DESIGN OF A MACHINING CENTRE – CRITERION OPTIMIZATION

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1. Introduction

Primary optimization should be performed already at the definition of initial designing tasks. These tasks usually follow from the market research or from the research of customers' needs. However, the first contradictions often appear already at the moment, when the designing task is determined. The marketing target is to introduce a product on the market. This product shall fulfil requirements of a large range of customers, it must be an innovative and competitive product. However, the market requirements and manufacture needs do not go together in many cases. The minimum application of components, which have been already used, introduction of technologies unknown within manufacture and application of new materials affect adversely complexity of design and manufacture, and due to this, also the necessary costs. This can result in decreasing the product competitive strength on the market. A particular compromise could be found already during this initial life phase of a designed product. Of course, it is necessary to react quickly to the market requirements in the current competitive environment; but it is also necessary to consider designing and manufacturing abilities of a particular company.

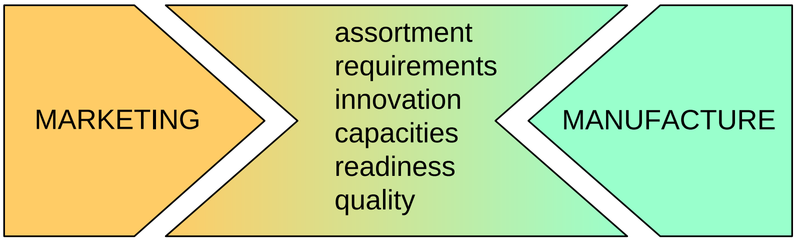

Fig. 1 Characteristic contradictions between marketing and manufacture [Vlčková 2005]

2. Optimization types used in the designing process of a machining centre

Optimization is a process whose target is to find the optimum solution of a given task, most of all using mathematic tools. The optimum solution is the best possible solution (an ideal one); however, it is not possible to reach this optimum solution in the majority of cases at designing. If any technical device shall be optimized, it is usually necessary to search the best possible solution – but a compromise one.

Three optimization types are used at designing of machine tools (machining centres):

- technical optimization,
- economic optimization,
- technical-economic optimization.

At technical optimization, the effort is to create a machining centre on the highest possible technical level, fulfilling the maximum demands on performance, rigidity and precision parameters. If the highest emphasis is placed on the total costs necessary to manufacture a machining centre, we speak about economic optimization. If the target is to design a machining centre on a relatively high technical level, keeping the adequate costs of development and manufacture, technical-economic optimization is selected.
Optimization at building a machining centre cannot be understood as a purely mathematic task; therefore, it is not easy to use mathematic methods to select its optimum building. Optimization at designing a machining centre is a task, whose target is most of all to find the best possible functional machine structure, to select suitable components and to perform the right selection of a proposed design solution. The diagram of particular optimization types is shown in Fig. 2.

Optimization at designing machining centres can be divided into:
- outside optimization,
- inside optimization.

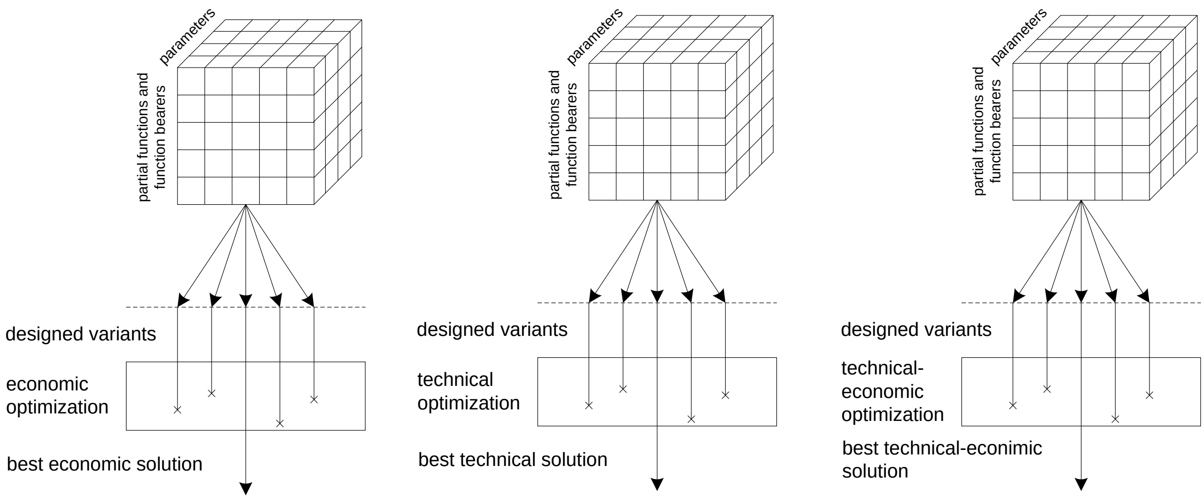

Fig. 2 Diagram of economic, technical and technical-economic optimization

Outside optimization has the task to select the best outside concept of a machining centre, considering the customers' wishes and the development of the newest trends in the field of its building. Inside optimization has the task to find the best possible solution of the inside structure of a future machining centre. [Marek 2004].

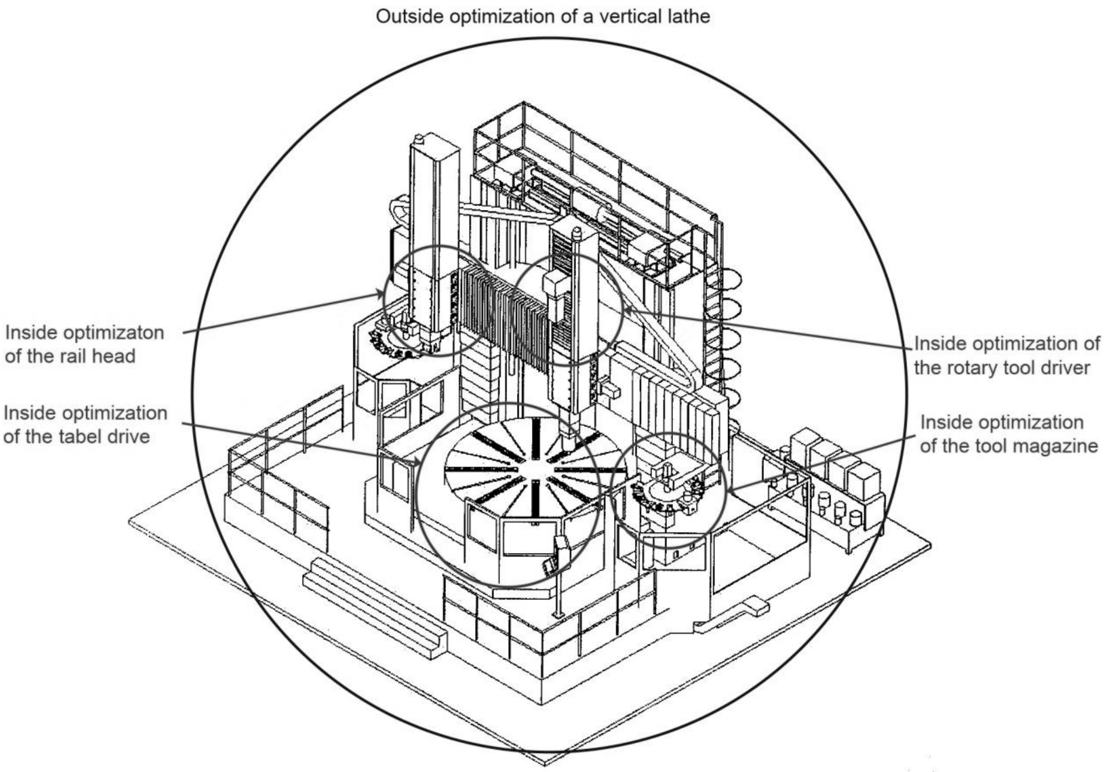

Fig. 3 Outside and inside optimization of a vertical lathe made by TOSHULIN company

Fig. 4 shows the successive process of technical-economic optimization at designing a machining centre. If optimization is performed, technical-economic optimization represents the mostly used type, because in the majority of cases the customer prefers a machine having high technical parameters, but at the same time a machine with a good price. The future machining centre is evaluated as the whole unit in the first optimization phase. Using optimization, one solution is chosen from several designed variants and this solution is then elaborated in details. The design structure and components used for particular assembly groups are most often optimized during the second phase. The building structure of these assembly groups follows from parameters required at the particular machine parts. Some concept variants can be created also in this phase and these variants must be evaluated from a technical point of view as well as from an economic point of view.

Big machining centres are often developed by some designing teams at the same time. Therefore, it is always necessary to take into account that the particular assembly groups of the future machine must be interconnected and they must cooperate. In order to make the optimization process more effective, it is possible to use e. g. linear programming. Linear programming is an optimization method which can be used better at the methodical designing way, where designing is exactly performed according to the directives and methodology prepared in advance. Linear programming is a purely mathematic task, whose target is to find the extreme (maximum or minimum) of the linear function with more variables, under the secondary conditions expressed by linear equations or non-equations. [Blecha 1999].

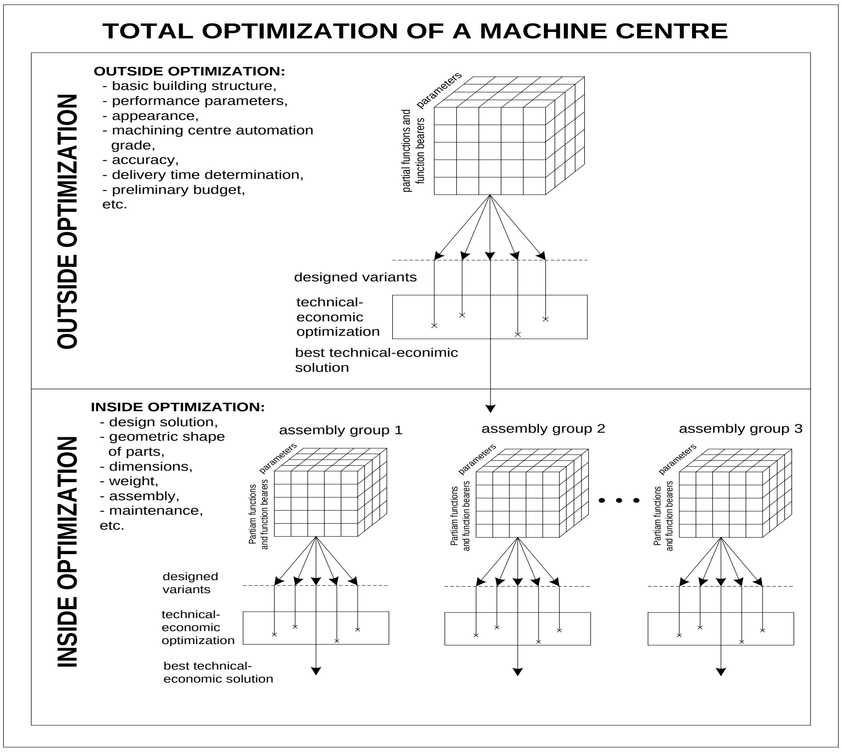

Fig. 4 Diagram of successive technical-economic optimization

3. Discussion about the designer's influence on creation of the costs necessary for the future product

It is possible to read the following *considerations* in literature:

- From experience, the engineering design determines irrevocably at least 70 % of later manufacturing costs, because the engineering design type also specifies the manufacturing way in advance. In order to keep the total costs as low as possible, designing must consider many rules and knowledge of almost all company's sections. [Conrad 2004].
- Due to development of electronic data processing and of numerical control systems used at machines, the efforts to obtain automation also in single-part production and in small-lot production increase their importance still more and more. While the high technical development level has been already reached in the manufacturing field as a result of these efforts and this is proved by application of high-automatized machines, as e. g. machining centres, CNC machines, production lines, etc., the fields of engineering design and work preparation can hardly notice application of comparable new designing and organization means. This fact is shown within the general company process in the multiple ways, because engineering design and work preparation represent problem places which influence the running time and due to this, the company's readiness to supply in the considerable way. In addition to time consideration of the product course through the company, consideration of costs proves the extraordinary importance of these branches, but especially the importance of engineering design (Fig. 5). The essential matter is the difference between determination of costs and reasons of costs. If only the costs caused by particular departments were taken into account, i. e. the number of worked hours and paid invoices, we could find the conclusion that engineering design and work preparation have only a negligible influence on the total product costs. However, the fact is that both of these sections determine the total product costs in the maximum possible way. Engineering design specifies e. g. the selected solution principle, materials, dimensions, accuracy and partly also the manufacturing process. [Opitz 1971].

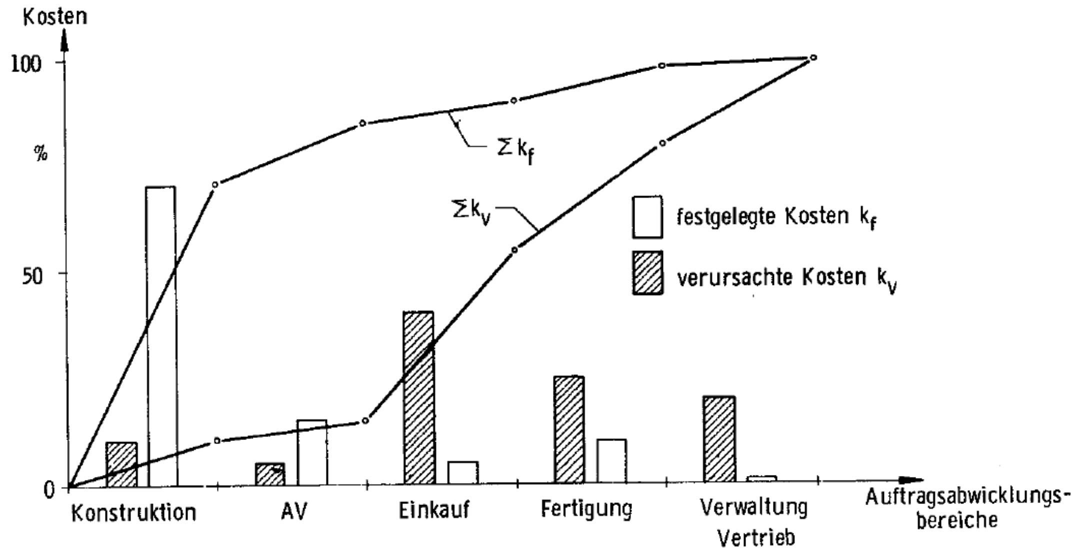

Fig. 5: Costs and reasons or costs origination in particular manufacturing sections [Opitz 1971]

The above-mentioned considerations were taken-over by a number of other authors (e. g. Pahl-Beitz) or the German VDI standard and they state more or less the same value. Let us notice that the latter author tried to verify the given value thanks to his functional post in one machinery company – so especially at design of machining centres.
He found the following conclusions:

- It is not possible to prove the particular mentioned value (approximately 70%), because this is a very difficult process, especially regarding to the fact that it is very complicated to specify the costs in the consequential stages (manufacture, assembly, sales, etc.);
- This influence of approx. 70 % can be determined at simple commodities, but not at the products consisting of many parts, as e. g. machining centres are (up to 10 000 parts);
- It is not necessary to discuss the fact that the designer influences a great part of these costs.

Acknowledgement

Technical-economic successive criterion optimization seems to be a huge tool leading to the target, if searching the optimum solution of a designing task. Moreover, the authors' effort was to pay attention to the fact that it is not so easy to determine the numerical statement of determined costs and caused costs, as it is sometimes mentioned in literature.

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