

Usability evaluation methods of machinery for inherent safety

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Abstract. According to the principles of risk prevention engineering measures have priority in design of machinery used by workers in workplaces, therefore the establishment of inherent safety is a major objective.

The adaptation and application of usability methods used in the domain of product design allow machinery designers to understand operators' foreseeable behaviour including possible operational errors and to fulfil design requirements laid down in directives and standards and to perform this soft but important design step.

Relevant definitions, concepts, legislative environment will be presented, and an introduction to new standards, application examples will be discussed.

Keywords: Safety of machinery, ergonomics, usability, inherent safety

1 Introduction

The safety of machinery [1] and the use of machinery by workers in the workplace [2] is strictly regulated. Wide range of safety criteria laid down in harmonised standards must be met, lots of guides and additional standards can be applied by the manufacturer. In the workplace the employer has several obligation related to health and safety of workers, including the provision of safe machinery used to achieve work tasks.

In spite of the effort made serious workplace accidents due to machinery use still happen. Wrong operator behaviour is one of the frequently identified root causes of accidents. On the other hand wrong worker behaviour means unidentified possible operators actions or the omission of foreseeing the operator behaviour.

2 Human-centred approach of a machinery design

The human-centred approach of a machinery design includes the consideration of [3]

- the designated group of workers for whom the design is intended,
- the physical, chemical, biological, organizational, social and cultural factors, and
- the work task, which is the required set of activities to achieve the intended outcome.

Tasks can be suitable more to humans or machines, e.g. machines are modest in decision making but strong in repetitive and monotonous tasks, while humans have restricted physical capacity but are well suited for a variety of tasks. [4]

The intended operators' task should e.g.

- provide sufficient feedback on the mistakes and correct performance,. [5]
- provide autonomy to the operator,
- fit to the capabilities of the intended operators,
- provide opportunity to improve skills.

The allocation of functions and tasks to the human or to technology makes tasks appropriate to the workers, and avoids adverse effects, both for the workers and the whole work system. Due to variations in situational, organisational or individual factors the actually performed task and the designed task should differ. [6]

In the implementation several ergonomics standard can be used to design [7]

- the operator-machinery interaction mentally [8] or physically [9]
- signals and controls [4]
- machinery dimension [10][11]

When using the methodology of work task design the characteristics of well-designed operators tasks should provide a theoretically good function allocation and work task specification. However to reach safety objectives feedback from operators should be obtained in the course of the design process, implementation or operative conditions, using e.g. checklists, observational studies, incident analysis.

Since behind ergonomics hazards there's a multi-factorial complexity and the ergonomic requirements connected to mental abilities have no measurable unit or concrete measures the result of the ergonomic risk assessment is expressed in the 3-zone rating system. The conditions leading unsafe operation are fall in the red zone, while the use of inherent safety approach, the safe operation, the fulfilled ergonomics principles greens.[12]

3 Reasonably foreseeable

Designer obligations in safe machinery design starts with the determination the limits of machinery, including the target group, the intended use and any reasonably foreseeable misuse. In the risk reduction process the safe operation for the life cycle, the function, the cost and the usability of the machine should be considered. [13]

Intended use means the use in accordance with information provided with a product or system, or, in the absence of such information, by generally understood patterns of usage, while the reasonably foreseeable misuse is the use of a product or system in a way not intended by the supplier, but which can result from readily predictable human behaviour [14]

Misuse as unintended behaviours of the worker can be e.g.

- loss of control on hand held machine,
- wrong reaction in case of unexpected function of the machine,
- mistakes in a monotonous task
- following the line of least resistance
- related to psycho-social risks
- due to individual characteristics.

According to the hierarchy of controls inherently safe machinery design measures should be taken to eliminate and / or to reduce the probability of occurrence or the severity potential sources of injury or damage to the health of people, or damage to property or the environment by changing the design or operating characteristics of the product or system. [14] In machinery design inherent safety means the elimination or reduction of hazards by designing the machinery itself or the interaction between the worker and the machinery with the suitable choice of features, e.g. changing the design or operating characteristics of the machine without the use of guards or protective devices. [13]

4 Usability of machinery

While several standards are accessible to design for the intended use, and a guidance is provided to help designers about ergonomic aspects during the development of machinery [15], to identify all reasonable (or possible) behaviour is still a challenge.

Based on ISO definitions usability of a machinery used at workplaces can be defined as the extent to which the machinery can be used by specified operators to achieve work task accurately and completely, of the resources expended and of the freedom from discomfort and positive attitudes towards their use. [16]

The Ergonomics of human-system interaction standard provides information on advantages, disadvantages of human-centred usability methods which can be used for design and evaluation. [17] The appropriate method can be selected according to the design activities being undertaken.

A new European standard offer methods for work analysis to support design.[18] This new standard makes distinction between the prescribed task and work activity, how the task expected to be done referring to the intended use of machinery and how the task is performed in reality respectively.

In the focus of the activity focused work system is the real observable work activity determined by means and resources and producing result and effects including the load-effect concept. [6] (Fig. 1.)

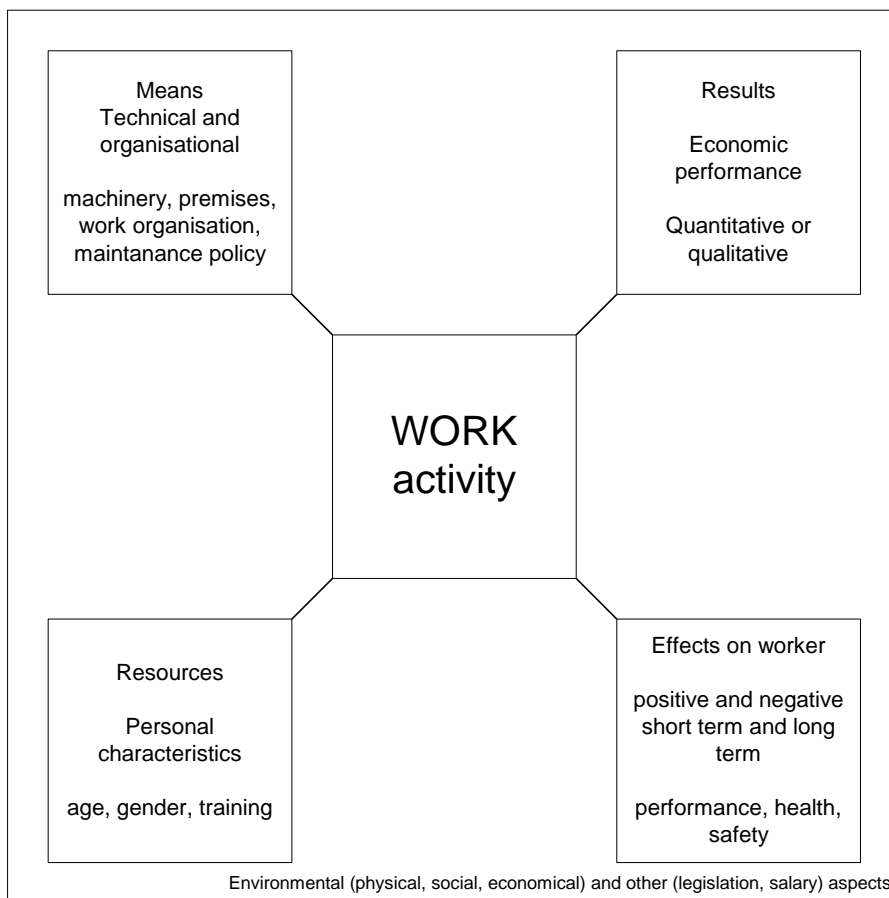


Fig. 1. “The activity focused work system” based on EN 16710-2

For work analysis the standard suggest the following methods:

- review of internal and external documents,
- measurement of physical work environment, human dimensions, psychological values
- observations of actual or simulated work activity,
- questioner,
- interviews.

5 Feedback method

Supplementing the overview on the methodology [19] to feedback of user behaviour as requested in machinery risk management [13] a detailed process to understand end users’ performance with machineries available in the new technical report. [20]

According to this technical report the value of simulations is uncontested but are not able to predict all the possible circumstances due to the limitations of simulation and the small sample of the target group. In other words simulations can’t predict every possible operator activity and therefore can not provide a comprehensive set of foreseeable misuse of machinery.

The feedback method is a structured way to solicit skilled workers opinion. [21] They have training and work experience on the installation, operation, maintenance of the machinery in question. The method lead by a specialist consists of

- preparation, collection of information related to the machine in question,
- observation of workplaces where this machine is used,
- structured interview with skilled workers,
- result validation,
- documentation.

The observation covers all aspects mentioned in the “activity focused work system” (Fig.1.) including all work phases in details from normal operation to unplanned maintenance. Signs of misuse can be identified by gathering information on near-misses and accidents with the machine.

Based on the work analysis a group of skilled workers reconstructs the work activity and carries out a systematic analysis of each work activity producing e.g. a list of critical aspects of the machinery.

6 Summary

Not identifying foreseeable operator behaviour in the machinery design process in the workplace means overseeing the possible worker actions. In reality concepts and methods are available to help designers to understand workers' behaviour, predict the possible acts and identify foreseeable behaviours.

The usability methods developed in the context of software and products design can be applied to

- define the scope of the machinery risk assessment more detailed,
- make a more comprehensive list of functions,
- provide a better function allocation and definition,
- write better instruction.

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