Zbigniew Kossowski, *Kazimierz Kopias

POLMATEX CENARO
Research Development Centre for Textile Machines
ul. Wólczańska 55/59, 90-608 Łódź, Poland
E-mail: kossowski@poczta.onet.pl

*Department for Knitting Technology and Structure of Knitted Fabrics
Technical University of Łódź
ul. Żeromskiego, 90-543 Łódź, Poland
E-mail:kopiaska@p.lodz.pl

Magnetoelectric Driving Device for Displacements of a Guide Needle Bar in a Weaving Loom

Abstract
The design and the working principles of a magnetoelectric actuator are presented. The designing principle is described, and the technical conditions required by an actuator are emphasised. A magnetoelectric actuator was designed and constructed on this basis, with the aim of driving the guide needle bar of a weaving loom equipped with rotating sinkers which form the shed and beat up the weft. The device described was tested under a loom's working conditions, and we concluded that it fulfils the demands stated.

Key words: *magnetoelectric actuator, guide needle bar, weaving loom, rotating sinkers.*

Introduction

Guide needle bars, in the shape of a support strip with guide needles mounted on it, are mainly used in warp knitting machines to guide the warp threads. The guide needles generally take the shape of a sinker with broadened end, with an opening in it through which the warp thread is threaded. Guide needle bars are also applied in looms with rotating mechanisms for weft forming and beating up the weft [1].

In all these applications, the guide needle bars are displaced abruptly (by impact jumps), and by small displacements, whose values depend on the needle gating graduation of the warp knitting machine, the kind of stitch manufactured, or on the graduation of sinker displacements which form the shed on a weaving loom.

Cam mechanisms are mainly applied to perform such displacements, whereas pneumatic mechanisms are used considerably less often, because of the need to apply additional compressed air installation. However, cam mechanisms have some disadvantages, the most serious of which is the relatively great inertia caused by the considerable number of intermediary links. The complexity of such a drive also results in smaller activity, maintaining the particular displacement positions. The mechanical elements of cam drives are displaced and become worn easily. It should also be mentioned that cam mechanisms are difficult to control, especially when the velocities and accelerations need to be changed. These negative features are of essential importance when considering the guide needle bars which drive the mechanisms dedicated to looms with rotating sinkers.

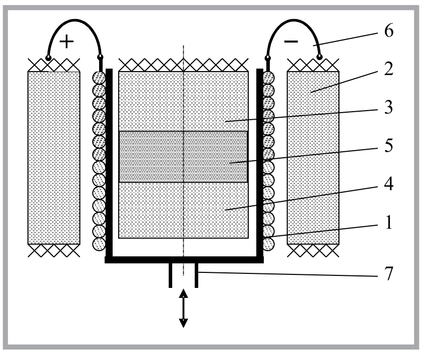


Figure 1. Scheme of an electromagnetic actuator; 1 – movable coil, 2 – jacket, 3 and 4 – shoes, 5 – permanent magnet, 6 – spring elements supplying the electric current, 7 – mechanical joint.

Aim of the investigation

The aim of the investigation presented in this paper was to develop a driving mechanism with features which would be advantageous compared to the parameters of the mechanisms hitherto used. An attempt was made to design such a mechanism with a significantly simpler structure, smaller dimensions, and which would be easy to control. Considering the intended application, an assumption was made that it should drive a guide needle bar with rotating sinkers which form the shed and beat up the weft.

Electromagnetic actuator. Assumption and preliminary design

Analysing the different possibilities for using driving devices, an electromagnetic actuator was chosen which was to be characterised by potential optimum features [2].

Such a device is simple in its construction, and thanks to the possibility of direct electric control, permits unlimited creation of the changes in force and linear displacements with time.

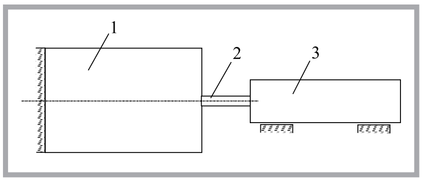


Figure 2. Model of a magnetoelectric drive of a guide needle bar; 1- unmoveable actuator, 2 – movable shaft driving the needle bar, 3 – movable guide needle bar with a mass of 1.7 kg.

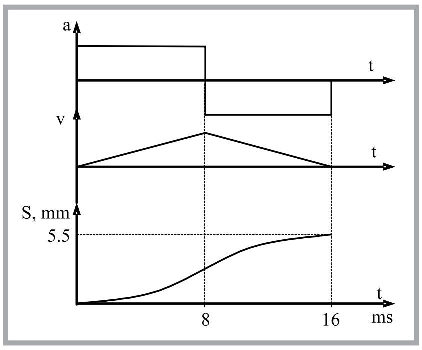


Figure 3. Character of displacements of the guide needle bar as a function of time; s- displacement, v – velocity, a – acceleration.

A brief scheme illustrating the concept of an electromagnetic actuator adapted for use in a loom with rotating sinkers is presented in Figure 1. Its action is based on the phenomenon of force generation as the effect of a magnetic field's interaction on a conductor through which electric current is flowing. A permanent, strong magnetic field generated in an air gap by a system of magnets and shoes interacts with coil windings placed in the air gap. As the effect of the current flowing through the coil, a force is generated in it, which is transmitted by a coil form on the element being driven. Changing the value and the direction of the current flowing in the coil, enables the value and the direction of the force generated to be controlled. The task accepted for the designed and constructed actuator was the displacement of the guide needle bar. It was accepted that the actuator would work as an independent device mounted together with a loom with rotating sinkers on a specially designed testing stand.

The actuator's working parameters result from the demands set for the weaving process and the structure of the elements being driven. In our case, the mass of the guide needle bar was 1.7 kg, the working travel 5.5 mm; the time over which this displacement would be realised was not to exceed 16 ms. The accuracy of any given position taken should be no worse than ±0.1 mm, and the frequency of switching-over should be equal to 1000 per min. The switch-over jumps must be synchronised with the positions of the loom's sinker shafts. The signals which release the switch-over jumps advantageously should be generated by an electrical proximity detector connected to the loom's driving shaft.

A simplified model of the system, presented in Figure 2, was accepted for preliminary determination of the actuator's parameters. The character of the displacements accepted is shown in Figure 3.

The following values of average and maximum velocity, and the required maximum acceleration, result from the above-mentioned assumptions:

v_{av} =5.5 mm/16 ms = 0.366 m/s
v_{max} 2 v_{av} = 0.733 m/s
a = v_{max}/t = 0.733 m/s/8 ms = 91.67 m/s^2

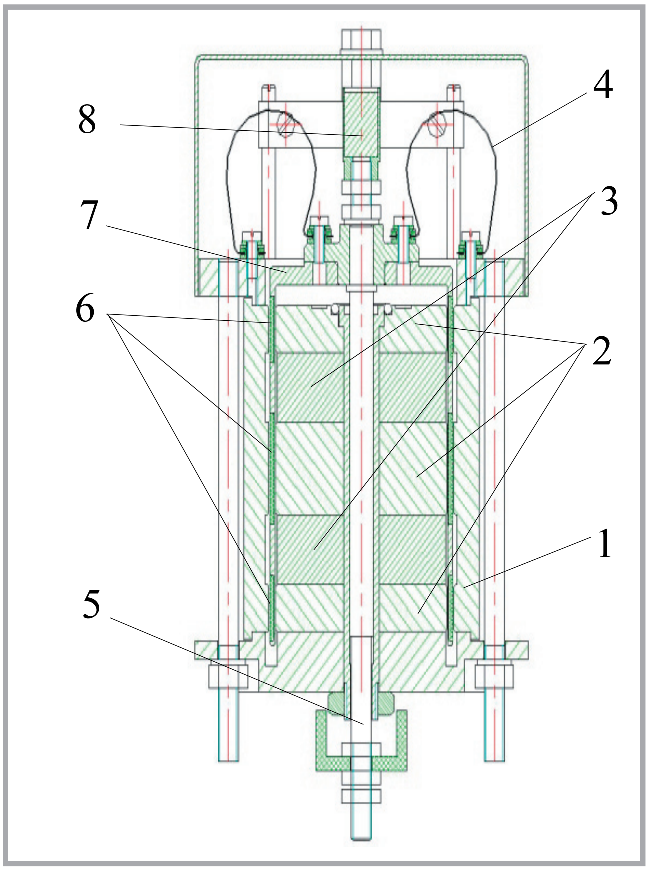
The knowledge of acceleration enables us to calculate the force which should be generated by the actuator:
F = ma = 1.7 kg×93.75 m/s^2 = 159.4 N

The calculations presented above are only estimates, and do not consider friction, damping, or other factors which are unknown at this stage of the investigation. According to the results achieved so far, the required force should be greater by 20 to 30%. Therefore the total force should be equal to about 200 N.

The assumptions presented above were the basis for selecting the actuator's configuration, calculating the dimensions of magnets and shoes, and the electrical parameters of the coil. The calculations of magnetic and electric parameters are very complex. Considering that the actuator we designed was a completely new solution, a need arose to carry out a series of analyses and preliminary calculations for many different constructional and dimensional configurations.

We developed a calculation model with the use of the Matlab Simulink program, which enables a computer simulation of the drive behaviour, with the aim of checking the selected parameters' correctness theoretically.

Figure 4. Electromagnetic actuator for driving a guide needle bar; 1 – jacket, 2 – shoes, 3 – magnets, 4 – current spring connectors, 5 – shaft, 6 – windings of the coil, 7 – carcass of the coil, 8 – magnet of the proximity detector.



Construction of the actuator

The design of the electromagnetic actuator was developed on the basis of the assumption presented above, as well as the simulation analysis carried out. Its structure is shown in Figure 4.

An actuator constructed on the basis of the presented design was operated on the stand in co-operation with a control unit. The aim of the control system was to change the voltage which supplied the coil, in such a way that the character of the displacements required of the guide needle bar driven by the actuator could be achieved. Furthermore, the needle bar

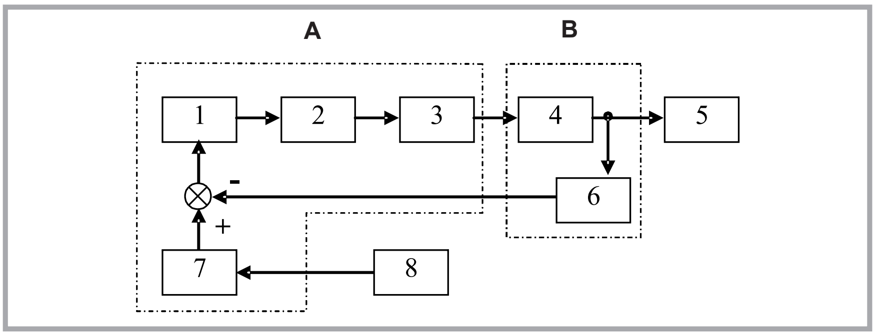


Figure 5. Block scheme of the drive control system; A - controller unit, B - actuator unit, 1 – PD controller, 2 – signal amplifier, 3 – H-type transistor bridge, 4 – magnetoelectric actuator, 5 – guide needle bar, 6 – proximity detector, 7 – unit transmitting the driving shaft position into the setting value of the needle bar position, 8 – proximity detector of the shaft driving the needle bar.

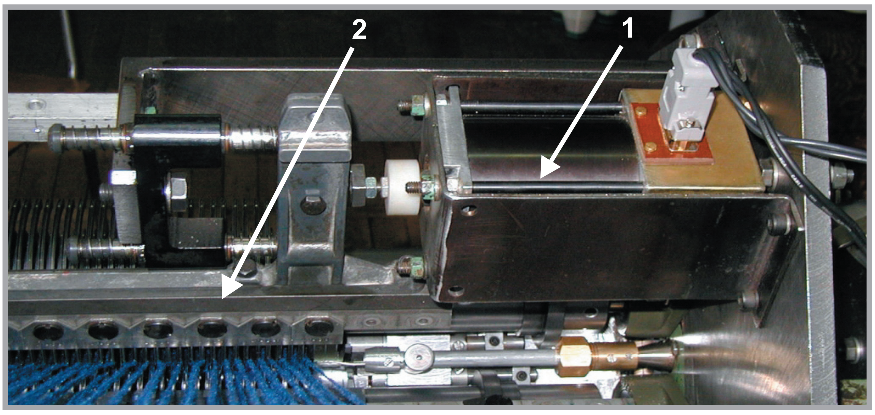


Figure 6. Connection of the actuator (1) with the machine's body and the guide needle bar (2).

was maintained by the control system at the particular positions with an accuracy of ±0.1 mm. After carrying out a series of analyses and model tests, the control system presented in Figure 5 was accepted.

The analogue proximity detector, which is necessary to realise the feedback for the control system, was designed on the basis of an original solution applied in the magnetoelectric timing gear system of a combustion engine [3]. The action of this detector is based on measuring, with the use of a Hall sensor, the horizontal component of the magnetic field as generated by a movable cylindrical magnet connected with the coil's carcass.

After successfully carrying out laboratory tests, which confirmed the correctness of the system's action, the actuator together with the control system and supply unit was arranged on the test stand of the weaving loom. Taking into account the research character of the test stand, the actuator and the supply unit have been further used as independent units, not permanently attached to the machine. The connection of the actuator with the machine's body and the guide needle bar is shown in Figure 6.

Summary

Investigations carried out with the use of a loom with rotating mechanism which forms the shed and beats up the weft, indicated the following:

- the parameters of the magnetoelectric actuator correspond to the preliminary assumed, and enable the realisation of the displacements required,
- the accuracy of maintaining a particular position is better than ±0.1 mm, and
- the analogue control system with a simple structure and PD character ensures a correct action of the actuator, and above all the achieving of the positions required in the shortest possible time without overshoot or oscillations.

Conclusions

- The developed type of magnetoelectric actuator can be used for driving the guide needle bar in looms with rotating sinkers, which form the shed and beat up the weft. This function has been confirmed in the details.
- The actuator developed can be used in warp knitting machines, although the finally construction should be tested in detail, depending on the machine used.
- The developed type of actuator can be applied to drive various machine elements, whose amount of displacement may change in succeeding working cycles, according to an assumed displacement programme.

Acknowledgment

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Leonardo da Vinci European Programme

Innovative, Using Multimedia, E-Learning for the Textile Industry

etex

19-20.06.2006 – Meeting of the participants' representatives at TU Łódż

The Department for Knitting Technology and Structure of Knitted Fabrics of the Faculty of Textile Engineering and Marketing at the Technical University of Łódź (TU Łódż) is participating as one of 13 partners in the two-year Leonardo da Vinci European Programme, which deals with textile science and technique; the programme is entitled 'Innovative, Using Multimedia E-Learning for the Textile Industry - etex'. The following six technical universities are participating in the programme: University of Liberec, Czech Republic; Leeds, Great Britain; Krefeld, Germany; Dornbin, Austria; Minho, Portugal; and Łódź, Poland, as well as textile associations and enterprises from the above-mentioned countries. The project's coordinator is the Education Centre of Saxony's Economy (Bildungswerk der Sächsischen Wirtschaft EV).

The university partners elaborate particular thematic sections concerning knitting structure, technique, and technology. The Department for Knitting Technology and Structure of Knitted Fabrics at TU Łódż is responsible for preparing the material concerned with multimedia education on knitting raw materials and yarns, as well as with the structure and technology of warp knitted fabrics. The structure of warp knitting machines will also be discussed.

After the project concludes in October 2007, the Faculty of Textile Engineering and Marketing will be equipped with a modern multimedia educational programme for the field of knitting, which will include a rich visualisation of processes, techniques and textile structures, as well as exercises which would enable supervision of the students' knowledge. This programme will significantly raise the quality of the students' education.

Department for Knitting Technology and Structure of Knitted Fabrics
Faculty of Textile Engineering and Marketing
Technical University of Łódź
ul. Żeromskiego 116,
90-924 Łódź, Poland
E-mail: kjkowalski@p.lodz.pl