

# Multi-Barrier Electromagnetic Tensioner for Control of Yarn Tension in Processing

## Abstract

We evaluate the known solutions regarding the tensioning of yarn in the operations of winding, warping, doubling, etc. The conventional tensioners that have so far been used in the textile industry are described and analysed. We present our own original design for a frictional electromagnetic tensioner in which the nipping load, applied to several ferromagnetic, flexibly inter-coupled nip plates (barriers) is induced by the poles of an electromagnet. Under each barrier (nip plate), the thread or yarn is imparted with part of the tension gain. Tests in which the practical operating performance of the electromagnetic tensioner was compared with that of the conventional disk and compensating tensioners showed that the electromagnetic tensioner was significantly superior.

**Key words:** electromagnetic tensioner; barrier plate; yarn tension; control.

## Introduction

In some textile technological operations such as the winding of yarns, weaving, warping, twisting, etc. the yarn is imparted with tension which – due to the varied resistance it encounters along its path – has a stochastic character with a clearly identifiable periodical component (the dynamic component). Not infrequently, the dynamic component instantaneously reaches a level that is destructive to the structure of the yarn, even up to the point of breakage.

The variation of yarn tension, especially in the formation of a package, has a negative effect on its technological properties, and therefore it is necessary to use suitable tension-stabilising devices on the winding machines, of. The function of such devices, called tensioners<sup>1)</sup>, is to ensure that the tension of the yarn is maintained at a pre-set mean level, and that its dynamic component is reduced to certain limits. In the textile industry, use is mainly made of mechanical tensioners which can be adjusted to the required yarn tension, although it is desirable that the modern machines should be outfitted with active computer-controlled tensioners with the possibility of programming yarn tension at the desired level independently of the motion parameters of the yarn and its initial tension.

At present, there are no effective yarn tensioning systems that would permit yarn tension to be controlled in the manner required by the technological process.

The presented design of a frictional tensioner in which the nipping force is distributed among several pliantly inter-coupled nipping elements ensures that the yarn being tensioned acquires part of the overall gain in tension. In special cases, the nipping load can be generated by compressed air or hydraulic means, instead of by an electromagnet. In addition to substantially reducing the dynamic component of tension, the tensioner, as presented, enables its mean value to be controlled.

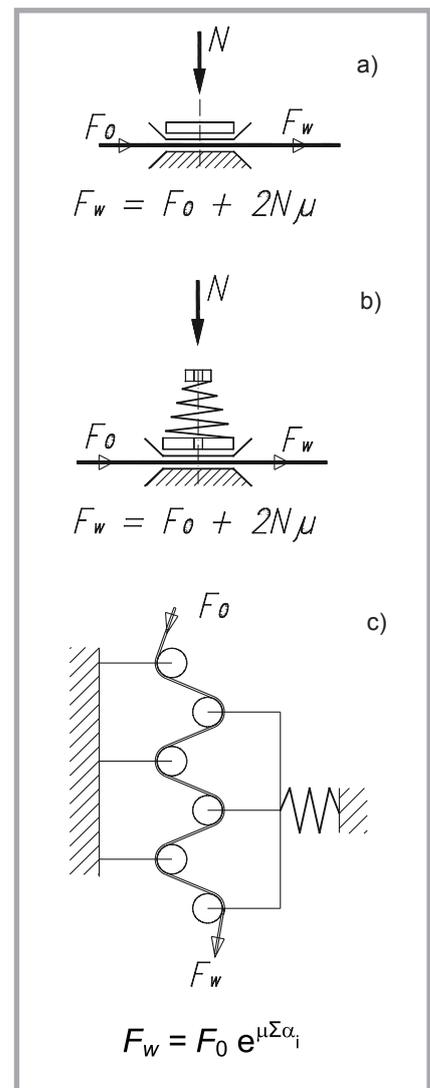
## Yarn tensioners; the contemporaneous state of the art

A scientific approach to the problem of tension generated in threads of yarn during the operations of winding, warping, and weaving was started at the Technical University of Łódź in the 1970s by Szosland [8] and co-workers (J. Lewiński, M. Czołczyński and M. Snycerski). Their work was pioneering in character and made a significant contribution to the improvement in quality of the aforementioned processes. The other publications are concerned only with fragmentary issues of the problem, and are focused on the practical aspects of the tensioners. According to Szosland, the known tensioners can be divided into the following two groups:

- Simple tensioners utilising the force of friction, which impart a definite tension to the thread of yarn by exerting a pre-set transverse pressure on it, or making it run round a fixed friction element that is circular in cross-section

tion and has the possibility of adjusting the wrap angle;

- Self-adjusting tensioners maintaining a constant (time-weighted mean) value of tension by means of various sys-



**Figure 1.** Schematic diagrams of simple tensioners: a) gravity-loaded tensioner; b) gravity/spring-loaded tensioner; c) wrapping tensioner.

tems of levers responding to changes in tension of the yarn by correspondingly varying the force of pressure of the spring-loaded elements.

The problem is therefore confined to the three basic solutions presented in Figure 1, where the principles of operation of the simple tensioners are illustrated together with description of the relationships between the output tension from tensioner  $F_w$  and input tension to the tensioner  $F_0$  with consideration of pressure  $N$ , friction coefficient  $\mu$ , and wrap angle  $\alpha$ .

The tensioners with nip applied transversely to the yarn path-line are divided into gravity-loaded tensioners, spring-loaded tensioners and gravity/spring-loaded tensioners, while the frictional (wrapping) tensioners are divided into ladder and clutch tensioners. The catalogues from Savio and Schlafhorst, the leading manufacturers of yarn-winding machines, refer to compensating roller tensioners in which the thread passes round an electro-magnetically braked roller.

A complex investigation of known mechanical tensioners with reference to the dynamic tension of yarn in warping was carried out by Lewiński [5], revealing their fundamental disadvantages. The author suggests that the disk tensioners do not adequately stabilise yarn tension in winding, because if a thick place or knot in the yarn impacts upon a disk, tension in the yarn grows rapidly, while the vibration which is induced by the impact reduces yarn tension to nil, although a repeated contact of the yarn with a disk generates in it an additional dynamic component of tension. This phenomenon takes place regardless of how the disk is loaded, although it is most apparent in the gravitational tensioners. Hence, instead of being reduced, the dynamic component of tension is increased.

Tensioners of the frictional type, in which the yarn encircles a fixed friction element of the circular cross-section, were investigated by Kapusta [3] who found that regardless of their design they exponentially augmented the vacillation of the initial tension of the yarn (according to Euler's relation), and they likewise amplified its dynamic component. In this group, only the compensating tensioners stabilise the mean value of yarn tension by varying the wrap angle to restore the balance of forces in the mechanical system. However, the compensation applies

only to the mean values of yarn tension. Upon a rapid change in the initial tension, the response of the wrap-angle adjusting system is dependent on the inertia of the moving elements, including those around which the taut yarn is encircled. A disadvantage of these tensioners is the occurrence of 'seizure' of the encircled elements at the bearing points of the system, and some phase shift of the output pressure in relation to the input pressure. As there are no better solutions, the industry has to put up with the drawbacks of the tensioners, since despite their imperfections they contribute some improvement to the quality of the process and product (the package).

Kapusta's work has helped to better understand the physical phenomena taking place in the tensioners, although questions still remain unanswered. This has encouraged the authors of the present publication to continue this work, especially to explore the aspect of tension control and reduction of the dynamic component of tension.

### The multi-barrier electromagnetic tensioner

The new tensioner, developed at the Institute of Terotechnology, is an electromagnetic tensioner provided with multiple barriers in the form of ferromagnetic plates which exert pressure on the yarn. Theoretically, the more plates, the better; but since the geometry of the machine is a limiting factor, there is no need for their number to be greater than 15 (if plate width < 4 mm).

A schematic diagram of the electromagnetic tensioner is presented in Figure 2.

The yarn thread passes between the ceramic plate fitted between two pole pieces of the electromagnet and ferromagnetic barriers (plates) mounted on a flexible strip suspended on the swing frame. All is enclosed in a housing with fitting holes, so as to form a closed magnetic circuit.

Tension in the yarn is dependent on the pressure of the plates, the pressure being a function of the magnetic stream corresponding to the amp-turns of the electromagnet. If a yarn is inserted in the tensioner, there will always be air gaps in its magnetic circuit which depend in size on the diameter of the moving yarn. Any

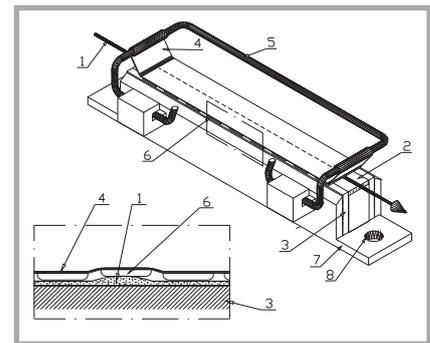


Figure 2. Electromagnetic tensioner: 1 – thread of yarn; 2 – ceramic plate; 3 – pole pieces; 4 – flexible tape; 5 – swing frame; 6 – ferromagnetic plates; 7 – housing; 8 – fitting holes.

local thick place in the yarn will increase the gap between the given barrier and the pole piece. This results in a significant increase in the magnetic resistance in the circuit leg of the barrier and a reduction of the magnetic stream. At the same time, assuming that the magnetic stream maintains a constant value in the whole system (Kirchoff's second law for magnetic circuits), the magnetic stream connecting the remaining pressure barriers will increase correspondingly, and eventually increase the forces acting on the yarn.

$$F_w = F_0 + \sum_{i=1}^{i=k} f_{w_i} \quad \text{where: } f_{w_i} = \mu \cdot N_i,$$

wherein:

- $f_{w_i}$  – the tension of yarn induced by the  $i$ -barrier;
- $N_i$  – the individual pressure of the  $i$ -barrier on yarn
- $\mu$  – coefficient of friction.

Since the nip is induced electromagnetically, the tensioner – in addition to imparting tension to the yarn and substantially reducing its dynamic component – may function as an individual or centrally controlled tension adjuster and, if need be, as a controller of the mean tension of the yarn also.

A schematic diagram of the electromagnetic tensioner for yarn tension control is presented in Figure 3.

The tensioner is designed to co-operate with a sensor for continuous measurement of yarn tension and a suitable signal converter with feedback for automatic selection of the required setting of yarn tension. With the present availability of miniature electronic hardware, the task should not be difficult to achieve.

Photographs of the tensioner, opened to show the armature, and the tensioner test

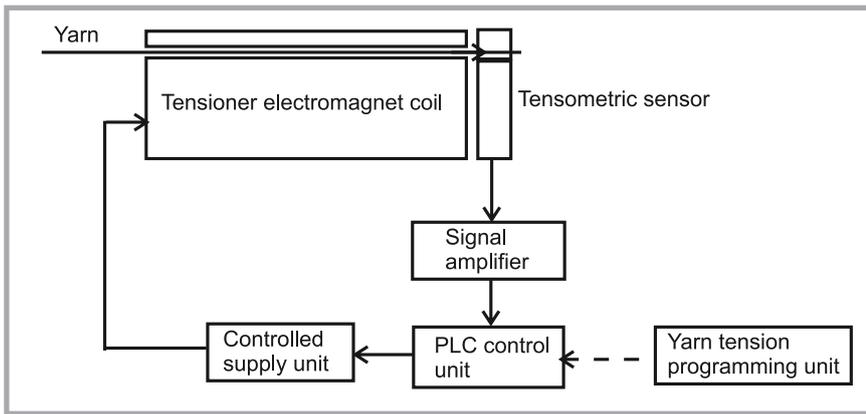


Figure 3. Schematic diagram of the electromagnetic tensioner for yarn tension control.

station with tensometric sensors are presented in Figure 4.

### A comparative study of tensioners

To characterise the properties of the multi-barrier electromagnetic tensioner, a study was carried out in which it was compared with the conventional disk tensioner (Majed) and compensating tensioner (Huys) [2].

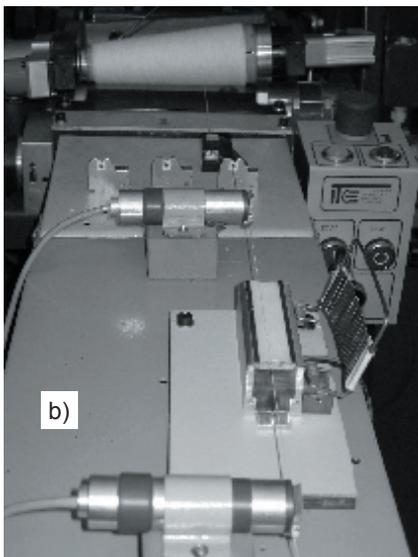
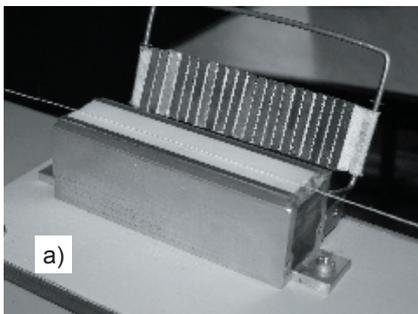


Figure 4. Electromagnetic tensioner; prototype design: a) tensioner in opened condition; b) test station.

Yarn tension was tested in the formation of a cross-conical package on a model computer-controlled precision doubler-winder. During the process, it was possible to adjust any of the settings, such as winding speed, number of yarn crossings along the package, length of wound yarn, etc. The tensioners were tested at yarn speeds ranging from 300 to 900 m/min, and at yarn tensions not higher than 100 cN.

The primary test was to record the length/time relations and the variable values of nip applied to the yarn by the tensioners tested. Yarn tension was tested using tensometric sensors<sup>2)</sup> for dynamic testing of the yarn.

The recorder was a Textronix TDS 220 oscilloscope, and the data base was provided by a PC on which, by using Excel, it was possible to calculate the statistical parameters, e.g. the mean arithmetic value of tension  $F_w$  in successive time intervals, standard deviation  $s$  as scatter of the test results, and the coefficient of variation  $v$  characterising the relative deviation of test results from the arithmetic mean  $F_w$ .

The effect of tensioner supply voltage as a factor influencing yarn tension at various values of winding speed is presented in Figure 5.

The comparative tension-time relationships recorded in the winding of a 50 tex cotton carded yarn at a constant mean tension of 50 cN and winding speed of 600 m/min are presented in Figure 6.

The tests proved the following statements:

- The existing relationship between the voltage supplied to the tensioner electromagnet and the tension in the yarn

induced by the nip of the ferromagnetic plates can be utilised to control the yarn tension in winding;

- In tests on the electromagnetic tensioner (Figure 6.a), it is clearly noticeable that the time-tension recording has a character of 'white noise', with a much higher frequency than on other tensioners, and with a stabilised amplitude about 20-25% of mean tension, although sporadic peaks (occurring when the yarn guide changes direction) may be as high as 40% of mean tension.

For comparison, with the compensating tensioner (Figure 6.b) and disk tensioner (Figure 6.c), the amplitudes of instantaneous values may be as high as 80-100% of the mean value of the tension. This means that the performance characteristics of the electromagnetic tensioner are significantly superior to those of the conventional tensioners.

Furthermore, the dimensions of the prototype electromagnetic tensioner, which are 80×30×35 mm, fall within the interval of the typical dimensions of all generally used tensioners.

The tensioner is for universal application, which means that it can be used equally well on knitting, weaving, winding, and warping machines. The authors envisage its use in the winding and forming of

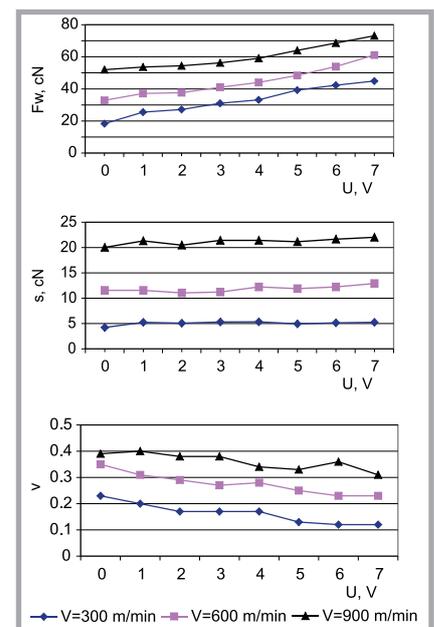
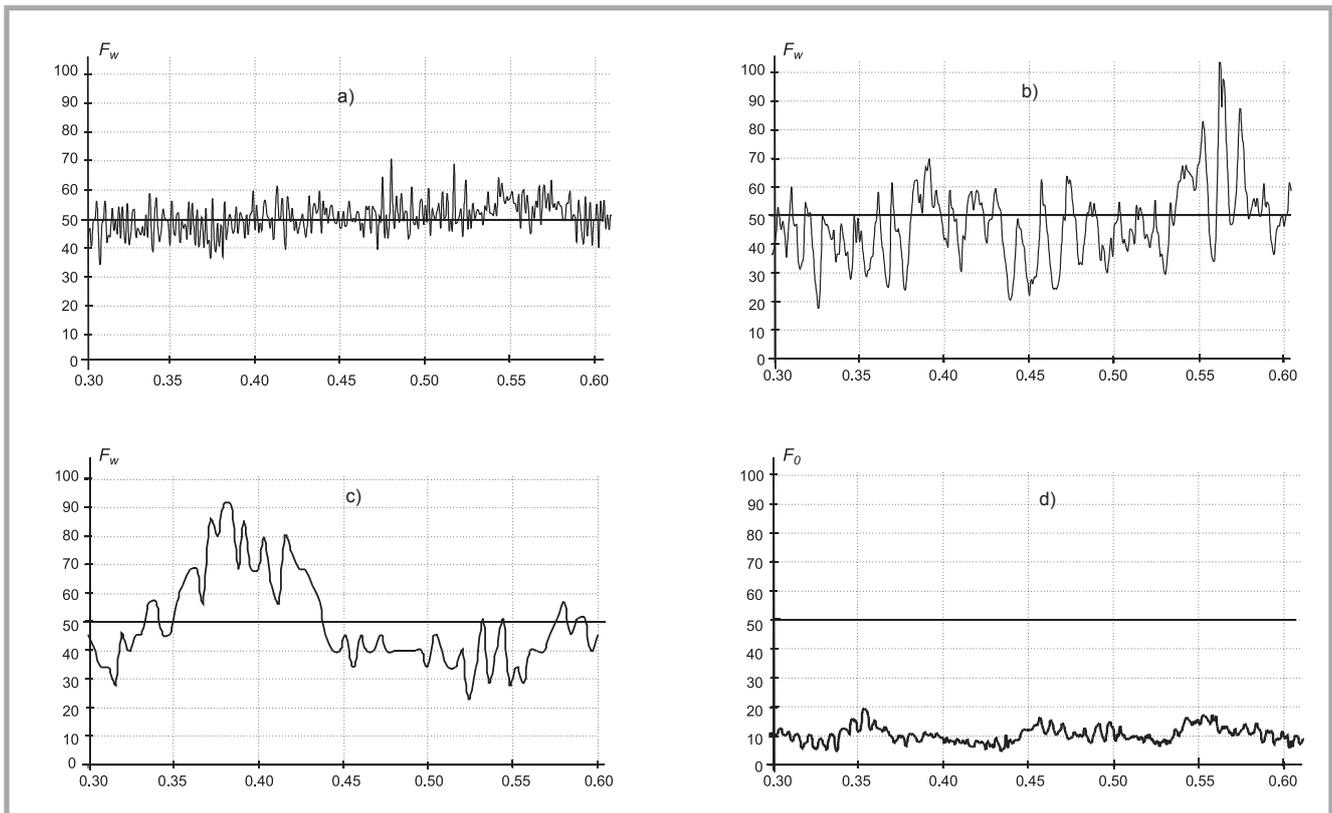


Figure 5. Effect of tensioner supply voltage on the statistical parameters at various values of linear speed of the yarn:  $F_w$  – arithmetic mean tension of yarn;  $s$  – standard deviation;  $v$  – coefficient of variation.



**Figure 6.** Graphs of yarn tension variation with time recorded at linear speed of 600 m/min and mean tension setting 50 cN; a) electromagnetic tensioner (our own design); b) Huys compensating tensioner; c) Majed disk tensioner; d) Yarn tension  $F_0$  before tensioners.

winder packages, among other possible applications, to vary the yarn tensions as a function of package diameter, which may be important in the case of certain synthetic fibres, and may in turn lead towards an optimisation of the winding process.

Currently, a controlled tensioner with rationalised geometry and magnetic properties is being developed.

## Summary

It has been shown that the multi-barrier electromagnetic tensioner is unquestionably a better technical solution than any of the known conventional tensioners used in the textile industry. First of all, it has no moving parts, its design is simple, and it is easy to fit on the machine and maintain. The magnetic circuit system of this tensioner ensures automatic compensation for the variation of tension in the yarn, which is also an advantage from the point of view of design. The mounting of the pressure (nip) barriers on a flexible strip considerably reduces the loss of friction in their guiding system (which improves the operating accuracy of the tensioner), while on the other hand reducing the mass of the accelerated elements, which gives an effective reduction of the

magnitude of the instantaneous changes of yarn tension.

The integration of the tensioner with the yarn tension sensor, which in co-operation with a specialised electronic system allows the tension to be controlled as required by the technological process, is an original solution not only for modern machines but also one that can be successfully applied to existing machines.

## Acknowledgments

This work has been carried out as part of the Task Project 'Model development of system of the yarn tension control in textile processes' No. 4 T08E 047 25, co-financed by the Ministry of Science and Information Technology.

## Editorial note

1) Tensioner – an adjustable device for braking the yarn while it is being unwound to give it a suitable regular tension [9].

2) Tensometric sensors designed and constructed by prof. K. Kowalski at the Technical University of Łódź.

## References

1. Fraser, B.W.; Ghosh, T.K.: 'On Unwinding Yarn from a Cylindrical Package'. *Prod. R. So. London* 1992.

2. HUYS N. S. [www.huys.tm.cam](http://www.huys.tm.cam), [www.zweigle.com](http://www.zweigle.com)
3. Kapusta, H.: 'Analysis of the thread-tensioner behaviour during the winding process'. Ph.D. thesis, Technical University of Łódź 1978.
4. Kurt W. Niederer: *New Yarn Tension Control Methods*. ATME 2003, Grinsboro NC.
5. Lewiński, J.: 'Dynamic threads' tension during the process of warping'. Doctoral thesis, Ph.D. thesis, Technical University of Łódź, 1975.
6. Ma, X.: 'Dynamic analysis of unwinding from cylindrical package' (in Polish). PhD thesis, Burlington Textile Library. NCSU 1997.
7. Wojtysiak, J. et al.: 'A model solution of yarn tension control system for textile processes'. Research project No 4 T08E 04725 ITeE Radom-Łódź, 2004.
8. Szosland, J.: 'Podstawy budowy i technologii tkanin'. WNT 1974.
9. Multi-author work – *Encyklopedia Techniki – przemysł lekki*, WNT-Warszawa 1986.
10. Przybył, K.: 'Modelling yarn tension in the process of manufacturing on the ring-spinning machine'. *Fibres & Textiles in Eastern Europe* Vol. 6 No. 3/1998 (22) pp. 30-33.
11. Yarn Tension Control Apparatus. US Patent No 4313578.
12. 'Yarn tensionar', Pat Appl. No. P-372024, 31.12.2004 of the Institute for Sustainable Technologies - National Research Institute, Radom.

Received 07.10.2005 Reviewed 13.04.2006