Fatigue behavior of syntactic Fe-36Ni foams under different stress ratios

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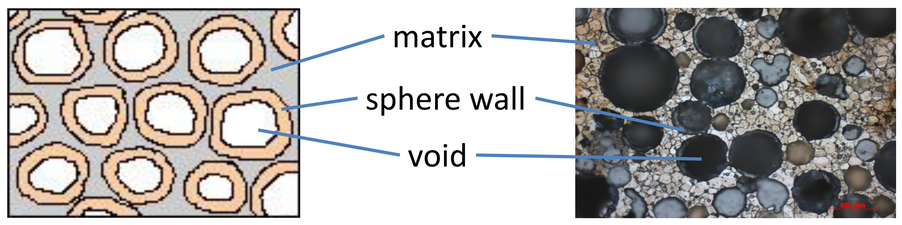
Introduction

Syntactic metal foams are a material class between classic closed-celled foams and particle reinforced composites. Porosity is created by hollow particles, integrated in a solid matrix. Different sphere types can be used: metal, ceramics, glass or cenospheres, see e.g. [1].

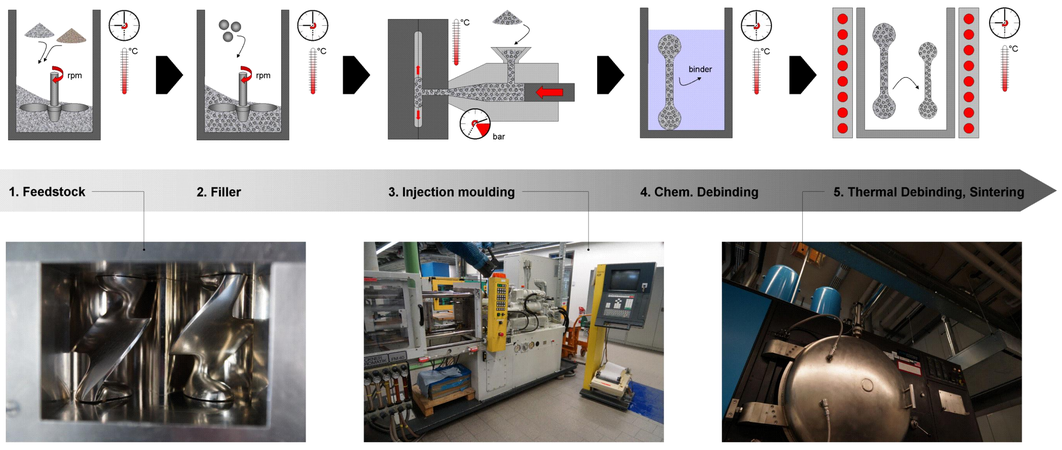


properties →
- excellent vibration damping
- high compression strength
- high specific energy absorption

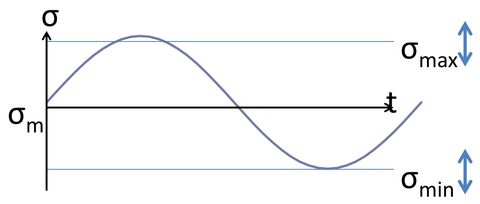
Objective of the project: Crash-relevant and vibration damping components are also subjected to cyclic loads. Therefore, the behaviour of syntactic foams under such loads are investigated for the example of FeNi36 foam.

Experimental approach

Dog-bone-shaped Fe-36Ni foam samples with different weight fractions (0/5/10wt%) of S60HS hollow particles were produced by means of metal injection moulding using a similar approach as described in [2].



fatigue testing stress ratio = -1, 0.1, 10

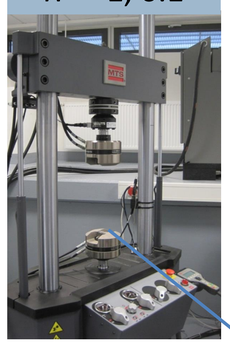


R	*Termination criteria*
10	>10^6 cycles compression displacement exceeding 3mm
0.1	>10^6 cycles specimen failure
-1	

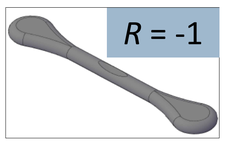
R	σ_a/[MPa]	ε_{pl}/[%]
10	0 wt%: -240…-330 5 wt%: -250 10 wt%: -230	0 wt%:1.1…2.9 5 wt%:1.4…1.7 10 wt%: 39.1…42.2
0.1 (Middle values)	0 wt%: 132…143 5 wt%: 55…82.5 10 wt%: 33…44	0 wt%: 1.71…4.43 5 wt%: 0.04…0.46 10 wt%: -0.05…0.08
-1	0 wt%: 200…290 5 wt%: 110…150 10 wt%: 60…80	0 wt%: 0.0030…0.0295 5 wt%: 0.0020…0.0235 10 wt%: 0.0010…0.0065

tension/fully reverse

R = -1, 0.1

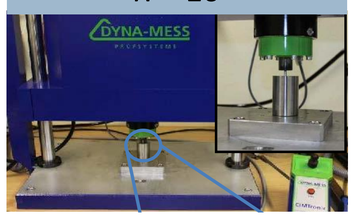


25 kN servo-hydraulic testing system

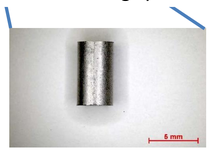


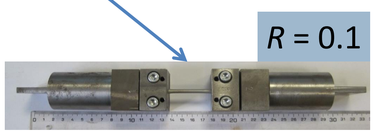
compression

R = 10



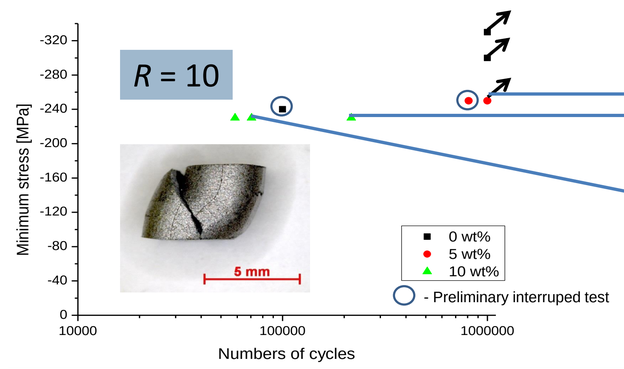
5 kN servo-pneumatic testing system



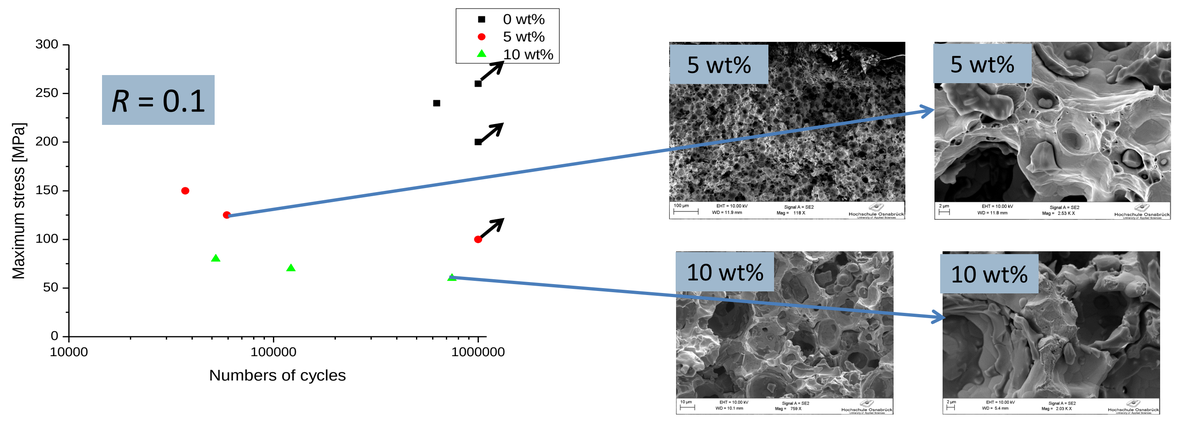


evaluation of fracture surface using SEM

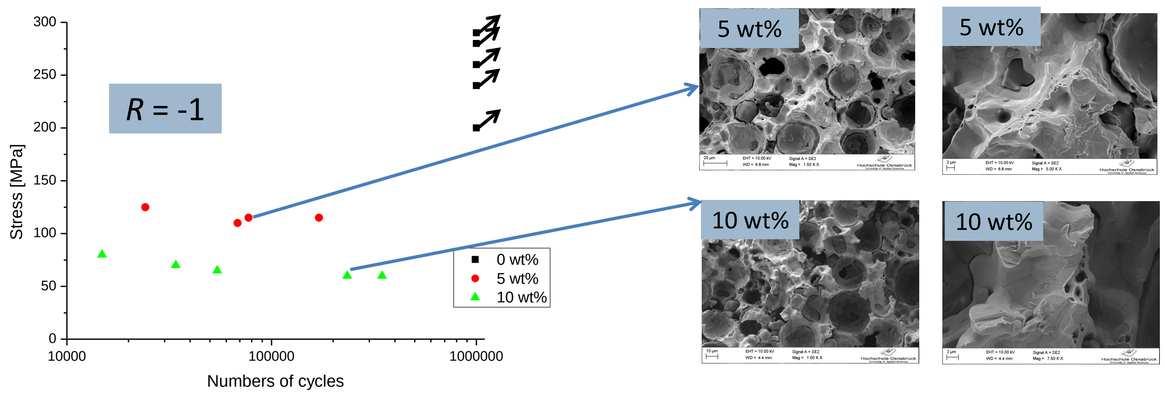
Results



- foams with 5wt%S60HS can be subjected to cyclic compression loads of 240MPa (close to the quasi-static 1% compression yield strength)
- for foams with 10wt%S60HS the stress limit is much lower
- ductile failure with increased crack propagation along the sphere-matrix interface



- foams with 5wt%S60HS can be subjected to cyclic tensile loads of 100MPa (close to the quasi-static 0.2% compression yield strength)
- for foams with 10wt%S60HS the stress limit is about 50MPa
- increased crack propagation along the sphere-matrix interface
- matrix fracture more of brittle type



- foams with 5wt%S60HS can be subjected to alternate loads of less than 100MPa
- for foams with 10wt%S60HS the stress limit is about 50MPa
- increased crack propagation along the sphere-matrix interface

Conclusions

- using the example of FeNi36 and S60SH micro hollow glass spheres the behaviour of syntactic foams under cyclic loads was investigated
- the foams show reduced allowable stress levels for all tested load modes (compression, tensile, alternating)
- maximum cyclic stresses are close to the quasi-static yield strengths ($R_{p0.2}$ and R_{p1})
- material fails in a ductile manner but with increasing sphere content the matrix fracture changes more to the brittle type
- these first results indicate sufficient fatigue behaviour for many of technical applications though more detailed investigations are still needed

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References:
[1] Joachim Baumeister, Jörg Weise, Metal foams for structural applications in transportation, in: Structural Materials and Processes in Transportation, Axel Herrmann (Herausgeber), Kambiz Kayvantash (Herausgeber), Matthias Busse (Herausgeber), Dirk Lehmhus (Herausgeber)ISBN 978-3-527-32787-4
[2] Poltersdorf, P., Nesic, S., Baumeister, J., Weise, J., Krupp, J., ‚Mechanical behavior of syntactic Fe-36Ni foams under monotonic and cyclic loading conditions, Cellmat 2012, 07.-09.11. 2012, Dresden.