

## The results of compliance determining of warranty duration of cylinder block heads personal repairing of YaMZ-236 motors

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**Abstract.** Based on statistical analysis of technical service companies we figured out some patterns of changes in the annual program of repair heads of cylinder blocks repairs of engines YaMZ-236 and the coefficient of variation of the daily batch of orders for repairs.

We chose one technological station, which enables us to perform all the programs of repairs, and the duration of the process does not exceed one day.

Due to the results of simulation modeling, the process of batches and service contracts for the repair of heads of cylinder blocks of engines YaMZ-236 we calculated the values of indicators for the guarantee-repair duration  $T_g$ : coefficient of the requirements satisfaction for warranty repair duration  $\xi_N$  and average duration of overguarantee downtimes  $\bar{\theta}$  in different years of the technological station working (and, respectively, for different values of the reservation capacity  $\rho_N$ ) and for different values of  $T_g$  (and, respectively, for different values of the time- reservation  $\rho_T$ ) in the case of both direct (FIFO) and reverse (LIFO) order of execution.

Based on statistical analysis of the results of mathematical modeling we determined the dependencies expectation  $M[\xi_N]$  and  $M[\bar{\theta}]$  of  $\rho_N$  and  $\rho_T$  for different priority of order fulfillment.

Calculations of total costs were done, directly related to the technological costs for repairs and payment of penalties for violation of the order fulfillment of guarantee repair duration  $T_g$ . Analysis of total dependences of the values of cost reservation capacity  $\rho_N$  made it possible to study the rational order of execution of orders for different values of the duration of warranty repair  $T_g$ .

**Key words:** cylinder heads of cylinder block engines, incoming flow of orders for repairs, warranty duration of repairs, factors and criteria for compliance.

### INTRODUCTION

The annual programs of repair companies are unstable because of changes in the number of cars in the

service area, as well as objective changes in technical condition of vehicles during their exploitation.

Incoming flow of orders to repair any units, including the heads of cylinder blocks, has a stochastic character, because it is a transformed stream of refusals, and the amount of daily orders  $-\delta_i$  – is a random variable.

Thus, when selecting technological lines (TL) and stations (TS) for repair enterprises we need not only to predict the value of annual repair program for the entire planned period of operation of the TL or TS, but also take into account the variability of the amount of daily batch of orders for repairs.

This problem is further complicated by the need to comply repair warranty duration  $T_g$ . Warranty repairs  $T_g$  is determined by the contract signed with the customer to perform services. According to the Law of Ukraine "On protection of consumers of agricultural machines" if the executor of the contract of works and technical services does not execute its work, delays the work and services under the contract, he pays the penalty at a rate of three percent of the cost of undone work or services for each day (hour, if the duration is specified by hours), unless otherwise provided by contract. [16]

Determination at the design stage performance of guarantee compliance duration personalized repair of heads of cylinder blocks of engines is essential to justify the choice of TS to ensure the effective operation of technical service companies throughout the planned service life of the TS.

### ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

The results of structural-parametric analysis and synthesis of technological processes of heads of cylinder blocks repairing, engines YaMZ-236, enabled a parametric study of a number of industrial structures of technological stations (TS) of repair of various capacities (Table). [17].

Here we present a well-known dependences of mathematical expectation of daily batch of orders  $M[\delta_i]$

and coefficient of variation  $v[\delta_i]$  of annual program of repair  $W_p$  of a repair company (Fig. 1):

$$M[\delta_i] = a_0 + a_1 \cdot W_p, \tag{1}$$

$$v[\delta_i] = b_0 + b_1 / W_p, \tag{2}$$

where  $a_0, a_1$  and  $b_0, b_1$  - regression coefficients value that are obtained for different brands of technology

[1-4]. In [5-15] we justified factors and criteria for compliance TG for impersonal and personal methods of repair. It is determined that Tg compliance factors of a personal repair method are: productivity reservation, time reservation and change of execution order: of orders - direct (FIFO) or reverse (LIFO).

**Table.** Parametric row of production structures of processing lines of heads of cylinder blocks of engines YaMZ-236 and YaMZ-240 repair in united process flow (fragment).

No. TS	Annual performance $Q_p$ , pcs.	Front of repair $f$ , pcs.	Number of workers $u$ , persons	Technological cancellation (TC)	Amount of main equipment of various types, pcs.														PZ, UAH.
					K/1	K/2	K/3	K/4	K/5	K/7	K/8	K/9	K/10	K/11	K/12	K/13	K/14		
1	391	1	1	Direct flow	1	1	1	1	1	1	1	1	1	1	1	1	1	497,11	
	427	2	2	Direct flow	1	1	1	1	1	1	1	1	1	1	1	1	1	534,06	
2	391	1	1	Direct flow	2	1	1	1	1	1	2	1	1	1	1	1	1	537,81	
	503	1	2	Ramified	2	1	1	1	1	1	2	1	1	1	1	1	1	483,88	

PURPOSE

As an indicator of the productivity performance reservation ratio we adopted the annual program of repairs over the years to the annual performance of TD  $\rho_N = WR / Q_a$  where  $Q_a$  - annual performance TD, pcs.

To quantify a reservation time  $\rho_T = T_g / M[T_{T.P.}]$  is taken, where  $M [T_{T.P.}] = 1$  day and night - the mathematical expectation of duration of the technological repair process, days and nights.

The criteria for warranty duration compliance we take the coefficient of guarantee satisfaction as to the duration  $\xi_{N} = W_N / W_p$ , the average overguarantee downtime  $\theta = \Sigma \theta_i / W_\theta$ , where  $W_N$  - number of orders executed in compliance with the warranty period;  $W_0 = W_p - W_N$  - number of orders for which repair warranty period has been exceeded.

We also considered various ways of enforcing the duration of the warranty repair TG.

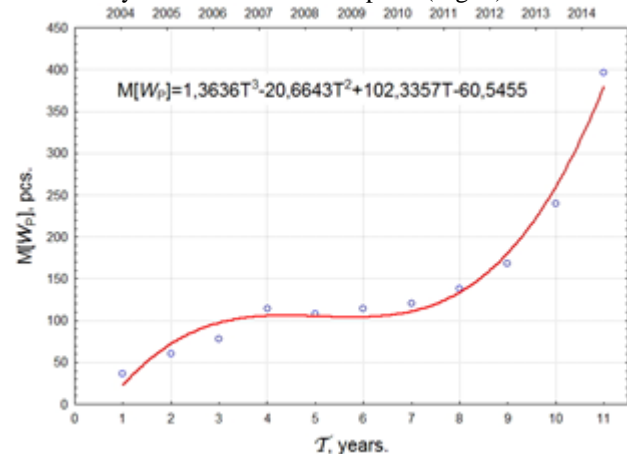
In particular, in the works [1-4, 6-15] determined the character of the compliance criteria warranty repair duration for different values of TG and  $\rho_N$  and  $\rho_T$  and incoming streams of different uniformity, reasonable TG conditions were justified in both impersonal and personal methods of repair of transmission units [5]. However, in these studies the changes in annual programs for the repair operation period of TL or TD are not taken into account.

Thus, determination of the values of the guarantee compliance duration of personal repair of cylinder blocks heads of engines for specific brand models considering changes in annual program for the years of operation the TL or TD has not yet been implemented.

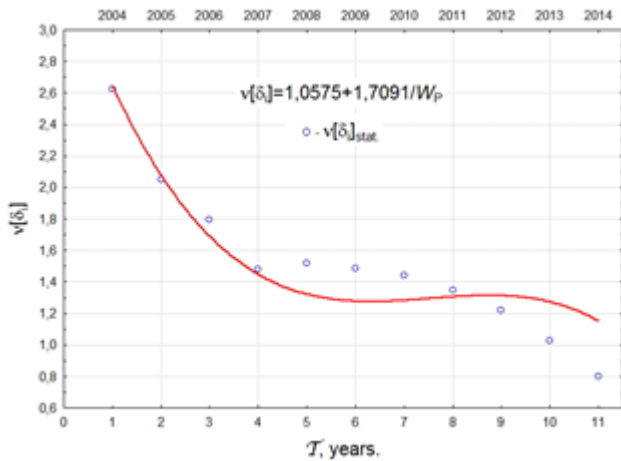
The purpose is to set criteria of guarantee compliance dependencies duration of personal repair of cylinder blocks heads of engines YaMZ TD-236 to a defined production structure and the indicators values of the performance reserve, productivity and time reserve and to justify the rational order of execution of orders for repairs.

MAIN RESULTS

Analysis of statistics of enterprises specialized on technical service of Lviv region showed that the annual program of repair of heads of cylinder blocks of engines YaMZ-236 in recent years significantly changed. We determined the regularities of changes in the annual program of repairs (Fig. 1) and the coefficient of variation of the daily batch of orders for repairs (Fig. 2).



**Fig. 1.** Model of a year program changes of repair of heads of cylinder blocks of engines YaMZ 236-operation over the years T of exploitation TD.



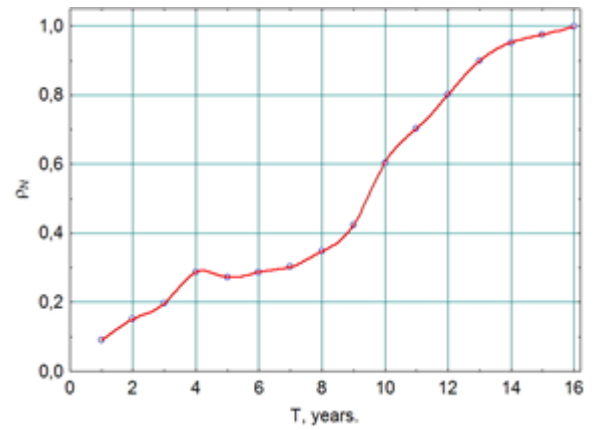
**Fig. 2.** Model of changes of daily batch coefficient of variation of orders for repair of heads of cylinder blocks of engines YaMZ 236 – operation over the years  $T$ , of exploitation TD.

Taking into consideration the maximum value of annual repair programs  $W_p^{\max}$  with a pre-synthesized parametric TD of repair of heads of cylinder blocks YaMZ-236 (Table) with the conditions compliance  $Q_p^{\max} \geq W_p^{\max}$  we selected TD of the required productivity. This is the first TD with an elementary production structure, where the number of basic repair and manufacturing equipment of all types is  $Kr = 1$  pc. Optimal annual productivity of this TD  $Q_p^{\text{opt}} = 391$  pcs., that equals the minimum share of exact technological costs PZtech, and is reached in case of repair of heads of cylinder blocks by one worker ( $u = 1$  pers.), on cocurrent (CC) type of process ( $f = 1$  pc.) and the maximum productivity  $Q_p^{\max} = 427$  pcs. in case of repair of heads of cylinder blocks by two workers ( $u = 2$  pers.) we also have a cocurrent (CC) type of process ( $f = 2$  pcs.).

We conducted a simulation process of batches of orders incoming for service repair of heads of cylinder blocks YaMZ-236. According to the values of mathematical expectation  $M[\delta_i]$ , derived from regression dependence (Fig. 1) we generated Poisson stream of orders for which the coefficient of variation  $v[\delta_i]$  corresponds to the theoretical model (2).

It must be noted that during the simulation the value depending on repair programs this year was examined to the corresponding value of the annual performance of the selected TD.

Due to changes in the values of the annual program of repairs over the years  $\tau$  and exploitation TD, we observe the changing values of the productivity reservation capacity that lie within  $\rho_N \in [0,09 \dots 0,9975]$  (Fig. 3).



**Fig. 3.** Change of the values of the performance of the productivity reservation  $\rho_N$  by years  $\tau$  of exploitation TD, according to the accepted models of prediction of the annual program of repair  $WP = f(\tau)$ .

According to the results of process modeling and service batches of orders for repair of heads of cylinder blocks of engines YaMZ-236 we calculated the values of guarantee repairs duration compliance  $\xi_N$  i  $\bar{\theta}$  for direct and reverse order of service orders and different values of the time factor of reservation  $\rho_T \in [1 \dots 10]$ .

We obtained the dependencies of expectation factor of repairs duration guaranteeing compliance  $M[\xi_N]$  on the values of the productivity reservation capacity  $\rho_N$  for  $\rho_T \in [1 \dots 10]$  and different priority of order fulfillment (Fig. 4).

We defined that for both direct and reverse order of execution of orders for repairs with the growth of  $\rho_N$  the value  $M[\xi_N]$  nonlinearly decrease, reaching its minimum in the condition  $\rho_N=1$ . Using the time reserve (increase  $\rho_T$ ) ensures nonlinear increase in the values of  $M[\xi_N]$ , however, more and more temporal redundancy provides the less growth in  $M[\xi_N]$ . The reverse sequence (LIFO) order of fulfillment makes it possible to achieve higher values of  $M[\xi_N]$  compared with direct one (FIFO).

There were also obtained dependances of mathematical expectancy of average overguarantee downtimes  $M[\bar{\theta}]$  on values of productivity reserving capacity  $\rho_N$  for  $\rho_T \in [1 \dots 10]$  and different priority order of fulfillment (Fig. 5).

It was defined that with increasing  $\rho_N$  values  $M[\bar{\theta}]$  are nonlinearly increasing for all  $\rho_T$ , peaking in condition if  $\rho_N=1$ . Low values of average duration of overguarantee downtimes  $M[\bar{\theta}]$  can be achieved by increasing the rate time reservation  $\rho_T$ , since the increase  $\rho_T$  (increase the length of warranty repair TG) provides nonlinear shortening of overguarantee downtime  $M[\bar{\theta}]$ . Meanwhile, the more time reserve is providing the less reserve shortenings  $M[\bar{\theta}]$ .

Direct sequence (FIFO) of orders fulfillment makes it possible to achieve lower values of  $M[\bar{\theta}]$  compared to the reverse (LIFO). For example, for  $\rho_T = 2$  using the direct order of execution of orders makes it possible to reduce the average length of overguarantee downtime fivefold, compared with a reverse one.

Increase of the value of time reserve  $\rho_T$  (increase the length of warranty repair TG) and enables to expand the range of values  $\rho_N$ , for which a high level of confidence there will be full compliance with the duration of the guarantee repairs TG ( $M[\xi_N]=1$  and  $M[\theta]=0$  days).

If a certain part orders  $W_0$  was done in violation of the guarantee duration repairing TG ( $M[\xi_N]<1$  i  $M[\theta]>0$  days), then, according to the current legislation, a repair company is obliged to pay compensation to customers of the services  $Z_{sh}$  for TG failure.

Thus, the total costs of the repair of heads of cylinder blocks  $\Sigma Z$  include both the actual technology costs  $Z_{teh} = PZ_{teh} \cdot W_p$ , which are caused by the production structure of TS, expenditure on wages for workers and work in progress, costs and compensation  $Z_{sh}$  for violation of warranty repair duration:

$$\Sigma Z = Z_{teh} + Z_{sh}. \tag{3}$$

The results of modeling defined the dependencies of mathematical expectations of the total cost of repairing of cylinder heads  $M[\Sigma Z]$  on the values of the time of reservation  $\rho_T$  and productivity reservation  $\rho_N$  (Fig. 6) for direct (FIFO), and reverse (LIFO) order of orders execution.

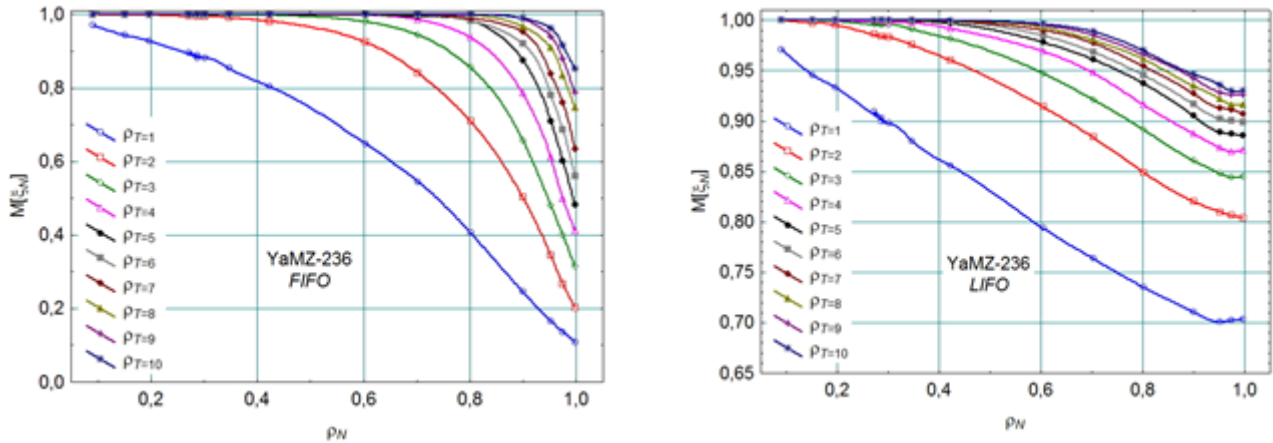


Fig. 4. Dependence of mathematical expectation index of satisfaction of guarantee demands as to the duration of the repair  $M[\xi_N]$  on the values of the productivity reservation capacity  $\rho_N$ .

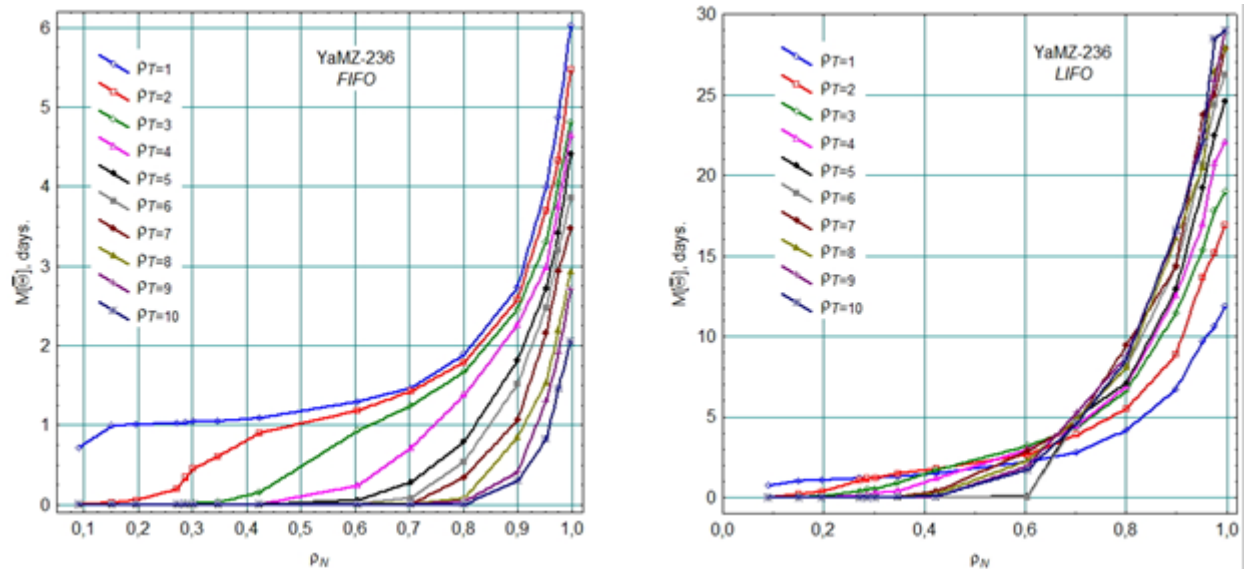
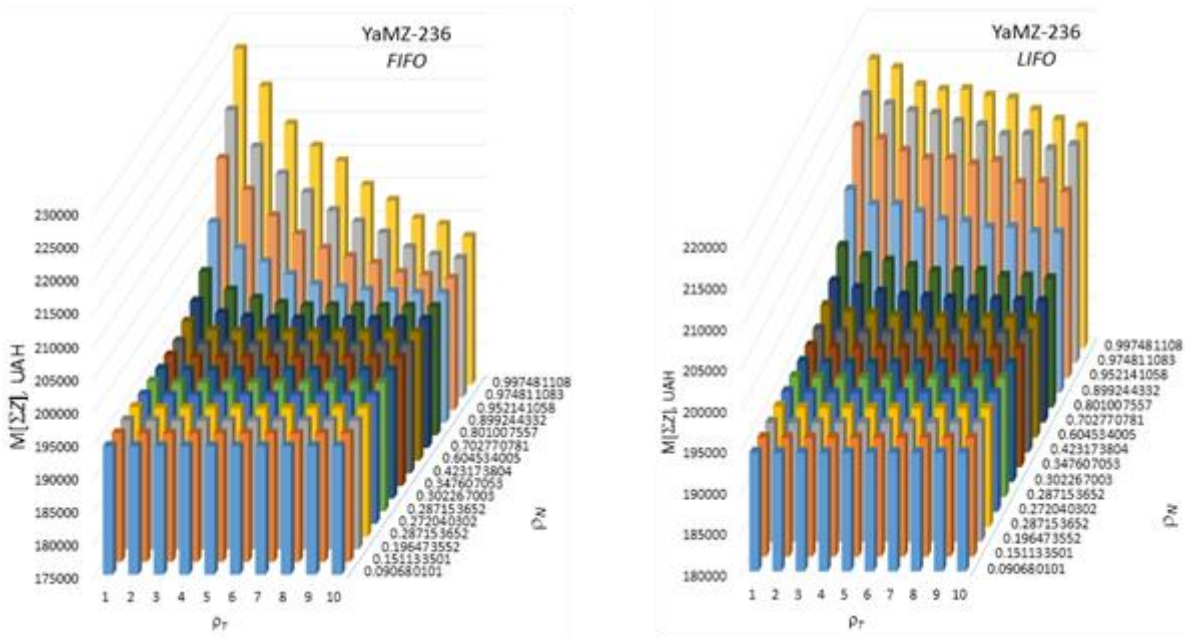


Fig. 5. Dependence of mathematical expectation of average duration of overguarantee downtimes  $M[\bar{\theta}]$  of the productivity reservation capacity  $\rho_N$ .

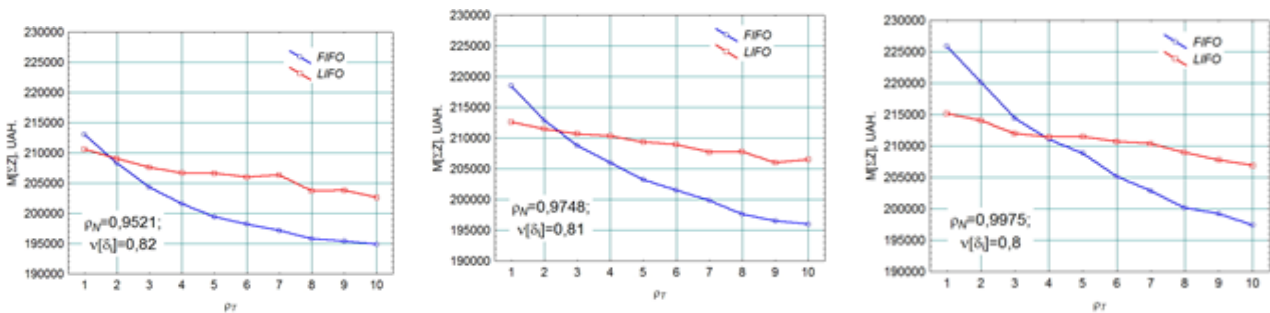


**Fig. 6.** Dependence of mathematical expectation of the total costs of repairing of cylinder heads  $M[\Sigma Z]$  on values of the reservation time  $\rho_T$  of productivity reservation capacity  $\rho_N$ .

Despite the considerable unevenness of daily orders (coefficient of variation of the daily batch  $v[\delta_i] \in [2,6 \dots 1,35]$ ) in the range of values  $\rho_T \in [1 \dots 10]$  and  $\rho_N \in [0,09 \dots 0,6]$ , the  $Z_{sh}$  fines are insignificant, that is why  $\Sigma Z \approx Z_{tech}$ . With further increase of  $\rho_N$  value, the  $M[\Sigma Z]$  increases significantly for all  $\rho_T$ . In the last year of the TS service, when  $\rho_N = 0,9975$ , and the coefficient of variation of the daily batch of orders is only  $v[\delta_i] = 0,8$ , the mathematical expected total costs  $M[\Sigma Z]$  reaches its

maximum value by a significant increase in costs failure to compensate customers repair warranty duration violation TG. (eg,  $\rho_T = 1$ , we have  $Z_{sh} \approx 0,18 \cdot Z_{tech}$ ).

Comparison of the  $M[\Sigma Z]$  values for different levels of TD loading of a repair service productivity (different values of the performance reserve  $\rho_N$ ) enabled rational justification service orders priority to repair heads of cylinder blocks (Fig. 7).



**Fig. 7.** Selection of the rational order of execution of orders for repair heads of cylinder blocks of YaMZ-236 engines for different values of temporal redundancy  $\rho_T$  different levels of batches of a repair service with productivity  $\rho_N$ .

When  $\rho_N = 0,9975$ , and the coefficient of variation of the daily batch of orders is only  $v[\delta_i] = 0,8$ , which is corresponding to the last year of planned period of operation TD ( $T = 14$ ), and direct sequence (FIFO) of repair orders performance is useful only if  $\rho_T \geq 4$ , and for minor repair warranty duration ( $\rho_T < 4$ ) more rationally would to use reverse one (LIFO).

It should also be noted that in case of reduction of enterprise's orders capacity (in case of  $\rho_N$  decrease) direct

order sequence fulfillment should be used for smaller values  $\rho_T$ . For example, if  $\rho_N = 0,975$  ( $v[\delta_i] = 0,81$ ), then direct sequencing is reasonable if  $TG = 3$  days and nights ( $\rho_T \geq 3$ ), and for  $\rho_N = 0,952$  ( $v[\delta_i] = 0,82$ ) – already when  $TG = 2$  days and nights ( $\rho_T \geq 2$ ). If  $\rho_N \leq 0,3$  direct and reverse order of execution of orders are equal for all  $\rho_T$ .



## CONCLUSIONS

1. In the model of change of a year program of repair of heads of cylinder blocks of YaMZ-236 engines during the years, we obtained on the basis of technical service businesses data in Lviv region, that for its performance it is sufficient to use elementary TD production structure, where the number of basic technological repairing equipment of all types equals one. However, the level of congestion TD due to productivity in different years of TD operation fluctuate within a considerable measure  $\rho_N=0,09\dots 0,9975$  due to the variability of the annual program of repair.

2. The results of simulation modeling of batches process and service contracts for the repair of heads of cylinder blocks of engines YaMZ-236 we found out that both direct and reverse order of execution of orders with increasing  $\rho_N$  the value  $M[\xi_N]$  nonlinearly reduces, and the value of  $M[\bar{\theta}]$  conversely, non-linearly increases, reaching its extremes in  $\rho_N=1$ . Using a time reserve (increase of  $\rho_T$ ) provides a nonlinear increase in the values of  $M[\xi_N]$  and nonlinear decrease of  $M[\bar{\theta}]$ , however, more and more temporal redundancy is increasing the less change in  $M[\xi_N]$  and  $M[\bar{\theta}]$ .

3. Analysis of the total costs of  $M[\Sigma Z]$  to repair heads of cylinder blocks, which include the actual cost of technological repairs  $Z_{tech}$  and  $Z_{sh}$  - costs of compensation for breach of warranty repair duration, showed that despite the considerable unevenness of the daily flow of orders in the range of values  $\rho_N \in [0,09\dots 0,6]$  for all  $\rho_T \in [1\dots 10]$  the value of fines  $Z_{sh}$  is insignificant, and therefore  $\Sigma Z \approx Z_{tech}$ . With further increase of  $\rho_N$  the value  $M[\Sigma Z]$  increase significantly for all  $\rho_T$  by increasing the costs for compensation for customers  $Z_{sh}$  failure of warranty repair duration TG, reaching its extreme value in cases where  $\rho_N \rightarrow 1$ . Using a time reserve (increase of  $\rho_T$ ) provides non-linear decrease of  $M[\Sigma Z]$  values, however, more and more temporal redundancy increasingly lessens the change in  $M[\Sigma Z]$ .

4. Based on the comparison of values  $M[\Sigma Z]$  for a different level of congestion of the selected TS which repairs heads of cylinder blocks YaMZ-236 engines, by productivity (different values  $\rho_N$ ), we defined that in the condition  $\rho_N \leq 0,3$  direct (FIFO) and reverse (LIFO) order of execution of orders are equal for all  $\rho_T$ . In case when by the level of congestion TD productivity increases (in case of increase  $\rho_N$ ), direct sequence (FIFO) of orders execution for repairs is useful only for more values of the reserve  $\rho_T$ , and for a small duration of the warranty repair TG it is reasonable to use a reversed (LIFO) order of execution of orders.

5. In order to minimize the total cost of repair heads of cylinder blocks YaMZ-236 engines we should consider increasing the duration of the warranty repair TG in those years of operation TS when the congestion level of productivity is very high. If it is impossible to change the terms of contracts with customers there, it is an urgent task of choosing the TS with a number of such parametric performance that will ensure the minimization of the total costs of repair  $\Sigma Z$  for the planned period of its exploitation.

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