Human Factor and Ergonomics in Essential Requirements for the Operation of Technical Equipment

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Abstract. The goal of ensuring the safety of technical equipment users lies at the heart of all design requirements classified as essential [3]. To achieve proper compliance with such requirements, it is essential to adopt solutions which meet the needs and expectations of the concerned parties. The choice of solutions must reflect the profiles of users, who are described as the so called human factor, as well as any criteria helpful in achieving the best possible matches for particular worker profiles. Described in terms of ergonomic criteria, the solutions should be seen as an integral part of the design process. By accounting for ergonomic criteria in such a process, it is possible to ensure that the conditions in which technical equipment is operated live up to the desired level of human-friendliness.

Keywords: Ergonomics principles, technical equipment, essential requirements.

1 Introduction

The requirements of the European safety system are designed to ensure that equipment is operated without endangering any involved persons.

Compliance with such requirements is, in fact, the prime responsibility of machine and equipment designers. The required safety level is achieved by applying solutions which comply with guidelines set out to serve as fundamental requirements. Compliance with such requirements, which incorporate technical safety principles, is achieved in a three-stage design process [2], [3], [7], [12]. Practicable solutions have been described in the new approach directives and further elaborated in harmonized standards containing sample measures to be taken to ensure conformity with the essential requirements.

To achieve protection against hazards, it is crucial to identify operational requirements and provide all those involved in the work process with proper guidance on working principles [4], [9].

Requirements as well as the ways to satisfy them must account for the specific profiles of users (the so called human factor) [1], [5], [11], so as to ensure the achievement of the required safety levels, protection against hazards and compliance with

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ergonomic design criteria. The ergonomic criteria, which are pivotal for ensuring that machines meet human needs and expectations, should be seen as an integral part of the design process. Leaving them ignored will bar the way to achieving conformity with the fundamental requirements.

2 Identifying the Design Requirements

2.1 Technical Safety Criteria

The purpose behind seeking compliance with technical safety requirements is to ensure safety in the operation of technical equipment. Safety requirements must allow workers to operate technical equipment without creating hazards or making the work strenuous for persons performing their assigned duties. This applies to operation in the face of anticipated hazards and to the option for defining the parameters of such hazards as well as to circumstances which cannot be foreseen [9]. In selecting adequate safety precautions, one should account for all individuals known to be involved in the operation. Particular focus should be placed on operators as well as maintenance and support services.

At each stage of operation, a major role is played by ergonomic criteria which describe the adjustment of technical equipment to user needs and expectations [5], [6], [8], [11]. In applying ergonomic criteria in the design process and in planning the conditions for the performance of operator tasks, emphasis should be placed on minimizing loads and strains. This can be achieved by [3]:

- accounting for the diversity of physical characteristics among operators,
- ensuring sufficient room for the safe performance of motions involved in the work of operators,
- ensuring that operators may utilize the machine's entire range of movements,
- ensuring the equipment can be overseen without the need for maintaining concentration for overly prolonged periods,
- ensuring the operator and the machine in their charge have ways available to effectively exchange messages.

The solutions must be instrumental to reducing hazards and strenuousness by relying on ergonomic criteria in technical equipment design. The top priority consideration in the process is human safety [1], [10].

Relevant requirements apply to all areas of potential hazard during equipment operation in keeping with operating manuals as well as during maintenance and repair work. In particular, this applies to controls and control systems, rules for normal and emergency activation and shutdowns, protection against hazards resulting from the ejection of objects and the emissions of gas and fumes, protection from moving parts and other items as well as protection against frost bites, burns, fire, explosions and electric shocks [2], [3].

The fundamental requirements designed to protect humans are associated with ergonomic criteria and determine the use of ergonomic principles in the design of technical machinery and equipment. These requirements ensure the proper:

- interaction between man and machine,
- collaboration among all individuals involved in equipment operation,
- compliance with psychological and social requirements pertaining to the operation of technical equipment,
- enhancement of human abilities to perform hazard reducing tasks.

Such ergonomic requirements and solutions help achieve the desired safety levels by employing design determinants which ensure the achievement of safe operating conditions. Furthermore, such requirements and solutions ensure safe operation by unambiguously defining how equipment operation is to proceed [7], [12].

2.2 Compliance with Design Requirements and Solution Development

The key requirements designed to ensure technical equipment operating safety are enshrined in the relevant legislation based on the principles embodied in the New Approach. The central legislative instrument for this purpose is Directive 2006/42/EC [2] which calls for the use of design solutions for the achievement of the desired technical compliance and to eliminate hazards.

In order to ensure compliance with the fundamental requirements during technical equipment design, it is necessary to verify the needs of all concerned parties while accounting for market demands. When assessing the option of applying specific solutions, proper account also needs to be taken of hazard assessments and the impact of hazards on any persons involved in the work. The design assessment methodology relies on the guidelines of the EN ISO 12100 [3] standard under which one is required to:

- identify any risks and limitations associated with the operation of technical equipment,
- verify requirements laid down in harmonized standards B and C,
- assess risks associated with operating technical equipment,
- apply prescriptive solutions to allow for the mitigation of impacts of the risk factors,
- ensure oversight over risk mitigation and define measures necessary to ensure that the required safety level is maintained continuously throughout the operation of technical equipment.

The procedure followed to achieve the expected level of compliance with the fundamental requirements is shown in Figure 1. The measures to be taken to that end should be seen as a strategy to minimize any risks taken with respect to technical equipment.

To ensure the work process proceeds effectively, the designer needs to recognize the ergonomic criteria essential for producing human-friendly solutions. The critical elements of such solutions are presented in Table 1.

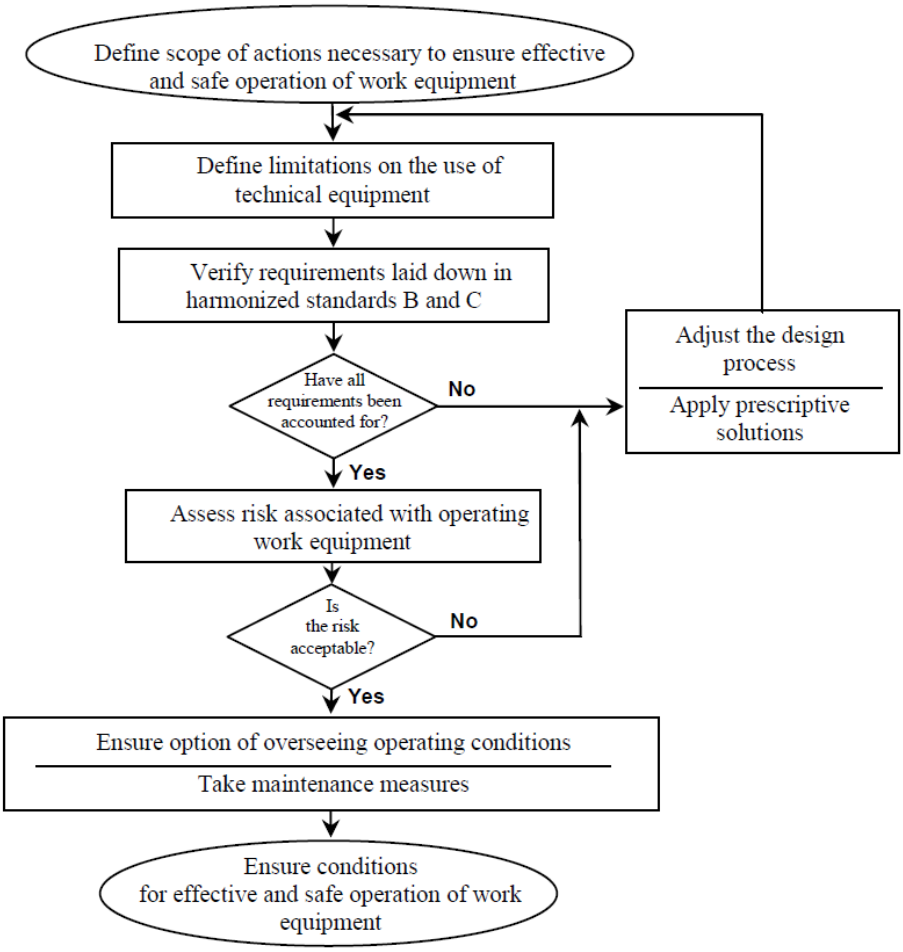

Fig. 1. Algorithm designed to ensure compliance with fundamental requirements.

In the measures taken, particular attention needs to be paid to the human factor, which is critical for [4]:

- applying ergonomic principles in the design process and producing work factors and workstations,
- any natural working skills and working skills acquired by workers,
- the awareness of hazards among any exposed individuals,
- the conviction that the tasks can be performed with unintended departures from the desired course of work,
- workers' propensity to deviate from adopted safe working procedures.

To gain the certainty that the actions taken to minimize hazards are indeed effective, designers need to account for attempts to block certain measures and by-pass any

existing safety precautions and systems. When dealing with the human factor, it is essential to learn why attempts to block measures and circumvent safety systems might be made.

Table 1. Role of ergonomic criteria and requirements accounted for in the design process

Design stage	Role of ergonomic criteria and requirements (associated with the human factor)
Identification of hazards and limitations	- define factors which reduce work effectiveness, - help identify factors which contribute to strenuousness, - help assess the significance of individual factors associated with persons entering workplace and their work engagements.
Verification of prescriptive requirements	- indicate standards containing ergonomic criteria of significance for the design process, - identify standards which help raise the effectiveness of operating technical equipment.
Risk assessment	- help apply ergonomic criteria in risk assessment, - bring particular attention to hazards affecting people in the equipment work zone.
Mitigation of risk factor impact	- indicate ergonomic solutions which mitigate the impact of risk factors, - help incorporate ergonomic criteria into risk impact mitigation process.
Oversight over risk mitigation	- help oversee the application of ergonomic criteria in risk mitigation.
Continuous maintenance of required safety level (compliance with requirements)	- treat ergonomic requirements as an integral part of design process.

3 Conclusions

While the responsibility for worker safety associated with the operation of technical equipment rests with the employer, the party liable for ensuring the proper conditions to achieve safety lies with the manufacturer which is subject to the fundamental requirements. Technical equipment should satisfy safety specifications and ergonomic requirements throughout its usable life. One needs to bear in mind that the majority of accidents and incidents result from failures to provide employees with proper procedures. Particularly high rates of errors leading to accidents can be found in maintenance operations. The reason for this is that maintenance work is highly complex and that maintenance personnel frequently work under time pressure, under insufficient supervision, without the required knowledge and under adverse external circumstances. Furthermore, errors made in the course of maintenance work often result in delayed accidents occurring during the regular operation of technical equipment [4]. As a consequence, since maintenance work is likely to contribute to accidents, it requires technical and organizational solutions which maximally reduce the likelihood of untoward events.

The ergonomic requirements applied in the design process should be perceived as an integral part of the body of requirements intended to ensure the safest possible operation of technical equipment. Ergonomic criteria highlight the necessity to adjust

technical equipment to the needs of users (operators, technical service providers) so as to avert any identified hazards.

The design safety requirements defined as fundamental should also be seen as guidelines for the development of conditions which ensure effective performance of work [11]. Such requirements must account for ergonomic criteria which need to be seen as mandatory.

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