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Vibration control using tangled metal wire particles

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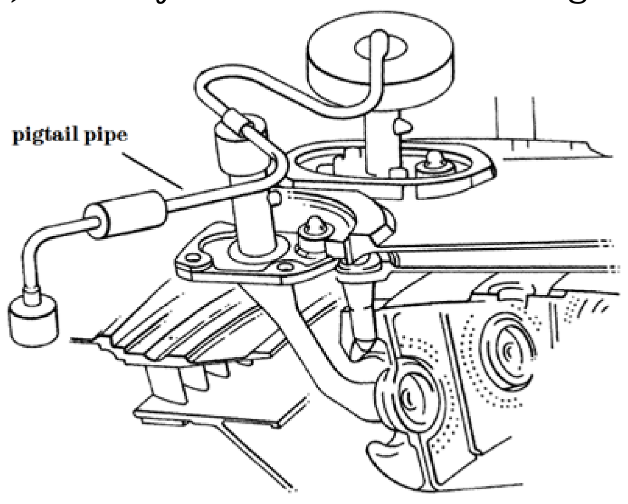
Background

Basic Features of rigid structures:

(1) Structure moves significantly under vibration but experiences very ***LOW dynamic strain***.
(2) Flexibility in one direction is not significantly higher than the others.



Engineering Scenario: Fuel pigtail pipe [1], [2]

(1) Operating temperature: 250-310°C
(2) Peak amplitude: >300g
(3) Excitation: Flowing fluid and casing transferred vibration

$$[M_s]\{\ddot{x}\}+[C_s]\{\dot{x}\}+[K_s]\{x\}=[M_f]\{\ddot{x}\}+[C_f]\{\dot{x}\}+[K_f]\{x\}+\{G\}$$

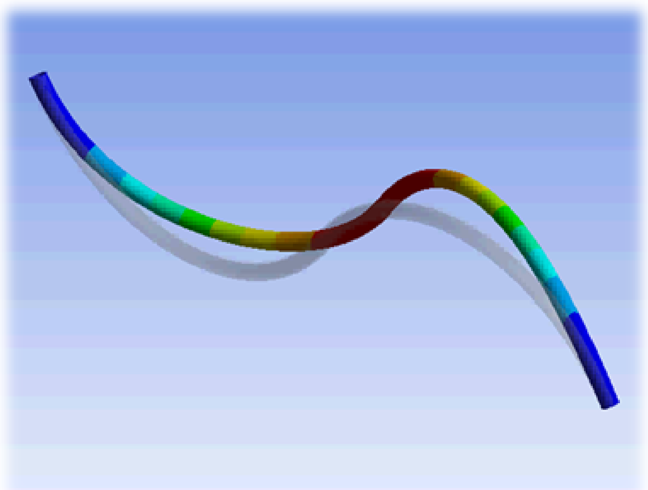
Negative damping   Mode coupling

Aim and Objectives

Aim:

Develop ***DAMPING*** techniques that are suitable for reducing ***RIGID*** structure vibration

- STRAIN-BASED damping techniques are **NOT** suitable
- Occupy LESS space in the mechanical structure
- GROUNDED damper is also **NOT** considered.



Objectives:

- mitigate **MULTI-MODE,MULTI-DIRECTIONAL** vibration
- endure high **STRESS** and **THERMAL** load
- adapt to **BROAD** frequencies

Tangled Metal Wire

Tangled metal wire particles (TMWP):

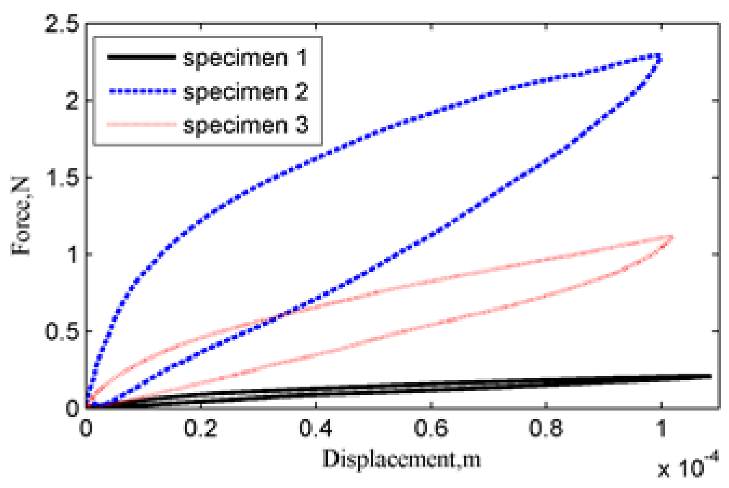
(1) Definition: porous material formed by compressing helical wires together in a mould [3]
(2) Features: light weight, temperature insensitive.
(3) From quasi-staic compressive test, the energy loss factor is up to 0.2 over a wide temperature ranges. [4]

Current problems

(1) ***Accurate model*** for damping of these particles has not been established.
(2) ***Damping mechanism*** for these particles remain uncertain.

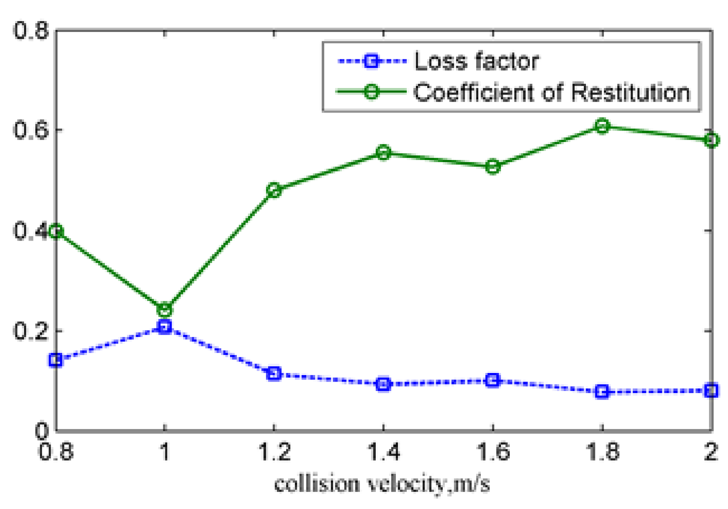
Individual TMWPs: Dynamic tensile test

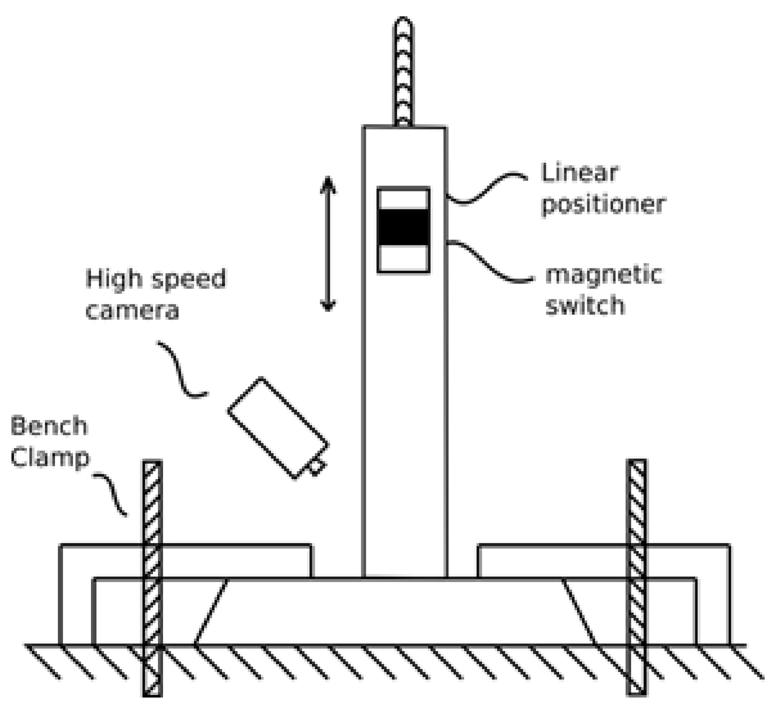
- The stiffness appears to vary between particles
- The stiffer particles provide greater relative energy loss.
- Particles show a ***SOFTENING BEHAVIOUR*** with dynamic amplitude



Individual TMWPs: Drop - rebound test

- Lower loss factor -> deformation is dominated by ***ELASTIC DEFORMATION*** rather than interwire friction





TMW PD

Tangled metal wire particle dampers:

(1) A Perspex cylinder cavity was used to contain the particles
(2) The mass ratio of particles and cavity is approx. 5%.

Damping estimation: [5]

(1) Complex power method

$$P(\omega)=F(\omega)V^*(\omega)=\frac{1}{2}[X^2c\omega^2+jX^2\omega(-m\omega^2+k)]$$

(2) Loss factor

$$\eta=\frac{\mathrm{Re}(P(\omega))}{\mathrm{Im}(P(\omega))}$$

Key findings:

(1) ***NO*** significant energy loss was identified for this damper.

(2) The ***lack of significant deformation*** of the particles and the ***LOW OVERALL MASS*** of particles present

		Excitation frequency (Hz)					
		50	70	100	150	200	300
Excitation Level (g)	0.3	0.0048	0.0017	0.000304	0.0125	0.000478	0.0016
	1	0.0016	0.000324	0.0039	0.0126	0.0053	0.0031
	3	0.0029	0.000307	0.0019	0.0151	0.0058	0.0068
	5	0.007	0.0029	0.006	0.0122	0.0098	0.0122
	10	0.0144	0.0038	0.015	0.0081	0.0044	0.0035

Energy loss for TWMPD (η)

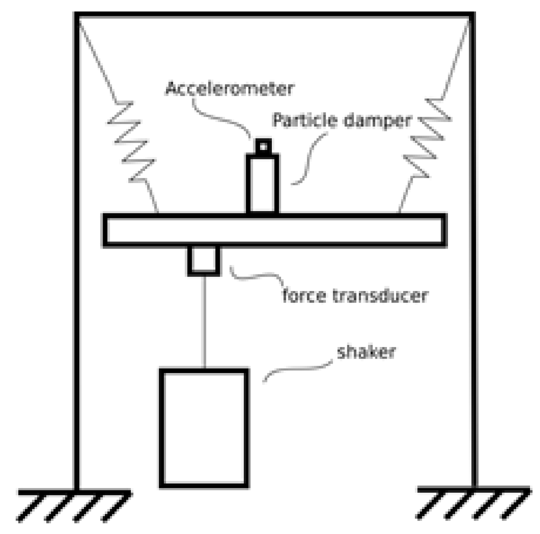
Box beam with TMWP

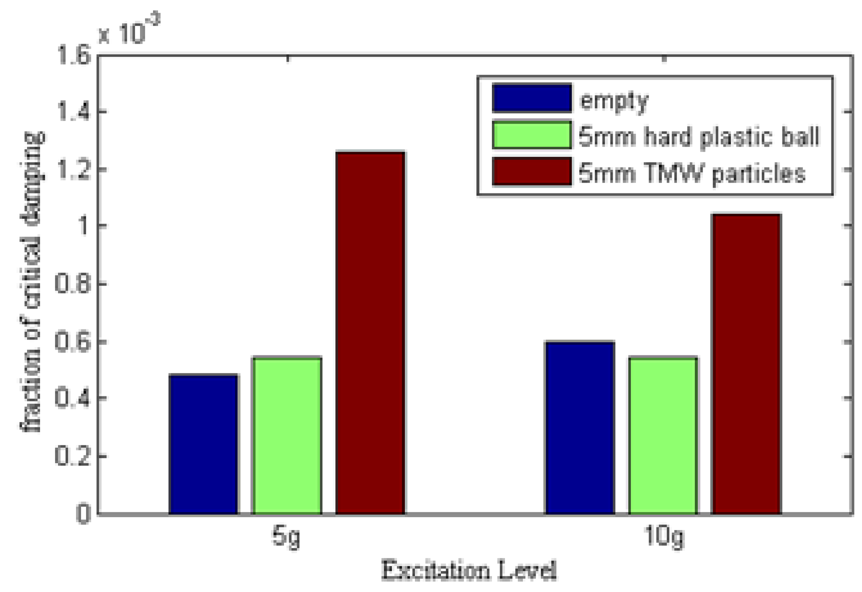
TMW Particle damper : Particle mode

Test configuration:

(1) For box beam with TMW particle dampers, a shaker test was arranged

(2) The performance of TMWPD is compared with the hard plastic sphere PD.





Key findings

(1) Overall damping levels are ***LOW***

(2) TMW particles did increase damping by a ***SMALL AMOUNT***.

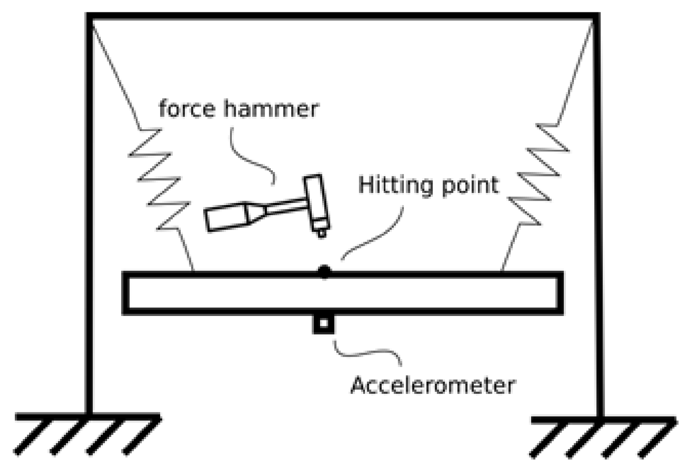
(3) Sliding and rotation can be observed during experiment

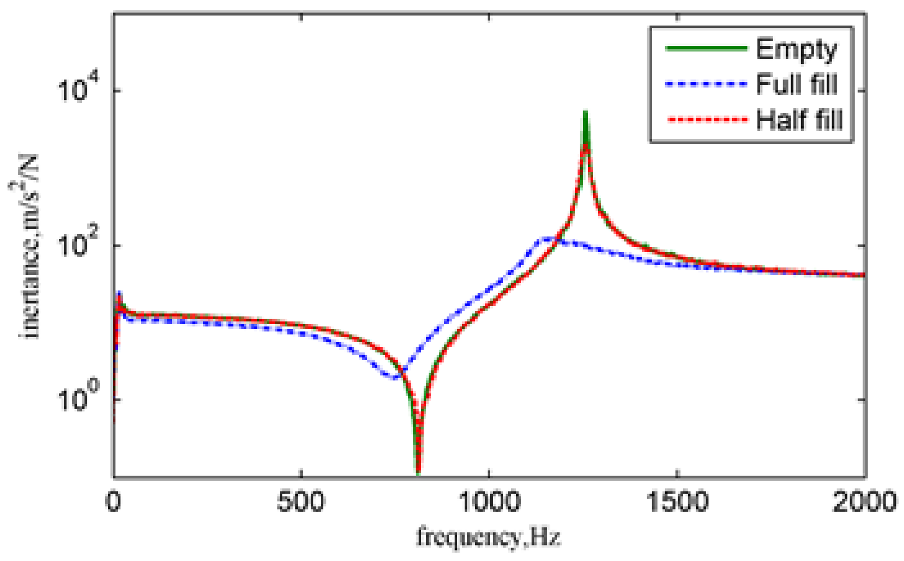
TMW as granular filler: Wave mode

Test configuration:

(1) For box beam with TMW particle dampers, a tap test was arranged to identify the performance of TMW fillers

(2) The self-weight of TMW filled beam is located between Aluminium swarf and mild steel swarf filled ones.





Key findings

(1) Fraction of critical damping for this box beam was approximately ***6%***

(2) ***TRANSVERSE*** internal vibration modes were activated.

(3) The performance dropped dramatically when the hollow structure is not fully filled

Concluding Remarks

(1) TMW particles have the capability to work as both as particle dampers and granular fill.

(2) A particle damper containing TMW particles is not effective due to the low inertia of TMW particles.

(3) Useful level of damping observed if TMW particles can develop internal wave modes within the granular medium

Reference

[1] Tang, N., "Vibration control for rigid structures," Mphil transfer report, Department of Mechanical Engineering, University of Sheffield, 2014.
[2] Tomlinson, G.R., "Particle vibration damper",Patents, 2003
[3] Chegodayev, D.E., "The designing of components made of metal rubber", Beijing: Industry Publishing Company of National Defence, 2000.
[4] Chandrasekhar, K., Rongong, J. A., & Cross, E. J., "Frequency and amplitude dependent behaviour of tangled metal wire dampers." Proceedings of International Conference on Noise and Vibration Engineering, Belgium, Sep 2014, pp 559-572
[5] Wong, C. X., Daniel, M. C., and Rongong, J. A., "Energy dissipation prediction of particle dampers." Journal of Sound and Vibration 319.1 (2009), pp. 91-118.