INTERNATIONAL STANDARD

ISO 18312-1

First edition
2012-01-15

Mechanical vibration and shock — Measurement of vibration power flow from machines into connected support structures —

Part 1:
Direct method

Vibrations et chocs mécaniques — Mesurage du flux de puissance vibratoire transmis par des machines aux structures de support dont elles sont solidaires — Partie 1: Méthode directe

Reference number
ISO 18312-1:2012(E)

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 18312-1 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration, shock and condition monitoring*.

ISO 18312 consists of the following parts, under the general title *Mechanical vibration and shock — Measurement of vibration power flow from machines into connected support structures*:

— *Part 1: Direct method*

— *Part 2: Indirect method*

Mechanical vibration and shock — Measurement of vibration power flow from machines into connected support structures —

Part 1: Direct method

1 Scope

This part of ISO 18312 specifies a method for evaluating the vibration power emitted by machines or pipelines, referred to hereinafter as machines, under operational conditions on to supporting structures to which the machines are directly connected via bolted joints. This part of ISO 18312 specifies the method for evaluating the vibration power components emitted in the six degrees of freedom of a Cartesian coordinate system at each joint, i.e. three translations and three rotations. The vibration power is determined by processing the signals from force and velocity (or acceleration) transducers mounted on to the bolted joints under operational conditions of interest. This method is applicable for machines under the assumption that their vibration can be characterized by a stationary random process.

The components of emitted vibration power in the frequency domain are obtained by computing the cross-spectrum of the force and velocity measurement pairs with a given narrow band width at each bolted joint.

This direct method assumes that the supporting structures are adequately rigid and, hence, it is not applicable to cases where the foundation or supporting structures are resilient, which will potentially go into a state of resonance within the frequency range of interest. Practical frequency limits of the method are specified in this part of ISO 18312.

This part of ISO 18312 can be used in operational conditions for:

a) specification of vibration power emission of machines at the (bolted) joints;

b) identification of vibration power severity;

c) resolving diagnostics issues;

d) planning vibration control measures.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 2041, *Mechanical vibration, shock and condition monitoring — Vocabulary*

ISO 5348, *Mechanical vibration and shock — Mechanical mounting of accelerometers*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2041 and the following apply.

3.1
vibration velocity vector
$\boldsymbol{v}^n$
velocity vector at the nth bolt joint, consisting of three translational and three rotational components along the coordinate axes x, y and z

3.2
vibration velocity component

v_i^n

component of the vibration velocity vector in the degree of freedom i at the nth bolted joint; i = 1, 2 and 3 for linear components in the x-, y-, and z-directions, respectively, and i = 4, 5 and 6 for angular components in the x-, y- and z-directions, respectively

3.3
vibration acceleration component

a_i^n

vibration acceleration component in the degree of freedom i at the nth bolted joint

3.4
root mean square value of acceleration component
r.m.s. value of acceleration component

$a_{i:\text{rms}}^n$

root mean square value of the vibration acceleration component in the degree of freedom i at the nth bolted joint

3.5
force vector

$\boldsymbol{F}^n$

vibration force vector at the nth joint, consisting of three components of linear force and three components of angular force, i.e. moment, along the coordinate axes x, y and z

3.6
force component

F_i^n

component of the vibration force vector in the degree of freedom i at the nth joint; i = 1, 2 and 3 for force components in the x-, y- and z-directions, respectively, and i = 4, 5 and 6 for moment components in the x-, y- and z-directions, respectively

3.7
vibration power component

P_i^n

vibration power in the degree of freedom i at the nth bolted joint, equal to the time-averaged scalar product of the vibration force vector and vibration velocity vector in the degree of freedom i at the nth bolted joint

Note to entry: A vibration power component is expressed in watts.

3.8
vibration power at a joint

P^n

vibration power at the nth bolted joint, equal to the sum of the vibration power components in each degree of freedom at that point

3.9
vibration power

P

sum of vibration power of the machine over all joints and in every degree of freedom

3.10
vibration power spectrum

$P(f, \Delta f)$

decomposition of the vibration power of the machine into frequency domain with a given centre frequency, f, narrow frequency band, Δf, equal to the sum of the vibration power spectra over all joints and in every degree of freedom

3.11
component of vibration power spectrum

$P_i^n(f, \Delta f)$

spectrum of the vibration power transmitted in the degree of freedom i at the nth joint

3.12
vibration power spectrum at a joint n

$P^n(f, \Delta f)$

spectrum of the vibration power transmitted at the nth joint

3.13
component of vibration power cross spectrum

$G_{F_i v_i}^n(f)$

cross spectrum of a vibration force component, $F_i(t)$, and a vibration velocity component, $v_i(t)$, in the degree of freedom i at the nth joint

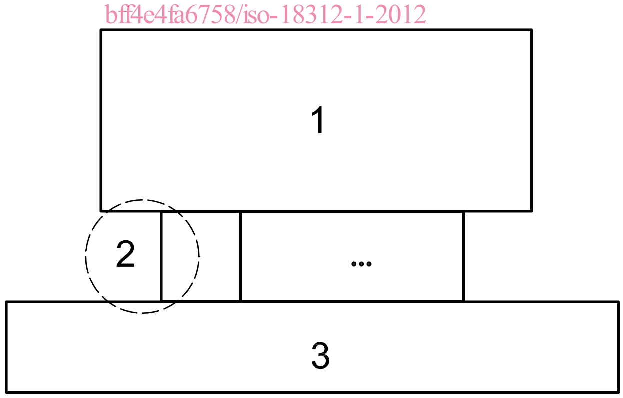
3.14
vibration power level

$$L_W = 10 \lg \frac{P}{P_0} \text{ dB}$$

common logarithm of the ratio of measured vibration power to the reference value, P_0 = 1 pW, corresponding to zero level of vibration power

4 Fundamentals

The layout of a machine bolted directly on to the foundation structure at multiple joints is shown in Figure 1 and the detail of a bolted joint is shown in Figure 2 together with a coordinate system, where the z-axis is chosen in parallel with the bolt axis.



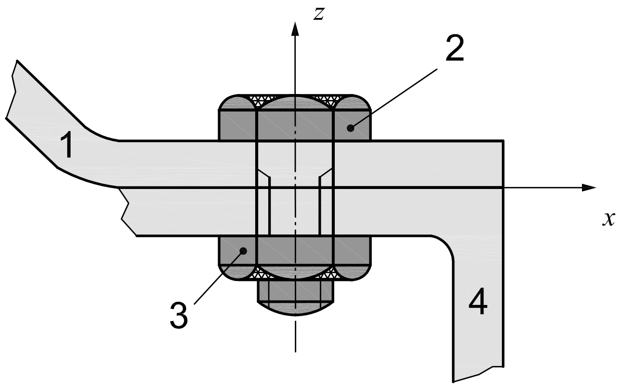
Key

1 machine

2 bolted joints

3 foundation

Figure 1 — Layout of machine bolted on to foundation directly at multiple joints



Key

1 machine leg

2 bolt

3 nut

4 foundation flange

Figure 2 — Coordinate system of a bolted joint

Vibration power emitted by the machine on to the foundation via the nth bolted joint is defined as the time average of scalar product of the force vector and velocity vector as follows:

$$P^n = \frac{1}{L}\int_0^L \boldsymbol{F}^n(t)\cdot \boldsymbol{v}^n(t)\,\mathrm{d}t = \frac{1}{L}\int_0^L \sum_{i=1}^{6} F_i^n(t) v_i^n(t)\,\mathrm{d}t = \sum_{i=1}^{6} \frac{1}{L}\int_0^L F_i^n(t) v_i^n(t)\,\mathrm{d}t \quad (1)$$

where the term within the summation on the most right hand side

$$\frac{1}{L}\int_0^L F_i^n(t) v_i^n(t)\,\mathrm{d}t \equiv P_i^n$$

denotes vibration power emitted in the degree of freedom i at the nth joint with the index i = 1 to 3 denoting the linear or translational degrees of freedom and the index i = 4 to 6 denoting the angular or rotational degrees of freedom. The record length L in Equation (1) shall be far greater than the fundamental period of the measured signals. In practice, contributions of the rotational components in Equation (1) due to angular velocities and moments may be omitted when difficulty of measurements exists. The total vibration power emitted by a machine with multiple bolted joints on to the support structure can be obtained just by summing up the vibration power transmitted via each bolted joint in Equation (1). Vibration power is a scalar quantity and, hence, the total vibration power emitted from a machine with a number of bolted joints, K, is given simply by a sum:

$$P = \sum_{n=1}^{K} P^n \quad (2)$$

The vibration power in the ith degree of freedom at the nth joint, P_i^n, can be resolved into the frequency domain by taking real parts of the cross power spectrum $G_{F_i v_i}^n(f,\Delta f)$ from the force signal $F_i^n(t)$ and velocity signal $v_i^n(t)$ using a commercial signal analyser as follows:

$$P_i^n(f,\Delta f) = \mathrm{Re}\left[G_{F_i v_i}^n(f,\Delta f)\right] \quad (3)$$

where Re[•] denotes the real part of a complex quantity • and the unit of $P_i^n(f,\Delta f) = \mathrm{Re}\left[G_{F_i v_i}^n(f,\Delta f)\right]$ is watt at a centre frequency, f, over a narrow frequency band, Δf, e.g. 1 Hz when the units of the force and velocity are newton and metre per second, respectively. If acceleration $a_i^n(t)$ in metre per second squared is measured instead of the velocity $v_i^n(t)$ in metre per second, the vibration power in Equation (3) is given in a slightly different format as follows:

$$P_i^n(f,\Delta f) = \frac{1}{2\pi f}\text{Im}\left[G_{F_i a_i}^n(f,\Delta f)\right] \tag{4}$$

where Im[•] denotes the imaginary part of the complex quantity •. The sum of the vibration power over frequencies, degrees of freedom, and all the mounts of interest can now be easily calculated. When a partial vibration power over a specific frequency range of interest, in hertz, e.g. from f_{min} to f_{max} is of interest, it can be obtained simply by summing the vibration power spectrum $P_i^n(f,\Delta f)$ in Equation (3) or (4) as follows:

$$P_i^n(f_{\text{min}} \sim f_{\text{max}}) = \sum_{k=1}^{N} P_i^n\left\{\left[f_{\text{min}} + (k-1)\Delta f\right], \Delta f\right\} \tag{5}$$

where N is the number of frequency points over the frequency range of interest given by

$$N = \frac{f_{\text{max}} - f_{\text{min}}}{\Delta f}$$

in case of a narrow frequency band analysis. Once the vibration power spectrum is available in a narrow band from Equations (3) and (4), the vibration power spectrum over one-third octave band or other octave bands can be obtained by simply summing over the bandwidths of interest.

5 Measurement

5.1 General

This part of ISO 18312 specifies how to evaluate the vibration power transmitted by a machine on to its foundation from the measurement of forces and vibration at the bolted joints. Such measurements are not limited to translational degrees of freedom, but may be extended to rotational degrees of freedom, depending upon the capabilities of the employed transducers. This clause explains how to install the vibration and force transducers.

5.2 Arrangement of vibration transducers

One multi-axial vibration transducer is placed on a joint bolt head as shown in Figures 3 and 4 such that the directions of measurement are aligned with the x- and z-coordinates described in Figure 2. A flat surface on the machine’s leg, close to the bolted joint, can also be used if multiple uni-axial transducers are to be placed individually. Details of mounting shall be in accordance with ISO 5348.

5.3 Measurement of forces

5.3.1 General

The forces acting through the bolted joints from the machine on to the foundation can be measured by placing one transducer (see Figure 3) or two transducers (see Figure 4) in the bolted joints. In both cases, this part of ISO 18312 assumes the use of integrated triaxial force transducers.

There should be no local resonance near the bolting joint for the method of force measurement by inserting the force transducers at the joint to be effective. A torque wrench should be used to maintain the torque with the force transducers inserted at the value without those.