Ergonomics of the workplace in the lean production system

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Abstract. The article considers the possibility of introducing ergonomic indicators of the workplace into the system of lean production of the machine-building enterprise. The feasibility of taking into account ergonomic indicators is proved by the main tool of lean production - mapping of the flow of creation of production of the "shaft" part. Studies have shown that the accounting of ergonomic indicators allows to identify losses related to psychophysical factors affecting the employee, environmental factors of the employee (including production equipment) and eliminate them by planning and developing appropriate measures.

The development of a production map of a certain product (process mapping) is the most common method of detecting losses in the production stream of a certain product. Since process shaping is aimed at reduction of production losses and improvement of synchronicity of operation, it is mandatory when building the flows of parts manufacturing at machine-building production facilities. The widespread practice in the field of mechanical engineering of using lean production, adapted the procedure of carting production processes in order to reduce the time of downtime, transportation, elimination of unnecessary movements of manufactured parts.

Ergonomics of the workplace, as a science of creation of comfortable and safe workplaces, occupies key positions in systems of labor protection management of enterprises of various industries [1, 2, 3], but is not evaluated in systems of lean production. However, taking ergonomic indicators into account in planning lean production may consist in carrying out a set of measures aimed at justification, ensuring, maintaining the required quality and mutual compatibility:

- workers in production;
- environmental worker;
- production equipment;
- technologies.

When studying the spatial organization of a workplace, it is necessary to identify the impact of its layout on the character of working movements, the working pose, and the degree of their rationality. Auxiliary equipment and equipment may be in the workplace. By observing the worker’s labor movements, motor and sensory activity zones can be determined. Involving the employee in these processes helps improve working conditions. In this case, the questionnaire method can be very informative.
Thus, examples of recommended measures to improve lean production based on ergonomic workplace indicators can be identified:

- placement of the control panel;
- rational arrangement of equipment;
- carrying out training of personnel;
- questioning;
- change the order in which parts are processed and moved;
- visualization.

These activities were tested and evaluated using the "shaft" part creation map at the Numerical Program Controlled (NC) machine operator’s workplace. In order to optimize the process, the lathe operations were previously transferred to CNC machines, thereby eliminating unnecessary movement of parts in sections and reducing the duration of the manufacturing cycle. The operator’s workplace is a separate production area, where, taking into account ergonomic indicators of the employee, rational organization of the workplace is increased. The area of the workplace should be such that, on the one hand, it guarantees permissible working conditions and, on the other, it is economically feasible.

When organizing the work center, the following were taken into account [4]:

- working position of the NC operator;
- space for operator accommodation taking into account areas of objects reach;
- possibility to view the workplace elements;
- possibility to view space outside the workplace;
- possibility to maintain records, place documentation and materials used by the NC operator;
- possibility to place the equipment required by the employee on the basis of the conducted questionnaire the convenience of the seat, possibility to adjust its height during sitting works;
- convenience of arrangement of production equipment;
- availability of working wishes, proposals to improve the workplace (figure 1).

![Figure 1. Layout of the machine operator workstation.1 - rack for accessories; 2 - bar supply magazine; 3 - machine; 4 - control panel; 5 - door; 6 - observation port; 7 - handle door; 8 - chip conveyor; 9 - table; 10 - wooden lattice; 11 -containers for parts, 12 - rack for containers with parts](image)

Figure 1. Layout of the machine operator workstation.1 - rack for accessories; 2 - bar supply magazine; 3 - machine; 4 - control panel; 5 - door; 6 - observation port; 7 - handle door; 8 - chip conveyor; 9 - table; 10 - wooden lattice; 11 -containers for parts, 12 - rack for containers with parts

In order to rationalize the workplace and reduce unearmarked working time periods, as well as taking into account the requirements of regulatory documents [5, 6, 7], the workplace of the CNC machine operator is organized taking into account the performance of labor operations within the reach area of the motor field. All tools in the workplace are located taking into account the employee’s questionnaire...
within range to eliminate unnecessary tilts, turns, squats and other movements causing fatigue and additional time. The normal reach zone in the horizontal plane is limited by an imaginary arc, outlined by the ends of the fingers of the hand, which moves with the center of rotation in the elbow joint. This zone is approximately 1000 mm in front and 300 mm deep. The maximum reach zone in the horizontal plane is limited by an imaginary arc, outlined by the ends of the fingers of a fully extended hand, which moves with the center of rotation in the shoulder joint. This zone is about 1500 mm on the front and 500 mm deep (figure 2).

**Figure 2.** Determination of the motor field of the NC operator.

The effectiveness of the developed measures to integrate ergonomic indicators of the workplace into the system of lean production was assessed from the point of view of the efficiency of the process to reduce the processing time and by the indicators of industrial injuries.

Due to rational organization of the workplace, the CNC machine operator performs fewer non-target movements, reduces fatigue of the worker, thereby reducing the duration of the manufacturing cycle, improving the quality of the processed parts and increasing productivity. Efficiency of using ergonomic parameters in lean production system is shown on the "shaft" part manufacturing flow map (figure 3).

**Figure 3.** "Shaft" part manufacturing flow map. 1 – Supplier, 2 – Consumer, 3 - Entrance control, 4 - Clock with NC (machine with numerical program control), 5 - Drilling with the CNC, 6 – Clock, 7 -Heat treatment, 8 – Marking, 9 – Polishing, 10 – Milling, 11 – Drilling, 12 – Metalwork, 13 - Marking with the CNC, $T_{av}$ - Value Adding Time, $T_{pm}$ - Total Part Manufacturing Time.
The value creation flow map, like any lean production tool, should be used to improve the production system. During the creation of the map it is possible to clearly identify "bottlenecks," various losses, assess working conditions. The VCFM envisages the creation of a "current state" map, which is compiled based on the analysis of the technological process and a "future state" map taking into account the measures to eliminate losses. On the basis of the presented data, the efficiency of the "shaft" part manufacturing process was calculated:

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E = \frac{T_{av}}{T_{tpm}} \times 100\% = \frac{10644}{11424} \times 100\% = 93\%
\]

The efficiency of the process determined on the basis of the Flow Map of part creation proves the need to study the spatial organization of the workplace. The development of measures in the four proposed directions together allows to identify the impact of the layout of the production equipment on the character of the working movements, the working pose, to determine the degree of their rationality, allows to increase the efficiency of the production process and contribute to the reduction of industrial injuries [8].

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