EFFICIENCY OF PRODUCTION AS ONE CRITERION FOR THE SELECTION OF THE AUTOMATION LEVEL OF PRODUCTION EQUIPMENT

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ABSTRACT

This paper considers the selection of an optimum automatiation level of production equipment. There is a multitude of criteria on basis of which the selection of an optimum automatization level can be done. One of those criteria, not the most important, is efficiency of production equipment . There has be done an analysis of 317 technological operations divided into forty-one group (group technology), in the factory "Zmaj". The results, the dependence of productivity on the automatization level of production equipment, are shown in this paper.

Keywords: Efficiency of production, Economy, Productivity, Automation level, production equipment.

1. INTRODUCTION

The purpose and goal of optimization of the automation level of production equipment is achieving greater efficiency of the production process, and the enterprise as a whole. Greater efficiency implies greater income too, and it is in the interest of any enterprise to increase their income. Income is the material basis of existence and development of an enterprise. Increase of income can be achieved by increasing the volume of production or by decreasing the cost of production. Efficiency of production can be evaluated by the amount of assets engaged in the realization of production, and also by the working resources and the level of their rational employment, because it is a big difference if income will be realized with lesser or bigger production means. Consequently, the goal of an enterprise is to create bigger income by engaging financial assets as rational as possible, i.e.:

- to achieve a maximum volume of production and income by minimum use of labor force,
- to achieve a maximum volume of production and income with minimum cost,
- to achieve a maximum volume of income by minimum engagement of production means,
- to achieve a maximum volume of production with a minimum amount of working time,

The basic principles of the profitability of an enterprise, i.e. the efficiency of production:

- Productivity
- Economy
- Profitability
2. AUTOMATION LEVEL OF THE PRODUCTION EQUIPMENT

Automation of the production equipment i.e. of production system has the task:
- to reduce physical effort of a man,
- to increase productivity,
- to increase product quality,
- to increase economical efficiency.

As a measure of automation for production equipment - machine, production process i.e. production system most frequently is used one measure named: level of automation. The automation level represents the relation of the number of automatized functions to total number of functions and can be determined by means of the formula: (Ivkovic & Rac, 1995.)

\[ A^0 = \frac{A_f}{A_u} \]  

where:
- \( A^0 \) - Automation level
- \( A_f \) - Number of automatized functions
- \( A_u \) - Total number of functions

Since nowadays is present a great number of different production equipment having available quite considerable variety of construction and technological characteristics it is therefore very difficult to make comparisons between them. In order to determine the number of automated functions and their comparing the sorting of their single characteristics can be done in different ways. One of them, neither the only one nor the final, is as the following: [Živković, D., 1998.]

1. Type of the equipment drive: manual, mechanical.
5. Number of working axes: one, two, three, four (4x90°), four(360x1°), more than four
10. Number of working spindles: one spindle, two spindles, more than two spindles

By using of listed eleven criterions with forty one parameter it can be estimated the level of automation for production equipment. The automation level of one machining system, that means automation level of the production equipment is determined by the following function: (Živković, 1998.)

\[ A^0 = f(K_1 - K_{11}; P_1 - P_{42}) \]  

The minimal automation level refers to the production equipment with manual machining and the maximum automation level to the computer integrated production equipment with automatic designing of product, technology and planning (CIM). Based on such classified characteristics of the production equipment it can be made the evaluation of the automation of their functions and, at extreme case, it can be determined even the automation level of the production equipment. (Ivkovic & Rac, 1995.).
The automatization level is one relative measure of the automatization which shows the development phase of managing information to which all changes are automated. For example: the automation level would be as follows: for a radial drill 0,12 for a radial drill with a circular table 0,15, for a horizontal drilling and milling machine 0,17, for a machining centre 0,48.

3. RESEARCH RESULTS

An analysis of 317 technological operations was conducted, divided into forty-one group (group technology), in the combine factory “Zmaj”, and we got the following results (table 1. for production equipment, and table 2., for transport equipment): (Zivkovic,1995.)

<table>
<thead>
<tr>
<th>Autom. level</th>
<th>Radial drill</th>
<th>Rad. drill with revol. table</th>
<th>Horiz. drill and mill</th>
<th>Machining centre</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,12</td>
<td>0,15</td>
<td>0,17</td>
<td>0,48</td>
<td></td>
</tr>
</tbody>
</table>

Average duration of an operation cycle (min./piece)

<table>
<thead>
<tr>
<th>Operat.</th>
<th>Radial drill</th>
<th>Rad. drill with revol. table</th>
<th>Horiz. drill and mill</th>
<th>Machining centre</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-</td>
<td>62,0</td>
<td>45,0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>7,8</td>
<td>7,3</td>
<td>7,1</td>
<td>6,9</td>
</tr>
<tr>
<td>3</td>
<td>10,2</td>
<td>9,7</td>
<td>9,5</td>
<td>9,3</td>
</tr>
<tr>
<td>4</td>
<td>10,2</td>
<td>9,7</td>
<td>9,5</td>
<td>9,3</td>
</tr>
</tbody>
</table>

Total cost of operations 2,3 and 4 (DM/piece)

Table 1. Exploitation costs for production equipment

When selecting production and transportation equipment there should be saved as much time and money as possible, to decrease the amortization period, to increase profit and productivity, and decrease maintenance and exploitation cost. Factors that affect working costs of production or transportation equipment are numerous. To make the right choice, it is necessary to make detailed analysis of all the relevant factors, which build the exploitation price of the selected production and transportation equipment.

The basic structure of costs of production and transportation equipment (invested equipment) is as follows:

1. Working equipment costs
   1.1 Cost of amortization (Ta)
   1.2 Maintenance costs (To)
   1.3 Cost of tools and accessories (T_{AP})

2. Energy costs
   2.1 Cost of fuel and energy used (T_{eA})
   2.2 Cost of lubricants etc. (T_{M})

3. Costs of foreign services (T_{SU})
4. Costs of interest rates and assurance (T_{ke})
5. Cost of labourers (T_{RS})
6. Cost of working space (T\textsubscript{RP})

Consequently, the structure of production i.e. transport equipment exploitation costs, mathematically expressed, is:

\[ T = T_a + T_0 + T_{AP} + T_{eA} + T_M + T_{SU} + T_{ko} + T_{RS} + T_{RP} \]  \hspace{1cm} (3)

Depending on the unit used for presenting particular, previously explained costs (mainly in dinar or german mark DM) and on the time period within which these costs have been observed (mainly year, month, day or hour) we get the exploitation costs of production i.e. transport equipment in corresponding units.

Costs of human resources. There exist different models for determining the cost of human resources. One of them, applicable in Serbia, is as follows:

\[ T_R S = T_{LD} + T_R + T_0 + T_Z \]  \hspace{1cm} (4)

and:

\[ T_{RS} = NSR \left(1 + K_2 + (1 + K_2)(K_3 + K_4)\right) \]  \hspace{1cm} (5)

where:

- \( T_{LD} = NSR \) - (din./month) - Cost of wages per production worker per month or per total number of workers
- \( N \) - (hour/month) - Average number of working hours in one month
- \( S \) - (din./hour) - Price of working hour in production
- \( R \) - Factor which takes into account being in excess of the working norm of a production worker
- \( T_R = K_1 T_{LD} \) - (din./month) - Cost of wages per administration worker.
- \( K_1 \) - Calculated rate of assets necessary for administration
- \( T_0 = K_2 (T_{LD} + T_R) \) - (din./month) - Cost of taxes on employee wages
- \( K_2 \) - Calculated rate for taxes on wage
- \( T_Z = K_3 (T_{LD} + T_R) \) - (din./month) - Cost of consumption in enterprise
- \( K_3 \) - Calculated rate of consumption in enterprise
- \( T_{LD} \) - Cost of wages of production workers
- \( T_R \) - Cost of wages for administration
- \( T_0 \) - Cost of other expenses (taxes, social sec. etc.)
- \( T_Z \) - Cost of consumption in enterprise

We can express the calculated costs in dinar per hour if we divide the resulting values of costs by the average number of working hours per month.

*Table 3. Costs as a function of the automation level of production equipment*

<table>
<thead>
<tr>
<th>Type of costs</th>
<th>Automation level</th>
</tr>
</thead>
<tbody>
<tr>
<td>(DM / h)</td>
<td>0.12</td>
</tr>
<tr>
<td>( T_A ) - Amortization costs</td>
<td>0.475</td>
</tr>
<tr>
<td>( T_O ) - Maintenance costs</td>
<td>1.037</td>
</tr>
<tr>
<td>( T_{AP} ) - Tools and equip. costs</td>
<td>0.14</td>
</tr>
<tr>
<td>( T_{eA} ) - Energy costs</td>
<td>0.13</td>
</tr>
<tr>
<td>( T_M ) - Lubricant costs</td>
<td>0.013</td>
</tr>
<tr>
<td>( T_{ko} ) - Inter. rates a. insurance</td>
<td>0.826</td>
</tr>
<tr>
<td>( T_{RP} ) - Work space costs</td>
<td>1.2</td>
</tr>
<tr>
<td>( T_{RS} ) - Costs of labour force</td>
<td>0.873</td>
</tr>
<tr>
<td>( T_{RS} + T_{SR} ) - costs</td>
<td>4.694</td>
</tr>
</tbody>
</table>
4. ECONOMY

If the production increases, and the costs for this production are decreasing, then the economy of production is higher. In other words, the level of economy increases when the the costs per unit of production are decreasing.

Economy of labour, as we have mentioned already, is the ratio between the achieved amount of production and the costs of production, and can be determined from the equations: (6. and 7.). Average values for the following parameters Q- max. number of pieces per year and T- production costs , and the corresponding level of labour economy - E., are shown in table 4:

<p>| Table 4. Level of economy as a function of the automation level of production equipment |
|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|</p>
<table>
<thead>
<tr>
<th>Autom. level</th>
<th>Radial drill</th>
<th>Rad. drill with revol.table</th>
<th>Horiz. Drill and mill</th>
<th>Machining centre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q-Max. number of pieces per year</td>
<td>5745</td>
<td>5955</td>
<td>6207</td>
<td>6141</td>
</tr>
<tr>
<td>Operation costs of prod. equip.(€/piece)</td>
<td>2,2</td>
<td>2,7</td>
<td>16,9</td>
<td>51,5</td>
</tr>
<tr>
<td>Transp. Costs (€/piece)</td>
<td>1,05</td>
<td>0,35</td>
<td>0,26</td>
<td>0,26</td>
</tr>
<tr>
<td>T-Total costs (€/piece)</td>
<td>3,25</td>
<td>3,05</td>
<td>17,16</td>
<td>51,76</td>
</tr>
<tr>
<td>T-Total costs (€/year)</td>
<td>18 671</td>
<td>18 163</td>
<td>106 512</td>
<td>317 858</td>
</tr>
<tr>
<td>E- Level of economy</td>
<td>0,308</td>
<td>0,328</td>
<td>0,058</td>
<td>0,019</td>
</tr>
</tbody>
</table>

5. PRODUCTIVITY

Productivity expressed in natural indicators can be determined from the: (9.). Average value for corresponding parameters P- Productivity, Q - Amount of product and L - Amount of engaged labor force, and the resulting productivity - P., are shown in table 5.

<table>
<thead>
<tr>
<th>Table 5. Productivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automat. level</td>
</tr>
<tr>
<td>Capacity Km( hour/year)</td>
</tr>
<tr>
<td>Duration of operation cycle tₐ (min)</td>
</tr>
<tr>
<td>Q- Number of poss. pieces per year</td>
</tr>
<tr>
<td>Engaged labor for. (man/hour)</td>
</tr>
<tr>
<td>Duration of trans. cycle(min)</td>
</tr>
<tr>
<td>Engaged lab. for. (man/hour)</td>
</tr>
<tr>
<td>L-Total engaged labor force(man hour)</td>
</tr>
<tr>
<td>P-Productivity</td>
</tr>
</tbody>
</table>

6. PRODUCTIBILITY

Productibility is defined as the number of processed pieces per unit of time, technological productibility can be calculated from (2). Resulting average values, as well as productibility values calculated for different levels of automation of production equipment are presented in table 6.

<p>| Table 6. Productibility values for different automation levels of production equipment |
|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|</p>
<table>
<thead>
<tr>
<th>Autom. level</th>
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</tr>
</thead>
<tbody>
<tr>
<td>t-time for operation (min)</td>
<td>28,2</td>
<td>26,7</td>
<td>26,1</td>
<td>25,4</td>
</tr>
<tr>
<td>P – Productibility</td>
<td>0,035</td>
<td>0,037</td>
<td>0,038</td>
<td>0,039</td>
</tr>
</tbody>
</table>
5. CONCLUSION

By establishing a relation between efficiency of production and automation level of production equipment, helps with the selection of a suitable technology, i.e. selection of a optimum automation level of production equipment. Of course, it is important to stress that efficiency of production is not the only, nor decisive criterion for the selection of technological operation, and the automation level of production equipment. Efficiency of production can only be one among the many other criteria. Their analysis can contribute to the selection of an optimum technological operation.

REFERENCES


