Increase of stability of functioning of a production system of machine-building enterprise

A A Rudenko¹, D V Antipov² and M O Iskoskov³

¹ Head of Department of “Management of the organization”, Togliatti State University, Belarusian str., 14, Togliatti, 445020, Russia
² Head of Department of “Commerce and production management”, Togliatti State University, Belarusian str., 14, Togliatti, 445020, Russia
³ Director of the Institute of Finance, Economy and Management, Togliatti State University, Belarusian str., 14, Togliatti, 445020, Russia

e-mail: rudenkoa.a@mail.ru, dmitrya@tltsu.ru, maksim250881@mail.ru

Abstract. In article approaches to an assessment of stability of functioning of a production system of machine-building enterprise are considered, criteria of an assessment of stability of functioning of a production system are defined and mechanisms of ensuring its stability are given

1. Introduction
The high competition in such industries as automotive industry and aircraft industry forces to fight constantly for preferences of the consumer of machine-building production and to increase its competitiveness. With the changes happening in the market, change both approaches to the organization and production management. Current trends assume the increase of flexibility of production expressed in implementation of individual requirements of customers (transition from a mass and mass production to production under the order), increase in productivity of productions for possibility of expansion of a share of the market, and also ensuring stability of functioning of a production system of machine-building production.

The Production System (PS) - set of the interconnected elements of system, the including elements of system of the organization and management and the elements of object of management necessary for realization of purpose – implementation of the production program meeting the requirements for productivity and quality.

Stability of functioning of a production system - ability to provide positive dynamics of changes in the set borders of the target indicators of stability characterizing key production factors.

For ensuring stability of functioning of a production system it is necessary to define factors, an assessment technique, and also to develop mechanisms of ensuring stability of functioning of a production system.

2. Results and discussions
The carried-out analysis of factors, allowed to reveal and classify the key factors influencing stability of functioning of PS. All factors were broken by us on internal and external. The external factors and characteristics expressed through quantitative indices are given in table 1.
Table 1. Environment factors

| Factor of influence of the market | The characteristics expressed through indicators |
|----------------------------------|--------------------------------------------------|
| 1. Factors of volumes (quantity) | Volumes of deliveries Sizes of party The nomenclature of the delivered production |
| 2. Cost factors                  | Production price Cost of storage, possession, service and operation of production |
| 3. Quality factors               | Deficiency / loss level from use of low-quality production Innovation of production (constructional, technological, distributive) Additional characteristics |
| 4. Time factors                  | for placements of the order Time of implementation of the order Time on modification of the order |

On the basis of the revealed external and internal factors, the block diagram in which the directions of ensuring stability of functioning of PS (figure 1) are defined is constructed.

![Block Diagram](image)

**Figure 1.** Factors and directions of ensuring stability of functioning of the industrial enterprise
Stability conditions of functioning of a production stream are:
1. Ensuring flexibility to volumes of deliveries and the sizes of the delivered parties – increase or reduction at the need arising at consumers.
2. Extension of the nomenclature of the made production for satisfaction of requirements of all existing target groups of consumers and convenience of acquisition of production (opportunity to buy production of all standard sizes and the accompanying production in one organization).
3. Minimization of the sizes of the ordered parties, for decrease in expenses during the forming and storage of stocks of machine-building production, thereby increase of turnover in a chain of deliveries.
4. Depreciation of production, including the cost of operation and possession of production.
5. Decrease in time of implementation of the order by production and delivery of machine-building production, including time for placement of the order, if necessary time for modification of the order, time of a production cycle and delivery of production.

It is offered to estimate stability of functioning through the complex indicator consisting of single economic and operational performance (table 2).

| Complex indicator | Single indicator                                      |
|-------------------|------------------------------------------------------|
| Capacity of a production system | 1. Marginal income                                  |
|                    | 2. Operational expenses                              |
|                    | 3. Work in progress stocks                           |
|                    | 4. The volume of the made production                 |
|                    | 5. Time of a production cycle                        |
|                    | 6. Labor input of production of the order            |

The complex indicator is on the basis of additive convolution of single indicators [1].

For an assessment of stability we will construct the F(t) function (figure 2). Stability of functioning determines by ability of PS to provide positive dynamics of change of its criterion function in the set borders throughout a long period.

![Figure 2. Function of stability of functioning](image)

Stability is defined by two criteria:
1. A stability indicator increment ($\Delta$) on the set time intervals (t).
2. Degree of compliance of the actual value of an indicator of F(t) * to planned F(t).
Limits of stability determine the acceptable level at which the organization possesses properties of stability and necessary protection against influence of external and internal system factors. Mathematically the condition of stability is determined by a formula:

\[
F(t) = \begin{cases} 
  k_1 y & 0 < t < t_1 \\
  k_2 y & t_1 < t < t_2 \\
  k_3 y & t_2 < t < t_3 \\
  \vdots & \\
  k_n y & t_{n-1} < t < t_n
\end{cases}
\]  

(1)

where \(k_1y, k_2y, k_3y, \ldots, k_ny\) – the linear functions defining target values of an indicator of stability on time intervals.

The target indicator of stability of functioning will pay off on a formula:

\[
\Delta F(t) = |F(t) - F(t)^*|; \quad |\Delta F(t)| \leq T
\]

(2)

where \(F(t)\) – the function defining planned values of a target indicator of stability of functioning; \(F(t)^*\) – the function defining the actual values of an indicator of stability of functioning; \(\Delta F(t)\) – the size defining stability; \(T\) – the admissible value of stability determined by limits of stability.

Target values of indicators and limit of stability are defined on the basis of creation of statistical control cards of averages and amplitude, SPC defined in a technique (statistical managements of processes).

Control of stability is exercised on the basis of logistic function (figure 5.3). Change of parameter of stability in time happens on a logistic curve on which areas of growth, stability and areas of loss of stability are defined.

Logistic function is expressed by Ferkhyudst's equation:

\[
F = \frac{A}{1 + 10^{a+bt}} + C
\]

(3)

where \(F\)-value of function; \(t\) – time; \(C\) – the lower asymptote (a limit with which function growth begins); \(a, b\) – the parameters defining an inclination, a bend and inflection points of the schedule of logistic function.
The equation of logistic function is expressed in the following logarithmic form:

\[
\log \left( \frac{A}{Y - C} - 1 \right) = a + bx, \quad \text{or} \quad \log Z = a + bx
\]  

"Hit" of parameter in a zone of loss of stability in which there are bifurcation changes transforming its qualitative definiteness, changing a trajectory of its further development leads to an uncontrollable state at which two options of an outcome of events are possible: PS copes with stability loss crisis, increasing the level of organizational development due to introduction of new approaches and technologies to the organization and production management, or PS doesn't overcome stability loss crisis. Thus the enterprise can stop being competitive that will lead to loss of a share or all market or to bankruptcy [2,3,4,5,6,7,8].

Stability of functioning of PS is influenced by external and internal factors – system restrictions. We carried out classification of system restrictions in which three groups are defined: technical, technological and organizational (table 3).

**Table 3. Classification of system restrictions.**

| Group         | System restriction                                                                 |
|---------------|-----------------------------------------------------------------------------------|
| 1. Technical  | - Capacities<br>- Design and technological innovations                              |
| 2. Technological | - Quality and competitiveness of products<br>- Production speed<br>- Volumes of reserves of materials, accessories, work in progress and finished goods in warehouses of the organization<br>- Reliability of a chain of deliveries<br>- Power of a chain of deliveries<br>- Cost of a chain of deliveries |
| 3. Organizational | - Speed of design of production<br>- Demand for products<br>- Efficiency of process of advance of production<br>- Financial resources<br>- Competence of the personnel of the organization |
For ensuring stability of functioning it is necessary to carry out the coordinating impacts on the system restrictions appearing when functioning PS. We developed the classification of the coordinating impacts on system restrictions given in table 4.

**Table 4.** The coordinating influences for elimination of system restrictions

| System restriction of production | The action directed on elimination of system restriction | Coordination parameter r |
|----------------------------------|--------------------------------------------------------|--------------------------|
| Site productivity                | - To reduce labor input of performance of operation (change of those, process) | - Labor input of technological operation of performance |
|                                  | - To add capacities on a site (increase in the equipment, the working personnel, operating time) | - Quantity of units of equipment |
|                                  | - To change the processing modes on technological operations | - Number of workers |
|                                  | - To reduce losses of working hours on a site | - Coefficient of loading of the equipment |
| Quality of performance of technological operations on a site | - To enter additional control operation | - Available operating time of a site. |
|                                  | - To introduce methods of "the built-in quality" and "protection against mistakes" (PokeYoke) | - Site productivity. |
|                                  | - To automate control operations | - Labor input on control operations |
|                                  | - To add additional completion for elimination of discrepancies on quality | - Reliability of control operations |
| Shortcoming or surplus of stocks of NZP | - To increase / lower reserves on sites | - Additional labor input on operations for ensuring quality. |
|                                  | - To introduce system of a pulling | - Award size |
|                                  | - To reduce the sizes of interoperational parties | - Labor input on control operations |
| High labor input of technological operations of a site | - To change technological processes | - Reliability of control operations |
|                                  | - To change the processing modes | - Additional labor input on operations for ensuring quality. |
| Long time of readjustment of the equipment | - To introduce methods of fast readjustment. | - Processing modes |
|                                  | - To change the sizes of interoperational party | - Labor input on technological operations |
| Losses of working hours          | - Change of system of compensation and awarding | - Labor input of readjustment |
| Low administrative competence of the personnel of production | - To train the personnel. | - Size of an award of workers |
|                                  | - To redistribute responsibility and powers of the personnel. | - Integrity of management. |
| Reliability and power of a chain of deliveries | - To develop standards and regulations. | - Adaptability of management. |
|                                  | - To lower a stock rate in knots of a chain of deliveries. | - Power of knots of a chain of deliveries. |
|                                  | - To increase quality and discipline of deliveries. | - Level of satisfaction of demand. |
|                                  | | - Reliability of knots of a chain by criteria of quality and terms. |
The coordinating influences are provided due to introduction of the modern administrative concepts and technologies applied in mechanical engineering. It is possible to distinguish such concepts from them as Economical production, TQM and JIT. Classification of concepts and methods of ensuring stability of PS (table 5) is developed.

**Table 5. Classification of methods of ensuring stability of functioning**

| Concept | Tools |
|---------|-------|
| 1. Lean | 1.1 SMED (fast readjustment) |
|         | 1.2 5 "S" (system of the organization and rationalization of the worker place) |
|         | 1.3 TPM (general service of the equipment) |
|         | 1.4 Poke-Yoke (protection against defects) |
|         | 1.5 Visualization |
|         | 1.6 Andon (visual system of feedback on production) |
| 2. JIT  | 2.1 KANBAN (system of regulation of streams of materials and goods in the organization and beyond its limits – with suppliers and customers) |
|         | 2.2 ABC-XYZ |
|         | 2.3 BBK method |
|         | 2.4 Plan of acceptance (selective control) |
|         | 2.5 FMEA analysis of a chain of deliveries |
| 3. TQM  | 3.1 Statistical methods (7 simple methods of management of quality) |
|         | 3.2 Standardization |
|         | 3.3 QFD |
|         | 3.4 Engineering techniques (FMEA, PPAP, MSA, QSA, SPC, APQP) |
|         | 3.5 ZERO DEFECT |

3. **Conclusion**

Stability of functioning is important property of a production system of machine-building enterprise. Stability is influenced by external and internal factors, system restrictions. For an assessment of stability it is necessary to define a complex indicator of capacity of PS. By means of the developed mathematical model it is possible to set stability of functioning of PS. At an exit of function of stability for borders of ensuring stability it is necessary to carry out coordination impacts on PS for the account introduction of modern administrative methods.

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