

INVESTIGATION ON THE OPTIMAL ARRANGEMENT OF THE HUMAN-MACHINE INTERFACE OF AUTOMATIC LATHES

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Keywords: human-machine-interaction, evaluation, blind operation

1. Introduction

This investigation examines indicators and controls with regard to their arrangement and their relation to a process and whose use by different operators is related to a complex sequence of operations. This requires a description and an evaluation of the human-machine-interaction compatible with the sequence of operations.

As an example, the human-machine interface (interface) of a modern automatic lathe was chosen to determine its optimal arrangement. The interface consists of an operator panel and a machine control panel (Figure 1.).

The constructional and operational development of turning machines shows that existing interface arrangements are neither based on history nor defined by regulations [Hirsch-Kreinsen 1993]. In particular cases, they are in fact determined by technical or economic limiting factors. The handedness, the body height and the degree of practice of the operators as well as their position in front of the machine, which changes accordingly to the required operation, were, to a large extent, not taken into consideration (Figure 2.). The indicators and controls on the interface must be perceived and operated under pressure of time and with full capacity depending on the observed state of the work area of the machine [Weber 1992]. This causes mental stress. Thus, human-machine-interaction is eased by parallel supervision of interface and work area [Boehle 1988].

In this context, the question is raised if an interface, normally arranged on the left or the right side of the work area, or an innovative centrally placed interface can be considered as the best arrangement variant (Figure 3.).

According to the present standard of knowledge, no general recommendations exist with regard to these problems and no adequate information can be found in machine tool, ergonomics and industrial design literature [Weck 2002].

Therefore, this issue can only be clarified by an extensive modelling and evaluation of the human-machine-system automatic lathe.

2. Modelling of operation variants of automatic lathes

A total of 12 operation variants result from the combination of three interface arrangement variants

- next to the left side,
- in the center of,
- next to the right side

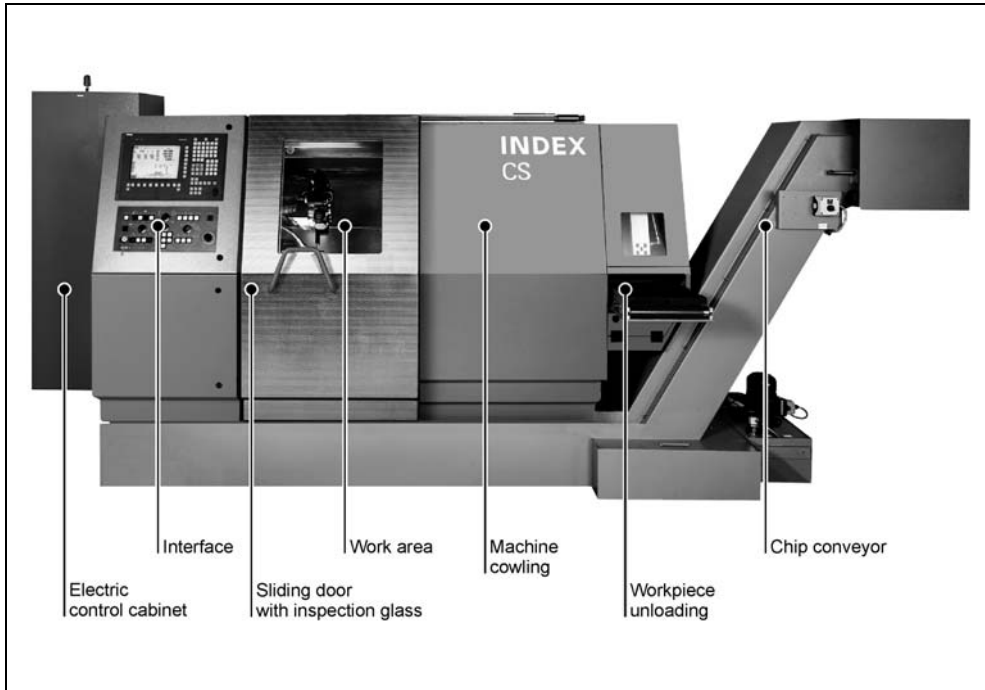


Figure 1. Automatic lathe (fabric photo of prototype machine, Index-Werke GmbH & Co. KG)

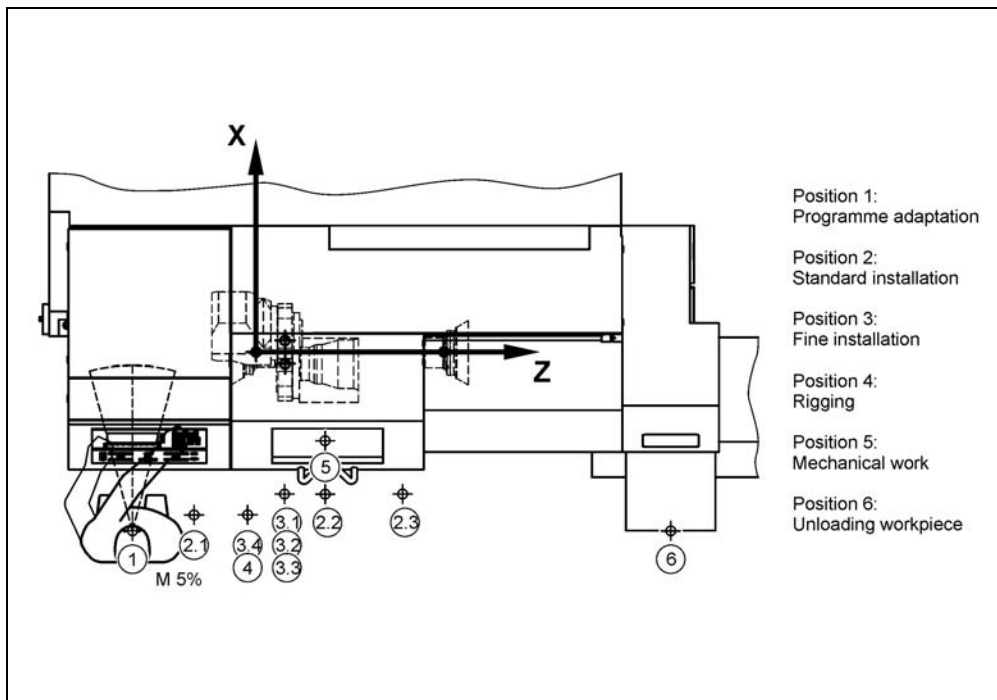


Figure 2. The positions of the operator in front of an automatic lathe (reference point: root of the nose)

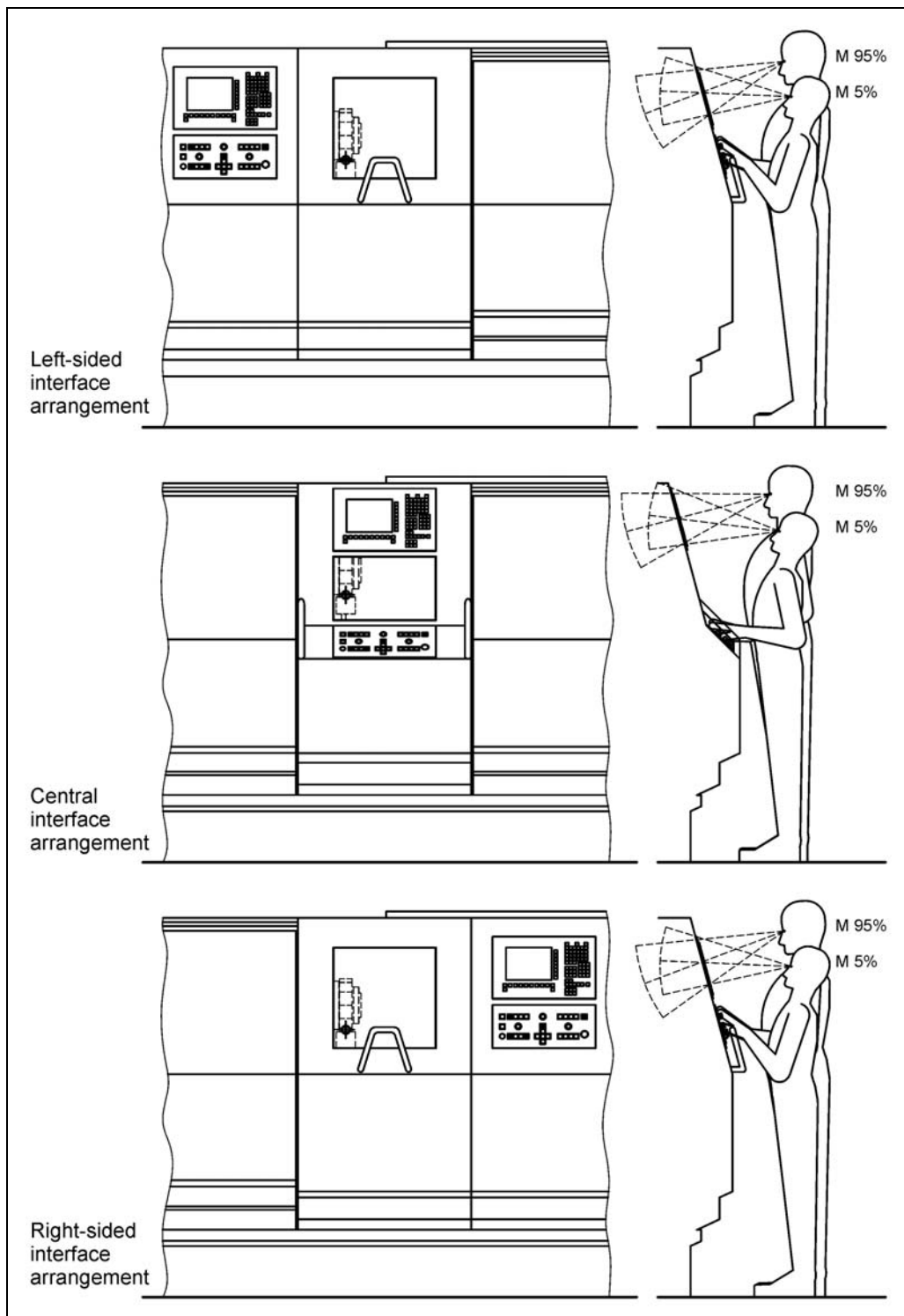


Figure 3. Interface arrangement variants of automatic lathes

of the work area of the automatic lathe and the differentiation of

- right-handed,
- left-handed,
- trained,
- untrained

operators.

Thereby, the interface components remain unchanged.

In a "worst-case" scenario, the group of operators is limited to the decisive 5 percentile man.

With the sequence of operations in the so-called "material number", a workpiece sample is produced. Mainly during the "material number", the operator of an automatic lathe is working in a regulatory and supervisory way in order to avoid, for example, machine failures through bugs or to optimize technology and geometry data. The sequence of operations is therefore directly connected to the machining process and difficult to plan. Nevertheless, from observations and expert interviews 30 tasks were determined which are accordingly repeated in chronological order. Examples for important and frequently performed tasks are:

- regulate feed rate override with rotary knob on machine control panel depending on observed chip form and colour, sound of machining process, running-in of tools, risk of collision,
- observe the machining process in the work area of the machine in comparison to displayed programme informations on the operator panel,
- start machining cycle with pushbutton on machine control panel to continue production,
- stop machining cycle with pushbutton on machine control panel depending on observed tool breakage, risk of collision, need to measure workpiece for quality inspections,
- type in programme modifications on the operator panel to correct bugs, tool compensations, change of tools.

In accordance with the basics of interface design the Petrinet presentation was selected as a suitable description of the human-machine-interaction [Cordes 1986, Seeger 2005]. The modelling of operation variants in Petrinet presentation offers – besides the detailed analysis of process elements of the machine and task elements of the human being – the possibility to link the design-oriented description of the operator to the control-relevant description of the automatic lathe (Figure 4.). Furthermore, human-machine-requirements are directly derivable from this description of the sequence of operations.

Altogether 360 different Petrinet representations resulted from the modelling adapted to the 30 tasks in 12 operation variants.

3. Evaluation of the sequence of operations on automatic lathes

Due to the complexity of the sequence of operations on automatic lathes it is extremely difficult to carry out a multidimensional evaluation with various criteria. An evaluation based on the criteria time is preferable.

As for an objective evaluation, task elements described in Petrinet presentations are assigned to specific movements of the long established Methods Time Measurement 1 (MTM-1) method, with pre-determined MTM-1 time standards for each MTM-1 specific movement [MTM 2004] (Figure 5.). Considering order and frequency of the respective tasks, due to their sum, a total time for the entire sequence of operations can already be estimated in the conceptual design stage of a development.

The evaluation results of total interface operation time clearly show that a central interface arrangement is the most suitable arrangement for all operators in terms of shortest time need (Figure 6.). The left-sided interface arrangement is an unfavourable arrangement for untrained right-handed operators. In comparison to the central interface arrangement, a 26 % longer operating time is needed.

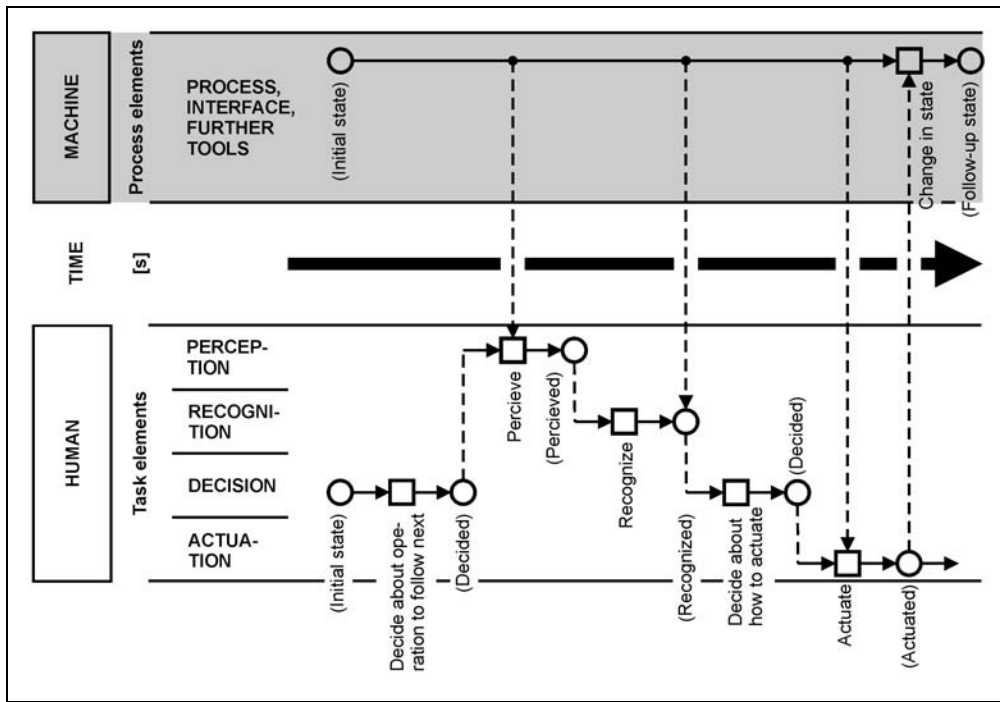


Figure 4. Modelling of the sequence of operations with task elements in Petrinet presentation

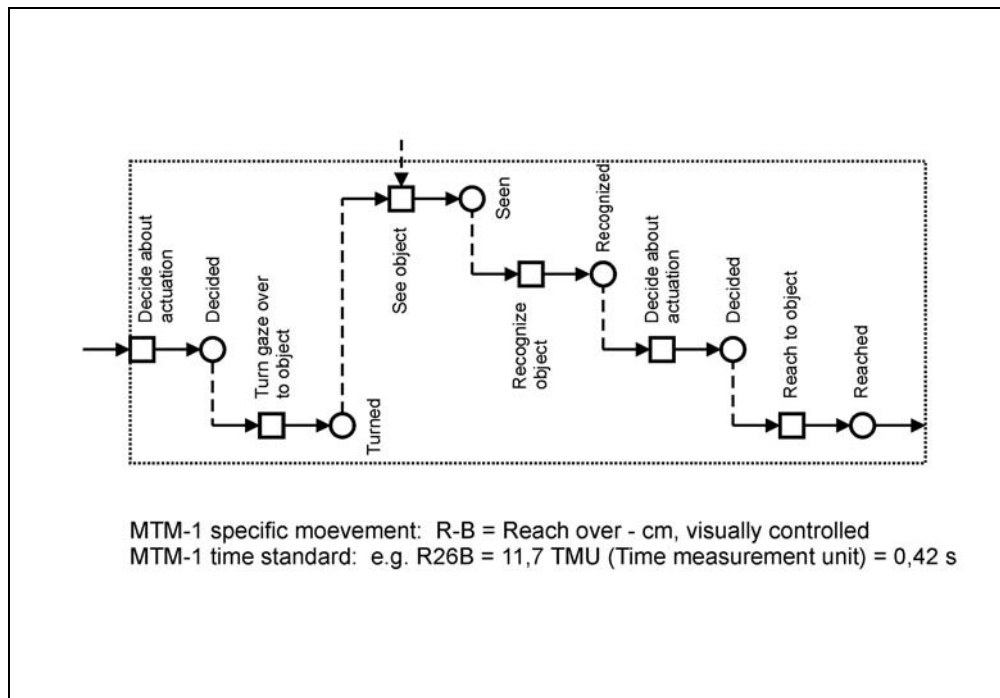


Figure 5. Assignment of task elements in Petrinet presentation to MTM-1 time standards

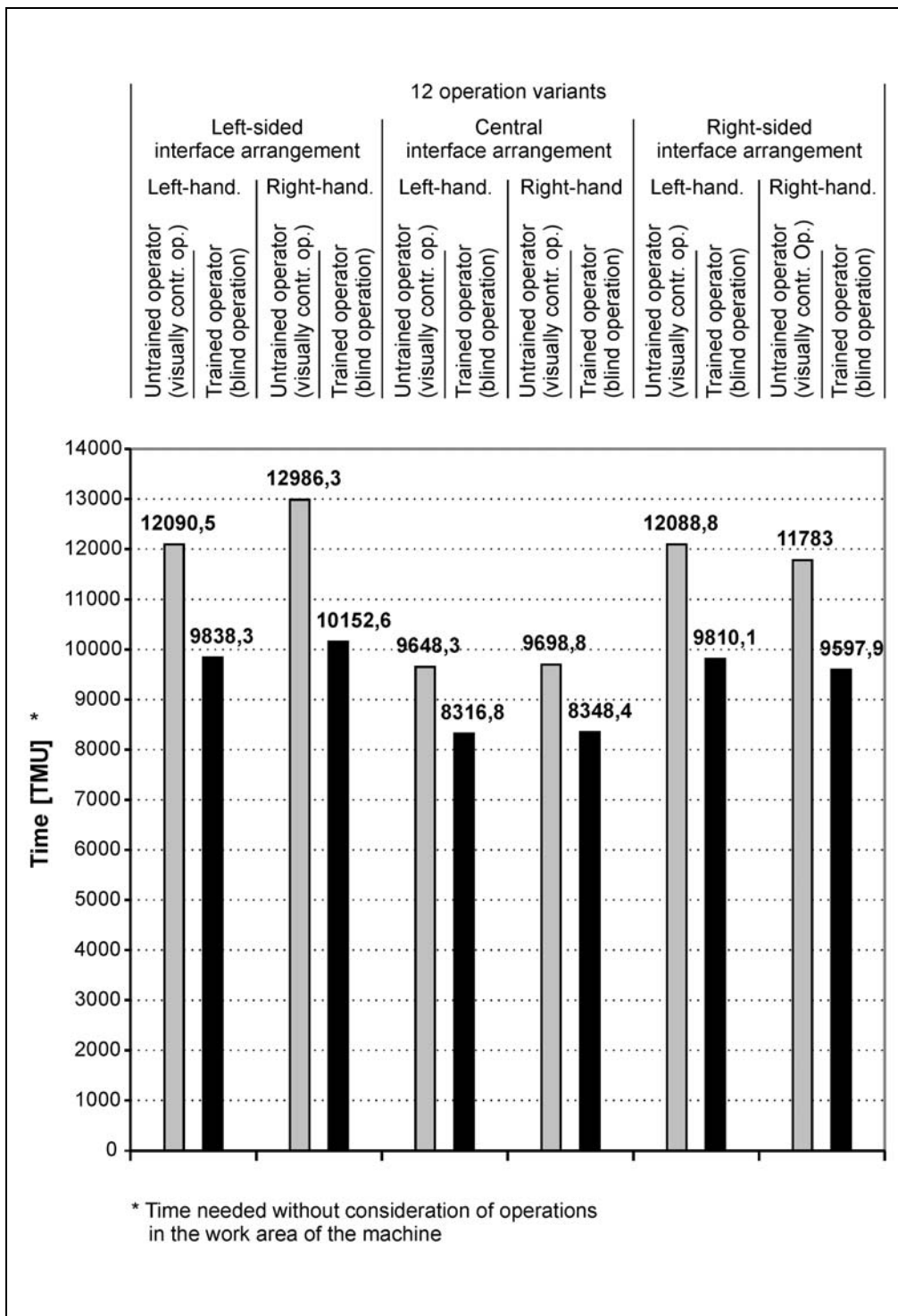


Figure 6. Comparison of total interface operation times during the "material number"

Longer operating times for the sidewise interface arrangements mostly result from additional side steps as well as repeated and longer hand and head movements for control manipulation or indicator supervision. In order to work in space within reach and sight, the operator has to change his positions in front of the machine more often than in case of central interface arrangement. Regardless of the change of positions sidewise interface arrangements always lead to uncomfortable, contorted postures – especially when the interface is not located on the side of the preferably used hand.

The interesting fact that a centrally arranged interface shows the smallest difference between trained and untrained operators can be interpreted as a favourable starting basis for operator training.

Partially, task elements like hearing and feeling are not clearly described by the MTM-1 method. Additional investigations of these elements as well as the estimation of additional influence factors show a small and constant extension of total interface operation time for all operating variants. But the ranking order does not change.

As an example, the MTM-1 time standards for trained operators, which are specified by the MTM-1 method under special consideration of the blind operation, need to be extended by practicable graduations.

In addition to this objective evaluation, a subjective evaluation by means of approval tests of simple mock-ups was carried out with test groups of trained and untrained operators.

The subjective evaluation confirms the results of the objective evaluation in a restricted way. Although all untrained test persons prefer the central interface arrangement, the trained test persons make objections against this arrangement. An explanation for their provisos may probably be found in aquired lasting habits as well as a lack of operability of the tested mock-ups.

4. Conclusion

By means of the criterion time an objective evaluation and selection of the interface arrangement variants of automatic lathes for different operators was carried out. The underlying modelling of the sequence of operations in the Petrinet representation considers central aspects of the human-machine-interaction. Exact data regarding the time needed by the operation variants could be provided by transmitting MTM-1 time standards, even though several MTM-1 specific movements are not clearly defined.

Therefore, this investigation contributes to the evaluation compatible to the sequence of operations of human-machine-systems by indicating how approved methods of process modelling and time analysis can be applied.

The tested example of optimal interface arrangement for automatic lathes shows the importance of an efficient operation in connection with the physical and mental relief of the operator.

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