures using 2D and 3D finite element models

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Adhesive joints provide an advanced solution for joining dissimilar materials, offering a combination of low weight and high mechanical strength. This study focuses on evaluating the strength of Single Lap Joints (SLJ) using the Cohesive Zone Model (CZM) to represent the adhesive's behavior. The adhesive mechanical response is governed by traction-separation laws (TSL). Two different TSLs, the triangular and the exponential laws, were considered. Also, it is addressed uncertainties caused by variations in the material properties and geometry of the test specimens. Additionally, to analyze the contribution of each uncertainty variable, the Plackett-Burman design of experiments (DoE) was employed. This statistical method allows for the reduction in the number of numerical simulations required. The numerical 2D and 3D numerical analysis were conducted to evaluate the uncertainties associated with joint construction variables, and their effects were quantified using the Main Effect index (ME). The results indicated that the type of TSL is crucial in determining the maximum load that SLJ joints can support. Specifically, the choice between triangular and exponential laws significantly impacted the predicted strength of the joint. Furthermore, viscous damping was found to play a significant role in the convergence and number of iterations required for the solution, highlighting its importance in the computational modeling process. Among all parameters, the fracture energy release rate had the greatest influence on the mechanical strength of the joint. This parameter essentially dictates how the adhesive layer absorbs and dissipates energy during failure, thereby determining the joint's overall performance. In conclusion, the methodology offers a comprehensive view of the parameters influencing joint behavior, allowing for their ranking and subsequent treatment in the design development of such joints. This research makes a contribution to the design and development of adhesive joints, providing a solid foundation for optimized and assertive design practices.

Failure modes and fracture analysis of DCB composite bonded joints using XFEM

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Understanding the failure modes in bonded joints made of composite materials is important for assessing their reliability concerning the different types of loading to which they are subjected. Among the important factors, the mechanical behavior of the adhesive is fundamental, as the failure modes and criteria to be used are derived from it. Thus, the choice between a brittle or ductile adhesive can result in a complex development of internal stresses along the bond line. So, this work aims to contribute to the study of adhesive fracture in bonded joints made of composite materials using the extended finite element method (XFEM) analysis. Finite element models were modeled using three-dimensional numerical analysis in Abaqus® software, to represent the Double Cantilever Beam (DCB) test, standardized in ASTM D5528, employing an eight-node hexahedral element (C3D8R) to model the composite laminates and the adhesive layer. After that, the mechanical strength of the adhesive was evaluated by the force vs. displacement curves and comparing them with experimental results from the literature. It can be concluded that the XFEM analysis method provides more accurate modeling of discontinuities or cracks in bonded adhesive joints since crack growth follows the path of greatest stress and is not restricted to the boundaries of the mesh element.

Evaluation of fracture energy in mode I in hybrid composites with natural fibers

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Os compósitos reforçados com fibras naturais representam uma família de compósitos com grande potencial de aplicação devido à sua leveza, boa resistência, eficiência econômica e sustentabilidade quando comparados a outros materiais mais comuns, em especial aos compósitos fabricados com fibras sintéticas. Contudo, apesar dos benefícios significativos, as fibras vegetais apresentam enormes desafios, com notável destaque para a sua elevada absorção de umidade, consequência da sua composição altamente hidrofílica, resultando na redução da resistência interfacial. Para superar esta limitação, a hibridização surge como uma abordagem promissora, envolvendo a combinação de materiais distintos para formar um único compósito. As fibras sintéticas, reconhecidas pela sua alta resistência à umidade, quando laminadas juntamente com fibras naturais, podem melhorar significativamente as propriedades mecânicas, alterando beneficamente a energia necessária para a fratura do material. Dessa forma, a hibridização possui benefícios tanto dos aspectos ecológicos das fibras naturais, mas também da alta resistência e rigidez das fibras sintéticas. Neste trabalho investiga-se o efeito da hibridização na energia crítica de fratura em modo I (G_{IC}) de juntas adesivas fabricadas com substratos compósitos de fibra natural, sintética e híbridos, bem como a carga máxima do ensaio *double cantilever beam* (DCB). Foram testadas quatro configurações distintas: i) Uma estrutura laminada com quatro camadas de reforço, todas utilizando fibras naturais, ii) Uma estrutura laminada composta por seis camadas, sendo a primeira e a última camadas reforçadas com fibra de vidro e as quatro camadas internas reforçadas com fibras naturais, iii) Uma estrutura laminada composta por oito camadas, sendo a duas primeiras e as duas últimas reforçadas com fibra de vidro e as quatro camadas internas reforçadas com fibras naturais, e iv) Uma estrutura laminada com nove camadas de reforço, todas utilizando fibras sintéticas. Os ensaios estão em andamento.

Development of a unified specimen for direct generation of cohesive zone law data of adhesives – Fracture components

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These days, several industrial players are actively looking for information on adhesive characterization processes since adhesive bonding is increasingly being used in industrial applications. However, due to how expensive, complex, and time-consuming the present methods are, many industries are unable to apply them, recuring to external specialized labs to do so. As such, the creation of a more unified and agile method has the potential to be a disruptive technology for a wide range of users, and possibly reducing product development times and costs.

The present work displays part of the development of this fully integrated adhesive characterization tool that can load specimens in several different conditions during a single test. To this extent the fracture components of the unified specimen, mode I (modified DCB) and mode II (Inverse-ELS) loading, were studied recurring to two different adhesives, to validate it on a wider spectrum. The results from the numerical and experimental tests were then compared against the standardised methods to access their validity and the specimen's capability to properly characterise an adhesive.

SESSÃO 7 – DURABILIDADE

CHAIR: BD SIMÕES (FEUP, PORTUGAL) E R DE MEDEIROS (UNIVERSIDADE DE SANTA CATARINA, BRASIL)

Fluência de juntas coladas submetidas ao envelhecimento higroscópico

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Os adesivos epóxi são amplamente apreciados por suas excelentes propriedades mecânicas e resistência química. No entanto, o seu comportamento em condições ambientais variadas, particularmente na presença de ciclos térmicos e de umidade, requer uma análise aprofundada para garantir a sua confiabilidade a longo prazo. O objetivo deste estudo é avaliar o impacto da temperatura e da difusão da água no desempenho mecânico de um adesivo epóxi comumente utilizado em diversas aplicações industriais. Neste estudo, amostras de adesivo epóxi foram imersas em água e envelhecidas em diferentes temperaturas. Ensaios gravimétricos permitiram a determinação das propriedades difusivas utilizando o modelo de Fick.

Os testes mecânicos permitiram evidenciar o impacto da presença de água e do envelhecimento térmico nas propriedades do adesivo epóxi. Os resultados permitem estudar de maneira separada os efeitos da temperatura e da umidade na durabilidade de um epóxi.

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Effect of an industrial painting process on mechanical strength of epoxy-based adhesive joints exposed to condensation humidity and salt-spray

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The development of new structural materials and manufacturing processes has increased research and development efforts in the field of adhesive joints in recent decades. Nowadays, due to the strong demand for lighter and more efficient vehicles and implements of the mobility sector, thin sheets, often of dissimilar materials, need to be joined. Despite the clear advantages of adhesive joints, such as lower stress concentration compared to bolted or riveted joints and fewer distortions compared to welded joints, the application of adhesives in mobile structures poses significant challenges in terms of both manufacturing and design aspects [1]. The main concerns are related to the influence of after-joining manufacturing processes, such as a multi-step painting procedure, on the mechanical behavior of the adhesive, as well as the impact of environmental conditions during the equipment's service life. Despite several studies report how moisture and temperature affect the strength of bulked and joint specimens, designers are faced with the difficult task of preventing the degradation of properties of adhesive joints [2,3,4]. The work presents how applying a paint coat in industrial conditions affected the resistance of adhesive joints in condensation humidity and salt-spray tests. The spectrum of temperatures applied during the painting process is also presented, as well as the consequences to the mechanical strength of the joints. Single-lap specimens, composed of structural steel substrates, joined with a heat-curing epoxy adhesive were adopted. Based on the results obtained so far, the cure temperature to which the specimens were exposed inside the painting room has been found to affect the strength of the adhesive joints.

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A design and validation process for structural bonded joints exposed to harsh service conditions

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Adhesive bonding is nowadays seen as a key joining process, finding use in a wide range of structural applications which exploit its versatility, wide material compatibility, outstanding mechanical performance, and unbeatable cost efficiency. adhesive bonding. However, even though the use of adhesives has grown, this is still a process which the industry does not fully master and thus one which generates important research challenges, restricting its usage and limiting its potential.

In the present work, the key results and lessons gathered from multiple works in the field of durability and joint design are shared and discussed. First, the development of mechanical characterization processes for structural adhesives is described, addressing the design of bespoke testing equipment and the development of data reductions processes which can adequately process the resultant data. The second key area is the evaluation of the behaviour of adhesive and joint performance under extreme environmental and loading conditions, which includes aspects such as fatigue, ageing, creep and impact loads. The development of advanced numerical models to support design activities is discussed next, defining the multiple custom numerical models which have been developed using continuum and damage mechanics to model the failure of bonded joints and adhesives under multiple loads and service conditions. Finally, manufacturing relevant aspects and research activities are discussed, addressing surface preparation techniques, curing and adhesive application optimization and the implementation of advanced non-destructive testing techniques that can identify the most serious defects which can be found in bonded joints. All these learnings and results are contextualized and connected with actual cases of study, clearly demonstrating how the developed knowledge has contributed to the state of the art in adhesive bonded processes.

Development of a cohesive zone model for characterizing the fracture behavior of pressure-sensitive adhesives

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Pressure-sensitive adhesives (PSAs) have become increasingly important in modern industries due to their versatility, ease of application, and strong initial adhesive force. They are widely used in electronics, automotive, and packaging sectors, where reliable bonding is crucial for product performance and durability. As PSAs find applications in more high-performance scenarios, understanding their fracture behavior under various loading conditions is essential for ensuring the safety and longevity of bonded structures.

In this study, the mode I fracture behavior of two double-sided acrylic PSAs was studied using double cantilever beam (DCB) geometries. The J-integral was estimated, and the crack tip opening displacements were measured using a DIC analysis, thereby allowing the extraction of a cohesive law using the direct method. The study then focused on the adhesive that presented a stable crack propagation under opening loading conditions, adopting a similar procedure to obtain a cohesive law for mode III testing conditions. The obtained cohesive laws were implemented in finite element software through a cohesive zone modeling approach. The load-displacement curves of the experimental and numerical models were compared to evaluate the performance of the cohesive law. Moreover, the mode I law was validated using a different geometry. Peel tests were numerically simulated using the cohesive law obtained from DCB geometries, and the results were compared with previously performed peel tests.

SESSÃO 8 – APLICAÇÕES

CHAIR: LFM DA SILVA (FEUP, PORTUGAL)
E S DE BARROS (CEFET/RJ, BRASIL)

Qualificação e desenvolvimento de procedimentos de aplicação de reparos em tubulações offshore

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A pesquisa visa explorar novas configurações dos reparos de adesivos e materiais compósitos de fornecedores nacionais já qualificados pelo CENPES/PETROBRAS em amostras tubulares que simulam defeitos comuns encontrados em ambientes operacionais. O objetivo central consiste em desenvolver conjuntos de reparo utilizando materiais compósitos laminados e adesivos estruturais comumente disponíveis no mercado, destinados a aplicações com vazamentos de água e óleo em tubulações no setor de Petróleo & Gás Natural [1], com o intuito de reparar danos com diâmetro de furo e/ou pressão de trabalho acima do qualificado, variando o seu tempo de cura. Para cada configuração, foram fabricadas amostras representativas, nas quais foram simulados vazamentos de óleo e água. Posteriormente, foi realizado o processo de aplicação dos reparos durante o vazamento, seguido pela avaliação de sua resistência à pressão hidrostática e fluência.

Com o objetivo de se confirmar os ganhos em eficiência das novas combinações dos materiais, as pressões de falha obtidas através de ensaios hidrostáticos serão processadas por meio de metodologias estatísticas utilizando o software ANOVA [2]. No mesmo contexto desta pesquisa, o objetivo também é avaliar se as diferenças observadas no tempo de cura dos reparos aplicados são significativas, permitindo otimizar o processo de reparo para maximizar a eficiência em termos de tempo versus tamanho de dano versus pressão.

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Melhoria da propriedade anticorrosiva de vernizes com nanopartículas de alumina e sílica

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Revestimentos orgânicos aplicados como vernizes sobre substratos metálicos frequentemente apresentam resistência reduzida à corrosão em comparação a tintas. A necessidade de transparência destes vernizes impede a incorporação de micropartículas para reforço, fazendo com que suas propriedades dependam fortemente da base polimérica utilizada na formulação [1]. Neste estudo, nanopartículas de alumina (1%) e sílica (2% e 6%) foram adicionadas a um verniz à base da blenda de polimetilmetacrilato-co-acrilato de 2-etil-hexila e poliestireno (P(MMA/2EHA)/PS) com o objetivo de aumentar a resistência à corrosão. Embora existam estudos sobre a adição de nanopartículas de alumina e sílica em vernizes de PMMA e PS [2,3], há pouca informação sobre sua influência no módulo de impedância de vernizes à base de P(MMA/2EHA)/PS. A obtenção dos vernizes nanoestruturados se deu em solução, com a dispersão das nanopartículas realizada por agitação mecânica seguida de sonicação para evitar aglomeração. A técnica de espectroscopia de impedância eletroquímica (EIE) foi utilizada para avaliar o verniz nanoestruturado aplicado sobre uma liga de aço carbono. Os resultados indicam que a incorporação de nanopartículas melhora as propriedades anticorrosivas dos revestimentos aplicados sobre substratos metálicos. Dessa forma, este trabalho contribui para o desenvolvimento de vernizes protetivos com maior resistência à corrosão, beneficiando o mercado da construção.

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Lignina kraft hidroxipropilada como resina taquificante em adesivo hot melt

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Os adesivos hot melt (HMA) são adesivos termoplásticos que, quando aquecidos, atingem uma viscosidade baixa, permitindo boa molhabilidade durante a aplicação e endurecem rapidamente ao resfriar. Esses adesivos não contêm solventes, oferecendo um processo limpo e seguro, além de proporcionar uma ligação forte e durável entre diversos materiais [1]. Em geral, um HMA é composto por um polímero base, cera para ajuste de viscosidade e resina taquificante, que confere coesão e adesão inicial. Exemplos comuns de resinas taquificantes incluem hidrocarbonetos e resinas terpeno-fenólicas, que possuem baixa massa molar, elevada temperatura de transição vítrea (T_g) e são materiais rígidos [2]. Neste contexto, a lignina, um dos polímeros mais abundantes na biomassa, surge como uma alternativa renovável às resinas taquificantes típicas. A lignina é uma fonte renovável rica em grupos funcionais fenólicos e alifáticos, com uma estrutura complexa e amorfa [3]. Neste trabalho, HMAs à base do copolímero etileno-acetato de vinila (EVA) foram produzidos utilizando lignina como substituto parcial ou total da resina taquificante. Foram avaliadas formulações com lignina kraft de grau industrial (KL) e KL hidroxipropilada (HKL), modificada com óxido de propileno, para analisar a interação entre os componentes da formulação. As misturas foram analisadas quanto à morfologia, comportamento viscoelástico e adesão prática em substratos de madeira. Os resultados demonstraram o potencial da lignina como resina taquificante, aumentando a coesão e adesão prática em formulações adequadas de HMA, promovendo o uso de um material renovável e de baixo custo.

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An experimental and numerical study of the reinforcement of steel plates with hybrid carbon/flax composite patches under flexural loading

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When adhesively bonded to the external surface of a metallic structure, Fiber-reinforced polymers (FRPs) can enhance strength and stiffness, compensate for material loss caused by corrosion, extend fatigue life, or allow a change in the structure's function [1]. Carbon fiber and glass fiber reinforced polymers are the predominant materials used for this repair technique. However, multiple researchers have highlighted the negative environmental impact of synthetic composite materials and their non-degradability. Flax fibers, in particular, show great potential as an alternative reinforcement material [2], and more research is needed to encourage the development and use of natural fibers, as well as bio-based resins and adhesives. Additionally, hybrid carbon/flax laminates offer an appealing balance between mechanical performance and environmental sustainability [3]. In this work, innovative hybrid carbon/flax composite patch configurations are proposed and bonded to rectangular steel plates using three types of adhesives. Both numerical and experimental three-point bending tests are conducted to assess the flexural behavior of the assemblies. An experimental setup has been developed to facilitate digital image correlation on the surface of the composite patch, allowing for precise monitoring of strain evolution during the tests.

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