

Vibration from riveting tools in the frequency range 6 Hz–10 MHz and Raynaud's phenomenon

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DANDANELL R, ENGSTRÖM K. Vibration from riveting tools in the frequency range 6 Hz–10 MHz and Raynaud's phenomenon. *Scand J Work Environ Health* 12 (1986) 338–342. The vibration characteristics of hand-held riveting hammers and bucking bars used in the aircraft industry were measured and recorded for frequencies from 6 Hz to 10 MHz. Three different measuring systems had to be used. Up to about 1 kHz a displacement transducer was used, up to about 50 kHz a piezoelectric accelerometer was used, and in the megahertz region an ultrasonic probe was used. The signals were analyzed according to the guidelines of the International Organization for Standardization (ISO/DIS 5349), and also according to methods common in environmental engineering. The weighted acceleration according to ISO/DIS 5349 was between 10 and 11 m/s² for typical riveting tools. Very high acceleration values were obtained for frequencies above those specified in ISO/DIS 5349. In a group of 288 riveters, about 50 % showed symptoms indicating Raynaud's phenomenon after about 10 years of work, although the daily exposure of riveting tools was about 1 min/d. The investigation showed that special precautions must be taken to measure the acceleration of percussion tools and that the risk criteria in ISO/DIS 5349 do not cover all the risks connected with percussion tools.

Key terms: acceleration, exposure, high-frequency vibration, narrow band, one-third octave band, pneumatic hammer, response analysis, risk assessment, vibration intensity, white finger.

More than 300 workers in the Aircraft Division of Saab-Scania in Linköping are riveters (2). As much as 50 % of them show symptoms of Raynaud's phenomenon after 10 years of work or more. A study was therefore initiated in order to measure vibration exposure during riveting and to establish a dose-response relationship for finger blanching among riveters.

Methods

During riveting, the rivet punch punches a stroke on the rivet head. The bucking bar, which is held against the other end of the rivet, then closes up the rivet. This cycle is repeated about 25 times until the rivet is completely closed. The whole procedure takes about 1 s. The bucking bar usually consists of a piece of steel. Figure 1 shows the time history of some typical strokes.

Shock accelerometers, which are designed to measure very high acceleration levels, perform unsatisfactorily at low frequencies when subjected to impact (6). To facilitate measurement in the whole frequency range up to 40 kHz, two entirely different measuring systems were used. The low-frequency range was measured with a displacement pick-up (Bofors RLL-2) which allowed measuring from zero frequency up to about 1 kHz. The high-frequency range was measured with

a piezoelectric accelerometer (Brüel & Kjaer 8309). This accelerometer allowed measurement up to 50 kHz. After amplification, the signals were tape-recorded. The dynamic range of the measurements was 50 dB.

As a tentative test an ultrasonic probe 1 mm in diameter was coupled to the bucking bar with a special coupling paste. The signal was recorded on an oscilloscope. This probe was calibrated for frequencies up to 10 MHz.

The signals from the displacement transducers were transformed into acceleration signals by differentiating twice and were used in the analyses within the frequency range from 6.3 Hz to about 1 kHz. From there up to 40 kHz the signals from the accelerometers were used.

The signals were analyzed according to both ISO/DIS 5349.2 (4) and other methods that are common in environmental engineering, namely, one-third octave-band analysis, narrow-band analysis, and response analysis.

Results

Riveting

The one-third octave-band analysis was carried out in the entire frequency range between 6 Hz and 40 Hz and is presented in figures 3 and 4. For comparison the weighting lines of the previous ISO/DIS 5349.2 have been drawn.

The weighted acceleration according to ISO/DIS 5343 was calculated from the one-third octave-band analysis and was 10 m/s² for the riveting hammer and 11 m/s² for the bucking bar.

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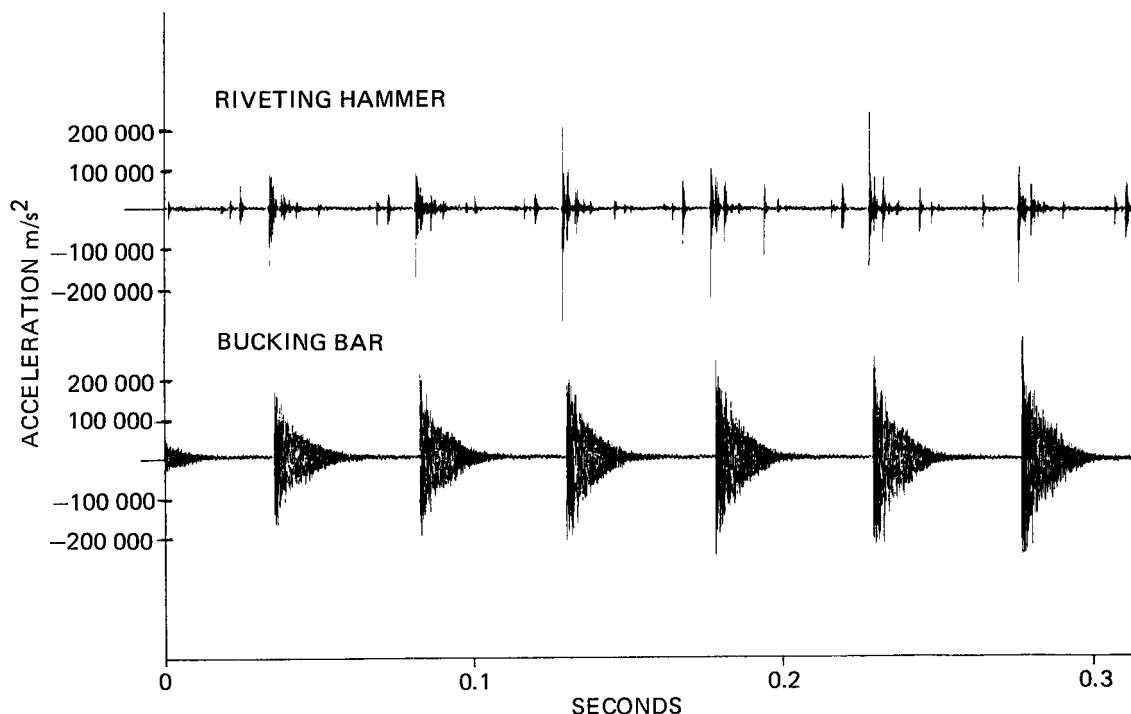


Figure 1. Acceleration of the riveting hammer and bucking bar as a function of time during some typical strokes.

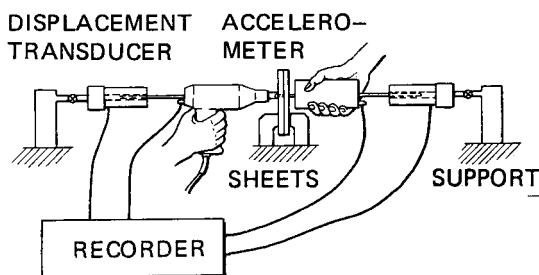


Figure 2. Test arrangement and measuring equipment.

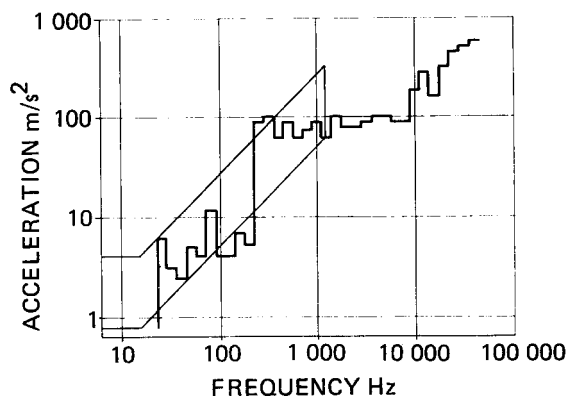


Figure 3. One-third octave-band spectrum for the riveting hammer.

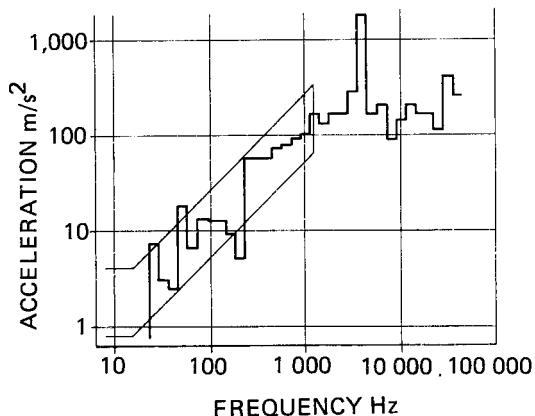


Figure 4. One-third octave-band spectrum for the bucking bar.

One section of the signal was frequency analyzed with narrow-band analysis (figures 5 and 6). The section chosen was long enough to give a representative average. The analysis showed a peak at about 4 kHz for the bucking bar. Calculation showed that this was the fundamental frequency.

In figures 7 and 8 the response spectra from three different rivetings with the same riveting hammer and bucking bar are presented. An acceleration response spectrum shows the theoretically calculated maximum response of a series of single-degree-of-freedom systems when each of them is subjected to a shock or any

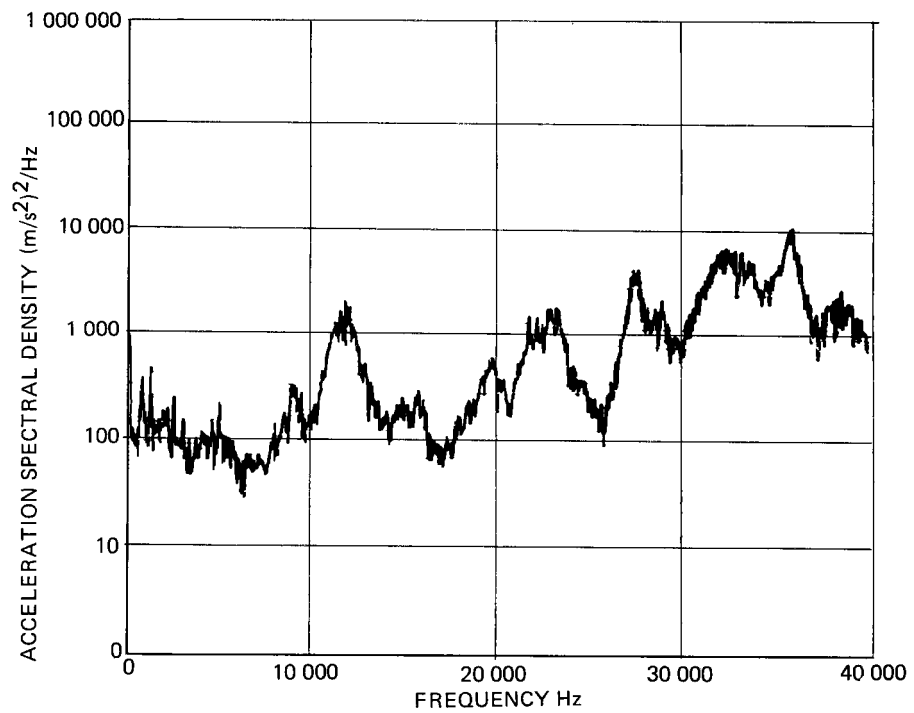


Figure 5. Narrow-band spectrum for the riveting hammer.

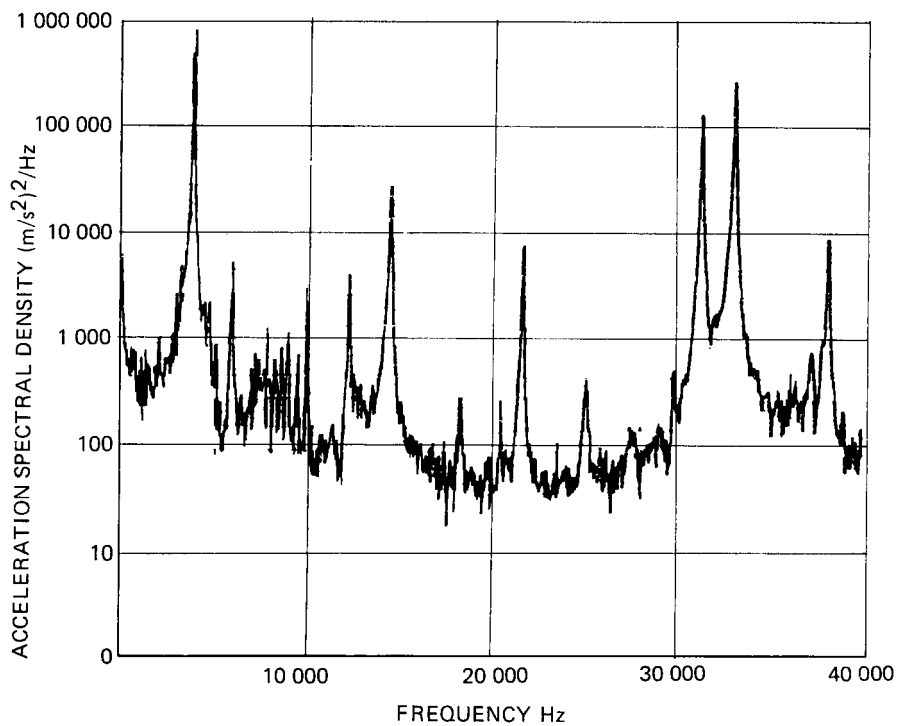


Figure 6. Narrow-band spectrum for the bucking bar.

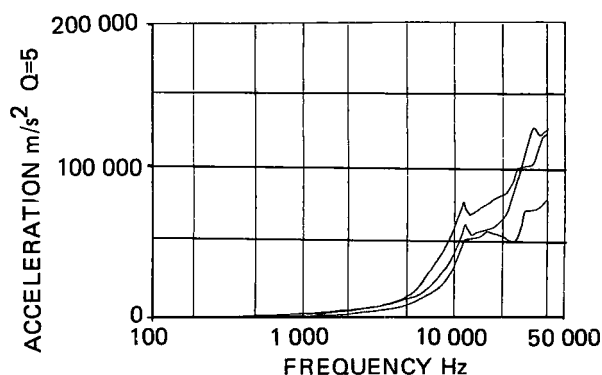


Figure 7. Response spectrum for the riveting hammer (Q = 5).

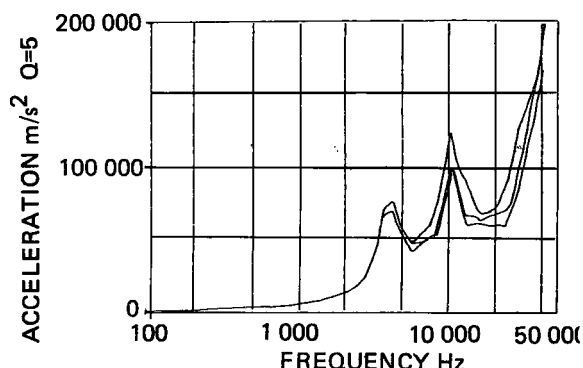


Figure 8. Response spectrum for the bucking bar (Q = 5).

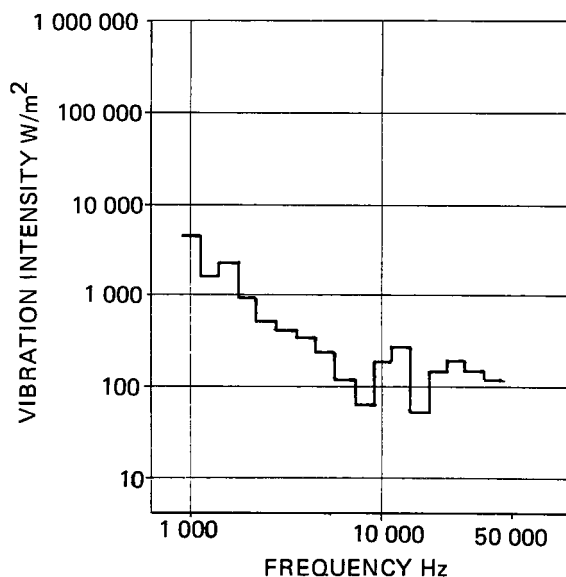


Figure 9. Vibration intensity expressed in watts per square meter for the riveting hammer.

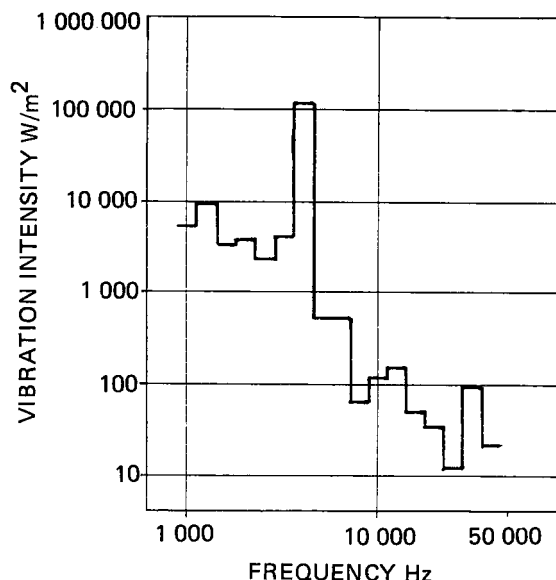


Figure 10. Vibration intensity expressed in watts per square meter for the bucking bar.

acceleration-time history (7). The numerical values obtained constitute a hypothetical measure of the response in the human being.

The spectrum can be calculated for any Q factor of the single-degree-of-freedom systems. Choice of the Q value is somewhat arbitrary; we chose $Q = 5$. However, the method works well for comparison between tools if the same Q factor is used and if it is realistic.

The measurement with the ultrasonic probe showed vibration intensities between 1 W/m^2 and 10 kW/m^2 in the frequency range of 200 to 700 kHz. There were also higher frequency components, but their intensity could not be evaluated with the instrument used.

Daily exposure time

During intensive riveting, the riveting hammer was in use, at the most, 6 % of the time riveting was going on. Between the riveting periods the work of prepara-

tion further reduces the actual riveting time. A riveting hammer is therefore very rarely in use more than a total of 15 min/workday with a mean of about 1 min/d.

Raynaud's phenomenon

Three hundred and forty riveters working at Saab-Scania in Linköping were studied (2). Their exposure time varied from one year up to 40 years, and 86 suffered from Raynaud's phenomenon (finger blanching). The guidelines in annex A of ISO/DIS 5349. 2 only considers exposure times up to 25 years. In our population 288 had worked up to 25 years, and 59 of them showed finger blanching. Fifty percent of those exposed for more than 10 years had Raynaud's phenomenon. During a typical workday the riveters use drills and rivet shavers in addition to the riveting equipment. These tools were measured and analyzed according to ISO/DIS 5349.2. The weighted acceleration was 2 m/s^2 for the drills and 5 m/s^2 for the rivet shavers.

Discussion

A risk assessment of the riveters according to annex A in ISO/DIS 5349, including all their vibrating tools and based upon the different individual exposures, gave an expected number of 14 injuries for the group of 288 riveters who had been using these tools up to 25 years. Our findings, 59 out of 288, exceeded the calculated risk by a factor of four. This result indicates that there must also be other factors that should be taken into account in ISO/DIS 5349.2 when risks for riveting tools are calculated. One obvious factor is the contribution from high frequencies. As shown in this study, acceleration was generated at frequencies well above 1 kHz. Lundström & Liszka (5) have presented a method for calculating the vibration intensity in watts per square meter from the one-third octave-band spectrum.

Vibration intensity calculated with Lundström & Liszka's method is shown in figures 9 and 10 for frequencies over 1 kHz. The total vibration intensity was around 10 kW/m² for the riveting hammer and around 250 kW/m² for the bucking bar. It should be noted that these are the mean values during the second that the riveting lasted.

An estimate of the time histories showed that acceleration higher than half the peak value appeared during 1.5 % of the riveting time. The maximum values therefore became much higher, in the region of 1 000 kW/m² for the riveting hammer and 25 000 kW/m² for the bucking bar.

Injuries during medical ultrasonic treatment have been described. Information in the literature about the injury risk varies. Some authors (1, 3) claim that risk of injury occurs at intensities above 1 to 10 kW/m². Lundström & Liszka (5) stated that machines generating ultrasound should be suspected of causing injuries at intensities around 10 W/m². They pointed out the need for continued studies of high-frequency vi-

bration in hand-held machines, a need which is also underlined by our study.

Response analysis gives a representative measure of the excitation as a function of frequency independent of the character of the time history. Its disadvantage is that the number of load cycles is normally not determined. However, the technique is well suited for nonstationary signals and may be useful in assessing risk of injury from percussion tools.

Acknowledgments

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