RESEARCH OF VARIABLE PARAMETERS OF NEEDLE THREAD TAKE-UP MECHANISMS AND DEVELOPMENT OF RECOMMENDATIONS FOR ADJUSTING MULTI-THREAD CHAIN STITCH SEWING MACHINES

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ABSTRACT

The purpose of this research is to develop specific recommendations for optimizing the adjustment of the thread take-up mechanisms of typical chain stitch sewing machines based on the analysis of the thread take-up process. These recommendations are intended to help manufacturers and machine operators achieve maximum productivity and increased product quality, while taking into account the specific techno-logical parameters of the operations performed on these machines. The research is aimed at increasing the efficiency of the sewing process, reducing machine setup time, and improving the overall result of the technological process in the sewing industry. The research uses an analytical method of determining and investigating functions of the actual thread take-up as the instantaneous sum of sections of the take-up contour when adjustable parameters of the mechanisms are changed, taking into account accepted assumptions. In the research, an analytical method was used to determine functions of the actual thread take-up as the instantaneous sum of sections of the take-up contour, taking into account the change in regulated parameters of the mechanisms. At the same time, assumptions were made that has simplified analysis and modelling of this process with sufficient accuracy of calculation results. The scientific novelty of this research lies in discovery of new relationships and establishment of regularities that determine influence of adjustable parameters on the nature and scope of the thread take-up function in chain stitch machines. Further re-search in this area can be aimed to the development of more efficient methods of adjustment and optimization of needle thread take-up mechanisms, as well as to the implementation of new technologies in pro-duction to improve productivity and quality of sewing operations. The obtained results became basis for the development of nomograms for determining the optimal values of adjustable parameters for needle thread take-up mechanisms of typical flat chain stitch machines, taking into account technological parameters of specific operations. These nomograms allow operators and manufacturers of sewing machines significantly simplify adjustment of these mechanisms when using operational equipment or when switching to other technological operations. The obtained results can be applied directly in production during adjustment or repairing of specified ma-chines to increase their productivity by reducing adjustment time and for improving the quality of the technological process.

KEYWORDS

Thread take-up mechanism of sewing machines; Sewing machines; Chain stitch; Thread take-up functions of sewing machines.

INTRODUCTION

Chain stitch sewing machines have significantly lower values of maintainability indicators comparing with corresponding indicators of shuttle machines. This is explained by the peculiarity of their structure (preferred location of main shaft in the platform, complexity of trajectories and laws of movement of loopers comparing to shuttles, preferred using of differential transport mechanisms, presence of such working tools as expanders and spreaders, etc.). These factors lead to complexity of their design and increase cost of maintenance. However, despite this, their share in general nomenclature of sewing equipment in production is constantly increasing, which is explained both by well-known advantages of chain stitches compared to shuttle stitches, and by great diversity of the structure of their stitches [1]. One of the main reasons is that repairability of the chain stitch sewing machines, at least several times higher than repairability of the shuttle sewing machines, is that the significant difficulties in setting-

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up thread take-up mechanisms, particularly needle ones.

Unlike shuttle machines, where needle thread take-up mechanisms [2] have only a few structural varieties with practically no adjustable parameters, the NTTM of the chain stitch machine has dozens of structural options, both purely mechanical and with electronic elements [2]. At the same time, usually, they have several adjustable parameters that affect the value and law of the effective take-up (*P(φ)*) of the thread [3-6]. However, in literature and instructions for the operation of specific machines, there is a complete lack of information about the quantitative effect of changing these parameters on nature of actual thread take-up function. Some sources mention possibility of more precise adjustment in case of using highly elastic threads [3] by changing the size of the thread receiver strokes.

In the works [7-10], the influence of thread tension during its unwinding from the bobbin on the quality of the stitch is examined. The authors in these works suggest equipping the existing thread feeding mechanisms with an additional system for monitoring thread tension during stitch formation.

The provided methodology for geometric modeling of chain stitches of type 406 [11] and type 504 [12] allows for the precise determination of thread consumption required to create a specific type of stitch, which eliminates the need for specific machine adjustments in accordance with the technological process of stitch formation.

Furthermore, in the study [13], the authors present the results of research on the impact of tension regulator settings on the quality of type 301 and 401 stitches, depending on material thickness and stitch length parameters. The authors provide mathematical relationships that enable achieving high-quality chain stitches by ensuring the appropriate tension on the thread regulator.

Additionally, there is no information about the separate effect of each parameter of the NTTM, on function of valid thread take-up, which complicates the process of their design and adjustment. Therefore, in practice, adjustment of NTTM is reduced to random selection of values of variable parameters, which significantly increases duration of this process.

STATEMENT OF THE TASK

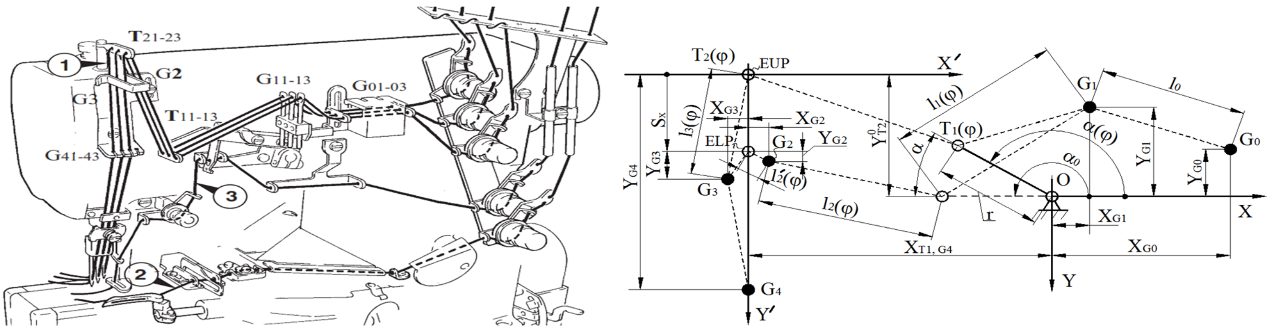
In works [14-17] obtained analytical definitions of function of necessary and valid take-up of needle threads of typical flat chain sewing machines, including sewing machines with a simple kinematic chain, which have only one thread receiver, that is fixed on the needle guide and regulation system of thread guides. At the same time at work [17] was conducted research of the effect of adjustable parameters on the value and law of ideal thread, and in [18-19] was performed comparative analysis of various structures of NTTM with a branched kinematic chain [2] in an example of sewing machines W562-05BB cl. of the company «Pegasus» [3] and CF 2300M-164 M class. of the company «Uamato» [4] and determining their advantages over take-up mechanisms formed by a simple kinematic chain. In works [15-16] was established that in order to achieve a high-quality stitch, it is necessary to ensure the correspondence between values of functions *P(φ)* and *P'(φ)* and this cannot be achieved only by stretching the threads. At the same time, in the paper [20] it is noted that the tension of the threads depends not only on the radius of curvature of the thread guides, but also on the type of threads, which also affects the actual thread take-up law *P(φ)*. This leads to the need of re-adjustment thread take-up mechanisms for all needles. The results of these works were taken as basis for conducting this study.

The main task is to identify influence of the values of the adjustable parameters on value and law of the valid thread take-up under various technological parameters, such as length of the stitch - t, thickness of the materials - m and type of thread, for the development of specific recommendations in form of nomograms for adjusting the NTTMs of typical chain stitch machines.

RESEARCH RESULTS

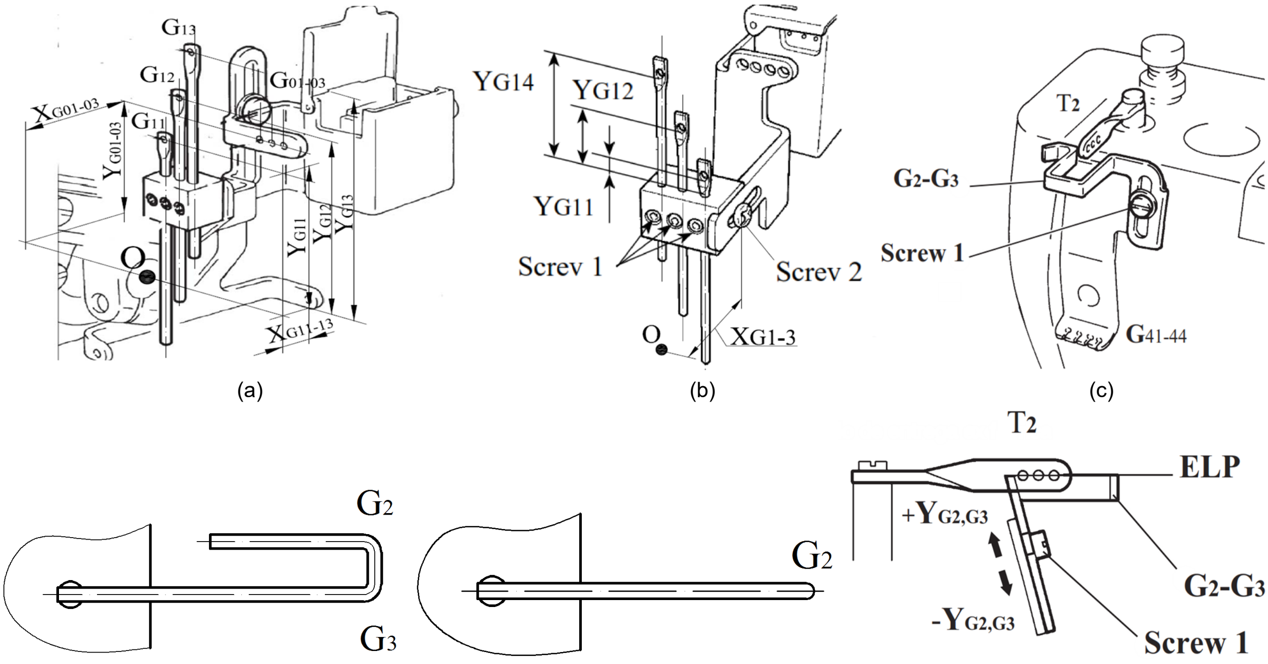
NTTMs formed by branched kinematic chain [2], unlike those formed by simple one, contain larger number of adjustable parameters. Their main characteristic is that they have thread receiver with separate mechanism and system of thread guides (Fig. 1). At the same time, compliance with laws of valid thread take-up *P(φ)* to necessary one P´(φ) for each specific needle is achieved by different positions of thread guides $G_{11\text{-}13}$ (Fig. 1(a), Fig. 2 (a,b)). In most cases, adjustment is performed vertically (Fig. 2(a)), or according to two coordinates (Fig. 2 (b)), which, usually, is recommended by equipment manufacturer. More precise accordance of configuring is achieved by using other adjustment parameters (Fig. 2, 3). Among them, it is worth highlighting positions of U-shaped (Fig. 2(c,d)) and I-shaped thread guides (Fig. 2 (e)) in relation to thread receiver T_2, which is fixed on the needle guide. Parameters of the thread receiver T_1, in turn, include its length R and its horizontal position - α_0 (Fig. 3).

Calculation of the parameters influence on law and value of needle thread take-up is for a group of sewing machines of leading manufacturers Pegasus and Yamato. To compare the laws of valid *P(φ)* thread take-up and necessary *P´(φ)* thread take-up law for the left needle is chosen, for the same purpose we choose the initial position of the thread guides G_{11}. As described in works [14-17] max value of the function *P´(φ)* has left needle, which is located lowest to the needle plate.



(a) (b)

Figure 1. Scheme of the thread take-up contours: (a) typical pattern of thread take-up for sewing machine of 600 class (1 – needle threads, 2 – loop thread, 3 – threads of the spreader); (b) calculation diagram of the NTTM's «take-up contour».



(a) (b) (c)

(d) (e) (f)

Figure 2. Parameters of thread guides *Gji*: (a) vertical adjustment, (b) both X and Y coordinates, (c,d) U-shaped thread guides of the W562-05BB «Pegasus» machine, (e) I-shaped thread guides of the CF 2300M-164M «Uamato» machine, (f) thread guides $G_{2\text{-}3}$ (G_2) adjustment parameters.

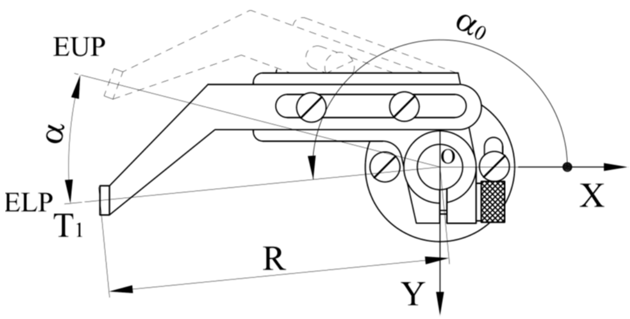


Figure 3. Adjustment parameters of thread receiver T1.

Calculation schemes of the contours of machine thread take-up contain i-th quantity of j-th types of thread receivers and thread guides, which are shown on Fig. 1(b) (where i-th types of j-th thread guides and thread receivers are marked accordingly by symbols Gji and Tji(φ)), and their construction is shown on Fig. 2, 3.

General diagram of thread filling ("take-up contour") of sewing machines W562-05BB "Pegasus", CF 2300M-164M «Uamato» are shown on Fig. 1, the difference is the parameter values and the type of thread guide applying [2]. Accordingly, following adjustable parameters can be defined. Thread guides $G_{11\text{-}13}$ of the W562-05BB "Pegasus" machine are adjustable only vertically $Y_{G11\text{-}13}$ (Fig. 2, a), and thread guide of the CF 2300M-164M «Uamato» machine has adjustment by two coordinates $X_{G11\text{-}13}$ and $Y_{G11\text{-}13}$ (Fig. 2, b). Sewing machine W562-05BB "Pegasus" uses U-shaped thread guides G_2-G_3 (Fig. 2 (c, d)), and CF 2300M-164M «Uamato» machine uses rod-shaped thread guides - G_2, (Fig. 2(e)). CF 2300M-164M «Uamato» which have adjustable vertical parameter relatively to extreme lowest position (ELP) of the thread receiver T_2, respectively - Y_{G2-3} (Fig. 2, f), and thread guide G_3 (Fig. 1(b)) is fixed motionless and has corresponding coordinates of Y_{G3} and X_{G3}. For the calculation location of the thread guides G_{41-43}, which close thread take-up contour and have their own coordinates (Fig. 1 (a)) are chosen to match projection of the needle guide axis and are located at the Y_{G4} coordinate. Thread receiver T_1 of W562-05BB «Pegasus» and CF 2300M-164M «Uamato» sewing machines has two adjustable parameters: slope angle to the abscissa axis at its extreme lowest position (ELP) - α_0 and length of thread receiver - R (Fig. 3).

Values of adjustable parameters ranges selected from possible design parameters for a specific machine are given in Table 1. Selected reference points are similar to the adjustment guidelines of the considered machines. As the start of G_2-G_3 thread guide coordinates countdown is selected coordinate of the thread receiver $T_2(\varphi)$ (Fig. 1, b) at its lowest position. For thread guide G_1 of both sewing machines, the Y_{G11} value is taken as zero, specified in the regulation manuals [3, 4]. As the origin of coordinates is taken point O - oscillation center of thread receiver T_1. $\alpha_0=2\pi$ is taken as zero at ELP of thread receiver T_1, in order to determine max effect of parameter α_0 during its variation, max value of the parameter R is taken, and values of the rest of the parameters are taken in the middle of variations range of value of the rest of the parameters of adjustment range.

Since actual thread take-up function $P(\varphi)$ depends on rotation angle of the main shaft - φ and three or four other variable parameters, in order to investigate the effect of each parameter on the value of $P(\varphi)$ function, sequential variations of these parameters were performed, while fixing values of others $(P(\varphi, a_0)$, $P(\varphi, R)$, $P(\varphi, Y_{G1})$, $P(\varphi, Y_{G2})$.

The calculation of the values of actual thread take-up function $P(\varphi)$ was performed according to the formulas given in works [14-19] depending on the type of thread take-up mechanism of sewing machines.

According to the calculation results, when varying one of the adjustable parameters spatial charts was build, for changes of the values of actual thread take-up function $P(\varphi, a_0)$, $P(\varphi, R)$, $P(\varphi, Y_{G1})$, $P(\varphi, Y_{G2})$ for each NTTM of W562-05M, class «Pegasus» and CF 2300M-164M class «Uamato» sewing machines. Along with this, diagrams to display values of these functions in parameters adjustment range with certain step were obtained (position 2 on Figures 4 and 5), and these values were compared with charts of the required needle take-up function $P'(\varphi)$ (position 2 on Figures 4 and 5) for the left needle of the relevant sewing machines.

The effect on $P(\varphi)$ of the final position of the thread receiver T_1, which is determined by parameter α_0, is shown on Fig. 4, 5(a). It can be seen from it that in the range of variation of parameter α_0, with negative values, take-up value changes insignificantly, and, vice versa, with positive values, take-up value increases significantly according to a nonlinear law.

As a result of varying values of the parameter R, given on Fig. 4, 5(b), it was discovered that when parameter R is decreased, the value of thread take-up increases, and, vice versa, when R is increased, it decreases. At the same time, changing of maximum of $P(\varphi)$ function is directly proportional to the changing of R parameter with an insignificant change in thread take-up law for both variants of NTTM of sewing machines.

RESULTS

The result of varying values of parameter Y_{G1} is depicted on Fig. 3, 5(c), it shows that changes of the maximum $P(\varphi)$ is directly proportional to changes of parameter Y_{G1}. At the same time, take-up law (in specified adjustment range) changes insignificantly.

At the same time, varying values of parameter Y_{G2-3} (Fig. 4(d)) leads to significant effect for both value and law of thread take-up. So, for instance, with parameter value Y_{G2-3}=1mm, chart horizontal section (Fig. 4(d), curve 1) of actual thread take-up function is observed, and with negative values, a significant change in values is observed and chart of the function becomes "saddle-shaped".

Table 1. Ranges of adjustable parameters changing.

Adjustable parameter		W562-05M, class, «Pegasus»	CF 2300M-164M, class, «Uamato»
		Adjustment range	
R [mm]		55÷75	50÷70
Y_{G1} [mm]		-20÷20	-20÷20
Y_{G2-3} [mm]		-10÷10	-10÷10
α_0 [°]		-20÷20	-20÷20
Relative coordinates of the uppermost position of thread receiver T_2 relative to the center point O of the thread receiver T_1 [mm]	x	62	148
	y	90	85

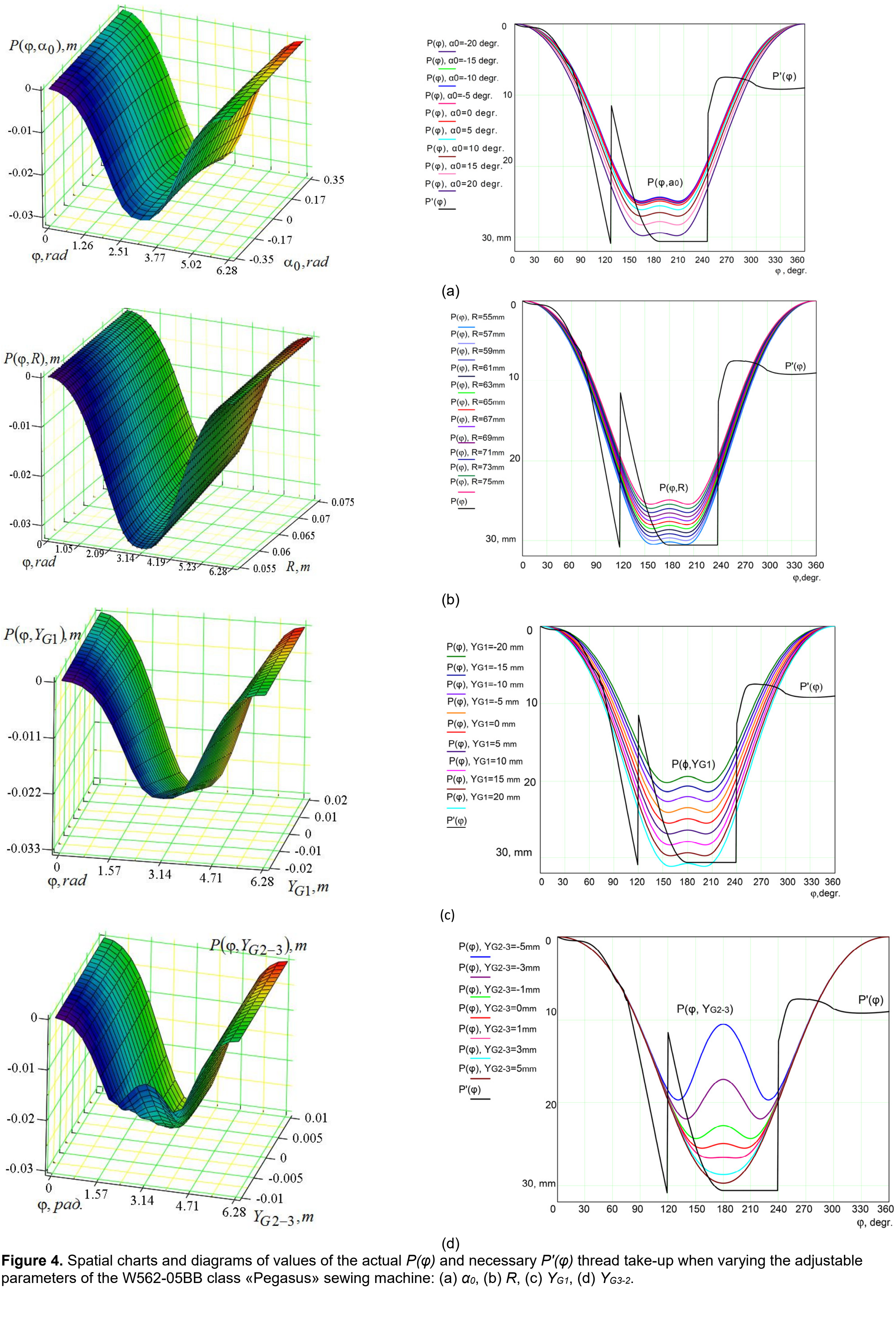
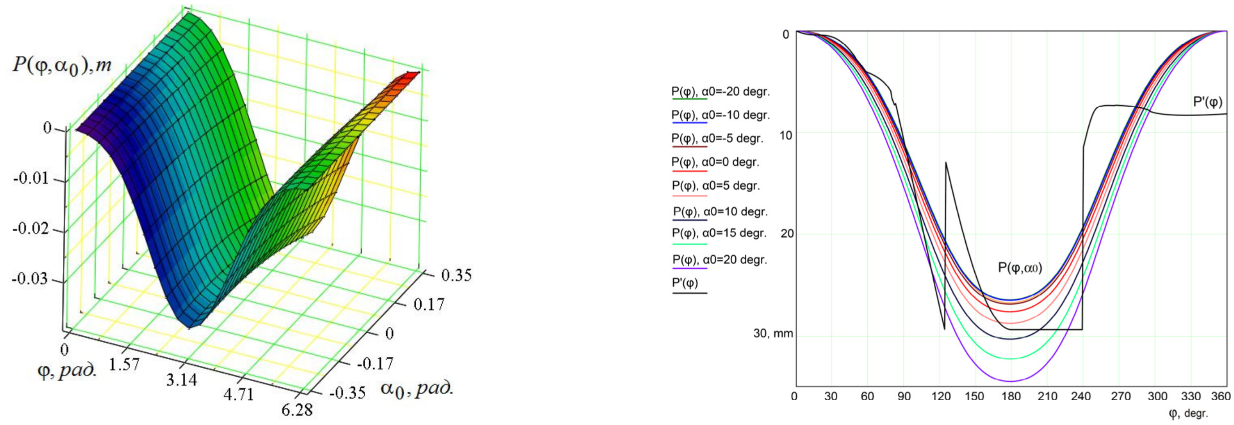
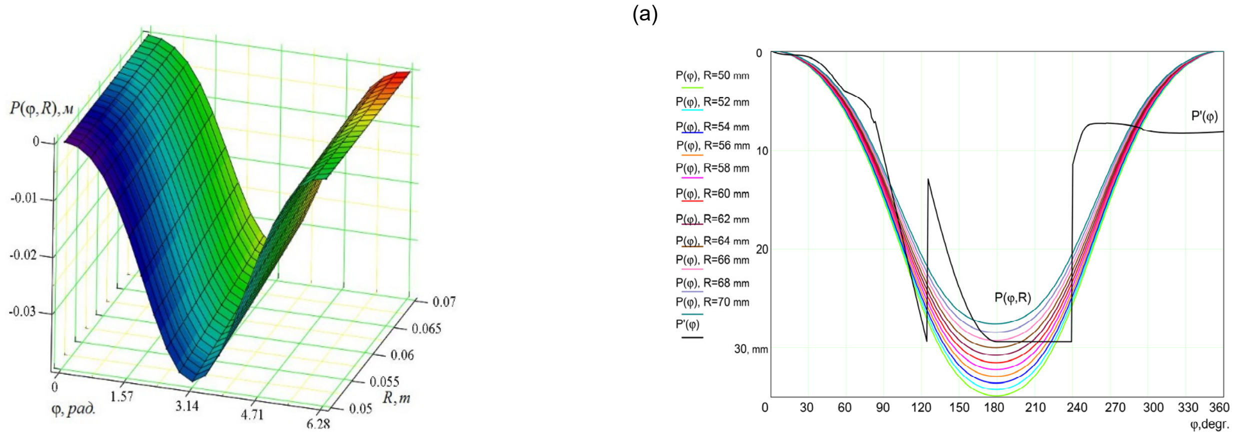


Figure 4. Spatial charts and diagrams of values of the actual *P(φ)* and necessary *P'(φ)* thread take-up when varying the adjustable parameters of the W562-05BB class «Pegasus» sewing machine: (a) α_0, (b) *R*, (c) Y_{G1}, (d) $Y_{G3\text{-}2}$.



(a)



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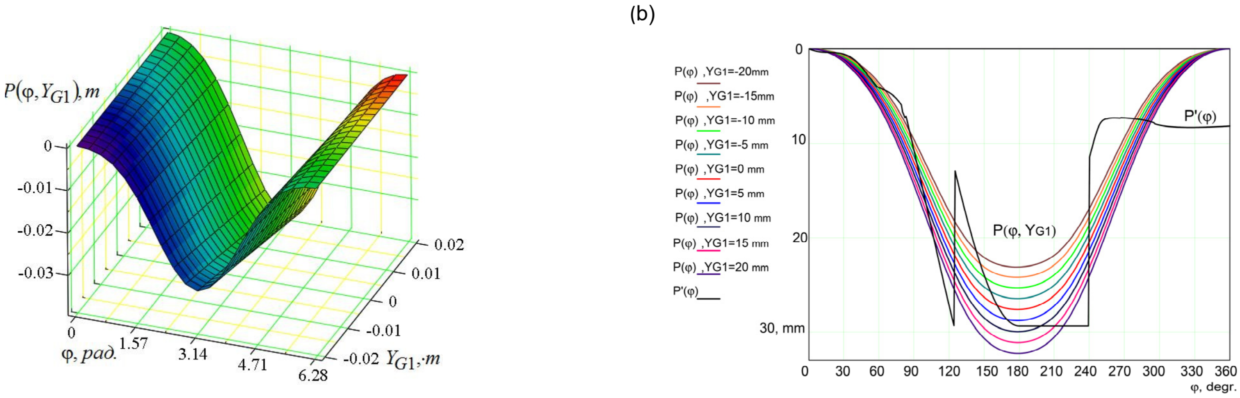
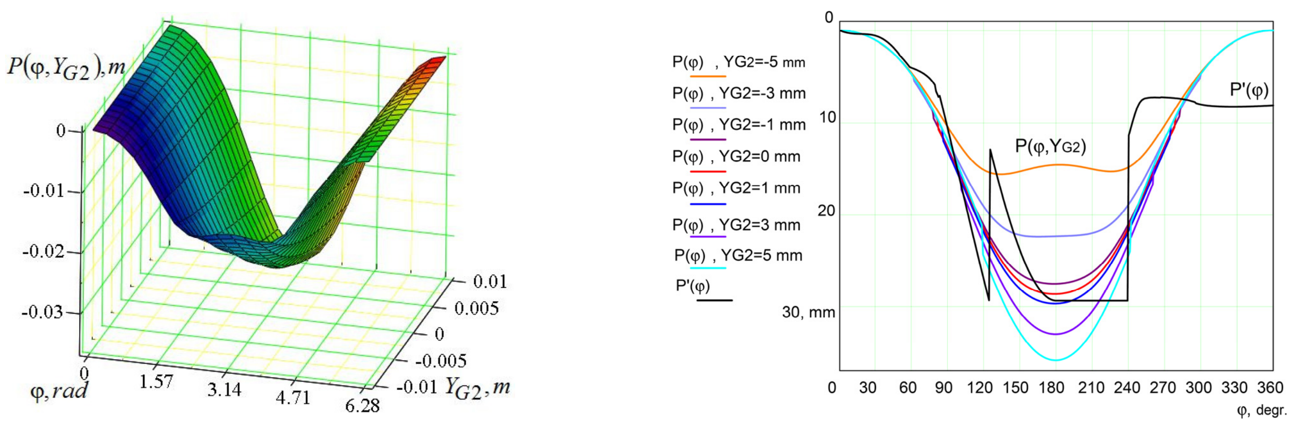


(c)



(d)

Figure 5. Spatial charts and diagrams of values of the actual P(φ) and necessary P'(φ) thread take-up when varying the adjustable parameters of the CF 2300M-164M class «Uamato» sewing machine: (a) α_0, (b) R, (c) Y_{G1}, (d) – Y_{G2}.

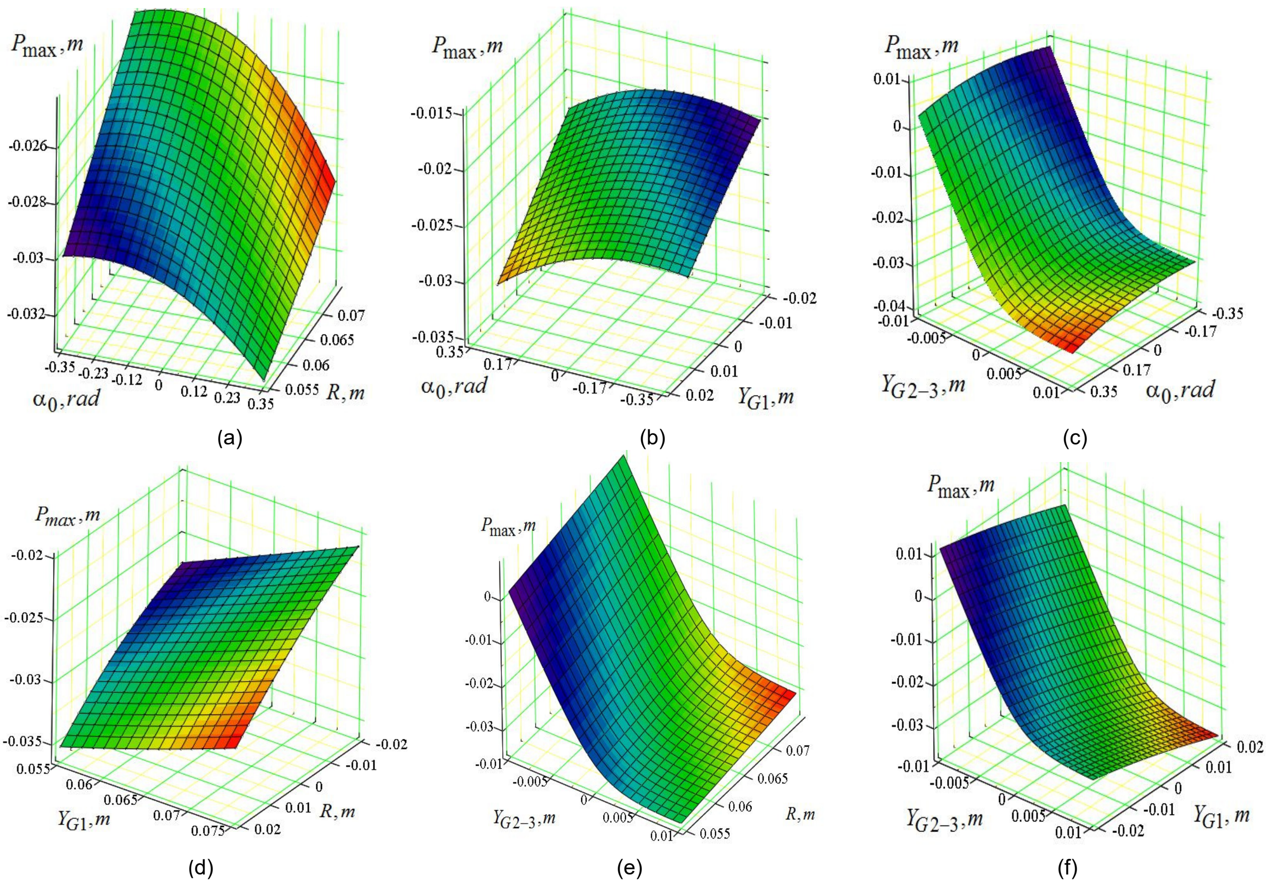


Figure 6. Charts of the maximum values of the actual thread take-up function *P(φ)* for W562-05BB class «Pegasus» sewing machine, when varying the parameter: (a) α_0 and R; (b) α_0 and Y_{G1}; (c) α_0 and Y_{G2-3}; (d) R and Y_{G1}; (e) R and Y_{G2-3}; (f) Y_{G2-3} and Y_{G1}.

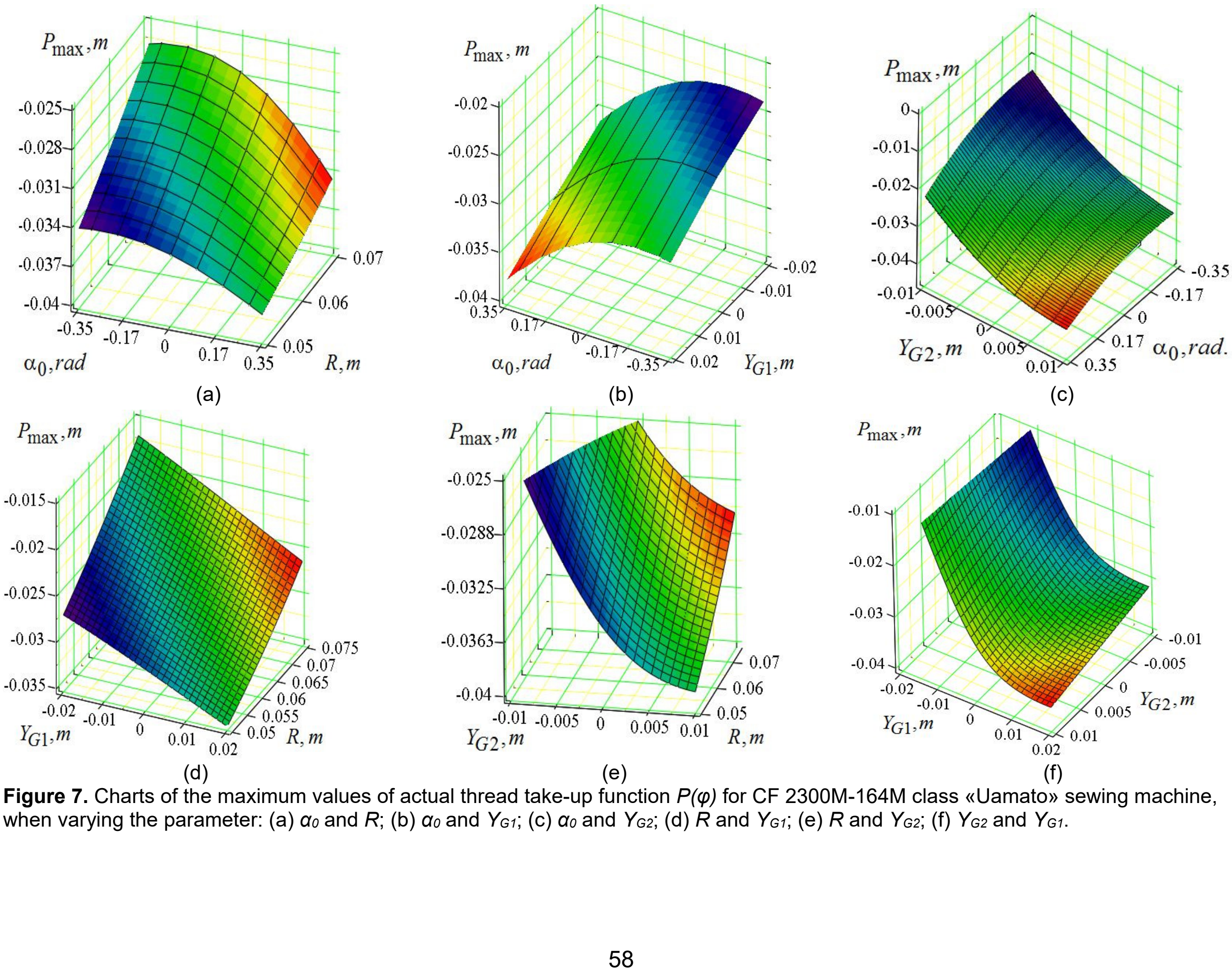
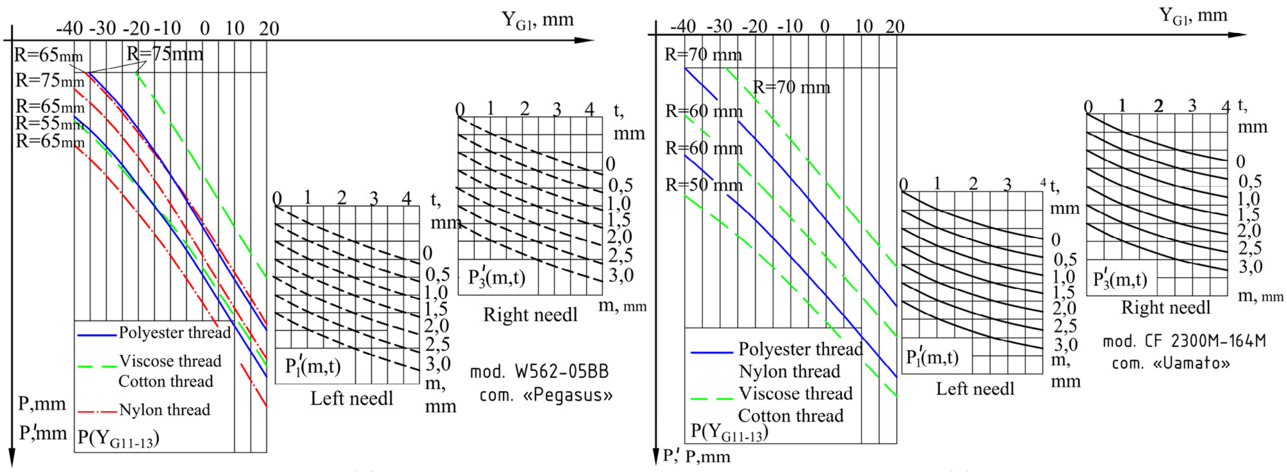


Figure 7. Charts of the maximum values of actual thread take-up function *P(φ)* for CF 2300M-164M class «Uamato» sewing machine, when varying the parameter: (a) α_0 and R; (b) α_0 and Y_{G1}; (c) α_0 and Y_{G2}; (d) R and Y_{G1}; (e) R and Y_{G2}; (f) Y_{G2} and Y_{G1}.



(a) (b)

Figure 8. Nomogram that determines value of NTTM parameters adjustment for sewing machines: (a) W562-05BB class «Pegasus» (α_0=0 degr., $Y_{G2\text{-}3}$=0 mm), (b) CF 2300M-164M class «Uamato» (α_0=0 degr., Y_{G2}=-4 mm).

The impact of parameter Y_{G2} for CF 2300M-164M class «Uamato» (Fig. 5 (d)) is also similar to the impact of parameter $Y_{G2\text{-}3}$ for W562-05BB class "Pegasus" machine (Fig. 4 (d)). However, the impact of parameter Y_{G2} (Fig. 5 (d)) is less important, since thread receiver with I-shaped thread guide forms only one new branch of thread take-up circuit in a certain period. An increase of horizontal linear part on *P(φ)* function chart is observed (Fig. 5 (g)) at the maximum values of Y_{G2} parameter.

The certain parameter value was determined by its varying, at which the greatest matching between values of function *P(φ)* and values of required thread take-up function *P´(φ)* was observed.

For investigation purposes of the impact of two selected parameters (with fixed values of other parameters), the actual thread take-up function *P(φ)* was analyzed for its maximum value P_{max} at $\varphi=\pi$. Pairwise influence of parameters on maximum value of the function *P(φ)* was performed for this purpose, which is illustrated by maximum response surface (Fig. 6, 7) accordingly W562-05BB class «Pegasus» and CF 2300M-164M class «Uamato» sewing machines models.

Parameters values were chosen as α_0=π, $Y_{G2\text{-}3}$=0 mm and Y_{G2}=0, respectively, for W562-05BB class «Pegasus» and CF 2300M-164M class «Uamato» sewing machines, with such values, the thread take-up law is closer to the values of required thread take-up function (Fig. 4 (a,d) and Fig. 5 (a, d)).

Analysis of the combined impact of α_0 and *R* parameters (Fig. 6(a), 7(a)) shows that the value of parameter α_0 has greater impact on maximum of *P(φ)* function than value of parameter R, while certain regularity is observed for NTTMs of both sewing machines. Thus, when varying parameters α_0 and Y_{G1} (Fig. 6(b), 7(b)) and α_0 and $Y_{G2\text{-}3}$ (Fig. 6(c)) and α_0 and Y_{G2} (Fig. 7(c)) more significant change in function maxima is observed. At the same time, pairwise changing of parameters $Y_{G2\text{-}3}$ and Y_{G2} with other parameters (Fig. 6(c,e,f)) and (Fig. 7(c,e,f)) on function maxima retains the weight of its influence, thus the variation of its values leads to significant increase or decrease in values of function maxima. Pairwise variation of Y_{G1} parameter values with α_0 parameters (Fig. 6(b,d), 7(b,d)), *R* (Fig. 6(a,d,e) and Fig. 7(a,d,e)) is more significant than the individual impact of these parameters. Thus, the greatest effect on function maxima is observed when varying parameters $Y_{G2\text{-}3}$, Y_{G2}, α_0, slightly smaller effect is observed when varying the parameter Y_{G1}, and weak effect has *R* parameter.

As a result, for each needle thread take-up mechanism of sewing machines, the optimal range of adjustment of its parameters was established.

Based on conducted analysis, nomograms (Figure 8) were developed, by using them it is possible to quickly and efficiently adjust needle thread take-up mechanisms of machines investigated in the work, depending on the technological parameters of technological process operations, particularly material thickness, stitch length and thread type.

Considering the fact that properties of «kapron» elementary and «kapron» complex threads are similar, parameters for these threads are selected accordingly to the «kapron» curve. Thus, when selecting adjustable NTTM parameters, the type of thread is taken into account by changing take-up amount of the thread for specific needle using adjustable parameters according to $G_{11\text{-}13}$.

The procedure of nomograms usage is following.

Determining *P'(m, t)* function maximum by given value of material thickness m depending on stitch length *t* (Figure 8). For this, firstly it is necessary to determine value of the parameter *R*, at which *P'(m, t)* function maximum value is reached for both uttermost needles, then to determine value of the parameter $Y_{G11\text{-}13}$ for each needle. This approach relates to the fact that thread receiver T_1 is shared between all needle threads and value of the parameter *R* will be the same for all of them. The obtained point, which corresponds to the maximum value of $P'(\varphi)$, is transferred parallel to abscissa axis on the curve of function $P(G_1)$ maximum of the corresponding thread. Based on the obtained value of function $P(G_1)$ maximum, the parameter G_1 is determined. To set the parameter R, it is necessary to transfer obtained point to $R(G_1)$ curve, and determine parameter R from it. In the case when value of the parameter R is outside nomogram's range, its value is accepted as maximum or minimum. The values of parameters α_0, $Y_{G2\text{-}3}$, Y_{G2} are set individually for each machine.

CONCLUSIONS

1. As a result of the conducted research, it was established that the control parameters can be divided into those that are responsible for changing the law of thread take-up Y_{G2}, $Y_{G2\text{-}3}$ or the amount of thread take-up Y_{G1}, R and α_0. Varying of parameter α_0 of the thread receiver T_1 leads to a change in both amount of thread take-up and law of the actual thread take-up function $P(\varphi)$.

2. It was found that nature of the thread take-up law is influenced by the type of thread guide, at the position of U-shaped $(Y_{G2\text{-}3})$ thread guide within the thread receiver T_2 at its extreme position, that allows to reach horizontal section with certain length of the $P(\varphi)$ function curve. At the same time, in order to achieve this value when using an I-shaped thread guide, the Y_{G2} parameters must be significantly larger.

3. The developed nomograms allows to set adjustable parameters values of the thread take-up mechanisms, which provide optimal conditions for the process of stitch formation, depending on the given technological indicators.

4. The application of these recommendations in production will significantly reduce the time spent on machine reconfiguration for other technological operations.

5. The proposed method can be used at development of similar recommendations for chain stitch sewing machines of other classes and purposes.

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