Applus DatapointLabs

Beyond Standards: Material Testing and Processing for Successful Simulations of Foam Materials (LAW90)

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TestCart

TestPaks

CAETestBench

EST 1995
ISO 17025 Quality

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Applus, DatapointLabs & Materials Characterization

Applus+ DatapointLabs

Applus Overview: **€1,558B** revenue | **23,387 staff** | **70+ countries** [2020]

Relevant Divisions:

Product Development & Validation

LABORATORIES DIVISION	IDIADA DIVISION (AUTOMOTIVE)
• Testing • Engineering • Product/System Certification • Multidisciplinary Laboratories	• Design & Engineering • Data Analysis & Simulation • Homologation Services • Testing & Proving Ground

Relevant Partner Laboratories:

Materials Characterization & Quality Assurance

USA | Ithaca

Spain | Barcelona

France | St. Etiènne

Norway | Bryne

USA | Detroit

Spain | Illescas

Germany | Bremen

China | Shanghai

DatapointLabs Summary Overview

Applus+ DatapointLabs

- Experience
  - 27 years of experience in materials testing and characterization
  - ISO 17025:2017 accredited, operating on an end-end digital platform
  - Nadcap accredited [Aerospace / Defense] (Metallic/Non-Metallic Materials Testing)
- Operations
  - Testing 2000+ materials per year
  - Standard 5-day turnaround
  - Comprehensive one-stop testing capability
    - 168 unique tests: all aspects of mechanical, thermal and rheological characterization
- Clientele
  - Global clientele of more than 1,800 companies in 49 countries
  - Market leader in materials testing for CAE simulation
  - Recognized as an approved materials test lab by leading OEMs

A2LA ACCREDITED
Certificate# 1242.01
ISO/IEC 17025:2017

Nadcap
Administered by PRI
ACCREDITED
Certificate# 17231205927
Non Metallic Materials Testing

Materials Testing for Product Development

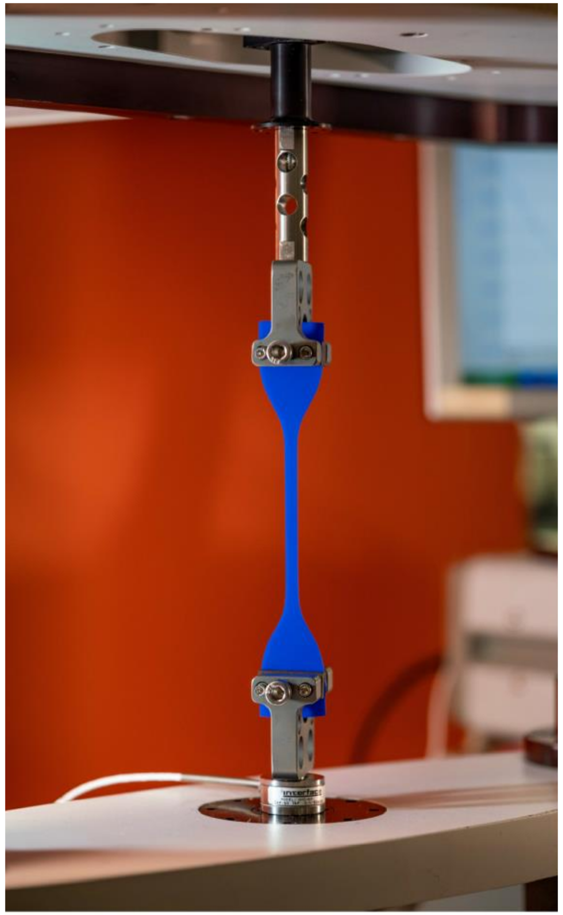
TestCart

Comprehensive online catalog and order system for 168 unique tests characterizing physical, thermal and flow properties of materials for use in R&D and product development metals, plastics, composites, rubber, foam, rubber, films

TestCart: Our testing solution

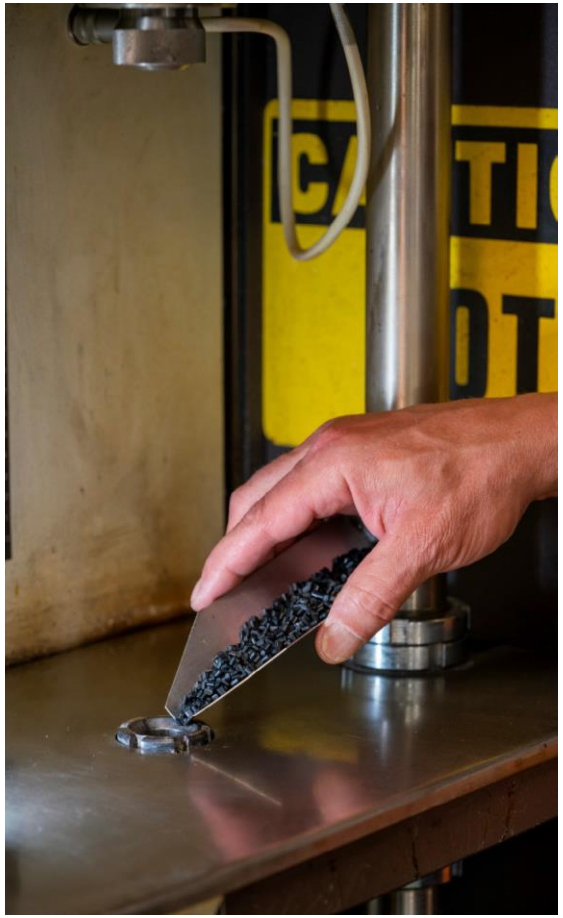
Applus DatapointLabs

Mechanical



Thermal

Rheological



Materials Testing for Product Development

Applus DatapointLabs

TestCart

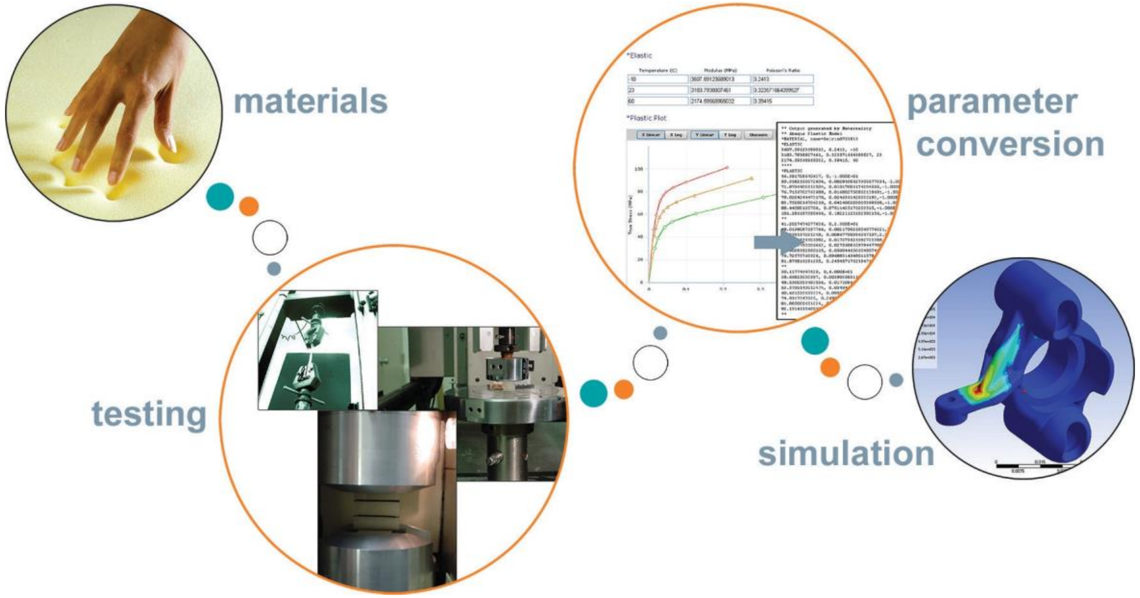
Comprehensive online catalog and order system for 168 unique tests characterizing physical, thermal and flow properties of materials for use in R&D and product development

metals, plastics, composites, rubber, foam, rubber, films

TestPaks®

Material testing and material parameter conversion to generate 179 material cards for 36 simulation (CAE) programs, including finite-element analysis, crash and drop-test simulations, injection-molding and other process simulations

TestPaks: from expert materials testing to CAE-ready material files

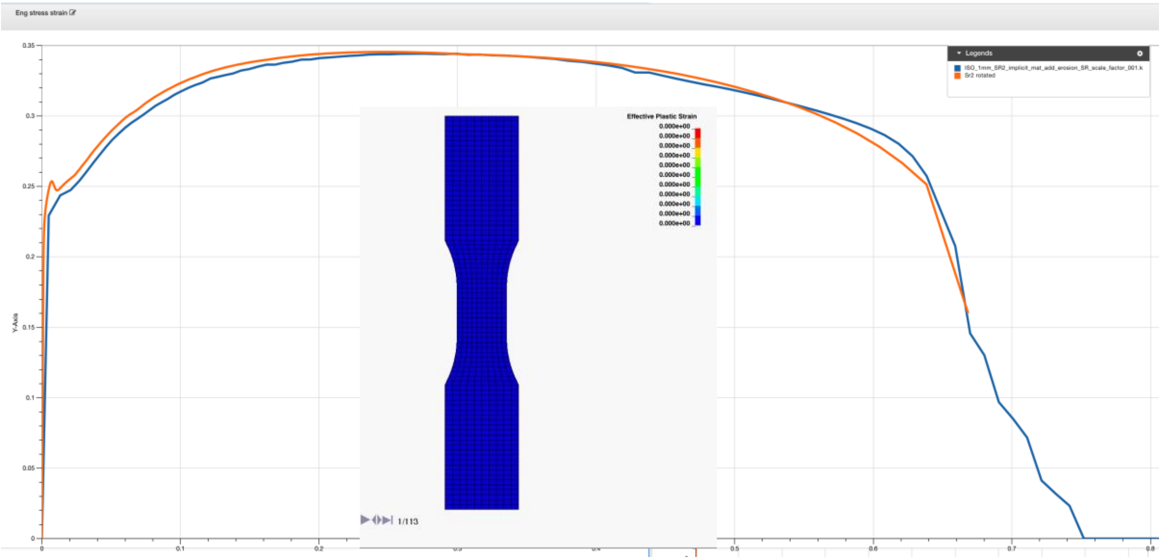


TestPaks® include

- Exact material testing to CAE material model requirements
- Conversion of raw characterization data to material model parameters
- Solver-formatted, CAE-ready material files

TestPaks: from expert materials testing to CAE-ready material files

Applus+ DatapointLabs



Models and tests available

- Injection molding tensile, compressive, shear, biaxial, and volumetric
- Hyperelastic linear and volumetric
- Elastomers and crushable foams viscoelastic and rate dependent
- Orthotropic for composites tensile, compressive, and shear
- Creep, fatigue and long-term behavior heat aging, moisture conditioning, and fluid exposure
- Failure for plastic and metals GISSMO and damage models

Materials Testing for Product Development

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CAETestBench™

Validate your simulation against a physical part, created and tested using a rigid protocol, which can be replicated in your solver – probe simulation accuracy and quantify its ability to replicate the test

Validations range from simple tensile modes to more complex, multi-axial modes, impact and failure

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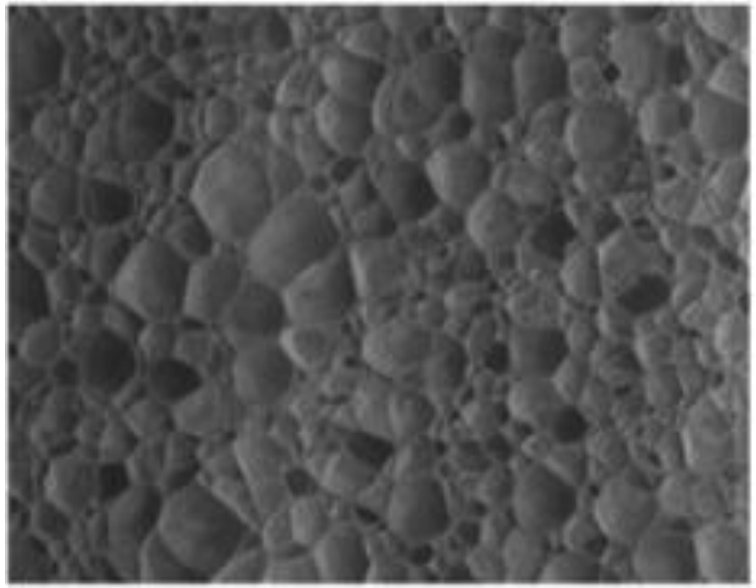
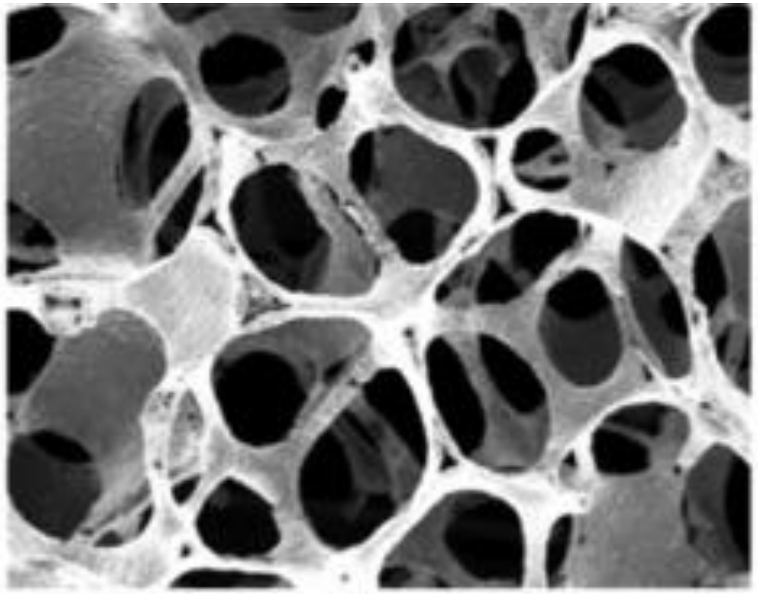
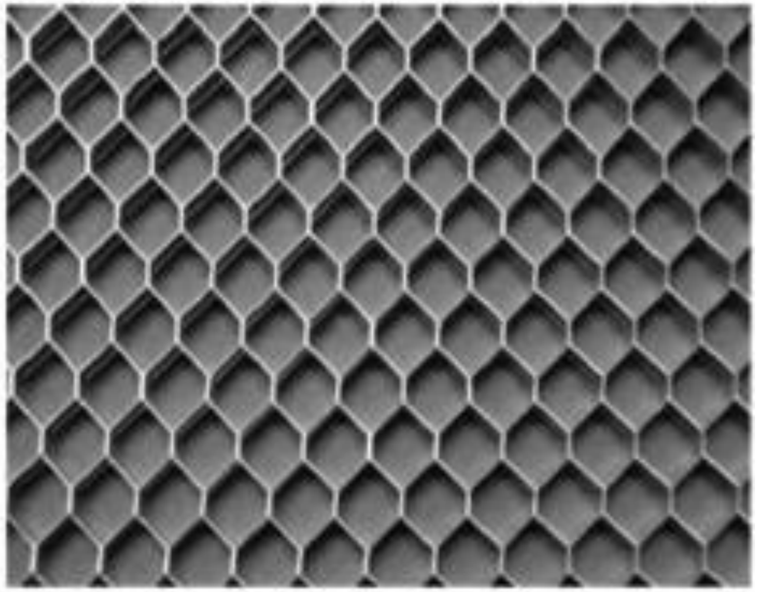
What are Foam Materials?



1 Closed-cell foam



2 Open-cell foam



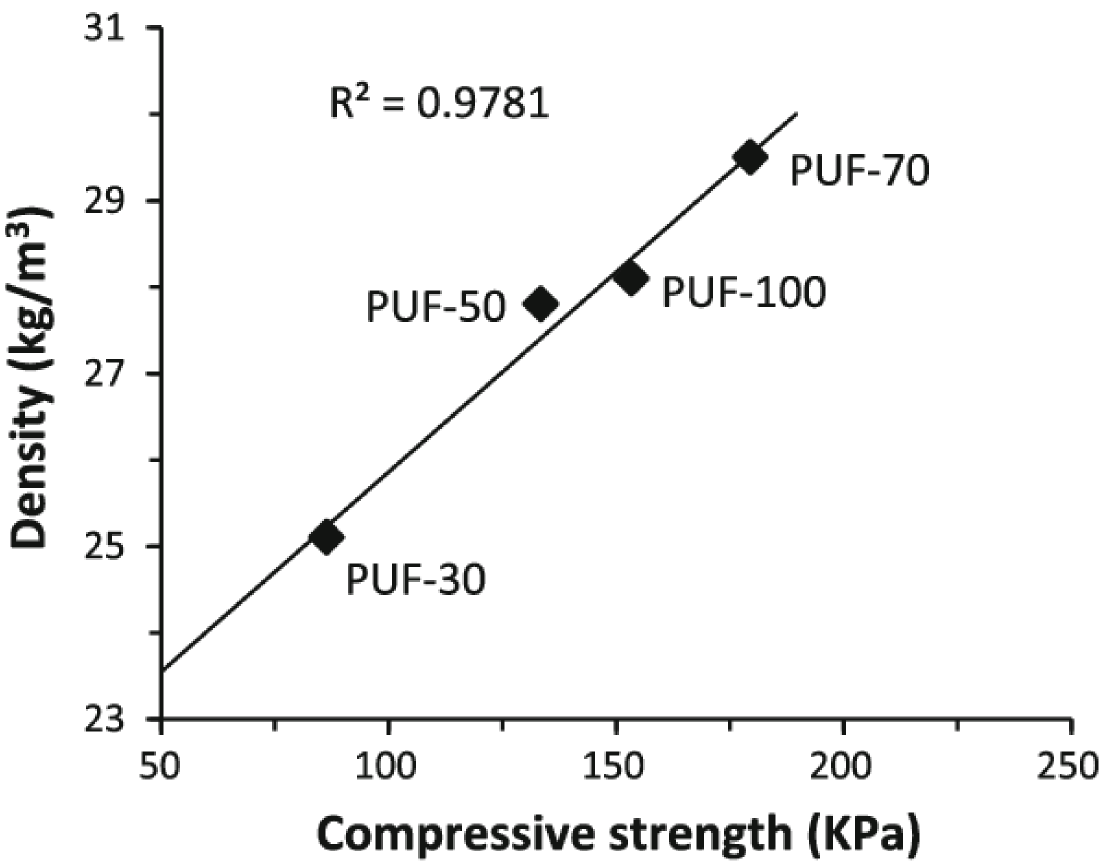
3 Honeycomb foam

Reproduced from Hitti, K., 2011. Direct Numerical Simulation of Complex Representative Volume Elements (RVEs): Generation, Resolution and Homogenization.

Mechanical Properties of Foam Materials

Mechanical properties depends on:

- Density

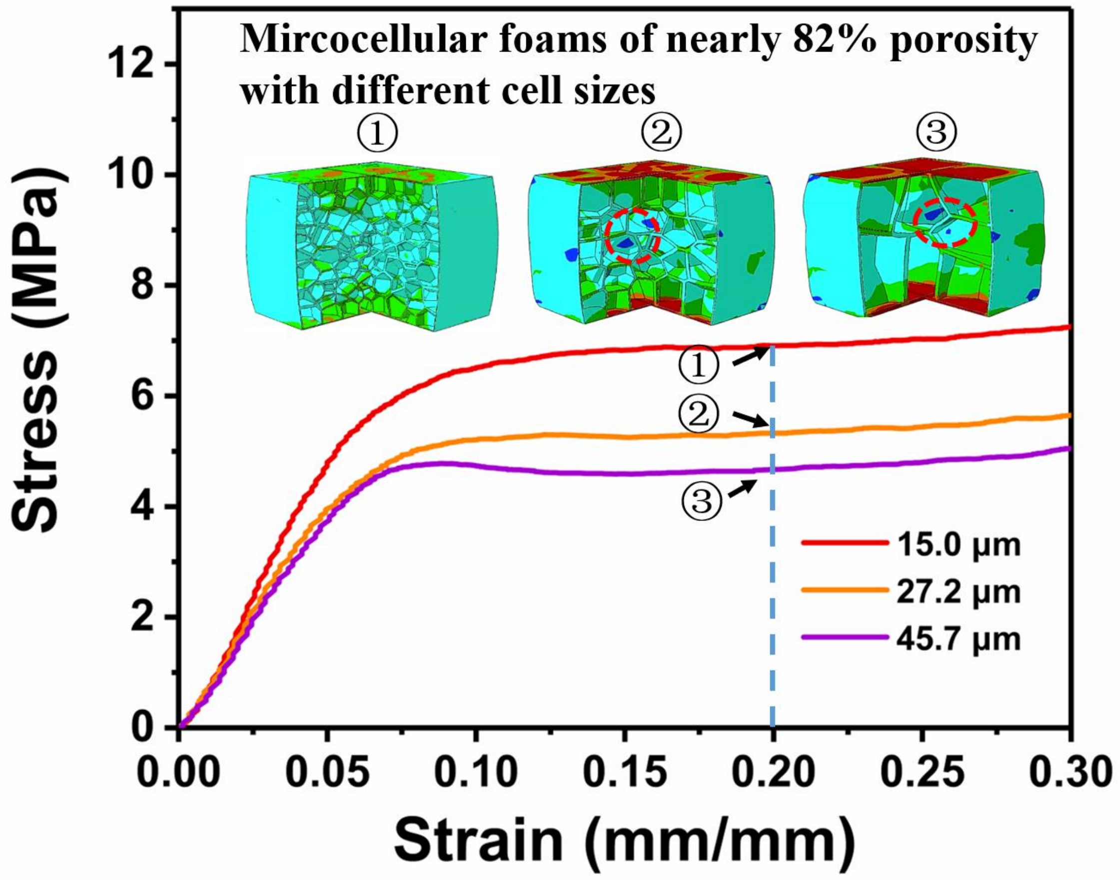


Reproduced from Luo, X. and Li Y. 2014. Synthesis and Characterization of Polyols and Polyurethan Foams from PET Waste and Crude Glycerol.

Mechanical Properties of Foam Materials

Mechanical properties depends on:

- Density
- Cell structure

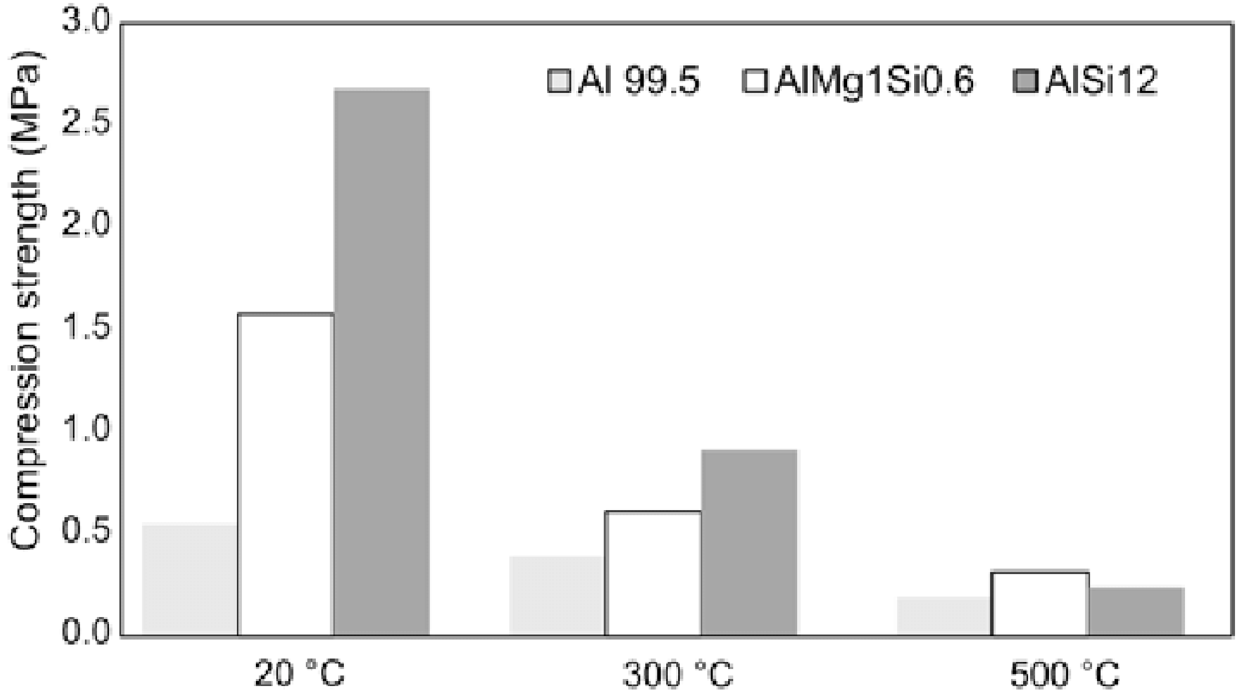


Reproduced from Zhang R., Chen J., et alt. 2020. Correlation between the structure and compressive property of PMMA microcellular foams fabricated by supercritical CO2 foaming method

Mechanical Properties of Foam Materials

Mechanical properties depends on:

- Density
- Cell structure
- Wall cell intrinsic material properties



Reproduced from Kováčik J., Orovčík L., Jerz J. 2016. High-temperature compression of closed cell aluminum foams

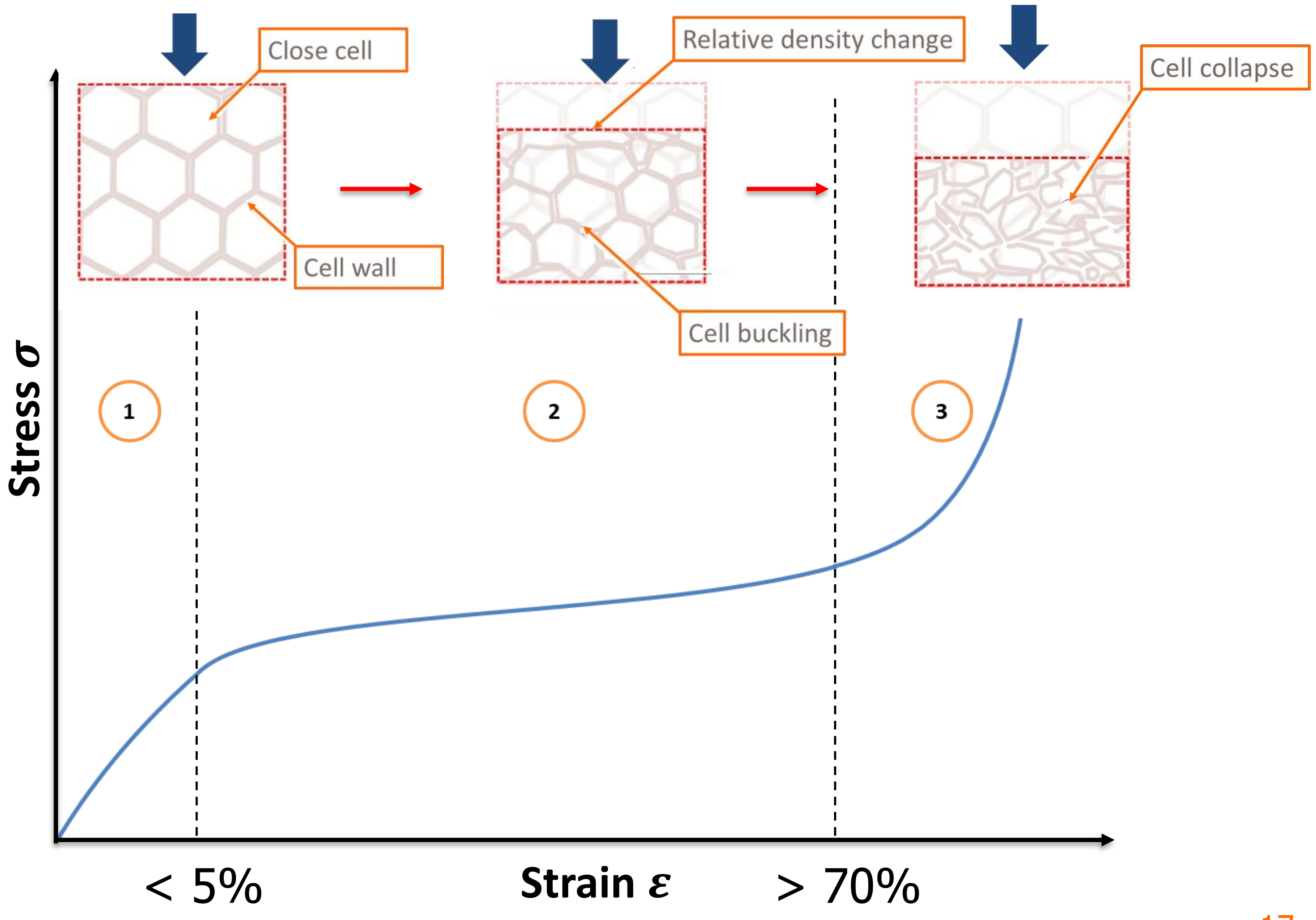
Typical Foam Behavior

- Non-linear (elastic or crushable) stress-strain response
- Zero Poisson ratio in compression
- Rate dependency
- Failure in tension and shear
- Larger deformation in compression

Typical Foam Behavior

Compression response

1. Elastic response
2. Deformation plateau
3. Densification



Reproduced from Park K., Kim H. et alt. 2019. Variation of mechanical characteristics of polyurethane foam: effect of test methods

LAW90: Definition

Radioss LAW90 describes the visco-elastic foam tabulated material

Reasons to use it

- Accurate modeling of foam behavior
- Strain-rate sensitivity
- Easy to implement
- Good correlation with experimental data
- Availability

LAW90: Definition

Applus DatapointLabs

Visco-elastic foam tabulated material

LAW definition

Density

Young Modulus

Strain-rate smoothing

Cutoff frequency for strain rate filtering

Poisson ratio

Shape factor

Hysteresis factor

```
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
##HWCOLOR materials 41645 3
/MAT/LAW90/41645
41645: Cold Formed - 20Kpa 75g/l
#              Rho_I
6.31000000000000E-11
#                   E0                MAT_NU
                  0.56                0.0001
#       NL   Ismooth                    Fcut                 Shape                 Hys
         6         11.00000000000000E+30                       0.7                   0.1
#  fct_idL                eps_dot                 Fscale
         1                   0.01                   1.00
         2                    0.1                   1.00
         3                    1.0                   1.00
         4                   10.0                   1.00
         5                  100.0                   1.00
         5                10000.0                   1.00
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
```

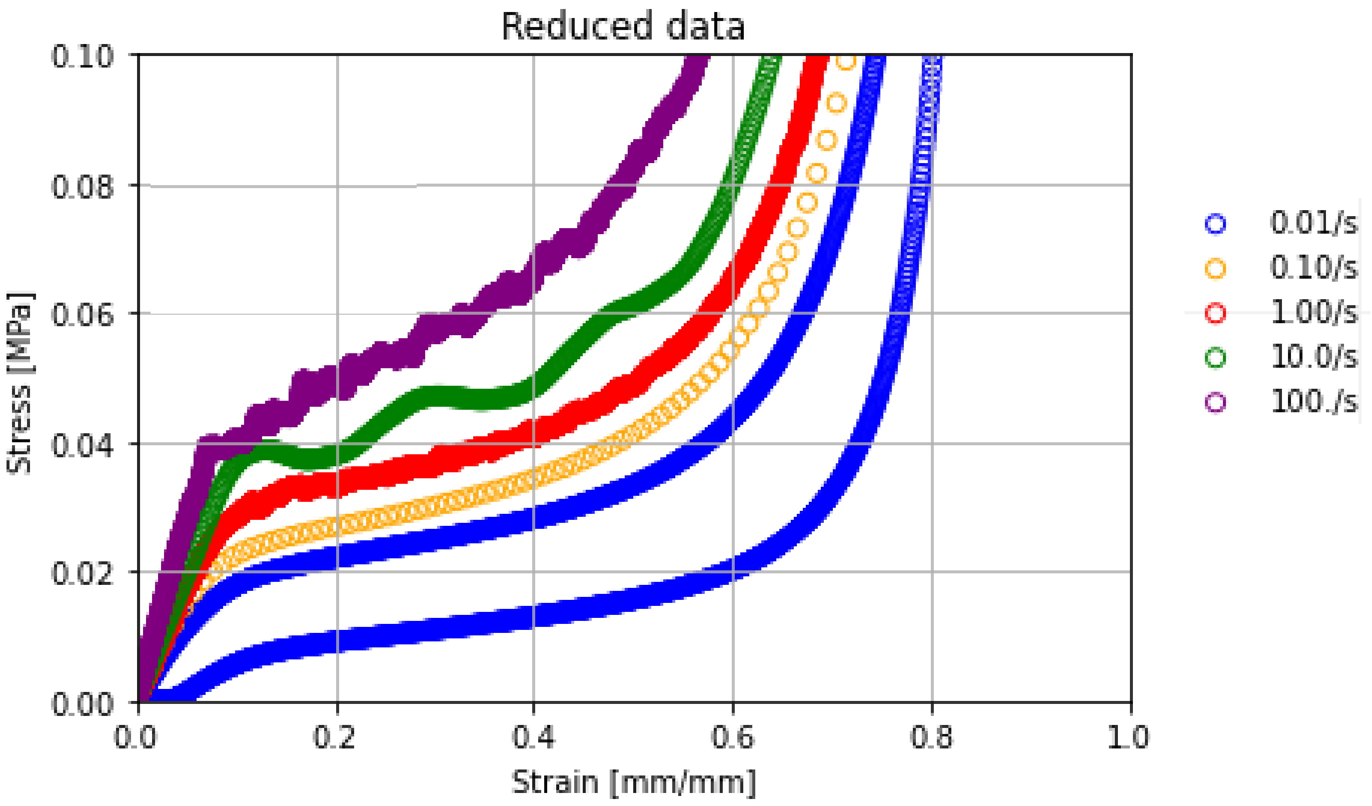
Stress-strain curve

Strain-rate

Scale factor

LAW90: Data Preparation

1. Compression test data
2. Smoothing the data and point reduction
3. Extrapolating the data
4. Filtering the date



LAW90: Data Preparation

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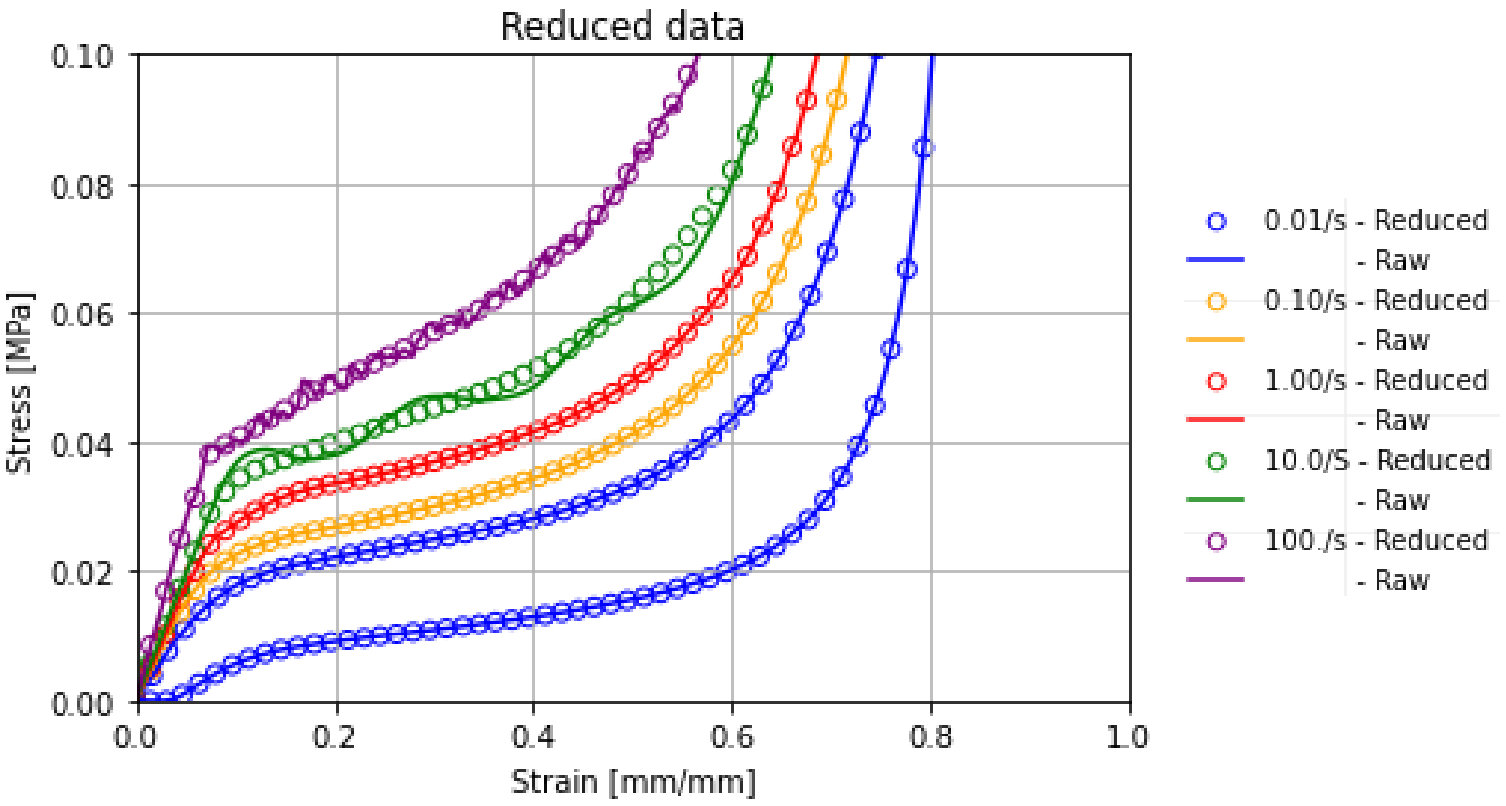

LAW90: Data Preparation

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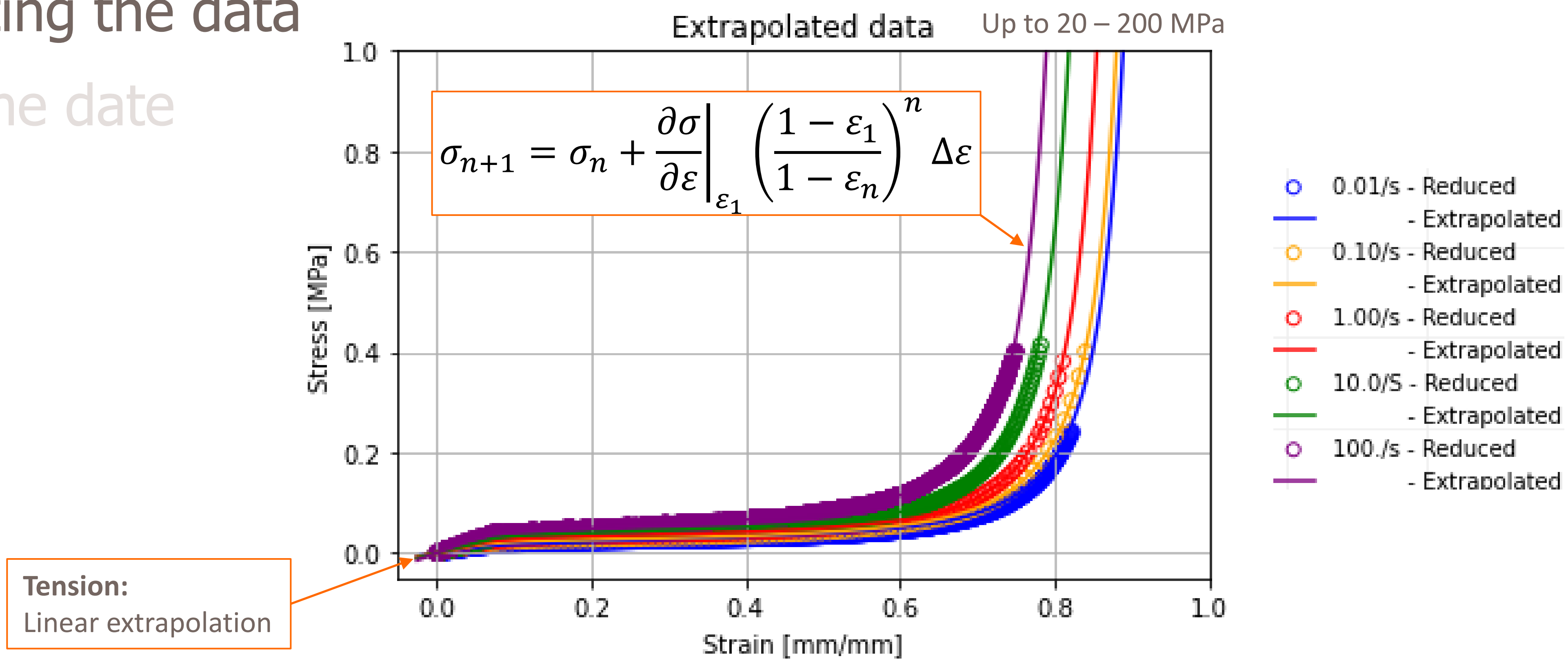
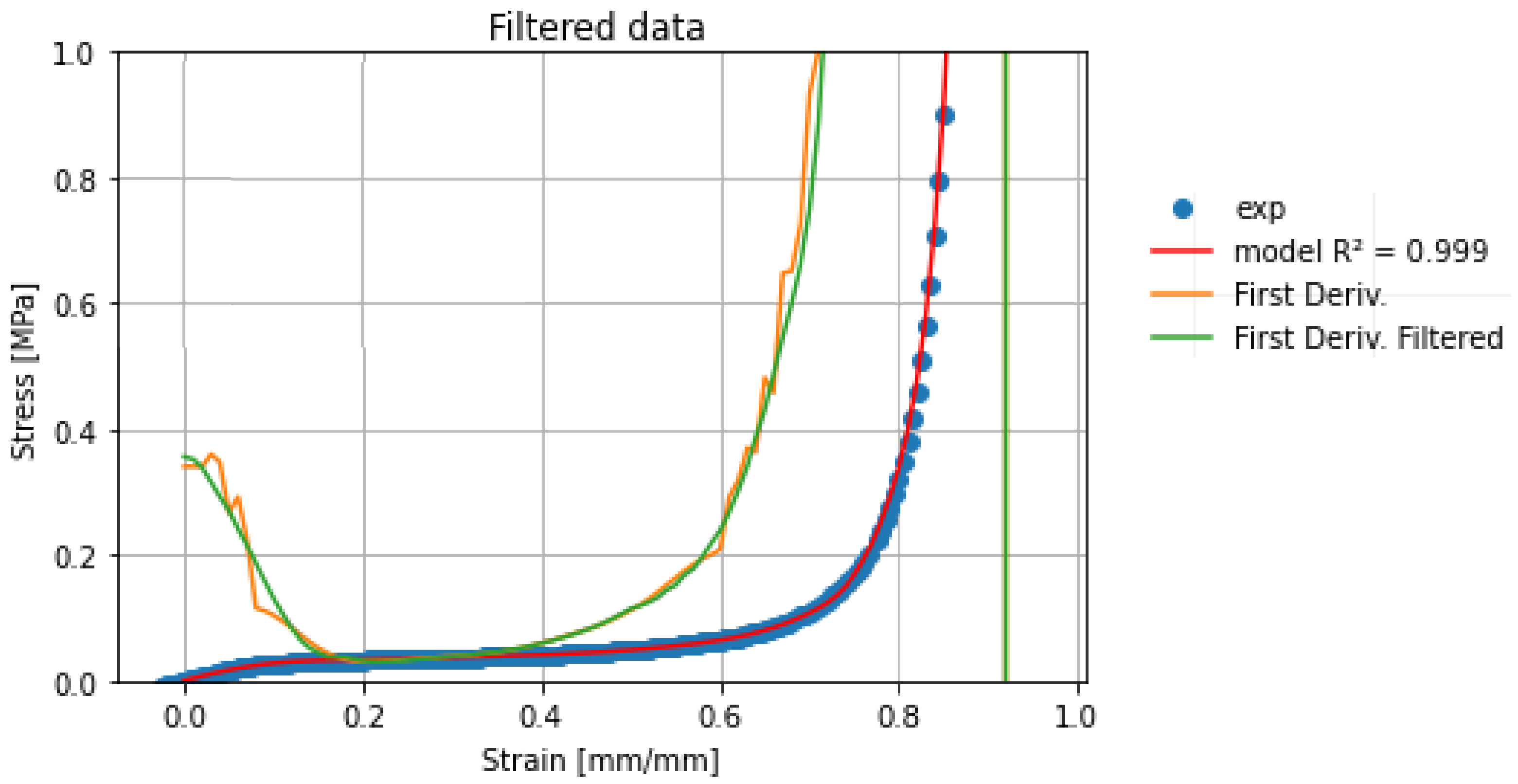


LAW90: Data Preparation

1. Compression test data
2. Smoothing the data
3. Extrapolating the data
4. Filtering the data
   - 1st derivative
   - Moving window filter
   - Integrate

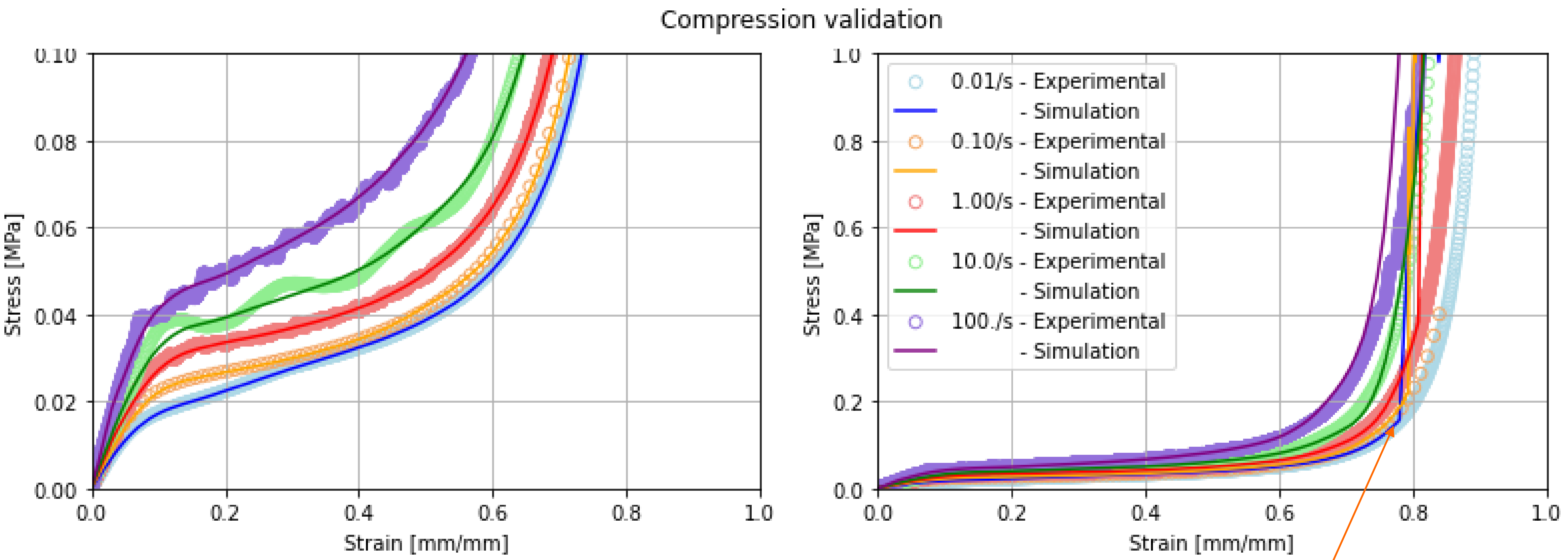
Thank you so much Marian Bulla for suggesting this additional step. Your contribution has been of great help, and we truly appreciate your input.



LAW90: Compression Validation

Method	ASTM D695-15 Standard Test Method for Compressive Properties Crash Material Models	
Solver	Radioss // OpenRadioss	
Specimen	form	cube
	thickness	26
Parameters	Crosshead speed	16.2 - 162000 mm/min
	material model	LAW90
	element formulation	24
	mesh type	hexahedral
	element size	10 mm
	boundary conditions	fixed base
	initial conditions	Upper surface displacements
	contact type	Type 7 (interior)

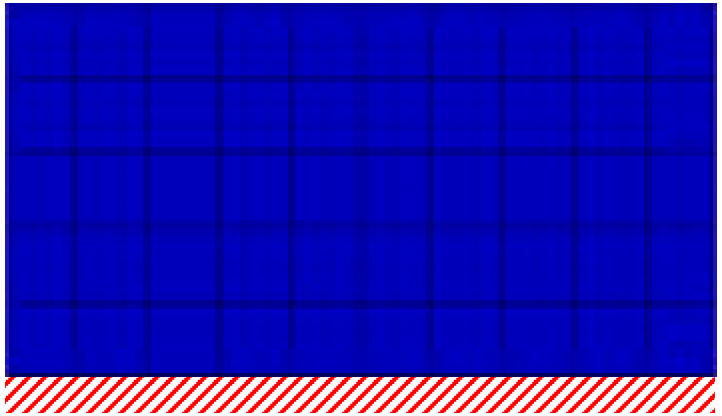
LAW90: Compression Validation



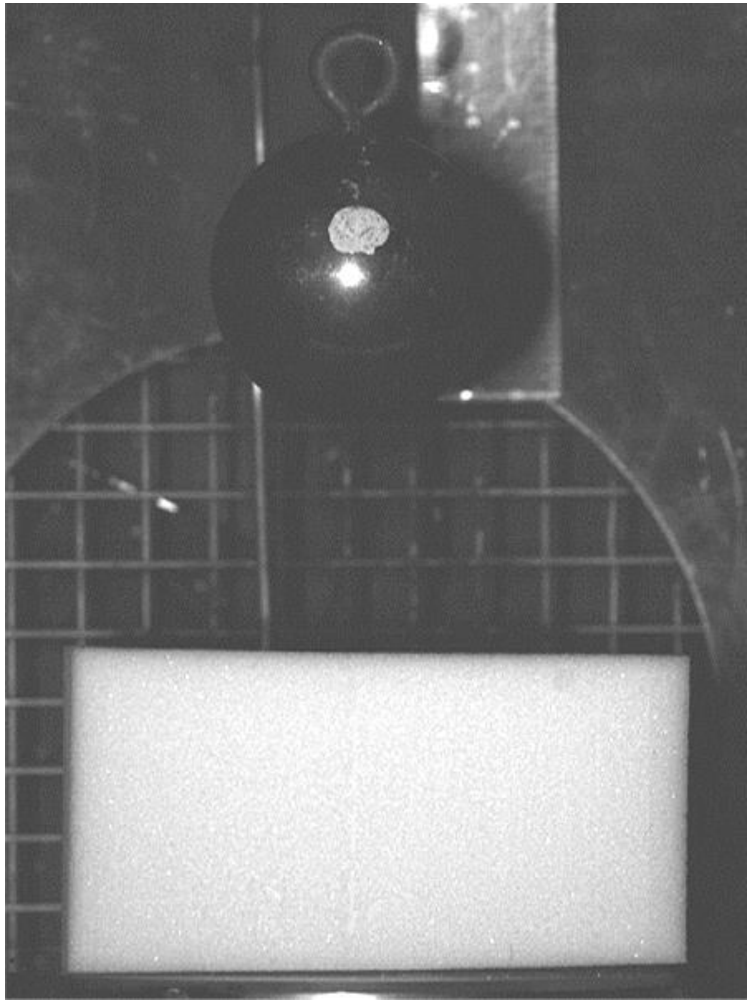
Derived instabilities from the timestep

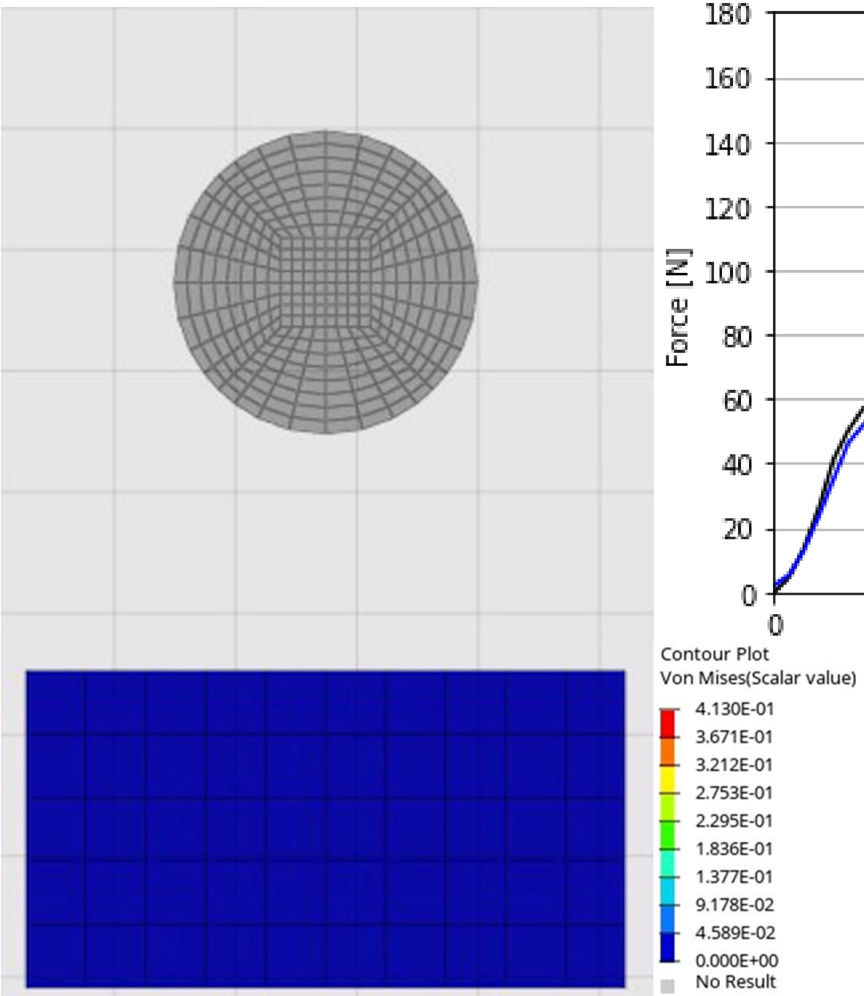
LAW90: Impact Validation

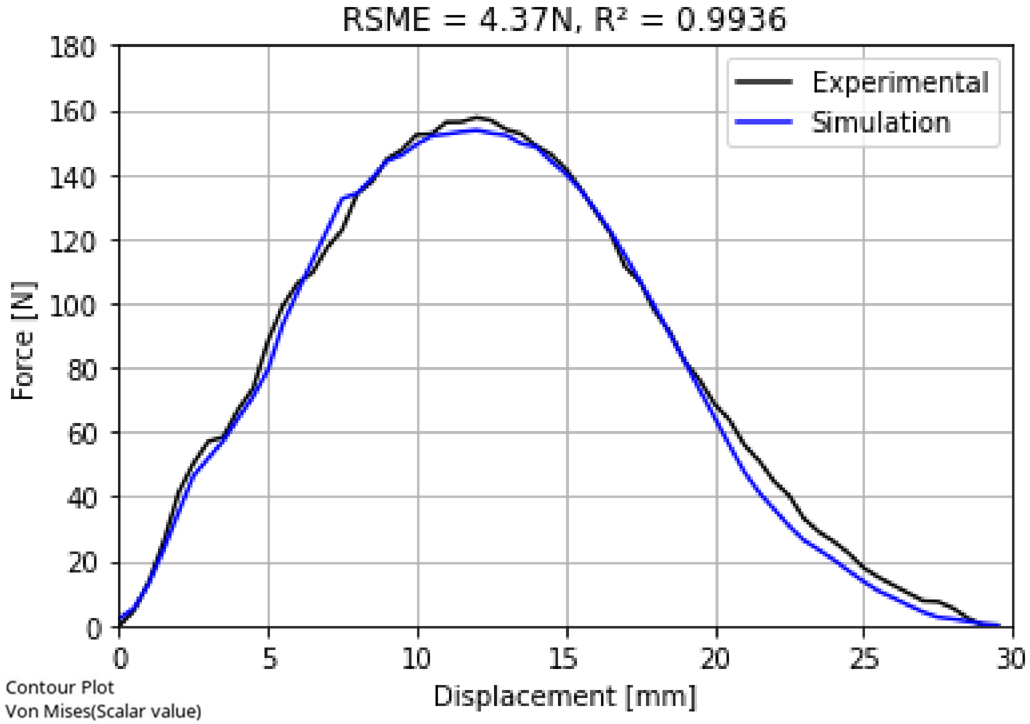
Method	DPL V-101 Falling Dart Impact Validation Crash Material Models	
Solver	Radioss // OpenRadioss	
Specimen	form	cube
	thickness	53
Parameters	impact velocity	2.30 m/s
	dart weight	0.54 kg
	dart diameter	50.8 mm
	material model	LAW90
	element formulation	24
	mesh type	hexahedral
	element size	10 mm
	boundary conditions	fixed base
	initial conditions	acceleration
	contact type	Type 7 (impact) Type 7 (interior)



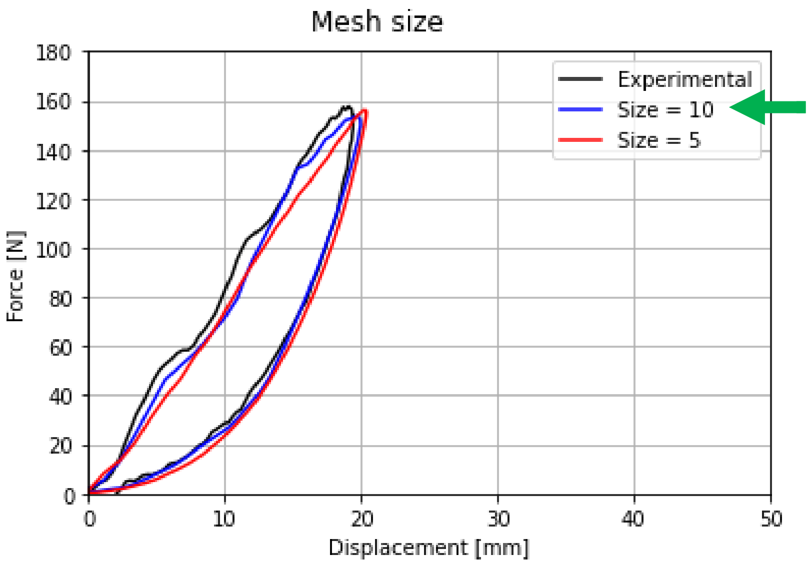
LAW90: Impact Validation

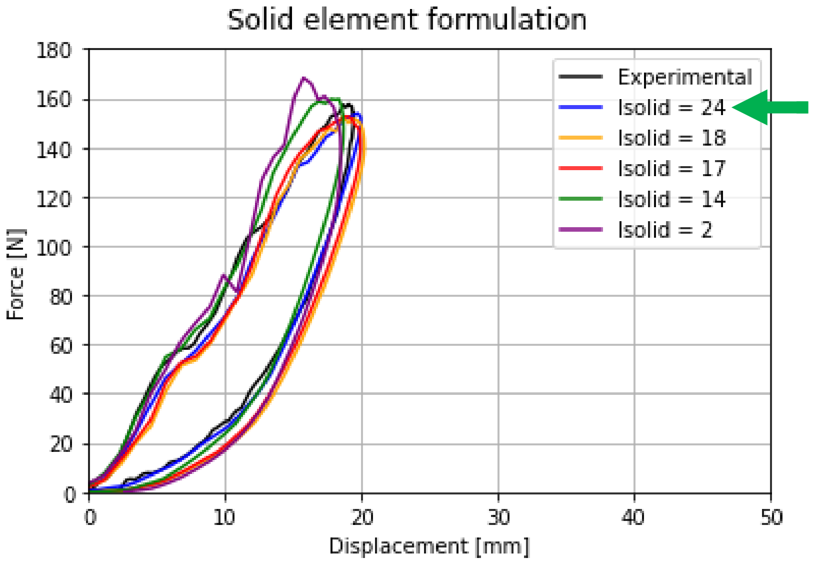


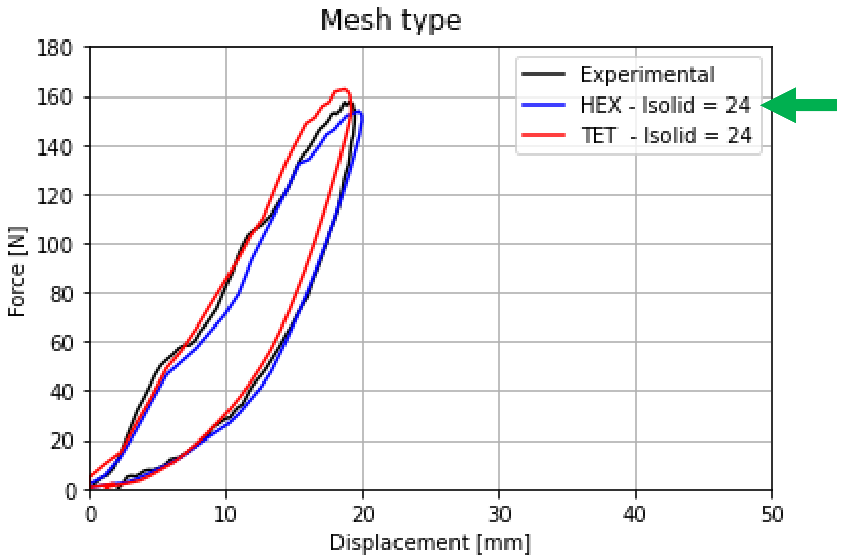


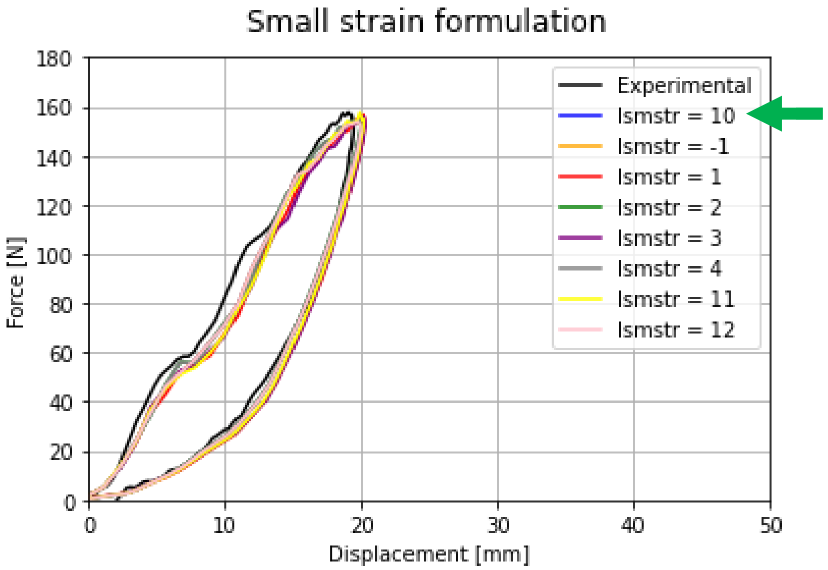


LAW90: Parameters Study









Conclusions and Remarks

- The use of the LAW90 material card has been successfully validated through compression and impact tests for simulating foam materials.
- **Experimental compression curves cannot be used directly** for material modeling, and **data pre-processing is necessary**.
- To ensure stability and accuracy, it is crucial to use **monotonically increasing imported curves**.
- When testing with strain-rate variables, the **Type 7 contact card must be used to limit the compression strain of the elements**. The strain limit corresponds to the point where densification begins in the model's curve with the highest strain-rate.
- In impact applications, it is essential to use an **impactor with smooth geometries**, as sharp geometries can cause instability due to mesh deformations.
- Various types of meshes, elements, and properties have been tested, and a **hexahedral mesh with Isolid=24, Ismrt=10, and size=10 is recommended** for succesful results.
- **For applications that require more precise unloading, the LAW70 card is recommended**. This card also uses experimental curves to calculate unloading, and it is important to prepare these curves in the same way as the load curves.

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