Mathematical Model of Elastic Heald

M. Bílek, Š. Kovář and J. Skřivánek

Abstract The paper is concerned with description of the mathematical model meant for an analysis of the movement of healds during the weaving cycle. The paper deals with the assessment of the current construction design fastening the heald into the heald shaft. The present condition is characterized by the increased heald loading which is caused by its impact on the supporting wire. As a result of this, the healds get considerably worn out and their service life of the heads is reduced. There is a possibility for passive resistance involvement to reduce the velocity of the heald impact on the supporting wire. In this variant of the solution, the friction between the heald and the supporting wire is used for the decreasing of the impact.

Keywords Weaving loom · Heald · Mathematical model · Shedding motion

1 Introduction

The means for realization of the paper objective has been a complex description of the system elastic heald—supporting wire, employing a verified mathematical model. Regarding the wide spectrum of diverse arrangement options for the system individual parts, the article does not intend to suggest any particular parameters of the construction design. However, the primary aim is to specify possible ways, which lead to its optimization.

It is not possible to find a larger amount of the papers which are focused on this theme in the case of the shedding motion analyzes. Some of them have been dealt

M. Bílek (✉) · Š. Kovář · J. Skřivánek
Technical University of Liberec, Liberec, Czech Republic
e-mail: martin.bilek@tul.cz

Š. Kovář
e-mail: simon.kovar@tul.cz

J. Skřivánek
e-mail: josef.skrivanek@tul.cz

J. Beran et al. (eds.), *Advances in Mechanism Design II*,
Mechanisms and Machine Science 44, DOI 10.1007/978-3-319-44087-3_42

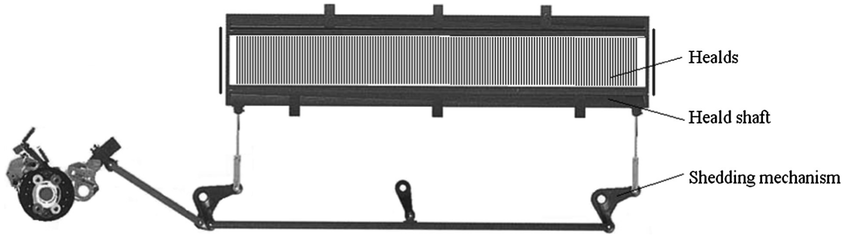


Fig. 1 Shedding mechanism

theoretically or experimentally with emphasis on the analysis heald frame [1, 2] or shedding motion [3, 4].

In general, the shedding mechanism can be classified into two sections: the driving section and the transforming section. In most cases the transforming section of the shedding mechanism involves joint mechanisms, which convert the rotational motion of the driving section into reciprocating motion of the heald shaft. Heald frame motion characteristics depend on the type of shedding motion.

The heald shaft is the frame in which there are fastened the healds operating warp threads (Fig. 1). The healds are fastened in this frame with a necessary designing play. Because of textile technology reasons, this play must enable axial displacement of the heald along the supporting wire. As the heald shaft performs reciprocating movement, the system of healds gets transferred during the weaving cycle. This transfer produces a load on the supporting wire upon which the healds impact, bringing as a consequence an increased stressing of the whole shedding mechanism.

2 Mathematical Model of the Elastic Heald

The studies realized up to now [5, 6] have shown that the heald is one of the most important part of the shedding motion and it exerts an important effect upon its dynamic loading. Because of this reason, it also constitutes one of the limiting elements, which impede the increase in its operational revolutions.

The heald is subjected to many forces, which determine the connection with the supporting wire. The most important ones are the dynamic forces of the heald, the warp forces in the sense of the shaft movement and the heald weight.

The analysis of the heald behaviour during the operating cycle has been realized using derived models of the heald. The motion equations describing the movement of the heald during the weaving process are complemented with motion equations of the shedding motion. In all compiled models, the mass of the heald mn is concentrated in one particle. The force T_o from the warp operates in the position of the thread eyelet. The action point of this force is located in one particle. It is possible to disregard the bowing of the heald due to its lateral loading. The derived models proceed from the assumption that the movement of the particle substituting the heald is carried out on a straight line.

At present, there are used flat healds made of a flat steel band by pressing process. The healds are contoured in the positions of their suspension eyes; however, it reduces their stiffness. Because of this reason, mathematical models have included different rigidities of the upper and lower sections of the heald (k_{nD}, k_{nH}) and different damping (b_{nD}, b_{nH}). In the mathematical model of the heald, Newtonian impact theory is employed. The drop description of the heald upon the supporting wire employs the presumption of a perfectly elastic impact.

There is a possibility for passive resistance involvement to reduce the velocity of the heald impact on the supporting wire. In this variant of the solution, the friction between the heald and the supporting wire is used for the decreasing of the impact. The proposal of the structural design using friction force for reducing the relative velocity of heald with respect to supporting wire is mentioned in [7] and scheme is on Fig. 2. In the referred design proposal, parts of inner surfaces of end eyelets are curved concavely, in order to create conditions for a slip of the end eyelet along a convex surface formed on the supporting wire. The relative velocity of the heald is reduced by effect of the friction force, and at the same time, the direction of the heald movement changes. In the solved case, there has been taken into account the calculation of the friction force according to this design proposal. In the following text, this mathematical model is referred to as the model 4.

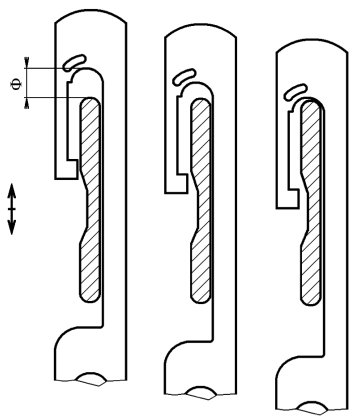


Fig. 2 Scheme of the design using friction force

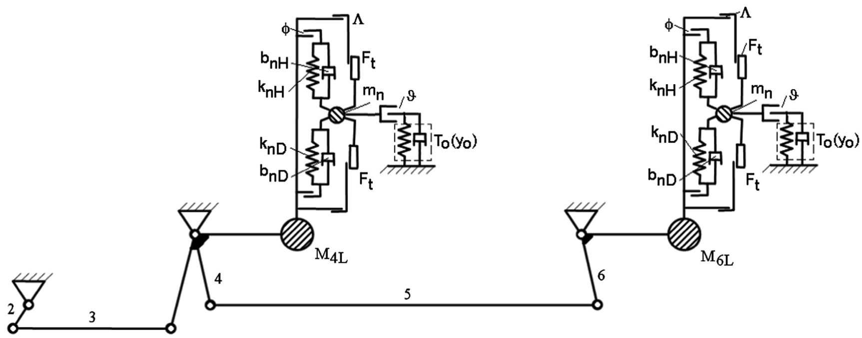


Fig. 3 Schematic model of the system shedding motion—elastic heald

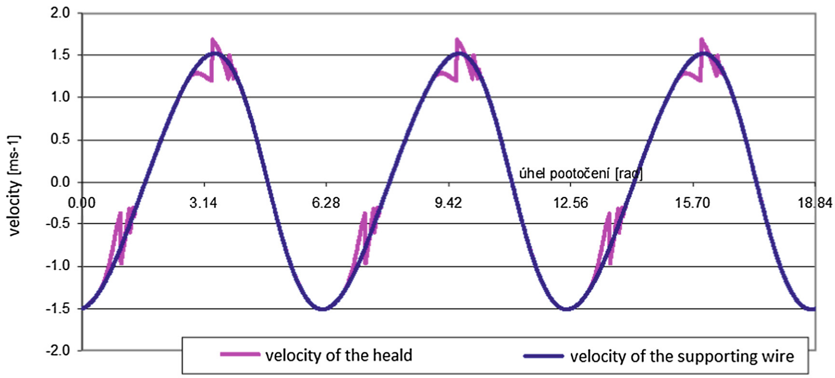
The mathematical model of the system with the impact damping of heald upon supporting wire is obtained by modification of the preceding model [5, 6]. The whole solved system can be represented schematically according to the Fig. 3. The motion equation describing the behavior of the heald during a revolution of the weaving loom has been complemented with a term characterizing the magnitude of the friction force.

The motion equation of this case can be written in the following form:

$$\begin{aligned} m_n \cdot \ddot{y}_{in} = T_o - m_n \cdot g + H \cdot k_{nH} \cdot (y_h - y_n) + H \cdot b_{nH} \cdot (\dot{y}_h - \dot{y}_n) \\ - D \cdot k_{nD} \cdot (y_n - y_d) - D \cdot b_{nD} \cdot (\dot{y}_n - \dot{y}_d) + H_2 \cdot F_{ty} \end{aligned} \tag{1}$$

The constants H, D and H_2 determine which members of the equation will be applied in the calculation.

The initial conditions of the solution proceed from the presumption that the heald is held on the upper supporting wire, and both its velocity and acceleration are identical with those of the upper supporting wire. The individual mathematical models has been solved using derived software. The solution of compiled differential equations describing the shedding motion coupled with an analysis of the heald movement during the weaving cycle has been effected by the Runge-Kutta method of the 4th order [5]. During the calculation, there have been studied the courses of the principal kinematic and force quantities of the system. The control algorithm of the calculation checks the position of the heald with respect to the supporting wire of the heald shaft. As mentioned above, there can arise six possible states which have been studied and on the basis of which there has been realized the calculation of the heald movement (Fig. 4).



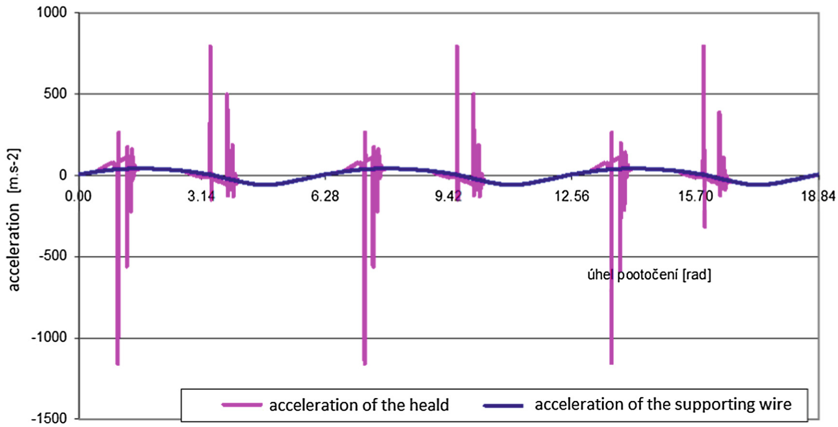


Fig. 4 The courses of velocity and acceleration of the heald shaft and of the heald for the operating velocity of the shedding motion 300 rpm

3 Conclusions

In order to reduce the impact velocity of heald on supporting wire, the friction between the heald and the supporting wire can be used, too. The friction force brings into the system a force effect, which causes a reduction of relative movement of the heald with respect to the supporting wire. In this order, the friction force does not affect the heald after its separation from the supporting wire, because the normal force between the heald and the supporting wire in this moment amounts to zero.

The use of passive resistances for reducing the velocity of heald impact upon the supporting wire proves to be less effective than the usage of a damping element [6]. The effect of the friction force is more significant with lower operating velocities. With increasing operating velocities, the effect of the friction force on the reduction of the maximum value of heald acceleration decreases.

Table 1 Maximum values of heald acceleration after its impact on upper support wire

	150 rpm of the shedding motion (m s^{-2})	300 rpm of the shedding motion (m s^{-2})	450 rpm of the shedding motion (m s^{-2})
Model 2	1.220	1.340	1.477
Model 3	746	963	1.066
Model 4	984	1.160	1.313

Table 2 Acceleration of heald after its impact on lower support wire (m s^{-2})

	150 rpm of the shedding motion (m s^{-2})	300 rpm of the shedding motion (m s^{-2})	450 rpm of the shedding motion (m s^{-2})
Model 2	671	906	1.080
Model 3	294	533	711
Model 4	567	783	955

Tables 1 and 2 shows maximum and minimum values of the heald acceleration after its impact upon upper and lower supporting wires, ascertained by means of the models 2 (without damping and friction force [5]), model 3 (heald with damping element [6]) and model 4 (design of heald with friction force). If we compare the courses of the heald acceleration obtained via the individual mathematical models, it is possible to state that the maximum reduction is achieved when employing the damping element [5, 6]. From the analysis there follows that the use of the friction force also reduces the maximum values of acceleration in comparison with a system without damping; however, this reduction is less significant than in case of the damping element.

Acknowledgments This publication was written as part of the project "Research of the processes of textile and single-purpose machines" with the support of the Specific University Research Grant and also the Institutional Endowment for the Long Term Conceptual Development of Research Institutes, as provided by the Ministry of Education, Youth and Sports of the Czech Republic.

References

1. Lee, D.G., Lee, C.S., Oh, J.H., Jeon, H.S.: Composite heddle frame for high-speed looms. Compos. Struct. **47**(1–4), 507–517 (1999). doi:10.1016/S0263-8223(00)00012-X
2. Xu, S., Feng, Z.: Modal analysis of heald frame and experimental verification. J. Soochow Univ. Eng. Sci. Ed. **28**(2), 34–36 (2008)
3. Guha, A., Amarnath, C., Kurien Issac, K., Talukdar, M.K., Joshi, S.: Linkage driven dobby with dwell. Text. Res. J. **79**(9), 804–809 (2009)
4. Eren, R., Aydemir, A.: Kinematic design method for six-bar linkage sley drive mechanisms in weaving. Indian J. Fibre Text. Res. **30**(3), 243–251 (2005)

5. Bílek, M., Skřivánek, J.: Mathematical modeling of the system shedding motion—heald—warp. AUTEX Res. J. **14**(2), 42–46 (2013). ISSN 1470-9589
6. Bílek, M., Skřivánek, J.: Mathematical model of the heald with damping element. AUTEX Res. J. **15**(1), 2–7 (2015). ISSN 1470-9589
7. Technical University of Liberec, Bílek, M., Kovář, Š.: Nitěnka pro tkací stroj (Loom heald), patent, CZ 305126