Application of SMED (Single Minutes Exchange of Die) for Production Optimization

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Abstract

For optimization of engineering production, it is proposed to use a system of quick changeover (SMED). The introduction of this approach will enhance, in particular, the increment of the coefficient of technical use of equipment A (availability factor) by reducing non-productive time downtime. In this case, A is used as the optimization parameter. Examples of technical decisions applying SMED are presented.

Keywords: Single minutes exchange of die (SMED), maintenance and repair system, availability coefficient, series volume

I. Introduction

The increasing the reliability of plant equipment can be carried out in several directions. Engineers and developers traditionally primarily pay attention to improving the strength and durability of products [1], which is directly related to manufacturing quality and control. But we cannot ignore such an important part of how the organization of production is performed.

Maintenance and Repair works maintain equipment in working condition [2]. The works of the Maintenance ensure the implementation of some of the most important stages in the life cycle of a product (PLM).

In [3], it is shown how changing the maintenance strategy over the past half-century in connection with the existing realities and their tasks that were designed to perform the technique corresponding stage of development were developed. The engineers considered gradual transition from strategies from "repair on failure" to "service status" and then to automated systems Maintenance and repair, "CMM – Computer Maintenance Management System. The latter involves the use of programs to build network graphs (e.g., PROJECT MANAGER, which is the part of MICROSOFT OFFICE).

II. Methods

As the method we selected the analysis of machine availability factor A. Therefore, the service is focused on reliability, ultimately aims is to improve integrated indices of quality of equipment, namely, availability factor A and the coefficient of the technical use the A_H [4].

$$A = \frac{E(Uptime)}{E(Uptime) + E(Downtime)} \quad (1)$$

$$A_H = \frac{E(Uptime)}{E(Uptime) + E(Downtime) + E(Hangover)} \quad (2)$$

In formulas (1) and (2): $E(Uptime)$ - the mean time of the product in working condition (Uptime); $E(Downtime)$ - the mean time of the product in the failed state (Downtime); $E(Hangover)$ – the mean time required for changeovers. Indicators A and A_H dimensionless, and the values $E(Uptime)$, $E(Downtime) and\ E(Hangover)$ have the dimension of time (e.g., hours).

The structures of the formulas show that A<1, AH<1 and Ah<A. The degree of closeness increased A to unity indicates a high reliability of the equipment and the condition AH→1 characterizes the compliance of the level of production to modern standards.

Mathematical aspects related to the interpretation of complex indicator A were considered in [5]. Previously, we developed a method that allows to build the confidence interval of values A [6].

Important resource for increasing the A_H is the reduction of exchange time, in connection with which we propose to discuss an approach which is one of the methods for lean production, namely Single Minute Exchange of dies (SMED).

The Toyota company in 1969 made the first drastic steps to reduce the time of changeover, preceded by a 19-year-old practice that allowed Japanese scientist S. Singo to make his discovery. The author of the concept "single minute exchange of die" Shigeo Shingo describes the essential principles of it approach [7]:

- The distinction between internal and external operations;
- Replacement internal operations to external;
- Standardize functions, not forms;
- Use functional clamps. Possible avoid the fastener;
- Maximum use of intermediate devices;
- Operations should be performed in parallel manner;
- Operations without further adjustment;
- The use of mechanization.

In the base of the method the division of operations of the readjustment into two categories lies 1) Internal, which are executed ONLY when the equipment is stopped. For example, the mold can be replaced only when the press is turned off; 2) External actions, on the other hand, can be performed during operation of the equipment. For example, it is possible to pick and sort the bolts of the press molds when the press is running.

The idea of acceleration is to replace as many internal activities into external. This reduces changeover by several times and thereby increases A_H.

III. Results

In the Fig.1 the distributions of A for one of the subsystems of the coal-mining excavator [6] are shown: (a) original; (b) after the hypothetical event SMED, which halved the non-productive loss of time. The distribution is constructed using a method developed by the authors [6], based on the statistical bootstrap [8].

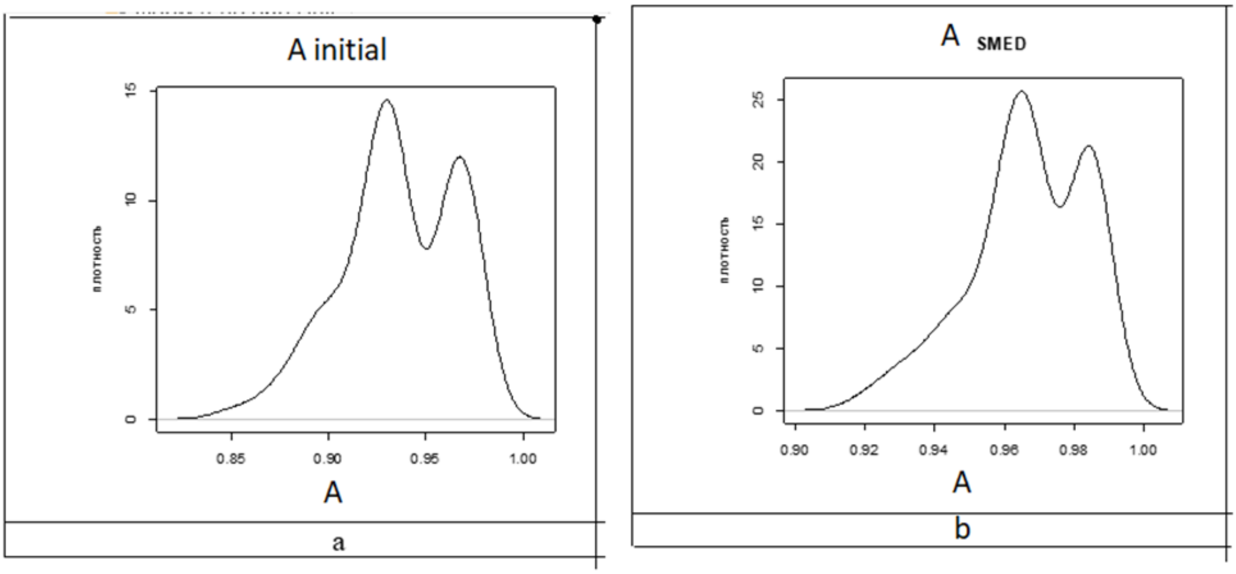

Figure 1. The graph of the probability density of the sub-system A of coal mining excavator: a - initial; b - after the SMED events

In the Table the summarizes statistical characteristics (“SUMMARY” function in R) distributions of the A values shown in Pic.1 is presented. Table data and graphs in Fig.1 are performed in the programming environment R [9].

Table. Statistical summary of the bootstrap distributions of A before (initial data) and after SMED events

	Minimum value min(A)	First quantile Q_1	Median	Mean value	Third quantile Q_3	Maximum value max(A)
Initial data	0.7850	0.8972	0.9302	0.9244	0.9626	0.9776
After SMED	0.9191	0.9591	0.9670	0.9665	0.9828	0.9889

From Figure 1 and the Table it might be seen that the median value of the reliability index in the hypothetical operations of SMED median A is shifting to larger values, namely, it increases from 0.9302 to 0.967.

The concept of SMED is one of the directions of development of "lean production" approach. Under the latter, for example, combating against non-productive storage is being made by switching to smaller series. In the economy of the future client - oriented production is performed, i.e. it is produced the exact amount of goods what the customer needs, and in the desired quantity.

For the small parties have become economically viable, it is necessary to reduce the changeover time, as mentioned above. In [10] the formulas, allowing to estimate the economic feasibility of a certain size party are presented.

First, the specific time of manufacture of details taking into account setup time is calculated:

$$t = (pK_1 + S_1)/K_1 \quad (3)$$

In the formula (3) p - machining time; S_1 – the set-up time prior to the event; K_1 is the size of the party prior to the event.

When calculating the new size of the party it is necessary to take into account that the specific time of manufacture remains unchanged:

$$K_2=S_2/(t-p) \quad (4)$$

The ratio K_1/K_2 shows how many times you can reduce the batch run, and it depends on the ratio S_1/S_2.

The average level of finished goods reserve:

$$C=(K+d)/2 \quad (5)$$

Here d is the minimum size of reserve of output production

As the size of the party depends on the time of changeover, then the reserve will depend on changeover times. Through the necessary transformation, the authors of [10] obtained the dependence of the reduction in reserve levels, resulting from the reduction in changeover times:

$$\Delta C=(S_2+d_2\, s +2Ds)/(S_1 +d_1 s +2Ds) \quad (6)$$

From the formula (6) it follows that the decrease of changeover times, increased reserve turnover and materials. This reduces the need for storage space and reduces the level of storage costs.

The Fig.2 schematically shows the impact of the costs of adjustment to the economically justified size of the party. The figure shows that the decrease of changeover time is greatly reduced economically reasonable series size.

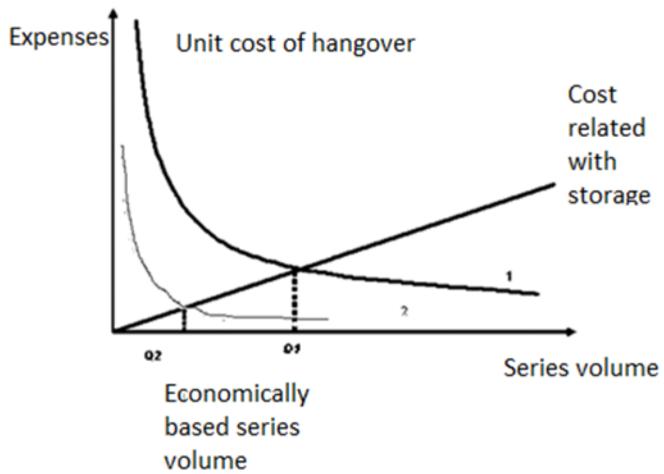

Figure. 2. Schematic representation based on the economically justified size of the party while reducing the changeover time (thin line shows the graph after the transition to SMED) [11].

IV. Examples of application

Techniques SMED applied in different fields of industry (not only engineering). In [7] it is described, in particular, examples of applications to optimize the change of cartridges in semi-automatic lathe, automatic screw machine, with the installation of replacement gears.

Techniques to implement fast changeovers is complicated and require special knowledge. To begin with, it is necessary to consider the specifics feature of the equipment and processes of its conversion. For example, for precision machining equipment, the most difficult is the elimination of the adjustment, without which under the deficit of qualified installers it is impossible to drastically reduce the changeover. For businesses related to the production of wire or cable production, the most important and significant technical solutions lie at the junction of the ends and wire.

In many industrial enterprises, the problems of installation the press molds (to ensure speed and accuracy of positioning) are being solved. In cases where changeover is conducted not on individual pieces of equipment and automated production line, the first-priority task is solving the task of the team of operators, technicians-mechanics and engineers of industrial automation. Only at the expense of the competent organization of their transitions from one equipment to another, it is sometimes possible to reduce the changeover time by 3-4 times, and it provides solid gain in uptime of the line.

The Fig. 3 shows two schemes to illustrate the technical solution for implementing a quick exchange of dies [7]. In practice the question of the stamps needs to be polished often raises. Thus, it is necessary to insert spacers to adjust the height of the stamps. One way to solve this problem is to replace the block with the thicker one on the value that needed to be removed by polish. Blocks used with this method of adjustment will usually be attached to the lower surface of the lower half of the stamp. In some cases, they can be attached to the top of the upper half of the stamp (Fig.3). This method can be considered as one of the applications of transfer functions from internal to the external operations.

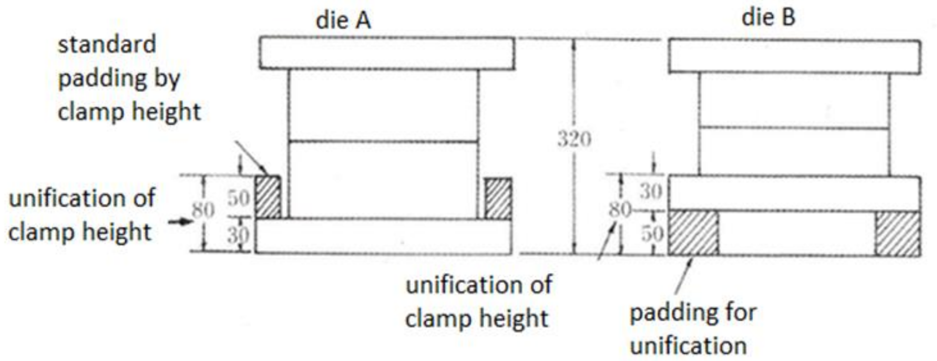

Figure 3. Standardization of the height of stamps clamps

Significant time reduction is the replacement of fasteners by the clamps. The direct attachment requires a large number of turns of the screw. The key to the development of the method in accordance with SMED is the understanding of the role of the number of threads that provide the necessary friction for reliable operation of the mechanism. It is necessary to revise the approach using only threaded connections. The Fig.4 shows an example of a spring clip to secure the gear on the shaft. The elastic energy of the spring provides a change of gears "one-touch". The mechanisms serving this purpose also include wedges, taper pins, ejectors. Promising are also the vacuum and magnetic methods for details installation.

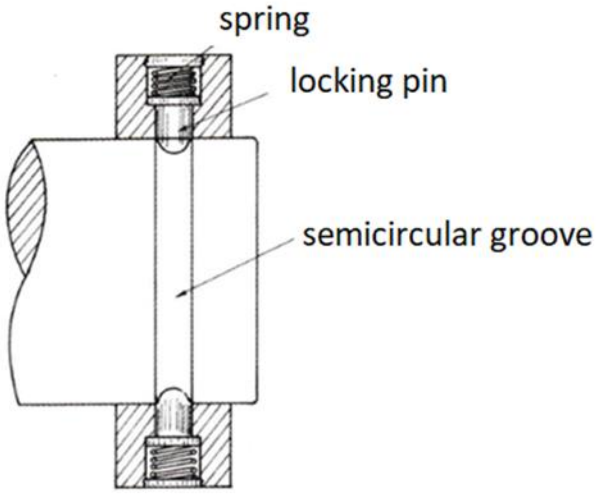

Figure 4. Spring clip for installation of a replacement gear

Conclusion

The basic principles of one of the tools of "lean production", namely, single minute exchange of die, SMED are considered. The importance of this approach at the present stage of technology development is shown. Examples of engineering solutions are presented. As an optimization parameter, we use the complex index of reliability, namely availability coefficient A and of technical use factor A_H. Some technical solutions are shown.

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