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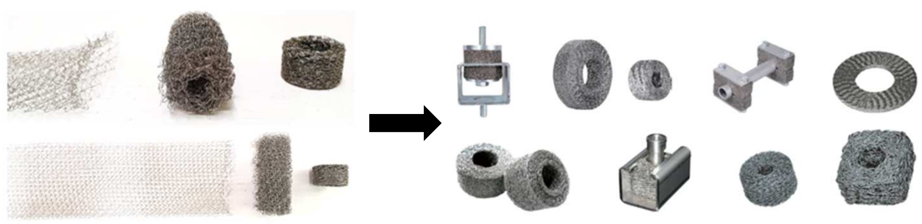
Lifetime calculation for metal wire mesh vibration dampers subjected to cyclic loads

Metal Cushion

- Metal cushions are derived from knitted wire (wire mesh) by pressing
- Applied in vibration engineering, when high damping, lifetime and robustness is needed [1]

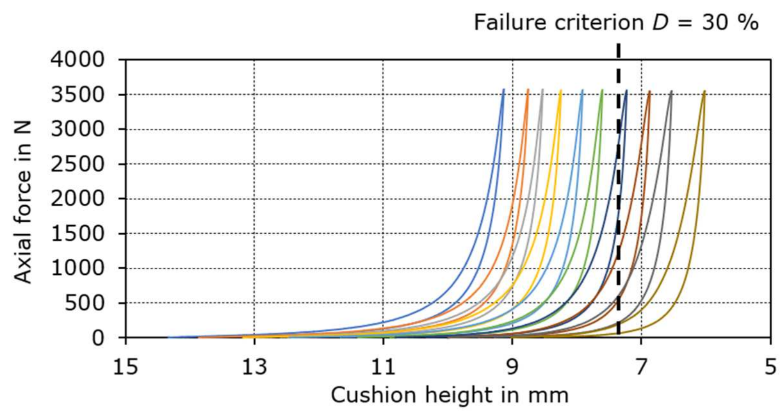


- Characteristic progressive force-deflection curve with hysteresis
- Full load capacity in one direction only (anisotropic material)
- Usually applied pre-tensioned in pairs as spring-damper system

Damage / Failure Criterion

- Three damage mechanisms are identified:
  - Plastic deformation
  - Breakage of individual wires
  - Abrasion of the wires at the contact points

- Height of cushion is decreasing over the fatigue lifetime
- Determination of damage degree by recording characteristic curve in intervals throughout fatigue tests



- Damage degree described by increase of absolute deflection subjected to test load compared to initial condition
- Damage degree for a specific test force: $D = \frac{h_0 - h_{p,i}}{h_0 - h_{p,0}} - 1$
- Exceeding the failure criterion of 30 % means no total failure of dampers

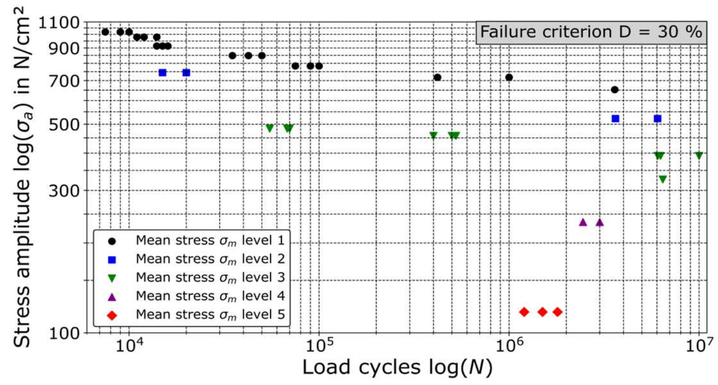
Experimental

- Tests were carried out on pulse test bench with individual metal cushions
- Purely axial sinusoidal force with constant amplitude per test run

- Tests were terminated when failure criterion was reached or ≥ 10^7 cycles
- No influence of test frequency on fatigue was detected (5 to 100 Hz)

Results

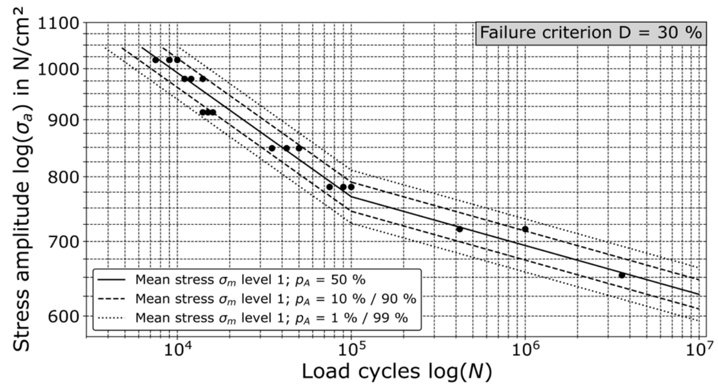
- Fatigue tests were performed at five levels of mean stress with different stress amplitudes
- Across all tests: The smaller the load and higher the lifetime, the more nonlinear is the progression of the damage degree



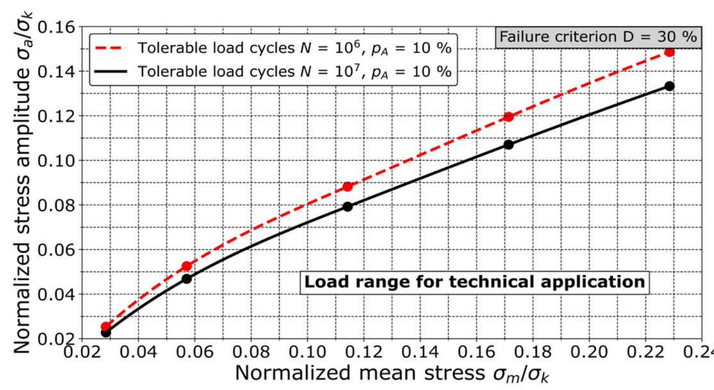
- Scatter of the test results increases with higher numbers of load cycles
- Fatigue lifetime is lowest, when the stress amplitude is close to the mean stress (low minimum stress)

Validation / Utilization

- Results are statistically evaluated using a linear approach [2] [3]
- S-N curve with two slope ranges for each mean stress level (best fit)



- Failure probability p_A = 10 % acceptable for given failure criterion
- Fatigue safety factor j = 3 suggested for metal cushion dimensioning



- Manufacturing surface pressure of a cushion is used as reference to normalize the stress and strength
- Mean stress sensitivity for different fatigue lifetimes can be used as limit curve for dimensioning of cushions

Conclusions / Outlook

- Lifetime-oriented design of metal cushions in development is feasible
- Evaluation of S-N curves for metal cushions similar as for solid metals
- Linear damage accumulation with the obtained test data as a basis can be applied to calculate the damage degree of cushions due to load spectra
- Data of individual metal cushions can normalized be applied to systems

Literature

[1] A. Pérez et al., *Metal cushion dampers for railway applications: A review*, Construction and Building Materials, vol. 238, Mar. 2020
[2] S. Einbock, *Betriebsfestigkeitsberechnung*, Norderstedt: Books on Demand, 2017
[3] E. Haibach, *Betriebsfestigkeit Verfahren und Daten zur Bauteilberechnung*, Heidelberg: Springer Verlag, 2002

R. Schroth [1]
[1] Hutchinson Stop-Choc GmbH & Co. KG
Benzstraße 42, 71272 Renningen, Germany

A. Wirz [1, 2]
[2] Pforzheim University, Mechanical Engineering
Tiefenbronner Straße 65, 75175 Pforzheim, Germany

S. Einbock [3]
[3] Einbock Akademie UG (haftungsbeschränkt)
C. v. Stauffenberg Straße 5, 71665 Vaihingen, Germany