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The Structure of the Embroidery Machine and Dynamic Analysis of the Needle Mechanism

Bekhruz Gaybulloev, Nigina Ergasheva, Ozod Rajabov

Undergraduate of the Bukhara Engineering Technological Institute, Bukhara, Uzbekistan
Undergraduate of the Bukhara Engineering Technological Institute, Bukhara, Uzbekistan
Senior lecturer (PhD) of the Department of Technological Machines and Equipment, Bukhara Engineering Technological Institute, Bukhara, Uzbekistan

ABSTRACT: This article provides an overview of embroidery on fabrics. The technological characteristics of embroidery machines used today are described. The article also provides a dynamic analysis of the needle mechanism of the embroidery machine. All the forces acting on the needle are taken into account. The force plan was constructed and the reaction forces acting on it were determined.

KEY WORDS: Fabric, Embroidery Machine, Semiautomatic, Needle, Force, Inertia, Moment, Center of Gravity

I. INTRODUCTION

Based on the introduction of new technology and advanced technology, as well as mechanization and automation of production in the ninth five-year period, serial production of more than 50 samples of new types of sewing equipment will be mastered. Among them are rejection-measuring machines for visual sorting of fabric with simultaneous automatic measurement of its length and width; a set of equipment for the manufacture of oblique edging; unit with a stacker for processing cuffs with right angles; semiautomatic device with a hopper for sewing buttons on shirts with their simultaneous movement; short-seam and long-seam semiautomatic devices for sewing stitches along a given contour (for applications on dresses); semi-automatic machines for processing knots of men's coats, etc. [1,2].

It is envisaged to carry out a large complex of search work to find high-performance mechanized methods of cutting tissue (cutting on presses, cutting with a laser beam, micro plasma, etc.) with its programmed movement.
Work is underway to mechanize loading and unloading operations and vehicles in labour-intensive areas of storage and preparation of fabric for cutting. Particular attention will be paid to the mechanization of sewing areas (procurement and assembly) and the introduction into production of specialized operational and semi-automatic machines.

An embroidery machine is a new level of craftsmanship for an inspired needlewoman who dreams of creating real masterpieces on fabric. Patterns of multi-coloured threads appear due to the fixed hoop that moves and works according to a specific pattern. Computerized devices have special software with which you can save your favourite designs, quickly and efficiently control settings. Such a sewing machine will help to develop your hobby, turning it into a profit, or substantially raise the existing commercial level [3].

II. STRUCTURAL ANALYSIS

Such devices became the opening of modern textile business, and working on them is very simple even for beginners. Thanks to computer control, you can create patterns from various types of threads - silk, viscose, polyester, cord. You just have to select the settings from the memory and start the device - and you will get embroidery, comparable in quality and beauty to manual. The best embroidery machine is one that works in all popular styles: cross-stitch, satin stitch, sequins, Richelieu and so on. The fabric can be cotton, for example, satin, and the threads must be necessarily high quality [4].

Semi-automatic sewing embroidery machine model BENT-ZQ-201U of Barudan company refers to single-head embroidery semiautomatic machines with numerical program control, performing embroidery with a double-thread shuttle stitch. The head of the machine 14 (Fig. 1) is mounted on the surface of the table 5. The commands for controlling the machine are set via the control panel 15. The drive of the machine 12 is located on the head of the machine. Pantograph 2 with drive 1 along the X axis is located on the table surface, and the drive along the Y axis is located in the longitudinal guides 6. The working area 4 in which the stitch is formed passes exactly under the head of the machine.

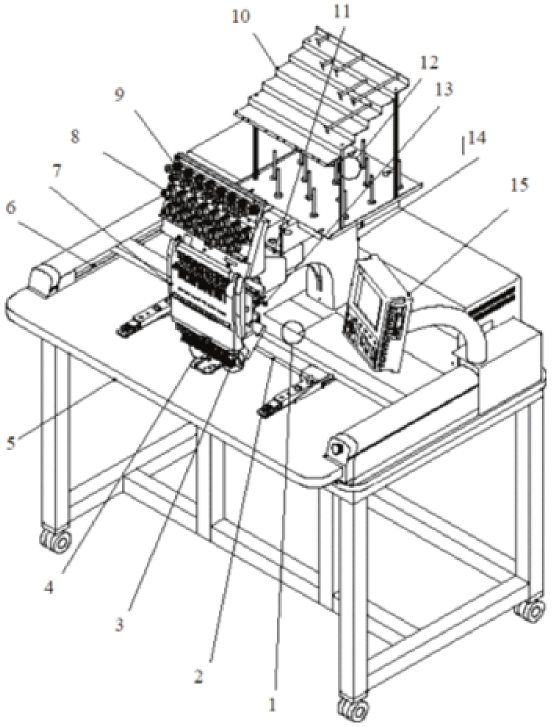

Fig.1. General view of the semi-automatic embroidery machine model BENT-ZQ-201U by Barudan

Technical characteristics of single-head sewing embroidery semiautomatic devices are presented in table. 1.

Threading in the machine is carried out from the bobbin mounted on the bobbin holder through the thread guides 10 upper thread guide 9 tension adjusters 8 to the thread guide on the bar under the thread take-up, eye of the thread take-up, again to the thread guide on the bar and into the needle. The shuttle thread from the bobbin has the usual threading into the bobbin case of the shuttle device [5].

Technical characteristics of single head semi-automatic embroidery machines

Table 1.

Characteristic	**Model**					
	BENT-ZQ-201U Barudan	**ESP 9000 Toyota**	**BE-1201 AC Brother**	**SWI- B-1501T SWF**	**TFMX- C Tajima**	**JAF 0115 ZSK**
The maximum frequency of rotation of the main shaft, min^{-1}	1200	1200	1200	1200	1200	1000
The sizes of the processing area, mm	300x450	575x410	450x300	520x360	450x520	500x500
Number of colors	15	15	12	15	15	15
Memory capacity,	65 000	280 000	480 000	2000000		1000000
Stitch patterns	10000000	99	100	99		99
Power Consumption, Watt	250	320	320	300	260	300

III. DYNAMIC ANALYSIS

The dynamics of needle mechanisms

The following forces act in the needle mechanism [6]:

a) the driving force imparted to the leading link in the form of a moving moment and determined after the force calculation;

b) the force of the useful resistance (the force of puncture of the material), determined by the formula $P = P_{\max} \cos\varphi$, where $P_{\max}$ is the maximum force of puncture ($P_{\max} = 0.4 \div 0.9\ kgs$); φ - the angle of rotation of the main shaft from the moment the needle enters the material to its lowest position ($\varphi = 90 \div 180^0$);

c) the force of harmful resistance spent on overcoming friction in translational and rotational pairs; due to the complexity of the calculation, it is not taken into account, and when finding the driving moment, a correction factor is introduced $\beta = 1.3 \div 1.5$;

d) weight forces; due to the fact that the weight of moving parts in high-speed sewing machines is insignificant (about 15-50 gs), they are neglected in the calculation;

e) inertia forces, which are the main forces in the needle mechanism. We find the inertia forces acting in the links of the mechanism.

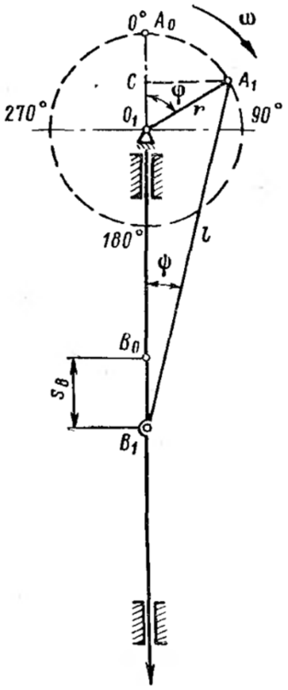

Fig.2. Kinematics of the needle mechanism

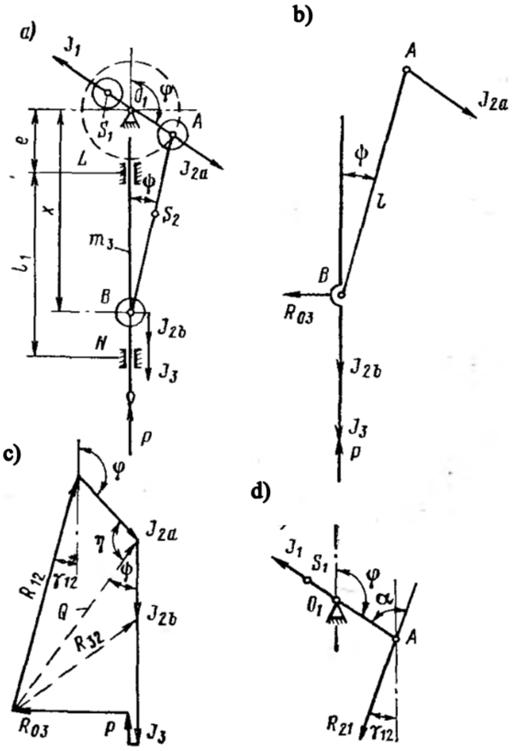

Fig.3. Dynamics of the needle mechanism: a - diagram of the mechanism with the placed masses; b - a group of 2-3 links; c - a plan of forces for a group of 2-3rd units; g-scheme and direction of forces in the 1st link

The leading link O_1A of the needle mechanism is made in conjunction with a counterweight, the centre of gravity of which is located at point S_1 (Fig.3, a). The mass of this counterweight is determined by balancing either one needle mechanism (in machines with a rotary thread take-up device of type 97 the class), or together with the thread take-up mechanism (in machines 22A, 252, 203 the class, etc.), or taking into account all mechanisms machines (full balancing of the machine).

Inertia force

$$J_1 = m_1 r_1 \omega_1^2 \qquad (1)$$

Where m_1 – is the mass of the counterweight in kg; r_1 is the distance from the axis of rotation O_1 to the center of gravity S_1, ω_1 – is the angular velocity of the leading link.

To find the inertia forces of the 2nd link, we apply the method of static mass replacement, that is, we place the entire mass m_2 of the connecting rod AB at points A (mass m_{2a}) and B (mass m_{2b}). We determine the point masses using the well-known formulas [7,8,9]:

$$m_{2a} = m_2 \frac{BS_2}{AB}; \tag{2}$$

$$m_{2b} = m_2 \frac{AS_2}{AB}, \tag{3}$$

Where S_2– the position of the center of gravity of the connecting rod.

The inertia forces of the 2nd link are equal to:

$$J_{2a} = m_{2a} r_1 \omega_1^2; \tag{5}$$

$$J_{2b} = m_{2a} r_1 \omega_1^2 (\cos\varphi - \lambda \cos 2\varphi); \tag{6}$$

The inertia force of the 3rd link with mass m_3 is found by the formula

$$J_3 = m_3 r_1 \omega_1^2 (\cos\varphi - \lambda \cos 2\varphi); \tag{7}$$

The direction of these forces is shown in Fig. Fig.3. b

To find the reactions in the joints, we break the mechanism into Assur groups. Consider the group of 2-3 links and replace the action of discarded bonds in the guide bushings L and N and in the hinge A, respectively, by reactions R_{03} and R_{12}. We conditionally apply reaction R_{03} to point B (Fig.3, b) and define it by composing the equation of moments of all the forces acting on the 3rd link relative to the hinge A:

$$\sum M_{23} = R_{03} l \cos\psi - (J_{2b} + J_3 - P) l \sin\psi = 0 \tag{8}$$

From this equation we determine R_{03}.

We write the equilibrium equation of the 2-3rd links

$$\sum P_{23} = J_3 + P + J_{2b} + R_{03} + J_{2a} + R_{12} = 0 \tag{9}$$

and on a certain scale we will build a force plan (Fig.3, c), from which we find the magnitude and direction of R_{12}.

Reactions R_{23} and R_{12} can also be found analytically:

$$R_{23} = R_{32} = \sqrt{R_{03}^2 + (J_3 - P)^2}\,; \qquad R_{12} = \sqrt{J_{2a}^2 + Q^2 - 2J_{2a} Q \cos\eta} \tag{10}$$

where Q – force acting along the connecting rod axis AB; $Q = \dfrac{R_{03}}{\sin\psi}$; η – angle between force vectors J_{2a} and Q (Fig.3, c):

$\varphi = 0 \div 90^0$. . . . . $.\eta = 180^0 - \varphi + \psi$

$\varphi = 90 \div 180^0$. . . . . $.\eta = \varphi - \psi$

$\varphi = 180 \div 270^0$. . . . . $.\eta = 360^0 - \varphi - \psi$

$\varphi = 270 \div 360^0$. . . . . $.\eta = \varphi - 180^0 + \psi$

The angle γ_{12} is found by the formula

$$\sin\gamma_{12} = \frac{R_{03} - J_{2a}\sin\varphi}{R_{12}} \tag{11}$$

Consider the 1st link (Fig.3, d) and determine the driving moment

$$M_{motor} = -\beta R_{21} r \sin\alpha \tag{12}$$

Where β – coefficient taking into account the effect of friction forces ($\beta = 1.3 \div 1.5$); α – the angle between the leading link O_1A and the reaction vector R_{12}:

$\varphi = 0 \div 90^0$. . . . . $.\alpha = \varphi \pm \gamma_{12}$

$\varphi = 90 \div 180^0$. . . . . $.\alpha = 180^0 - \varphi \pm \gamma_{12}$

$\varphi = 180 \div 270^0$. . . . . $.\alpha = \varphi - 180^0 \pm \gamma_{12}$

$$\varphi = 270 \div 360^0. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad .\alpha = 360^0 - \varphi \pm \gamma_{12}$$

IV. CONCLUSION AND FUTURE WORK

The study provides general information on embroidery machines. The technological characteristics of embroidery machines used today are described. The needle mechanism of the embroidery machine was dynamically analysed. All the forces acting on the needle are taken into account. On this basis, a force plan was constructed and the reaction forces acting on it were identified. The main purpose of the dynamic analysis of the needle mechanism of the embroidery machine is to select the desired needle mark based on the density of the embroidery

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