Differences in compression load behaviour of aluminium foam between static and dynamical testing

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Prof. Drossel

Differences in compression load behaviour of aluminium foam between static and dynamical testing

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Differences in compression load behaviour of aluminium foam between static and dynamical testing

- Contents:

  - Incentive
  - Tested materials
  - Test conditions
  - Test devices
  - Results
  - Conclusion

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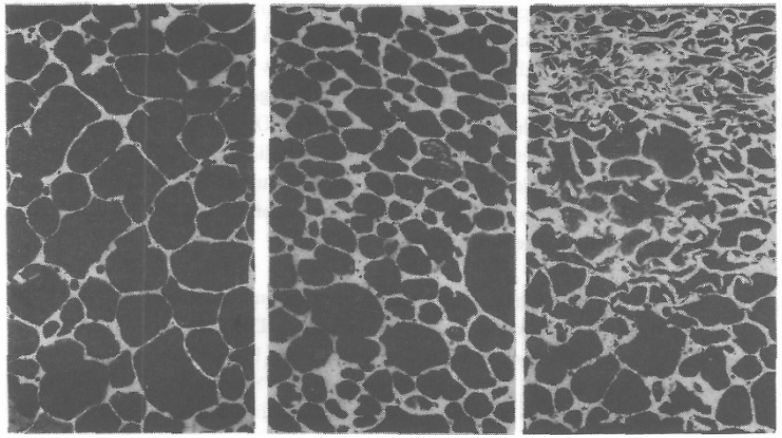
Differences in compression load behaviour of aluminium foam between static and dynamical testing

- Incentive:

  - Good energy absorption capacity for cellular materials, especially metal foam, preferably in direction of compression
  - Pores are deformed one after the other by absorbing energy
  - So stress keeps constant by a long time of deformation (plateau)
  - Possibility to dissipate crash energy in a efficient way
  - Knowledge of material properties



Original structure | 20% deformation | 60% deformation

Reference: Weber, M.: Herstellung von Metallschäumen und Beschreibung der Werkstoffeigenschaften, Metall-Innovation-Technologie, Bremen 1997

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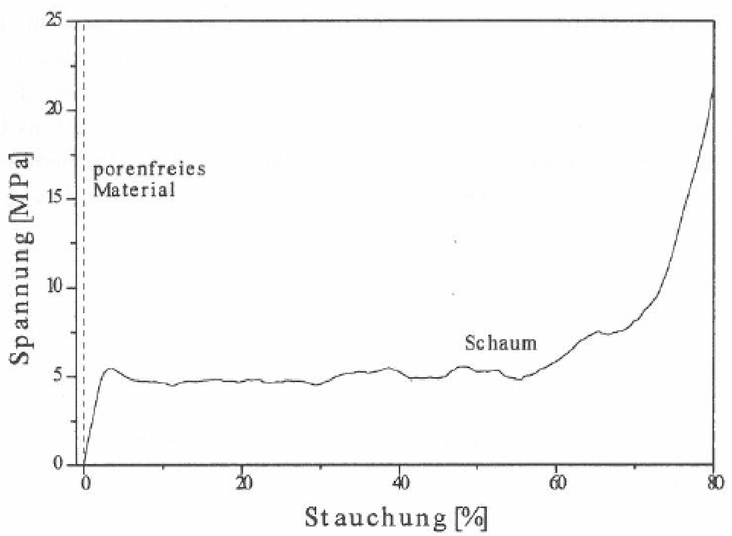

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- Incentive:

  - Different positions in literature about strain rate dependency of aluminium foam:

  - Deshpande and Fleck / I.W. Hall, M. Guden und C. J. Yu report about tests, which result in **no** strain rate dependency of stress values

  - A. Paul and U. Ramamurty / Mukai et al. report about results **with a** strain rate dependency of stress values

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Differences in compression load behaviour of aluminium foam between static and dynamical testing

- Tested materials:
  - Aluminium foam
  - With closed pores
  - Variable aluminium alloys

    Al99,5 (EN AW-1050A)

    AlSi12 (EN AC-44100)

    AlMgSi0,5 (EN AW-6060)
  - Manufacturing: powder metallurgical route / melting route

Picture: Test samples for compression tests

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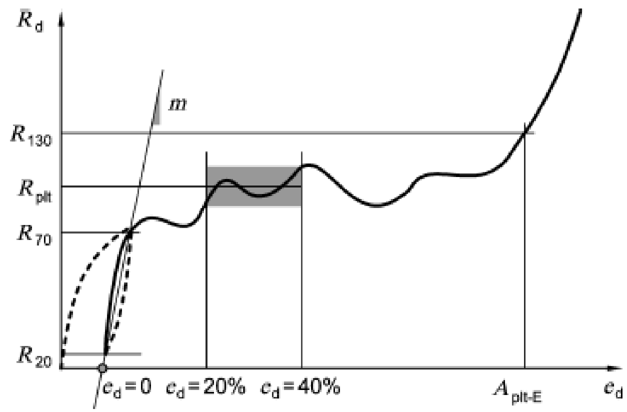
Differences in compression load behaviour of aluminium foam between static and dynamical testing

- Test conditions:
  - Compression tests, because compression behaviour for most foams better than tensile behaviour (brittleness)
  - Quasi-static tests according to DIN 50134 (Compression test of cellular materials)
  - Same sample dimensions for high speed tests to ensure comparability



Reference: DIN 50134 Testing of metallic materials –compression test of metallic cellular materials, Beuth Verlag, 2008

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Differences in compression load behaviour of aluminium foam between static and dynamical testing

- Test conditions:

  - Sample dimensions according to DIN 50134
  - Cylindrical samples for the powder metallurgical aluminium foam
  - Ø50mm, height 100mm
  - Sample dimensions for melting route foam is rectangular prism
  - 50mm x 50mm, height 100mm
  - No influence of different geometry, evaluation is done in the field of stress (area independent)

Picture: Different dimensions of test samples for compression tests

Differences in compression load behaviour of aluminium foam between static and dynamical testing

- Test devices:
  - Quasi-static testing
    - Universal tensile-/ compression test machine „ZMART.PRO“, Fa. Zwick Roell
    - Maximum force: 50kN
    - Test velocity: 0,001m/s

Picture: Universal Tensile-/ Compression test machine „ZMART.PRO“, Fa. Zwick Roell

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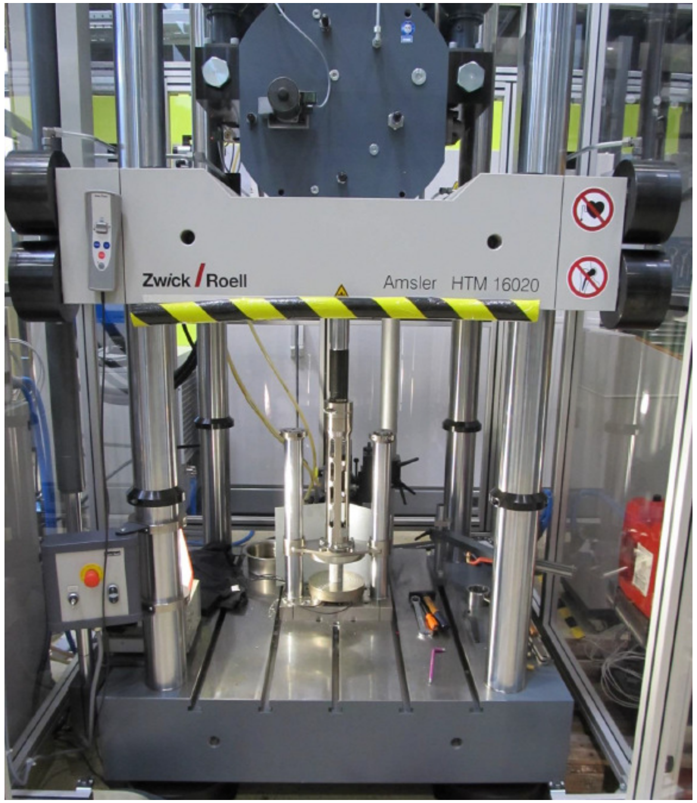
Differences in compression load behaviour of aluminium foam between static and dynamical testing

- Test devices:
  - High speed tests
    - High speed tensile-/ compression test machine „Amsler HTM 16020“, Fa. Zwick Roell
    - Maximum energy: 6kJ
    - Maximum test speed: 20m/s
    - Used test speed: 13m/s



Picture: High speed tensile-/ compression test machine „Amsler HTM 16020“, Fa. Zwick Roell

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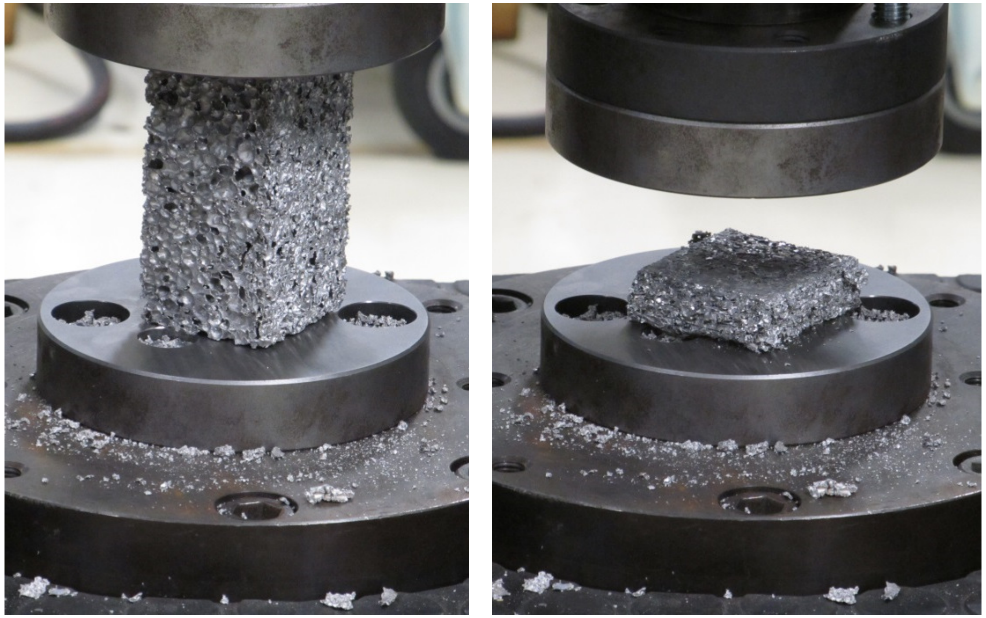
Differences in compression load behaviour of aluminium foam between static and dynamical testing

- Results:
  - Quasi-static test



Picture: Beginning and end of a quasi-static test

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Differences in compression load behaviour of aluminium foam between static and dynamical testing

- Results:

  - Quasi-static test

  - Dependency of compressive stress and foam density
  - Increasing density leads to a less distinct plateau
  - In some cases brittle material behaviour has been observed

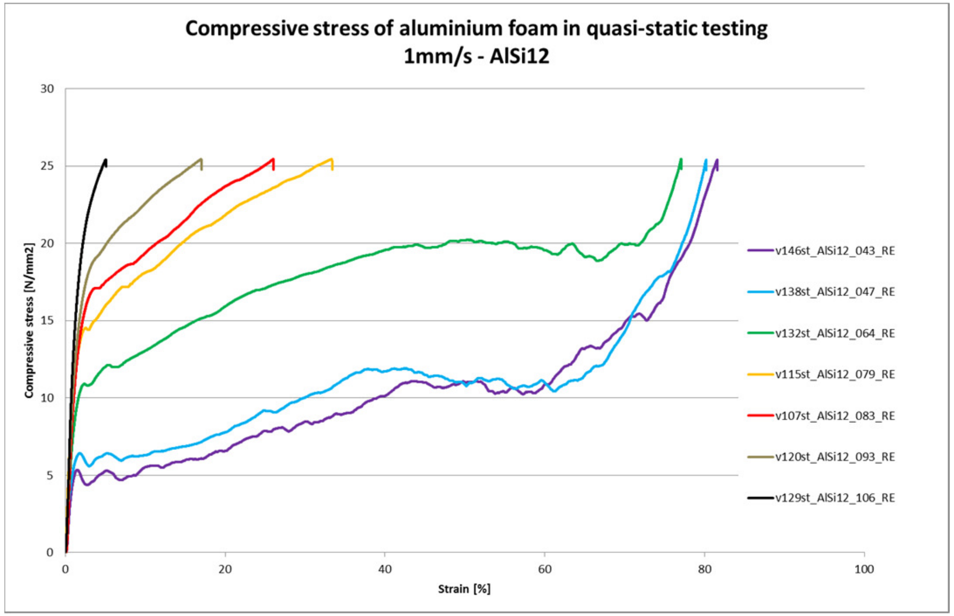

Figure: Quasi-static stress-strain curve with different foam densities

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Differences in compression load behaviour of aluminium foam between static and dynamical testing

- Results:
  - Quasi-static test
  - No clear tendency between different alloys
  - Partly more variance in curves of one material than between curves of different alloys

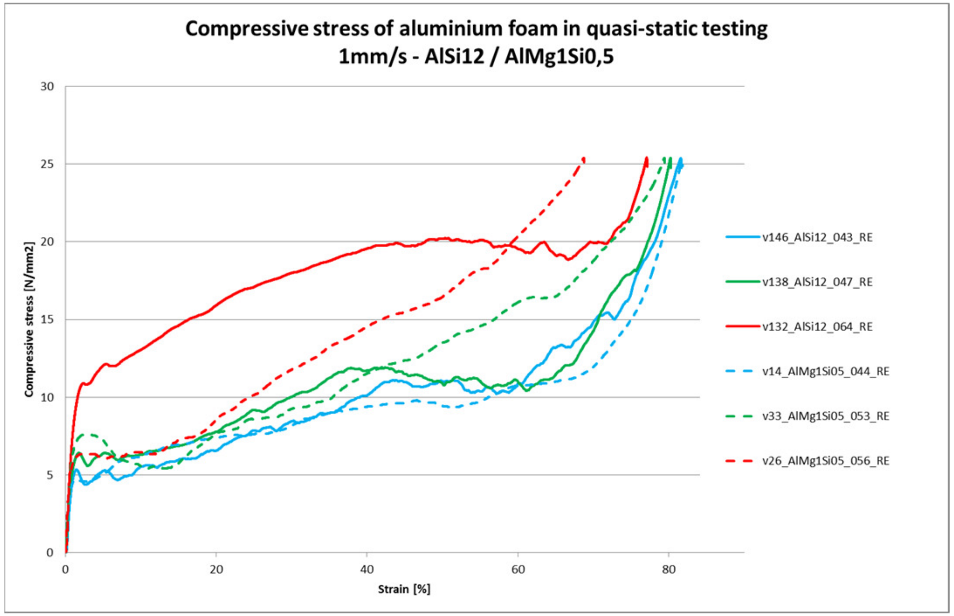

Figure: Quasi-static stress-strain curve with different foam densities

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Differences in compression load behaviour of aluminium foam between static and dynamical testing

- Results:

  - Quasi-static test
  - Very smooth stress-strain curve of melt metal-lurgical aluminium foam
  - More variance in stress-strain curve of aluminium foam from the powder metallurgical route
  - Influence of outer foam skin observable

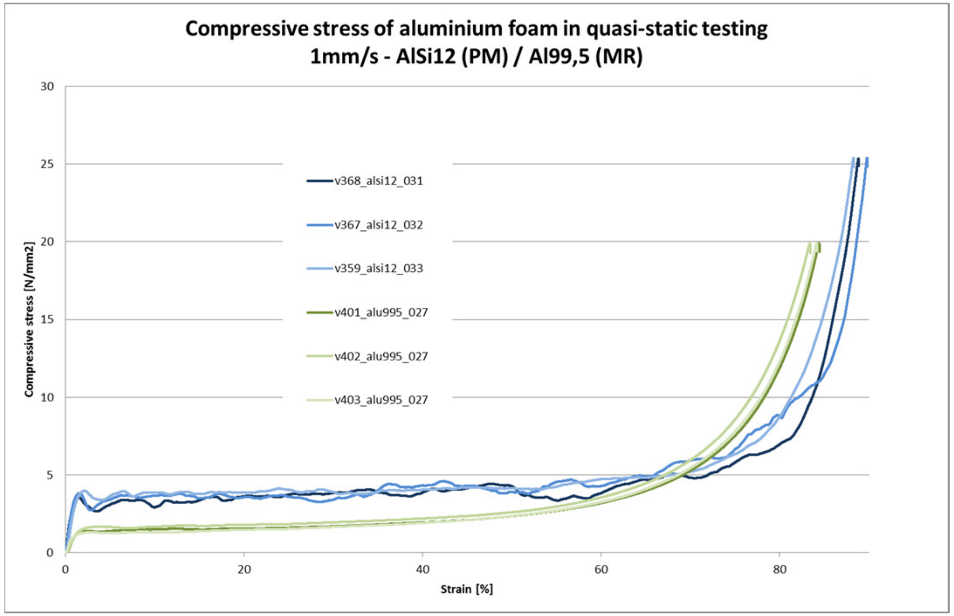

Figure: Dynamic stress-strain curve of powder metallurgical aluminium foam and aluminium foam from the melting route

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Differences in compression load behaviour of aluminium foam between static and dynamical testing

- Results:

  - **Dynamic** test

  - Like in the quasi-static test dependency of stress and density observable
  - Higher density results in higher stress values
  - Some samples reveal brittle material behaviour (fracture)

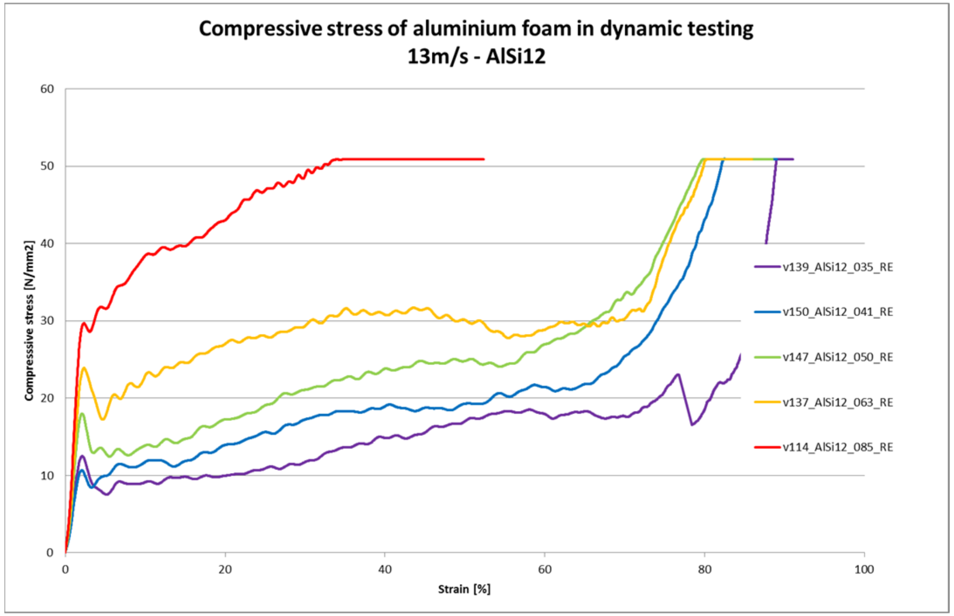

Figure: Dynamic stress-strain curve with different foam densities

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Differences in compression load behaviour of aluminium foam between static and dynamical testing

- Results:

  - **Dynamic** test

  - Also no clear correlation of the results dependent on the alloy

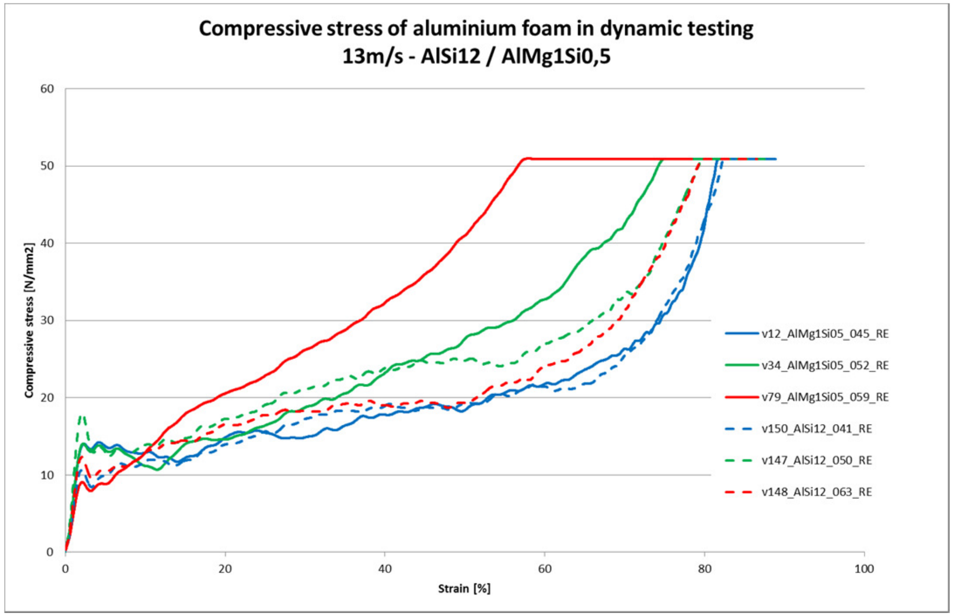

Figure: Dynamic stress-strain curve with different foam alloys

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Differences in compression load behaviour of aluminium foam between static and dynamical testing

- Results:

  - **Dynamic** test

  - Very smooth stress-strain curve of aluminium foam from melting route
  - More variance in stress-strain curve of aluminium foam from the powder metallurgical route
  - Influence of outer foam skin observable

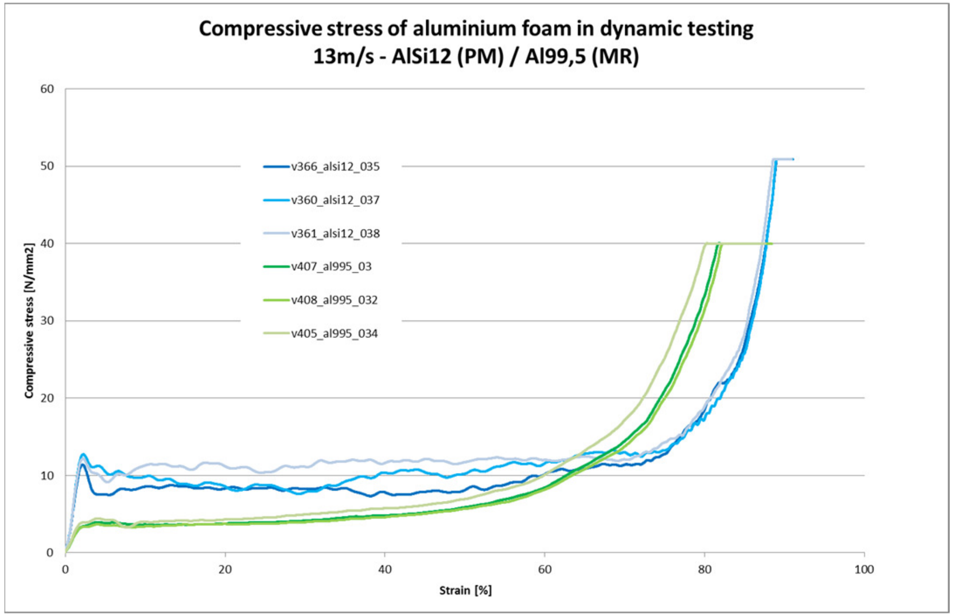

Figure: Dynamic stress-strain curve of powder metallurgical aluminium foam and aluminium foam from the melting route

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Differences in compression load behaviour of aluminium foam between static and dynamical testing

- Results:
  - **Quasi-static / dynamic** tests
  - Comparison between quasi-static and dynamic stress-strain-curves shows the **same trend**
  - But dynamic curves reveal up to **100% higher** stress values
  - Important for dimen-sioning crash boxes and bumpers

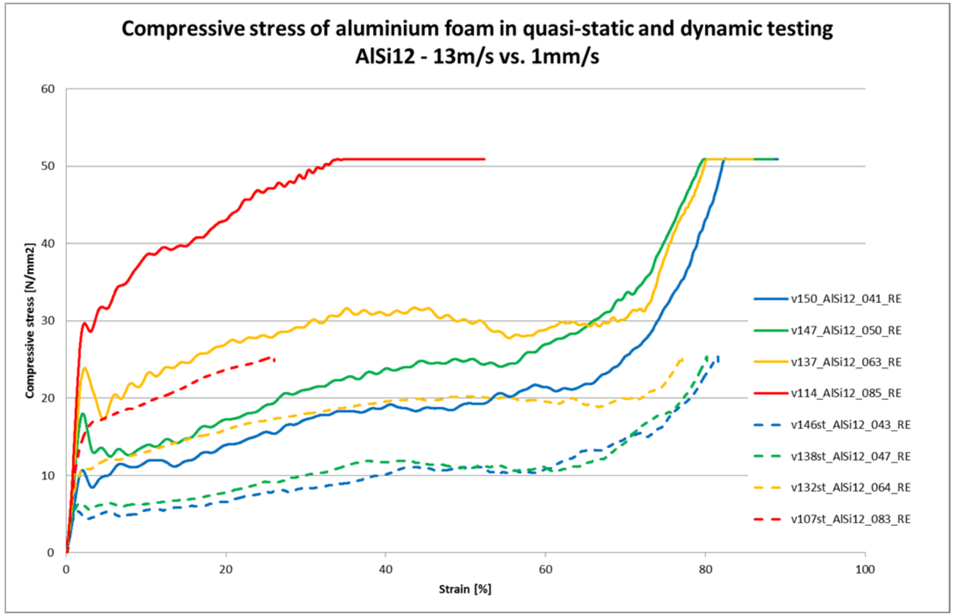

Figure: Comparison quasi-static and high speed stress-strain-curves of aluminium foam

Differences in compression load behaviour of aluminium foam between static and dynamical testing

- Conclusion:

  - **Strain rate dependency** of aluminium foam could be proven
  - **Increase** of compressive stress up to **100%** by increasing deformation speed from 0,001m/s to 13m/s
  - Difference to other test settings – **larger test sample dimensions**, so more restraint for gas inside the pores

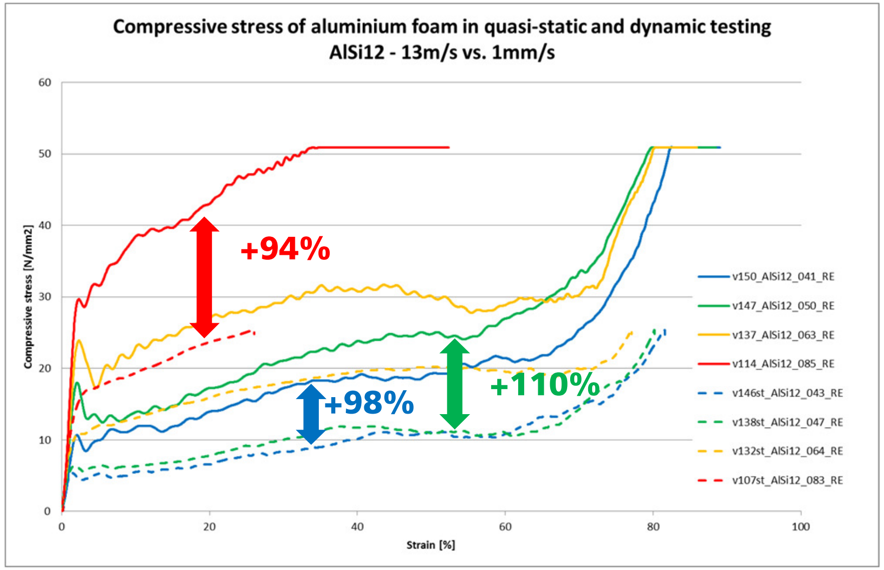

Figure: Increase of stress values from quasi-static to high speed deformation

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