KINEMATIC STUDY OF A CRANK–LEVER MECHANISM FOR GENERATING THE COMPLEX MOTION OF A COMB-LIKE LINK IN A WOOL SCOURING BATH

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Abstract: *This paper investigates the kinematic characteristics of a mechanism that generates the complex motion of a comb-like link used to move wool through a scouring bath. The rotary motion supplied by an electric motor and reducer is transmitted to a two-sided mechanism by a chain drive. Four-bar mechanisms convert the rotary motion into a complex closed-path motion of the working link. The resulting motion is transmitted to the comb-like link, ensuring the movement of the wool mass along the bath. The kinematic operating principle of the mechanism and its main motion parameters are analyzed.*

Key words: *wool scouring bath, comb-like link, crank, lever, four-bar mechanism, kinematic analysis, chain drive, trajectory, angular velocity.*

INTRODUCTION

Wool contains natural grease, perspiration residues, dust, mineral particles, and other mechanical impurities, which must be effectively removed before subsequent technological processes. Under industrial conditions, this process is generally carried out by passing wool through scouring baths and ensuring the movement of the wool mass using mechanically driven working elements.

The productivity and washing quality of a wool-scouring machine depend largely on the motion pattern of the wool mass in the bath. A working element in the form of a comb, rake, or harrow must enter the wool mass, move it a certain distance, then leave the wool mass and return to its initial position. Therefore, instead of a simple rotary or simple reciprocating motion, it is desirable to generate a complex closed-path motion of the working element.

An important advantage of four-bar mechanisms is their ability to transform the rotary motion of a driving crank into a complex trajectory of a point on the coupler link. This principle is used in the mechanism under study. Low-speed rotary motion is supplied to crank O_1A through an electric motor and reducer. This motion is transmitted through link AC to lever CD. Point B, located on link AC, moves along a closed trajectory resembling an ellipse, shown in red in the schematic.

On the second side of the mechanism, links O_2E–EG–GH, having the same geometric arrangement, are installed. Since shafts O_1 and O_2 are connected by a sprocket-and-chain drive, the motion of the two mechanisms is synchronized. As a result, the motions of points B and F are transmitted to the two sides of the comb-like link, generating the motion required to move the wool mass in one direction along the bath.

The aim of this paper is to analyze the kinematic scheme of the mechanism used in a wool-scouring bath, determine the main kinematic parameters based on the specified geometric dimensions and rotational speed, and evaluate the complex motion of points B and F from a technological perspective.

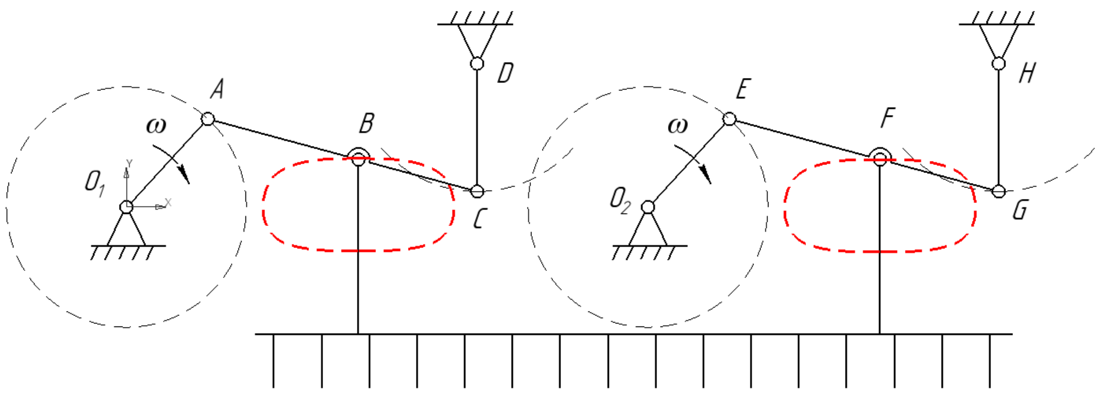

Figure 1. Kinematic scheme of the mechanism driving the comb-like link of the wool-scouring bath.

Materials and Methods

The two-sided symmetrical mechanism shown in Figure 1 was adopted as the object of study. The first side consists of crank O_1A, coupler link AC, and oscillating lever CD. The second side consists of the geometrically corresponding crank O_2E, coupler link EG, and lever GH.

Using the reducer installed at the output of the electric motor, the driving shaft of the mechanism is rotated at a speed of 3 rpm. The angular velocity is determined by the following relation:

$$\omega_1 = 2\pi n_1 / 60$$

For the given value $n_1 = 3$ rpm:

$$\omega_1 = (2\pi \cdot 3) / 60 = 0.314\, rad/s$$

Thus, the angular velocity of crank O_1A is 0.314 rad/s. The time required for one complete revolution is:

$$T = 60 / n_1 = 60 / 3 = 20\, s$$

Therefore, one complete kinematic cycle of the mechanism lasts 20 s.

Shafts O_1 and O_2 are interconnected by a sprocket-and-chain drive. If the numbers of teeth on the driving and driven sprockets are equal, the transmission ratio is equal to unity:

$$i\_z = z_2 / z_1 = 1$$

In this case:

$$n_2 = n_1 = 3\, rpm$$

$$\omega_2 = \omega_1 = 0.314\, rad/s$$

Thus, the cranks on the left and right sides of the mechanism rotate at the same angular velocity. Their phase positions can be matched during installation of the chain on the sprockets.

The first mechanism consists of links O_1–A–C–D. The link O_1D is fixed, O_1A is the crank, AC is the coupler link, and CD is the oscillating lever. Let the crank, coupler, and lever lengths be denoted by L_2, L_3, and L_4, respectively.

The geometric configuration of the mechanism can be expressed by the vector equation:

$$O_1A + AC = O_1D + DC$$

With the coordinate system attached to point O_1, let θ denote the angular position of the crank. The coordinates of point A are:

$$x\_A = L_2 \cos\theta$$

$$y\_A = L_2 \sin\theta$$

For point C:

$$x\_C = x\_A + L_3 \cos\varphi$$

$$y\_C = y\_A + L_3 \sin\varphi$$

Here, φ is the angular position of coupler link AC. Since point C moves along an arc of radius CD = L_4 about point D, the following geometric condition is satisfied:

$$(x\_C - L_1)^2 + y\_C^2 = L_4{}^2$$

These equations make it possible to determine the position of point C and, consequently, the position of lever CD for each angular position of the crank.

Point B is located on coupler link AC. Its relative position along the coupler is expressed by the coefficient λ:

$$\lambda = AB / AC$$

The coordinates of point B are:

$$x\_B = x\_A + \lambda L_3 \cos\varphi$$

$$y\_B = y\_A + \lambda L_3 \sin\varphi$$

When the crank rotates from θ = 0° to 360°, point B forms a closed complex curve. The red trajectory shown in the schematic represents the technologically required path of this coupler point. The same equations can be used to determine the trajectory of point F for the second mechanism.

When the crank rotates at a constant angular velocity, the linear velocity of point A along its circular path is:

$$v\_A = \omega_1 L_2$$

Substituting the given parameters:

$$v\_A = 0.314 \cdot 200 = 62.8\, mm/s$$

Thus, the instantaneous linear velocity of point A is 62.8 mm/s. The velocity of point B depends on the angular position of the mechanism and varies throughout one cycle.

According to the calculations, a 200 mm crank O_1A is used as the main driving element of the mechanism. When the crank rotational speed is set to 3 rpm, its angular velocity is 0.314 rad/s. This value provides a relatively slow and controlled working cycle of the mechanism.

One complete revolution of the crank takes 20 s. Therefore, when the phase synchronization is correctly maintained, one complete motion cycle of point B along its closed trajectory also corresponds to 20 s. This parameter is a key time characteristic for determining the working and return phases of the comb-like link in the bath.

When the transmission ratio of the chain drive is equal to unity, shafts O_1 and O_2 rotate at the same speed. Consequently, the left and right mechanisms operate in the same cycle. This ensures coordination of the motion transmitted from both sides of the comb-like link and reduces the possibility of tilting of the working link relative to the bath.

The complex closed trajectories of points B and F are of primary technological importance. During the working part of the trajectory, the comb-like link enters the wool mass and moves it forward along the bath. In the subsequent part, the working element leaves the wool mass and performs the return motion. Thus, one complete cycle can conditionally be divided into the stages of entry into the working zone, forward movement, exit from the working zone, and return.

Because the rotational speed of the crank is low, the motion of the comb-like link is also relatively slow. This may be beneficial for reducing sudden dynamic effects on the wool mass and preventing excessive entanglement of the fibers. At the same time, assessment of the actual technological efficiency should also take into account the wool mass, bath dimensions, flow of the washing liquid, and geometric parameters of the comb teeth.

To further improve the mechanism, it is advisable to numerically model the trajectory of point B and determine the working stroke length from its horizontal coordinate x_B(t). In addition, velocity and acceleration diagrams of points B and F can be constructed to evaluate the dynamic loads of the mechanism.

CONCLUSION

The mechanism proposed for driving the comb-like link in the wool-scouring bath makes it possible to transform the rotary motion of the electric motor into a complex closed motion required from a technological point of view.

When the transmission ratio of the chain drive is assumed to be unity, shafts O_1 and O_2 operate at the same rotational speed. This ensures synchronized operation of the two-sided mechanism.

The rotary motion of the crank is transformed through coupler links AC and EG and levers CD and GH into complex closed trajectories of points B and F. This motion is transmitted to the comb-like link, enabling the wool mass to be moved forward in the bath and the working element to be returned for the next cycle.

In further studies, after specifying the center-to-center distance O_1D and the exact position of point B on coupler link AC, it will be possible to determine the exact equations of the trajectories of points B and F, the maximum working stroke, velocities and accelerations, and to select the optimal geometric parameters of the mechanism.

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