SLOVENSKI STANDARD
SIST EN 1005-5:2007

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Varnost strojev - Ļloveġke fiziļ ne zmogljivosti - 5. del: Ocena tveganja rokovanja z veliko pogostostjo ponavljanja

Safety of machinery - Human physical performance - Part 5: Risk assessment for repetitive handling at high frequency

Sicherheit von Maschinen - Menschliche körperliche Leistung - Teil 5: Risikobeurteilung für kurzzyklische Tätigkeiten bei hohen Handhabungsfrequenzen

Sécurité des machines - Performance physique humaine - Partie 5: Appréciation du risque relatif a la manipulation répétitive a fréquence élevée

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN Management Centre has the same status as the official versions.

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Contents

Foreword

This document (EN 1005-5:2007) has been prepared by Technical Committee CEN/TC 122 "Ergonomics", the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by August 2007, and conflicting national standards shall be withdrawn at the latest by August 2007.

As a result of the assessment of the CEN consultant the standard will be published a non-harmonized standard (no reference to Machinery directive and no publication in the Official Journal of EC).

EN 1005 consists of the following Parts, under the general title *Safety of machinery — Human physical performance*:

— *Part 1: Terms and definitions (harmonized standard);*

— *Part 2: Manual handling of machinery and component parts of machinery (harmonized standard);*

— *Part 3: Recommended force limits for machinery operation (harmonized standard);*

— *Part 4 : Evaluation of working postures and movements in relation to machinery (harmonized standard);*

— *Part 5: Risk assessment for repetitive handling at high frequency (non-harmonized standard).*

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Introduction

Within the life cycle of a machine from construction to dismantling, various machine-related actions may require repetitive handling at high frequency. Repetitive handling at high frequency can cause musculoskeletal strain and the risk of fatigue, discomfort and musculoskeletal disorders. The designer of a machine should seek to minimise these health risks by taking into account a variety of risk factors including the frequency of actions, the force, postures, durations, lack of recovery and other additional factors.

NOTE 1 Although factors such as duration and lack of recovery periods are relevant factors when assessing risk in relation to human physical performance in the workplace, these factors are controlled by the member states own national legislation, contract agreements with social partners and are not in the scope of this European Standard.

The risk assessment method in this European Standard gives guidance to the designer how to reduce health risks for the operator.

This European Standard is written in conformity with EN ISO 12100-1 and provides the user with guidance for hazard identification for harm through musculoskeletal overload and tools for qualitative and, to an extent, a quantitative risk assessment. The risk assessment tools also indicate how to achieve risk reduction. This European Standard does not deal with risks related to accidents.

The recommendations provided by this European Standard are based on available scientific evidence concerning the physiology and epidemiology of manual work. The knowledge is, however, limited and the suggested guidelines are subject to changes according to future research.

This European Standard is a type B standard as stated in EN ISO 12100-1.

The provisions of this European Standard can be supplemented or modified by a type C standard.

NOTE 2 For machines which are covered by the scope of a type C standard and which have been designed and built according to the provisions of that standard, the provisions of that type C standard take precedence over the provisions of this type B standard.

1 Scope

This European Standard presents guidance to the designer of machinery or its component parts and the writer of type C standards in assessing and controlling health and safety risks due to machine-related repetitive handling at high frequency.

This European Standard specifies reference data for action frequency of the upper limbs during machinery operation, and it presents a risk assessment method intended for risk reduction option analysis.

This European Standard applies to machinery for professional operation by the healthy adult working population. This European Standard is not applicable for repetitive movements and related risks of the neck, back and lower limbs.

2 Normative references

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

EN 614-1, *Safety of machinery — Ergonomic design principles — Part 1: Terminology and general principles*

EN 614-2, *Safety of machinery — Ergonomic design principles — Part 2: Interactions between the design of machinery and work tasks*

EN 1005-2, *Safety of machinery — Human physical performance — Part 2: Manual handling of machinery and component parts of machinery*

EN 1005-3:2002, *Safety of machinery — Human physical performance — Part 3: Recommended force limits for machinery operation*

EN 1005-4:2005, *Safety of machinery — Human physical performance — Part 4: Evaluation of working postures and movements in relation to machinery*

EN 1050, *Safety of machinery — Principles for risk assessment*

EN ISO 12100-1, *Safety of machinery — Basic concepts, general principles for design — Part 1: Basic terminology, methodology (ISO 12100-1:2003)*

EN ISO 12100-2, *Safety of machinery — Basic concepts, general principles for design — Part 2: Technical principles (ISO 12100-2:2003)*

EN ISO 14738:2002, *Safety of machinery — Anthropometric requirements for the design of workstations at machinery (ISO 14738:2002)*

ISO/IEC Guide 51, *Safety aspects — Guidelines for their inclusion in standards*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

NOTE Terms and definitions used in EN and ISO standards referred to in this European Standard are also valid for this European Standard.

3.1
repetitive task
task characterized by repeated work cycles

3.2
work cycle
sequence of technical actions that are repeated always the same way

3.3
cycle time
time elapsing from the moment when one operator begins a work cycle to the moment that the same work cycle is started (in seconds)

3.4
technical action
elementary manual actions required to complete the operations within the work cycle, such as holding, turning, pushing, cutting

3.5
repetitiveness
characteristic of task when a person is continuously repeating the same work cycle, technical actions and movements

3.6
frequency of actions
number of technical actions per minute

3.7
force
physical effort of the operator required to execute the technical actions

3.8
postures and movements
positions and movements of body segment(s) or joint(s) required to execute the technical actions

3.9
recovery time
period of rest following a period of activity in which restoration of human tissue can occur (in minutes)

3.10
additional factors
risk factors which include other factors for which there is evidence of causal or aggravating relationship with work-related musculoskeletal disorders of the upper limb, e.g. vibrations, local pressure, cold environment, cold surfaces

4 Abbreviations

For the purposes of this document, the following abbreviations apply.

Acronyms	**Legend for abbreviations**
Ad_M	Additional factors Multiplier
ATA	Number of Actual Technical Actions within a shift
CF	“Constant of Frequency” of technical actions per minute
D	net Duration in minutes of each repetitive task
Du_M	Duration Multiplier
FCT	Foreseeable duration of the Cycle Time (in seconds)

FF	Foreseeable Frequency of technical actions per minute
Fo_M	Force Multiplier
j	generic repetitive tasks
MSDs	Musculo-Skeletal Disorders
n	Number of repetitive task/s performed during shift
NEP	Number of Exposed Persons
NPA	Number of Persons Affected by one or more UL-WMSDs
NTC	Number of technical actions in the work cycle
OCRA	OCcupational Repetitive Action
PA	Prevalence (%) of persons Affected
RF	Reference Frequency of technical actions per minute
Po_M	Posture Multiplier
Rc_M	Recovery Multiplier
Re_M	Repetitiveness Multiplier
RTA	Number of Reference Technical Actions within a shift
S.E.	Standard Error
UL-WMSDs	Upper Limb Work-related Musculo-Skeletal Disorders

5 Requirements

5.1 The application of standards relevant to this document

The designer shall consider the principles given in EN 1050, EN 614-1 and EN 614-2, EN 1005-2, EN 1005-3, EN 1005-4, EN ISO 12100-1 and EN ISO 12100-2 and EN ISO 14738.

5.2 General aspects

The designer of a machine is required to:

a) conduct an assessment of risk of musculoskeletal disorders due to machine related repetitive work;

b) take account in the assessment of the single and combined effects from the most relevant risk factors as repetitiveness, force, working postures, foreseen work duration, lack of recovery periods and additional factors;

c) if possible try to avoid risk 'at the source' or alternatively to minimise these health risks by changes in the machinery design (automation, technical aids);

d) when all is done to minimize the risk it is an obligation to inform about residual risks in instructions for use.

Machines and related tasks shall be designed in a way, so that activities demanding high frequency can be performed adequately with respect to the force required, the posture of the limbs and the foreseeable presence of recovery periods. In addition machines and related tasks shall be designed to allow for variations in movements. Additional factors (see 3.11) have to be considered.

When designing machinery and work tasks, the designer shall ensure that the following ergonomics characteristics of well-designed work tasks are fulfilled. These characteristics take into account the differences and dynamic characteristics of the intended operator population, and shall be pursued by designing machinery and machinery related work tasks in interaction (EN 614-2).

Thus, in design process the designer shall also (see EN 614-2):

i) avoid overload as well as under load of the operator, which may lead to unnecessary or excessive strain, fatigue or to errors. Frequency, duration and intensity of perceptual, cognitive and motor activities shall be designed so as to avoid these consequences;

ii) avoid repetitiveness for the operator, which may lead to unbalanced work strain and thus to physical disorders as well as to sensations of monotony, satiation, boredom or to dissatisfaction.

Short work cycles should therefore be avoided. The operator shall be provided with an appropriate variety of tasks or activities. If repetitive task cannot be avoided:

- cycle time shall not be determined solely on the basis of average time measures or estimated under normal conditions;
- allowances shall be given for deviations from normal conditions;
- very short cycle times shall be avoided;
- opportunities shall be given to the operator to work at his/her own pace, rather than at set pace;
- working on moving objects shall be avoided.

5.3 Risk assessment

5.3.1 General

In this standard risk assessment of musculoskeletal disorders of the upper limb resulting from repetitive handling is described.

The technical action is identified as the specific characteristic relevant to repetitive movements of the upper extremities. The technical action is factored by its relative frequency during a certain time period.

The frequency of technical actions of the upper limbs is related to other risk factors such as force (the greater the force, the lower the frequency), posture (the greater the joint excursion, the longer the time necessary to carry out an action) and recovery periods (if well distributed during the shift, they increase the recovery of muscular function).

Some additional factors can increase the need for force (e.g. awkward tools or personal protective equipment e.g. gloves that interfere with the grasp or movements). Other additional factors can cause damage to human tissue e.g. muscles, tendons and vessels (vibration, compression, cold surfaces).

Data from recent epidemiological studies on workers exposed to repetitive movements of upper limbs allow, among others, designers to forecast from exposure indexes the occurrence of the consequences for Upper Limbs Work-related Musculoskeletal Disorders (UL-WMSDs) [32, 34, 35]. Annex D describes a method of determination. The acceptable situation occurs when the exposure index, given in 5.3.3 (method 2) is not exceeding a level that corresponds to the occurrence of UL-WMSDs as observed in a working population not exposed to occupational risks for the upper limbs [11, 34].

When repetitive handling is unavoidable then a risk assessment and risk reduction approach shall be adopted. In accordance with ISO Guide 51 and EN 1050, this should follow a four-step approach: hazard identification, risk estimation, risk evaluation and risk reduction.

It is recommended to simulate tasks at least once by actual users with a full-size model/prototype of the machinery or the machinery itself (refer to EN 614-1, ergonomic task 'evaluate with users'; see also EN 1005-4:2005, 4.2 ‘Guidance towards risk assessment’).

The following procedure should be adopted when conducting a risk assessment of machinery design involving repetitive handling (Figure 1).

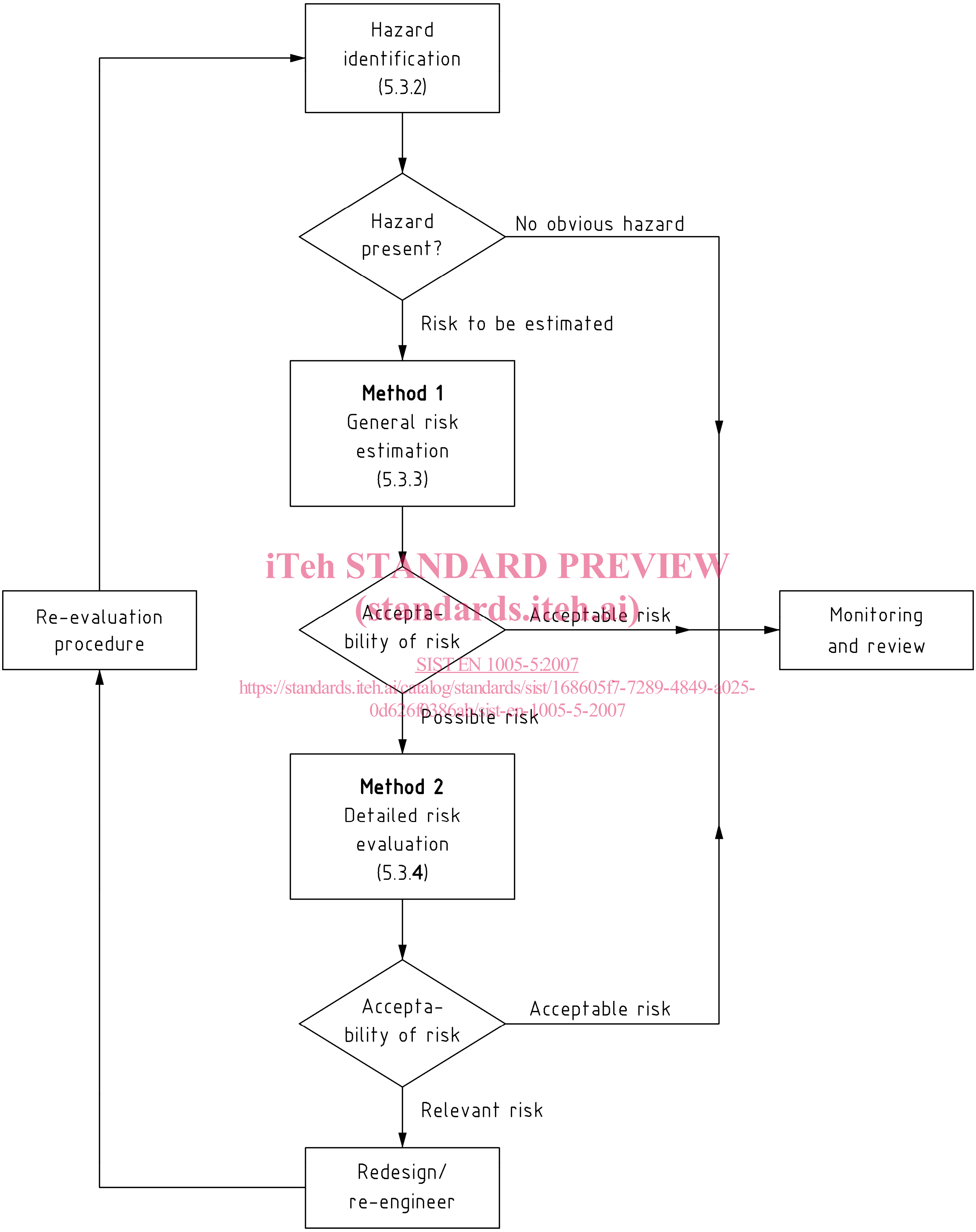

Figure 1 — Risk assessment model

The first stage of the risk assessment is to identify whether hazards exist which may expose individuals to a risk. If such hazards are present, then a more detailed risk assessment may be necessary. When determining a risk assessment, consideration should be given to the following risk factors:

a) Repetitiveness:
As the movement frequency increases and/or the cycle duration decreases, the risk increases. Frequent repetitive movements giving rise to a risk of musculoskeletal disorders may vary depending on the context of the movement pattern and the individual.

b) Force:
Tasks should involve smooth force exertions, avoiding sudden or jerky movements. Handling precision (accurate picking and placement), the type and nature of the grip may introduce additional muscular effort.

c) Posture and movement:
Work tasks and operations should provide variations to the working posture. The work tasks should avoid extreme ranges of joint movement and there is a need to avoid prolonged static postures. Complex postures involving combined movements (e.g. flexed and twisted) may present greater risk.

d) Duration and insufficient recovery:
Duration can be broken down in a number of ways. The opportunity for recovery or rest can fall within each of these work periods. Insufficient time for the body to recover between repetitive movements (i.e. lack of recovery time) increases the risk of musculoskeletal disorders.

NOTE The designer has no direct influence on the real task duration and recovery time at the machine. He has to refer to a typical scenario of repetitive task duration up to 8 hours per shift with 2 breaks of 10 minutes plus the lunch break. The designer should mention in the "Information for use" if critical values for task duration and recovery time are determined in the risk analysis, e.g. task duration, job duration, and work shift duration.

e) Additional factors:
General consideration should be given to the following additional risk factors:

1) object characteristics (e.g. contact forces, shape, dimensions, coupling, object temperature);

2) vibration and impact forces;

3) environmental conditions (e.g. lighting, climate, noise);

4) individual and organisational factors (e.g. skills, the level of training, age, gender, health problems, pregnancy).

5.3.2 Hazard identification

If the following conditions are satisfied, there is no hazard due to repetitive tasks for upper limbs:

— the task is not characterized by work cycles;

— the task is characterized by work cycles, but perceptual or cognitive activities are clearly prevalent and upper limb movements are residual.

For all the machinery / task combinations in which cyclic manual activities are foreseen, a risk estimation shall be applied.

For each manual task to be performed on machinery, the designer shall:

— identify and count the technical actions (for each upper limb) needed to carry out the work cycle (NTC);

— define the foreseeable duration of the cycle time (FCT);

— consider the force, posture, foreseeable duration and frequency of recovery periods;

— consider the possibility of rotation between different tasks, at the machinery, e.g. starting procedures, shift of tools and/or settings, loading- and unloading procedures, fetching of materials, maintenance, cleaning'.

A risk estimation model is presented in 5.3.3 (Method 1). A detailed risk evaluation model will be presented in 5.3.4 (Method 2).

When the characteristics described in Method 1 are fully and simultaneously present, it is possible to affirm that risk exposure to repetitive movements at high frequency is acceptable.

Where one or more of the listed characteristics for the different risk factors are not satisfied, the designer shall use a more detailed evaluation (Method 2, 5.3.4).

5.3.3 Risk estimation and simple evaluation of machinery related repetitive handling at high frequency (Method 1)

5.3.3.1 Check of the risk factors

The designer shall check if, considering the main risk factors (force, awkward postures and movements, repetitiveness, frequency of technical actions, additional factors), for each upper limb, the following conditions are satisfied:

a) Absence of force, or use of force in accordance with the criteria regarding the recommended force limits as reported in EN 1005-3.

b) Absence of awkward postures and movements considering the same conditions as summarized below:

i) the upper arm postures and movements are in the range between 0° and 20° (EN 1005-4:2005, Figure 6, Zone 1);

ii) the articular movements of the elbow and wrist do not exceed 50 % of the maximum articular range [12, 14], as described in Table 1 and Annex B;

iii) the kinds of grasp are "power grip", or "pinch lasting no more than 1/3 of the cycle time", as described in Table 1 and Annex B [12, 15, 26].

c) Low repetitiveness.

This is true if [40, 41]:

i) the cycle time is more than 30 s.

ii) the same kinds of technical action are not repeated for more than 50 % of the cycle time.

d) Frequency of technical actions for both upper limbs is less than 40 technical actions per minute. If the frequency is higher than 40 actions per minute for at least one upper limb then move on to Method 2. In order to compute the frequency of technical actions/min (see Annex A for identification of technical action), use the following equation:

$$FF = \frac{NTC \cdot 60}{FCT} \qquad \textbf{(1)}$$

where

FF is the foreseeable frequency of technical actions per minute;

FCT is foreseeable duration of the cycle time in seconds;

NTC is the number of technical actions (for each upper limb) in the work cycle needed to carry out the task.

e) Absence of additional factors (physical and mechanical factors).

The task should not include hand/arm vibration, shock (such as hammering), localized compression on anatomical structures due to tools, exposure to cold, use of inadequate gloves for grasping etc. [11, 12, 13] (Annex G).

5.3.3.2 Final estimation and evaluation of machinery design by Method 1

When every condition shown in 5.3.3.1, points a), b), c), d) and e) are satisfied for each upper limb, the exposure is acceptable. If one or more conditions mentioned in Method 1 are not met, the designer shall analyse in more detail each risk factor that interferes with the frequency of actions by Method 2.

5.3.4 Detailed risk evaluation of machinery related repetitive handling at high frequency: risk reduction and risk reduction option analysis (Method 2)

5.3.4.1 Evaluation of acceptable frequency of actions when one or more risk factors are present

5.3.4.1.1 General

If one or more conditions defined in Method 1 are not satisfied, the designer shall analyse in more detail each risk factor that has an impact upon the frequency of technical actions. Since different risk factors can be present to a greater or lesser extent, and in a variety of combinations, then different levels of risk can be expected.

The level of risk is assessed with reference to the *OCRA* method [11, 13, 33]. The *OCRA* index, when assessing a single repetitive task in a shift (mono task job), is given by the ratio between the foreseeable frequency (FF) of technical actions needed to carry out the task, and the reference frequency (RF) of technical actions, for each upper limb (see Annex A for identification of technical action). This is a particular procedure for mono task jobs. For multitask jobs see Annex H.

In this context:

$$OCRA\ index = \frac{FF}{RF}$$

The foreseeable frequency (number per minute) of technical actions needed to carry out the task (FF) is given by the following equation:

$$FF = \frac{NTC \cdot 60}{FCT}$$

where

FCT is foreseeable duration of the cycle time in seconds;

NTC is the number of technical actions (for each upper limb) needed to carry out the task during one cycle.

The following equation calculates the reference frequency (number per minute) of technical actions (RF) on a work cycle base:

$$RF = CF \times Po_M \times Re_M \times Ad_M \times Fo_M \times (Rc_M \times Du_M)$$

where

CF is the “constant of frequency” of technical actions per minute = 30;

Po_M; Re_M; Ad_M; Fo_M are multipliers for the risk factors postures, repetitiveness, additional, force;

Rc_M is the multiplier for the risk factor “lack of recovery period”;