Hierarchical selection of technological equipment for the production system

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Abstract. In this paper, a study of technical and economic indicators is used in the design and selection of production equipment. Since the indicators currently used are considered independently of each other, they are rarely agreed upon. To overcome this drawback, it is proposed to consider them depending on five levels: parametric, structural, technological, economic and social. This immediately introduces the hierarchical subordination of indicators and their connection with social needs and a rapidly changing economic environment. As an example, a reconfigurable production system is considered, the equipment load factor, which requires increased flexibility from the system, is chosen as the main parameter. The reconfigurable production system, in addition to software or parametric flexibility, allows you to increase it due to the ease of changing the production structure, and when it is not enough, and this can move to reconfigurable production, which provides greater adaptation to changing conditions and expands the range of products produced through the use of transforming machines. The developed approach is applied to the technological system of a regional enterprise. The results, presented in the form of histograms, show a progressive increase in the equipment load factor as it moves along the hierarchical scheme. Thus, to answer the question what equipment should be designed or selected at the operating enterprise, it is necessary to consider five hierarchical levels with their own indicators each. At the same time, the indicators of the lower level can be determined only after the determination of the indicators of the higher level.

1. Introduction

When designing a complex technological system or selecting production equipment for an operating enterprise, the starting conditions are the requirements for the values of the main indicators that it must provide in its operation [1]. The more complex the technological system, the greater the loss in its implementation can be made and, therefore, the more strictly the values of these indicators must be justified. The study is devoted to a multi-level substantiation of the values of indicators of the designed technological system using this approach to re-configurable production systems.

2. Theory

First of all, the technological system should provide decent quality products [2-4], while it should be optimal for financial and energy costs [5]. Of course, the technological system must be reliable and for this there are also strict requirements [6]. Finally, the technological system must be efficient and this is most important. Sometimes they speak specifically about economic efficiency [7]. However, there is some difference in the opinions of researchers [8-10].
It is clear that a project of a complex technological system must meet the requirements in many respects. However, all these indicators are often viewed out of touch with each other and, as a result, are not consistent with each other.

R.T. Abdrashitov in his doctoral dissertation [11] developed a multi-level system for selecting optimization criteria, which includes four levels: parametric, structural, technological and economic. In this case, the selection criterion is revealed at the top level and goes down to the bottom level, that is, an economic criterion is necessary for technology selection, a technological criterion for structure selection, and a structural criterion for selection of parameters. However, the economy can be successful, but be beyond moral, environmental, legal, political and other restrictions. Therefore, the social level should dominate the economic level (Figure 1).

![Figure 1. Hierarchy choice levels of indicators.](image)

Thus, when designing or choosing a technological system, it is first necessary to find its social niche, that is, the social need for which it is created. Then, at the economic level, assess the scale of this need, the urgency of demand and the possibilities of the population in a particular market, take into account social constraints and identify the necessary production capacity. At the technological level, focusing on economic indicators and, above all, on the cost of production, it is necessary to determine the technology and its detailing for each operation. For example, the thread on the product can be cut manually with a die, on a lathe, rolled, obtained by stamping or even casting. All these technologies have a different relationship of cost with the scale of production, and, of course, it is necessary to choose the optimal one. After that, the structural level is determined - the equipment necessary for the chosen technology, its performance, sequence of location and technological interrelations. Finally, on the parametric level, we determine the speed and depth of cut, the knurling speed - in a word with the technological modes implemented on the selected equipment.
3. Model
Let us consider the application of the above theory to the design or selection of a reconfigurable production system [12-15]. The driving idea in increasing the productivity of production systems is to increase the equipment load factor. Due to the dynamically developing society, economy and markets, it is difficult to find an area where mass production of similar products is necessary. Coupled with the demand for increased load, this requires increased flexibility from production systems. The first step on this path is the use of flexible production systems that can only change the manufactured product by changing the computer control program. This way of giving flexibility corresponds to the lower level of Figure 1 - parametric, and only sometimes; the second level, for example, at the time of equipment breakdown, is the technological route designed to bypass the faulty machine, that is, the structure changes.

However, such flexibility is not enough, and then it is necessary to apply a structural rearrangement of equipment [16], for which it is made of the same type of cells with the ease of formation of any of the most complex structure - this design decision refers to the structural level and is provided by reconfigurable production systems. Sometimes it is necessary to change even the technology of manufacturing products, which provides a new direction in increasing the flexibility of production systems - reconfigurable manufacturing and enterprises (reconfigurable enterprises [17]), which should be based on transforming machines, which make it possible to facilitate the change of production technology to the maximum.

It would seem easy to provide flexibility at the economic and social levels. However, we must not forget that the implementation of measures for such an increase in flexibility must be supported by technological support at all lower levels, and this is quite expensive. However, this significantly increases the survivability of the technological system [18].

4. Data and method
Let us suppose you need to design or select equipment for a technological system with practical application at a regional enterprise.

The product range includes: two types of products with similar technological regimes, as well as an additional type of product with a close, primarily equipment, technological process. Next, there is a product with similar manufacturing technology; finally, there is an additional market for such products, as well as socially significant related products that allow production with the existing capabilities of a regional production system.

As you can see, the assortment is quite diverse and allows for a quick variation of volumes and assortment to obtain significant savings of resources by following the market demand.

To test the usefulness of the project proposals, you can consider the results of the work of a real technological system, which was chosen as a regional enterprise. From the products to study the effectiveness of the developed methodology, products were selected in accordance with the conditions discussed above, observations were made of the work of one outlet, and the result, to calculate load factor, was multiplied by the total number of points. The statistics obtained are summarized in table 1.

| Indicators                  | Product 1 | Product 2 | Product 3 | Product 4 | Product 5 |
|-----------------------------|-----------|-----------|-----------|-----------|-----------|
| Price (kg)                  | 38        | 41        | 68        | 86        | 167       |
| Daily demand               | 135       | 97        | 45        | 55        | 100       |
| Average production time, min| 0.5       | 1.1       | 2.5       | 4.4       | 9.7       |
| Total time, min            | 31680     | ."."      | ."."      | ."."      | ."."      |
5. Results and discussion

Figure 2 shows the histograms of the load factor depending on the level of the considered indicators and, accordingly, the capabilities of the designed technological system.

![Histogram of changes in the load factor of the technological system depending on the level.](load_factor)

From the obtained results it follows that at the parametric level (V), by changing the technological modes, it is possible to manufacture only two types of products and therefore the load factor is small. At level IV - structural, it is possible to manufacture an additional type of product with a slight variation in the structure of the technological system. At the third technological level, another type of product is added now with close technology. At the II economic level, an increase in the sales ratio leads to an increase in the load factor of the technological system. Finally, at the I social level, additional technological equipment is added for parallel production of a related socially significant product, therefore the load factors of the original technological system and the additional one are represented by two columns.

6. Conclusion

Thus, to answer the question what equipment should be designed or selected to complete a complex production system, it is necessary to consider five hierarchical levels with their own indicators each. At the same time, the indicators of the lower level can be determined only after the determination of the indicators of the higher level. The main criterion for selecting the design parameters of the technological system is the equipment load factor, which in turn places increasing demands on the flexibility of the technological system.

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