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DESIGNING OF MANUAL WORKSTATION STRUCTURE WITH EMPHASIS ON ERGONOMICS

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Abstract: *Objective of ergonomic design is, among others, adaptation of manual workstations, workplace, working space, environmental conditions and lighting intensity to human properties and skills. Ergonomically designed workstation in production system with modular structure brings many benefits, e.g. increased motivation and satisfaction of employee, higher performance, productivity, efficiency, and processing quality. This article is a reference to help methodically plan, design and implement ergonomic workstations by considering variables such as employee size, type of task, lighting, and other key factors. The goal is to present the rules of ergonomic for work systems: body height and working height; work area; reach zone; parts presentation; range of vision; lighting; adjustment of work equipment. Using of the modular building- block system for designing individual workplaces enables flexibility and optimal adaptation to task and individual employee concerned.*

Keywords: *design principles; ergonomic rules; modular workstation; modelling*

1. INTRODUCTION

Workstations and assembly cells are at the heart of many manufacturing operations. Working space and workstations play a vital role in worker productivity. It is therefore critical that they are designed to be as ergonomic, flexible and efficient as possible. The goal for the design of workplaces is to design for as many personnel as possible. Traditional standard workstations in manufacturing system were bolted down and required workers to deal with a work surface that was in a fixed position. Ergonomic considerations often are not given priority. On the present, integration of the wide range of human characteristics (e.g. anthropometry, ability, proportion, strength) in the planning process is essential. Design of working systems by ergonomics is described under harmonized standards (e.g. EN ISO 6385). It is a known fact that the ergonomically ideal layout of workstations and workplaces not only stimulates the efficient manufacture of product in general, but also has direct benefits with respect to reducing the psychological demands placed on employees. Modular structure of equipments in manual production line can be easily modified to improve ergonomics, add or remove features, or change dimensions, and the work area can be quickly rearranged for optimal productivity.

2. ERGONOMIC RULES TO DESIGNING OF MANUAL WORKSTATIONS

The term "ergonomics" is a combination of the Greek words "ergon" – work and "nomos" – law. The most important factors for designing work equipment are the working height, proper sizing of the reach zones and required leg room, as well as definition of the appropriate range of vision. All of these dimensions are derived from a "standardized" body height. Every workplace must be designed for a certain height range and not for one particular height of person. The aim when designing every workplace is to accommodate a range of heights (DIN 33406) from 1540 to 1871 mm (with shoes). [4] Further criteria that must be taken into account [5]:

- ✓ *Foot and leg room, depth and adjustment range of the footrest*
- ✓ *Size and variation of workpiece dimensions*
- ✓ *Occurring forces and weights*
- ✓ *Changing types of equipment and insert heights*
- ✓ *Greatly varying vision distances*
- ✓ *Local specifications (deviating body heights, legal requirements, etc.)*

✓ *Aspects related to methods, safety, and efficiency.*

2.1. Body height and working height

Manual workstations must accommodate a wide range of body heights to ensure that the largest percentage of the population is covered. The optimum working height is based on the body height range and the type of activity to be performed. The average optimum working height for average requirements is 1125 mm for sit-down/stand-up workstations. [4]

Height-adjustable workstations are the most flexible solution for dealing with extremely varied workpiece/component dimensions and large differences in employee heights. The concept permits changes in posture, which reduces stress and increases performance. [6]

2.2. Work area

The aim is for the distance of employee from the front edge of workbench to be as small as possible. The distance to the working area influences the following: position of the arms, viewing distance and inclination of the head. The work area height should always be between 800 mm and 1500 mm. [3] The following rules must be observed [5]:

- ✓ *Avoid work above the heart (over 1500 mm): Otherwise, the circulation of blood and oxygen to the muscles is reduced, which leads to a drop in performance*
- ✓ *Work that requires bending (below 800 mm) exerts employees disproportionately and should be avoided*
- ✓ *Promote dynamic activities: static manual work (such as holding an object continuously) inhibits the circulation of blood and oxygen to the muscles. This can lead to a drop in performance and processing quality*
- ✓ *Allow for alternating physical exertion: for example, through sit-down/stand-up workstations or job rotation. Alternating physical exertion reduces stress on the employee and increases performance*
- ✓ *Minimize exertion: for example, through the use of manual roller sections or lifting aids, as well by selecting lighter weight materials.*

2.3. Reach zone

The following rules apply for an ergonomic reach zone design: all containers, equipment, and operating elements must be easily accessible and arranged in the anatomic/physiological range of movement for the employee. All reach distances should be as short as possible to avoid redundant, non-value- added movements. Grab containers and parts containers that are in direct reach of the employee are ideal. Torso rotations and shoulder movements, particularly when under exertion (with weights ≥ 1 kg), should be avoided whenever possible. [4]

Characterization of the reach zones at workstation (see fig. 1) [3]:

Area A: Center of work, two-handed zone

- ✓ *Optimum for working with both hands, as both hands can reach this zone and are in the employee's field of view*
- ✓ *For fine motor movements*
- ✓ *Area for workpiece support, workpiece pallet, or equipment*
- ✓ *Possible to handle lighter weights and also enables improved inspection and coordination activities*
- ✓ *Pure lower arm movements*
- ✓ *Smaller muscle groups are in use.*

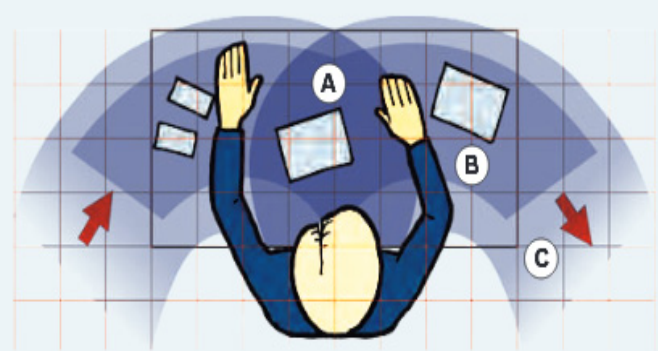

Figure 1. Reach zones at workstation. [3]

Area B: Large reach zone

- ✓ *For gross motor movements*
- ✓ *Area for tools and parts that are often grabbed with one hand*
- ✓ *Upper and lower arm movements without use of the shoulders and rotation of the torso.*

Area C: Extended one-hand zone

- ✓ *For occasional handling, e.g. of empty containers or transferring parts to the range of movement for the next employee*
- ✓ *With shoulder and torso movement.*

2.4. Range of vision

For optimal workstation design, it's important to follow recommendations on proper ergonomics for

vision. Can be differentiating between two vision areas (see fig. 2) [5]:

- ✓ In the field of view (red vision area), several objects can be seen in focus simultaneously without moving the eyes or head. Additional focusing for depth may be required here.
- ✓ In the visual field (light grey vision area) objects can be seen by moving the eyes but not the head. Additional focusing for depth may also be necessary here.

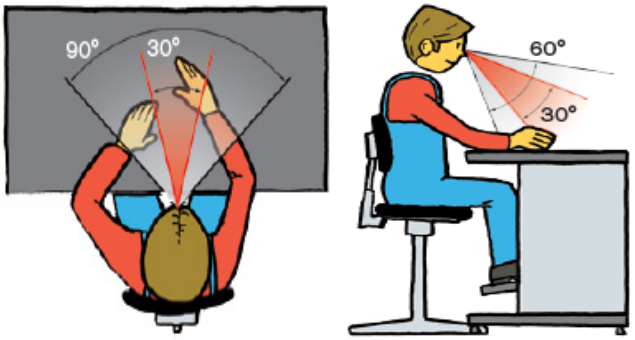

Figure 2. Illustration of vision areas: the field of view and the visual field. [5]

The following aspects must be taken into account during planning [5]:

- ✓ Avoid unnecessary eye and head movements
- ✓ Implementing vision distances that are as identical as possible eliminates refocusing
- ✓ Avoid fastening locations not visible to the worker.

Complying with these three recommendations facilitates work and increases productivity.

2.5. Lighting

The right light, adapted to the activity at the workstation, is a basic prerequisite for high efficiency and processing quality. Optimum lighting prevents fatigue, improves concentration, and reduces the risk of errors. Match light intensity to the work task [9]:

- ✓ Standard assembly tasks: 500~750 lux
- ✓ Complex tasks (e.g. electrical assembly): 1000~1500 lux
- ✓ Delicate and/or critical work: 1500~2000 lux.

Important aspects for planning workstation lighting include [4]:

- ✓ Avoid strong contrasts
- ✓ Avoid glare and reflection.

For example, DIN EN 12 464 contains the required mid-range lighting intensities.

2.6. Adjustment of work equipment

To maintain performance and promote productivity, all work equipment near the workstation must be precisely adjusted to the employee and their activity. Correct adjustment of the table, chair, footrest, and grab containers, as well as the position of tools and material shuttles, minimizes movements, thus reducing physical exertion and employee absences (see fig. 3).

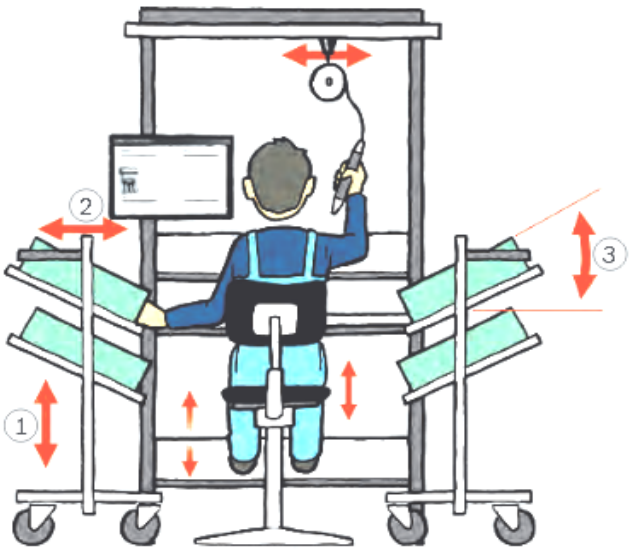

Figure 3. Adjustable workstation to the employee (1 = height, 2 = depth, 3 = angle). [5]

A few important considerations [7]:

- ✓ When adjusting the chair and footrest, make sure that the thighs and calves form a right angle.
- ✓ Information boards should be hung at eye level to avoid unnecessary head movements.
- ✓ The angle of the shelves for material supply should be adjusted to create short, direct reach distances.
- ✓ Use lifting aids to supply heavy parts.
- ✓ With height-adjustable workstations, the optimum working height can be adjusted according to the size of the person or product.
- ✓ If processes, products, or employees change frequently, check the work equipment regularly to ensure proper ergonomic adjustment.

The general workstation design principles can be summarized as reference [4]:

- ✓ Make the workstation adjustable
- ✓ Locate materials box to reduce twisting
- ✓ Set work surface according to type of task
- ✓ Provide adjustable chairs

- ✓ *Allow workers to alternate between standing and sitting*
- ✓ *Support the limbs (elbow, wrist, arm, foot rest)*
- ✓ *Use gravity to move materials*
- ✓ *Design for proper arm movements*
- ✓ *Provide simple dials and displays*
- ✓ *Consider environmental conditions.*

If processes, products, or employees change frequently, check the work equipment regularly to ensure proper ergonomic adjustment. The worker must be protected from ergonomic problems.

A properly designed flexible workcell must be easy to reconfigure. The main benefit from using of adjustable ergonomic workstations is improve productivity – it has been demonstrated that providing employees with adjustable, ergonomically designed workstations can improve individual productivity by 20%, lowering stress and fatigue improves product quality. [7]

For example, applied modular structures from aluminium profiles system are not welded (see fig. 4); the design can be easily modified if ergonomic improvements are identified. Adjustable workstations allow users to adjust to their own comfort level, alternate between sitting and standing positions and adjust to accommodate different users in multi-shift operations. [6]

Manual flexible worktables are designed to provide a wide range of sizes and adjustments.

3. COMPUTER- AIDED DESIGN OF WORKSTATIONS ERGONOMICS

Ergonomic simulation can be used to evaluate a work cell to reviewing the interaction between the human model and the work environment such as reach analysis or posture requirements.

In addition to improving the performance of the production system, virtual ergonomic simulation can reduce engineering lead-time and cost by getting the ergonomic design right the first time and avoiding the need to go back and make changes later, when they will be more difficult and expensive. Simulation of human factors can lower the cost of work-related injuries by introducing ergonomics earlier in the design process. A wide range of manikins can be used in the simulation to determine how different types of people will interact with the work cell. Before anything is built or even ordered in the physical world, the virtual workplace can be easily modified by reconfiguring the work cell layout, tooling and equipment to optimize the worker's motions. [8]

Figure 4. A few examples of adjustable workstations from aluminium profiles system. [6]

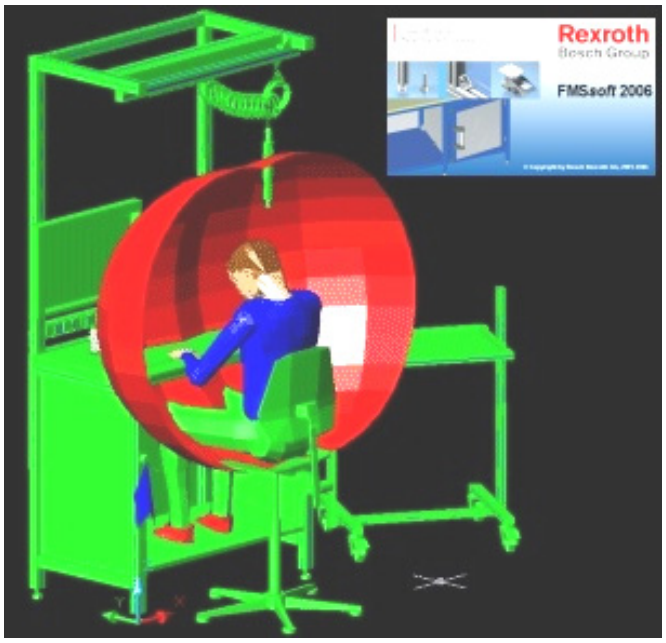

Figure 5. Example of software to modular workstation design modelling. [5]

Figure 5 presents the example of computer- aided application to visualise design of manual workstation based on profiles modular system and to modelling of ergonomics parameters.

The rapidly emerging technology of virtual ergonomics allows designers and engineers to overcome these issues by enabling the simulation of human interaction and ergonomic behaviour between production stations from the earliest stages of the design process. [8]

4. CONCLUSION

Ergonomic workstations are much more than just comfortable. They also support efficiency. An ergonomic workstation design plays a decisive role in reducing waste during production. If work tasks and equipment do not include ergonomic principles in their design, workers may have exposure to undue physical stress, strain, and overexertion, awkward postures, forceful exertions, repetitive motion, and heavy lifting.

The ergonomic design of work areas is crucial not only for compliance with health and safety regulations but also for employee comfort and efficiency. An ergonomically designed work area will reduce injuries and fatigue, while increasing productivity. Statistically, a disregard of ergonomic principles when designing workstations has been shown to result in reduced performance of between 5% - 20%, due to back and neck pain alone.

The modular workstations are designed to provide a balance between human well-being and performance. In addition, modular construction permits complete freedom in system configurations.

The building blocks from aluminium profile system provide all the modules that are need to ergonomically design and arrange of workstations in production plant.

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