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NOTES

Integration of Ergonomics Into Hand Tool Design: Principle and Presentation of an Example

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The development of ergonomic tools responds to health protection needs on the part of workers, especially the work related musculoskeletal disorders of the upper limbs and to the development of ergonomic tools to take into account the needs of the factories. Only an ergonomic design process can enable tool manufacturers to meet these requirements. Three factors are involved: integration of ergonomics into the design process, definition of the different ergonomic stages involved, and finally knowledge of the different factors involved in hand tool design. This document examines these 3 elements in more detail and presents briefly a project of research whose main purpose is to integrate ergonomic criteria into a design process.

hand tool ergonomic design

1. INTRODUCTION

For some years now, ergonomic hand tool design has stimulated renewed interest amongst users, manufacturers, and researchers. In the past, emphasis

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was placed on hand tool function in order to improve efficiency and allow for standardization. The tool was required to satisfactorily fulfil the task for which it had been designed, to respond to the needs of the greatest possible number of users, and to be as cheap as possible. Consequently, a given tool was designed to be used by all potential users. However, in recent years, approaches have changed and new notions of increased comfort and reduced biomechanical solicitation with regard to users' functional capacities have been introduced into tool design. There are several reasons for this development.

The rise of work related musculoskeletal disorders of the upper limbs (WRMSD) is the most important and these disorders are particularly widespread in industries that make use of hand tools. A study (Myers & Trent, 1988) indicated that WRMSD accounted for 24% of all reported hand tools injuries. Secondly, the development of new technologies (artificial intelligence, robotics) and new forms of production process organization (just in time, ISO 9000 quality certification) have also had an impact. Such factors require a greater range of skills, greater know-how, and deeper implication in the work process itself on the part of employees. New tool requirements have emerged from this background. Finally competition between hand tool manufacturers has led to widening of the skills and know-how required of manufacturers, including ergonomics, if they are to respond to market forces. In practice, tool manufacturers must take three new types of need into account in the manufacture of hand tools. These are

- integration of ergonomics into the design process,
- definition of the different ergonomic stages involved in the design process,
- knowledge of the different factors involved in the design of hand tools.

The objectives that ergonomic study into hand tools aims to achieve are constantly changing with technical progress, changes in the organization of work, and the expectations of operators. Safety objectives, comfort, and even considerations of style have been added to considerations of improved efficiency in tool design. In order to meet these new, interrelated requirements, researchers have resorted to a variety of methodological approaches derived from a number of different disciplines (mechanics, physiology, psychology, sociology). An ergonomic tool must be a safe, efficient tool, which must also make less demands on upper limbs if risk of WRMSD is to be reduced. The objective of this document is to analyze these three requirements, firstly, in order to help manufacturers master ergonomic hand tool design processes and secondly to help users to develop specifications that will adequately express their particular needs in this field, and to present shortly a project of research whose main purpose is to integrate ergonomics criteria into a design process.

2. INTEGRATING ERGONOMICS INTO THE DESIGN PROCESS

The design process should be structured methodically. Indeed, it is generally accepted today that 75% of the total cost involved in the development and industrialization of a product is determined at the very outset of the design process.

Method in a design process (Figure 1) involves an approach in which different "models" (language, technical experience, know-how, etc.), on the one hand, and different "tools," on the other hand, are brought together. By tools here is understood all the techniques involved in the analysis of the functioning of a part or the whole of the design process.

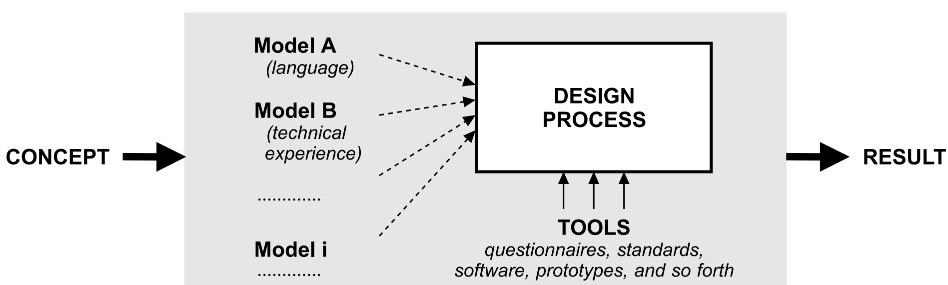

Figure 1. Method structure.

A general design procedure involves a group of project participants (marketing, design, manufacturing) and a number of phases (definition of needs, specifications, general and detailed design). The approach adopted must achieve the highest possible integration of these different elements if the project is to run smoothly.

Traditional design process techniques have envisaged project participants and phases in a sequential manner. The result of such an approach is that considerable difficulties occur in introducing ergonomics into the design process. To overcome such difficulties, two approaches are to be recommended. On the one hand, iterative models, amongst which are to be found the spiral model for phase organization, should be adopted. On the other hand, concurrent engineering for the management of the different protagonists in the process is advisable.

Without going into too much detail, this concept aims to provide for the simultaneous integration of process management and the different phases in product development. It is essentially an organizational device allowing for improved communication between the different project participants (including ergonomics).

The spiral model (Figure 2) makes use of both functional analysis and prototyping techniques. It allows for the integration of all project participants before completion of each design phase. In addition, prototypes—which are intermediary objects that each project participant readily understands—re-enter attention on the product and improve communication in general.

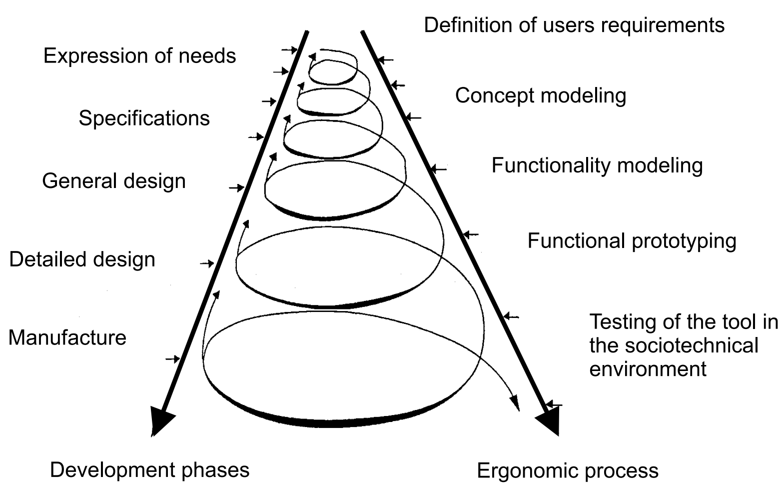

Figure 2. Spiral model for an ergonomic development process (Laprie, 1996).

3. DEFINITION OF THE DIFFERENT ERGONOMIC STAGES IN THE DESIGN PROCESS

Increasing awareness that (a) the user, (b) the tool, (c) the workplace, the environment, and the task itself are inextricably linked has led to reconsideration of the content and meaning of the design process (see Figure 3). Indeed, each of the three elements just emphasized interacts with the two others. Only by using ergonomics can this objective be achieved. Three basic stages can be outlined:

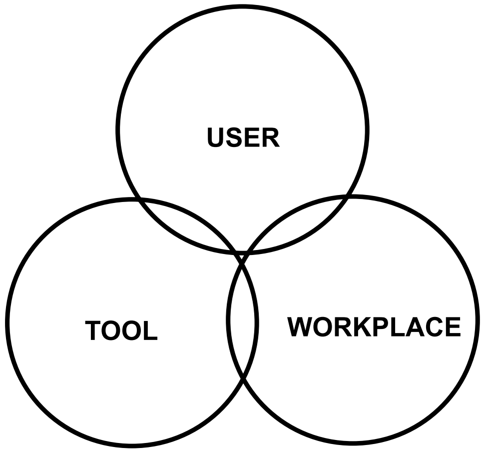

Figure 3. The user, the tool, and the workplace interact with one another and they should be taken into account in an ergonomic hand tool design process.

- Stage 1. Definition of user requirements (see Figure 2) and expectations after detailed observation of the work process and work context. Employee characteristics (training, anthropometrics measurements, etc.) are also defined during this phase. Tool specifications finally emerge from the study of user needs and work processes.
- Stage 2. Design of a new tool prototype based on tool specifications and laboratory simulation and study of the biomechanical solicitation produced by the new tool by comparison with the tool previously used. This stage includes all other phases—that is, concept modeling, functionality modeling, functional prototyping (see Figure 2)—relating to tool function, styling, and so forth.
- Stage 3. After formal completion of the second stage, test of prototypes by a large sample of users in real workplace situations. The trial should be conducted over a sufficiently long period (several weeks) and feedback on the user's perception of the new tool should be regularly sought according to a procedure similar to that used in the first phase. If satisfactory results are obtained, the tool can then be considered duly certified for those situations in which it has been tried and tested. Users must be trained and encouraged to use the prototypes over a sufficiently long period before final judgement is given.

4. CRITERIA INVOLVED IN THE DESIGN OF HAND TOOLS

This section recalls shortly different elements making up the diagram given in Figure 3, which must be taken into account in an ergonomics design process. All these factors are described in detail in the literature (Fraser, 1980; Mattila & Landau, 2000; Mital & Kilbom, 1992; Radwin & Haney, 1995).

4.1. Tool Design

Tool weight, center of gravity, handle form and dimensions, handle length, handle material and texture trigger, guards, inclination of the tool, handle relation to the functional part of the tool, vibration, and reaction torque are the main elements to take into account in regard to tool design.

4.2. User Elements

Anthropometrics considerations in connection with age and gender, right-handed and left-handed users, experience and technique, training, and so forth, have a great incidence on the design of hand tools.

4.3. Environmental Factors, Work Tasks, and Work Stations

Right tool for the job, posture, environmental conditions, use of gloves, tool supports and reaction torque bars, tool maintenance are examples of workplace factors.

5. A PILOT STUDY ON DESIGN OF INDUSTRIAL KNIVES

With the same objectives as those defined in the Eurohandtool project[1], the Institut National de Recherche et de Sécurité launched an Ergonomic Hand Tool Design project in 1999. This project concerns the design of industrial

[1] "Eurohandtool: usability, ergonomics, quality and productivity of non-powered hand tools"—European Commission Brite Euram Project BE96-3735 coordinated by Tampere University of Technology, 1997–1999. For further information, see Mattila & Landau (2000).

knives. Indeed, it is well-known that working conditions are difficult in meat processing plants. WRMSD are particularly important in slaughterhouses and in the meat cutting industry (Armstrong, Foulke, Bradley, & Golstein, 1982; Roto & Kivi, 1984). Due to the great variability of biologic products, boning and carving operations cannot be automated. The knife is still the emblematic tool of the cutting industry. Improving cutting performance and decreasing biomechanical stresses of the user require introducing ergonomics in the design process (Armstrong et al., 1982; Bobjer, 1989).

This project is organised around three axes, which interact with each other (see Figure 4):

Figure 4. The basic structure of the project.

- Axis 1 is related to the design process itself. The aim of this axis is to test different design processes, which are able to take into account ergonomic considerations. So, some design methods such as Functional Expression of need and tender specifications method, or Quality Function Deployment method have been tested.
- Axis 2 concerns the definition of ergonomic design criteria. To reach this goal, ergonomic studies have been conducted. For example, the first step that cannot be ignored in such an approach is to gather all information on the use of the existing tool and particularly to record the problems of the users at the workplace. To reach this goal, a study was made up of
  - interviews with (a) managers of slaughterhouse and meat packing plants to know more about their main choice criteria (price, effectiveness, safety, hygiene, and so forth), (b) operators to find out their experience and viewpoint on the tools used;
  - a direct or a video observation (or both) of the conditions in which knives were used.

  This study showed that the main problem related to handling of the knives reported by the users concerns the fact that the handle slips in the hand. So, it is important to define grip criteria.
- Axis 3 is related to technical studies, which are in the case of the knife necessary, for example, to improve the mechanical quality of the blade

but also to define the optimal characteristics of the blade edge in order to improve cutting performance and decrease the cutting force of the operators. To achieve this objective, a special test device has been built.

The expected results are (a) a methodology for ergonomic design of hand tools and (b) ergonomic design criteria to be used by knives manufacturers.

6. CONCLUSION

Gjessing, Schoenborn, and Cohen (1994) illustrated the importance of adopting a participatory ergonomic approach to the study of tool design in authentic work situations involving habitual tool users. Ergonomic field observation techniques should be applied to hand tools in order to provide specifications that will guide choices made by designers. It is generally admitted that no tool can in itself be considered as ergonomic. It can only be considered as such if it is properly adapted to all the different uses to which a specific user puts it. Given that work situations are by nature diverse, it is difficult to design a universal tool that is adapted to all possible work situations.

Moreover, in certain work situations, it may well be more profitable and efficient, as much in terms of production quality as in terms of reduced risk of WRMSD, to modify certain parameters of the work situation (the object on which the tool is used or an element in the production process, for instance) than to modify the tool. Consequently, tool design includes the tool itself, as previously defined, but also advice, training, and above all the ability to study the specific details of a given work process.

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