

Mechanical vibration resonance measurements and concerns for plastic encapsulated control modules and power modules in traction applications

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Materials Science & Technology

Purpose/ Introduction

- For railway traction applications, vibration tests are performed according to EN 61373
- This standard is based on mechanical vibrations originating from the wheel-rail-system, ending at 250 Hz
- Modern power electronics generates acoustic vibrations up to 2 kHz, other sources [1] indicated some kHz for railway applications, which is not considered in this standard.
- Power converters use modules with casting-compound embedded power- and control-electronics
- Both soft (rubber-like) and hard compounds are in use, frequently even combined
- We wanted to know, whether internal components within such modules suffer mechanical resonances and vibrations, which might become dangerous for the internal interconnects and wirings

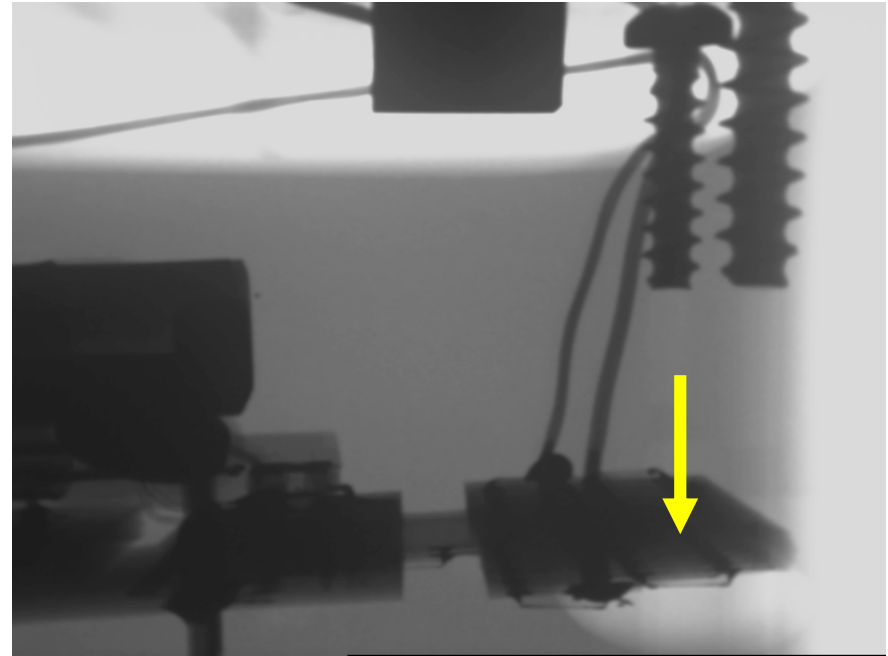
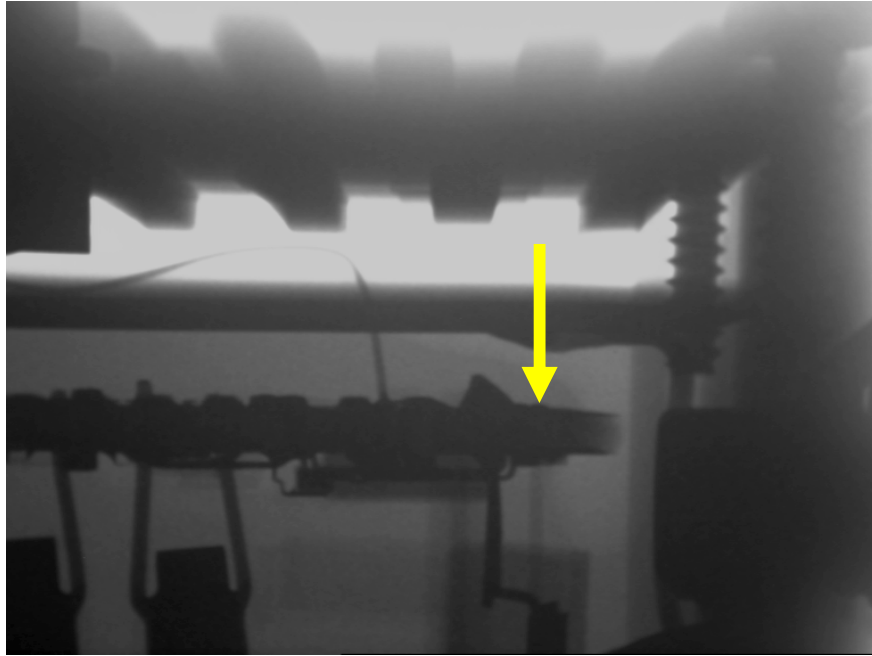
[1] David Thompson, "Railway Noise and Vibration - Mechanisms, Modelling and Means of Control", Elsevier Ltd., 2009, ISBN-13: 978-0-08-045147-3

X-ray pre-characterization and module decapsulation



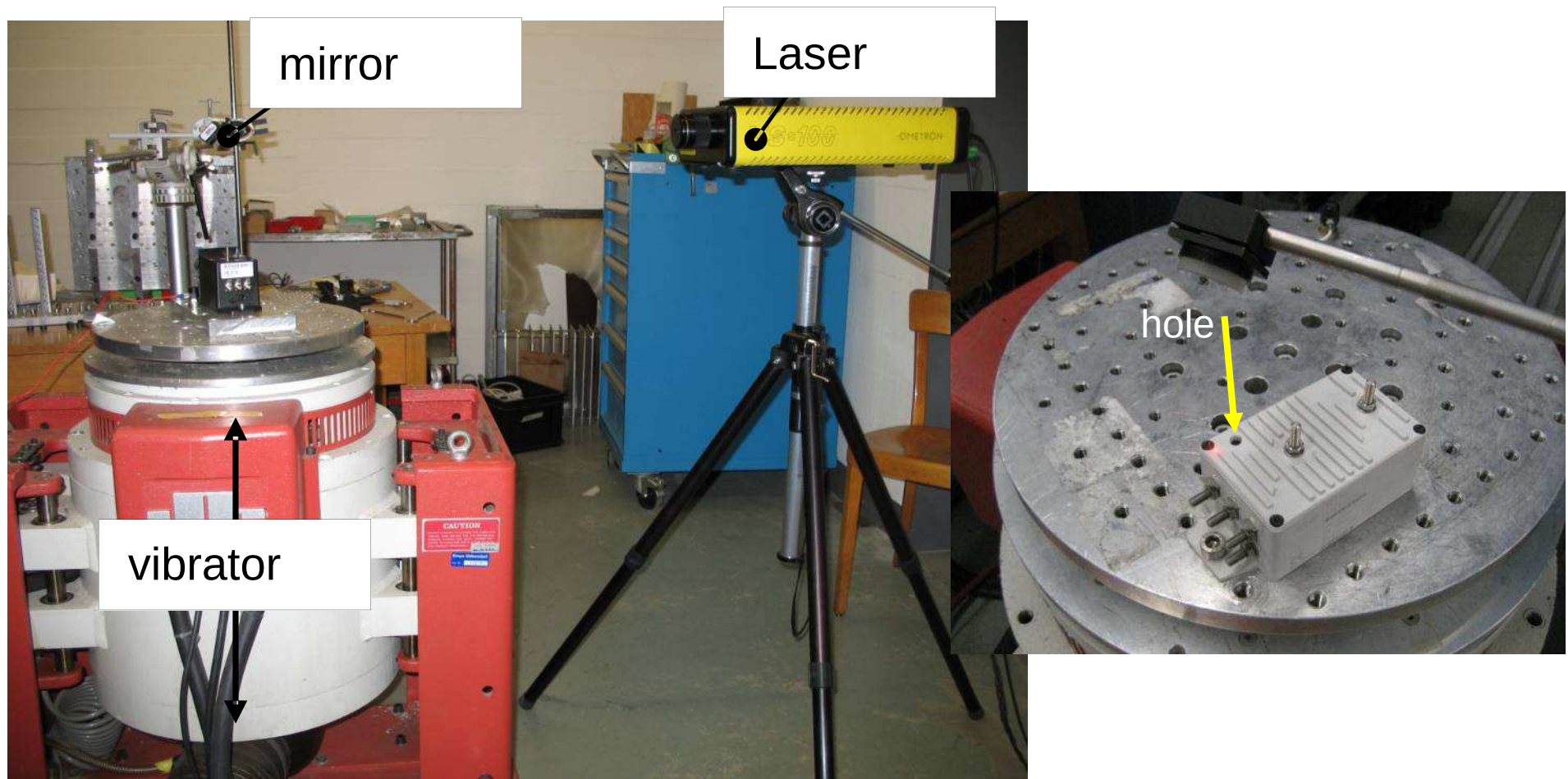
X-ray pre-characterization and a sample decap allows to see where internal components might be at risk, where hard respectively soft embedding materials were used etc...

Preparation of measurement



Creating measurement points on critical components within the module (previously identified by decapsulation of a second sample) by X-ray-controlled drilling of access holes

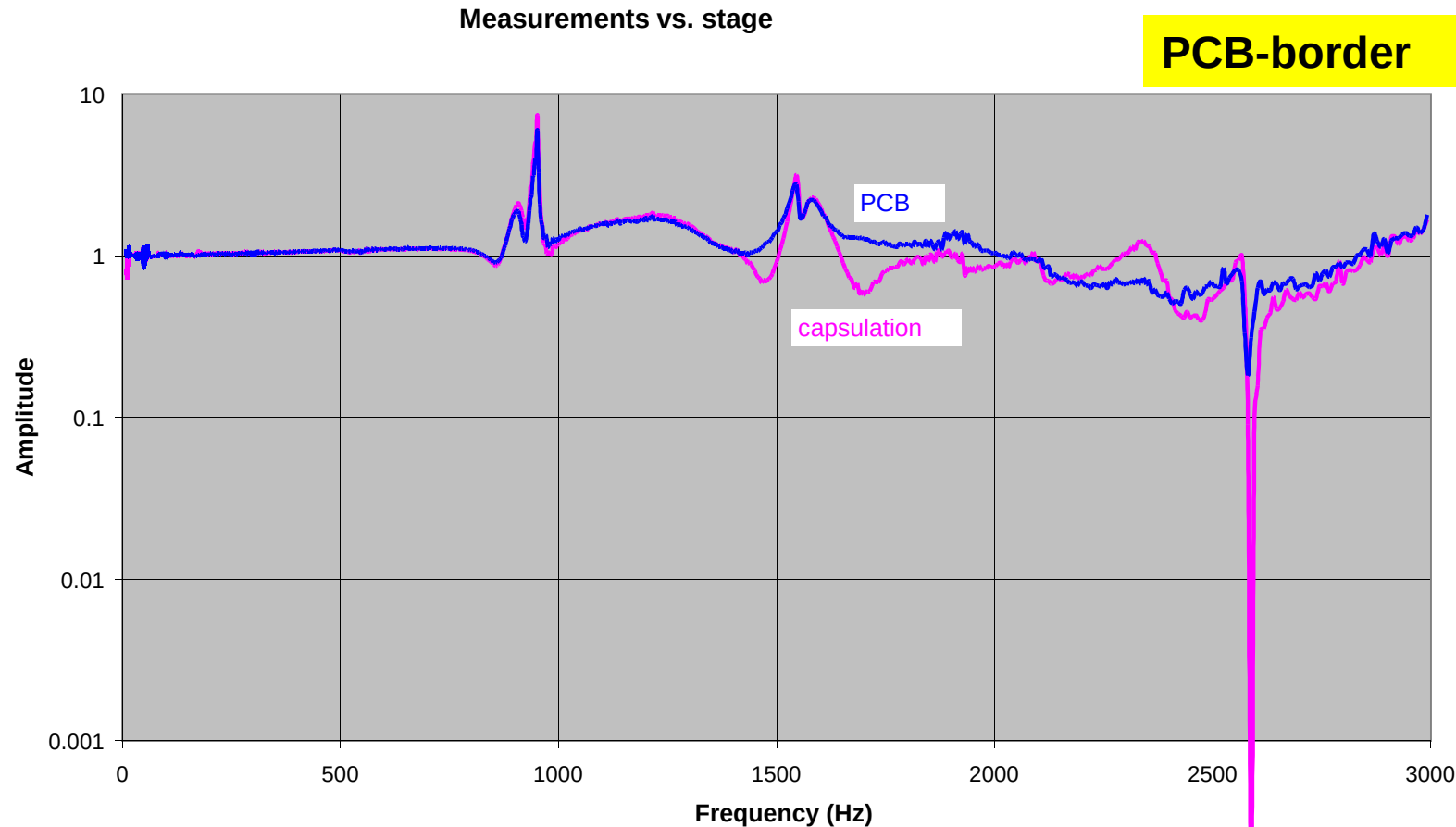
Vibration examination



Measurement setup/ principle:

The laser beam is deflected by the mirror to the sample and reflected there. Signal delay and phase are recorded. Thus, the absolute position of the measurement can be determined dynamically at any time.

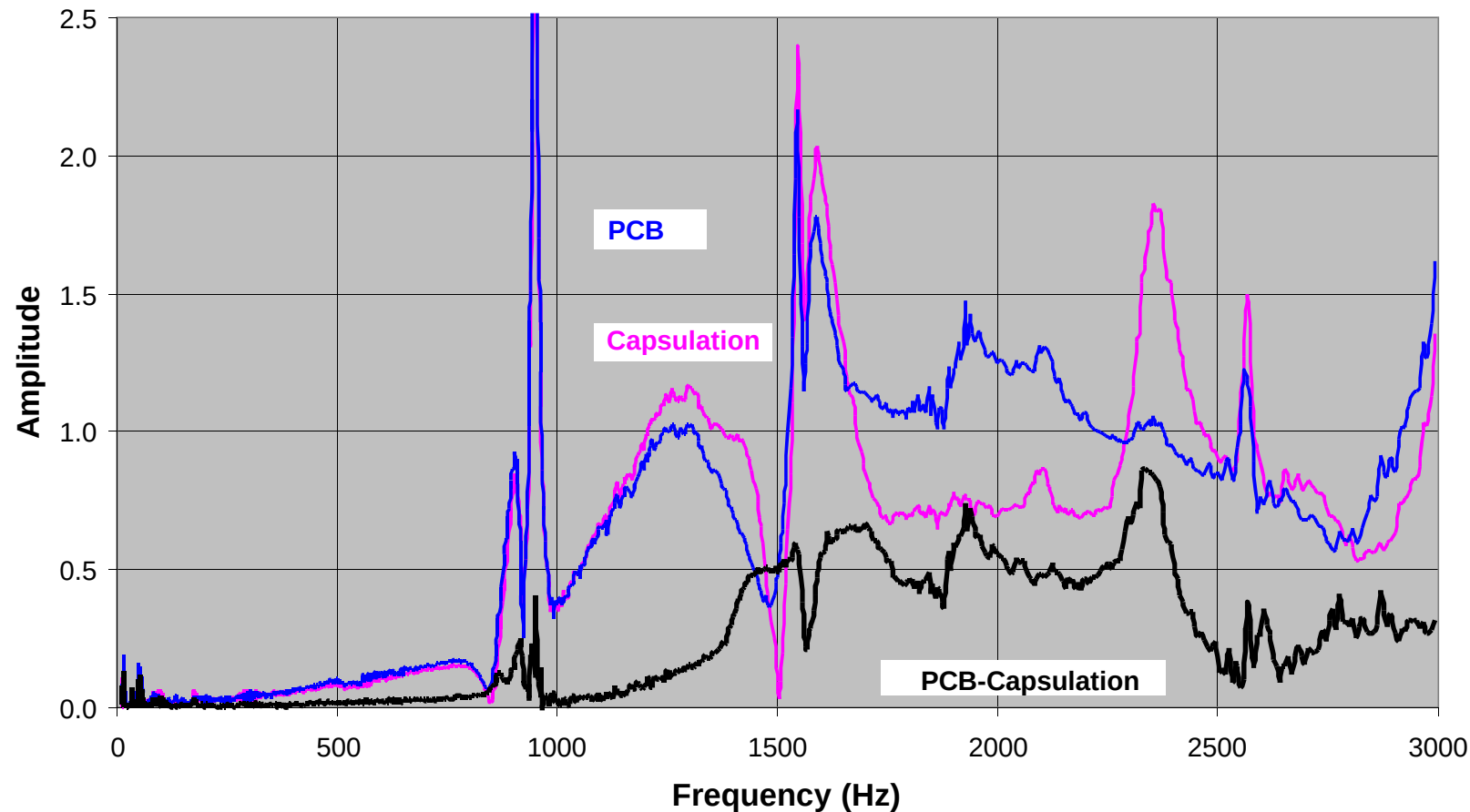
Natural resonance test



At an amplitude (ratio) of 1, no relative movement to the stage happens; at >1400Hz the PCB movement seems to be damped versus the module capsulation. However, between 900 and 1400Hz oscillation overshoots were found as well as capsulation resonances at 1800 and 2500Hz. The peaks at 900, 1550 and 2550Hz are natural resonances of the stage.

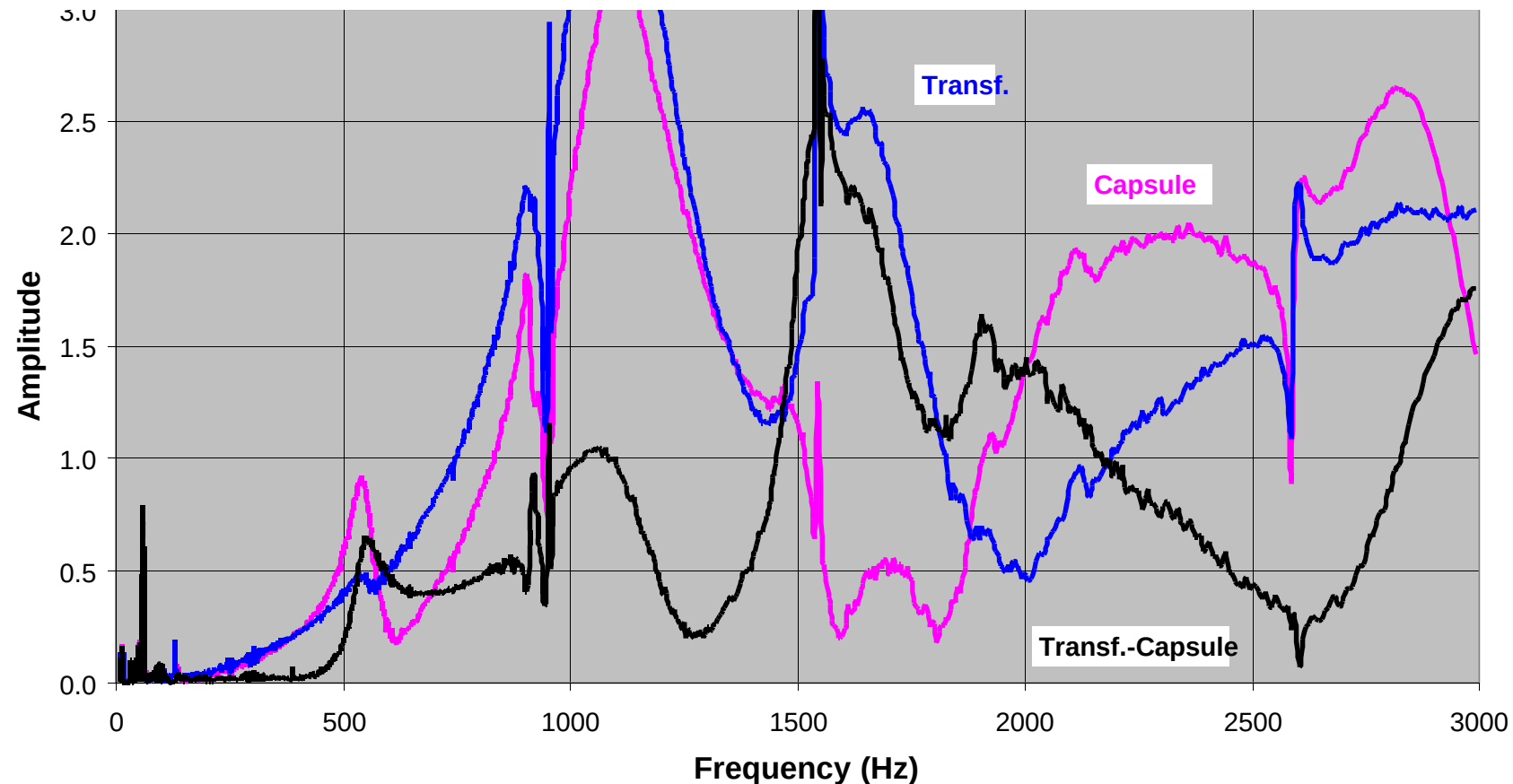
Standardized differential view (PCB)

Differential movement evaluation



For a correct differential view, we have to consider the phase in addition to the related amplitude. This standardization shows clearly significant relative vibrational stress between PCB and encapsulation above 1600 Hz

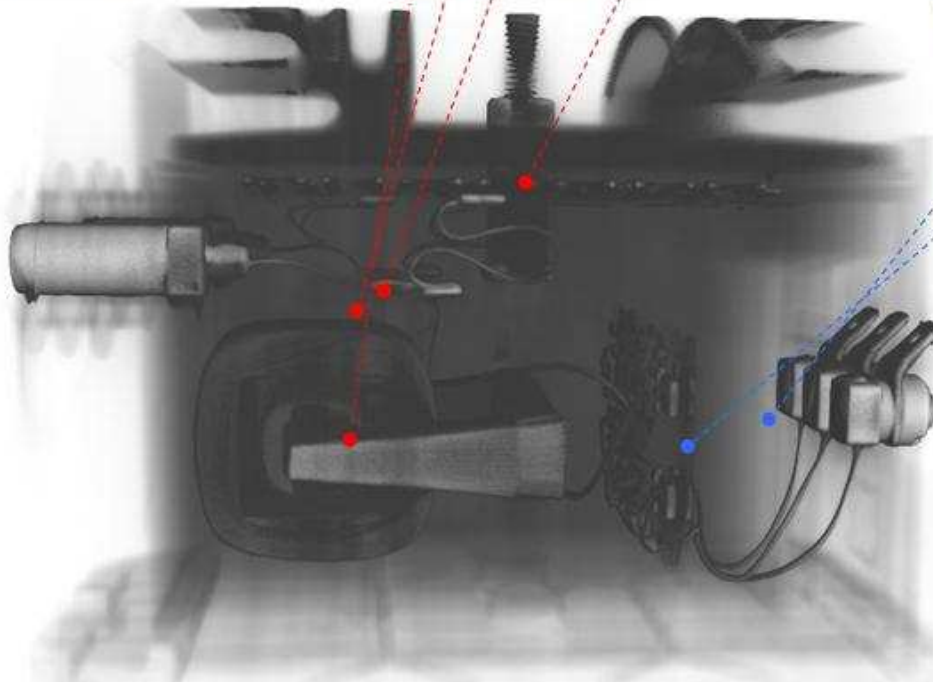
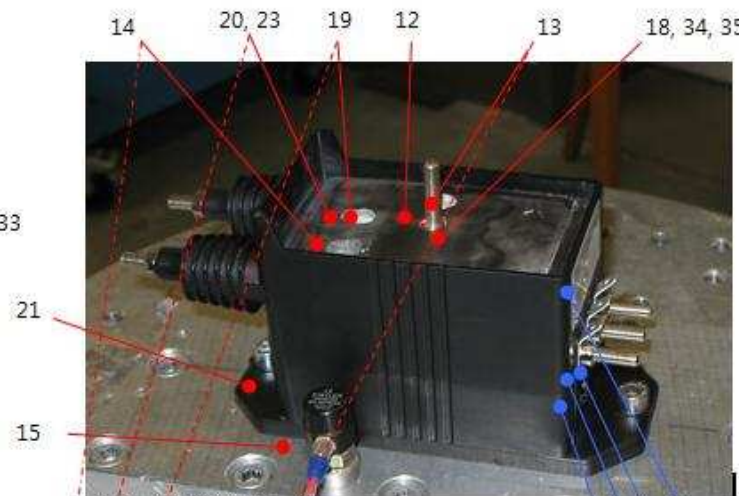
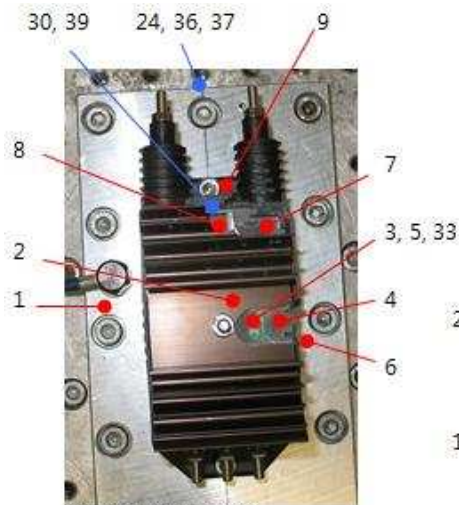
Differential view of a transformer within the module



Above 600 Hz significant vibrations of the transformer versus the module encapsulation, between 1500 and 1700 Hz very strong

Fixation of measurement points

By X-ray controlled drilling of holes, the measurement access was prepared for the horizontal (bottom left) mounting (red) resp. for the vertical (right) mounting (blue)



Conclusion

- Valuable pre-characterisation of modules for vibration-critical applications
- Standards for railway applications needs revisions concerning $f > 250\text{Hz}$
- Added-value strongly depends from starting assumptions and correct setup characterisation (which elements are on risk, fixing of test points, set-up-resonance etc)