Synthesis of a new harrow type wool transport mechanism

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Синтез нового типа баронного механизма в шерстомоечной машине

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Abstract: *in this article, we are given the scientific results of the synthesis of motion of a new harrow type mechanism of wool scouring machine to reduce fiber entanglement.*
Аннотация: *в этой статье даны научные результаты синтеза движения нового баронного механизма в шерстомоечной машине с учётом снижения запутанности волокна.*

Ключевые слова: *шерстное волокно, органик веществ, минеральные веществ, шерстомоечная машина, баронный механизм, четырёхзвенный рычажный механизм.*
Keywords: *wool fiber, organic impurities, mineral impurities, wool scouring machine, wool transport mechanism, four bar linkage.*

The wool processing requires the scouring at its initial stage, to remove the contaminants of the raw wool. Dust and vegetable matters remove in burring machines. Grease and suints remove in bowls of the scouring machine, which are filled by hot water containing soda-soap or some alkali [1, 2, 3, 4]. During the scouring process, the wool entangles by the motion of transport mechanism of the conventional scouring machine. The entanglement cause many problems at the next stages of the wool processing.

Conventional wool scouring machines consist of 4-5 bowls [4]. Three of them fill with hot water and the remaining two with pure cold or sometimes hot water for rinsing purposes. Each bowl has a wool transport mechanism and in between bowls, there are squeeze rollers. Prongs or rakes of the mechanism immerse the wool into the scouring liquor and propel it to the end of the bowl.

Basic mechanical motions of aqueous scour bowl design have not changed greatly, and the most of the wool still scoured in aqueous system using rake and harrow machines [4].

In the conventional scouring machines, the motion of the harrow is obtained by the crank and cam mechanisms. Changing of the cam profile obtains any desired trajectory of the harrow motion. However, manufacturing of cam mechanism is more costly than linkages.

During the working process of scouring machine, the prongs pass forward with elliptical motion or sweep through the scouring liquor, and thus carry the wool forward, than, at the same time scour it by moving through the liquor (Figure 1). The prongs catch and immerse the wool deeply into the scouring liquor and carrying it forward to the end of the bowl. As a result, fibre entanglement increases during the washing process by wool transport mechanism.

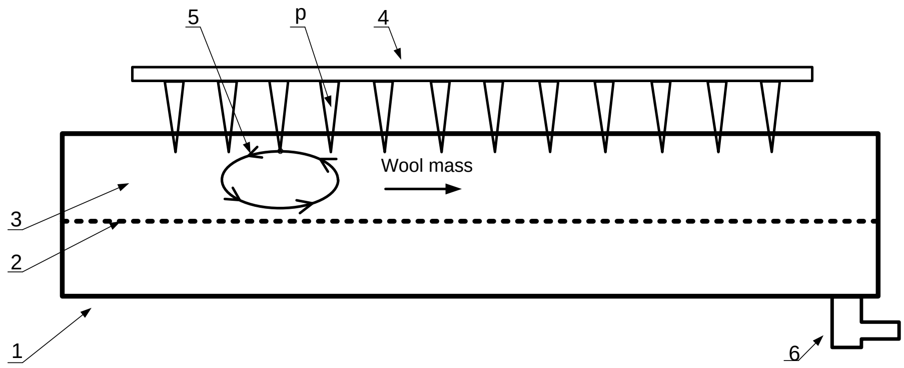

Fig. 1. Trajectory of motion of the conventional Harrow mechanism
1-scouring bowl, 2-perforated false bottom, 3-scouring liquor, 4-harrow,
5-trajectory of motion of the prong, 6-sediment outlet

The following four different ways [5] can used to reduce fibre entanglement:

- Modification of existing machines;
- Radically changing the design of the scouring machine;
- Changing the scouring medium;
- Changing the scouring configuration.

This research focuses on the design of a new wool transport mechanism in order to reduce fibre entanglement and damage based on the improving of motion of the mechanism by developing its topological structure. In order to reduce the mechanical acts of the prongs to the fibres, the trajectory of the prongs was determined as an approximate straight-line in certain length of rotation of the wool transport mechanism. In Figure 2, from point ***b*** to point ***c*** shows the approximate straight-line trajectory of the prong.

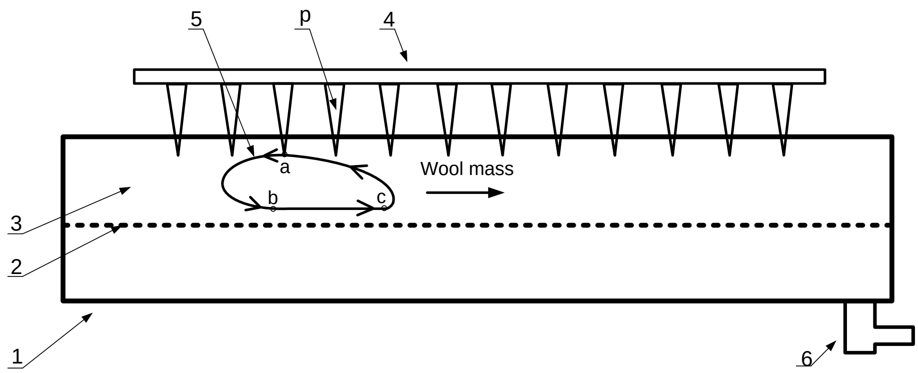

Fig. 2. Trajectory of motion of the proposed wool transport mechanism
1-bowl or tank, 2-perforated false bottom, 3-scouring liquor, 4-harrow,
5-trajectory of the prong, 6-sediment outlet

Straight-line mechanisms divided into three categories [6]:

1. Exact straight-line mechanisms.
2. Approximate straight-line mechanisms.
3. Straight line copying mechanisms.

Straight-line mechanisms are very important for some industrial applications. The first straight line mechanism invented and produced by James Watt in 1784 [7]. After Watt's straight-line mechanism, several new type straight-line mechanisms were investigated. These are James White's hypocycloidal straight-line mechanism, about 1800, Freemantle straight-line linkage, later called the Scott Russell linkage in 1803, an American pioneer Oliver Evans's "Columbian" engine, or "grasshopper" straight-line linkage in 1813, Richard Robert's approximate straight line linkage in 1841, Sarrus's exact straight-line linkage in 1853, Russian mathematician Pafnutiy Chebyshev's approximate straight-line mechanism in 1867, Peaucellier exact straight-line linkage, in 1873, Hart's exact straight-line mechanism in 1874 [8].

Another example of coupler curves of the four bar linkages has been investigated by Hrones and Nelson. They have completed approximately 7300 coupler curves of four bar linkages in their "Atlas of four bar coupler curves" [9]. It defines the linkage geometry for each of its Grashof’s crank-rocker linkages. According to [10] these coupler curves was drawn to large scale and constitutes a very practical tool for the designer, who paging through, can find a shape and configuration suitable for a given application. It is a useful reference to provide a starting point for design and analysis.

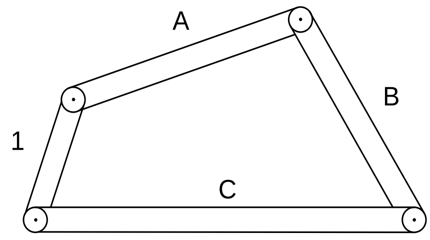

Fig. 3. Four bar linkage [9]

According to [9] a four bar linkage is schematically shown in Figure 3. It consists of the four links having pin-to-pin lengths of 1, A, B, and C. The geometry of the linkage has been determined by the three ratios A/1, B/1, and C/1. Up to this point, the four-bar linkage has been represented as consisting of four lines. Actually, each member is a solid body, which from purely theoretical aspects can be considered as being of indefinite extent. Each point of the body has been numbered as row and columns for the named of these points by the authors of this research work (Figure 4).

According to the geometry of the scouring bowl, the crank and the rocker have been chosen. The crank should be fixed on the upper sides of the bowl and the lever should be fixed side of the bowl.

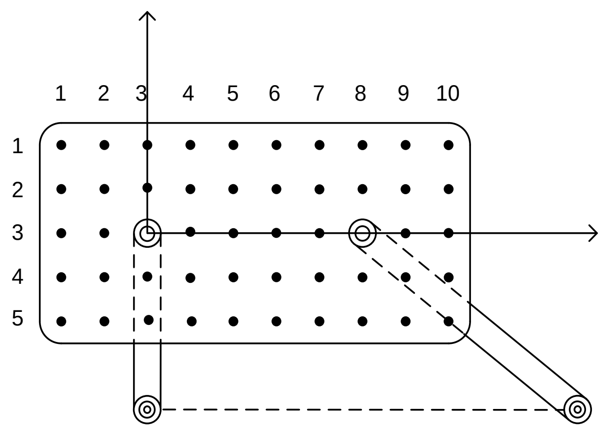

Fig. 4. Behavior of the points [9]

According to [10], when A=4.0, B=3.0 and C=4,5 (Figure 5) nearly between 5x6 and 5x7 points (Figure 4) will be drawn approximately straight line path.

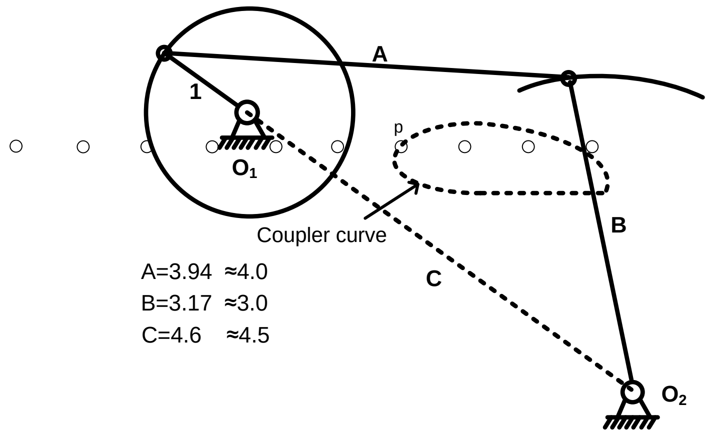

*Fig. 5. Trajectory of point **p** of the coupler A. When A=4.0; B=3.0 and C=4.5 (Adapted from [9], page 620)*

Figure 5 represents a best solution for the desired trajectory of the harrow motion. In future works, the point ***p*** has been connected to the two ends of the coupler A. The proposed four bar linkage is shown in Figure 6. The desired point has been found, when 1=250; A=985/250=3.9; B=793/250=3.2 and C=1150/250=4.6.

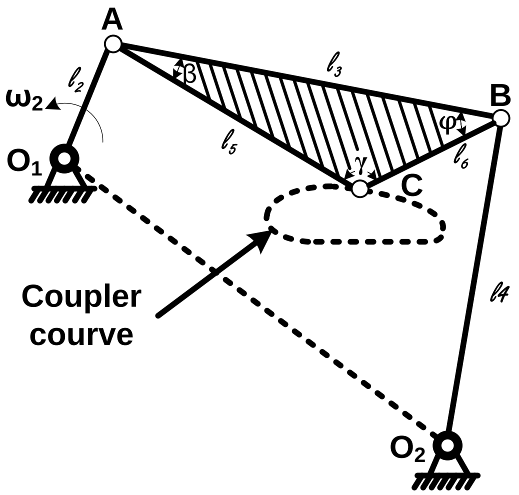

Fig. 6. The proposed four bar linkage

Referring to Figure 6, the point C can be imagined as connected to the longitudinal girth of the harrow by revolute joint. The longitudinal girth requires connection by revolute joints at least at two points in order to obtain full rotation. O_2BC dyad has been parallel replaced through connecting rods BE and CD. The completely proposed mechanism is shown in Figure 7.

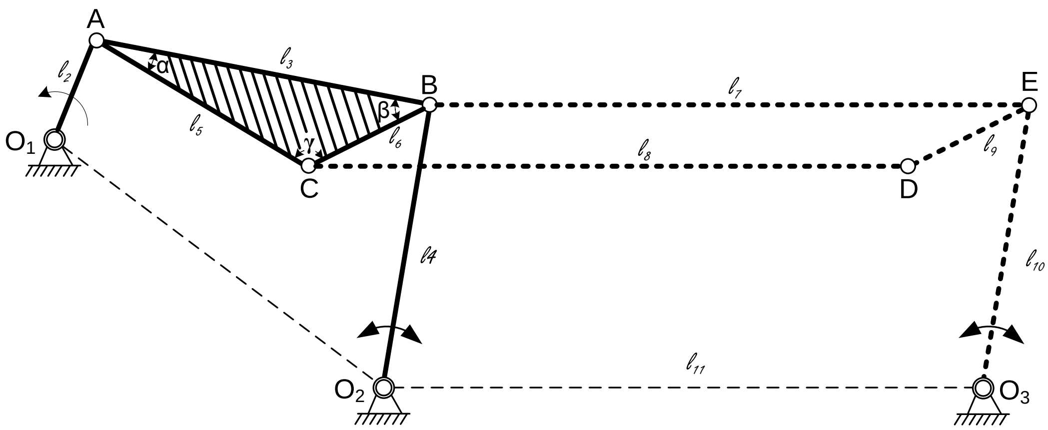

Fig. 7. Proposed wool transport mechanism

The proposed mechanism consists of eight links, and ten lower kinematic pairs (Figure 7). Shafts $\boldsymbol{O_1}$, $\boldsymbol{O_2}$, and $\boldsymbol{O_3}$ are mounted on the frame of the proposed machine, $\boldsymbol{O_1A}$ is a crank, rotates 360^0 counterclockwise direction. ***ABC*** is a coupler**,** ternary link**, *BE*, *CD*** and ***DE*** are connecting rods, $\boldsymbol{O_2B}$ and $\boldsymbol{O_3E}$ are levers, legs of the harrow that rotate with an oscillation motion.

Mobility of the proposed mechanism.

Number of links, n= 8;

Number of low pairs, j= 10;

Number of higher pairs, h= 0;

Mobility of the mechanism can be computed by Grubler's equation [6]:

$$\boldsymbol{DOF = 3(n-1) - 2j - 1h = 3(8-1) - 2\cdot 10 - 1\cdot 0 = 21 - 20 - 0 = 1};$$

In Figure 8, ***1*** represents the bowl or tank, forming the body or frame of the proposed machine that contains the scouring liquor ***2.*** Wool is fed into it by feeding conveyor ***3***, driven by belts 4, or gearing in any ordinary ways.

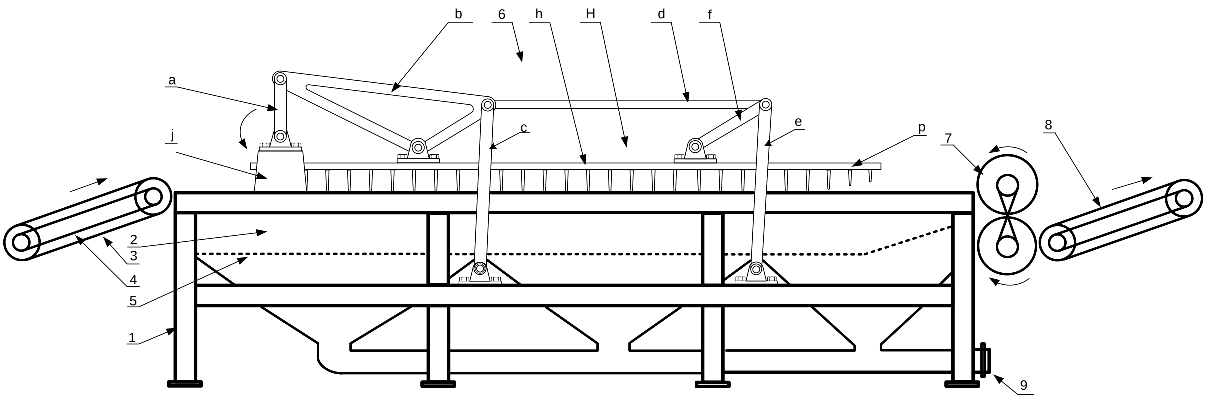

Fig. 8. Proposed wool transport mechanism in the scouring machine
1- Bowl or tank, 2- Scouring liquor, 3- Feeding conveyor, 4- Belt, 5- Perforated false bottom, 6- Harrow mechanism: a-crank, b- coupler, c and e-levers, d -connecting rod, H-harrow platform: h-longitudinal girth, p-prongs, 7-Squeeze rollers, 8-Feeding conveyor, 9- Sediment outlet

The raw wool or greasy wool drops from the feeding conveyor ***3*** into the bowl ***1***, the prongs ***p,*** which are all mounted on longitudinal girths ***h,*** of the harrow***, H,*** catch and immerse into the scouring liquor and carrying it forward toward to the squeeze rollers **7.** Upon the side walls of the bowl ***1***, are secured standard or columns ***j***, provided at their upper end with bearing for cross shaft O_1 driven by belt drive from electromotor. On the shaft O_1 secured a crank ***a.*** The end of the crank is pivoted at one end of the coupler ***b;*** one end of the coupler ***b*** is pivoted at a cross bar **C,** secured to the longitudinal girth ***h*** of the harrow ***H.*** One end of the coupler ***b*** is pivoted at a cross bar ***B.*** Besides of the bowl ***1,*** secured O_2, and O_3 shafts. O_2 and O_3 said cross shafts are secured two levers ***c*** and ***e.*** Lever ***c*** is pivoted at the upper end to the cross bar ***B.*** Lever ***e*** is pivoted at the upper end to the cross bar ***E*** respectively. Cross bars ***B*** and ***E*** connected together by a rod ***d.*** Cross bars ***D*** and ***E*** connected together by a rod ***f.*** Cross bar ***D*** secured to the longitudinal girth ***h*** of the harrow ***H.***

In the position of harrow operating mechanism the coupler ***b***, under the action crank ***a***, is slowly moving the harrow ***H,*** toward the delivery end until said crank is about to travel from its upper to its lower half circle, whereby the harrow ***H*** is downward into the scouring liquor ***2***. The crank ***a*** revolves, levers ***c*** and ***e*** oscillate by the connecting rods.

The prongs of harrow pass the wool and carries forward to the squeeze rollers ***7***, which squeeze out the liquor from the wool. The dirty liquor returns to the bowl. The squeeze rollers deliver the wool to the next feeding conveyor ***8***. And scouring process continues in the next bowls.

Near the bottom of the bowl ***1***, there is a perforated false bottom ***5***, through which the liquor may pass, but not the wool, and below this bottom there should be a sediment outlet ***9***, for the sediment or emptying the bowl of the scouring liquor.

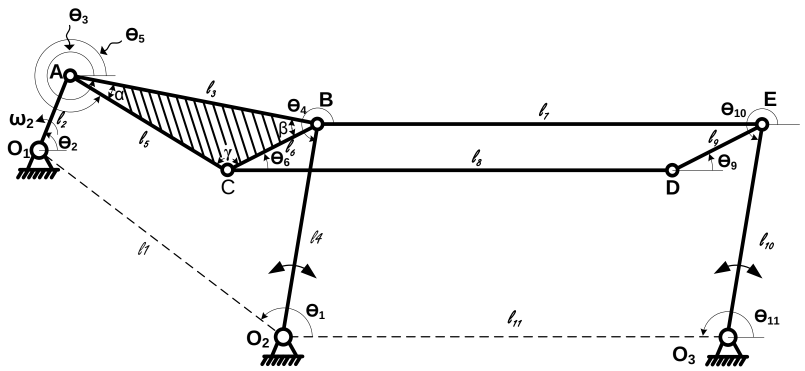

Fig. 9. Geometry of the proposed wool transport mechanism

In Figure 9, l_1=1150 mm; distance between shafts O_1 and O_2; l_2=250 mm; length of the crank O_1A; l_3=985 mm; length of *AB* side of the coupler ABC or ternary link, l_5=671 mm; length of AC side of the coupler ABC, l_6=440 mm; length of *BC* side of the coupler ABC, l_4=793 mm; length of O_2B lever, l_7=2000 mm; length of BE connecting rod, l_8=2000 mm; length of CD connecting rod, l_9=440 mm; length of ED connecting rod, l_{10}=793 mm; length of O_3E lever, l_{11}=2000 distance between shafts O_2 and O_3.

Referring to the topology of the proposed mechanism (Figure 9), it can be seen, the proposed mechanism is constructed based on the four bar linkage. Results of the kinematic and kinetostatic analysis of the proposed mechanism will be discussed in next publications.

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