HAND ARM VIBRATION

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Definition and Quantification of Shock/Peak/Transient Vibration

Hans Lindell, RISE, Research Institues of Sweden

Why handle shock and high frequecy vibration?

1 Scope

This part of ISO 5349 specifies general requirements for measuring and reporting hand-transmitted vibration exposure in three orthogonal axes. It defines a frequency weighting and band-limiting filters to allow uniform comparison of measurements. The values obtained can be used to predict adverse effects of hand-transmitted vibration over the frequency range covered by the octave bands from 8 Hz to 1 000 Hz.

This part of ISO 5349 is applicable to periodic and to random or non-periodic vibration. Provisionally, this part of ISO 5349 is also applicable to repeated shock type excitation (impact).

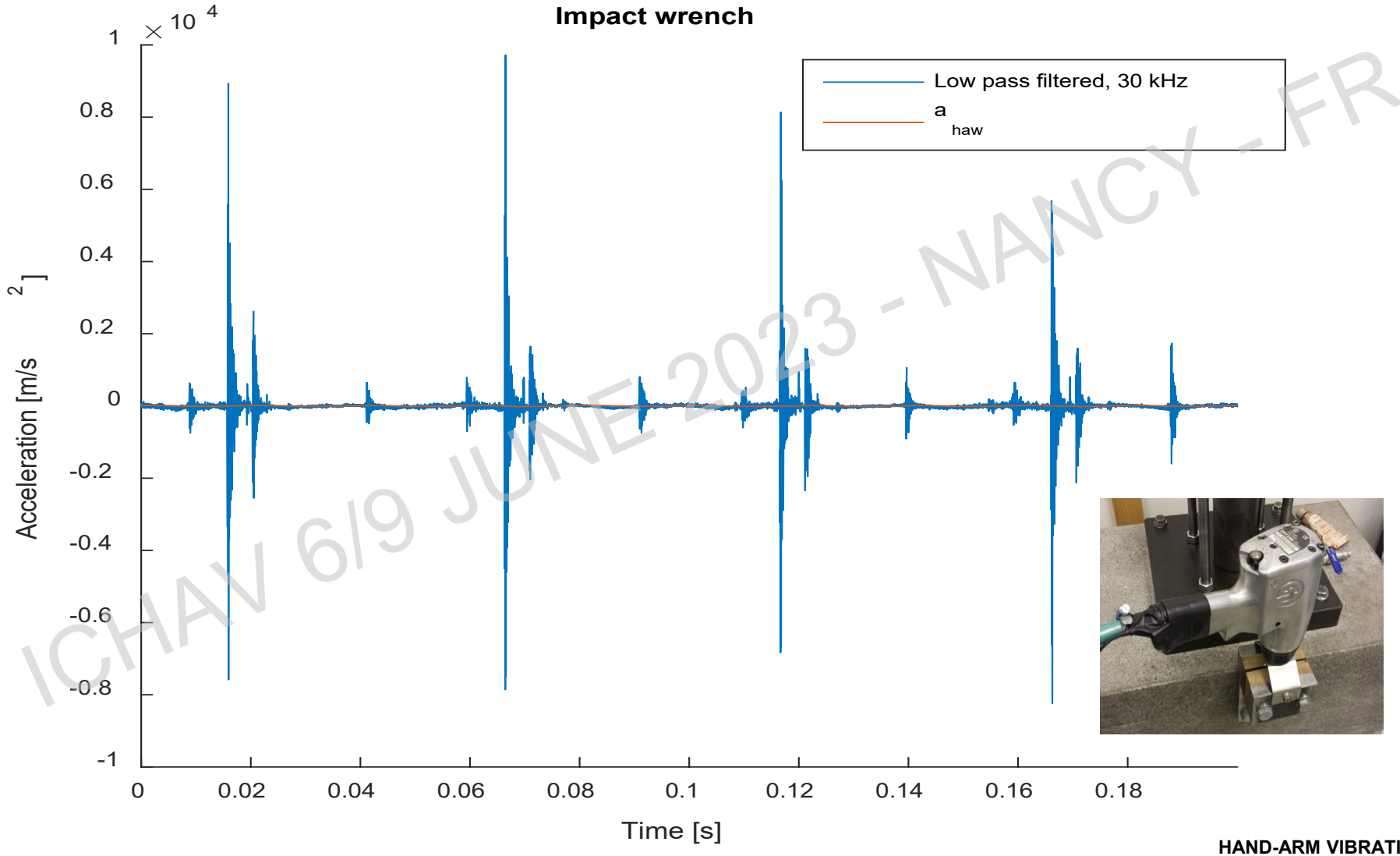
NOTE 1 The time dependency for human response to repeated shocks is not fully known. Application of this part of ISO 5349 for such vibration is to be made with caution.

This part of ISO 5349 provides guidance for the evaluation of hand-transmitted vibration exposure, specified in terms of a frequency-weighted vibration acceleration and daily exposure time. It does not define limits of safe vibration exposure.

Resolution from WG3 meeting in Vienna 1985:

WG3 will consider a revision to ISO 5349 at its next meeting on the subject of high frequency and shock vibration provided more epidemilogical data are available at that time.

Typical vibration from an impact wrench

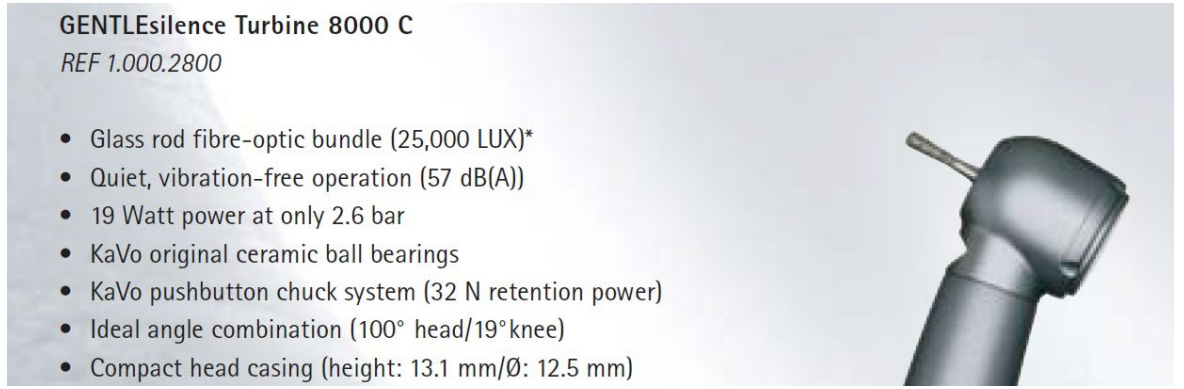


Consequences of not handling shocks and frequencies > 1250 Hz

- Machines with shock/impact vibration are since long suspected to be underestimated of risk for HAVS
- Obviously harmful vibration exposure are overlooked:
  - Gripping impact wrench socket or a chisel with the naked hand, (approx. 10 m/s^2_{haw})
  - Putting hand in ultrasonic cleaning bath
- E.g. dental tools which often have a rotational speed > 6000 rps can market as ”Vibration-Free”

This results in:

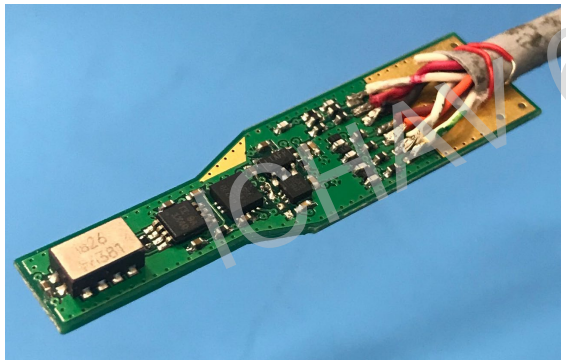
- No incentive for machine producers for reduction
- No possibilities for user to require reduction
- HAVS research is hampered, especially epidemiological

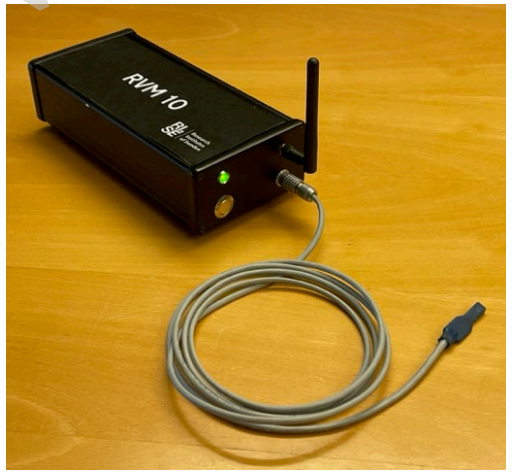


The reason of the current situation of < 1250 Hz

- ISO 5349-1 is essentially based on the perception threshold for vibration.
- This results in that, what you don't feel will not harm you
- At the time of development of ISO 5349-1 it was very difficult to measure > 1250 due to existing measurement technology.

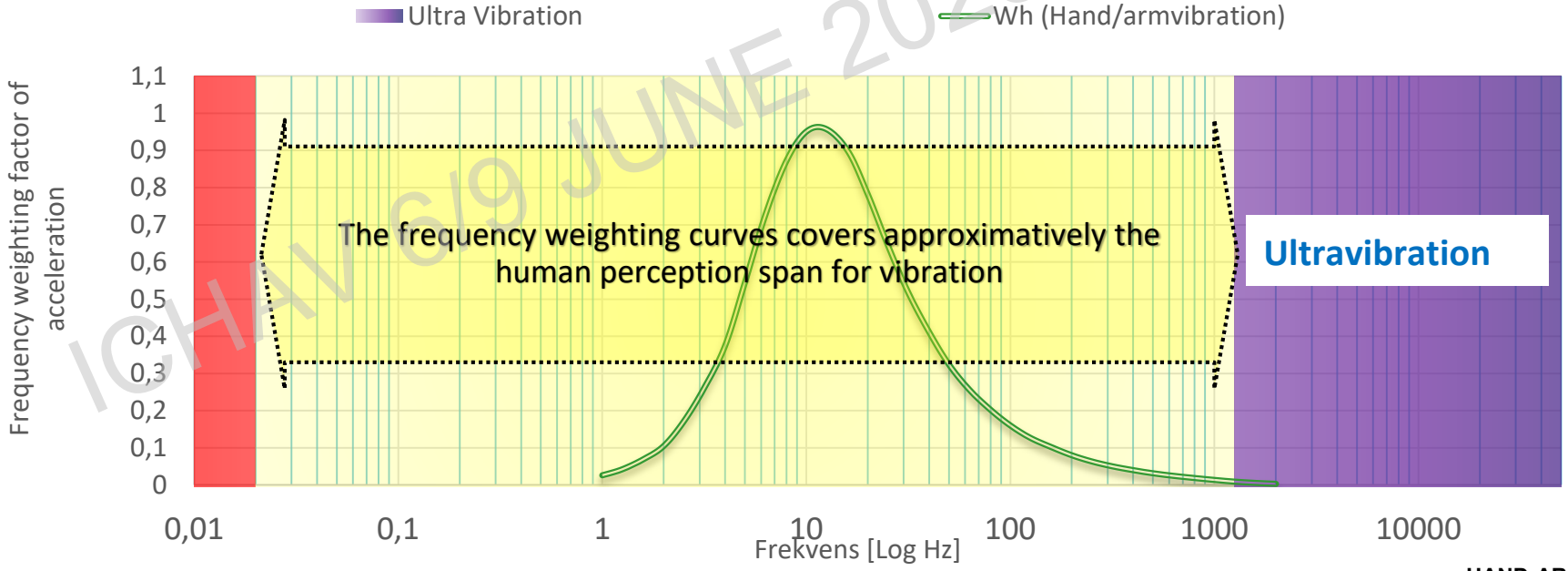
Acceleration measurement has developed tremendously with MEMS accelerometer and Laser Doppler Vibrometer and computational power.





Wish list on shock and high frequency vibration

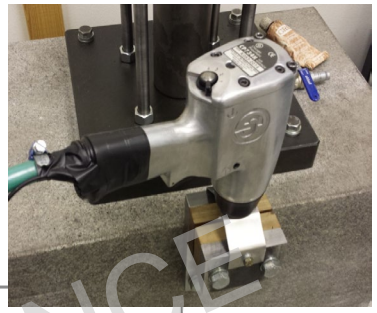
1. Need for a mathematical **quantification** of shocks and ultra vibration, **Vibration Peak Amplitude (VPM)**
2. Need for a mathematical consistent **definition** of shocks, **Vibration Shock Index (VSI)**
3. Need to have a name on vibrations above the perception threshold, >1250 Hz. A suggestion is **Ultravibration** in analogy with Ultrasound and Ultraviolet which are both phenomena with a frequency above the human perception threshold.

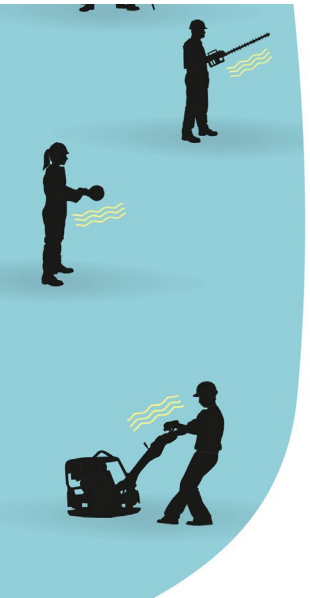


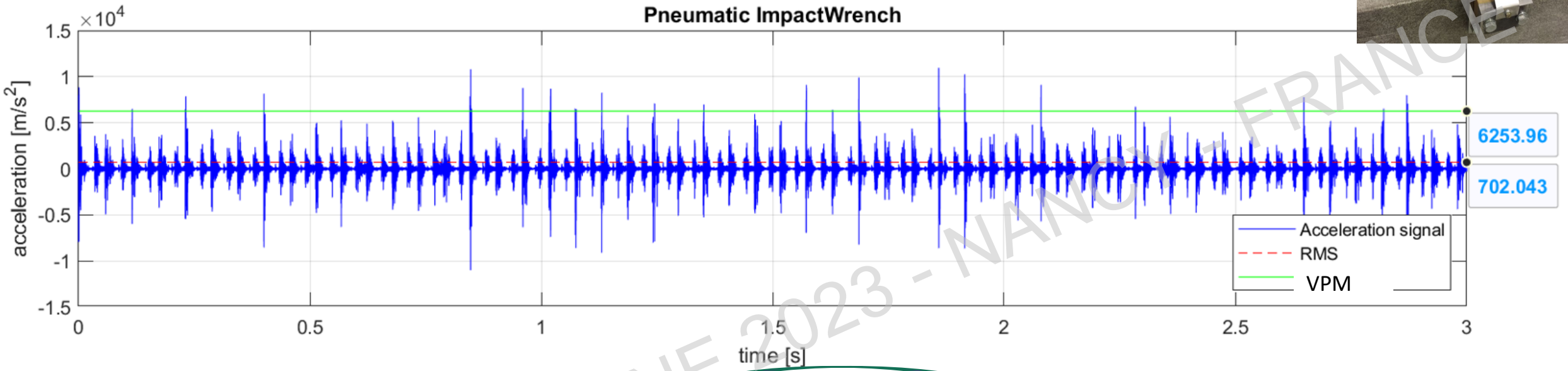
General requirements for quantification and definition of shock

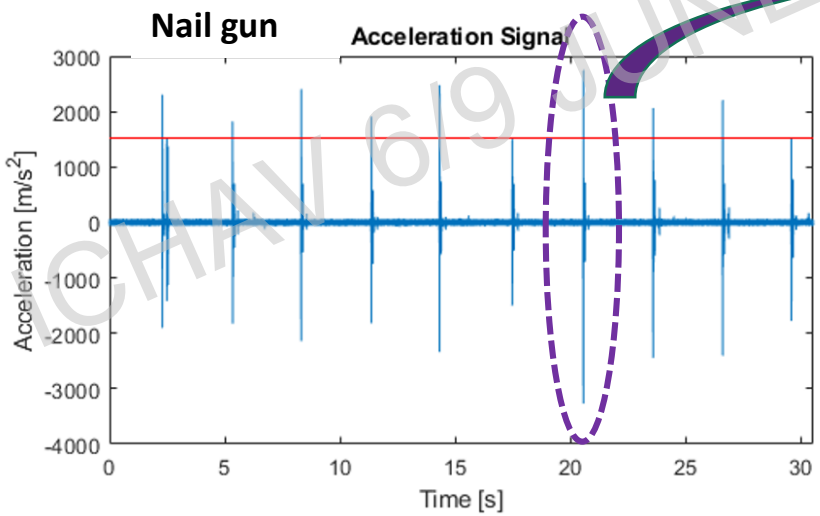
- **Dimensions:**
  - VPM (Vibration Peak Magnitude), acceleration in m/s^2.
  - VSI (Vibration Shock Index), dimensionless and defined as 1 for pure harmonic signal.
- **Intuitive:**
  - VPM should be a value between zero and the maximum amplitude of the vibration signal. When there are shocks in the signal, the VPM should be a value representative for the shocks.
  - VSI should increase with the increased content of shock starting at 1 for a pure harmonic signal.
- **Relevant:** The acceleration should be measure at a frequency sufficiently high to be able to cover the main energy content transferred to the biological tissue of interest => *Frequency index*
- **Unambiguous:** The definitions should be completely clear and to remove all subjectivity in the calculation process.
- **Robust:** The VSI/VPM should show robust numerical/statistical properties.

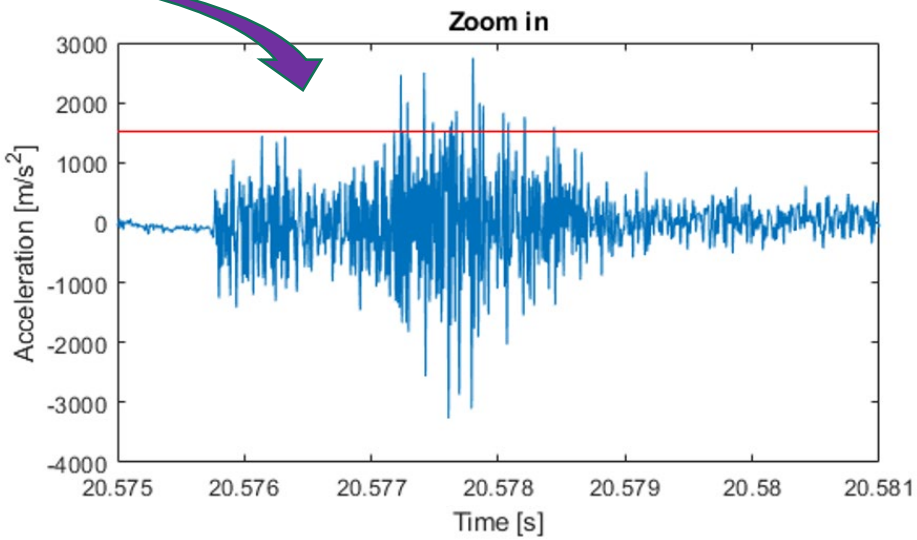
How to quantify the peak acceleration?
- Vibration Peak Magnitude (VPM)











Vibration Peak Magnitude (VPM)
- Rooth Weighted Mean Square algorithm

$$VPM_{xHz} = \sqrt{\frac{\sum_{i=1}^{i=N} a_i^{2+2k}}{\sum_{i=1}^{i=N} a_i^{2k}}}$$

$a_i = acceleration\ value\ sample$
$N = Number\ of\ samples$

- k=0, results in RMS
- k=2:
  - intuitive representation of peak acceleration
  - only positive numbers

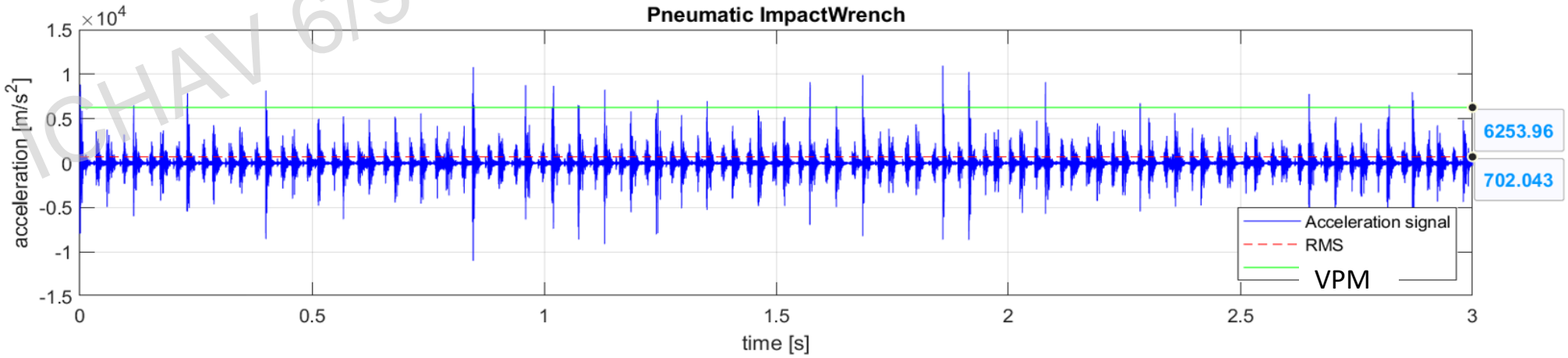
$$VPM_{xHz} = \sqrt{\frac{\sum_{i=1}^{i=N} a_i^{6}}{\sum_{i=1}^{i=N} a_i^{4}}}$$

More information: Definition and Quantification of Shock/Impact/Transient Vibrations
https://arxiv.org/abs/2211.08999

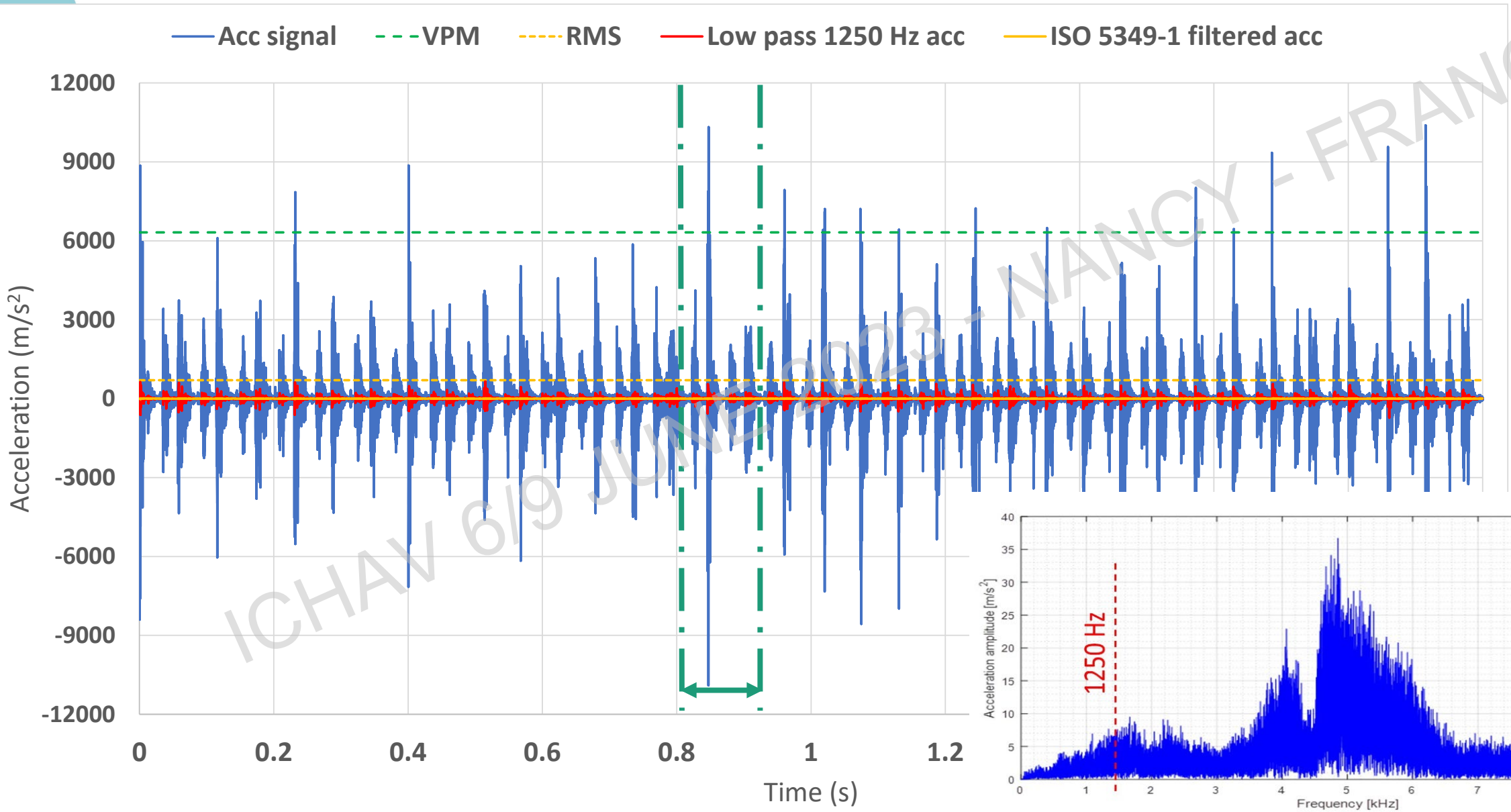
Vibration Shock Index (VSI)

- Describes the ammount of shock content of a signal
- Dimensionless
- Is the ratio between the average peak, VPM and the RMS
- Defined as 1 for harmonic signal
- Compare Crest Factor

$$VSI = \frac{VPM}{RMS} \times \sqrt{2/3}$$



The effect of upper frequency and weightning



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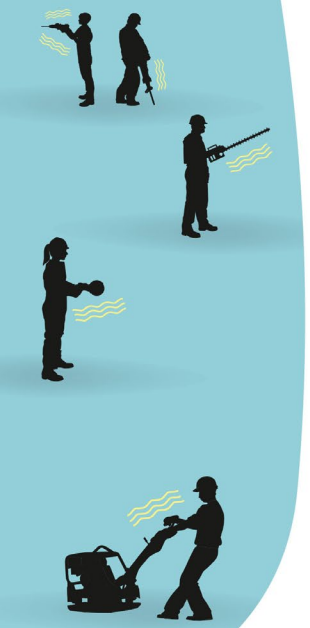

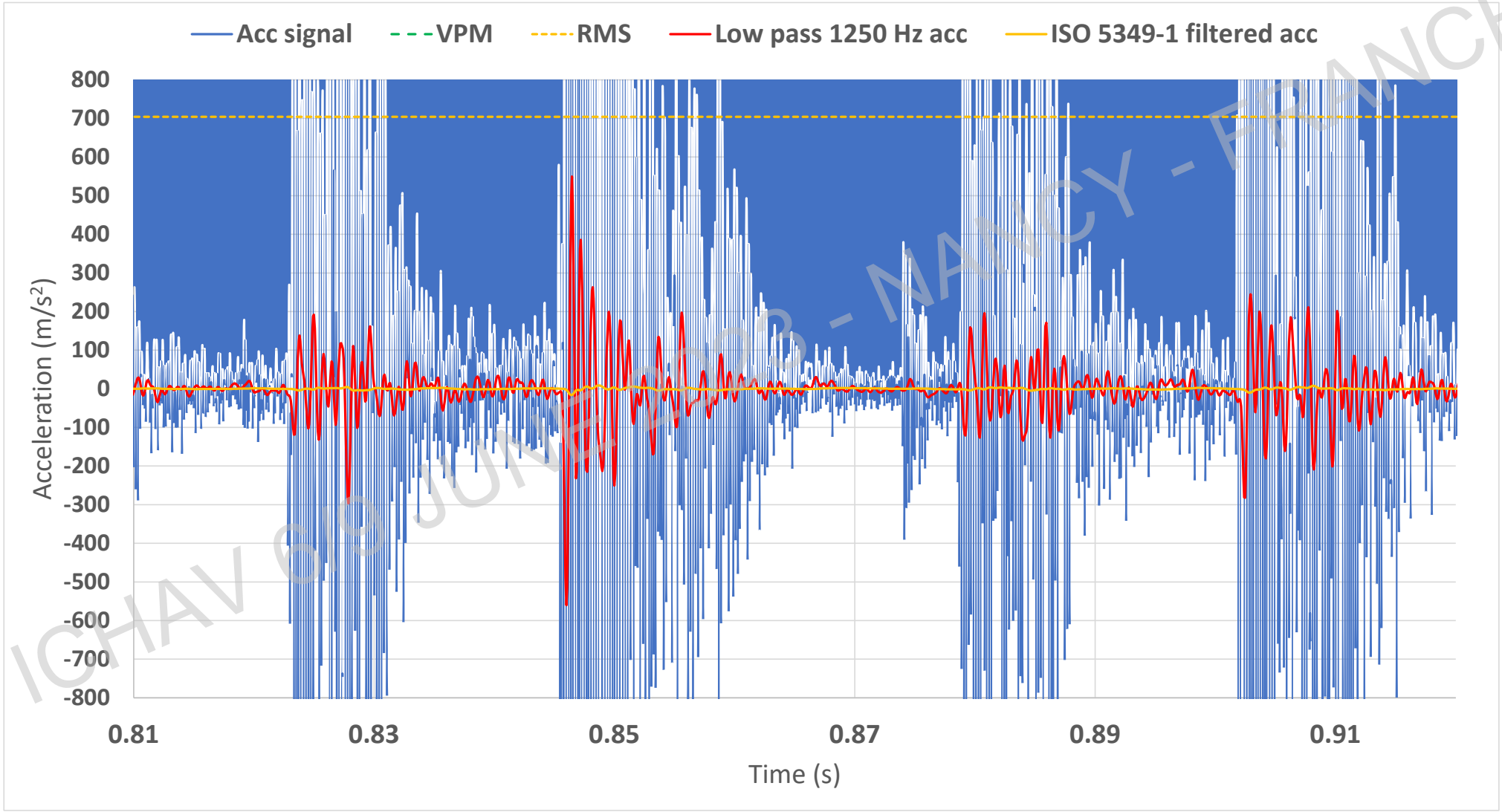

VSI, VPM and RMS on different tools

Machine	VSI_{10kHz}	VPM_{10kHz} [m/s^2]	RMS_{10kHz} [m/s^2]	RMS_{1250Hz} [m/s^2]
Angle grinder	2.1	721	344	21
Reciprocating saw	6.2	1170	188	50
Impact wrench	11.4	7 840	690	78
Nail gun	48.7	1 520	31	16

Conclusion

- Shock vibration can be measured, quantified and defined
- Vibration Peak Magnitude, VPM, is a candidate to a metric that represents the average peak acceleration
- Vibration Shock Index, VSI, is a candidate to a metric that represents the shock content in a signal
- The acceleration should be measure at a frequency sufficiently high to be able to cover the main energy content transferred to the biological tissue of interest.