



HISTRATE

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

2025 Conference
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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

Ballistic strength of polyethylene composites based on bidirectional and unidirectional fibers under the high-speed ballistic impact

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Abstract: The purpose is to investigate the behavior of composites made of ultra-high molecular weight polyethylene woven fabrics and unidirectional tapes under the high-speed ballistic impact. Ballistic composites based on bidirectional and unidirectional fibers are manufactured and subjected to ballistics tests. The unidirectional composites have shown superior performance as compared to bidirectional ones due to their lower extent of the reflective impact wave i.e. the ballistic impact wave is transmitted to higher composite area. Due to the crossover points in bidirectional composites, the greater extent of the ballistic wave is reflected, rendering the ballistic impact to smaller composite area.

1. Experiment

1.1. Materials

Plain woven HPPE fabric was used as reinforcement for bidirectional composites and as a matrix polyvinylbutyral (PVB) modified phenolic resin of resole type was used. The impregnation of the fabric with the resin was done on a semi-industrial vertical impregnating machine. The unidirectional tape, which was pre-processed into prepreg, consists of four layers of unidirectional fibers cross plied at 0°/90° orientation, as shown in Figure 1, and sandwiched with a thermoplastic film.

Table 1. The properties of unidirectional and bidirectional prepreps

Property	Unit	Unidirectional prepreg	Bidirectional prepreps
Resin type		thermoplastic	thermoset (phenolic resin)
Resin content	%	20±1	20±1
Gel time at 150°C	seconds	-	96
Areal weight	g/m ²	244±7	240±7
Volatiles content	%	<1.5	<1.5

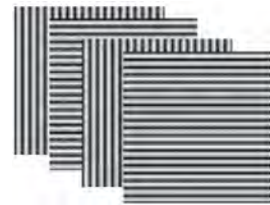


Fig. 1. Construction of unidirectional prepreg

1.2. Molding

The composites were constructed by laying up a multiple number of prepreg plies in accordance with the targeted areal weight and cured at elevated temperature. Each type of composite is manufactured in four different areal weights, 3, 5, 7 and 9 kg/m². This areal range is chosen because it is common for personal ballistic protection. All composites were molded at 130 °C under molding pressure of 10 MPa.

1.3. Ballistic test

Ballistic strength of the composites was assessed by measuring their ballistic strength i.e. V_{50} ballistic limit. V_{50} ballistic limit is a statistical test originally developed by the US military to evaluate hard armor [1,2]. V_{50} testing experimentally identifies the velocity at which a bullet has a 50% chance of penetrating the test object. Fundamental to the concept of ballistic limit is a relationship between probability of penetration of the armor and the striking velocity of the projectile. The projectile-armor relationship satisfies the mathematical conditions of probability distribution i.e. for low velocities probability approaches zero; for high velocities the probability approaches one; and between those extremes of velocity, the probability increases with increasing velocity. When the general model describes physical behavior, probability of penetration can be treated as a probability distribution and is usually described as a Gaussian or normal distribution.

The ballistic test is performed by firing 5.56mm, 1.5 g fragment simulating projectiles on to the composite panel. All test panels (400 mm x 400 mm) prior to testing, are conditioned at 20±2 °C and relative humidity of 65±5%. At least 14 projectiles are being fired at the test panels and their velocities measured. A projectile which passes through the panel or causes material to be thrown off of the back of the panel is considered complete penetration. All other impacts are defined as being partial penetrations. The V_{50} ballistic limit velocity for a panel is defined as that velocity for which the probability of penetration of the projectile is exactly 0.5. The subscript 50 designates the percentage of that probability of penetration. After a number of projectiles have been fired the V_{50} is calculated as the meaning of the velocities recorded for the fair impact consisting of the seven highest velocities for partial

penetration and the seven lowest velocities for complete penetration providing that all fourteen fall within a bracket of 60 m/s [2].

2. Results and Discussion

The results of the ballistic test are given in Table 2.

Table 2. Ballistic strength of the composites, V_{50} (m/s)

Composite	Areal weight of composites			
	3 kg/m ²	5 kg/m ²	7 kg/m ²	9 kg/m ²
BD-HPPE	319.1	412.9	498.2	557.3
UD-HPPE	401.1	517.4	601.9	682.1

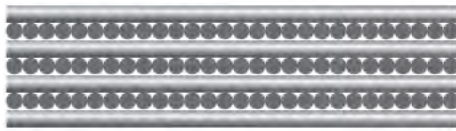


Fig. 3. Cross-section of UD composite

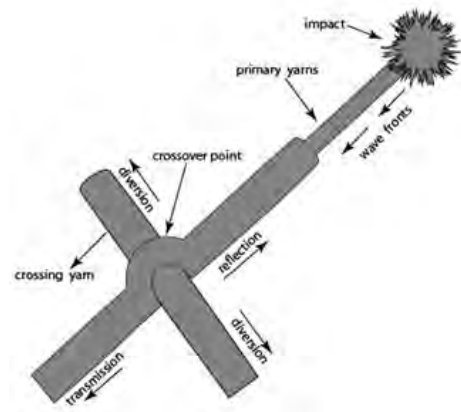


Fig.2. Longitudinal wave propagation in fabric after ballistic impact

In the above table “BD” and “UD” designate bidirectional (fabric) and unidirectional composites respectively. Textiles are used to protect against two categories of ballistic projectiles. Bullets from handguns and rifles form one category. These bullets are designed to deform when they hit a body or another object as this is the most effective way to stop a living being. They use a lot of their kinetic energy in the deformation, so they are relatively easy to stop by e.g. bullet-resistant vest. The other category is formed by fragments from exploding shells and grenades. These fragments are smaller than bullets and they have sharp edges and do not deform. For testing purposes (which was done in the ballistic laboratory of the military contractor “Eurokompozit” from Prilep, Macedonia) we used fragment simulating projectiles (FSP) with a well-defined weight and shape in accordance to NATO standard STANAG 2920 [3]. Analyzing the test results, Table 1, one can conclude that there is a distinct difference in ballistic resistance between woven fabric composites and unidirectional tape composites although these composites are similar in many ways. Unidirectional tape composites have performed much better than their counterparts based on woven fabric. When a projectile hits a woven fabric a shock or strain wave is introduced which spreads through yarns. The primary impacted yarns interact with other yarns by means of couplings at the cross-over points of the fabric. The strain wave can thus spread over a large number of yarns. The positive effect of this mechanism is that energy will be absorbed over a relatively large area. The velocity of the strain wave and of the energy dissipation is directly related to the modulus of fibers [3,4]. The disadvantage of a woven fabric is that the cross-over points reflect part of strain waves and somehow hamper the propagation of the wave, Figure. The cross-over points can be seen as fixed ends. At fixed ends the amplitude of the reflected wave has the same direction as the amplitude of the original strain wave and must therefore be superposed. Thus, a large number of strain waves, travelling in both directions, are introduced into the yarn. The resulting effect is that the elongation in the yarn can reach its maximum, the elongation-at-break, and the projectile can perforate the first few layers. So the effect of cross-over points in fabrics is not always positive. This was the reason for the development of UD materials. In UD material the fibers are laid unidirectional, bonded with a thermoplastic matrix and then cross-plied, Figure 1. In this unidirectional construction the yarns have no real cross-over points as in woven fabric. There are cross-over points only between the different layers, Figure 4, but not within a single layer. There is, definitely, an interaction between the cross-plied layers of fibers, but the part of the strain wave that is reflected is much smaller [4-6]. Thus, in UD composites, because of the lack of cross-over points, the strain wave can travel unhampered at a greater distance from the impact point and engage greater surface i.e. mass of the composite in stopping the projectile. This means that the kinetic energy of the projectile will be absorbed over a larger area compared to fabric composites, which results in better ballistic performance by UD composites.

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