A Novel Mechanism for Driving the Sley in a Shuttle Loom

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ABSTRACT

In spite of extraordinary progress in the technology of weaving, the majority of weavers, particularly in the developing world, use shuttle looms. These looms suffer from various deficiencies, one of them being the severe abrasion between warp threads and shuttle, particularly when the shuttle leaves the shed. This can be avoided or reduced by allowing the sley to dwell near the back centre. Changing the drive of the sley from the currently used four bar mechanism to a cam driven mechanism will easily achieve this objective. However, weavers currently using shuttle looms are reluctant to accept this modification because of the significant increase in cost that it entails. A compromise would be a six bar mechanism which can give a dwell or "near dwell" condition, i.e. very slow motion, near the back centre. Such a mechanism, based on the Watt chain, has been explored in this paper. It gives 0.06 degrees of maximum angular displacement of the output link for 95 degrees rotation of the input link. The suitability of the mechanism in satisfying the other requirements of sley movement of a shuttle loom has also been discussed.

1.0 Introduction

In an age in which shuttle-less looms can run at 1500 ppm (picks per minute), it is worth noting that shuttle looms running at 110 - 250 ppm are widely used, particularly in the developing world. About 86% of the world's looms are still shuttle looms and in countries like India, about 98% of looms are shuttle looms [1]. Though the number of shuttle-less looms is increasing at a much faster pace than the number of shuttle looms, the latter are expected to remain significant contributors to the weaving sector in the near future. However, they are clearly inferior to the shuttle-less looms both in terms of speed of operation as well as quality of weaving. One of the reasons of this inferior quality weaving is the severe abrasion between warp threads and the shuttle, especially when the shuttle leaves the shed. For a cotton loom running with beat-up at 0° of the crank shaft rotation and healds levelling at 270°, the shuttle is assumed to enter the shed at 110° and leave at 240°. Under such conditions, the depth of shed would be 24.4mm and 9.4mm during the entry and exit respectively, of shuttle from the shed [2]. If the height of the front wall of the shuttle were 28mm, then the corresponding bending factors would be 0.87 and 0.34 respectively. The latter would cause considerable deflection of the warp threads as shown in figure 2.

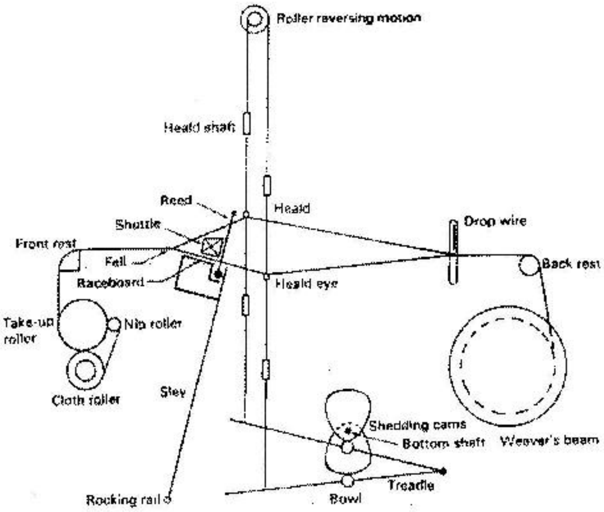


Figure 1: Schematic side view of a loom

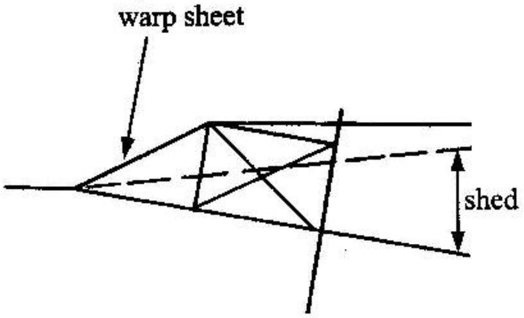


Figure 2 : Deflection of warp sheet with a bending factor of 0.34

The low bending factor (arising from the low depth of shed) during exit of the shuttle is caused by two factors.

1. The healds start closing during shuttle flight.
2. The sley starts moving forward during the latter half of the shuttle's flight.

The contribution of the second factor can be eliminated or reduced by making the sley dwell near the back centre during the flight of the shuttle. This can be easily achieved by using a cam to drive the sley. However, changing the sley drive from the currently used four bar mechanism to a cam would entail an increase in cost, which the users of shuttle looms in the developing world are unwilling to accept. As a compromise, an attempt has been made in this paper to arrive at a six bar mechanism which will give a dwell or "near-dwell" (i.e. very slow movement) to the sley during the shuttle flight.

2.0 Principle of the mechanism

When a four bar linkage is used as a crank-rocker mechanism, the rocker has to slow down, stop and reverse its direction of motion twice during every rotation of the crank at its two dead centre positions. During these momentary stoppages, the crank and the coupler are collinear. The rocker has a slow motion before and after these instants. Let another four bar linkage be coupled to the rocker of this of this crank rocker as shown in figure 3. The complete mechanism is a six bar Watt chain. If the second four bar chain is also at a dead centre position simultaneous with the first attaining such a position, then the final output (rocker) not only comes to rest but attains a very slow motion before and after this instant.

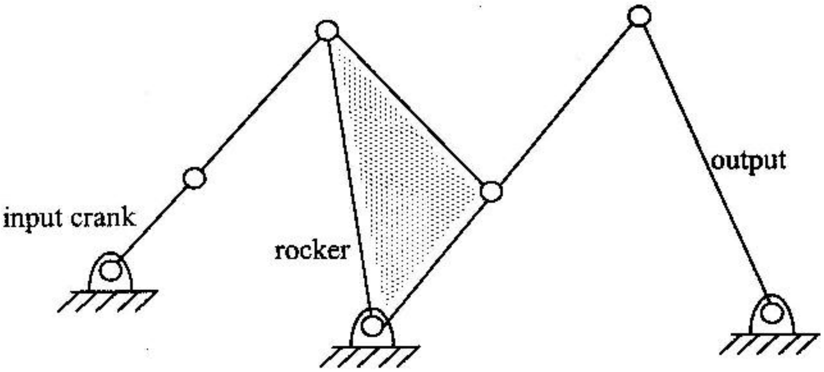


Figure 3: Rocker of a four bar chain driving another four bar chain

It is felt that with appropriate link lengths, it might be possible to make this motion slow enough to approximate the dwell of a cam driven mechanism.

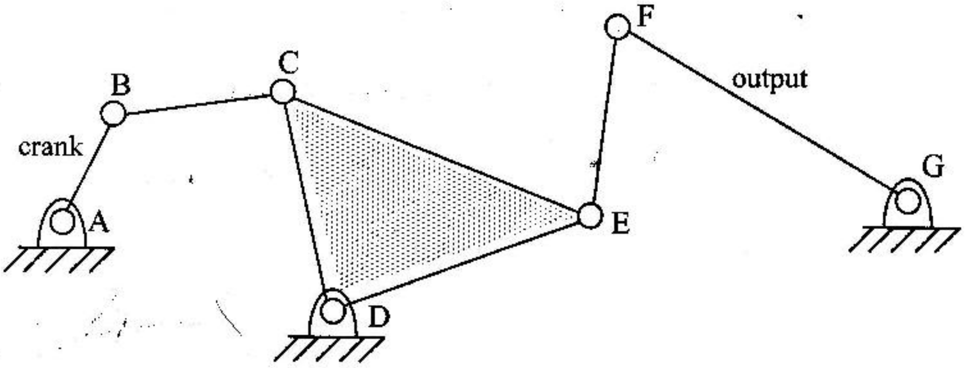
3.0 Simulation of the mechanism

Hain [3] presents procedures for the synthesis of crank rocker mechanisms to meet given time ratios and rocker angles. But what is required here is the performance over an entire cycle. Available synthesis techniques do not address performance over entire an cycle [4] and recourse had to be taken to simulation. Mechanisms built on the principle described in Section 2.0 were simulated in the software ADAMS

(MSC Software corporation). The crank (input) was rotated and corresponding angular displacement of the output link was observed and plotted. The crank was rotated at one degree per second for ease of simulation. This corresponds to a loom running at 0.17 picks per minute - a very slow and unrealistic speed. The following analysis is still relevant because angular displacement of the output link, from which the following inferences have been drawn, will remain same at all speeds. At higher speeds, the angular velocity and acceleration curves of the output link would only have to be rescaled.

The number of workable mechanisms which could be built from the above principle was limited by the requirement for complete rotation of the crank (input). Grashov's criteria had to be satisfied for the first four bar chain. In addition, certain orientations and lengths of the output link also impeded complete rotation of the crank.

The plots of angular displacement of the output link of different mechanisms were studied. Most were found to have a nearly flat region, corresponding to very slow motion of the output link. The aim was to choose the mechanism which gave the slowest motion for the largest crank rotation. There were quite a few mechanisms which apparently satisfied this criteria. On closer examination, many of them had to be rejected because during the period of slow motion, the output link was found to reach a limit, retreat, go to another limit and retreat again. This perturbation in the period of slow motion (near-dwell condition) might cause problems during shuttle flight when such a device is used to drive the sley in a loom. In order to reduce chances of shuttle fly off, only perturbations less than 0.1° were deemed acceptable. With this criterion, and a "reasonable" link length, the mechanism shown in figure 4 was found to be the best among those which were studied.



AB	89.4	BC	171.1	CD	274.6
DE	314.0	CE	340.6	EF	270.0
FG	426.4	AD	233.4	DG	642.0
AG	808.9				

Figure 4: Proposed mechanism for sley drive (the table gives link lengths in any unit)

It was found to give a near-dwell condition (very slow motion) to the output link with a perturbation of less than 0.1° for 100° of crank rotation (from 94° to 194°). The authors do not claim this to be the best possible mechanism to satisfy this criterion. It was observed that, in general, increasing the length of links other than the crank gave better mechanisms. However, such mechanisms would require more space and would be difficult to incorporate into a loom. In the mechanism in figure 4, the ratio of the longest to shortest link is less than five, an important requirement when one considers out-of-plane forces.

An attempt was also made to ensure that the transmission angles fall below fall within 90°±65°. Many mechanisms with long link lengths that provided near-dwell conditions over large crank angles had very low transmission angles and were rejected. In this mechanism, the transmission angle of the first four bar linkage (ABCD) varies from 26.7⁰ to 89.7⁰ and that of the second four bar linkage (DEFG) varies from 50.3⁰ to 79.6⁰. Larger oscillations of the output link leads to lower transmission angles.

4.0 Motion of the mechanism

The crank of the mechanism shown in figure 4 was rotated through 360° at 1°/s and angular displacement, velocity and acceleration of the output link were plotted (Figures 5, 6 and 7).

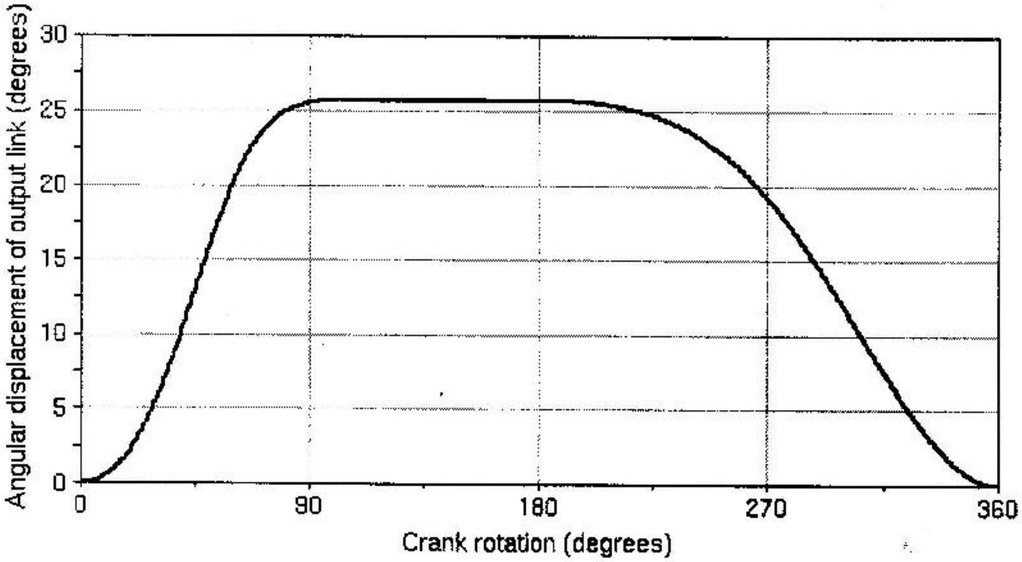


Figure 5: Angular displacement of output link

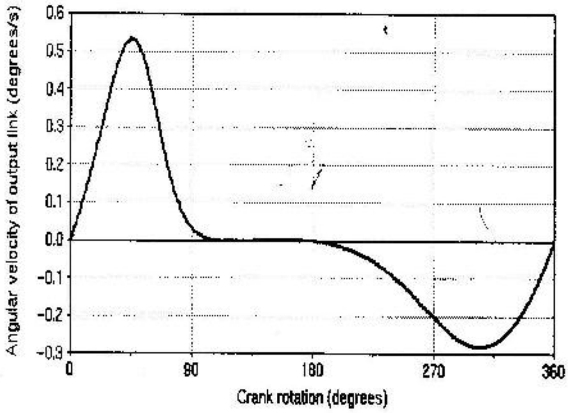


Figure 6: Angular velocity of the output link

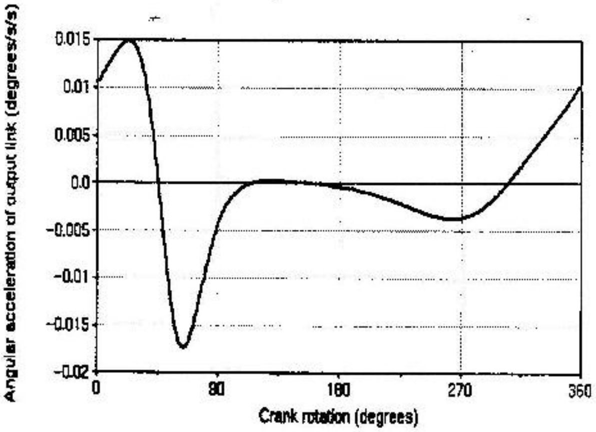


Figure 7: Angular acceleration of the output link

One extreme position of the output link (where there is no apparent dwell) was chosen as the starting position. Angular displacement of crank was measured with this position as 0°. From the displacement diagram (figure 5) it is seen that the output link rotates through 25.7°. That the apparent dwell is not really a dwell but includes a small perturbation can be observed by zooming onto that portion of the displacement diagram. This has been done in figure 8.

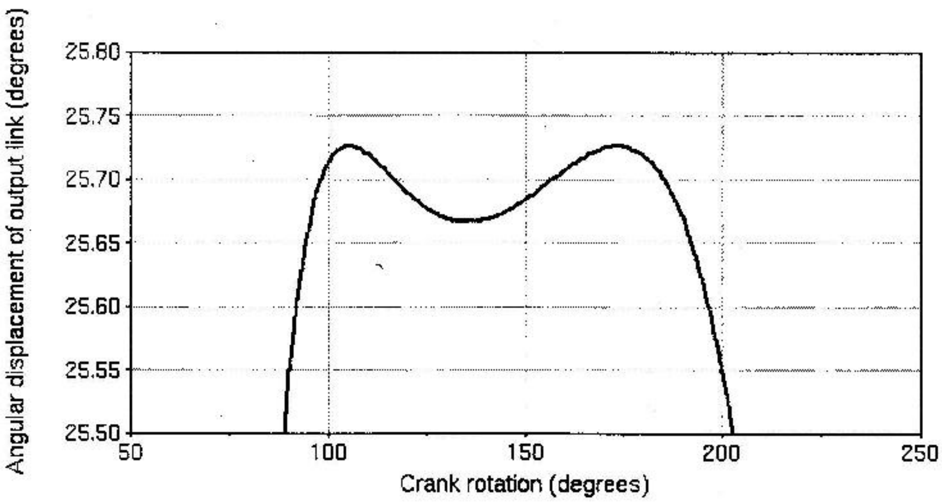


Figure 8: Zooming on to the apparent dwell

The perturbation is quite small. It is less than 0.1° over 100° of crank rotation (from 94° to 194°). If fact, the perturbation is only 0.06° over 95° of crank rotation (from 95° to 190°). This represents only 0.23% of the total rotation of the output link. The velocity and acceleration diagrams (figures 6 and 7) do not show any sharp peaks or discontinuities as is expected from a linkage mechanism.

5.0 Suitability of the mechanism for a sley

In the following discussion, it is assumed that in a cotton loom with a four bar mechanism driving the sley, beat-up takes place at 0° of the crank rotation, healds level at 270°, shuttle enters the shed at 110° and leaves the shed at 240°. As has been discussed in section 1.0, the low bending factor (high deflection of warp sheet by front end of the shuttle) during the shuttle's exit from the shed can be attributed to two factors:

1. The healds start closing during shuttle flight.
2. The sley starts moving forward during the latter half of the shuttle's flight.

The first factor can be addressed by early picking. The scope for that is limited in a normal loom because the shuttle flight should coincide with the slowest motion of the sley, which happens at 180°. The second factor can be addressed by allowing the sley to dwell at its backmost position and arranging shuttle flight during that period.

If an extension of the output link of the mechanism proposed here is used as the sley, then it is seen from figure 5 that after beat-up, the sley will quickly come to its backmost position and enter the near-dwell phase. At the end of this phase, the sley will come to the beat-up point with a motion that starts off slowly and gradually speeds up. In order to address the second factor mentioned earlier, the time of the shuttle's flight must be adjusted to make best use of the near-dwell region. However, that will give an improvement in bending factor only if it is achieved by allowing picking to happen earlier. Otherwise, the contribution of the first factor will tend to worsen the bending factor and the net effect of both the factors is difficult to predict.

The 110° to 240° motion of shuttle through the shed, when combined with the proposed sley drive mechanism, will allow picking to occur when the sley is nearly stationary. The shuttle will come out of the shed when the sley has just started moving forward. However, shuttle flight should correspond to slowest movement of the sley. Assuming that the shuttle takes 130° of the crank rotation to traverse the shed, the problem then reduces to choosing the 130° window in the crank rotation which gives least rotation to the output link (sley). Table 1 shows a range of 130° windows and the corresponding rotations of the output link. The calculation for the total rotation of the output link (last column) takes into account the fact that between shuttle entry and exit from the shed, the sley has attained a rotational displacement of 25.7259°

and has then retreated. The values in the table have been rounded off from more accurate values for ease of study.

Table 1: Choosing the best window for shuttle flight.

Crank Rotation (degrees)		Output Link Rotation (degrees)		
Shuttle Entry	Shuttle Exit	Shuttle Entry	Shuttle Exit	Total
70	200	23.38	25.55	2.346
75	205	24.32	25.45	1.406
80	210	24.94	25.32	0.786
81	211	25.04	25.29	0.690
82	212	25.12	25.26	0.605
83	213	25.20	25.23	0.529
84	214	25.27	25.19	0.532
85	215	25.33	25.16	0.568
86	216	25.38	25.12	0.606
87	217	25.43	25.08	0.645
88	218	25.48	25.04	0.687
89	219	25.51	25.00	0.730
90	220	25.55	24.95	0.776
95	225	25.66	24.70	1.026
100	230	25.71	24.39	1.336
105	235	25.73	24.01	1.720
110	240	25.72	23.57	2.156

From this table, the best window is seen to be a shuttle entry into the shed at 83° of the crank rotation and exit at 213°. The sley rotates through 0.53° during this period which is only 2% of its total rotation.

Thus, the best window (from the point of view of the second factor) requires picking to occur earlier than what occurs in normal looms. This assures an improvement in bending factor of the warp sheet.

6.0 Conclusion

The four bar mechanism used for driving the sley in shuttle looms constrains the shuttle to deflect the warp sheet considerably during its exit from the shed. This paper proposes a six bar mechanism based on the Watt chain in which the output link - used as a sley - has very slow motion for nearly 100° of the crank rotation. Changing the time of entry of the shuttle into the shed from the currently used 110° to 83° will make best use of this "near- dwell zone" for shuttle flight. This change will also cause a smaller part of the shuttle's motion to fall in the shed closing zone (assuming the healds to be level at 270°). Both these reasons will cause less deflection of the warp sheet by the shuttle.

Reference

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4 Roth, B, The Major Solved and Open Problems in the Design of Mechanisms, Proceedings, NaCoMM 2001, IIT Kharagpur, Dec. 2001, pp 1 to 12

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