



# HISTRATE

Advanced Composites  
Under High Strain Loading:  
A Route to Certification-  
by-Analysis

2025 Conference  
4th - 5th June 2025



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## Preface

We present the **Book of Abstracts for the Second HISTRATE Conference — *Advanced Composites under High STRAin raTEs Loading: A Route to Certification-by-Analysis***, held from June 4 to 5, 2025, in San Sebastian, Spain. Following the enthusiastic response to the first edition of HISTRATE conference, this year's event reaffirms its role as a dedicated forum for specialists working at the intersection of composite materials, dynamic loading, and computational certification methodologies. Nestled between the rolling green hills of the Basque Country and the sparkling waters of the Bay of Biscay, San Sebastián offers a stunning setting for intellectual exchange.

As advanced composite materials play an increasingly central role in industries such as aerospace, automotive, defense, marine, and renewable energy where lightweight, high-performance, and impact-resistant structures are vital. The accurate understanding of their behavior under high strain rate conditions has become both a scientific and engineering imperative. In parallel, the concept of certification-by-analysis is gaining momentum as an efficient, reliable, and cost-effective alternative to traditional testing regimes. This shift relies fundamentally on the development of validated, high-fidelity numerical models capable of predicting material and structural responses under dynamic events with confidence.

The HISTRATE conference series was started to bring together an international community of researchers, engineers, industry representatives, and regulatory stakeholders to exchange knowledge, share new methodologies, and discuss both the advances achieved and the hurdles yet to be overcome in the domain of composites. The 2025 edition focuses particularly on integrating experimental, numerical, and analytical approaches to support and accelerate the transition towards certification-by-analysis for composite structures subjected to high strain rate loading.

This Book of Abstracts reflects the diversity, depth, and forward-looking spirit of the conference. It compiles contributions from 35 universities, 11 academic research centers, and 5 industrial research centers, covering a broad spectrum of topics. These include innovative experimental techniques for dynamic characterization, advances in constitutive modeling and failure criteria under high strain rates, multiscale simulation approaches, novel composite architectures for improved dynamic performance, and strategies for integrating numerical predictions into certification pathways. Emerging themes such as the use of artificial intelligence and machine learning in high-strain-rate material modeling, and the role of uncertainty quantification in predictive simulations, are also represented. The conference united authors from Belgium (2), Bulgaria (2), Czech Republic (3), Cyprus (1), France (1), Georgia (2), Germany (3), Greece (3), Ireland (1), Italy (5), Latvia (2), Lithuania (1), The Netherlands (2), North Macedonia (5), Poland (7), Slovakia (2), Turkiye (12), UK (9). One third of the corresponding authors are early career researchers.

The conference program features keynote lectures by experts from industry, technical sessions and poster presentations organized around thematic tracks in the COST CA21155 Working groups and the Action use cases, including research from early-career scientists. This dynamic format is designed to foster both formal and informal exchanges, encouraging collaborations that extend beyond the conference itself.

We wish to thank all the authors for their valuable contributions, the reviewers for their thorough evaluations, and the members of the organizing and scientific committees for their

tireless work in shaping this conference. Special recognition is also due to our host from University of the Basque Country for their organizing efforts and generous support.

We believe this collection of abstracts will serve not only as a useful reference but also as a lasting record of the ongoing efforts to push the boundaries of composite material technology and certification practices under dynamic loading conditions.

**The HISTRATE 2025 Organizing Committee**

# Modelling and Characterisation of UD Thermoplastic Laminates under Dynamic Loading

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**Abstract:** This paper describes work-in-progress on modelling and characterisation of an AS4/PEEK UD composite undergoing compression at the range of loading rates from  $1 \times 10^{-3} s^{-1}$  to  $2 \times 10^3 s^{-1}$ . The material at quasistatic rates was tested by using a servo hydraulic test machine, whilst the high strain rate testing was conducted by using Split Hopkinson Pressure bar (SHPB) rig. Simulation programme was conducted with LS Dyna explicit solver where the composite was modelled at quasi-continuum and micro scale with linear hexahedral solid elements. A selection of experimental results was compared to simulation results and the results agree well in terms of measured maximum stress at failure and effective laminate stress obtained in the simulation.

**Keywords:** AS4/PEEK UD composite, thermoplastic composite, LS Dyna models, finite element methods;

## 1. Introduction

Fibre reinforced polymers laminates are widely used in aerospace and automotive industry, because of their high specific stiffness and strength, with the growing interest in carbon-thermoplastic laminates. Design and materials characterisation under compression are still based on the experimental testing but these campaigns are very costly and time consuming [1-7]. Simulation methods, combined with appropriate constitutive models, including failure criteria, and realistic boundary conditions can enable engineers to predict performance and accelerate the components design. However, a limited number of publications is available on numerical investigations of the compression behaviour of carbon thermoplastic laminates [7-10], particularly at the elevated loading rates. Consequently, the objective of the work presented in this paper is modelling and characterisation of the AS4-PEEK composite laminate, where the material is tested at the range of loading, starting from the quasistatic up to the high rate loading and modelled by using LS-Dyna FEM solver [11].

## 2. Experimental characterisation at a range of strain rates

Using a servo-hydraulic testing machine to characterise the mechanical properties of composites under static and quasi-static loading conditions provide a comprehensive understanding of their strength, stiffness, failure modes and fatigue behaviour. The precision and versatility of servo-hydraulic testing machines enable the testing under various mechanical conditions and help optimise designs for reliability, durability, and performance.

The material tested here is unidirectional AS4/PEEK preprag laminate, which consists of 32 plies and the stack sequence [0/45/-45/90]<sub>4s</sub>. The quasistatic loading was conducted with the specimen shown in Fig. 1a, on the 200kN servo hydraulic machine with max loading rate 200 mm/s, shown in Fig. 1b. The quasistatic tests were conducted at the loading rates of 0.01mm/s, 1mm/s and 100mm/s, which correspond to the strain rates of  $1 \times 10^{-3} s^{-1}$ ,  $10^{-1} s^{-1}$  and  $10 s^{-1}$ , respectively. PCO edge 5.5 camera and Veritas Constellation 120 lamps were used for first two tests, whilst equipment for the highest loading rate included: NI USB-6366 acquisition board, ultra-high speed laser displacement sensors Keyence LK-G5000 and sensor head LK-H157, piezoelectric load cell Kistler 9106A, Charge amplifier Kistler 5015, High speed camera IDT OS8-S3 and Veritas Constellation 120lamps. Three tests were performed at each loading rate and the stress strain curves are given in Fig. 2.

The same material was also tested at higher strain rates using the SHPB setup, with cylindrical specimen. The apparatus consists of Maraging 300 bars Ø 25mm (striker 2m, Input bar 2m and output bar 4 m), Ohmic and semiconductor strain-gages, strain gage amplifier EFS SGA02 high-speed (cut-off frequency of 500 kHz) and fast transient recorder GAGE CSE8482-H2 (sample-rate 10 MHz). The strain gauges are mounted on the incident and transmission bars to measure the elastic strain waves generated at impact of the incident bar and determine the stress-strain response of the material. Two loading rates of 8000mm/s and 18000mm/s, which

respectively correspond to strain rates of  $800s^{-1}$  and  $1800s^{-1}$ , were testes with three samples to check for the repeatability. The average test results for the two loading rates are given in Table 1.

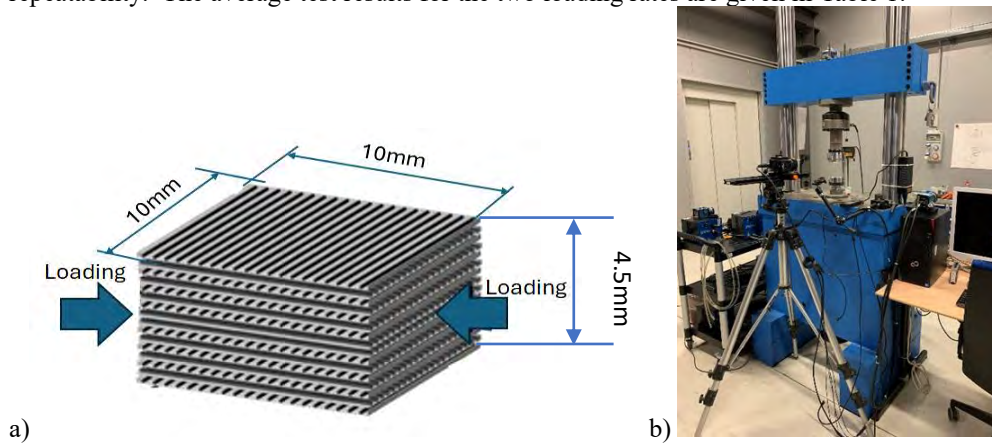


Fig. 1 a) AS4/PEEK laminate for compression testing b) Servo-hydraulic testing machine

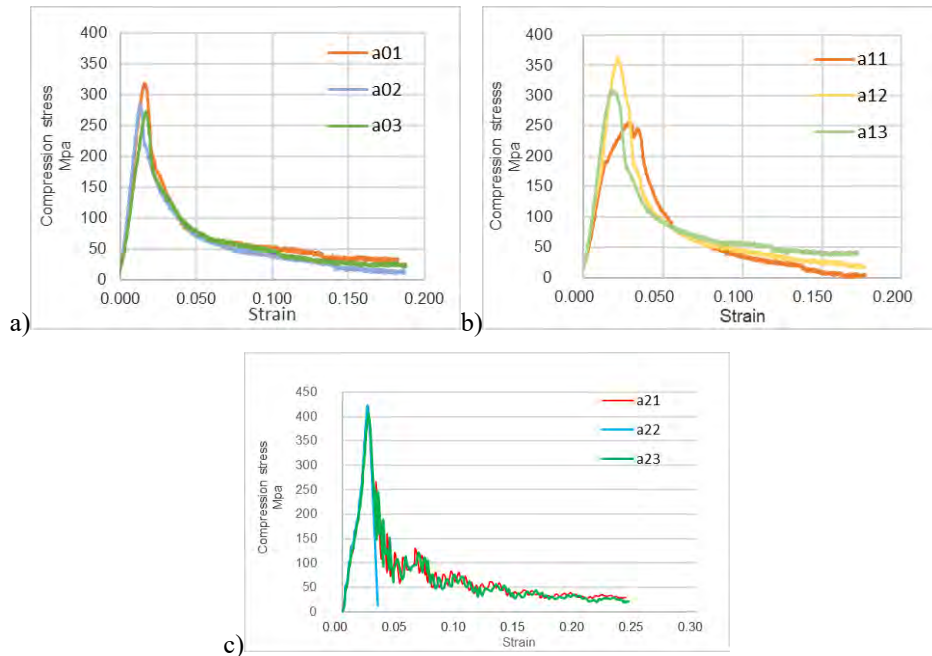


Fig. 2 Stress – Strain curves obtained with UD AS4-PEEK under compression at loading rates: a)  $v=0.01$  mm/s, b)  $v=1$  mm/s and c)  $v=100$  mm/s

Table 1 Loading strain rates and maximum compression stress obtained in SHPB tests.

Specimens	Thermoplastic resin	Velocity mm/s	Strain Rates (/s)	loading directions in the compression test	Compression stress MPa
<b>Avg</b>	PEEK	8 000	800	In-plane loading	<b>400,2</b>
<b>Avg</b>	PEEK	18 000	1 800	In-plane loading	<b>460,2</b>

### 3. Modelling of compression tests

The finite element models of the samples used in the quasistatic testing are developed by using LS Dyna and linear solid hexahedral elements available there in. Two discretisation methods were developed: a) quasi-continuum approach, where the plies are modelled individually by using three elements through thickness and element aspect ratio one, shown in Fig. 3a); and b) micromechanical approach, where the matrix and fibres are modelled individually. Only the bottom part of the laminate was modelled with symmetry boundary conditions applied on the Z plane so that the quasi continuum model consists of 1,920,000 solid elements. The composite

material was modelled by using material type 59 [11], based on Tsai – Wu ellipsoidal failure surface criteria. The simulation results for the stress strain curves obtained in each individual ply are shown in Fig. 3b) for the loading rate of  $1\text{ mm/s}$ . The effective laminate stress calculated from this result based on the load balance through the thickness of the laminate agrees well with the experimental results in terms of maximum stress at failure being within 10% of the average experimental value.

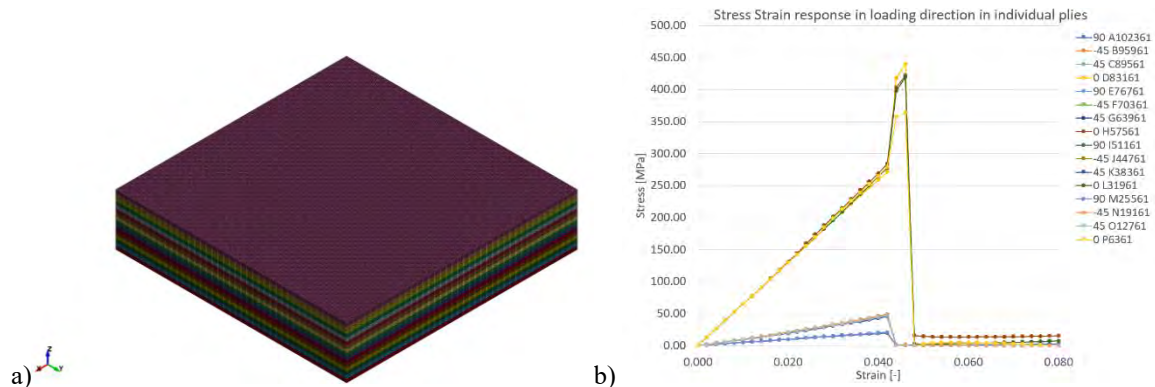


Fig. 3 a) FEM Model developed for analysis AS4/PEEK laminate under compression loading b) Stress strain curves in the loading direction obtained in the individual plies in the simulation at  $v=1\text{ mm/s}$

#### 4. Conclusions

The AS4/PEEK UD laminate has been characterised for the range of the loading rates relevant for automotive and aerospace applications and the high fidelity models of the tests have been developed. The first simulation results agree well with the experimental results. The future work will include a comprehensive simulation programme both at the quasi continuum and micromechanical scale. The latter will allow for analysis of the matrix dominated rate effects onto the overall material response and calculation of the smeared material properties, which will significantly reduce the size and computational costs of the real world/component models.

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