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HAND-ARM VIBRATION MEASUREMENTS

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Hand-arm vibrations are of importance for operators of many hand-held tools and devices. Exposure to vibration may lead to physical damage, a phenomenon which has been widely recognized and led to various attempts to introduce regulations regarding exposure levels.

The hand-arm system can be approximated by the damped two-mass-spring system in fig. 1. Above 80 Hz, the input impedance of the hand-arm system is mainly determined by the soft tissue in the palm and on the fingers. Below 80 Hz, vibrations are transmitted to the mass of the hand and this mass (m_h=0.5kg) determines the impedance. Below 30 Hz, there is influence from the mass of the arm, m_a.[1]

These characteristic frequencies are varying with the direction, the grip force and the pressure or pulling forces applied to the handle. The impedance characteristics in fig. 2 are based on measurements on a number of persons, and show the influence of varying grip force.

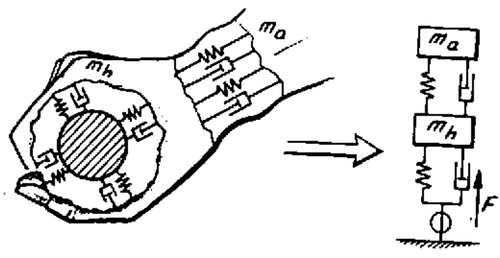

Fig. 1. Two-mass-spring model of hand-arm system

Increased grip force raises the characteristic frequencies, because the springs in the hand-arm system become stiffer.

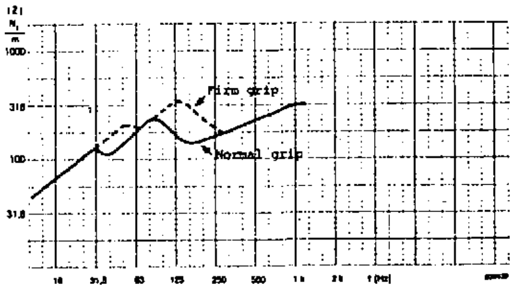

Fig. 2. Impedance characteristics of hand-arm system

Traditionally according to ISO DP 5349, the r.m.s. acceleration at the entrance to the hand is measured. The result of such measurements is depending on the input impedance of the hand-arm system. As mentioned in DP 5349, it is reasonable to assume that the biological effects to a large extent is dependant on the energy transmitted to the hand-arm system. The set-up shown in fig. 3 has been used to investigate the relationships between the acceleration level and the power transmitted to the hand from a test handle mounted on a vibration exciter. The power P delivered from the vibration exciter to the handle is given by

$$P = \langle F \cdot v \rangle_t = \langle F \cdot \int a d\tau \rangle_t \qquad (1)$$

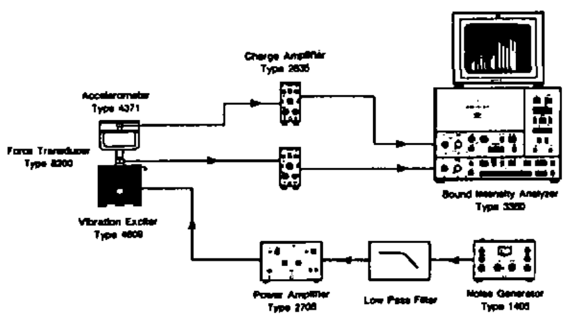

Fig. 3. Set-up for measuring power transmitted to the hand-arm system

where F is the force acting on the handle, v the resulting velocity, a the resulting acceleration and $\langle\rangle_t$ denotes a time averaging. Since the power loss in the handle is insignificant, the measured power must be transmitted to the hand-arm system.

Below 80 Hz, the dissipated power decreases, because the impedance of the hand-arm system is mostly made up of the mass of the hand, and power cannot be dissipated in masses, only in dampers. Above 80 Hz, the power is almost constant and is dissipated mostly in the soft tissue of the palm and fingers. The curve in fig. 4 is for a normal grip force which is possible to maintain for longer periods.

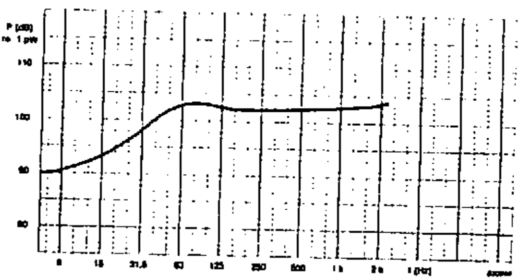

Fig. 4. Power transmitted to hand-arm system for a constant weighted acceleration level at 120 dB

The relationship between the acceleration and transmitted power is given by

$$P = v^2 \cdot \mathrm{Re}(Z) = \left(\frac{a}{2 \cdot \pi f}\right)^2 \cdot \mathrm{Re}(Z) \tag{2}$$

where f is the frequency and Re(Z) is the real part of the hand-arm impedance. Since the impedance Z is varying with the direction, the grip force and the pressure or pulling forces applied, the transmitted power will also be varying.

When using larger grip forces the acceleration level on the handle is reduced, fig. 5, due to the increased impedance. This means that a measurement according to DP 5349 would give a lower result. The transmitted power is also decreased at lower frequencies, fig. 6, but at higher frequencies the power is increased, due to the better coupling between the handle and the hand.

That means: above 100 Hz a decrease in acceleration is accompanied by an increase in power transmission.

The changes in acceleration and transmitted power, shown in fig. 5 and 6, are specific for the vibration exciter and test handle used here. The changes are determined by both the impedance of the hand-arm and

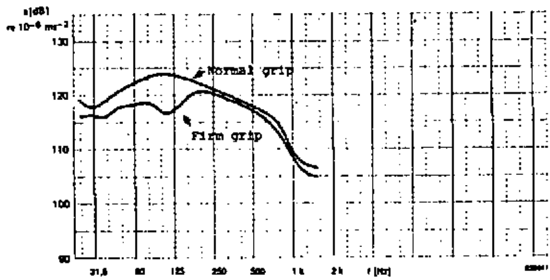

Fig. 5. Acceleration level on test handle

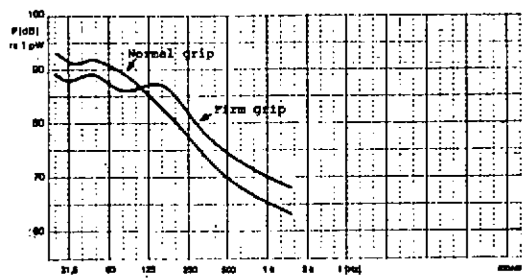

Fig. 6. Power transmitted to hand-arm system

the generator impedance of the vibration generator. In this case, the vibration exciter acts as a constant force generator, the force being determined by the output voltage of the power amplifier. Other vibration sources may give constant velocity or may have a more complicated generator impedance, as found for an anti-vibration chain saw.

REFERENCE

[1] Per Rasmussen, "Undersøgelse af Hånd-Arm Vibrationer", Department of Machine Design, Technical University of Denmark, 1982.