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Ergonomic workplace

Abstract: Proper ergonomic design of each workplace together with finding a suitable method of work with the appropriate time standards ensures a better structure of technological operation with the increased efficiency of sewing machines. Position for working at a sewing machine should enable the mobility of limbs, ergonomically favourable arrangement of working zones and the visible ones and a stable balance state in performing the work process.

Keywords: ergonomics, workplace, movement analysis.

4.1 Ergonomic workplace

Employees in industry often deal with problems of health, safety, motivation and efficiency of workers, depending on the production process and working space. According to the European Foundation for the Improvement of Living and Working Conditions in EU countries 62% of workplaces include repetitive movements of arms and hands, 46% body positions that cause pain and fatigue, 35% handling heavy burdens, 56% of jobs require work with the short timescale and 54% work in a fast pace, 42% do not allow vacations and 31% are against free rhythm. About 40% of all employees during at least 25% of their working time are exposed to at least three factors for the development of diseases of systems for movement. In order to solve these problems, it is necessary to take steps to prevent or mitigate the troubles arising in the workplace during a production process which also have a bad effect on the life and work of workers in industry. Basic steps are as follows:

(1) *Technical–organizational* – the introduction of a production technology often makes a serious problem in psychophysical strain for a man and his safety at work, social interaction and communication, the monotony which occurs due to depletion of work and fatigue due to the hardship and rhythm of work. In order to solve these problems, it is necessary to take technical–organizational steps such as separating humans from machines, automation, replacement of workplace and expansion of work.

(2) Technical–safety – to prevent accidents and troubles at work, they must be taken care of when introducing new machines, tools and designing workplace.
(3) Ergonomic – when designing the workspace, machines, tools and devices, to facilitate human work and adjust the work to his psychophysical abilities. Ergonomic measures include the problems of methods of work.

Ergonomics (Greek: Ergon = work + Nomos = custom, law) is an interdisciplinary field of science about the work that deals with the research of biological, psychological and sociological moments of human labour in the adaptation of human to machine and vice versa. The term ergonomics was created by Murrell K F H in 1949. Human Factors Engineering and Human Factors is a synonym for ergonomics.

There are several definitions of ergonomics:

- According to the "father of ergonomics," Alphonse Chapanis (1985) ergonomics is a discipline that examines the characteristics of behaviour, abilities, limitations and other characteristics of people and applies discovered information to the design of tools, machines, systems, tasks, jobs and environment so that they can be used productively, safely, comfortably and effectively.
- By the International Ergonomics Association, ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance. Ergonomics contribute to the design and evaluation of tasks, jobs, products, environments and systems in order to make them compatible with the needs, abilities and limitations of people.
- By James H. Stramler (1993) ergonomics is that field which is involved in conducting research regarding human psychological, social, physical, and biological characteristics, maintaining the information obtained from that research, and working to apply that information with respect to the design, operation, or use of products or systems for optimizing human performance, health, safety, and/or habitability.
- Ergonomics is now predominantly observed as an interdisciplinary part of science of work. According to R. Hackstein, the science of work is "a combination of theoretical, descriptive and experimental, natural and social sciences...about human labour as a conscious and planned, body and spiritual activity which aims to satisfy basic needs first, and then the other ones..."

Put simply, the science of work deals with parsing and designing of working systems and working environment, trying to establish, on the basis of scientific

knowledge, all necessary measures that would improve and facilitate the work and life of a man in industry. The main difference between the ergonomics and science of work is that the area of ergonomics is theoretical, and ergonomics should be viewed in its practical dimension – as technology.

The task of ergonomics is to optimize the human–machine–environment system, adjusting the working conditions to physical, physiological and psychophysical nature of man, considering relevant differences among people in regard to jobs and the workplace. Thus, the task of ergonomics is the alignment of parts of the system (man–machine–environment–organization) with the help of component parts of the science of work, namely anthropometry, work physiology, psychology, sociology, work technology, work pedagogy and organization of work. Not only does ergonomics increase efficiency and productivity of manufacturing or business systems, but it also improves the health, safety and comfort of man in his working environment.

German School of ergonomics defines macro-ergonomics more orientated to sociology, and micro-ergonomics orientated to improve performances of whole system and reduces stress caused by work.

The main goal of micro-ergonomics is to improve the performance of the work system and reduce stress analysis: task, working environment and man–machine interaction. The concept of stress–strain is the traditional approach to assessing the working system. The basic concept is that every workplace is characterized by external factors, which are the same for all individuals who react differently depending on the individual characteristics and abilities. The stress is different from the parameters of stress (defined by numbers), stress factors (given only descriptively) and the time of stress exposure. In order to understand the factors that have the influence on work, the structure of Human–Machine System (HMS) must be examined by monitoring human labour in relation to the information and the speed of information flow. This includes setting up the task, its putting into action, the performing of the task and the result of performing the task. A feedback closes the control loop formed for the human–machine system and shows that the operator is generally capable of comparing the task and the result. All the disorders of this process are the impacts of environment. While analysing the task defining, there are

- tasks with predominantly physical strain. Here, some people define the difference between static and dynamic physical work. In both cases, stress can be quantified by defining the physical requirements.
- tasks with predominantly mental strain (intellectual work). A generalized concept for defining this stress in numbers does not exist. Intellectual work is therefore taken as a factor of stress.
- tasks with both requirements (physical and mental).

While analysing environmental impacts (ergonomics of environment), there are

(a) physical environmental impacts which can be measured, as well as their impact on man and can be assessed quantitatively (lighting, noise, mechanical vibrations, air-conditioning, toxic gases, radiation, dust, dirt and humidity).
(b) social environmental impacts which can not be measured physically and therefore are marked differently (they are sometimes called a work sociology or industrial psychology).

Macro-ergonomics deals with the systematic structure and organization of workflow considering the task, the content and the time factors. It can be divided into the organizational structure and the organization of work processes. The goal of macro-ergonomics is not an individual workplace but the interaction between many workplaces. Its goal is testing ergonomic requirements at this level. In this context, the term macro work can be used as well. The unit area of macro-organization can be divided if a unit operating system is transferred to a higher operating task in the context of a group. The analysis of workflow provides the right-in-time information necessary for the task that should be performed within the organizational unit and on the basis of internal dependences. This allows the specifying of capacity requirements of humans, the means of production and the time of their utilisation. In particular, ways of communication and possible losses of information are determined in order to optimize the interaction between workers and working funds. The development of innovative telecommunications and computer technology is a new challenge for the organization of work.

Environmental conditions are defined as those that do not directly influence the work process and the process of communication but, similarly to micro-ergonomics, change it indirectly. It is important to emphasize the difference between the impact that can not be changed by the organization of work and the influence that can be optimized by the corresponding design of workflow and organizational structure of cooperation.

On the output side of the working process, performance improvement can be obtained by organizational steps, with personally verified methods of the quality of working object and the results respectively developed on one side, and on the other there is the worker under the influence of motivational factors.

Many of the cases described can not simply be proved by an experiment. Therefore, partial detailed simulation methods are often used, and through cumulative key numbers they describe personal acceptance, personal qualifications, waiting time, overlapping by simultaneous upcoming order to provide the assessment of organizational changes and new structures.

4.2 Division of ergonomics

There are several divisions of ergonomics according to the types and specific human traits and characteristics of human interaction with the environment.

Types of ergonomics are conceptual ergonomics, system ergonomics, corrective ergonomics, software ergonomics and hardware ergonomics.

4.2.1 Conceptual ergonomics

Conceptual ergonomics deals with the designing of ergonomic measures in the very beginning of construction of a working system and therefore is the cheapest one. This ergonomics includes the tasks of improving the conditions of life and work in two areas:

- the area of humanity and
- the area of economy.

In the area of humanity, the ergonomics must reduce the strain of workers, reduce the risks at work, allow a holiday, increase the satisfaction and interest in work and make work pleasant. It is important to reduce health problems at work, improve the protection while working, reduce the harmful influence of environment and perform the work easily.

The tasks of ergonomics from the perspective of economy are increase the accuracy of work, speed up the rhythm, ensure the feasibility of labour, reduce the work requirements, reduce costs, facilitate decision-making, improve information flow and utilization of time.

Ergonomics must provide the increase of motivation, quantity and quality of work. In order to meet the specified requirements, they must shape the ergonomic measures that arise as a general result of a system ergonomics.

4.2.2 System ergonomics

The task of system ergonomics is to take care of the coordination functions of a manufacturing system. It takes care of personal and mechanical functions in which the man in the production system must not be under any kind of strain. System ergonomics pays attention not only to some parts of the system (man, machine, environment), but also to the whole system. According to B. Doring (1976), system ergonomics has several areas of interest:

- designing organization of working system,
- organization flow (process) of work system,
- designing workplace,
- designing working areas,
- designing working environment and
- selection and training of employees.

The base of a system ergonomics is a conceptual ergonomics. After the situation is established conceptually, the system ergonomics decides about the steps to be taken. System ergonomics is a sort of methodical, technological procedure that is performed when developing a workplace. During the implementation of the functions of system ergonomics, human psychophysical capabilities must always be taken care of.

4.2.3 Corrective ergonomics

Corrective ergonomics occurs in the later period of realization or utilisation of the working system. It implies meeting the ergonomic requirements subsequently, so it is less successful and more expensive than the previously mentioned types of ergonomics. It is subjected to many limitations because the ergonomic principles are neglected in its development phase. Corrective measures are therefore based on reliable experiences. Corrective ergonomics is based on the principle: "You see – you look – you improve". The representative of this ergonomics is Barnes (1968), who defined 22 principles for the rationalization of work as a whole and they are 8 principles related to the economy of movement, 8 principles related to the regulation of workplace and 6 principles related to methods and principles of designing tools and equipment.

4.2.4 Software ergonomics

Software ergonomics is an interdisciplinary part of science of work that deals with direct or indirect effects of software products in the human–machine–environment system. It includes biological, psychological and social aspects of interaction between a man and a software. The aims of software ergonomics are

- improvement of adopting information technology,
- improvement of work motivation,
- increase of work competence,
- development of personality and
- optimization of strain in introducing new technologies.

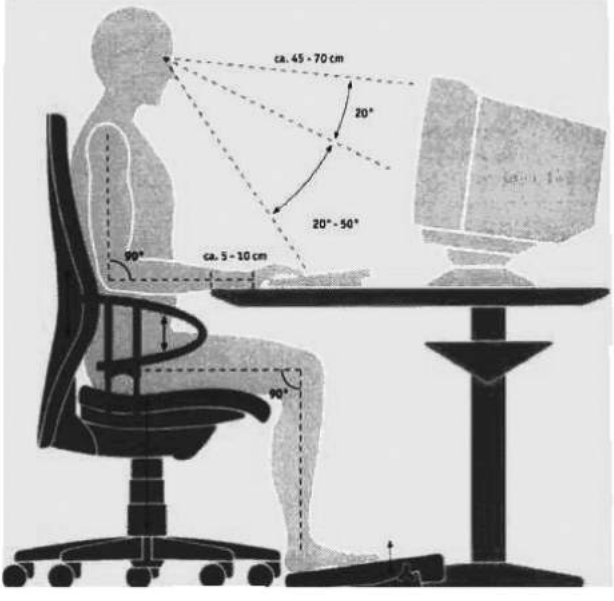
By introducing computers, a man no longer manages the machine directly but indirectly, because of which he must dispose of all the components that will allow him a certain level of freedom when coping with work tasks and goals within the cores of software ergonomics.

The usage of information technology allows the increase of production with the help of new technologies; it enables the increase of efficiency of processing information by introducing better methods and procedures.

Software ergonomics is also concerned that because of the strain transfer from physical to mental side of man, a worker shouldn't be under too big or too small strain. That's why, while working at the computer (a sitting workplace), it is important to know the following:

(1) Feet must be laid flat on the floor.
(2) The knee joint must be bent to 90º, i.e. set from 20º to 45º below the hips.
(3) Elbows must be laid parallel on the table or with minor deviations.
(4) Shoulders must be flat and straight, but also relaxed.
(5) The screen must be at least 50 cm away from the head and must be in the eye sight without moving the head.
(6) Wrists must be flat and under no strain.
(7) Keys on the keyboard must be pressed very lightly without using much force.

In the countries with developed industry the concern about adjusting the workplace to the worker gradually becomes a subject of interest because of physiological (health), psychological (selection and satisfaction), and economic reasons (production quantity and quality). The ergonomic position while working on a computer, according to the European Union Council Directives 90/270/EEC, is shown in Figure 4.1.



4.1 Ergonomic positions while working on computer.

4.2.5 Hardware ergonomics

"Classical ergonomics" actually means this type of ergonomics. It does not deal with the working content such as technical–physical components of computer systems, direct and indirect environment of system; for example, suitable construction of the place of the apparatus, the height of the place, a chair, its parameters and reflective surfaces.

According to the specific human traits and characteristics of human interaction with the environment, ergonomics is divided into: physical ergonomics, cognitive ergonomics and organizational ergonomics.

Physical ergonomics deals with anatomical, anthropometrical, psychological and biomechanical characteristics of human beings in their relationship with physical activity attitudes towards work, handling with materials, frequent injuries due to movement, muscle–bone disorders, organization of working space, safety and health.

Cognitive ergonomics deals with mental processes such as perception, memory, thinking and mobility and the way they are affected by the interaction with the remains of the observed system. The most important aspects include mental effort, decision making, interaction with computers, human reliability and work stress.

Organizational ergonomics studies the optimization of socio-technical systems, including their organizational structure, rules and processes. This ergonomics includes communication, organization of work, teams and teamwork, communal ergonomics, cooperative work and management.

4.3 Ergonomic conditions

Designing a workplace is a very important segment of the intangible strategies of motivation since the attitudes towards work and the pleasure of it significantly affect the motivation at work, and also the entire life of the individual. Programs of redesigning the workplace try very hard to make the job interesting and challenging. Significant individual approaches to designing workplaces are job rotation, where people are periodically moved from one specialized job to another in order to prevent monotony and boredom. However, the real motivational potentials are best activated by the enrichment of work which spreads vertically, including various tasks and skills, responsibilities and autonomies.

Basic characteristics of the work to be taken into account when designing the jobs are skill variety, identity and task integrity, the importance of the task, autonomy and feedback. In addition to the individual, there are also group accesses to designing a workplace. Thus, in integrated working groups workers are given a number of task assignments instead of one, and in autonomous

working groups they are only given the goal, and it is up to them to determine the working responsibilities, time for rest, etc.

Participation as the level of taking part of employees in decision-making processes concerning important aspects of work has a significant influence on the increase of employees' motivation, encouraging creative and overall potentials of people, improving the quality of decisions and the success of BPS.

Management by Objectives is an important strategy of modern management in raising motivation, quality, human resources, flexibility and responsiveness to changes in the environment. This defines areas of responsibilities and standards of behaviour for each production unit.

One of the biggest problems is the resistance of the workers who often do not believe that the system of stimulating rewards is objective and fair. One of the important conditions of success of stimulating rewards is to gain the confidence of workers, so salaries should be supplemented with good designing of a workplace.

In order to design a workplace, it is necessary to know ergonomic conditions. Ergonomic conditions are physiological, psycho-sociological, anthropometric and ecological conditions of work.

(1) Physiological conditions are related to studying working capacities of man and various influences on working capacity. Physiology is the study of functioning of certain organs of living beings, as well as chemical and physical processes that are being carried out inside of them. Physiology of work is a special branch of physiology which is limited to the body of a man who works. A man is most capable of making best sport (and physical) results when he is about 25, and of mental (and organizational) results when he is about 45 years old.

    Rational usage of working capacity of man is not only a matter of being humane, but also of being economical. If a man in his early age or when too old is entrusted tasks to which he is not physiologically (physically) equal to, it significantly affects the efficiency of human life. Such a man is ill much more during his working life.

(2) Psycho-sociological conditions of work are related primarily to achieving a sense of satisfaction in work. The satisfaction of a man who works is influenced by many factors which are largely related to the motivation for work. Mental fatigue occurs due to excessive mental strain during a certain period of time. It is manifested as fatigue which can be eliminated by frequent periods of rest during shifts. Monotony in work has a negative influence not only on the concentration of workers, but also on his satisfaction. It can be eliminated by changing the organization of work. Mental saturation is a condition which occurs when there is a resistance against accepting or continuing the

performing of a particular work activity. It is manifested as irritability, anxiety and a loss of will for work. Stress occurs when a worker feels threatened due to strain or danger to which he is exposed in the course of performing the work. Stress occurs when a worker believes that he is under too much strain, or when he has the impression that he can not affect the situation.

(3) Anthropometric working conditions refer to the conditions in which a man in the workplace should be ensured in order to adjust the work performed up to anthropometric (dimensional) features of man.

(4) Ecological conditions of work are a new attitude towards the environment.

Unless ergonomic principles are complied with, a man is exposed to a series of risk factors which has been confirmed in thousands of epidemiological researches, laboratory tests and histories of diseases including action force, repetitive movements, uncomfortable body position, bad posture, vibration, stress and coolness. Some examples of risk factors that may lead to the occurrence of musculoskeletal and other disorders are as follows:

- *Unnatural and static positions.* Bending or lowering the body due to holding or lifting heavy objects; pulling out or pushing objects into blocked areas; frequently repeated tasks which include leaning, bending forward, kneeling or squatting, working with arms bent or distorted, using hands below waist or above the shoulders; standing or sitting most of the shifts; working with arms or hands in the same position over a longer period of time without changing posture or resting.
- *Putting a lot of force into the movement*. Lifting (lifting heavy loads with one hand or without the help of mechanical devices; lifting heavy loads with bending, reaching above shoulders or leaning) pushing, pulling, carrying (manual cranes for pallets or other carts which are difficult to move; uneven surfaces and cracks in the floor or panels with low edges that can catch wheels while pushing; pulling objects instead of pushing them; manual transport of heavy objects to big distances) and using tools which are too small or too large for the hands of workers.
- *Repetitive movements* (rapid movements of hands; movements that are performed for several hours without rest; jobs that require a repeating force of the fingers – packaging, putting labels on products).
- *Contact stress* (contact with sharp or hard edges, working with machines for cutting – knives).
- *Vibrations* (using tools on the electric drive – vibrations of hands and arms, driving forklifts, trucks and other vehicles – whole body vibration).
- Coldness – working in cold environment without proper clothing.

Many of the musculoskeletal injuries can be prevented. Employers must reduce any risks identified in the process to the lowest possible level by introducing control measures. It is important to consult the workers then because they know most about the job. This means that the job should be adjusted to the worker, not the worker to the job.

Just like designing the workplace in the classical industrial situations, there are several ways of performing the work nowadays: standing, sitting, and mixed (the best) workplace. In designing the workplace it is necessary to use the ergonomic rules that will decide on the posture of the body at work, e.g. comfortable position of hands, the spatial freedom of movements of hands in all directions when standing, sitting and combined work, the height of workplace, microclimate, etc. It aims to reduce psychophysical load in order to prevent fatigue, monotony, stress or mental saturation.

In constructing a new workplace or analysing the old one it is necessary to pay attention to the following factors:

- Anthropometric factors (the height of a man because of reaching to handles or buttons on the machine).
- Biomechanical factors (the way in which a force acts on our wrists, the method of transporting material and handling it, body posture at work – sitting or standing, if there is a possibility of adjusting the height of chairs).
- Physiological factors (the way of functioning of human body).
- Factors related to the construction of work (jobs are divided into smaller segments; introducing workers to the goal and purpose of work).
- Factors related to the information and the control of work (if the information is presented in the simplest way).
- Working environment factors (noise and vibration, lighting, air conditioning, protective equipment at work).

In designing a workplace it is necessary to pay attention to the conditions of work and harmonize with four characteristics of workers. These are motor-physical (height, weight), sensory (hearing, vision), mental (intellectual ability, memory, attention) and spiritual (morality) characteristics. It is necessary to avoid unnatural body postures, such as leaning on the back or aside, and to lean forward 15° maximum; working with arms held out, because it reduces the accuracy of work; squatting and stooping. It is necessary to take into consideration the relationship between static and dynamic muscle work (the relationship between the angles of different parts of the body, the mass distribution of individual body segments, the duration of a movement and the risk of a posture) using

- indirect methods – taking photographs or recording workers,
- direct methods – watching the man working,

- subjective methods – analysis of employees, i.e. when a worker is asked about his movements at work.

4.4 Movement analysis

The study of schedule of a technological operation reveals the schedule that allows a shorter path of movement and optimal sequence of grips and movements in the operation. Better schedule and sequence lead to the increasing of labour productivity and better humanization in work, as well as better utilization of existing resources, shortening the total length of moving the objects of work, reducing the number of grips, shortening the duration of the operation.

Organizational model is different from the production technology and it can be made in a written form or acquired during a long series of repetitions, and it is caused by:

- schedule in the workplace,
- sequence of performing the task and
- interdependence of performing the grips.

The following rules are particularly important:

- workplace must have the optimal size,
- working conditions should correspond to standards,
- equipment should enable work in a standing or sitting position (employee elects),
- equipment should be located in the optimal zone is selected according to the frequency of handling,
- arrange the equipment to provide the optimal sequence of movements in the operation and
- arrange the equipment for supplying the workplace so that it should be optimal in relation to employees and inter phase transport.

When planning the performing of an operation, i.e. determining the ways of performing an operation, certain principles, which provide better performing of operations and less strain of a man at work, are very important.

- Both hands should work without interruption.

This principle avoids unnecessary delays in work, and the usage of one hand puts uneven pressure on human body.

- Hand moves should be simultaneous.

This principle ensures less mental effort, because a simultaneous beginning or ending of two movements requires only one command of human brain.

- Hand moves should be symmetrical.

The movements of left and right hand are "the same" for the human brain only if they are symmetrical. This means that each hand moves as an image in the mirror of the other hand. It takes only one mental effort, not two, to control the symmetrical movements.

- Hand moves should be reduced to the lowest class.

This principle suggests that less force and more speed require less muscle mass and vice versa. Thus, human energy will be used rationally. Classes of muscle mass correspond to classes of movements. Movements "from the elbow" are the most suitable ones for removing the product. As for the movements that must be frequently repeated, such as the wrench and wring, the optimal movements are "from the wrist".

- Use the force of inertia in movement.

When stopping the load which is moving (breaking), there is the force of inertia that pulls the load further in the direction of movement. This force depends on the speed of movement and the weight of load. This force should be used when planning to perform an operation.

- Movements should be punctured.

A lot of researches proved that the movement with sudden changes of direction causes the loss of up to 80% of time on controlling the power of inertia while stopping and developing of speed when moving in opposite directions. That is why only smooth and continuous movements are recommended.

- Movements should be ballistic.

The characteristics of a ballistic movement are that at the very beginning of the movement the hand muscle gives the force to the burden. Hand muscles are relaxed during the movement.

- Movements are to be performed in natural rhythm.

Man is prone to the rhythm in work and this tendency should be used. Natural rhythm eliminates unexpected delays. Durations of operations, which are repeated, are shorter and more equal if a natural rhythm of movement is used. In this way a man develops working habits and does not put any effort and time into making decisions during the work.

The following rules are especially taken care of:

- whenever possible eliminate the grip,
- whenever possible connect with the previous or the following grip or movement,
- whenever possible do a set of grip in several areas simultaneously,
- whenever possible release hands and perform grips by feet,

- change the sequence whenever it leads to more efficient work,
- loaded grip should be performed by those parts of the body whose features are most appropriate,
- sequence of hand movements should be designed to be simultaneous, symmetrical, and in opposite directions.

In order to study the sequence of grips and movements when performing an operation various methods are used, such as:

(1) *The method of model* – the model map – for studying the arrangement of equipment and commands when performing an operation, i.e. a technical means a model of work is drawn into, such as:
   - changing of arrangement of equipments in the workplace,
   - providing the procurement of organizational supplies and perform their schedule,
   - reconstruction of existing equipment.

The method of model allows the increase of productivity, the improvement in humanization of work and better utilization of the surface and volume of a workplace.

(2) *The method of thread* studies the arrangement of equipment in the workplace while performing an operation. By pulling a thread from one landing point of the object of work to another along the approximate path of their movement, it is possible to study the schedule of the workplace, taking into consideration the impact of movement of the object of work. The method of thread allows determining the shortest path of items or tools in order to change the schedule and introduce the organizational aids, the increase of productivity, the improvement in humanization of work, better utilization of the surface of a workplace: shortening the total path of movement of the object of work.

(3) *The method of stroke* studies the arrangement of equipment in the workplace when performing an operation. Graphical models of equipment are applied in the workplace and strokes of workers are drawn in the shapes of curves which represent the projection of body bearing on the plane of moving.

A small circle is noted down at the beginning of a stroke, an arrow at the end. Strokes are separated by boundary points which represent the inaction or grips that do not belong to the grip of transport. The shortest total path allows the increase of productivity and humanization of work, better utilization of the surface of a workplace, reducing the total path of movement of workers which reduces the energy while carrying the object of work.

(4) *The method of a map of the sequence of grips on work object* studies the schedule of grips on the work object while performing an operation. The

actions undertaken are changing the sequence of grips on a work object while performing an operation; the elimination or reduction of certain grips (relief) are suggested while performing certain grips. The method of a map of the sequence of grips on work object allows the increase of productivity and humanization of work, especially the shortening of a total path of work object, reducing the number of grips, shortening the duration of the operation.

(5) *The method of spatial schedule and the sequence of grips* studies the sequence of grips while performing the operation in the workplace, as well as the arrangement of equipment. The change of the sequence of grips while performing the operation is carried out, the elimination of certain grips is suggested, together with actions to change the schedule. The method of spatial schedule and the sequence of grips helps to achieve the increase of productivity and humanization of work, as well as shortening the path of moving the work objects, shortening the duration, shortening the length of movement of workers.

(6) *The method of a map of grips* studies the sequence of grips while performing an operation as well as the arrangement of equipment and commands on the workplace. The change of the sequence of grips while performing an operation is carried out. The elimination or reduction of certain grips (relief) is suggested, together with actions to change the arrangement of equipment and commands. The method allows the increase of productivity and the improvement in humanization of work, better utilization of existing resources, shortening the total length of moving the work object, the length of path, the number of grips, the duration of the operation, the relative time of work.

(7) *The method of a map of movement* studies the interdependence of movements when performing an operation and the sequence of movements and arrangement of equipment and commands in the workplace. The change in the interdependence of movement is carried out; the elimination of certain movements is suggested, as well as shortening (relief) of their performance. The method allows the increase of productivity and humanization of work, better utilization of certain resources, shortening the total path of moving the objects of work, reducing the number of movements and shortening the duration of operations.

(8) *The method of a map of interdependence grips* studies the interdependence of grips performed during the operation in the workplace. The map of interdependent grips follows the process of work and not the object of work, therefore all the grips are grouped into three larger sets: work, transportation and waiting. The resources are shown on the abscissa, and the cumulative time on the ordinate. The change of interdependent grips in performing the operation is carried out, as well as the elimination

of certain periods of waiting, or their reduction and parallel work on various resources. The method allows the increase of productivity and humanization of work, proper utilization of existing resources and shortening the total duration of the operation cycle.

(9) *The method of movement* studies the arrangement of equipment and commands in the workplace, the sequence of movements and interdependence of movements of left and right hand. The change of the arrangement of equipment and commands is carried out; the change of the sequence of movements when performing an operation is suggested, as well as the elimination of certain movements and changes in the interdependence of movements of left and right hand when performing an operation. The method of movement allows the increase of productivity and humanization of work, better utilization of a working place, shortening the total length of the hand movements of workers, reducing the number of movements, synchronization of movements of left and right hand and shortening the duration of the operation.

4.5 Ergonomic design of workplace in garment industry

Different types of technology have the influence in different ways of working. For example, a line of clothing production is based on the measurement of partial working time, where a chronometer determines the average time for each work element within the time study and the motion study. That is how a man is brought into the rhythm of production line by a number of movements which can be well calculated, but certainly not the best ones for each individual worker.

Proper ergonomic design of each workplace, along with finding suitable methods of work with the appropriate time standards ensures better structure of technological operations with the increased efficiency of sewing machines. Working posture at sewing machines should allow the mobility of the limbs, ergonomically favourable arrangement of working and visible zones and a stable balanced state when performing the work process.

Technological processes of sewing clothes are performed on production lines with a large number of technological operations where each technological operation does not last long and has a significant psychological, physical workload for each worker. The material which goes through the process of work, due to its physical–mechanical characteristics, requires a careful handling when taking, assembling, positioning and putting it aside. Therefore, the structure of technological operations is mostly (65%) related to the handling of material within support-hand technological grips. The very processing on a machine (sewing grip) is performed during the machine or machine-hand time (25%),

while 10% of time is used for non-production work. When designing workplace in the process of sewing it is necessary to achieve dimensional harmony of human–machine system of inter-phase transport, with the correct physiological posture of sitting, which allows rapid and accurate movements of the motor when switching on the machine and processing the work object, a high level of coordination of movements, a correct position of the spine and good position of the head. The posture of the body of workers, the complexity of the structure of individual movements within the performance of technological operation of sewing and the level of muscular and visual control of the worker depend on the type of technological operation, the type of sewing machine, its technical equipment, machinery and the layout system of workplaces.

When designing workplace in garment industry it is necessary to apply five principles of ergonomics:

(1) Ergonomic principles in designing workplace.
(2) Ergonomic principles in designing working processes.
(3) Ergonomic principles in determining working time.
(4) Ergonomic principles in handling material and tools.
(5) Ergonomic principles in designing environment.

(1) *Ergonomic principles in designing workplace*
- Properly designing workplace should make possible for the work to be performed either in standing or sitting posture.
- Workplace height should be such that a standing work can be replaced by a sitting one.
- There should be enough space at the workplace for the operator to stretch his legs comfortably.
- Each operator should have a seat of such type and height as to assume proper posture in work.
- Armrest should be provided if the nature of work allows.

(2) *Ergonomic principles in designing working processes*
- In performing an operation, the posture which should be applied, requires the minimum energy consumption.
- Work should be organised in easy and natural rhythm.
- Standing posture should be used only when higher force should be applied by hands or when movements are necessary (cutting material, trim, Figure 4.2).
- Work should be organised so as to use both hand simultaneously whenever possible.
- Hand should be freed from work whenever possible and while serving the tools or machines done by feet (work on special sewing machines whenever possible, Figure 4.3).

4.2 Work on press.

4.3 Work on special sewing machines whenever possible.

4.4 Position of elbows at work.

- To make a movement maximally economical, it is necessary to employ adequate muscle masses.
- Sewing workplaces are shaped assuming that the worker has good visual skills, i.e. favourable working posture which consists of slightly bent upper part of the back with a work line of sight that can include flexible front of the head in a comfortable posture to a maximum of 30° and an additional eye rotation of 10°. This posture allows field of vision with the viewing angle ±1°, which achieves high visual acuity required for accurate management of technological operations of sewing.
- This is to specify the height of sitting, the height and the size of desktop machines, pedal position, distance of chairs, with the necessary sight and visual acuity and the ability to perform simultaneous movements of hands, legs and torso (Figure 4.4).
- The procedure of designing the workplace in a sewing room requires determining the angles of kinematic system, whereby a suitable position of the foot on the pedal of a sewing machine is at angle of 90–100°, while angles suitable for joints of under knee-upper knee are 90–110°, and upper knee-torso 90–95°. This is the way to get ergonomically functional and physiologically correct sitting working posture, with the proper arrangement of equipment and means of work, proper angles of vision and distances.

4.5 Wrong positions of work pieces.

(3) *Ergonomic principles in determining working time*
- Production time can be determined only for the operator who is skilled for the job and has average experience.
- Pause for the handling loads, improper body postures in work and monotony should also be taught about when calculate manufacturing time, as they seriously impact fatigue coefficient.
- Real coefficient and additional time, including lunch break, breaks for physiological needs and justifiable organisational losses should be calculated and included into the norm (see Chapter 3).

(4) *Ergonomic principles in handling material and tools*
- Operator should be free from transport procedures as much as possible.
- Hand should be free from holding all the work pieces.
- Each instance of handling the material should be provided it is economically feasible, mechanical or automated.
- Tools, materials and work pieces to be handled should be positioned so that the operator is not required to bend his body, if possible (Figure 4.5).
- Tools should be put at the workplace whenever possible (Figure 4.6).

4.6 Tools on workplace.

- Recommended force for a permanent lifting operation under favourable conditions is for men 176N and 98N for women. For occasional lifting under favourable conditions the force is 490N for men and 294 for women operators. If work includes permanent load bearing permissible load is 392N to 490N for men and 147 to 196N for women. This is important when transport and taking the textile material on cutting table.

(5) *Ergonomic principles in designing environment*

- When using both daylight and artificial illumination, the light source should always be to the left.
- Intensity, distribution and type of illumination should prevent excess strain of the eyes.
- It is necessary to find the appropriate intensity, timing and type of illumination that will ensure a smooth performing of the production process throughout the work day.
- Lights are placed on that way that 60% of light comes from the main source, while the other part comes from additional lights in each workplace. A number of other factors are also taken into consideration, such as the height of working space, the coefficients of reflection of surfaces of the workspace (e.g. table or wall), and the amount of

4.7 The light in a cutting room.

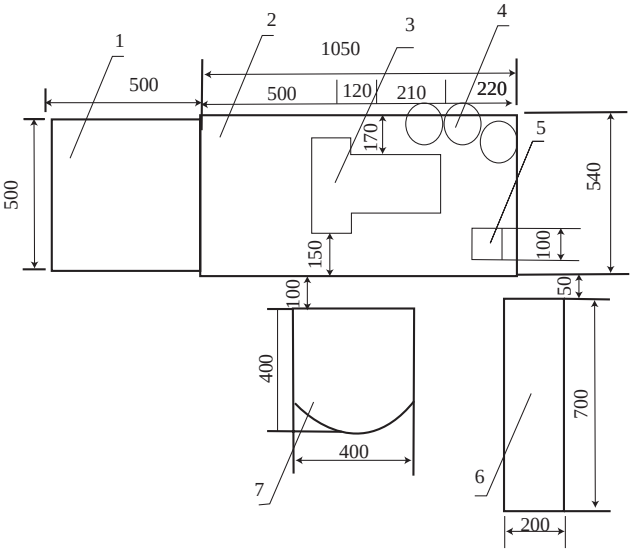
natural light in the room. The light in a cutting room is shown in Figure 4.7.

- Individual sources of light on sewing machine for work with dark materials and topstitch (Figure 4.8).
- Approximate illumination values are as follows: 60 lx rooms with low frequency; 120 lx light strain of the eyes; 500 lx normal strain of the eyes (for reading and writing); 1000 lx high strain of the eyes.
- Illumination values for cutting and sewing dark material 600 to 1000 lx.
- Illumination values for cutting and sewing lighter material to 500 lx.
- Illumination values for the CAD system ranges between 300 and 600 lx.
- Workroom temperature should be adapted to the type of work to be done, as normal functioning of the organism is closely connected with constant inner temperature of the body.
- Comfort is achieved at relative air humidity of 50 to 70 %, with the following temperatures in workrooms: 20 to 21 ºC light, sitting office work; 18 ºC light work in standing posture; 17 ºC hard work; and 15ºC very hard work.
- Air exchange in the room should be at least 45m^3/h per person, for light and 90m^3/h per person for hard physical labour.

4.8 Individual sources of light on sewing machine.

- Sewing room and finishing room require the usage of fans and air conditioning in summer. If they are used in warm periods, the difference between external and internal temperature should not exceed 7 ºC and relative humidity from 40% to 60%. It is advisable that the temperature in a working day should vary in 1-2 ºC.
- Minimal work area per person should be $4m^2$. On Figure 4.9 there are dimensions of sewing machine.
- Noise and vibrations distract the worker from the work object causing tension and unrest, and if they last long they can cause fatigue and insomnia. Longer exposure to noise can lead to ear damage, whereas faster vibrations cause rapid heartbeat, increase blood pressure, reduce sight and make other problems in the body of worker.
- To organise work properly noise should not exceed 50 dB(A) for intellectual work, 70 dB(A) for office and similar work and 90 dB(A) for other types of work. Table 4.1 gives the allowable noise levels depending on the type of work.

Where: a – the noise made by a machine or device which is directly handled by the worker,



1. Slanted conveyor belt, 2. sewing machine table, 3. sewing machine head, 4. cotton reel stand, 5. label box,6. movable stand, 7. chair

4.9 Dimensions of sewing machine.

Table 4.1 The allowable noise levels depending on the type of work

Type of work	The allowable noise levels on workplace, dB(A)		
	a	b	c
physical work without requiring mental strain and perception of environment by hearing	90	84	80
physical work focused on accuracy and concentration; periodical monitoring and environmental control by hearing; driving of means of transport	80	74	70
work that is done by frequent voice commands and acoustic signals; work that requires constant monitoring of environment by hearing; routine work mainly of mental character	–	70	60
routine work mostly of mental character that requires concentration	70	64	55

(Continued)

mental work focused on the control of work of group of people who perform mostly physical work, work that requires concentration or direct speaking and telephone communication	–	60	50
mental work focused on the control of work of group of people who perform mostly mental work, work that requires concentration, right speaking and telephone communication; work exclusively related to talks over the means of communication	–	55	45
mental work that requires large concentration, exclusion from the environment, precise psychomobility or communication with a group of people	–	–	40
mental work related to great responsibility, communication to deal with a group of people	-	-	35

b – the noise made by a machine or device which is not handled by the worker,

c – the noise made by non-production sources (device for ventilation or air conditioning, other factories, street traffic, etc.).

- Colour in the working premises affects the feeling of warmth or coldness of the workers. Various tests showed that brighter colours have a pleasant effect on workers, increase their concentration, mood and speed of work, whereas cold and dark colours create a feeling of apathy, bad mood and sleepiness of workers.
- Music removes fatigue among the majority of workers, reduces monotony and anxiety at work, if the optimal duration of music is two and a half hours in one day, in intervals of 12 – 20 min.
- Proper hygienic conditions should be provided, as well as adequate number of rest room and adequate devices in them.
- Workplaces should be kept clean at all times.

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