DYNAMICS OF THE FRAME OF SMALL-DIAMETER KNITTING MACHINE

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Abstract

The paper is concerned with the problems of the frame of small-diameter knitting machines. The knitting machine frame undergoes designing alterations nowadays, directed to minimisation of production costs. This trend entails a decrease of the stiffness of its structure. One of the most important parts of the frame is the silent-block, serving as vibration-insulating element between the base plate and the frame of the machine. In the paper there are ascertained the visco-elastic properties of three types of silent-blocks, employed in knitting machines.

1 Introduction

The principal objective of the majority of structural and technological modifications realised in knitting machines has been to increase their productivity and to cut down both production costs and costs of procurement. The firm Uniplet Třebíč s.r.o., manufacturer of small-diameter knitting machines, has followed this way as well. Its production program comprehends the machines of the Ange series. They are fully electronic, small-diameter four-system knitting machines for the manufacture of conventional or plush sock goods with double welt, pouch heel and toe and coloured fancy patterns (fig.1). At present, these machines are fully automated in principle. The majority of functions are governed electronically, or in combination with pneumatic elements. The maximum operating speed of the machine is 320 r. p.m.

The present trend of reducing the production costs of these machines also entails changes in the area of the design of knitting machine frames (fig.2). It concerns primarily an increased effectiveness of their manufacture and minimisation of costs through economy of material, reduction of the number of manufacturing operations (machining, assembly etc.) and simplification of the shapes.

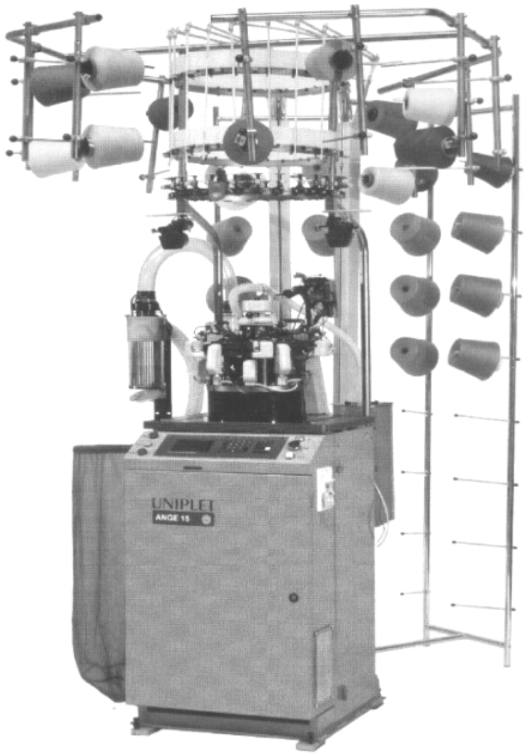

Fig. 1 Small-diameter knitting machine

However, these changes have resulted in a decrease of their stiffness and in changes of their dynamic characteristics. The decrease of the stiffness of the frame is shown most in the moments of knitting the heel and toe of the sock, which is realised by the rotation reverse movement of the needle cylinder.

The deformation of the frame of the knitting machine is attributed in a large degree to the dynamic moment produced during the run-up and braking of the driving system and of the needle cylinder, manifesting itself mainly by the deflection of the base plate of the knitting machine. It depends upon the moment of inertia of the rotary moving masses. A high effect upon the value of the dynamic moment is exerted by the course of run-up and braking of these masses, from which results the course of the acceleration. When knitting a sock, and parts of the toe and heel in particular, the operating regime of the machine performs a reverse movement of the needle cylinder, during which the deflections of the base plate attain their maximum values; the same applies to torsional deflections of the frame resulting from this state. This phenomenon has been documented by numerous measurements [1,2].

2 Characteristics of the frame

The basic frame of the machine is formed by a framework of parts connected mutually by welds. The frame consists of a base, sideboards, cross beams, the base plate of the knitting cylinder, flexible damping elements (silent-blocks) and struts. The shape, the mutual connection and position of the said parts define the rigidity of the system to a large degree. The base plate is connected to the frame by silent-blocks, serving to reduce the transfer of vibrations upon the frame. For fastening of silent-blocks a screwed connection to the cross beams has been selected. The small-diameter knitting machines are set with silent-blocks of cylindrical shapes.

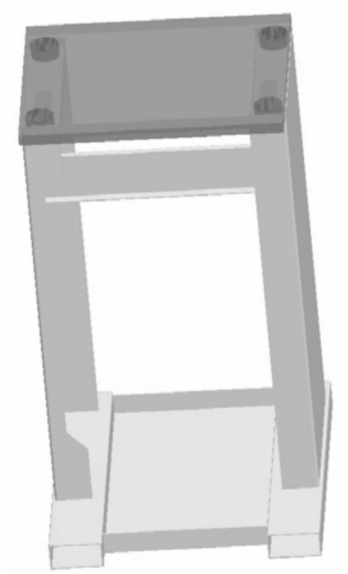

Fig. 2 Frame of knitting machine

For obtaining the information of the behaviour of the system there serves its complex description by means of a verified mathematical model. The mathematical model of the system compiled in a complex manner enables to study the points at issue in detail, to propose an effective way of determining suitable parameters of the system, and to compare realised modifications; it allows for its optimisation too. The results obtained by the solution of the compiled models can be of help in setting the orientation of further development. A partial objective of the solution is to carry out an analysis of the design and determination of mutual links and dependencies. The results of the work will enable to propose certain exact procedures for obtaining suitable parameters of the design of the knitting machine frame, and, consequently, they will allow realising a complex proposal of a new generation of small-diameter knitting machines, based in employment of controlled drives.

The transmission of vibrations between the base plate of the machine and its frame is to be reduced by silent-blocks. In order to be able to devise a true mathematical model of the frame, it is necessary to know the mechanical properties of silent-blocks.

3 Measuring and determination of mechanical characteristics of silent-blocks

The dynamic methods of determination of deforming and damping characteristics of the material employ cyclical deformations of the sinusoidal wave (1) primarily.

$$x(t)= r_0 + r\sin(\omega t) , \qquad (1)$$

Where: r_0 – mean value of the amplitude, r – amplitude, ω – angular frequency, t – time.
However, owing to viscous properties of the material, a part of the work brought into the system is converted in heat irreversibly. The fig. 3 represents the dependence of the sum of damping and elastic forces of the silent-block on the amplitude of the deflection at a steadied harmonic course. The dissipation of energy in form of the work W_D is determined by the area of the hysteresis loop. This dissipation characterises the degree of internal damping, which is proportional to the energy converted in heat.

For the description of the characteristics of a damped mechanical system, viscous damping is employed most often. Its important advantage is the fact that it can be expressed simply, however, in the majority of cases, it characterises the behaviour of the real system. This model of behaviour of internal damping of the material is often understood as the so-called equivalent viscous damping. This parameter characterises the magnitude of the energy dissipation per one period of harmonic movement. If we have determined the value of energy Wd of the factual damping force, we can compare it with the work of equivalent viscous damping at harmonic vibration described by the relation (1). The referred dissipation energy is given by the relation (2) and on a base of it, the equivalent damping by the relation (3).

$$W_D = \int b_{ekv} \dot{x}\, dx = \int_0^{\frac{2\pi}{\omega}} b_{ekv} r^2 \omega^2 \cos^2 \omega t dt = \pi b_{ekv} \omega^2 r^2 \qquad (2)$$

For the constant b_{ekv} of equivalent damping there applies the following relation

$$b_{ekv} = \frac{W_D}{\pi \omega r^2} \qquad (3)$$

The aim of the realised measuring has been the determination of visco-elastic properties of the material of silent-blocks. For measuring, the silent-blocks of three different values of stiffness have been employed, which are used in the manufactured machines. In the text, these silent-blocks are designated in accordance with the value of their stiffness (High, Medium, Low Stiffness). All measured silent-blocks are of the same dimensions (diameter 65 and height 37 mm).

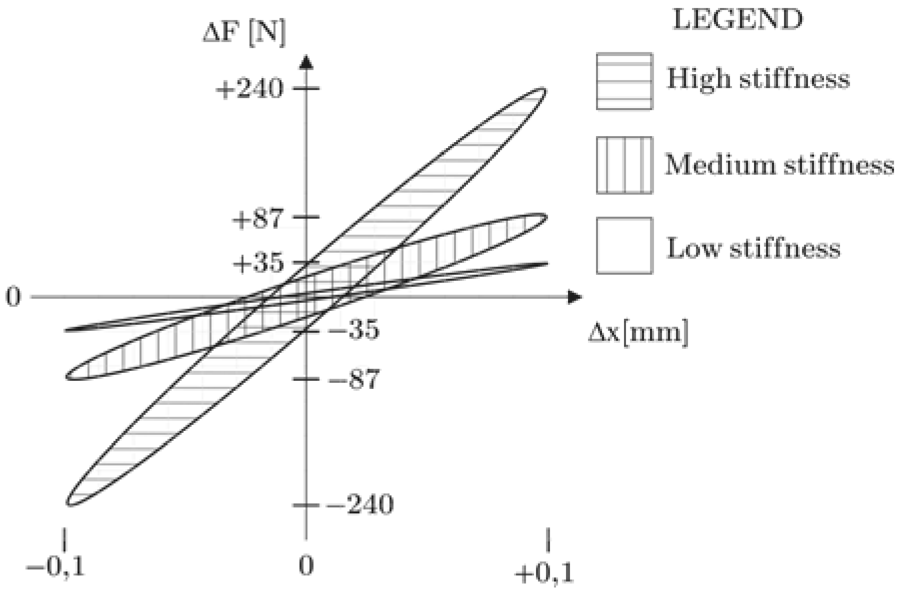

Fig. 3 Hysteresis curves

On the testing appliance Instron Electropuls E1000, the silent-blocks have been loaded with single-axis harmonic course of the change of the position *x(t)* according to the relation (1).

The values of the amplitudes r_0 and r have been constant in the whole measuring range. The employed values of frequencies f have been 5, 10, 20 Hz. The result of the measuring is a summary of data that represent the courses of loading and unloading of the silent-block. The output consists in hysteresis curves characterising the material properties, the area and inclination of which result from the material properties of the silent-block (fig. 3). The silent-block has been compressed by 0.5 mm since the first contact of the head with the front of the silent-block in the loading axis, which corresponds to the mean value of the amplitude. The amplitude of the compression has been adjusted to 0.1 mm. The force spent on the compression has been dependent on the stiffness, and consequently, it has varied with the individual silent-blocks. The obtained material values of the silent-blocks are summarized in Tab. 1 and 2.

Tab. 1 Stiffness of the silent-blocks

Silent-block	High stiffness	Medium stiffness	Low stiffness
Stiffness (compression load) [N/m]	$2398,3x10^3$	$874,6x10^3$	$349,5x10^3$
Stiffness (shear load) [N/m]	$262,8\ x10^3$	$151,1x10^3$	$55,2\ x10^3$

Tab. 2 Damping of the silent-blocks

Loading frequency [Hz]	Damping b_{ekv} [$N.s.m^{-1}$]		
	High stiffness	Medium stiffness	Low stiffness
5	7655,8	2435,8	327,3
10	3827,9	1217,9	163,7
20	1913,9	608,9	81,8

The measuring has shown that in the given loading range the silent-block can be modelled by means of the Kelvin-Voigt visco-elastic rheological model. The non-linearity of the material is hardly noticeable. These results allow for substituting the behaviour of a silent-block in the mathematical model by means of a linear material description.

There has been compiled a mathematical model of the frame in the software ProEngineer [3], which substitutes the real one with a sufficient accuracy. In this phase of the solution, the model serves for the description of behaviour of the machine at various types of the loading, resulting from individual regimes of knitting the sock. The individual parts of the frame contain a great number of technological and assembly elements, which are not of essential importance and have not been taken in consideration in the model as far as the rigidity is concerned, because of the endeavour to simplify it.

The fundamental studies describing the deformation properties of the machine frame have been carried out. These studies describe the effect on displacement of the base plate. In Fig. 4 the application of silent-blocks with low rigidity is displayed. It is evident that the most important one is the orientation of the base plate due to the dynamic torque from the engine.

4 Conclusion

For the modification of the design with the aim of analysis and optimization of the knitting machine frame, its mathematical model was built. The assembled model can effectively analyze the various modifications of the frame and propose the most appropriate topology of components. The paper shows the analysis of the frame behaviour with the change of the silent-blocks types. The analysis results illustrate unsuitability of the silent-blocks application with low stiffness. The inappropriate application of the silent-blocks increases the base plate deflection five-times compared to the silent-blocks with high rigidity. There is a significant deflection of the base plate of the small diameter knitting machine in the reverse movement. As a result of this there is an adverse effect on the final products and the increased failure rate of this machine.

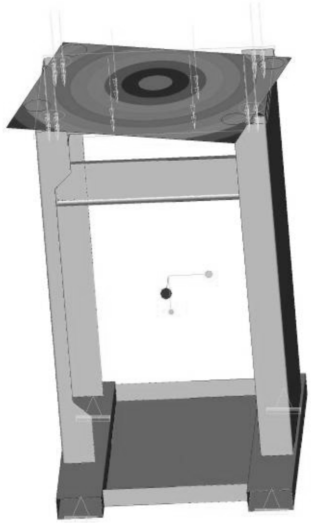

Fig. 4 Representation of loading of the frame

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DYNAMIKA RÁMU MALOPRŮMĚROVÉHO PLETACÍHO STROJE

Příspěvek se zabývá problematikou rámu maloprůměrových pletacích strojů. Rám pletacího stroje prochází v současné době konstrukčními změnami směřující k minimalizaci výrobních nákladů. Tento trend přináší snížení jeho tuhosti konstrukce. Jedna z nejvýznamnějších částí rámu s ohledem na jeho dynamické chování jsou silentbloky, sloužící jako vibroizolační prvek mezi základní deskou a rámem stroje. V příspěvku jsou zjišťovány viskoelastické vlastnosti tří typů silentbloků, požívaných na pletacích strojích

RAHMENDYNAMIK BEI DER STRICKMASCHINE FÜR KLEINE DURCHMESSER

Der Beitrag behandelt die Problematik des Rahmens bei den Strickmaschinen für kleine Durchmesser. Gegenwärtig erfolgen beim Rahmen der Strickmaschine die auf Minimierung der Produktionskosten gerichteten Konstruktionsänderungen. Dieser Trend bringt eine Verminderung der Steifigkeit der Rahmenkonstruktion mit sich. Einer der bedeutendsten Teile des Rahmens mit Bezug auf sein dynamisches Verhalten sind die als Element der Schwingungsisolierung zwischen der Grundplatte und dem Maschinenrahmen dienenden Schwingungspuffer. Im Beitrag werden die Zähigkeits- und Elastizitätseigenschaften bei drei Typen der bei den Strickmaschinen verwendeten Schwingungspuffer ermittelt.

DYNAMIKA RAMY MAŁOŚREDNICOWEJ MASZYNY DZIEWIARSKIEJ

Artykuł poświęcony jest problematyce ramy małośrednicowych maszyn dziewiarskich. Obecnie przeprowadzane są zmiany konstrukcyjne ramy maszyny dziewiarskiej, zmierzające do minimalizacji kosztów produkcji. Taki trend pozwala na obniżenie sztywności jej konstrukcji. Jedną z najważniejszych części ramy z punktu widzenia jej dynamicznego zachowania są silentbloki służące jako element wibroizolacyjny między płytą podstawy a ramą maszyny. W artykule są definiowane właściwości wiskoelastyczne trzech typów silentbloków stosowanych w maszynach dziewiarskich.