Design and Development of a Heddle Shaft Mechanism for Air-Jet Weaving Machines

F. Schwarzfischer, S. Kurtenbach, J. Onischke and B. Corves

Abstract Air-jet weaving is the most productive weaving procedure. However, it is also the most energy-intensive procedure. In order to save energy newly developed high-volume-low-pressure relay nozzles can be used. The application of these nozzles requires changes in the heddle shaft movement. The design and development of a suitable mechanism to drive the heddle shaft is presented. After the determination of requirements a structural synthesis is conducted. The outcome of the structural synthesis is a set of mechanisms which in principal can solve the motion task. Subsequently a dimensional synthesis is performed to determine the kinematic parameters of each structure. The different mechanisms are then compared to each other. The most suited mechanism is a combination of a linkage and a cam mechanism. In order to improve the dynamic behavior of the heddle shaft mechanism a Fourier analysis of the shaft motion is carried out. The Fourier series of the shaft motion is then truncated and the disk cam profile is redesigned in order to drive the shaft with the desired harmonic motion. The result of the design and development process is a new heddle shaft mechanism for air-jet weaving machines with high-volume-low-pressure (HVLP) relay nozzles.

Keywords Mechanism design · Cam design · Air-jet weaving machine · Heddle frame mechanism

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1 Introduction

Weaving is one of the oldest techniques for the production of fabric. Sets of yarns are interlaced at right angles to form cloth. Nowadays weaving is no longer handcraft but executed automatically by weaving machines. Figure 1 shows the basic structure of a weaving machine. The warp yarns are unrolled from the warp beam. Then they are guided through the weaving machine in longitudinal direction. Each warp yarn is threaded through one heddle eye. The heddle eyes are part of the heddles, which are mounted on the heddle frames.

The minimum number of heddle frames is two, as shown in Fig. 1. In case of complex weaving patterns, more heddle frames are required. The heddle frames move the warp yarns in vertical direction in order to create the shed. At maximum displacement of the heddle frames, the shed is called "open shed". The filling yarn is then inserted at right angle to the warp yarns into the open shed. The reed performs a rotating motion and beats the filling yarn against the woven cloth that has already been formed. The heddle frames switch position and the filling yarn is inserted into the newly opened shed. A new cycle starts. The cloth take-up roll serves to wind up the woven cloth [1].

Weaving machines can be classified with respect to the method of the insertion of the filling yarn. Common methods are shuttle weaving, projectile waving, rapier weaving and jet weaving. Jet weaving uses a fluid to transport the filling yarn through the open weaving shed and can be subdivided into water-jet and air-jet weaving. In the latter method the filling yarn is accelerated by a main nozzle and guided through the open shed by relay nozzles [1].

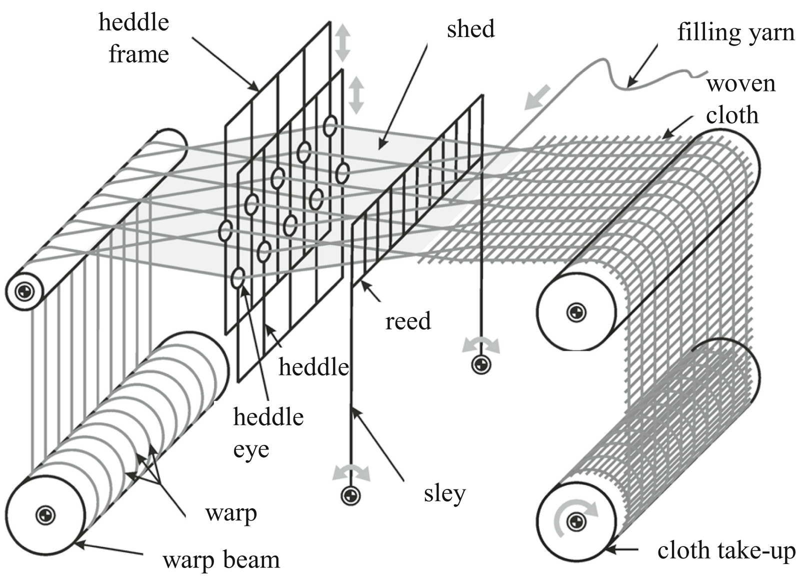

Fig. 1 Basic structure of a weaving machine

Air-jet weaving is the most productive weaving procedure. However, it is also the most energy-intensive procedure. In order to save energy newly developed high-volume-low-pressure relay nozzles can be used. The application of these nozzles requires changes in the heddle shaft movement. This is due to their increased external dimensions, which require a movement of the relay nozzles [2]. The purpose of this study was the development of a heddle frame mechanism with a new motion profile to allow the application of the new relay nozzles.

2 Materials and Methods

In order to develop the heddle shaft mechanism, a mechanism synthesis had to be conducted. The requirements for the mechanism were identified by conducting measurements on the real weaving machine and by simulating the machine using the newly developed HVLP relay nozzles.

2.1 Requirement Elicitation

To measure the movement of the reed and the current heddle frame movement an optical coordinate-measuring device was utilized. The measured reed movement was used as an input for an existing kinematic model of the weaving machine. The necessary heddle frame movement to allow the application of the new HVLP relay nozzles was determined. The input of the measured heddle frame movement into the kinematic model of the weaving machine showed the need to change the heddle frame movement. However, the high operating speed should be maintained.

2.2 Design and Development Process

In order to develop the heddle frame mechanism, the motion task was split into subtasks. This step was carried out according to the procedures outlined in [3]. Following the procedure in [4], a morphological box containing solutions for the different subtasks was set up. Combining the solutions of the subtasks, solutions for the complete system were derived. The different solutions for the complete system were compared using qualitative evaluation criteria. In order to reduce the number of solutions, only the best assessed solutions were considered for the following steps. In the next steps, mechanism synthesis had to be carried out for the subtask-solutions containing mechanisms.

2.3 Mechanism Synthesis

The mechanism synthesis can be subdivided into the structural and the dimensional synthesis. The determination of mechanisms that in principle can fulfil the motion task is the objective of the structural synthesis. The structural synthesis is followed by the dimensional synthesis. It contains the step of defining the dimensions of the mechanism, which means choosing the length of the links and the positions of the joints. The methods described in [5–7] are used to carry out the dimensional synthesis. In order to determine the dimensioning of cam disks, the Hodograph-Procedure described in [8] is employed. The result of the procedure is the position of the axis of rotation of the cam disk as well as its transfer function. The transfer function of the cam disk is then modified following the procedure outlined in [9, 10]. A so-called high-speed (HS) profile is calculated. Contrary to the normal disk cam profile, the HS transfer function is continuous as it is built up by a finite number of harmonics.

3 Results

The motion task of the heddle frame mechanism is defined by the rotational input motion and the desired output motion, the vertical movement of the heddle frame (s). Figure 2 shows the structure of the motion task.

The complete heddle frame mechanism is shown in Fig. 3. The vertical motion of the heddle frame is created by two guiding mechanisms. These mechanisms are

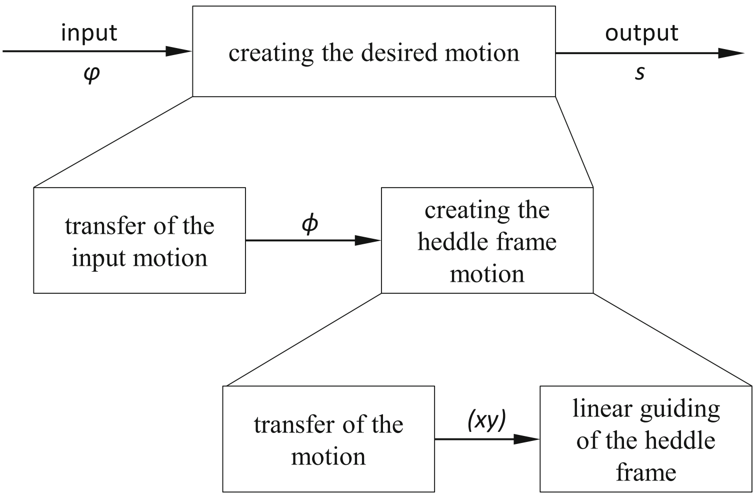

Fig. 2 Structure of the motion task for the heddle frame mechanism

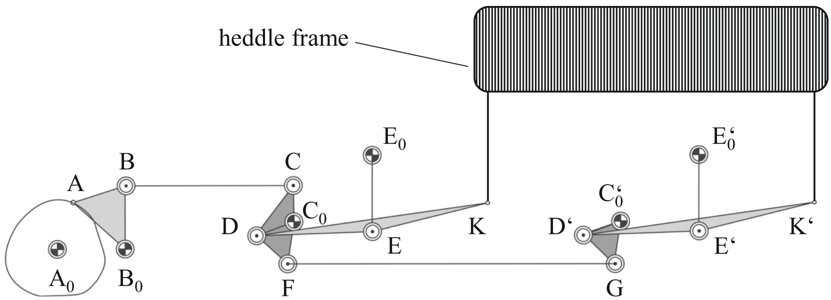

Fig. 3 Heddle frame mechanism

two four-bar linkages C_0–D–E–E_0 and C_0'–D′–E′–E_0'. Both mechanisms are coupled by a four-bar linkage C_0–F–G–C_0' to assure a parallel motion. The heddle frame is connected to the coupler points K and K'. As the four-bar linkages C_0–D–E–E_0 and C_0'–D′–E′–E_0' are almost similar to the Chebyshev lambda mechanism, K and K′ perform an approximate straight-line motion. The guiding mechanisms are driven by another four-bar mechanism B_0–B–C–C_0. The link B_0–B of this mechanism is driven by a cam disk, which transfers the input motion.

In order to decrease vibrations of the heddle frame, a harmonic synthesis of the heddle-frame motion was carried out. Figure 4 shows the heddle frame motion and its amplitude spectrum.

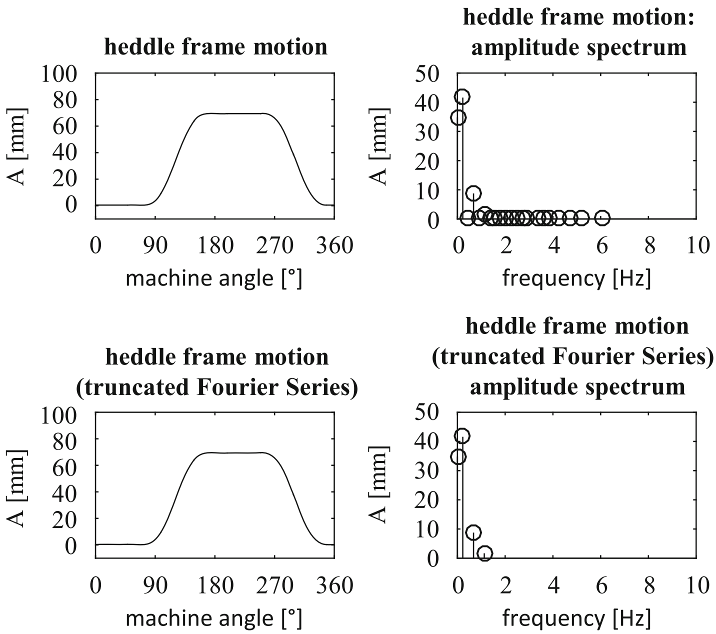

Fig. 4 Heddle frame motion and modified HS heddle frame motion

Furthermore, a modified heddle frame motion is depicted. Although only three harmonics are considered, the modified heddle frame motion is very close to the desired heddle frame motion.

The developed heddle frame mechanism can fulfil the requirements and allows the application of the newly developed HVLP relay nozzles. The mechanism is thin enough to allow the application of various mechanisms in a row, as it is necessary for complex weaving patterns.

4 Conclusion

Newly developed low pressure relay nozzles can contribute to energy savings in air-jet weaving. However, the application of these relay nozzles requires changes in the heddle frame movement of the weaving machine. The design and development of a suitable heddle frame mechanism was outlined in this paper. The mechanism is able to fulfil the requirements for the application of the new relay nozzles. In order to allow the application also for very high operating speeds, transfer function of the heddle frame mechanism was optimized using a HS cam disk.

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