REDUCTION OF VIBRATIONS GENERATED BY AN IMPACT WRENCH

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1. INTRODUCTION

The 2002/44/EC directive of the European Parliament and of the Council established the minimum health and safety requirements regarding the exposure of workers to vibration.[1] The international standard coding hand-arm vibration (HAV) measurements establishes that the risk must be assessed using the vibration daily exposure A(8), determined from the weighted vibration measured at the hand vibrating part interface along three mutually perpendicular axes.[2] Given the definition of A(8), the exposure is affected by the vibration source amplitude and spectrum, by the operator biomechanical characteristics, and by the exposure time. The EU directive also defines the A(8) limits, together with the corrective actions that must be undertaken by the employer when these limits are exceeded. Corrective actions are based on vibration reduction or on limiting the time exposed to vibration. Reduction of the vibration can be obtained either by acting on the sources (e.g., changing the working principle of tools) or by auxiliary equipment to reduce the vibration transmitted to the operator.

We describe here the design and the verification of an anti vibration device (AVD) meant to reduce the HAV transmitted by an impact wrench. The tool has been initially characterized using different operators, postures, air pressures, grip and push forces. The optimal AVD mechanical characteristics have been identified starting from the average vibration spectrum and design constraints (AVD mass, deflection, damping along the three axes). Experimentally verified AVD performances demonstrated the validity of the proposed approach.

2. METHOD

2.1. Tool Description and Characterization

The tool studied is an impact wrench - the Ingersoll–Rand 3940 P2 Ti. The tool mass is 9.6 kg, the maximum torque is 3390 Nm, the free rotation speed is 5300 rpm and the tool is capable of 800 impacts per minute. According to the manufacturer, the tool produces both very high sound pressure level (106.6 dB(A)) and high vibration (10.9 m/s^2). The tool is used for fastening and unfastening bolts with both horizontal and vertical axes, in the presence of coke dust and water. A picture of the tool is shown in Figure 1. The users typically grip the tool with two hands: one grips the tool on the main handle, while the other is usually placed on the air supply (not shown in the figure).

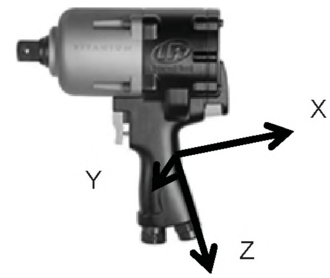

Figure 1. Impact wrench and reference coordinate system.

The tool vibration has been measured both in the field and on a purposely designed workbench: the effect of air pressure was included in the analysis. The non weighted vibration spectra possess components up to 2 kHz. The average weighted vibration spectra are shown in Figure 2.

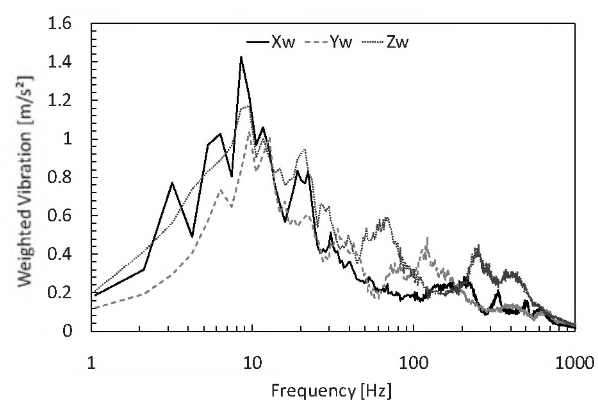

Figure 2. Vibration spectra for different working conditions.

Relevant frequency components are present both in the low frequency region (from 3 to 30 Hz) and at high frequencies, where no attenuation is provided by the metallic impact wrench frame. The weighted vibration levels along the X, Y and Z axes were 5.9, 6.4 and 8.8 m/s^2. The vector sum acceleration a_v was 12.4 m/s^2, i.e., slightly larger than the value declared by the manufacturer. A similar value (11.7m/s^2) was measured on the secondary grip (air supply pipe).

2.2. Method

The interaction between the tool and the operator was modeled with the lumped parameter scheme of Figure 3. The characteristics of the velocity generators (v_{eq}, three generators for each handle) were identified under the hypothesis of purely inertial tool impedance (Z_{eq} equal to $1/j\omega{\cdot}m$ where m is the tool mass) and with operator impedances derived from ISO 10068:1998[3].

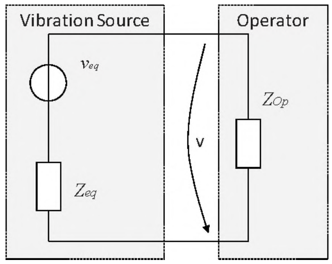

Figure 3. Characterization of the tool as a vibration generator

Once the characteristics of the vibration generators along the three axes have been identified, the characteristics of the suspension systems (stiffness k, viscous coefficient c and suspended mass m_{susp}) were identified with a constrained nonlinear optimization. The constraints considered in the suspension design concerned the total suspension system mass (lower than 1 kg), the maximum static deflection under the tool weight (10 mm) and some constructive details (damping achieved only with the materials' elastic hysteresis, vibration attenuation along three axes and use of both hands during fastening and unfastening operations). A simplified model considering each handle independently from the other was adopted. Also in this case, the three Z_{op} were derived from the ISO 10068:1998.[3]

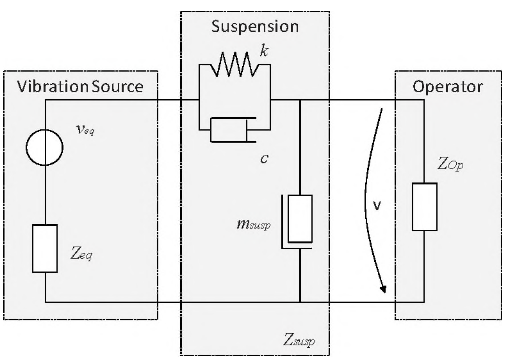

Figure 4. Lumped parameter scheme for interaction between the source, the suspension and the operator for each axis of each handle.

Given the nominal suspension characteristics, finite elements analysis was used to identify a geometry allowing the desired stiffness along the axial and radial directions to be obtained. Isolators were designed so as to have a nonlinear (increasing stiffness) behavior, in order to prevent the suspension from being ineffective in presence of high static handles loads. The mounting scheme is shown in Figure 5. Two different handles prototypes were designed and realized (Figure 6): both granted similar vibration attenuation, but the left one was judged more comfortable by users. In one case the pneumatic switch was moved to the rear handle for a more ergonomic tool control.

3. RESULTS

Given the nonlinear behavior of the elastic elements, vibration transmissibility strongly depended on the static forces that the operator exerts on the handles.

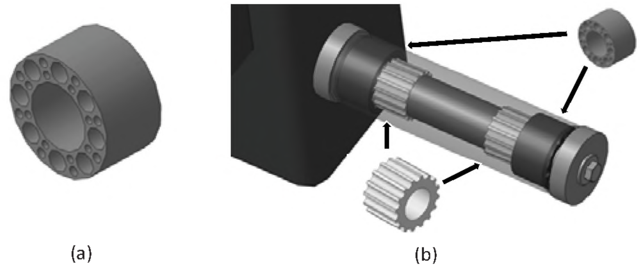

Figure 5. Isolators, a, and mounting on the lateral handle, b.

Figure 6. Pictorial views of the two handle prototypes

Laboratory characterizations were therefore scarcely representative. With the proposed solution a_v was reduced to 5.3 m/s^2 on the rear handle and 8.2 m/s^2 on the lateral handle (average of 30 on-field tests performed by three operators in fastening and unfastening operations) (see Figure 7). This vibration leads to practically no limitations given the typical fraction of time the tool is used during a normal work shift.

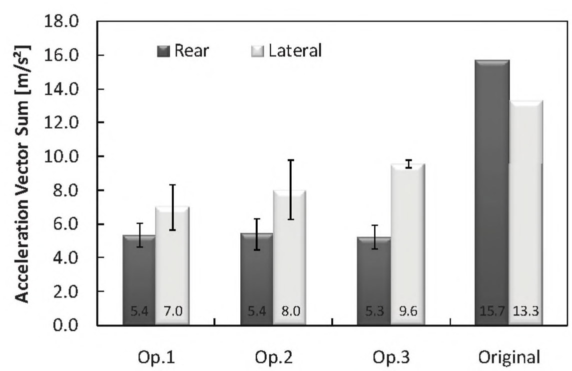

Figure 7. Performances of the proposed AVD

REFERENCES

1. EU Directive 2002/44/EC (2002). *On the Minimum Health and Safety Requirements Regarding the Exposure of Workers to the Risks Arising from Physical Agents.*

2. ISO 5349-1:2001. (2001). *Mechanical Vibration - Measurement and Evaluation of Human Exposure to Hand Transmitted Vibration - Part 1: General Requirements* (International Organization for Standardization, Geneva).

3. ISO 10068:1998. *Mechanical Vibration and Shock - Free, Mechanical Impedance of the Human Hand-Arm System at the Driving Point* (International Organization for Standardization, Geneva).