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RESEARCH OF IMPACT OF LAYOUT OVERHAUL SYSTEM ON EFFECTIVENESS AND EFFICIENCY OF OVERHAUL PROCESS

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Abstract: This paper presents the results of the research on the effect of the concept of Lean tools **-** Layout to the duration of a cycle of repair and the distribution of the workload at the overhaul cycle in the process of overhaul of technical systems, by the regulation (reconfiguration) of technological systems and distribution of jobs in the spatial structures of overhaul systems in a way to maintain a balanced flow of materials and components necessary for the realization of the process of technical overhaul of the system. Studies of its application were made in the real overhaul system in the process of the repair of a turbojet engine by the simulation of the work processes using Microsoft Project and Microsoft Office Excel software tools. The research results established the principles of the duration of the overhaul cycles and changes in the workload at the repair cycle in the function of Layout, which can be reliably used to assess the impact of Lean tools on process of effectiveness and efficiency of the studied technical system overhaul.
Keywords: Lean tools, layout, overhaul cycle, technical system, overhaul system

1. INTRODUCTION

The modern labor market conditions require an increased efficiency of work processes from a request for a product or service to its realization. For this purpose, reducing the cycle time and employing more efficient and effective labor are becoming more and more important. Therefore, numerous studies have been focused on the use of various managing tools and techniques in achieving optimal solutions in the management of work processes of production systems. It is known that the flow of materials through the production system, information flows, and the quality of human resources greatly affect the cycle-time. Special importance in the analysis of services is given to production and service organizations for technical overhaul of the system (repair systems). Work processes in overhaul systems are far more complex and demanding from the standpoint of the interdisciplinary knowledge and skills of workers. In such systems it rarely occurs that certain operating time can be standardized and that the available workers with qualifications can be loaded or employ in an equal way.

From the above mentioned it can be concluded that in the process of work of production and service organizations for technical overhaul of the systems goals for the establishment of a functioning organization, that is, the arrangement of the process of work that will provide a high degree of flexibility in the organization and management oriented towards the customer must be imposed.

Design of the functional organization measured by the effectiveness and efficiency of the work process includes organizational regulation of series of interdependent group of influential factors on whose intensity the successful outcome of each work process depends. The ultimate goal is to reach as many effects with less invested funds or that the cost per unit of the technical system overhaul should be as small as possible. In this way, managers who lead the production are forced to permanently remove activities that generate losses for the company using simultaneously efficient managing methods, procedures and tools. In addition, minimizing process is transmitted to the individual elements of the organizational structure, such as spatial resolution (the schedule of technological systems and jobs in

manufacturing plants – Layout), while maintaining market power and position. An approach to the creating of such environment in enterprises is characterized as Lean manufacturing, Lean doctrine or Lean concept [11].
The aim of the concept of Lean is to eliminate sources of loss, or „free spaces“, which are essentially useless time and losses due to early investment in production. Eliminating the stock is the biggest problem, because it requires synchronization of very close process, those that connect different functions within the company. This concept involves constant organizational and managing modernization. It is about an activity to reduce production costs by reducing all forms of losses expressed in factory flow, losses due to the stuck of the means of production, delay in information, energy, inventory management, design. This creates a system that will eliminate the losses in the process of work of organizational systems, taking what is essential for reproduction, production and which affects the increase in the cost of production (equipment, materials, labor, time, etc.).
Systematic and constant search for useless activities at all levels of the work process and their elimination or reduction have an indirect influence on the quality and costs of the company. New methods to train personnel – tools and developed information technology make it possible to accelerate research and enable continuous cost reduction and improvement of product quality according to customers` wishes in all elements of the work or the business cycle.

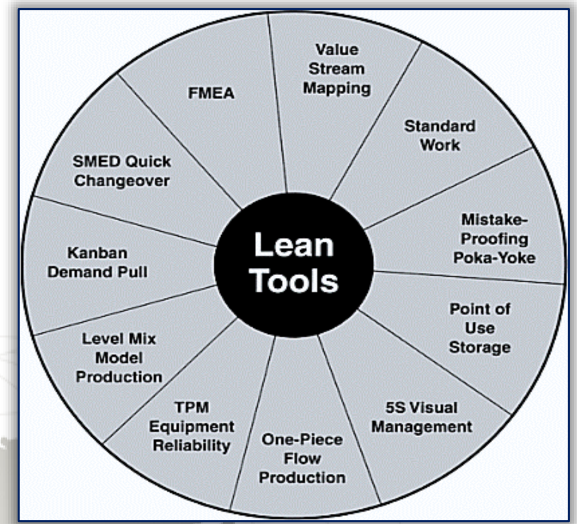

Figure 1. Scheme of some significant Lean management methods and tools[2]

Using various tools and techniques of Lean concept (Figure 1) aims to standardize and then continuously improve the quality of work processes in enterprises. The reasons for this should be sought in the fact that the standard operating procedures provide standard product quality. They were developed during years of research by successful companies in highly developed countries in order to satisfy users of products and services and other stakeholders. If applied correctly, the tools and techniques of Lean concepts enables continuous improvement with minimal investment [6,8,9,11,12,13]. So today, many companies are investing huge funds in the development and implementation of the Lean concept of tools that will allow them the ability to continuous and rapid adaptation to the conditions that are constantly changing [10].
Previous studies [1,7] have shown that Lean concept, in addition to the automotive industry which initiated the development of the concept, has gradually been recognized in other manufacturing, service and administrative organizations, and the results are compelling. The question therefore is: „the extent to which the developed tools and methods of Lean concept can be applied to the work processes in manufacturing and service organizations involved in overhaul of technical systems and with what success?“
The overhaul is the most complex aspect of maintenance and depends primarily on the technical system in repair and overhaul system. Technological level and the materials used are characteristics of the materials used in the technical system overhaul, while the character of technological, organizational and management structure and production technology, human resources and material resources (funds for work, economic resources and material sources of production and service organizations used in the process of repair and its needs) are characteristics of a system overhaul.
The process of preparation and carrying out of technical overhaul of the system is structured in the following stages [5]:
≡ preparation of the technical system overhaul,
≡ reception of the technical system for overhaul,
≡ repair of the technical system,
≡ handing over the technical system to the user.
In the process of the repair the most important stage is the repair of the technical system, which lasts the longest, whose implementation requires a specific organizational overhaul system with qualified and experienced participants in the work processes and the involvement of sizable funds (up to 70%

of the cost of a new technical system) [5]. In further discussion about of repairing process just a phase of the repair of technical systems will be taken into consideration.
The system overhaul (plant) in the present study presents a rounded organizational and technological unit dedicated to defect and repair technical systems in failure, i.e. technical systems that have lost prescribed technical and operational characteristics.
Unlike mass-production, where time and resources are constantly repeated, overhaul system work items are different for each case of overhaul, they are composed of multiple components, cycle-time is far longer, and more varied resources were used. Thus, the overhaul of these technical systems can be viewed as a project [4]. If we look at the overhaul as a project, managing the process of overhaul is more complex than in traditional, conventional productions. Therefore, in such systems, complex tools for effective managing overhaul cycle both software and management tools must be used. In the present study, both types of tools will be used: (a) software – Microsoft Project and (b) Lean tool – Layout.
For this purpose, the paper considers the impact of distribution of technological systems and jobs at the system overhaul (plant) of the duration of repair cycles and distribution of the workload at the repair cycle for the following reasons [1]:

≡ The flows of materials, information and sequences of operations affect the layout of scheduling technological systems and jobs in the spatial structures of production systems and they have a primary importance in achieving a more efficient work processes – Lean goals.
≡ It is commonly known that, among other tools and techniques of Lean concepts, Layout achieved significant success in reducing the production cycle in the automotive industry.
≡ Research shows that using Layout in spatial structures of enterprises engaged in serial production of cycle production can be reduced by 20% in the system for the production of hydraulic hoses, or by 400% in the system for the production of brake disks for motor vehicles.

Therefore, a relevant research has been is carried out in terms of verifying how many applications of Layout in the process of the overhaul of technical systems can contribute to the increase of regulation of flows of objects of work, and the effectiveness and efficiency of the process of overhaul in the production and service organizations that deal with the overhaul of technical systems, and thus the satisfaction of their customers.
Effects of Layout implementation in spatial structures of production and service organizations for overhaul of technical systems will be considered in the context of:

≡ duration of overhaul cycle,
≡ the distribution of the workload at the repair cycle,
≡ flow of objects of work.

In this paper the dependent variable is effectiveness. Layout of spatial structure of production and service organizations dealing with the overhaul of technical systems is an independent variable.

2. LAYOUT

Formation Regulating the distribution of technological systems and jobs in the spatial structures of production systems is of great importance in achieving the goals of Lean, because the distribution of technological systems and jobs is primary for those who want to become Lean. Spatial structures of the system consist of technological systems and workplaces which are placed in a way that maintains a uniform flow of materials and components needed for the implementation of the production program. Workers in these structures are qualified and trained for rapid and precise performing work processes [1].
Distribution of technological systems and jobs should provide a uniform flow of material and objects of work on the principle of one team flow. Here, the trajectory of each object or product takes place through the process as a unit in time, without sudden interruptions, according to the intention, within the customer's needs. So, Lean concept implies the spatial structure of the production system formed by the present approach (work unit), as opposed to traditional organized production system as it was done on procedural and functional approach.
The advantages of creating production structures of the present approach in relation to the process or function approach are [1]:

≡ shorter production cycle,
≡ improved quality - less chance of working again for parts of poorer quality,
≡ less material handling,
≡ improve coordination and synergies in the work,

≡ decrease in inventories of raw materials and parts,
≡ simplified planning and scheduling,
≡ rational use of space.

Particularly suitable are working units in the form of passing Latin letter „U“ (Fig. 2), for minimizing movement of workers within the business units and enable workers to attend more technological systems because the components during processing are not handled in all technological systems or insufficient utilization rates of individual technological systems.

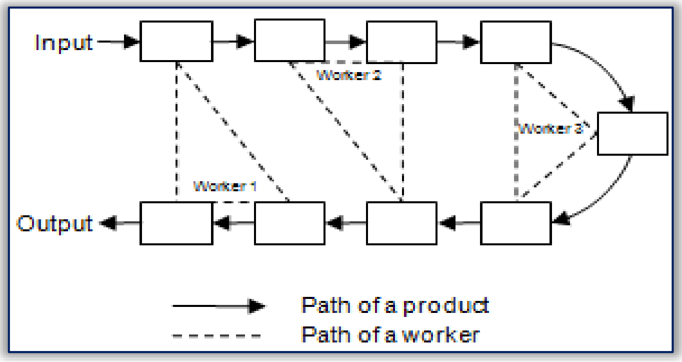

Figure 2. Scheme of work unit

Working units are the basis of effective production in production systems of Lean enterprises. This is a group of technological systems and workers who handle them, organized so as to obtain a steady stream. The approach is based on the application of Lean tools concept – Nagara system, which in human resources imperatively requires greater interdisciplinarity, i. e. diversity of activities of individuals (multiqualified workers) in order to achieve full efficiency. Thus educated workers are assigned handling more technological systems to reduce the number of workers in the production process, to balance the distribution of work and cost-effective work processes, and all this will significantly influence the effectiveness and efficiency of each production system. After training and adapting among workers in the work unit a synergistic effect is created and the production cycle of a certain item is shortened.

3. ILLUSTRATIVE EXAMPLE

The study included overhaul of the system of real production and service organization for the production and repair of gas turbine engine. In the past, the overhaul was carried out in two plants: Plant-I; overhaul of turbojet engine type „A“ and Plant II; overhaul of turbojet engine type „B“.

The idea was to rearrange the Plant-II for „other“ purposes, and that by upgrading the annex to Plant-I a spacious ambiance of joint overhaul should be created i.e. that the above two types of overhaul merge into one, and that turbojet engines of type „A“ and Type „B“ overhaul at the same workplaces.

During the reporting system overhaul flow analysis of objects of work has been applied (Figure 3) to improve technological systems and jobs distribution – Layout.

The results of this analysis are summarized by the general attitude that can lead to improved spatial structure – of Layout's overhaul of the system, regulating thereby flows of objects of works so as to be one-way. These attitudes are [5]:

≡ to build a plant surface protection at the site of the system overhaul. In the observed production and service organization this plant is in the second company located about two kilometers from the system overhaul;
≡ to finish the expansion of the annex to the existing system overhaul (I-Plant);
≡ to make a distribution of technological systems and jobs over the approaching objects of work flows;
≡ to arrange places for disposal of items of work in addition to workplaces, which are integral parts of the workplace;
≡ to form a space to receive and dispatch the objects of work from other workplaces, which is an integral part of the workplace.

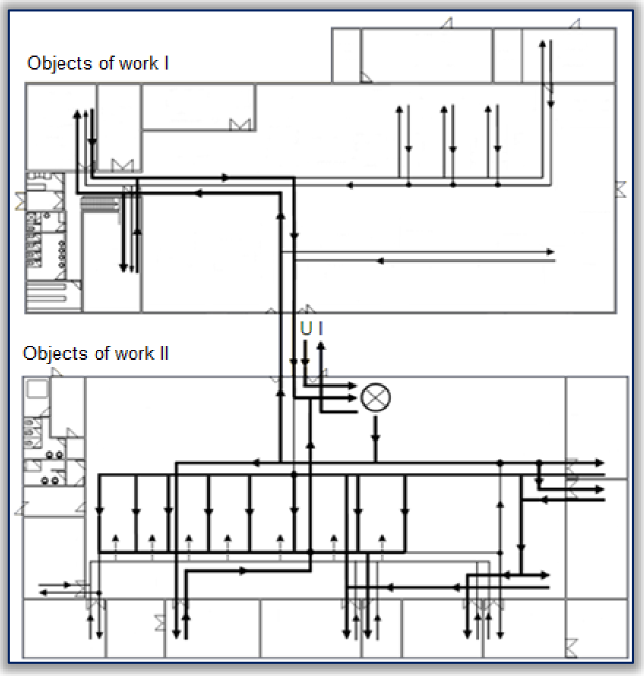

Figure 3. Overhaul system with existing flows of objects of work

In order to achieve these attitudes, it is necessary to reconfigure the spatial structure of the system overhaul presented in Figure 4. The picture presented shows that the proposed solution for distribution of technological systems and jobs largely regulates the flow of objects of work, arranging them in progressive and irreversible flows and that it has a higher degree of the use of space in relation to the existing spatial structure of the system overhaul.

4. RESEARCH RESULTS

Layout impact research on the duration of repair cycles and the distribution of the workload at the repair cycle, by organizing (reconfigurating) technological systems and jobs in spatial structures of the system overhaul was carried out with the support of software tools Microsoft Project and Microsoft Office Excel in real production and service organization for the production and repair of gas turbine engines.

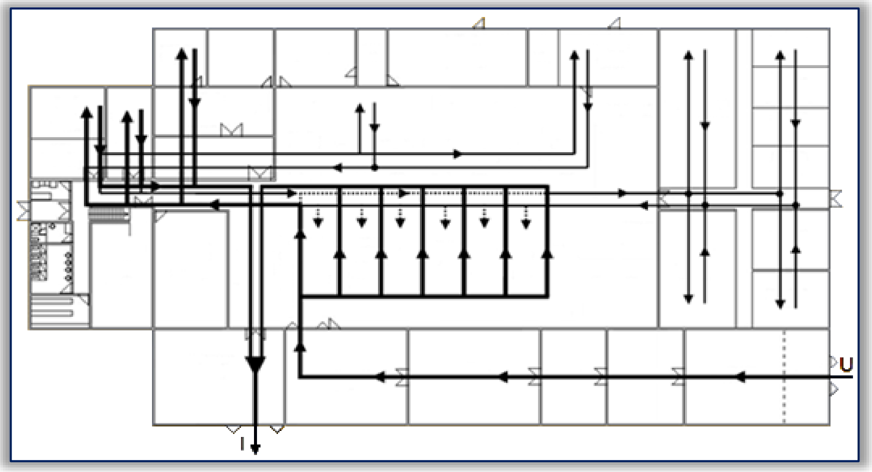

Figure 4. Flows of objects of work in reconfigured overhaul system

Limitations of the study include:

- ≡ The overhaul of turbine engine is carried out under controlled conditions which imply the existence of a high organizational and technological regulation of the system overhaul, and working and technological documentation. From the above mentioned, the repair of aggregates and „major“ turbojet engines assemblies in earlier Layout repairing systems (Plant-II) has been carried out on „dedicated“ lines.
- ≡ Workers are integrated into a single, common repair process with a set of 33 multiqualified workers (Lean concept tool – Nagara system has been applied) compared to the previous period with two repair processes with a set of 68 workers.
- ≡ The planning of the realization of the repair by using work orders has been carried out according to the methodology of managing implementation of the project by using Microsof Project software tool.
- ≡ Transport times of the objects of work between workplaces are determined in the function of the means of transport and the distance between (i) and (i+1) of the workplace and as such, they determined the delay time (i+1) of operations in the Microsoft Project software tool.

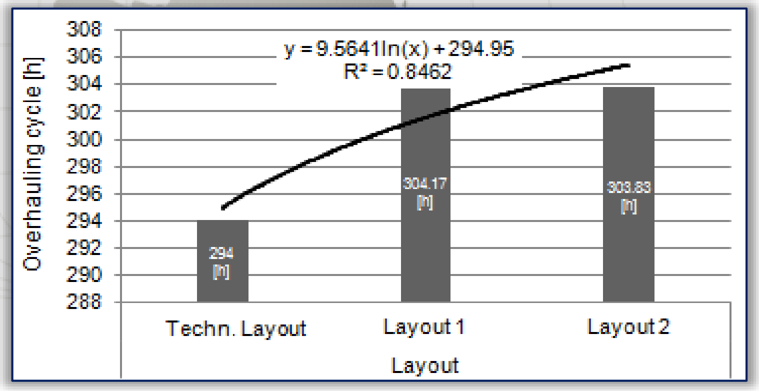

Figure 5. Influence of Layout on duration of the overhaul cycle

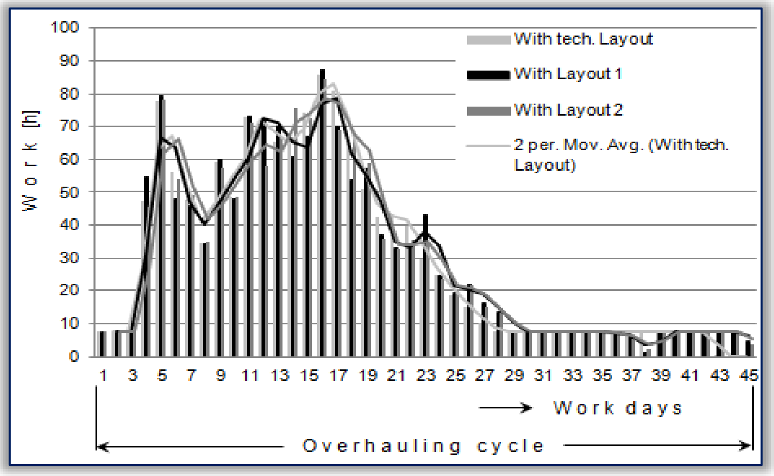

Figure 6. Diagram of the distribution of the workload at the overhaul cycle in the function of Layout

Baseline data in the application of Lean tools are: reconfigured Layout system overhaul (Figure 4) and repair technologies of the studied turbojet engine. The technology of its repair is defined by work order containing: the name of the operation, work center, time (planned and spent), and the overhaul (necessary work yes/no), verification of the quality of performed operation and more.

Output data has been processed by Microsoft Project and Microsoft Office Excel software tools. The results of processing the output data of the research of the influence of Layout on the length of the overhaul cycle is shown in Figure 5 and its influence on the division of work at the repair cycle is presented in Figure 6.

By analyzing the results of the research of the influence of Layout on the overhaul cycle and division of work at the overhaul cycle (Figure 5 and 6), it can be concluded that the analyzed Layouts do not significantly affect neither the duration of the overhaul cycle nor the distribution of the workload at the overhaul cycle in the process of repairs of turbojet engines. This is so because the duration of the overhaul cycle, as a project is determined by specific time duration of work orders for the repair of aggregates and assemblies on the critical path. However, the reconfiguration of the spatial structure will greatly contribute to the organization of objects of work flows, arranging them in a progressive and irreversible trends, as shown in Figure 4, and will also contribute to substantial reduction of the cycles of work orders for repairs of aggregates and components that are not on the critical path [5].

Table 1. Contains the result of comparing in pairs with the final result

LAYOUT		JUST-IN-TIME			
		without NAGARA SYSTEM		with NAGARA SYSTEM	
		without	with	without	with
with	LAYOUT 1	334.92	338.75	323.75	333.67
	LAYOUT 2	333.67	337.75	321.08	332.67

Table 2. Specific effects and coefficients for Trc

Factorial Fit: T_{rc} versus NAGARA SYSTEM. JUST IN TIME. LAYOUT		
Estimated Effects and Coefficients for T_{rc} (coded units)		
Term	Effect	Coef
Constant		332,033
NAGARA System	7,355	3.678
Just-In-Time	- 8,480	- 4.240
Layout	- 1,480	- 0,740
NAGARA System*Just-In-Time	3,400	1,700
NAGARA System*Layout	0,480	0,240
Just-In-Time*Layout	- 0,355	- 0,178
NAGARA System*Just-In-Time*Layout	0,355	0,178

The confirmation of the results achieved in the study of influence of Layout on the overhaul cycle can be analytically successfully shown and simulated by using factor analysis 23. In a broader consideration three Lean concept tools has been applied (Nagara system – a factor A, Just-In-Time – factor B and Layout – factor C). Table 1 presents data of mean time of overhaul cycles of the studied turbojet engine. As measuring characteristic for observation, the time duration of the overhaul cycle – Trc has been included. The analysis of their impact and their correlation link is resolved by using MINITAB software tools which run a complete regression analysis and analysis of variance. The confirmed effects, the coefficients of the regression model and analysis of variance – ANOVA are given in Table 2. Graphic impact of the observed factors on the repair cycle – Trc is shown in Figure 7.

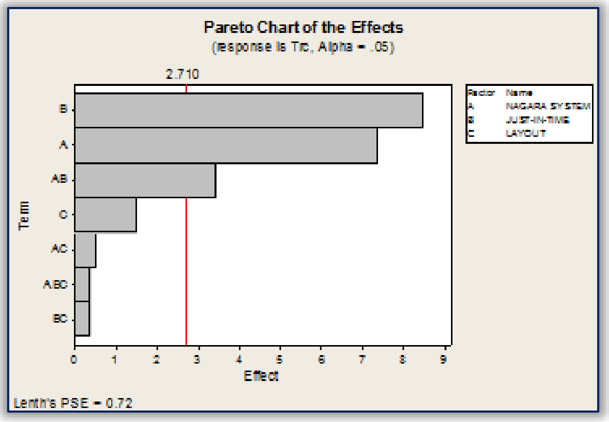

Figure 7. Pareto diagram of factor influence on the overhaul system – Trc

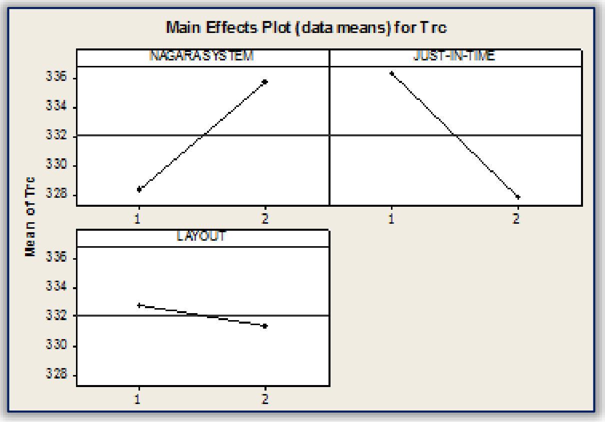

Figure 8. Effects of the main factors in the observation time of repairing cycle

The diagram in the figure shows that the greatest impact on the duration of the overhaul cycle has a factor „B“, followed by a factor „A“ and a combination of factors, „AB“. In addition, the factor „C“ and the combination of factors, „AC“, „ABC“ and „BC“ does not substantially affect the duration of the

overhaul cycle. Regression analysis reveals and ranks the importance of certain factors in the following order:
1. Just-In-Time,
2. Nagara system,
3. Layout.

The behavior of the main effects of factors (Nagara system, Just-In-Time and Layout) in overhaul cycle is shown in Figure 8.

The spatial position level consisting of overhaul cycle – Trc with two factors (Nagara Layout system) is shown in Figure 9.

Regression equations of conduct of overhaul cycle time – Trc obtained by regression analysis:

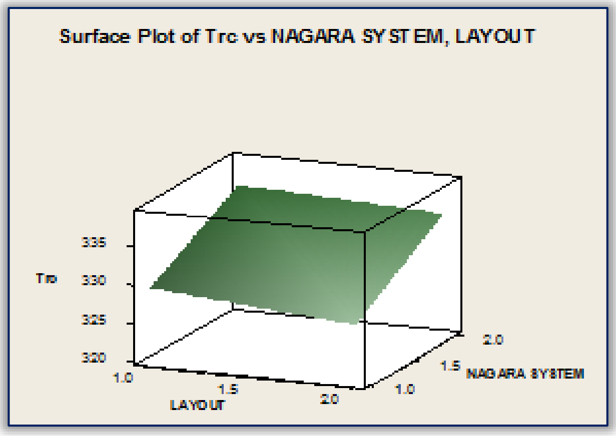

Figure 9. Position level Trc – Layout – Nagara system

$$T_{rc} = f(A,B,C) = 336 + 7,36 \cdot A - 8,48 \cdot B - 1,48 \cdot C \quad (1)$$

Regression equation leads to the principle of on the base of which the overhaul cycle takes place bringing the effectiveness of the technical overhaul system process in the functional dependence of the efficiency of process of the work of overhaul system.

Why has there been no decrease in repairing cycle by reconfiguration of technology systems and jobs (Layout) in spatial structures of overhaul system, compared to a visible reduction of the production cycle in companies with series production?

≡ First, the production cycle of manufacturing parts in series production is determined by the individual work orders.
≡ Secondly, the duration of the overhaul cycle is determined by the sum of tome duration of work orders for the repair of assemblies and aggregates on the critical path and the transport time between operations.
≡ Third, turbojet engine overhaul is carried out under controlled conditions which imply the existence of working and technological documentation, and high organizational and technological regulation of the overhaul system.
≡ Fourth, the repair of aggregates and assemblies of treated turbojet engines that are on the critical path and in the current Layout of the overhaul system (Plant-II) is performed in the „dedicated“ overhaul lines.

CONCLUSION

The research presented in this paper and the results suggest that the observed overhaul system Layout does not affect considerably the duration of the overhaul cycles or the distribution of work at the overhaul cycle in the process of the overhaul of turbojet engines. However, reconfiguration of the spatial structure flows will lead to the regulation of the objects of work flows, arranging them in progressive and irreversible flows, and also to the reducing of the cycle of repairs of aggregates and components (work orders) that are not on the critical path, increasing their „total time reserves“. In this way the conditions for their implementation are created by moving them forward or backward in the function of the availability of multiqualified workers.

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