Organizational and technological compatibility of the technological processes of all different types of maintenance of KhTZ-3522 tractors in the joint technological flow

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Received July 03.2017: accepted July 31.2017

Abstract. The work is devoted to systematic substantiation of productivity, production structure and specialization of service station (SS) of KhTZ-3522 tractors. Based on the technical and economic comparative analysis of the results of modeling of the technological processes (TPs) of the second and third line maintenance, third line maintenance before current repair (BCR) and line maintenance before major repair (BMR) of KhTZ-3522 tractors, the parametrical series of production structures of service stations (SSs) both mono- and poly technological specialization, which can work effectively in a wide range of the general annual program of orders, and in the conditions of seasonal fluctuations of orders for the maintenance of these tractors, are founded. The results of calculations of the system of indicators of organizational and technological compatibility (OTC) of TPs of the second and third line maintenance, third line maintenance BCR and third line maintenance BMR of KhTZ-3522 tractors in the joint technological flow are presented. The dependencies of these indicators on the total annual program of orders for service stations of different productivity are analyzed. According to the results of the analysis, the poly technological specialization of such service stations is substantiated.

Key words: KhTZ-3522 tractors, maintenance, technological processes, organizational and technological compatibility, service stations, specialization.

INTRODUCTION

New tractors KhTZ-3510 (drawbar category – 0,9) and KhTZ-3522 (drawbar category – 1,4), manufactured by Kharkiv Tractor Plant (KhTZ), appeared in small agrarian enterprises of Ukraine in the early 2000's. However, the technical service base for these new KhTZ tractor brands has not yet been created in Ukraine.

The achievement of high values of the coefficient of technical use of these tractors presumes timely and qualitative maintenance. The manufacturer provided five different types of maintenance for these tractors: first (service interval – 250 hours), second (service interval – 500 hours) and third (service interval – 1000 hours) line maintenance and additionally third line maintenance before current repair (service interval – 2000 hours) and third line maintenance before main repair (service interval – 8000 hours). The list of operations for each type of maintenance is determined by the manufacturer [16, 20]. The structure of technical maintenance cycle is organized so that operations of all previous line maintenances are included in the following line maintenance.

Research of TPs of maintenance was carried out on an example of tractors KhTZ-3522, since these tractors are constructively more complex then KhTZ-3510 tractors – they are equipped with front drive axle.

Real the operations of first line maintenance are performed by tractor drivers directly at the place of tractors use. To perform the operations of second line maintenance of KhTZ-3522 tractors need to use 14 different types of special equipment and tools (r = 14), to perform the operations of third line maintenance – 15 different types (r = 15), to perform the operations of third line maintenance before current repair (BCR) – 21 different types (r = 21) and to perform the operations of third line maintenance before main repair (BMR) – 26 different types (r = 26). Therefore, qualified masters at stationary posts of service stations must carry out these complex types of maintenance [15, 19].

Creating an effective repair and servicing base for agriculture techniques requires scientific systematic approach, based on the application of methods of structural and parametric optimization of technical service processes, in particular, technological processes that are performed on stationary posts [18].

The substantiation of the program W_A, the performance Q_A, the production structure and the specialization of the technical service enterprises is a complex system task [18], which involves the use of an iterative procedure for the solution of interdependent parametric and structural optimization tasks [5].

Regarding the technical service processes performed on stationary posts, the task of substantiating their parameters and structure was for the first time solved using the graph theory and schedules for the TP of the current repair of tractors [21], but the interdependence between all parameters and performance indicators of the TP was not taken into account. The application of the iteration procedure has made it possible to eliminate this defect in relation to the tasks of determining the parameters and indicators of efficiency of the TPs of maintenance of KhTZ tractors [10-13], as well as the substantiation of the production structure of the SSs of KhTZ tractors [12, 18].

The ground for the determination of specialization of selected production units of the technical service enterprises is OTC of the processes performed there [6, 8]. The property of the OTC is determined by the similarity of the construction design of the machines and the technology of the work, the flexibility of the equipment used, the similarity of the structure of different TPs, which are united in the joint technological flow, and also depends on the overall annual program of work (general program), and on the quantitative proportion of various processes (partial programs) in the general program. If for a certain value of a general program and a certain proportion of partial programs, the cost of implementing different TPs in the joint flow is less than the cost of implementing the same TPs separately, then it is considered to be OTC of these processes [1].

The system of indicators for the assessment of the OTC both for a separate value of productivity of production lines or stations and to evaluate OTC for production lines or stations in general has been previously well-grounded [2, 9]. The dependences of OTC indices on the work level of production lines and production units is also researched [3, 4].

In the case of OTC of the different TPs, a multidisciplinary or poly technological specialization is appropriate.

The aim of the study is to increase the efficiency of the technical service of the KhTZ-3522 tractors by way of substantiation of the specialization (mono- or poly technological) of branded SSs of different capacity and production structure from the corresponding parametric series.

MATERIAL AND METHODS

The sets of possible different variants of production structures of service stations, which provide the same annual Q_A capacity, has been synthesized according to the results of the analysis of the mutual dependencies between different parameters and performance indicators of TPs of all different types of maintenance of KhTZ-3522 tractors. Those mutual dependencies are obtained by modeling these TPs using the theory of graphs and heuristic algorithms of the theory of schedules [9].

The feasibility and economic comparison of various possible options was made on the basis of the total cash expenditure for the entire annual maintenance program ΣZ. The total cash ΣZ included the costs determined by the production structure of the service station Z_{SS} (wages of workers, allowance for keeping and depreciation of equipment and industrial premises, payment for power electric etc.), and also the costs which are determined by the technology of performance Z_{lm} (costs for fuel, lubricants and other process materials etc.). The arrangement of the comparison results made it possible to form parametric series of SSs for KhTZ-3522 tractors (Tables 1, 2) with different production structure and capacity of mono technological specialization (for the performance of only second or only third line technical maintenance respectively). The optimal capacity for each maintenance item from the parametric series was determined by the criterion for minimizing specific costs ($C = \Sigma Z/Q_A) \rightarrow$ min.

For the quantitative assessment of the properties of the OTC, the system of indicators with a certain technical, technological and production content [7] is used, and the method for calculating these indices has been developed in advance [14].

RESULTS AND DISCUSSION

Initially, the parametric series of production structures of SSs for all four options of mono technological specialization (for second line maintenance only, for third line maintenance only, for third line maintenance BCR only and for third line maintenance BMR only) was based on results of simulation of the corresponding four different TPs of maintenance of KhTZ-3522 tractors.

Five different variants of production structures have been included to each parametric series of SSs for all four options of mono technological specialization. These variants differ in the number of equipment of individual types (high-pressure jet cleaners Karcher K5 Compact K_{r1}, mobile machines Flexbimec-5903 for washing parts K_{r6} and universal devices C-230 for oiling K_{r7}), in the number of stationary posts f, and, consequently, in the production area. The list of all other types of required equipment for each of the four options of KhTZ-3522 tractors maintenance is determined by the technology of work [16, 20]. Since all other types of necessary equipment are intended to perform only one operation, the number of equipment of all other types K_r = 1 pcs.

The capacity of each variant of the production structure of the SS may vary within a sufficiently wide range, depending on the number of employees engaged, which enables the adaptation of service station performance to seasonal variations in the number of orders as well as the annual change in the number of tractors in the service area (Tables 1, 2).

For example (Table 1), the first variant of the production structure of the service station for the second line maintenance of KhTZ-3522 tractors can provide maximum annual capacity Q_A = 896 orders per year, if the number of workers is u = 4 persons. If the number of workers is u = 1 person, then annual capacity will be only Q_A = 296 orders per year. For this production structure optimal performance that meets the minimum specific costs is 799 orders per year, when three workers work (u = 3 persons).

The second variant of the production structure of the service station for the second line maintenance is characterized by an increase in the number of equipment (high-pressure jet washing machines Karcher K5 Compact K_{r1}= 4 pcs, mobile machines Flexbimec-5903 for washing parts K_{r6} = 2 pcs and universal devices C-230 for filling oil K_{r7} = 2 pcs). This variant can provide maximum annual capacity Q_A = 1040 orders per year, if the number of workers is u = 8 persons. For this production structure optimal performance is a bit bigger and it is 877 orders per year, when three workers work (u = 3 persons).

The next three variants of the production structure of the SSs for the second line maintenance of KhTZ-3522 tractors are characterized by an increase in the number of posts f and working area respectively. Each next variant has a wider range of productivity changes by attracting a different number of workers. The optimal performance of each next variant is also higher than the previous one and it is achieved for an ever greater number of workers.

To the parametric series of SSs for the third line maintenance BMR of KhTZ-3522 tractors (Table 2) also includes five different variants of production structures. These variants are very similar to the corresponding variants of production structures of service stations for the second line maintenance of these tractors and differ only in the use of additional type of equipment (r = 26).

Table 1. The parametric series of service stations with different production structure and capacity for the second line maintenance of KhTZ-3522 tractors

№ of SS	Annual capacity Q_A, orders	Amount of equipment and tools*, pcs.			Number of posts f, units	Number of workers u, persons	Economic indicators			
		K_{r1}	K_{r6}	K_{r7}			Z_{SS}, UAH	$Z_{l\text{-}m}$, UAH	ΣZ, UAH	C, UAH
I	296	1	1	1	1	1	117474,96	1844719,36	1962194,3	6629,03
	562					2	165474,96	3502473,92	3667948,9	6526,6
	799 opt					3 opt	213474,96	4979495,84	5192970,8	6499,34
	896					4	261474,96	5584015,36	5845490,3	6523,98
II	296	4	2	2	1	1	126167,96	1844719,36	1970887,3	6658,4
	593					2	174167,96	3695670,88	3869838,8	6525,87
	877 opt					3 opt	222167,96	5465604,32	5687772,3	6485,49
	1040					4	270167,96	6481446,4	6751614,4	6491,94
III	296	4	2	2	2	1	138516,47	1844719,36	1983235,8	6700,12
	605					2	186516,47	3770456,8	3956973,3	6540,45
	903					3	234516,47	5627640,48	5862157,0	6491,87
	1217					4	282516,47	7584538,72	7867055,2	6464,3
	1522 opt					5 opt	330516,47	9485347,52	9815863,99	6449,32
	1739					6	378516,47	10837726,2	11216242,7	6449,82
	1916					7	426516,47	11940818,6	12367335,0	6454,77
	2049					8	474516,47	12769695,8	13244212,3	6463,74
IV	296	4	2	2	3	1	153975,39	1844719,36	1998694,8	6752,35
	614					2	201975,39	3826546,24	4028521,6	6561,11
	915					3	249975,39	5702426,4	5952401,8	6505,36
	1217					4	297975,39	7584538,72	7882514,1	6477
	1510					5	345975,39	9410561,6	9756537,0	6461,28
	1784					6	393975,39	11118173,4	11512148,8	6453
	2049					7	441975,39	12769695,8	13211671,2	6447,86
	2300 opt					8 opt	489975,39	14333968	14823943,4	6445,19
	2493					9	537975,39	15536774,9	16074750,3	6447,95
	2555					10	585975,39	15923168,8	16509144,2	6461,5
V	296	4	2	2	4	1	176541,69	1844719,36	2021261,1	6828,58
	616					2	224541,69	3839010,56	4063552,3	6596,68
	920					3	272541,69	5733587,2	6006128,9	6528,4
	1224					4	320541,69	7628163,84	7948705,5	6494,04
	1522					5	368541,69	9485347,52	9853889,2	6474,3
	1815					6	416541,69	11311370,4	11727912,1	6461,66
	2090					7	464541,69	13025214,4	13489756,1	6454,43
	2379					8	512541,69	14826308,6	15338850,3	6447,6
	2620 opt					9 opt	560541,69	16328259,2	16888800,9	6446,11
	2797					10	608541,69	17431351,5	18039893,2	6449,73
	3000					11	656541,69	18696480	19353021,7	6451,01
	3136					12	704541,69	19544053,8	20248595,5	6456,82
	3234					13	752541,69	20154805,4	20907347,1	6464,86
	3338					14	800541,69	20802950,1	21603491,8	6471,99

* Amount of equipment and tools: $K_{r2} = K_{r3} = K_{r4} = K_{r5} = K_{r8} = K_{r9} =\ldots= K_{r14}$ = 1 pcs.

Table 2. The parametric series of service stations (SS) with different production structure and capacity for the third line maintenance before main repair (BMR) of KhTZ-3522 tractors

№ of SS	**Annual capacity Q_A, orders**	**Amount of equipment and tools*, pcs.**			**Number of posts *f*, units**	**Number of workers *u*, persons**	**Economic indicators**			
		K_{r1}	K_{r6}	K_{r7}			Z_{SS}, UAH	$Z_{l\text{-}m}$, UAH	ΣZ, UAH	*C*, UAH
I	110	1	1	1	1	1	251238,7	950233,9	1201472,6	10922,48
	216					2	299238,7	1865913,8	2165152,6	10023,85
	314					3	347238,7	2712485,9	3059724,6	9744,35
	361					4 opt	395238,7	3118494,9	3513733,6	9733,33
	372					5	443238,7	3213518,3	3656757	9829,99
	375					6	491238,7	3239433,8	3730672,5	9948,46
II	110	4	2	2	1	1	259931,7	950233,9	1210165,6	11001,51
	220					2	307931,7	1900467,8	2208399,5	10038,18
	328					3	355931,7	2833424,7	3189356,4	9723,65
	390					4	403931,7	3369011,1	3772942,8	9674,21
	485					5 op	451931,7	4189667,7	4641599,4	9570,31
	490					6	499931,7	4232860,1	4732791,8	9658,76
III	110	4	2	2	2	1	275390,6	950233,9	1225624,5	11142,04
	222					2	323390,6	1917744,8	2241135,4	10095,2
	332					3	371390,6	2867978,7	3239369,3	9757,14
	443					4	419390,6	3826851,1	4246241,7	9585,2
	543					5	467390,6	4690700,1	5158090,7	9499,25
	634					6	515390,6	5476802,7	5992193,3	9451,41
	699					7 op	563390,6	6038304,5	6601695,1	9444,49
	744					8	611390,6	6427036,6	7038427,2	9460,25
	766					9	659390,6	6617083,3	7276474,0	9499,31
	778					10	707390,6	6720745,2	7428135,9	9547,73
IV	110	4	2	2	3	1	275390,6	950233,9	1225624,5	11142,04
	223					2	323390,6	1926383,3	2249773,9	10088,67
	334					3	371390,6	2885255,7	3256646,3	9750,44
	444					4	419390,6	3835489,6	4254880,2	9583,06
	554					5	467390,6	4785723,5	5253114,1	9482,16
	657					6	515390,6	5675487,9	6190878,8	9422,95
	747					7	563390,6	6452952,3	7016342,7	9392,69
	831					8 opt	611390,6	7178585,2	7789975,8	9374,22
	884					9	659390,6	7636425,2	8295815,8	9384,41
	932					10	707390,6	8051072,7	8758463,3	9397,49
	945					11	755390,6	8163373,1	8918763,7	9437,85
	953					12	803390,6	8232481,0	9035871,6	9481,5
V	110	4	2	2	4	1	297956,9	950233,9	1248190,8	11347,19
	224					2	345956,9	1935021,8	2280978,7	10182,94
	335					3	393956,9	2893894,2	3287851,1	9814,48
	446					4	441956,9	3852766,5	4294723,5	9629,42
	559					5	489956,9	4828915,9	5318872,9	9514,98
	659					6	537956,9	5692764,9	6230721,9	9454,81
	761					7	585956,9	6573890,9	7159847,8	9408,47
	866					8 opt	633956,9	7480932,3	8114889,3	9370,54
	900					9	681956,9	7774641	8456597,9	9396,22
	958					10	729956,9	8275673,4	9005630,4	9400,45
	976					11	777956,9	8431166,2	9209123,2	9435,58
	985					12	825956,9	8508912,7	9334869,6	9477,02
	1009					13	873956,9	8716236,4	9590193,4	9504,65
	1029					14	921956,9	8889006,2	9810963,2	9534,46

* Amount of equipment and tools: $K_{r2} = K_{r3} = K_{r4} = K_{r5} = K_{r8} = K_{r9} = \ldots = K_{r26} = 1$ pcs.

However, it should be noted that for similar variants of the production structure, the maximum and optimal values of annual capacity of SSs for the third line maintenance BMR of KhTZ-3522 tractors are significantly lower than the corresponding values of SSs for the second line maintenance.

For example, the maximum annual capacity of the third variant of the production structure of the SS for the second line maintenance of KhTZ-3522 tractors is Q_A = =2049 orders per year, and the maximum annual capacity of the third variant of the production structure of the service station for the third line maintenance BMR of KhTZ-3522 tractors is only Q_A = 778 orders per year. This significant difference is explained by the greater labor-intensive characteristic of the TPs of the third line maintenance BMR.

Because all operations of the second and third line maintenance and third line maintenance BCR of KhTZ-3522 tractors are also performed during the third line maintenance BMR of these tractors, therefore the parametric series of SSs of mono technological specialization for the third line maintenance BMR only corresponds to the parametric series of SSs of poly technological specialization of KhTZ-3522 tractors, where you can perform all four different types of technical maintenance in the joint technological flow (Table 3).

It should be noted, that the capacity of SSs for maintenance of KhTZ-3522 tractors of the poly technological specialization depends on the ratio of orders for different types of maintenance: maximum capacity $Q_{A\ max}$ is reached, when all orders will be executed for only second line maintenance, but minimal capacity $Q_{A\ min}$, when all orders will be for the third line maintenance BMR only (Table 3).

The system of OTC indicators includes coefficients of OTC α_W, level of OTC β_W and relative level of OTC γ_W, that are calculated for a particular value of the annual program $W_{A\ min}$, provided, that any ratio of partial programs of orders for all different types of technical maintenance in the total program of orders $W_{A\ min}$ is equally probable.

When diverse combinations of different TPs in the joint technological flow are considered, then full compatibility of all types of maintenance, as well as many variants of partial compatibility, are possible.

Three modes of partial compatibility were considered in this case: a) mode 3 & 1 of partial OTC – three TPs of different maintenance in the joint technological flow and one TP of maintenance – separately; b) mode 2 & 2 of partial OTC – two TPs of different maintenance in the first joint technological flow and two another TPs of different maintenance in the second joint technological flow); b) mode 2 & 1 & 1 of partial OTC – two TPs of some two different maintenance in the joint technological flow and TPs of two another different maintenance – separately.

Dependencies of OTC indicators of the TPs of all four types of maintenance of KhTZ-3522 tractors in the joint technological flow on annual program $W_{A\ min}$ (by the number of orders for third line maintenance BMR), received for the fifth variant of the production structure of the SS of the poly technological specialization (Table 3), shown in Figures 1, 2.

These dependencies are discontinuous functions, intervals of continuity which coincide with the intervals of programs for the fifth variant of the production structure of the SS of the poly technological specialization, where the number of workers *u* unchanged (Figures 1, 2).

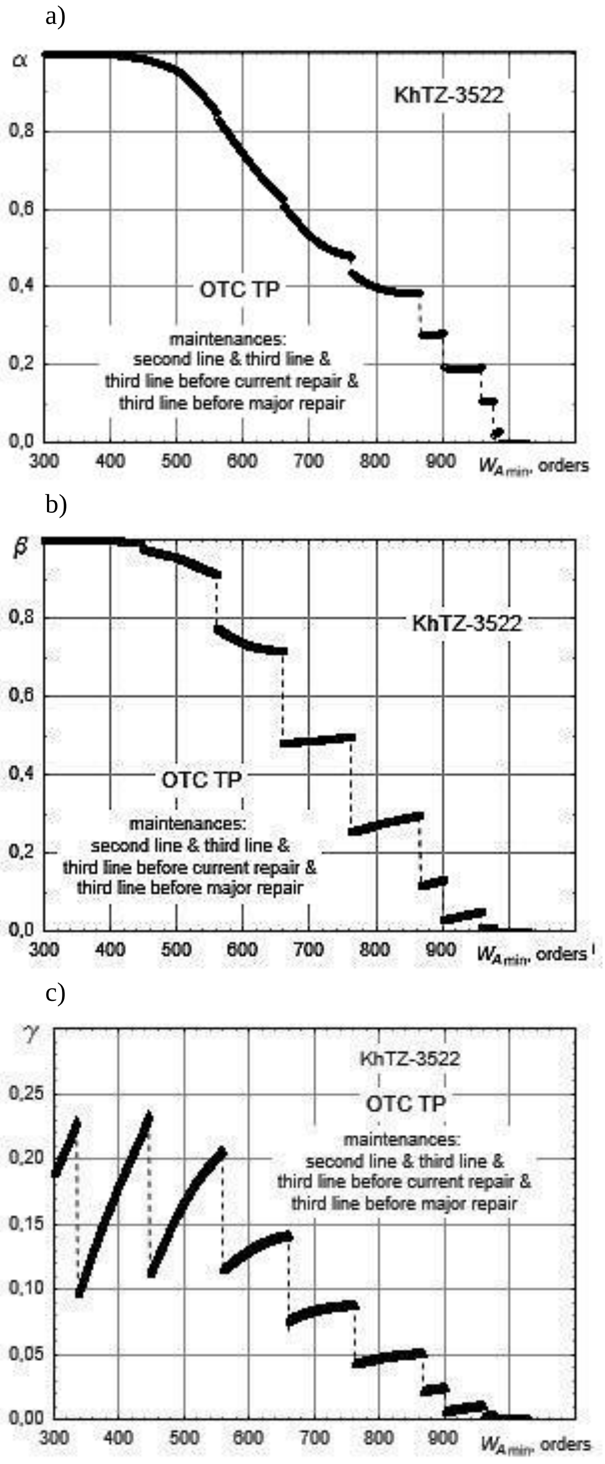

Fig. 1. Dependences of the indices of complete OTC of TPs of all different types of maintenance of KhTZ-3522 tractors in the joint technological flow on the annual number of orders for maintenance before main repair $W_{A\ min}$ for fifth variant of the production structure of the SS of poly technological specialization

As you can see (Figure 1) on the intervals of continuity with growing the total annual program $W_{A\ \min}$ the values of the coefficient of complete OTC α_W and the coefficient of the level of complete OTC β_W remains constant, if a complete OTC of TPs of various types of maintenance in the joint technological flow is in evidence ($\alpha_W = \beta_W = 1$), or decreases or increases nonlinearly.

When the program $W_{A\ \min}$ increases, the values of the coefficient of the relative level of complete OTC γ_W on the intervals of continuity remains constant or non-linearly increases even if a complete OTC of TPs of various types of maintenance of KhTZ-3522 tractors ($\alpha_W = \beta_W = 1$) in a joint flow is in evidence.

a) b)

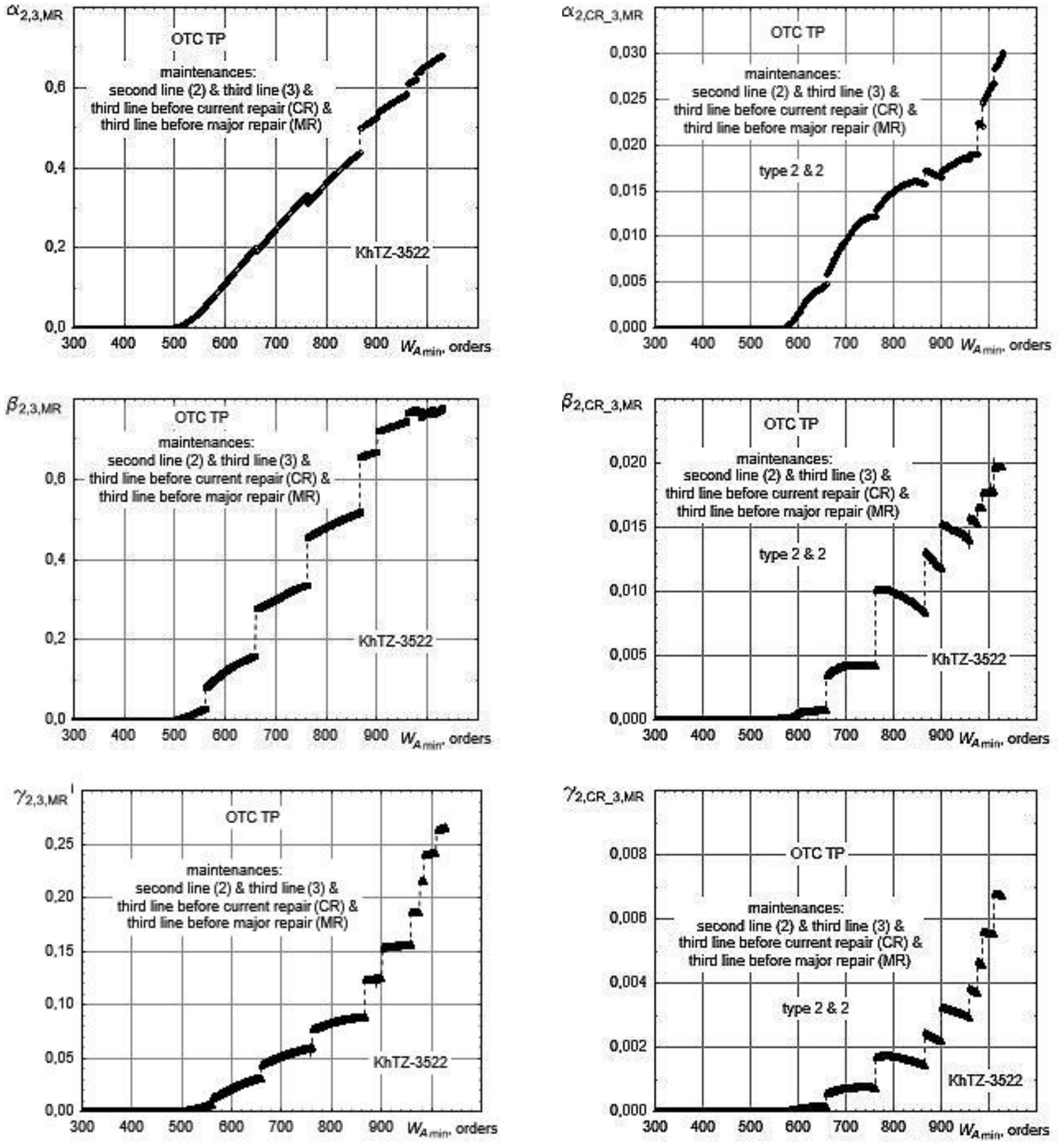

Fig. 2. Dependences of the indices of two different modes of partial OTC of TP of all different types of maintenance of KhTZ-3522 tractors on the annual number of orders for third line maintenance BMR $W_{A\ \min}$ for fifth variant of the production structure of the SS of poly technological specialization:
a) mode 3 & 1 of partial OTC –(three TPs in the joint technological flow and one TP separately);
b) mode 2 & 2 of partial OTC –(two TPs in the first joint technological flow and another two TPs in the second joint technological flow)

As you can see (Figure 2, a) for the partial OTC for mode 3 & 1 (three TPs of second, third and third line maintenance BMR are executed in the joint technological flow and one TP of third line maintenance BCR is executed separately) with growing the total annual program $W_{A\ \min}$ the values of the coefficient of partial OTC $\alpha_{2,3,MR}$ the coefficient of the level of partial OTC $\beta_{2,3,MR}$ and the coefficient of the relative level of partial OTC $\gamma_{2,3,MR}$ remains constant and equal 0 on the intervals of continuity, if a complete OTC of TPs of all various types of maintenance in the joint technological flow is in evidence ($\alpha_W = \beta_W = 1$). For the values of an annual program $W_{A\ \min}$, where $\alpha_W < 1$ and $\beta_W < 1$, coefficient of partial OTC $\alpha_{2,3,MR}$, $\beta_{2,3,MR}$ and $\gamma_{2,3,MR}$ decrease or increase nonlinearly on the intervals of continuity.

As you can see (Figure 2, b) for the partial OTC for mode 2 & 2 (two TPs of second line maintenance and third line maintenance BCR are executed in the first joint technological flow and another two TPs of third line maintenance and third line maintenance BMR are executed in the second joint technological flow) with growing the total annual program $W_{A\ \min}$ the values of the coefficient of partial OTC $\alpha_{2,CR\_3,MR}$ the coefficient of the level of partial OTC $\beta_{2,CR\_3,MR}$ and the coefficient of the relative level of partial OTC $\gamma_{2,CR\_3,MR}$ remains constant and equal 0 on the intervals of continuity, if a complete OTC of TPs of all various types of maintenance in the joint technological flow is in evidence ($\alpha_W = \beta_W = 1$). For the values of an annual program $W_{A\ \min}$, where $\alpha_W < 1$ and $\beta_W < 1$, coefficient of partial OTC $\alpha_{2,CR\_3,MR}$, $\beta_{2,CR\_3,MR}$ and $\gamma_{2,CR\_3,MR}$ decrease or increase nonlinearly on the intervals of continuity.

The analysis of the results of calculating the values of complete OTC indicators of the TPs of all four different types of maintenance for SSs of poly technological specialization with different production structure and capacity from parametric series (Table 3), which was conducted under the additional condition that any values of the annual program $W_{A\ \min}$ (by the annual number of third line BMR maintenance orders), that are possible for a constant number of workers u = const, are equally probable, allowed to reveal certain regularities.

Firstly, for each variant of the production structure of the SSs, with an increase in the number of workers u, the values of complete `OTC indexes does not increase. For example, for the third variant of the production structure of the SS, where the TPs of all maintenance of tractors KhTZ-3522 are executed in the joint technological flow by two workers (u = 2 persons) – $\alpha = \beta = 1{,}0$ i $\gamma = 0{,}2676$; and when u = 8 persons – $\alpha = 0{,}5446$, $\beta = 0{,}4395$, $\gamma = 0{,}0726$ (Table 3).

Secondly, for SSs with a more complex production structure and higher capacity the values of the complete OTC indicators are lower. For example, if for the third variant of the production structure of the SS in general $\alpha = 0{,}8931$, $\beta = 0{,}8819$ i $\gamma = 0{,}2119$, then for fifth variant of the production structure of the SS in general $\alpha = 0{,}7211$, $\beta = 0{,}6907$ i $\gamma = 0{,}1265$ (Table 3).

Thirdly, the most sensitive to the growth of the overall annual program $W_{A\ \min}$ (by the annual number of third line BMR maintenance orders) is the coefficient of the relative level of complete OTC γ.

The analysis of the results of calculating the values of partial OTC indicators for mode 3 & 1 (three TPs of different maintenance are executed in the joint technological flow and one TP is executed separately) and for mode 2 & 2 (two TPs of different maintenance are executed in the first joint technological flow and another two TPs of different maintenance are executed in the second joint technological flow) for SSs of poly technological specialization with different production structure and capacity from parametric series (Tables 4-6), which was conducted under the additional condition that any values of the annual program $W_{A\ \min}$ (by the annual number of third line BMR maintenance orders), that are possible for a constant number of workers u = = const, are equally probable, allowed to reveal another certain regularities.

Firstly, for each variant of the production structure of the SSs of poly technological specialization, with an increase in the number of workers u, the values of indexes of all modes of partial `OTC does not decrease. For example, for the third variant of the production structure of the SS of poly technological specialization and for the mode of partial compatibility 3 & 1 (when three TPs of third, third line maintenance BCR and third line maintenance BMR are executed in the joint technological flow and one TP of second line maintenance is executed separately), where the TPs of maintenance of tractors KhTZ-3522 are executed by five workers (u = 5 persons) was received – $\alpha_{3,CR,MR} = 0{,}044$, $\beta_{3,CR,MR} = 0{,}0286$ i $\gamma_{3,CR,MR} = 0{,}0066$; and when u = 8 persons – $\alpha_{3,CR,MR} = 0{,}2347$, $\beta_{3,CR,MR} = 0{,}2465$, $\gamma_{3,CR,MR} = 0{,}0407$ (Tables 4-6).

For SSs of poly technological specialization in general with a more complex production structure and higher capacity the values of the partial OTC indicators are not lower. For example, if for the third variant of the production structure of the SS of poly technological specialization and for the mode of partial compatibility 2 & 2 (two TPs of second line maintenance and third line maintenance BMR are executed in the first joint technological flow and another two TPs of third line and third line maintenance BCR are executed in the second joint technological flow) in general $\alpha_{2,MR\_3,CR} = 0{,}0008$, $\beta_{2,MR\_3,CR} = 0{,}0006$ i $\gamma_{2,MR\_3,CR} = 0{,}0001$, then for fifth variant of the production structure of the SS of poly technological specialization in general $\alpha_{2,MR\_3,CR} = 0{,}0023$, $\beta_{2,MR\_3,CR} = 0{,}0018$ i $\gamma_{2,MR\_3,CR} = 0{,}0003$ (Tables 4-6).

CONCLUSIONS

1. The formed parametric series of production facilities of service stations for maintenance of KhTZ-3522 tractors both mono- and poly technological specialization (Tables 1-6) are the basis for the choice of the effective design solutions with taking into account, firstly, the forecast of annual changes in the total number of maintenance orders due to the changes in the number of these tractors in the service area, and, secondly, the prediction of seasonal fluctuations in the flow of orders due to the objective variation of use of these tractors in agriculture.

Table 3. The results of calculation of indexes of organizational and technological compatibility (OTC) of all different types of maintenance of KhTZ-3522 tractors for service stations (SS) with different production structure and capacity from parametric series

№ of SS	Annual capacity Q_A, orders		Amount of equipment and tools*, pcs.			Number of posts *f*, units	Number of workers *u*, persons	Indexes of organizational and technological compatibility (OTC)		
	$Q_{A\ max}$ for second line maintenance	$Q_{A\ min}$ for third line maintenance before MR	K_{r1}	K_{r6}	K_{r7}			α	β	γ
I	296	110	1	1	1	1	1	1	1	0,4758
	562	216					2	1	1	0,3586
	799	314					3	1	1	0,2901
	896	361					4	1	1	0,2089
	896	372					5	0,9991	0,9998	0,1089
	896	375					6	0,5341	0,5955	0,027
	for first service station in general							**0,9962**	**0,9968**	**0,3449**
II	296	110	4	2	2	1	1	1	1	0,4262
	593	220					2	1	1	0,3279
	877	328					3	1	1	0,2822
	1040	390					4	1	1	0,2259
	1040	485					5	0,9976	0,9993	0,1206
	1040	490					6	0,9182	0,9485	0,0554
	for second service station in general							**0,9987**	**0,9991**	**0,2828**
III	296	110	4	2	2	2	1	1	1	0,3463
	605	222					2	1	1	0,2676
	903	332					3	1	1	0,2409
	1217	443					4	0,9982	0,9989	0,2397
	1522	543					5	0,9507	0,9689	0,2227
	1739	634					6	0,8268	0,8609	0,1727
	1916	699					7	0,6748	0,6639	0,1167
	2049	744					8	0,5446	0,4395	0,0726
	2049	766					9	0,4754	0,2227	0,0351
	2049	778					10	0,2765	0,0516	0,0085
	for third service station in general							**0,8931**	**0,8819**	**0,2119**
IV	296	110	4	2	2	3	1	1	1	0,3463
	614	223					2	1	1	0,2699
	915	334					3	1	1	0,2447
	1217	444					4	0,9982	0,9989	0,2397
	1510	554					5	0,9497	0,9687	0,2229
	1784	657					6	0,7769	0,8317	0,1709
	2049	747					7	0,5758	0,6124	0,1122
	2300	831					8	0,4349	0,3895	0,0671
	2493	884					9	0,3186	0,2012	0,0356
	2555	932					10	0,2401	0,08	0,0155
	2555	945					11	0,1551	0,0208	0,0046
	2555	953					12	0,0239	0,0004	0,0001
	for fourth service station in general							**0,7832**	**0,7742**	**0,191**
V	296	110	4	2	2	4	1	1	1	0,2444
	616	224					2	1	1	0,1879
	920	335					3	1	1	0,1750
	1224	446					4	0,9977	0,9977	0,1784
	1522	559					5	0,9401	0,9431	0,1721
	1815	659					6	0,7239	0,7335	0,1323
	2090	761					7	0,5284	0,4906	0,0843
	2379	866					8	0,3997	0,2798	0,0048
	2620	900					9	0,2795	0,1249	0,0233
	2797	958					10	0,1921	0,0414	0,0087
	3000	976					11	0,1085	0,0105	0,0026
	3136	985					12	0,0271	0,0010	0,0003
	3234	1009					13	0,0012	0,0001	≈0
	3338	1029					14	0,0009	0,0002	0,0001
	for fifth service station in general							**0,7211**	**0,6907**	**0,1265**

* Amount of equipment and tools: $K_{r2} = K_{r3} = K_{r4} = K_{r5} = K_{r8} = K_{r9} = \ldots = K_{r25} = K_{26} = 1$ pcs.

Table 4. The results of calculation of values of coefficients of partial organizational and technological compatibility (OTC) of all different types of maintenance of KhTZ-3522 tractors for service stations (SS) with different production structure and capacity from parametric series

№ of SS	Annual capacity Q_A, orders		Coefficients of partial organizational and technological compatibility (OTC)*						
	$Q_{A\ max}$ for second line maintenance	$Q_{A\ min}$ for third line maintenance before MR	for mode 3 & 1				for mode 2 & 2		
			$\alpha_{2,3,CR}$	$\alpha_{2,3,MR}$	$\alpha_{3,CR,MR}$	$\alpha_{3,CR,MR}$	$\alpha_{2,3\_CR,MR}$	$\alpha_{2,CR\_3,MR}$	$\alpha_{2,MR\_3,CR}$
I	296	110	0	0	0	0	0	0	0
	562	216	0	0	0	0	0	0	0
	799	314	0	0	0	0	0	0	0
	896	361	0	0	0	0	0	0	0
	896	372	0	0	0,0001	0	0,0008	0	0
	896	375	0	0	0,0337	0,116	0,3162	0	0
	for first SS in general		**0**	**0**	**0,0003**	**0,0009**	**0,0026**	**0**	**0**
II	296	110	0	0	0	0	0	0	0
	593	220	0	0	0	0	0	0	0
	877	328	0	0	0	0	0	0	0
	1040	390	0	0	0	0	0	0	0
	1040	485	0	0	0,0006	0	0,0019	0	0
	1040	490	0	0	0,0099	0,007	0,065	0	0
	for second SS in general		**0**	**0**	**0,0002**	**0,0001**	**0,001**	**0**	**0**
III	296	110	0	0	0	0	0	0	0
	605	222	0	0	0	0	0	0	0
	903	332	0	0	0	0	0	0	0
	1217	443	0	0	0,0018	0	0	0	0
	1522	543	0,0002	0,0049	0,0440	0	0	0	0,0003
	1739	634	0,0014	0,0532	0,1179	0	0	0,0003	0,0004
	1916	699	0,0026	0,1280	0,1871	0	0	0,0056	0,0020
	2049	744	0,0032	0,1992	0,2347	0	0	0,0137	0,0045
	2049	766	0,0032	0,2232	0,2681	0,0001	0,0073	0,0175	0,0053
	2049	778	0,0031	0,2354	0,2919	0,0126	0,1564	0,0186	0,0055
	for third SS in general		**0,0007**	**0,0392**	**0,0613**	**0,0002**	**0,0026**	**0,0021**	**0,0008**
IV	296	110	0	0	0	0	0	0	0
	614	223	0	0	0	0	0	0	0
	915	334	0	0	0	0	0	0	0
	1217	444	0	0	0,0018	0	0	0	0
	1510	554	0,0003	0,0101	0,0396	0	0	0	≈0
	1784	657	0,0021	0,0997	0,1206	0	0	0,0003	0,0004
	2049	747	0,0031	0,2387	0,1743	0	0	0,0055	0,0025
	2300	831	0,0031	0,3406	0,2029	0	0	0,0133	0,0052
	2493	884	0,003	0,4178	0,2351	0	0	0,0185	0,0070
	2555	932	0,003	0,4782	0,2525	0	≈0	0,0191	0,0072
	2555	945	0,0243	0,5022	0,2731	0,0015	0,0155	0,0205	0,0077
	2555	953	0,0351	0,5090	0,2839	0,0017	0,1093	0,0265	0,0105
	for fourth SS in general		**0,0018**	**0,1235**	**0,0844**	**≈0**	**0,0011**	**0,0042**	**0,0017**
V	296	110	0	0	0	0	0	0	0
	616	224	0	0	0	0	0	0	0
	920	335	0	0	0	0	0	0	0
	1224	446	0	0,0002	0,0021	0	0	0	0,0001
	1522	559	0,0004	0,0130	0,0461	0	0	0	0,0003
	1815	659	0,0024	0,1300	0,1406	0	0	0,0024	0,0007
	2090	761	0,0031	0,2644	0,1908	0	0	0,0101	0,0031
	2379	866	0,0031	0,3808	0,1956	0	0	0,0152	0,0057
	2620	900	0,0030	0,5146	0,1793	0	0,0001	0,0169	0,0066
	2797	958	0,0029	0,5631	0,2166	0,0004	0,0002	0,0181	0,0066
	3000	976	0,0145	0,6163	0,2342	0,0002	0,0007	0,0190	0,0065
	3136	985	0,0330	0,6398	0,2357	0,0012	0,0323	0,0223	0,0086
	3234	1009	0,0295	0,6573	0,2308	0,0011	0,0441	0,0258	0,0103
	3338	1029	0,0230	0,6753	0,2226	0,0004	0,0368	0,0292	0,0117
	for fifth SS in general		**0,0029**	**0,1734**	**0,0922**	**0,0001**	**0,0021**	**0,0061**	**0,0023**

* The values of coefficients of partial OTC for all other modes of partial OTC are equal 0.

Table 5. The results of calculation of values of coefficients of level of partial organizational and technological compatibility (OTC) of all different types of maintenance of KhTZ-3522 tractors for service stations (SS) with different production structure and capacity from parametric series

№ of SS	Annual capacity Q_A, orders		Coefficients of level of partial organizational and technological compatibility (OTC)*						
	$Q_{A\ max}$ for second line maintenance	$Q_{A\ min}$ for third line maintenance before MR	for mode 3 & 1				for mode 2 & 2		
			$\beta_{2,3,CR}$	$\beta_{2,3,MR}$	$\beta_{3,CR,MR}$	$\beta_{3,CR,MR}$	$\beta_{2,3\_CR,MR}$	$\beta_{2,CR\_3,MR}$	$\beta_{2,MR\_3,CR}$
I	296	110	0	0	0	0	0	0	0
	562	216	0	0	0	0	0	0	0
	799	314	0	0	0	0	0	0	0
	896	361	0	0	0	0	0	0	0
	896	372	0	0	≈0	0	0,0002	0	0
	896	375	0	0	0,0292	0,1114	0,2639	0	0
	for first SS in general		**0**	**0**	**0,0002**	**0,0009**	**0,0021**	**0**	**0**
II	296	110	0	0	0	0	0	0	0
	593	220	0	0	0	0	0	0	0
	877	328	0	0	0	0	0	0	0
	1040	390	0	0	0	0	0	0	0
	1040	485	0	0	0,0001	0	0,0005	0	0
	1040	490	0	0	0,0072	0,0049	0,0394	0	0
	for second SS in general		**0**	**0**	**0,0001**	**0,0001**	**0,0007**	**0**	**0**
III	296	110	0	0	0	0	0	0	0
	605	222	0	0	0	0	0	0	0
	903	332	0	0	0	0	0	0	0
	1217	443	0	0	0,0011	0	0	0	0
	1522	543	0,0001	0,0023	0,0286	0	0	0	0,0001
	1739	634	0,0013	0,0457	0,0917	0	0	0,0001	0,0002
	1916	699	0,0037	0,1553	0,1736	0	0	0,0024	0,0011
	2049	744	0,0059	0,2965	0,2465	0	0	0,0081	0,0036
	2049	766	0,0072	0,4086	0,3390	≈0	0,0012	0,0152	0,0060
	2049	778	0,0076	0,4726	0,4091	0,0024	0,0278	0,0212	0,0077
	for third SS in general		**0,0011**	**0,0549**	**0,0595**	**≈0**	**0,0005**	**0,0014**	**0,0006**
IV	296	110	0	0	0	0	0	0	0
	614	223	0	0	0	0	0	0	0
	915	334	0	0	0	0	0	0	0
	1217	444	0	0	0,0011	0	0	0	0
	1510	554	0,0001	0,0047	0,0264	0	0	0	0,0001
	1784	657	0,0018	0,0770	0,0891	0	0	0,0001	0,0002
	2049	747	0,0042	0,2340	0,1460	0	0	0,0023	0,0012
	2300	831	0,0055	0,4059	0,1885	0	0	0,0072	0,0034
	2493	884	0,0060	0,5553	0,2194	0	0	0,0124	0,0055
	2555	932	0,0060	0,6577	0,2338	0	0,0001	0,0157	0,0066
	2555	945	0,0079	0,6948	0,2491	≈0	0,0016	0,0182	0,0075
	2555	953	0,0112	0,6818	0,2618	0,0003	0,0166	0,0200	0,0080
	for fourth SS in general		**0,0019**	**0,1466**	**0,0731**	**≈0**	**0,0002**	**0,0028**	**0,0013**
V	296	110	0	0	0	0	0	0	0
	616	224	0	0	0	0	0	0	0
	920	335	0	0	0	0	0	0	0
	1224	446	0	≈0	0,0023	0	0	0	≈0
	1522	559	0,0003	0,0011	0,0453	0	0	0	0,0002
	1815	659	0,0028	0,1330	0,1298	0	0	0,0006	0,0004
	2090	761	0,0050	0,3120	0,1864	0	0	0,0042	0,0019
	2379	866	0,0059	0,4922	0,2084	0	0	0,0095	0,0042
	2620	900	0,0061	0,6644	0,1866	0	0,0002	0,0124	0,0053
	2797	958	0,0058	0,7334	0,1984	≈0	0,0004	0,0147	0,0059
	3000	976	0,0077	0,7705	0,1891	≈0	0,0007	0,0010	0,0156
	3136	985	0,0111	0,7705	0,1896	≈0	0,0051	0,0165	0,0060
	3234	1009	0,0127	0,7664	0,1873	0,0002	0,0093	0,0177	0,0064
	3338	1029	0,0114	0,7701	0,1812	0,0001	0,0103	0,0197	0,0071
	for fifth SS in general		**0,0027**	**0,2125**	**0,0881**	**≈0**	**0,0005**	**0,0037**	**0,0018**

* The values of coefficients of level of partial OTC for all other modes of partial OTC are equal 0.

Table 6. The results of calculation of values of coefficients of relative level of partial organizational and technological compatibility (OTC) of all different types of maintenance of KhTZ-3522 tractors for service stations (SS) with different production structure and capacity from parametric series

№ of SS	Annual capacity Q_A, orders		Coefficients of relative level of partial organizational and technological compatibility (OTC)*						
	$Q_{A\ max}$ for second line maintenance	$Q_{A\ min}$ for third line maintenance before MR	for mode 3 & 1				for mode 2 & 2		
			$\gamma_{2,3,CR}$	$\gamma_{2,3,MR}$	$\gamma_{3,CR,MR}$	$\gamma_{3,CR,MR}$	$\gamma_{2,3\_CR,MR}$	$\gamma_{2,CR\_3,MR}$	$\gamma_{2,MR\_3,CR}$
I	296	110	0	0	0	0	0	0	0
	562	216	0	0	0	0	0	0	0
	799	314	0	0	0	0	0	0	0
	896	361	0	0	0	0	0	0	0
	896	372	0	0	≈0	0	≈0	0	0
	896	375	0	0	0,0013	0,0051	0,0120	0	0
	for first SS in general		**0**	**0**	**≈0**	**≈0**	**0,0001**	**0**	**0**
II	296	110	0	0	0	0	0	0	0
	593	220	0	0	0	0	0	0	0
	877	328	0	0	0	0	0	0	0
	1040	390	0	0	0	0	0	0	0
	1040	485	0	0	≈0	0	0,0001	0	0
	1040	490	0	0	0,0004	0,0003	0,0023	0	0
	for second SS in general		**0**	**0**	**≈0**	**≈0**	**0,0001**	**0**	**0**
III	296	110	0	0	0	0	0	0	0
	605	222	0	0	0	0	0	0	0
	903	332	0	0	0	0	0	0	0
	1217	443	0	0	0,0003	0	0	0	0
	1522	543	≈0	0,0005	0,0066	0	0	0	≈0
	1739	634	0,0003	0,0092	0,0184	0	0	≈0	≈0
	1916	699	0,0007	0,0273	0,0305	0	0	0,0004	0,0002
	2049	744	0,0010	0,0490	0,0407	0	0	0,0013	0,0006
	2049	766	0,0011	0,0645	0,0535	≈0	0,0002	0,0024	0,0010
	2049	778	0,0013	0,0781	0,0676	0,0004	0,0046	0,0035	0,0013
	for third SS in general		**0,0002**	**0,0093**	**0,0106**	**≈0**	**0,0001**	**0,0002**	**0,0001**
IV	296	110	0	0	0	0	0	0	0
	614	223	0	0	0	0	0	0	0
	915	334	0	0	0	0	0	0	0
	1217	444	0	0	0,0003	0	0	0	0
	1510	554	≈0	0,0011	0,0061	0	0	0	≈0
	1784	657	0,0004	0,0158	0,0183	0	0	≈0	≈0
	2049	747	0,0008	0,0429	0,0267	0	0	0,0004	0,0002
	2300	831	0,0010	0,0699	0,0325	0	0	0,0012	0,0006
	2493	884	0,0011	0,0982	0,0388	0	0	0,0022	0,0010
	2555	932	0,0012	0,1276	0,0454	0	≈0	0,0031	0,0013
	2555	945	0,0017	0,1521	0,0545	≈0	0,0004	0,0040	0,0016
	2555	953	0,0028	0,1732	0,0665	0,0001	0,0042	0,0051	0,0020
	for fourth SS in general		**0,0004**	**0,0276**	**0,0139**	**≈0**	**≈0**	**0,0005**	**0,0002**
V	296	110	0	0	0	0	0	0	0
	616	224	0	0	0	0	0	0	0
	920	335	0	0	0	0	0	0	0
	1224	446	0	≈0	0,0004	0	0	0	≈0
	1522	559	0,0001	0,0020	0,0083	0	0	0	≈0
	1815	659	0,0005	0,0240	0,0234	0	0	0,0001	0,0001
	2090	761	0,0009	0,0536	0,0320	0	0	0,0007	0,0003
	2379	866	0,0010	0,0844	0,0357	0	0	0,0016	0,0007
	2620	900	0,0011	0,1239	0,0348	0	≈0	0,0023	0,0010
	2797	958	0,0012	0,1547	0,0418	≈0	0,0001	0,0031	0,0012
	3000	976	0,0019	0,1868	0,0458	≈0	0,0002	0,0038	0,0014
	3136	985	0,0011	0,2153	0,0530	≈0	0,0014	0,0046	0,0017
	3234	1009	0,0040	0,2409	0,0589	≈0	0,0029	0,0056	0,0020
	3338	1029	0,0039	0,2641	0,0621	≈0	0,0035	0,0068	0,0024
	for fifth SS in general		**0,0006**	**0,0454**	**0,0175**	**≈0**	**0,0002**	**0,0009**	**0,0003**
* The values of coefficients of relative level of partial OTC for all other modes of partial OTC are equal 0.									

2. At the same time, the obtained values of complete OTC indicators of the TPs of all types of maintenance of KhTZ-3522 tractors in the joint flow for all five variants of production structures of SSs designate the expediency of their poly technological specialization.

REFERENCES

1. **Kuzminskyj R.D., 1992.** Organizational and technological compatibility of processes of repair of various objects in a joint flow. Bulletin of Lviv State Agrarian University: Reliability and repair of machines in agriculture, 17 – 29. (in Ukrainian).
2. **Kuzminskyj R.D., 1992.** The system of indicators of organizational and technological compatibility of repair processes. Bulletin of Lviv State Agrarian University: Reliability and repair of machines in agriculture, 29 – 40. (in Ukrainian).
3. **Kuzminskyj R.D., 1993.** Influence of tact on indicators of organizational and technological compatibility of disassembly and assembly of carriage balancer suspensions of class 3.0 tractors in a joint flow. Bulletin of Lviv State Agrarian University: Reliability and repair of machines in agriculture, 14 – 26. (in Ukrainian).
4. **Kuzminskyj R.D., 1993.** Results of calculation of areas and coefficients of organizational and technological compatibility for technological lines. Bulletin of Lviv State Agrarian University: Reliability and repair of machines in agriculture, 27 – 38. (in Ukrainian).
5. **Kuzminskyj R.D., 2005.** Structure, parameters and efficiency of technological processes of repair. Bulletin of Lviv State Agrarian University: Agroengineering research, 9, 50–60. (in Ukrainian).
6. **Kuzminskyj R.D., 2006.** An organizational and technological compatibility of different objects repair processes in joint technological flow as the basis of formation of the firm technical service. Agricultural machines. Collection of scientific articles, 14, 114–124. (in Ukrainian).
7. **Kuzminskyj R.D., 2006.** An improvement of the indicators system of organizational and technological compatibility of different objects repair processes in joint technological flow. Theory and practice of development of the agro-industrial complex: Materials of the international scientific and practical forum, 2, 354–359. (in Ukrainian).
8. **Kuzminskyj R.D., 2009.** Substantiation of specialization of technological lines of repair of units and machine aggregates based on the model dynamics of the change of partial programs. Bulletin of Lviv State Agrarian University: Agroengineering research, №13 (V.2), 107 – 115. (in Ukrainian).
9. **Kuzminskyj R.D., 2011.** Calculation of organizational and technological compatibility of processes of repair of various objects taking into account the dynamics of the change of partial programs. Collection of scientific works of the Kirovograd National Technical University: Engineering in agricultural production, industrial engineering, automation, 24 (II), 50 – 53. (in Ukrainian).
10. **Kuzminskyj R.D., Barabash R.I., 2006.** Parameters and performance indicators of technological processes of technical service performed on stationary posts. Bulletin of Lviv State Agrarian University: Agroengineering research, 10, 66 – 73. (in Ukrainian).
11. **Kuzminskyj R.D., Barabash R.I., 2015.** Increase of percentage of uptime of tractors KhTZ by reducing duration of their maintenance. Bulletin of Kharkiv National Technical University of Agriculture named after P. Vasilenko: Problems of reliability of machines and means of mechanization of agricultural production, 163, 78 – 83. (in Ukrainian).
12. **Kuzminskyj R.D., Barabash R.I., 2015.** The results of modeling of technological processes of maintenance of KhTZ–3522 tractors. Scientific discussion: Issues of technical sciences, 4(25), 97–107. (in Ukrainian).
13. **Kuzminskyj R.D., Ivanyshyn V.V., Barabash R.I., Tkach O.V., 2016.** Effect of increasing the number of posts on performance indicators of technological processes of maintenance of KhTZ–3522 tractors. Collection of scientific works of the Podilsky state agricultural and technical university: Technical sciences, 24 (2), 175 – 184. (in Ukrainian).
14. **Kuzminskyj R.D., Stukalec I.G., 2008.** Calculation of the indicators of organizational and technological compatibility of different objects repair processes for single tact value. Ecological, technological and socio-economic aspects of the use of material and technical base of the agro-industrial complex: Materials of the international scientific and practical forum, 406–409. (in Ukrainian).
15. **Molodyk M.V., Morgun A.M., Shapoval L.I. at all., 2001.** Organizational forms of technical service and forecast of their development in market conditions of management in the agroindustrial complex of Ukraine. Recommendations. National Scientific Center «Institute of Mechanization and Electrification of Agriculture», 170 p. (in Ukrainian).
16. Process flow charts of pre-sales service and maintenance of KhTZ-3512, KhTZ-3522 tractors. Kharkov Tractor Plant named after S. Ordzhonikidze, 2014, 80 p. (in Ukrainian).
17. **Semkovych O.D., Kuzminskyj R.D., Chukhrai V.E., Oliskevych M.S., 2001.** Formation and development of the theory of repair and recovery processes. News of Agrarian Sciences. Special issue, September, 90–96. (in Ukrainian).
18. **Sydorchuk O.V., Kuzminskyj R.D., Barabash R.I., Mykhajluk M.A., 2013.** Justification of production structure of service stations for maintenance of KhTZ tractors. Bulletin of Lviv National Agrarian University: Agroengineering research. 17, 54–64. (in Ukrainian).
19. **Sydorchuk O.V., Senchuk S.R., Kukharuk O.V., 2001.** Scientific bases of engineering management of technical service of crop farming. Monograph, 172 p. (in Ukrainian).
20. Tractor KhTZ–3512. Operating instructions. 3512.00.001. Kharkov Tractor Plant named after S. Ordzhonikidze, 2014, 46 p. (in Ukrainian).
21. **Tymochko V.O., 1994.** Effective production structure of technological stations of current repairs of tractors of classes 0,9 and 1,4. Dis. Cand. Tech. Sciences: 05.20.03, 241 p. (in Ukrainian).