More Exact Approaches to Modernization and Renewal of the Manufacturing Base

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***Abstrakt* – Globalized development strategies in industry are currently focused on developing intelligent manufacturing concepts called Industry 4.0. Companies around the world will be forced to adopt this concept, especially in terms of maintaining competitiveness. One of the most serious obstacles of developing the concept of intelligent production is physical and moral obsolescence of the manufacturing base in general. Despite the fact that companies have historically renewed their manufacturing base, automated and robotized manufacturing processes and systems, nowadays highly current question of determining the form and timing of further modernization and renewal of the manufacturing base for intelligent production purposes. The authors present a model to determine optimal time to start upgrading and renewing the production base based on formulating and comparing costs of means of production throughout their lifecycle, including consideration of their moral obsolescence.**

***Keywords* – production technique, physical obsolescence, moral obsolescence, innovations, Industry 4.0, upgrading of production base, time and cost modelling**

1. Introduction

Development strategies in industry are currently focusing on developing the concept, Industry 4.0, from a globalized perspective. This is basically the 4th industrial revolution called "intelligent industry".

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In connection with its beginning and maintaining production competitiveness, it will be important to innovate and upgrade used manufacturing handling and controlling technology as a key element of more efficient with lower cost production and fewer employees meeting the criteria of best available technology and technology in the future, in addition to importing top products and intelligent manufacturing base.

With an increase of innovation level of production, problems arise also related to an optimal use of the means of production, their modernization and gradual renewing for use in intelligent manufacturing. The question in this context is to estimate the right time for the renewing and innovation of production device.

2. Physical and moral obsolescence of production technique

With regard to physical and moral obsolescence, it is necessary to optimize contradictions between exaggerated preventive modernization and renewing which guarantees 100% reliability, low operating costs, high productivity and a delayed solution to problem of losses, arising increasing costs for servicing and maintenance of obsolete production devices and systems. It is necessary to take into account continuous shortening of innovation cycles and introduction of more progressive production technologies [5].

In all categories of production machinery, design improvements are being developed to:

- Increasing production to provide required accuracy of shape and required quality of surface of parts,
- Simplifying and facilitating machine operators (ergonomics, operator automation),
- Low weight and small dimensions or high power per machine unit weight and per unit of built-up area, environmental performance,
- Economic efficiency of the machine, i.e. low procurement and operating costs,

- Technology of machine construction, i.e. simple production of all components and assembly units of the machine and its simple assembly.

In the category of industrial robots and other handling devices, nature of flow of material, dependence on technological devices, flexibility and degree of automation are based on attribution and assessment of suitability [1, 3].

In the category of control devices, it is based on a hierarchy of control functions and on basis of technological and handling devices.

A particular approach is required if individual production devices are a part of more intelligent production complexes, in particular [2]:

- Production lines,
- Integrated production sections,
- Flexible production systems,
- Robotic systems,
- Fully automated, integrated computer-assisted production clusters.

In this case, priority is given to mutual compatibility of production facilities and their classification into generational development classes. A high proportion of production means applied in production clusters is currently mainly in production of higher types.

In a perspective of the choice of types of production devices for intelligent production, it is important to have a dynamic approach to determining the selection parameters for their detailed analysis and appropriate extrapolation.

3. Modelling the time-cost functions of modernization and renewing the production base

An analytical solution for determining optimal time for efficient use of production devices and systems results from individual phases of their use during their working life. It is necessary to distinguish the following phases:

- An initial period in which production means and systems have standard and optimized baseline technical, technological, economic and environmental parameters.
- A period of using during which the state of the means of production and of the systems changes depending on the time, or on the number of manufactured products linearly due to their wear, aging physical and moral.
- A period of use of the production means and systems during which worn parts are renewed by replacement and repairs or are upgraded, automated, robotized, and so on in order to improve operational and other properties.
- A period of unreasonably increasing operating costs for production devices and systems (increased energy consumption, labour, environmental unacceptability, etc.).
- A period when the operational characteristics (technical, economic, environmental) of the production means and systems are depleted, they are being shut down and the residual value (component, material recycling) is realized.
- When identifying the optimal time to start upgrading, or renewal, it is based on an economic point of view. An innovative model for optimal time determination is shown in Figure 1. The costs specification is shown in Table 1.

In determining the optimum time, the procurement costs, the residual value of the means and systems, the costs of the user to maintain capacity per unit of production and the rate of the growth of costs during aging- physical and moral - are taken into account. In dimensioning, it is important to accurately express the exponentially growing costs of aging production devices and systems. This usually includes [4]:

- A decrease in productivity (k_1 t).
- Increase in energy consumption (k_2 t).
- More complex operation and maintenance (k_3 t).
- Losses due to better utilization of the deposited funds (k_4 t).
- Environmental impacts of operation (k_5 t).

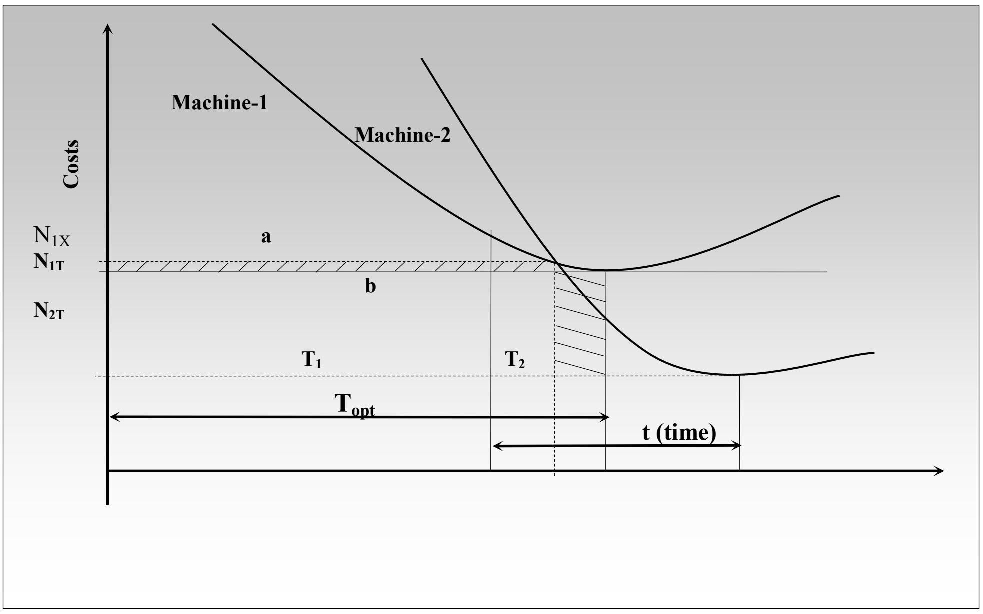

Figure 1. Model for determination of optimal time to start of upgrading or renewal of the manufacturing base

Table 1. Costs specification for production means during their working life

Type of costs	**Characteristics**
One-off $\mathbf{N_j = C_n - C_z}$	- for purchasing of devices where: N_j - one-off costs C_n - purchasing prices C_z - residual value
Linear dependent $\mathbf{N_1 = k \;.\; t}$	- costs for energy, wages, and so on where: t – time k – coefficient of dependence of costs on unit of production
Exponentially increasing $\mathbf{N_{ex} = k_{ex} \;.\; t^{\delta}}$	- caused by shortening the operation of the device between its two repairs, etc. where: t - time k_{ex} - coefficient, determining of standardized value of exponential costs of user δ - exponent characterizing a degree of growth of costs during aging
Total costs $\mathbf{N_{celk} = N_j + N_1 + N_{ex}}$	- Total costs for the device during its time of use
δ	**Optimal time of use**
$$T_{opt} = \sqrt{\frac{N_j}{(\delta - 1)\,.\,k_{ex}}}$$	This time can be calculated from the extreme of function of the relative costs per unit of time
$$T_{opt} = \frac{N_i}{T} + k + \sum_{i=1}^{n} k_i \,.\, t^{\delta\, i - 1}$$	This time can be calculated from the total function of the relative costs where n is the number of considered components of exponential costs

For production means and systems with different working life of elements and nodes, dimensioning requests to determine the optimal time of operation of individual upgraded and renewed elements, nodes and units, and then the optimal time of use of the manufacturing device as a whole. If the period of partial upgrading and renewal is a mutual multiple, it is possible to determine the period of replacement of the means of production and systems from the total function of the relative costs [7].

Apart from physical wear, the production means and systems are subject to moral wear and tear analysis in relation to intelligent manufacturing. The moral wear is reflected in a change in economic and environmental value of the production means and systems to modern, more productive, more environmentally efficient and cheaper options. The moral wear is a continuous process resulting from scientific and technological development. It is necessary to analyse two kinds of the moral wear. The first one results from a reduction in the procurement and operating costs of new production means and systems at constant performance parameters, the second one from an increase in production and the economic and environmental characteristics of new production means and systems at the same cost of procurement [7, 8].

Correction of the time of use with regard to moral wear of the second kind needs to be realized when the user has a possibility to procure more efficient means of production or systems. It is necessary to determine when obsolete production means and systems are to be modernized before the period of their economic use or to replace them with a new, complexly more efficient. The correction is based on a comparison of costs per unit of production of the compared means and systems, Fig. 2.

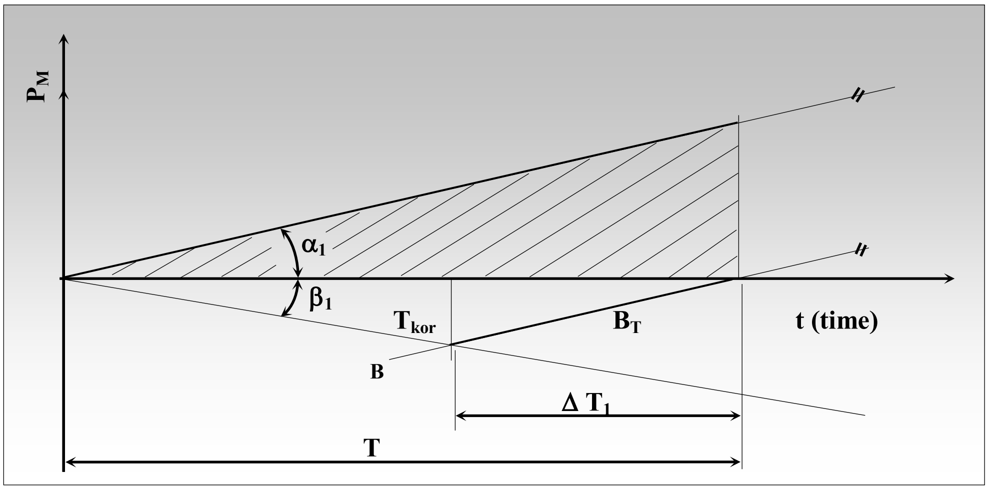

Figure 2. Correction of time of beginning of modernization or renewal regarding moral wear

Both types of the moral wear are independent of each other and they enable combinations of moral wear [6].

An assessment of the physical and technical condition is divided into two parts:

- An assessment of optimal utilization intervals between terms of their improvement (repairs) and moment of moral obsolescence, depending on the characteristics of increase in the labour productivity that can be achieved on the given device (modernization).
- A determination of boundaries of technical novelty based on the labour productivity ensured according to plan in the individual stages of improvement.

Exact calculations of the boundaries of technical novelty of the production devices and systems have not been yet fully utilized. In particular, approximate evaluation methods are used. Methods of indirectly determining the technical state of the production means and systems are most used at the time of introduction of the new models in the market. Practice shows that the development and industrial adoption of the new types of production means and systems is being realized in 10 to 15 years. This also practically determines interval of the technical obsolescence of existing production means and systems.

5. Conclusion

The development of production processes, production systems and their scientific knowledge, like other scientific fields and practical activities, is not uniform, but more often with preferential development of some components, technological, handling, controlling, logistic. The components that are at the forefront of the development are characterized by high technical level, efficiency and economic and environmental performance. Less examined components are a potential innovation reserve for continuous improvement of the functional characteristics of a complex production system. An unsystematic development of production processes and systems does not meet the requirements, and an urgent task is their harmonious development aimed at increasing flexibility, intelligence and meeting the criteria of the best available technology in the field of activity.

The strategic preparation of intelligent manufacturing integrates all the necessary activities which an achievement of technical, technological, environmental and economic objectives linked to sustainability of production depends on. Strategic production preparation provides effective ways to achieve set objectives (economic and environmental budgets are created, product quality is tightened, price is objectified, production time is shortened, etc.), provides efficient production means and working objects (raw materials, semi-finished products and purchased parts). Special production means are produced according to the relevant documentation, manufacturing base in industry is innovated and renewed, intelligent independence is growing.

In implementing the Industry 4.0 concept, the correct timing of the renewal of the manufacturing base plays an important role. Correct decisions in this respect have to be based on more accurate models and methodologies on progressive development trends.

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