(REFEREED RESEARCH)

THE IMPACT OF THE FREQUENCY OF REED VIBRATIONS ON IMPROVING THE CONDITIONS IN THICKENING DENSE TECHNICAL FABRICS

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Received: 29.01.2016 Accepted: 08.09. 2016

ABSTRACT

The design of a vibration beat-up mechanism with a flexible reed and magnetoelectric vibration exciter is presented. A simulation model consisting of a thickening zone, working elements and electrically excited vibrations is elaborated. The results of the simulations of the vibration thickening of fabric are presented. The impact of the reed vibration in relation to the decrease in the dynamic loads of the warp or the increase in the produced fabric thickening of the weft is analysed. It was found that frequency improves the thickening condition. However, there is a threshold frequency beyond which the thickening condition cannot be further improved.

Keywords: Vibrating thickening of fabric, magnetoelectric vibration exciter, flexible weaving reed, beat-up mechanism.

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1. INTRODUCTION

A significant amount of initial and dynamic load build-ups occurs on warps during the thickening of densely woven technical fabrics made from aramid fibres, such as Kevlar or Twaron [1]. This is especially significant in relation to high capacities of modern looms. The German manufacturer of the *Yager SK560* loom, which has a double beating-up arrangement, has stated that the preliminary warp tension comes to *15,000N/m,* although the dynamic load during the thickening of wefts comes to *22,000N/m*. The speed of threading is *6 wefts/s*, where the width of the loom reeds comes to *3m*. Schönherr-Stäubli- Gruppe, the manufacturer of the *Alpha 500 Tech* loom, claims that the warp tension during thickening may exceed *12,000N/m*, while the width of the loom reeds comes to *5.3m*. Meanwhile, the Swedish manufacturer of the *Texo* looms claims that the preliminary load of the warp reaches *15,000N/m*, while the dynamic load during thickening-up is *30,000N/m*. The width of the loom reeds may reach up to be *9m*. The frequency of threading is up to *2.5 wefts/s* [2]. To improve the conditions of weft thickening, the reed is introduced by means of vibration. Additional vibration movements of the reed is characterized by a significantly lower amplitude and a higher frequency in relation to the essential movement of the reed, which results from the movement of the sley. Figure 1 shows a new beat-up vibration mechanism. The rigid sley 1 performs a programmed rotary-returnable movement around the axis, which implements the essential movement of the reed. In addition, reed 2 performs the vibration movement in relation to the sley using its own flexibility with regard to the reed blade. This movement is enforced by electromagnetic exciter 3 [3]. An increase in the frequency of the vibrating movement of the reed favours a reduction in the dynamic loads of the warp or the density of the produced fabric wefts. Assuming that the periodic constant voltage power supply of the exciter is the same, the increase in its frequency reduces the resonance amplitude of the reed movement [4]. In turn, the optimal range of the parameter is determined.

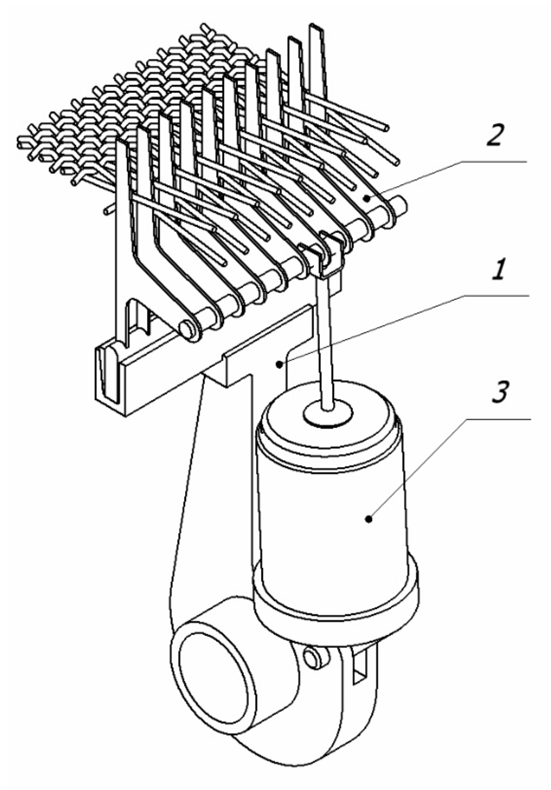


Fig. 1. Vibration beat-up mechanism

2. MATERIAL AND METHOD

Figure 2 presents a schematic model of a system consisting of a sley with a vibrating reed and a thickening zone (beat-up zone) in the wefts. The reed movement is analysed at the height of the fabric fell. Primary reed motion y_b is associated with the sley movement. The reed displacement relative to sley y_w is similar to the displacement of the moving parts in the exciter.

The movement of the weft inserted by reed y is the sum of the displacements of y_1 and y_2, according to relationship (1). The momentary relocation of the weft on the warp is marked y_l. The momentary displacement of the fabric fell on the fabric-warp system is marked y_2. The tension in the warp and fabric is, respectively, the sum or the difference between the pretension of warp Q_0 and the forces arising from the stiffness and damping [5], according to the dependencies (2 and 3). The dynamic reed load during thickening, which is defined as beating-up force Q_d, arises from the difference in tension between warp Q_S and fabric Q_T, according to dependency (4). The momentary pitch of newly introduced weft thread p arises from the difference between the contact distance between the newly introduced weft, the weft previously introduced as y_{max} and the momentary displacement of the weft on warp threads y_1 [6], according to dependency (5).

$$y = y_1 + y_2 = y_b + y_w , \tag{1}$$

$$Q_S = Q_0 + y_2 \cdot k_S + \dot{y}_2 \cdot c_S , \tag{2}$$

$$Q_T = Q_0 - y_2 \cdot k_T + \dot{y}_2 \cdot c_T , \tag{3}$$

$$Q_d = Q_T - Q_S \tag{4}$$

$$p = y_{\max} - y_1 \tag{5}$$

where k_S, k_T represent the warp and fabric stiffness and c_S, c_T represent the warp and fabric damping coefficient.

Figure 3 presents the predetermined value of the beating-up force in relation to the tension of warp Q_d/Q_S as a function of the momentary pitch of the new weft in relation to the diameter of thread *p/d* [5, 7].

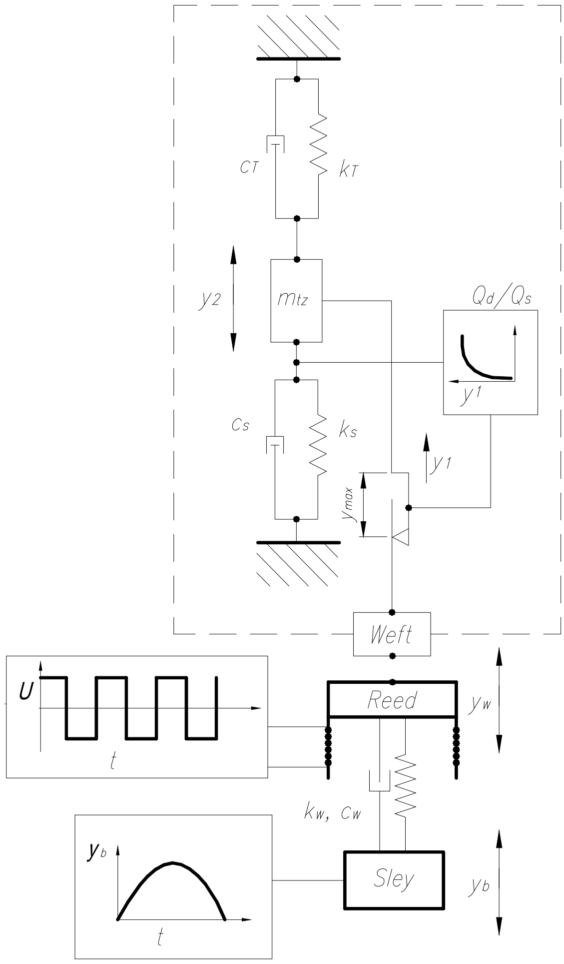
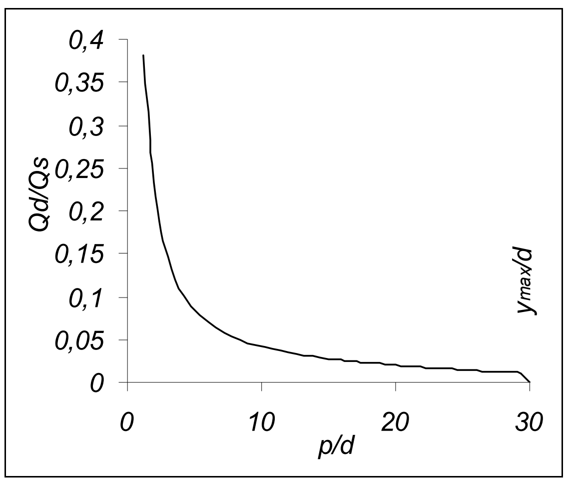


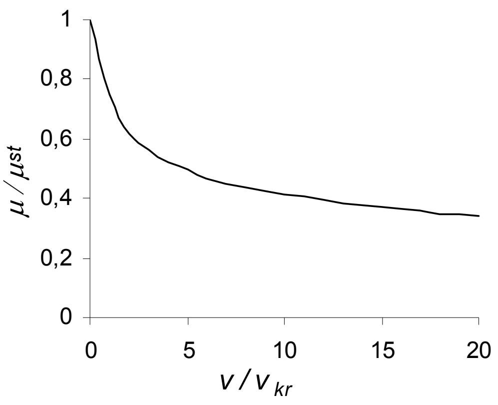
Fig. 2. SG1 System simulation model



[SG1]

Fig. 3. Ratio of Q_d/Q_S forces as a function of the relative pitch of new weft

A classic dry friction model [8], supplemented by an additional resisting force, resulting from the phenomenon of clinging, was assumed [9]. Adopted on the basis of the literature data [10], the run of the friction coefficient, which is a function relating to the speed of the movement of the weft on the warp, is represented by Figure 4. The value of the critical speed, which is a conventional boundary of static friction, was adopted at $v_{kr}=0.1m/s$.



[SG2]

Fig. 4. Relative friction coefficient of the weft on the warp as a function of relative speed

A fundamental vibration system stiffness k_w stems from reed susceptibility to bending, which defines its resonance frequency of f_w. The value of damping coefficient c_w is mainly due to the resistance action of the electromagnetic actuator [11]. By indicating excitation force Q_w, the equivalent mass of the reed and the moving parts of actuator m_w, the sum of the forces along the axis of the exciter is described by dependence (6).

The electromagnetic exciter, whose moving parts consist of coils, is characterized by relatively fixed inductance L, in terms of its movement [12]. With this assumption, marking C_e as an electric constant of the exciter means that the sum of the drop in voltage within the electric circuit is described by dependence (7) [13].The electric constant is the product of the magnetic induction in the magnetic circuit of the exciter and the lengths of wire wound around the coil. The excitation force is described by dependence (8).

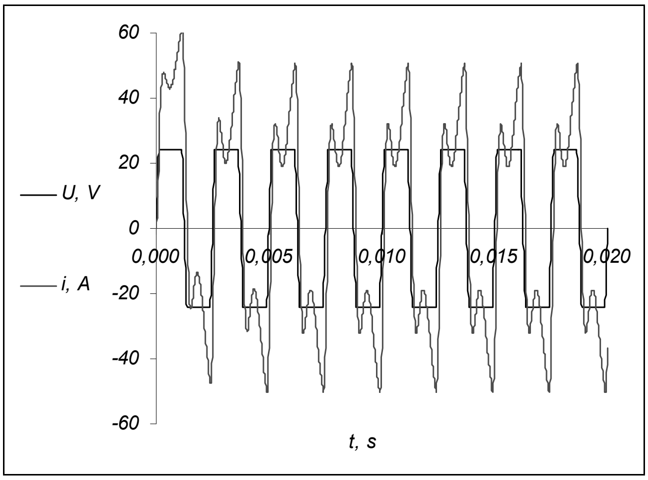
$$Q_d = \ddot{y}_w m_w + \dot{y}_w c_w + y_w k_w + Q_w , \tag{6}$$

$$\dot{y}_w C_e + L \frac{di}{dt} + Ri = u(t) , \tag{7}$$

$$Q_w = C_e i . \tag{8}$$

Dependencies described by equations (1-8) were modelled in the dynamic simulation module within the *Inventor 2009* software. For the calculation of electric parameters, the following values have been adopted: actuator coil induction $L=1mH$; resistance $R=0.1\Omega$; the value of the electric constant $C_e=5N/A$; the voltage of the power supply of the exciter $U=\pm 25V$; and the test frequency range $f_w=0\text{-}800Hz$. The value of the friction coefficient for the contact between threads was adopted as for aramid fibres, i.e., $\mu=0.28\text{-}0.11$ [14-19]. The range in the values of dynamic parameters of the model refers to a reed width of *200mm,* which is less than one exciter in the vibrating movement. Other values are as follows:

- Stiffness – system (reed blades=100) $k_w=1,000\text{-}16,000N/mm$, warp $k_S=60N/mm$, fabric $k_T=120N/mm$
- Damping coefficient – system $c_w=0.1Ns/mm$, warp $c_S=0.02Ns/mm$, fabric $c_T=0.03Ns/m$
- Thread diameter $d=1mm$
- Weight equivalent in vibrating system $m_w=0.18kg$
- Contact distance between the newly introduced weft and the previously introduced weft $y_{max}=10mm$
- Frequency of sley operation $f_b=5Hz$



[SG3]

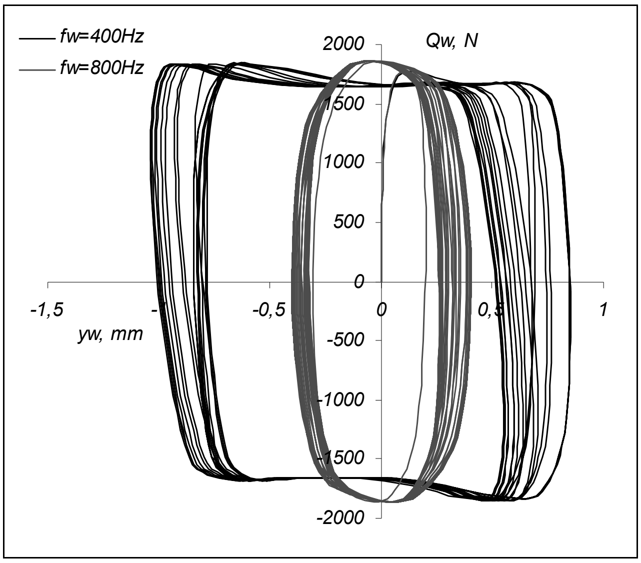
Fig. 5. Voltage and amperage of exciter coils as a function of time ($f_w=400Hz$)

4. RESULTS AND DISCUSSION

Simulation results are presented in the form of passes, examples of which are shown in Figures 5-9. The process concerning the supply voltage and the current of the coils is shown in Figure 5.

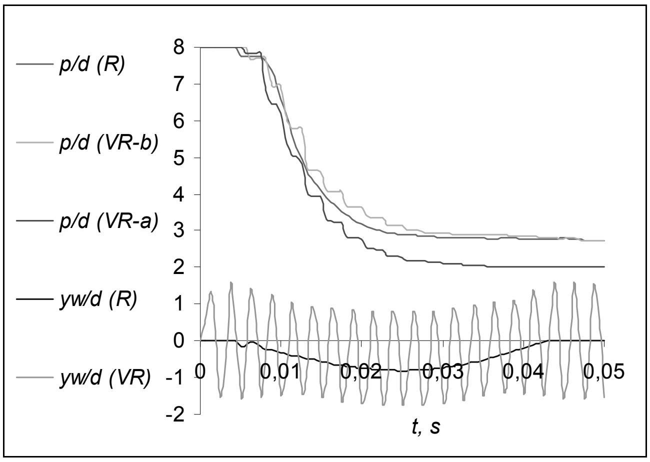
Figure 6 shows the excitation force in relation to the dislocation of the reed at the height of the fabric fell for two values of the excitation frequency. In the simulated changes involving the stiffness of the reed system in relation to the sley, the analysed frequency was concerned with resonance. By increasing the frequency, the amplitude of the vibration movement of the reed decreases.

In Figure 7, the one-cycle thickening runs of the relative momentary pitch of the produced fabric and the displacement of the reed against the sley are imposed upon themselves. The amplitude of vibration movement Y_w decreases, according to the fabric fell distance, from the moment of contact between reed and thickening weft, until the operating value Y_{wo} characteristic is reached for the beat-up datum. This is affected by the dynamic parameters of warp and fabric.



[SG4]

Fig. 5. Excitation force in relation to reed displacement *(f_w=400Hz and f_w=800Hz)*



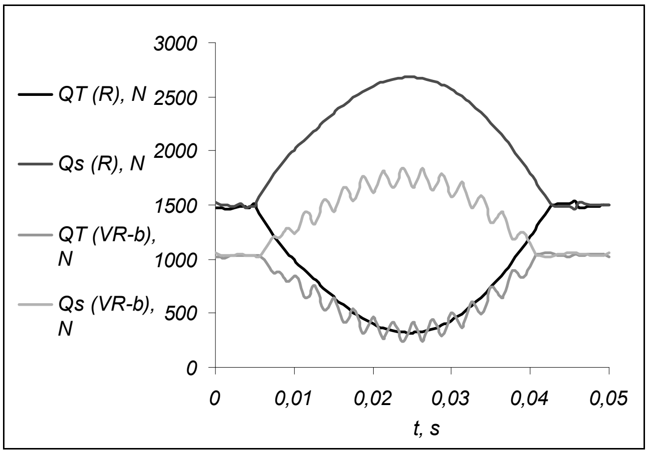
[SG5]

Fig. 7. Relative momentary pitch and displacement of the reed during vibrating reed thickening and rigid reed thickening *(f_w=400Hz)*

The comparative analysis of waveforms was based on three cases of fabric thickening as follows: 1) a rigid reed *(R)*; 2) a vibrating reed with a reduced fabric pitch, without changing the beating-up force *(VR-a)*; and 3) a vibrating reed with a reduced beating-up force and the same fabric pitch *(VR-b)*.

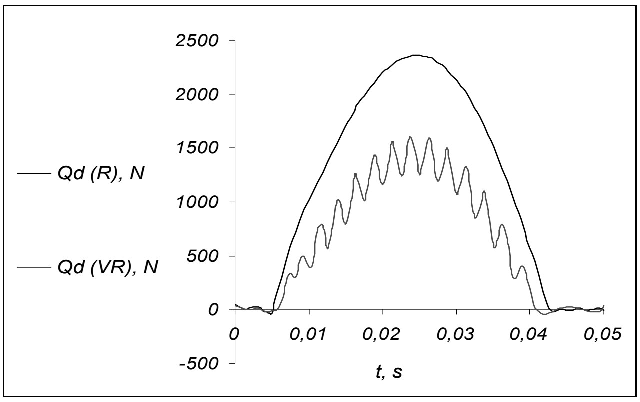
Figure 8 compares the warp tension forces and fabric during thickening for cases 1 and 3. During thickening with a reduced beating-up force *(VR-b)*, the warp preload tension can be reduced without risk of losing the fabrics, such that the tension in the fabric does not drop below a certain minimum level when the sley reaches the extreme front position. In simulations, 20% of warp preload tension was assumed.

Figure 9 shows the beating-up force designated on the basis of dependencies (4) for tests 1 *(R)* and 3 *(VR-b)* during a single thickening cycle.



[SG6]

Fig. 8. Reducing dynamic loads in the warp and the warp preload tension due to thickening by the vibrating reed *(f_w=400Hz)*

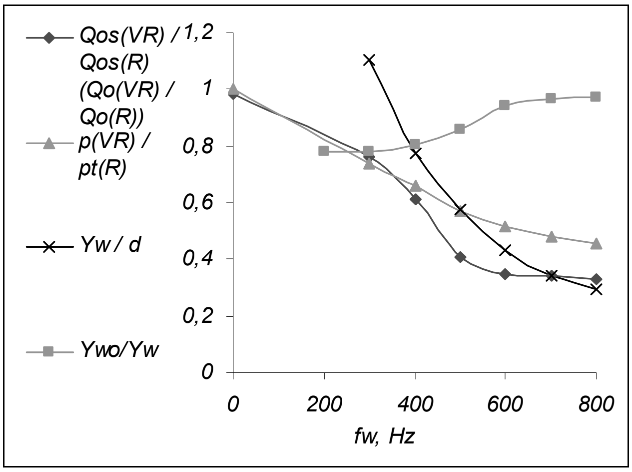


[SG7][SG8]

Fig. 9. Beating-up forces during thickening of the fabric with a rigid reed and a vibrating reed *(f_w=400Hz)*

In terms of the test case 3 *(VR-b)* option, the relative reduction in the warp preload tension and the warp dynamic load (Fig. 8) is determined. In terms of test case 2 *(VR-a)*, the relative reduction in the pitch of the produced fabric is defined (Fig. 7). The results refer to the terms in case 1 *(R)*. Furthermore, the relative amplitude of the vibration movement in the reed refers to the diameter of the thread.

In Figure 10, the results of the analysis of the performed simulation are presented as a function of the frequency of the reed-vibrating movement. Increasing the frequency affects the reduction of the warp dynamic load during the weft thickening by more than 60%. To a similar extent, the preload tension in the warp may be reduced. Increasing the frequency of a reed-vibrating movement makes it possible to increase the thickening achieved in the produced fabric by up to 50%. However, there is a frequency threshold beyond which thickening may not be further improved. In terms of this research, the frequency is in the range of *f_w=600-800Hz*. The reduction in the relative amplitude of the reed vibration movement, which is measured at the height of the fabric fell and in relation to the diameter of thread Y_w/d, is shown. The course of operating amplitude in relation to the amplitude occurring just before the contact between the reed and thickening weft Y_{wo}/Y_w is also shown. At higher frequencies, the effect of dynamic parameters of both warp and fabric is small in relation to parameters with regard to resonance of the system.



[SG9]

Fig. 10. Relative warp dynamic load, warp preload tension, pitch of weft in fabrics and amplitudes of reed vibration movement as functions of reed vibration frequency

5. CONCLUSION

The results of simulation studies indicate that, during thickening of dense technical fabric, the increase in the frequency of the reed-vibrating movement makes it possible to significantly reduce the warp load by up to 60%. Producing more dense fabrics is also possible. This phenomenon happens despite the decreasing amplitude in the reed-vibrating movement. However, there exists a threshold frequency beyond which the conditions for the thickening process of fabric are not further improved. In the case of this research, that frequency is in the range of f_w*=600-800Hz*. Besides, the increase in frequency shrinks the difference between the amplitude of the reed-vibrating movement, which existed before contact was made between reed and fabric, and the operation amplitude in the beat-up datum.

No data from the existing literature on vibration thickening for dense technical fabrics have been found. Results on experimental studies, which compartmentally confirm the results presented in this paper, are given in [4]. However, these studies were carried out with light yarns, where the effect of vibration thickening was not so high. To validate the results obtained from the simulation, experimental studies need to be carried out on vibration thickening of dense fabrics.

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