

ENHAnCE Featuring Engineering

EHAnCE MINISIMPOSIUM, THESIS CONTEST and SHOWCASE at JEC PARIS

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Document index

| ntroduction | 3 |
|-------------------------------------|----|
| Symposium | 3 |
| EC showcase | 4 |
| Business meetings and point of view | 5 |
| ESR 1, Shankar Galiana | 5 |
| ESR 2, Aravind Balaji | 7 |
| ESR 3, Amond Allouko | 9 |
| Conclussions | 12 |
| Thesis contest | 12 |
| References | 16 |
| Annexes | 17 |



Introduction

This document presents several activities related to the dissemination of the project results, consisting of the organization and development of a congress symposium, the assistance of an international showcase and the celebration of a thesis contest.

These activities are oriented toward improving the motivation, creativity and innovative potential of the researchers to enhance their careers and advance their research based on opportunities for acquisition and transfer of new knowledge.

Symposium

A symposium was organized and chaired by the ENHAnCE Coordinator at the 8th International Conference on Computational Methods in Structural Dynamics and Earthquake Engineering (COMPDYN 2021) streamed from Athens, Greece, on 28/30th of June 2021 in conjunction with the 4th International Conference on Uncertainty Quantification in Computational Sciences and Engineering (UNCECOMP 2021) and the 14th International Conference on Evolutionary and Deterministic Methods for Design, Optimization and Control (EUROGEN 2021).

The title of the symposium was "Condition Based Maintenance and post-prognostics of composite structures: An ENHAnCE platform", number 22 of the symposiums celebrated at this venue. It aims at providing a platform for idea exchange and knowledge dissemination through the latest developments in the field of condition-based maintenance and post-prognostics decision-making of complex composite structures. More information can be consulted at <u>https://2021.compdyn.org/</u>.

Topics relevant to the symposium included implementations and algorithmic solutions for:

- Wave interaction with damage modelling
- Damage detection methods for industrial composites
- Bayesian and AI identification methods
- Physics and data-driven prognostics modelling
- -Structural Health Monitoring solutions, including built-in sensors and devices

-Prognostics algorithm embedment within IoT technology and contributions to the implementation of such methods on real-life applications



A presentation about "Reduction of Petri Net Maintenance Modelling Complexity Via Approximate Bayesian Computation" was carried out by one of the Early State Researchers, along with a paper "C20141- An Approximate Bayesian approach for complexity reduction of Petri Nets models". Certificates are included in the Annexes.

In addition to this, another article was published in the Proceedings of this Conference, with the title: "Particle filter-based hybrid damage prognosis considering bias", authored also by one of the Early Stage Researchers of ENHAnCE. This article can be accessed online through the link: https://generalconferencefiles.s3.eu-west-1.amazonaws.com/compdyn_2021_proceedings_v1.pdf

JEC showcase

The Early State Researchers from ENHAnCe attended the JEC World showcase, the world's leading composites event which took place in Paris from 3 to 5th of March 2022. This showcase is dedicated to exhibiting the state of the art in composite materials, technologies and production processes, along with their applications sectors, with 1350 exhibitors, the presence of 112 countries, 250 speakers, 26 pavilions and more than 600 innovations presented.



Figure 1. Main features of the JEC showcase

At Paris Villepinte Parc des expositions, in hall 5 and hall 6, it took place the 2022 section, whose topic was about the sustainability of composites materials. During the event, all the composite materials actors worldwide were regrouped in one place. This was an opportunity for early-stage researchers to learn more about the process of composite materials, from the raw material producers to the final products. In order to have a structured stand visit, appointments for business meetings were requested. According to their position in the value chain, the aim of the meetings was to understand the whole process of composite materials.



Business meetings and point of view from the researchers

ESR 1, Shankar Galiana

During the visit, different aspects of the ESR1 research has been discussed. The discussions have been focused on the research topics and spreading the ENHAnCE project through the assistant hosts. The Main discussed research topics were raw materials for transducer manufacturing, reinforcement orientation for the embedment composite, functionalized materials for the signal acquisition, testing characterization of the transducer properties, transducer implementation possibilities to the host structures, and possible final structure applications of the transducer networks.



Figure 2. TFP Tech stitched reinforcement

Regarding raw materials for the transducer manufacturing, thermoplastic composite reinforcement suppliers (Hexcel [1], Victrex [2], Toray [3] and Mitsubishi Chemical [4]) has been visited to discuss the suitability of E-glass reinforcement to be embedded in high-performance thermoplastic. Also, the available different formulations of the LM-PAEK and how they can be supplied, either in separated glass mats and the LM-PAEK films for its pre-processing, in consolidated reinforced pre-preg lamina, or in additive manufacturing spools.

For the reinforcement orientation of the embedment materials, some discussions have been held with stitching machine suppliers (TFP Tech [5]), to check the feasibility to directly stick the glass reinforcement in the proper shape in a thermoplastic lamina for its post-process. From the multifunctional perspective, some possible solutions for the rheological response of thermoplastic embedment composite and interface were discussed and discarded (3M [6]), but some possible solutions where arise when discussing about small demonstrators of embedded printed circuits in thermoplastic material (EU-RECAT [7]).





Figure 3. EURECAT embedded circuit

A new testing methodology was shown by one of the host assistants (IMCE [8]), where when hitting a coupon plate and acquiring the vibration signal with an accelerometer, by reverse engineering using FEA, the material mechanical properties are computed. This test can also be made at different temperatures. Finally, there were several demonstrators of composite structures such as cars, tanks, or structure parts. Some meetings have been held regarding it to understand its structural loads state as the main problems that they face such as in the hydrogen tanks (Voith [9]).



Figure 4. Voith Hydrogen tank

Also, over a technology demonstrator on welding thermoplastic composites, different welding integration strategies of the transducers were discussed (Fokker [10]).



ESR 2, Aravind Balaji

The main focus with respect to the research of ESR is to develop a framework where the Acousto-Ultrasonicbased Structural Health Monitoring (AU-SHM) system becomes an integral part of manufacturing process of smart composites structures, relying on data obtained from multi-physical models and finally to predict it'slifespan. ESR2 primarily conduct my research at a private applied research center, Cenaero ASBL, Belgium in collaboration with Politecnico di Milano, Italy. Cenaero ASBL[11], with the presence of Senior Researchengineer and Polymer Composite Technologies leader, Mr. David Dumas was involved in the event to share innovative simulation solutions for high performace composites within the fields of aeronautical design, space-crafts and manufacturing processes and to promote projects namely ENHANCE ITN-MCSA, Horizon Europe DIDEAROT and WINGS.

The integral focus of research on ESR2 lies in the prediction of manufacturing defects in the form of residual stresses arising from the curing of composites structures. The state-of-the-art methodology to predict such manufacturing defects is the Finite Element (FE) visco-elastic constitutive models. At Hexagon[12] booth in the event, ESR2 made a connection with one of the business development managers, Mr. Nicloas Jalbertwith the domain of Machine Learning (ML) solutions. The interaction was focused on the implementation on one of Hexagon's machine learning tools (ODYSSEE suite) for exploitation of new material data and in decision-making/analysis of manufacturing process effects on composites parts/prototypes.

With respect to the state-of-the-art FE visco-elastic constitutive models, numerical convergence issues with respect to the contact between the mould and the composites parts are quite common. Comprehensive interactions were made with the RD development senior manager of Dassault Systemes[13], Dr. Huidi Ji with respect to the numerical tool, Abaqus CAE on how such issues could be migrated with solutions such as mesh adaption etc., especially in the areas close to the outer skin of the composites parts. In addition to this, ESR2 had interesting discussions on the recent innovative solutions on different applications with the Mechanical Industry Process Consult and Management Senior Director, Mr. Daniel Pyzak. One such innovative solutions is the wing-sail structure used for sailing, refer to Figure 5.





Figure 5. Wing-sail structure, from Dassault Systemes

The latter part of the research of ESR2 is with the implementation of the contribution of residual stresses in damage mechanics simulation tool and to predict of optimal location of sensors to detect delamination and predict remaining useful life. Different models on the sharp crack using Linear Elastic Fracture Mechanics and smeared crack using Cohesive Zone Modeling, Thick Level Set, Lipshitz Regularization, Phase Field etc., exist to predict the damage in composites and in particular the phenomenon of delamination and finally, to predict the loss in load-carrying capacity. A comprehensive discussion on some of the models was made with the experts at Altair, [14]. Some experimental validation with respect to different modes within delaminations is required to validate the above mentioned models.

Several extensive interactions were made with organizations such as Grasse Zur Ingenieurgesellschaft mbH[15] (with Dr. Fabian Grasse), Metravib[16] (with Mr.Brice Taillet) and ZwickRoell GmbH Co. KG (with Dr. Hannes Körber) [17] on the experimental set-up of composite coupons with embedded AU-SHM systems for mode I, mode II and mixed-mode cases and the chal-lenges involved and such possible collaborations are possible in the near future with respect to composite testing. In addition to the above mentioned technical interactions, ESR2 participated in a few JEC conferences on the topics namely, Rethinking Composite Materials Manufacturing: The Path to Sustainable Production, Simulation - The Key to Sustainable Product Development byAltair, New Hybrid Process Through Additive Manufacturing For Increasing Performances in Structural Composite



Parts by9T Labs[18], 'FutureComposites: Combining Accessible Design, Scalable Simulation Reliable Manufacture" by Dassault Sys-temes, refer Figure 6, Using Sensors to Improve Sustainability in Composites Manufacturing, Design and Life Cycle by Composites World[19] and Innovative 4.0 Training Dedicated to the Transformation Processes of Thermoset and Thermoplastic Composites" by Composites Academy [20].



Figure 6. JEC conference session

ESR 3, Amond Allouko

Since ESR3 topic is about a hybrid modal approach for the SHM of composite materials, using elastic guided waves and finite elements, this event allows knowing more about the monitoring development used in the industry for composite materials up to date. The event was organized in both hall 5 and hall 6. In the hall 5, the companies can be set in the following categories:

•Natural fibers companies

- •Carbon Fiber manufacturing companies
- Machinery companies
- Monitoring companies

Some exciting innovations were presented there like the "The augmented wood" from the company WOODOO. By chemical treatments of the wood, the wood is used as a screen to diffuse images. This wood can be used in luxury cars or planes to give more interactions compared to classical wood.



The machinery companies present the latest version of their products. We attended some demonstrations about ATL (Automated tap layer) and AFL (Automated Fiber Placement) for composite piece manufacturing. We assisted during training week 3 in Madrid with similar demonstrations. The monitoring companies were generally focused either on the use of ultrasound (Bulk Waves) for defect determination or on determining the elastic properties of materials. We were impressed by the product of the company IMCE, by smashing a sample of the composite plate, they can find the elastic properties in efficient and quick post-treatments. We did not see acoustic characterization for composite materials, which gives more interest to our research. The carbon fiber manufacturing companies present the products they can make according to the specifications of their clients. They can also sell the raw bobbin of carbon fibers.



Figure 7. mTorres full composite fuselage demonstrator

Hall 6 was dedicated to innovative products that can be performed with composite materials. Most of the companies' products are for aeronautic usage. Figure.7 shows a full fuselage demonstrators of the company mTorres. The challenge is to solve the electric conductivity problems encountered up to now in the plane fuselage full composite manufacturing.



Figure 8. PROFACTOR's process scan



We appreciate pretty much the NDT scan laser of the company PROFACTOR. This technology can monitor the fiber orientations during the layup process of composite material. It can be combined with ATL or AFL in order to get real-time monitoring during the process. The operator can then stop the process to correct the mistake layer by layer to have a final perfect product. This photo was taken in front of an aircraft frame in a composite material that is a collaboration between DLR and TuDelft. By the lightweight concept crucial in aeronautics, they designed a damping process based on composite springs. The following pictures show some interesting automotive projects presented during the event.



Figure 9. ESRs and car body in composites



Conclussions

The JEC WORLD 2022 was an exciting event for us, an opportunity to learn nearest to the industrial companies about the composite manufacturing process. As we are working on PHM for composite materials with ultrasonic techniques, we focused our attention on the latest improvements in the monitoring of composite material. We had "positive" disappointments because the monitoring process was performed either during the manufacturing process to minimize the residual strength or in the lifecycle with only the ultrasonic "bulk" waves method.

The ultrasonic method by guided waves is not (or few) mentioned, because of the difficulties of correlating practical results with efficient simulation tools to propagate the elastic waves in 3D composite materials. This shows how the results of our work are needed from the industrial point of view.

Thesis contest

A thesis competition was run for the Early Stage Researchers in which they were asked to present their doctoral research in no longer than three minutes using a poster and/or no more than three overhead slides.

This contest challenged their presentation skills and give them an opportunity to present their work to a general but technical audience – something that all researchers should be able to do if they are to communicate the importance of their work effectively.

There was a small judging committee composed of the Coordinator, the Tutor Mentor and several Supervisors who decided on which presentation was the best, based on the clarity, the quality of the science, and the level of technical understanding that the presenter demonstrates.

Presentations included details of the motivation for the research, the results achieved so far, the potential impact of the work, and what conclusions have been drawn to date. The quality was so high that finally, the result was a tie.





Figure 10. Thesis contest and presentations from the ESRs: Amond, Aravind and Thianzi





Figure 11. Thesis contest and presentations from the ESRs: Wen, Tasdiq and Morteza





Figure 12. Thesis contest and presentations from the ESRs: Ali and Juan



References

- [1] Hexcel Comp.(<u>https://www.hexcel.com</u>)
- [2] Victrex Comp.(<u>https://www.victrex.com</u>)
- [3] Toray Comp.(<u>https://www.toray.com</u>)
- [4] Mitsubishi Chemical Comp.(https://eu.mitsubishi-chemical.com)
- [5] TFP Tech Comp.(<u>https://www.tfp-tech.de</u>)
- [6] 3M Comp.(<u>https://www.3m.com</u>)
- [7] EURECAT Org.(<u>https://eurecat.org</u>)
- [8] IMCE Comp.(<u>https://imce.eu</u>)
- [9] Voith Comp.(<u>https://www.voith.com</u>)
- [10] Fokker Comp.(<u>https://www.gknaerospace.com</u>)
- [11] Cenaero ASBL (<u>https://www.cenaero.be/</u>)
- [12] Hexagon (https://hexagon.com/)
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- [18] 9T Labs (<u>https://www.9tlabs.com/</u>)
- [19] Composites World (<u>https://www.compositesworld.com/</u>)

[20] Composites Academy (<u>https://www.composites-academy.com/</u>) mtoRRES (<u>https://mtorres.com/</u>)



Annexes

1. Symposium certificate

European Community on Computational Methods i Applied Sciences matic Conference **COMPDYN 2021** 8th International Conference on **Computational Methods in** Structural Dynamics and Earthquake Engineering 28-30 June 2021, Athens, Greece An IACM Special Interest Conference e-mail: info@compdyn.org url: http://2021.compdyn.org Certificate This is to certify that Dr Manuel Chiachío Ruano organized and chaired the Minisymposium 22 "Condition Based Maintenance and post-prognostics of composite structures: An ENHAnCE platform" in the context of the 8th International Conference on Computational Methods in Structural Dynamics and Earthquake Engineering (COMPDYN 2021) streamed from Athens, Greece, on 28-30 June 2021 in conjunction with the 4th International Conference on Uncertainty Quantification in Computational Sciences and Engineering (UNCECOMP 2021) and the 14th International Conference on Evolutionary and Deterministic Methods for Design, Optimization and Control (EUROGEN 2021). Sincerely, Manolis Papadrakakis On behalf of COMPDYN 2021 Organizers



2. Certificate of a paper presentation

European Community on Computational Methods in Applied Sciences OMAS hematic Conference **COMPDYN 2021** 8th International Conference on Computational Methods in Structural Dynamics and Earthquake Engineering 28-30 June 2021, Athens, Greece e-mail: info@compdyn.org url: http://2021.compdyn.org An IACM Special Interest Conference Certificate of Presentation This is to certify that Mr Ali Saleh presented the paper "C20141 - AN APPROXIMATE BAYESIAN APPROACH FOR COMPLEXITY REDUCTION OF PETRI NET MODELS" at 8th International Conference on Computational Methods in Structural Dynamics and Earthquake Engineering (COMPDYN 2021) streamed from Athens, Greece, on 28-30 June 2021 in conjunction with the 4th International Conference on Uncertainty Quantification in Computational Sciences and Engineering (UNCECOMP 2021) and the 14th International Conference on Evolutionary and Deterministic Methods for Design, Optimization and Control (EUROGEN 2021). Sincerely, Manolis Papadrakakis On behalf of COMPDYN 2021 Organizers