INTERNATIONAL STANDARD

# ISO 15230

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# Mechanical vibration and shock — Coupling forces at the man-machine interface for hand-transmitted vibration

*Vibrations et chocs mécaniques — Forces de couplage à l'interface homme-machine en cas de vibrations transmises par les mains*



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# Contents

Page





 

# Foreword

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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.

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ISO 15230 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration, shock and condition monitoring*, Subcommittee SC 4, *Human exposure to mechanical vibration and shock*.

## Introduction

The coupling forces between the hand-arm system and a hand-held or hand-guided machine during its use are very important factors. Although these forces are of interest for both vibrating and non-vibrating machines, the primary focus of this International Standard is to provide a set of descriptions of the forces at the man-machine interface that are primarily for the hand-arm system in contact with a vibrating surface of a machine.

The coupling forces involved in the operation of a vibrating machine generally consist of two different components. The first component is the force applied by the hand-arm system, which is used to provide necessary control and guidance of the machine and to achieve desired productivity. This quasi-static force (frequency below 5 Hz) is the focus of this International Standard. The second component is the biodynamic force which results from the biodynamic response of the hand-arm system to a vibration.

Different couplings of the hand to a vibrating surface can affect the human body in two different ways.

— The relationship between the measured handle vibration and the resultant transmission of vibration to the hand-arm system might be altered. This alteration modifies the exposure and the vibration effect to the hand-arm system.

— The coupling can result in a synergistic effect with vibration exposure which affects anatomical structures, such as the vascular system, nerves, joints, tendons.



Currently, many machine situations have been modelled by numerous basic physiological studies investigating the effect of vibration on the human body, which use push force and gripping force to describe the coupling force between the hand and the machine handle.



This International Standard can assist in the reporting of coupling data in epidemiological or laboratory research.

In the future, the measurements taken at the workplace for the determination and evaluation of mechanical vibration affecting human beings could need to take into account the influence of the contact of the hand-arm system in the vibrating surface. The measurements of relevant coupling forces and the vibration acceleration will need to be taken simultaneously to account for the potential interactions.

# Mechanical vibration and shock — Coupling forces at the man-machine interface for hand-transmitted vibration

## 1 Scope

This International Standard describes the coupling parameters between the hands of a machine operator and a vibrating surface of the machine.

The coupling between the hand and the vibrating surface can be described using different parameters and component parts of these parameters:

— force parameters, such as push, pull and grip;

— parameters such as pressure exerted on skin.

In addition, informative annexes provide guidelines for measuring procedures, the measurement of the force and pressure parameters, and information on the requirements for measuring instrumentation, as well as a calibration method.



This International Standard does not deal with forces which act tangentially to the hand.



## 2 Symbols and abbreviated terms

### 2.1 Symbols

$F$ force

$i$ integer for summation

$n$ total number of elements to be summed

$p_i$ local pressure at surface element $i$

$S$ surface

$t$ time

$T$ duration of operation

$\alpha$ hand-oriented angle of the dividing plane

$\beta$ machine-oriented angle of the dividing plane

$\delta$ coefficient of the proportionality for the gripping force

$\gamma$ coefficient of the proportionality for the push force

## 2.2 Subscripts

| | |
|---|---|
| BD | biodynamic force |
| c | contact |
| coup | coupling |
| f | feed |
| g | guiding |
| gr | gripping |
| l | lifting |
| m | mean value |
| max | maximum |
| n | normal |
| pu | push or pull |
| $x$, $y$, $z$ | Cartesian coordinates |

# 3 Parameters at man-machine interface



## 3.1 Pressure exerted on skin

### 3.1.1 Area element of surface



The area element of the surface, $S_i$, is given using Equation (1):

$$\vec{S}_i = S_i \cdot \vec{S}_{\mathrm{n},i} \quad (1)$$

with the unit vector, $\vec{S}_{\mathrm{n},i}$, in the normal direction to the area element. (See Figure 1.)

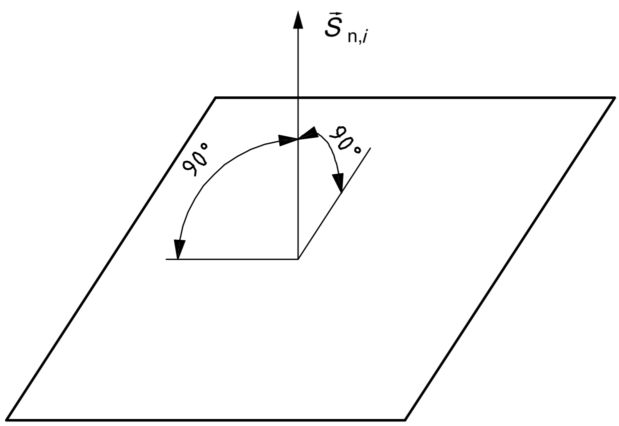



**Figure 1 — Direction of the area elements, $S_i$**

### 3.1.2 Local pressure

The local pressure, $p_i$, exerted on an area element of the surface, $S_i$, of the hand skin is given as the ratio between the perpendicular component of the area element contact force, $F_{c,i}$ (see 3.1.5), applied in the middle of this area element and the area of this surface, as given by Equation (2):

$$p_i = \frac{F_{c,i}}{S_i} \tag{2}$$

When reporting local pressure values, the area element surface area should be reported.

NOTE Depending on the operator, hand location, tool and task, local pressure $p_i$ usually ranges between zero and 0,8 N/mm$^2$. Values above this pressure range can be perceived as painful.

### 3.1.3 Mean pressure

The mean pressure, $p_m$, exerted on the surface of the hand in contact with the machine or a part of the machine is calculated as average pressure using Equation (3):

$$p_m = \frac{\sum_{i=1}^{n} p_i \cdot S_i}{\sum_{i=1}^{n} S_i} \tag{3}$$



### 3.1.4 Maximum local pressure

The maximum local pressure, $p_{max}$, is the highest pressure value measured on the hand surface in contact with the machine, calculated using Equation (4):



$$p_{max} = \max\{p_i\} \tag{4}$$

### 3.1.5 Elemental contact force

The elemental contact force, $F_{c,i}$, is given by Equation (5):

$$F_{c,i} = p_i \cdot S_i \tag{5}$$

where

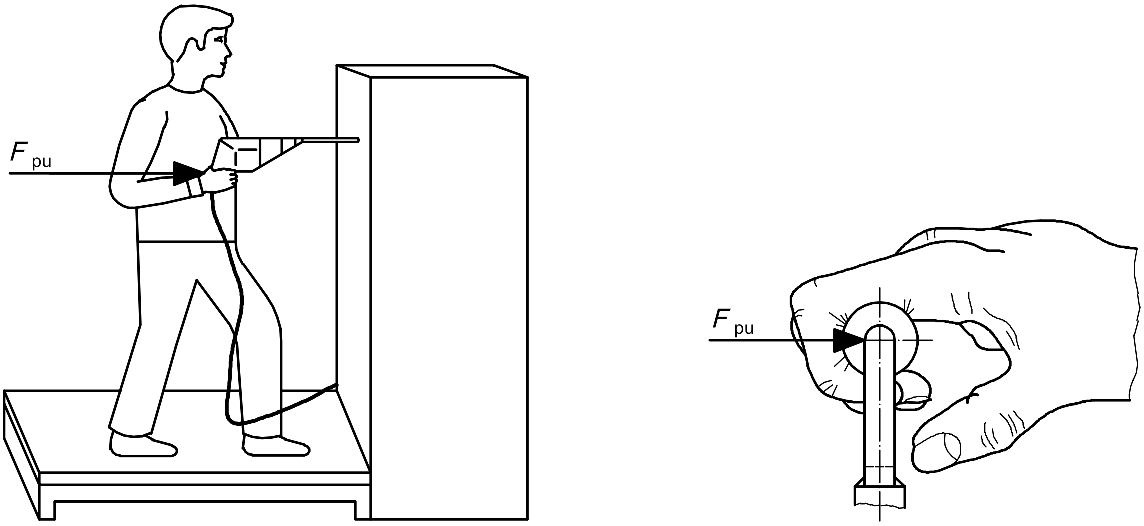
$p_i$ is the pressure over the $i$th surface element;

$S_i$ is the elemental surface area of the hand skin.

The direction of $F_{c,i}$ is normal to the vibrating surface.

## 3.2 Push/pull force

The push force, $F_{pu}$, is the force exerted by the operator away from his shoulder on the vibrating surface via each hand and not compensated within the coupling surface of the hand. The pull force, $F_{pu}$, is the force exerted by the operator towards his shoulder via each hand. (See Figure 2.)




a) Push force b) Pull force

**Figure 2 — Example of push force, $F_{pu}$, and pull force, $F_{pu}$**

NOTE 1 In some cases, the operation involves both push and pull forces. The push and pull forces can act at different positions on the hand. However, both forces are denoted by $F_{pu}$.

NOTE 2 Push force $F_{pu}$ can be a very significant force, such as the required pushing of a drill, and needs always to be considered.



## 3.3 Guiding force

The guiding force, $F_g$, is the force exerted by the operator on the vibrating surface via either hand in a horizontal or nearly horizontal plane tangentially to the push and/or pull force and not compensated within the coupling surface of the hand. This force is mostly necessary to hold or to move the machine, workpiece or control lever. (See Figure 3.)

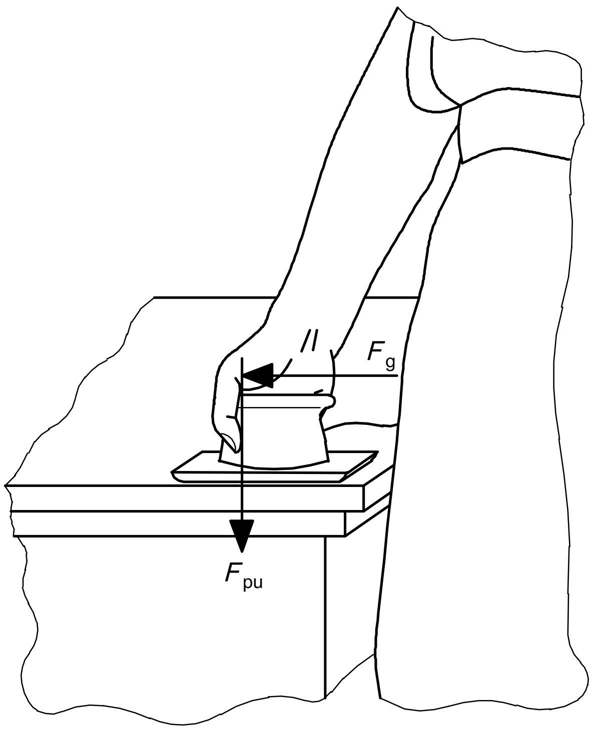
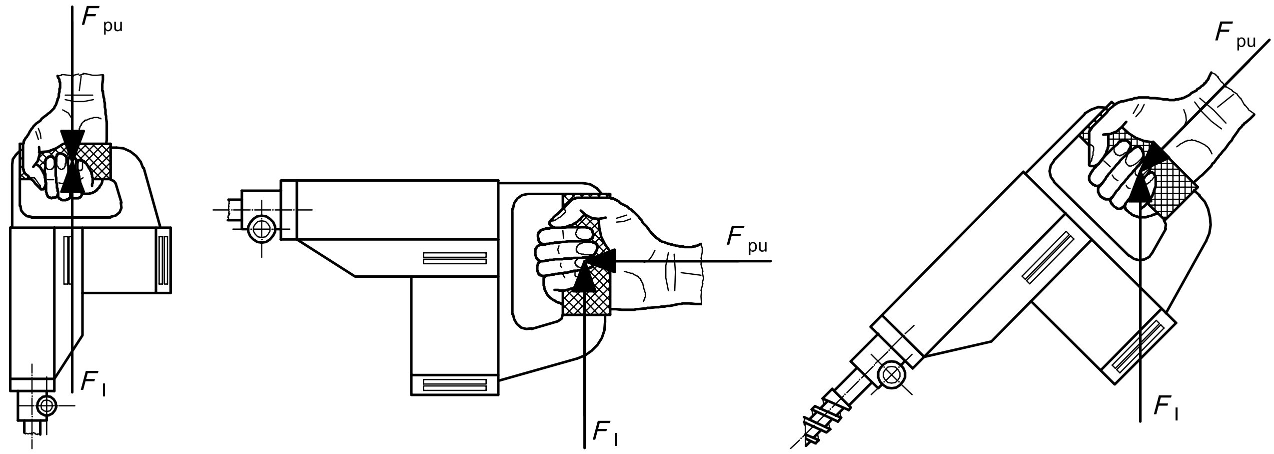



**Figure 3 — Example of guiding force, $F_g$, with indication of push force, $F_{pu}$**

NOTE $F_g$ has the potential to be a low magnitude force when the surface is horizontal.

### 3.4 Lifting force

The lifting force, $F_l$, is the force which is necessary to counteract the machine weight. (See Figure 4.)




a) b) c)

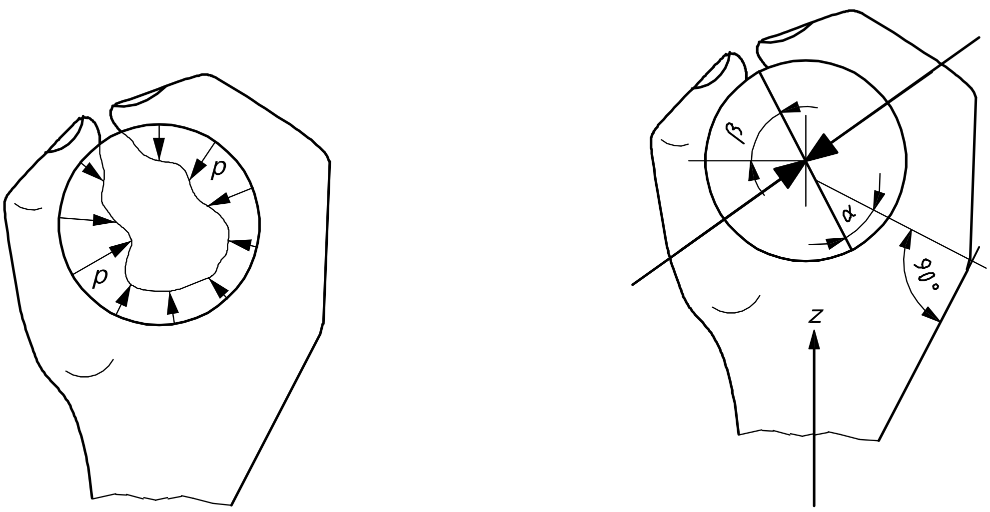
**Figure 4 — Example of lifting force, $F_l$, with indication of push force, $F_{pu}$**

NOTE In some cases, it is possible for lifting force, $F_l$, to equal push/pull force, $F_{pu}$ [see Figure 4 a)].



### 3.5 Gripping force

The gripping force, $F_{gr}$, is half the sum of the force components acting towards an axis inside the handle without push, pull or lifting forces. Simplified, the gripping force is the clamp-like force exerted by the hand of the operator when enclosing the handle. The force is compensated within the hand by a gripping force acting in the opposite direction towards a dividing plane. (See Figure 5.)




a) **Pressure field, *p***

b) **Clamp-like force**

**Key**

$\alpha$ hand-oriented angle of the dividing plane

$\beta$ machine-oriented angle of the dividing plane

NOTE The $z$ axis is along the forearm.

**Figure 5 — Example of gripping force, $F_{gr}$, as clamp-like force**

NOTE 1 When the operator is gripping a cylindrical handle, the direction of the main gripping force is generally parallel to the $z$ axis as defined in ISO 8727.

NOTE 2 Because the grip contact pressure is usually unevenly distributed around the handle, the magnitude of the gripping force is generally a function of the reference axis or dividing plane. The orientation of the maximum or minimum gripping force generally depends on handle dimensions, hand sizes and hand-grip posture. For simplicity's sake, the gripping force in the forearm-based $z$ axis shown in Figure 5 b) is conventionally used in the measurement and/or control of the gripping force in laboratory studies.

## 3.6 Feed force

The feed force, $F_f$, is the external force acting on the machine. (See Figure 6.)

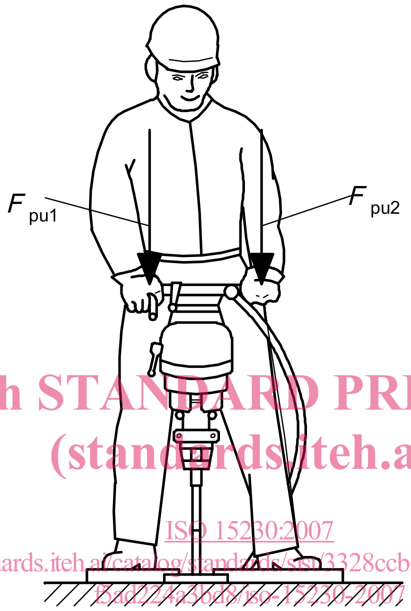




**Figure 6 — Example of feed force, $F_f$**

NOTE In Figure 6, the feed force, $F_f$, is equal to the sum of the push force, $F_{pu1}$, $F_{pu2}$. Whereas, in Figure 2 a), the feed force, $F_f$, is equal to the push force, $F_{pu}$.

## 3.7 Contact forces

In general, the contact forces, $F_c$, are those forces which act between the hand and the vibrating surface. They are the elemental forces integrated over the contact area (see 3.1.5). These are vector forces which act both perpendicularly and tangentially to the vibrating surface. The tangential force is not considered at this time because of the difficulty of measurement. The contact force can represent the average values of pressures but might not provide information on distributions resulting in moments that can balance external moments, which can be described as torques around specific axes (see 3.9). The moments or torques can be calculated when the pressure distribution is available.

This International Standard concentrates on the perpendicular component of these contact forces, $F_c$, which, for many vibrating surfaces, are those which primarily effect the transmission of vibration into the hand (see Figure 7).

The contact forces can be determined through integration of the measured pressure distribution between the hand and the handle. Studies have shown that the total static contact forces can be related to the gripping and push forces, $F_{gr}$ and $F_{pu}$, through a linear relationship, Equation (6):

$$F_c = \delta F_{gr} + \gamma F_{pu} \quad (6)$$