Vibration Control of Cotton Ginning Machine by Linkage Balancing+

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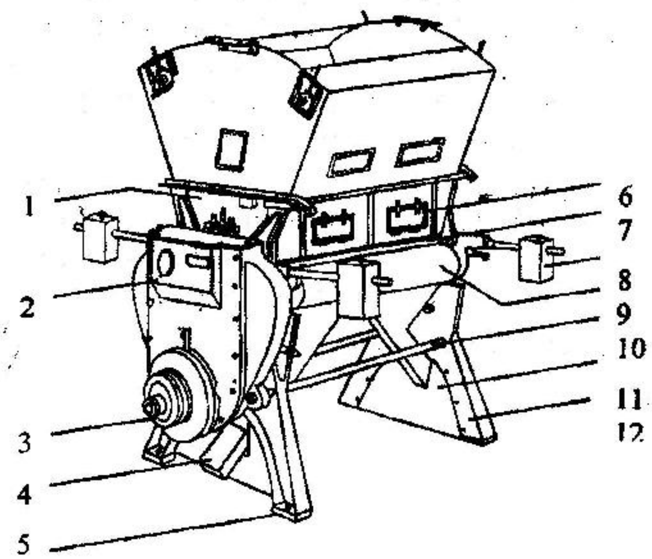
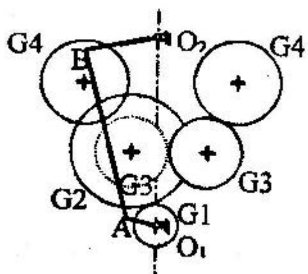
Introduction:

Ginning is the process of separation of cotton fibers from its seed. In the cotton ginning machine there is a fixed knife & a moving knife. This moving knife is called as beater and it oscillates about its central longitudinal axis of the beater. The fixed knife is in contact with the roller made of leather linings. The distance between the roller and the fixed knife is adjusted according to the quality of raw cotton. Using this fixed knife & the rollers cotton fibers are captured and the beater beats the held cotton to remove the seed from it.

The beater is allowed to oscillate with the help of a four bar mechanism and the rollers are allowed to rotate with the help of gear linkage as shown in Fig 01.



1. Upper Panel
2. Gear Box
3. Main Pulley with Hub
4. Seed Channel
5. Frame Gear Side
6. Hopper Sheet
7. Seed Guard
8. Weight
9. Roller
10. Cross Bar
11. Lower Panel
12. Frame OffSide



G4 : Rollers
G1, G2, G3 : Gear Train

Fig 01 : Four Bar Chain & Gear Train in Ginning Machine

In the above process the main parts, which contribute to the actual working, are beater and the roller. The beater is allowed to oscillate with the help of a four bar mechanism O_1ABO_2 as shown in Fig 01. The rollers are allowed to rotate with the help of gear train G1, G2, G3 and G4.

Objective: Central Institute of Research on Cotton Technology (CIRCOT), Nagpur, a unit of CSIR, New Delhi, India, complained about the vibration problem in this machine. We have recorded the vibration signatures [1,2]* on the frame with four bar chain and without four bar chain. These vibration signatures showed the high vibration level when the four bar linkage was present in the system. So in this work, we decided to balance this four bar linkage. This study is restricted only upto the calculation of the balance weights and not the incorporation of these in the machine and confirming the performance.

Diagnosis & Approach

As stated earlier it is understood that there are two driving mechanisms with which the whole machine works. There is a gear train mechanism to rotate two leather-lined rollers in opposite directions and a four bar linkage to oscillates the beater.

We have operated the machine individually by providing one mechanism at a time and observed the effect on vibration level. This test has revealed that the vibration level is more when four bar chain is operated as compared to where only when the gear train is operated.

Again from the vibration signatures it also clear that the high peaks are present only at the input shaft speed as compared to the peaks obtained at other locations.

From the above observation it is diagnosed that the main cause of the vibration and hence of the noise is due to the unbalanced four bar mechanism present in the ginning machine. Therefore it is required to balance this four bar mechanism.

Approach

Mechanism design cannot be complete without focusing attention on the interface between that mechanism and its mounting frame. **Berkof and Lowen [3,4,5,6,7,8,9,10,11]** have addressed this problem in depth. Two methods, complementing each other, have been developed, permitting elimination of both shaking forces and shaking moments transmitted to ground. In the present investigation balance weights are calculated using this approach of balancing the linkages.

It is well known that, during running condition, the total center of mass of the mechanism changes it's position which creates the considerable unbalanced shaking forces and shaking moments. These unbalanced shaking forces and moments thus generated by an unbalanced linkage are transmitted to its frame giving rise to the vibration, noise, wear and may cause fatigue problem.

Thus balancing of linkages comprises of two parts

1) Balancing of Shaking Force

2) Blanching of Shaking Moments

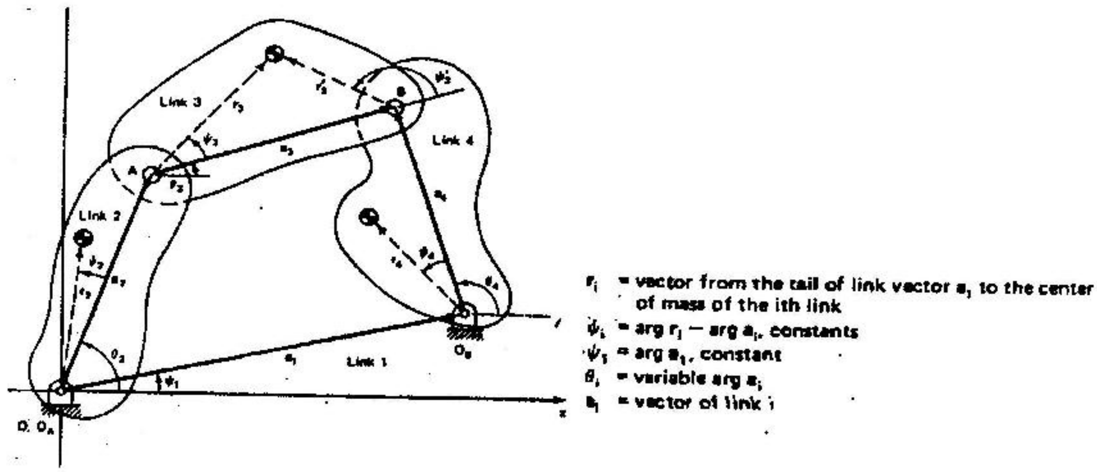


Fig 02 : Balancing of Linkage

Balancing of Shaking Forces

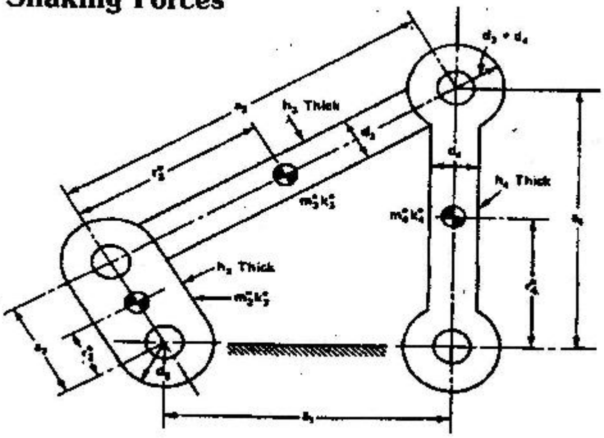


Fig 03 : Unbalanced Four-bar Linkage to be Completely Force and Moment Balanced [1]

Parameters*

Length, a_i (cm)

Width, d_i (cm)

Thickness, h_i (cm)

Mass, m^o_i (kg)

r^o_i (cm)

ψ^o_i (deg)

k^o_i (cm)

θi (deg)

*Parameters are as explained in the above Figures 03 and 04.

Total Moving Mass of the system = $\sum_{i=2}^{4} m_i$

If r_s = Vector defining center of mass of system

Then, $M \times r_s = \sum_{i=2}^{4} m_i r_i$

Where, $r_2 = r_2 e^{i(\theta_2 + \psi_2)}$

$r_3 = r_3 e^{i(\theta_3 + \psi_3)} + a_2 e^{i(\theta_3)}$

$r_4 = r_4 e^{i(\theta_4 + \psi_4)} + a_1 e^{i(\psi_1)}$

Substituting in the above equation we get

$$M\mathbf{r}_s = m_2 r_2 e^{i(\theta_2+\psi_2)} + m_3(r_3 e^{i(\theta_3+\psi_3)} + a_2 e^{i\theta_2}) + m_4(r_4 e^{i(\theta_4+\psi_4)} + a_1 e^{i\psi_1})$$

Again the loop closure equation is

$$a_2 e^{i(\theta 2)} + a_3 e^{i(\theta 3)} - a_3 e^{i(\theta 4)} - a_1 e^{i(\theta 1)} = 0$$

$$Mr_s = \left[m_2 r_2 e^{i\psi_2} + m_3 a_2 - m_3 r_3 \frac{a_2}{a_3} e^{i\psi_3} \right] e^{i\theta_2}$$

$$+ \left[m_4 r_4 e^{i\psi_4} + \frac{a_4}{a_3} m_3 r_3 e^{i\psi_3} \right] e^{i\theta_4} + \left[m_4 a_1 + m_3 r_3 \frac{a_1}{a_3} e^{i\psi_3} \right] e^{i\psi_1}$$

Which is of the form

$$M\mathbf{r}_s = \mathbf{A} e^{i\theta_2} + \mathbf{B} e^{i\theta_4} + \mathbf{C}$$

If the time-dependent terms vanish (i.e., if $\mathbf{A} = \mathbf{B} = 0$), then $M\mathbf{r}_s$ is constant, meting the criterion required for complete force balance. When $\mathbf{A} = 0$,

$$m_2 r_2 e^{i\psi_2} + m_3 a_2 - m_3 r_3 \frac{a_2}{a_3} e^{i\psi_3} = 0$$

Using all above equations and canceling all the linearly time dependent terms we get

$$\mathbf{r}_s = \frac{1}{M} \left(m_4 a_1 + m_3 r_3 \frac{a_1}{a_3} e^{i\psi_3} \right) e^{i\psi_1} = \frac{1}{M} \mathbf{C}$$

Balancing of Shaking Moment :

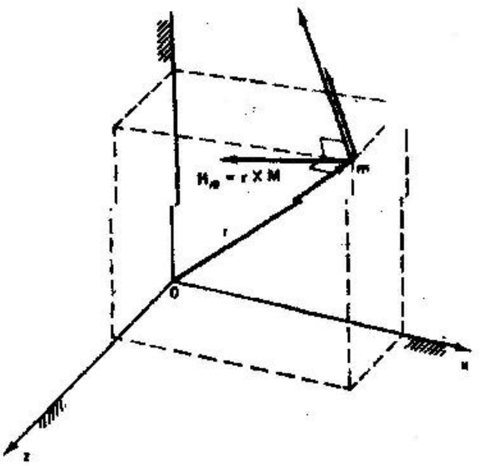


Fig 05 : Definition of momentum M and moment of momentum (or angular momentum) H/o of the point mass *m* located at r and moving at velocity y = r with respect to three-dimensional cartesian coordinates system *Oxyz*.

- Momentum is a vector colinear with velocity

- Principle of momentum states that rate of change of angular momentum equals sum of externally applied moments.

i.e. $M_o = -\frac{d}{dt} H_o$

Where, M_o = Externally applied moments

H_o = Angular momentum of the system

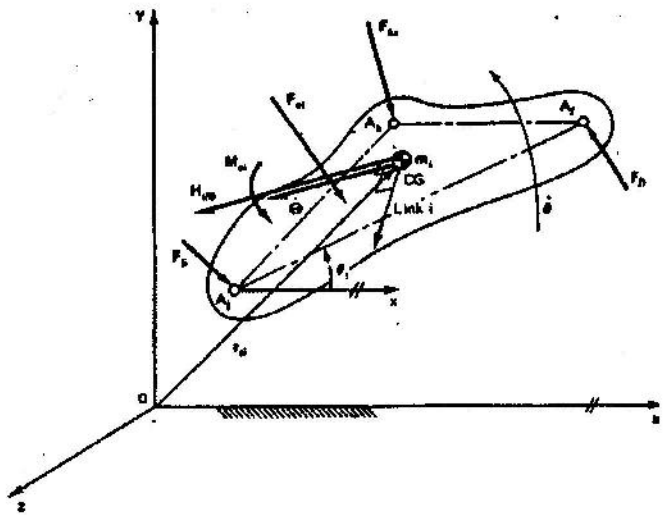


Fig 06 : Arbitrary link i in rotation about the z axis.

Oxyz represents the right handed system

Any externally applied moments are given by

$$\mathbf{M}_{i/0} = \mathbf{M}_{ei} + \mathbf{r}_{ei} \times \mathbf{F}_{ei} + \mathbf{M}_{ki} + \mathbf{r}_{ki} \times \mathbf{F}_{ki} + \mathbf{r}_{gi} \times \mathbf{F}_{gi} + \mathbf{M}_{gi}$$

where the subscript *ei* implies externally applied

gi implies from ground

ki implies from another link

Solving we get

$$\sum_{i=2}^{n}(M_{ei} + r_{ei} x F_{ei}) - M_{M/G/O} = -\frac{d}{dt}H_o$$

Application : the four bar chain has the following specification :

Sr. No.	Links* (a_i)	Length (cm)	Weight (kgf)	Width, d_i (cm)	Thickness h_i (cm)
1.	Crank (O_1A)	3.5	0.37	ψ5.5	2
2.	Coupler (AB)	48.5	4.20	4	05
3.	Output Link (O_2B)	11.43	6.10	0.5	-
4.	Fixed Link (O_1 O_2)	50	-	-	-
5	Motor Speed	1450-1460 RPM			

* As shown in the following figure 01.

Using the above said approach of balancing the four bar linkage, we have calculated the weights of the counterbalance masses that we have proposed to attach to the present unbalance linkage which will make the linkage balanced and thus will eliminate the vibrations as well as noise problem. These balance weights are as shown in the following Fig 08.

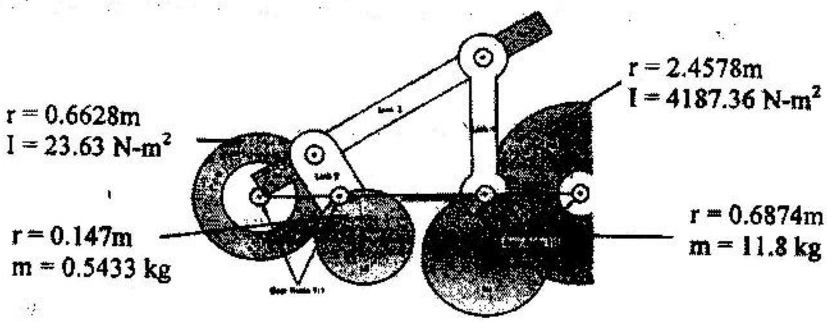


Fig. 08: Funy force-and moment-balanced in-line four-bar linkage of Ginning Machine. Shaded area is material added to achieve (a) force- and (b) moment-balance.

Computer Simulation: We have computerized this process of balancing so that the counter weights can be calculated easily and quickly.

Conclusion

Due to the present space constraints it is not possible to incorporate these calculated balanced weights in the present unbalanced ginning machine. This can be considered as a matter of further development. It is required to redesign the existing machine, fabricate it and test for vibration & noise response.

Reference :

1 Rao JS and Dukipatti RV, *Mechanisms and Machine Theory*, Second Edition, Newage International pub., ISBN -812240426X, 1998.

2 Victor Wowk, *Machinery Vibration-Measurement and Analysis*, McGraw Hill Inc., ISBNO-07-071936-5,1991.

3 Berkof RS, "On the Optimization of Mass Distribution in Mechanisms," , Ph.D. thesis, *City University of New York, 1969.*

4 Berkof RS "Complete Force and Moment Balancing of Inline Four-Bar Linkages,", *Journal of Mechanism and Machine Theory*, 8, no.3 (1973), pp. 397-410.

5 Berkof RS and G.G. Lowen, "A New Method for Completely Force Balancing Simple Linkages," *Journal of Engineering for Industry,* no.1 (1969), pp. 21-6.

6 Berkof RS and G.G. Lowen, "Theory of Shaking Moment Optimization of Force-Balanced Four-Bar Linkages," *Journal of Engineering for Industry,* 93B, no.1 (1971), pp. 53-60.

7 Berkof RS, "The Input Torque in Linkages," *Journal of Mechanism and Machine Theory,* 14 (1979), pp. 61-73.

8 Berkof RS, "Force Balancing ofa Six-Bar Linkage," *Proceedings of the Fifth World Congress on Theory of Machines and Mechanisms, pp. 1082-85. New York: American Society of Mechanical Engineers, 1979.*

9 Berkof RS, A.G. Erdman, D. Hewitt, T. Bjorklund, D. Harvey, et al., "*Mechanism Case Studies IV,*", *ASME Paper* No. 78-DET-19, 1978.

10 Berkof RS, and Lowen, GG, "Theory of Shaking Moment Optimization of Force-Balanced Four-Bar Linkages," *Journal Of Engineering For Industry, Trans. Asme,* Series B, Vol. 93, No.1. Keb. 1971, pp. 53-60.

11 Berkof RS, J. Boomgaarden, A.G. Erdman, et al., "Mechanism Case Studies VI," ASME Paper No. 82-DET-47, 1982.

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* Numbers in the bracket shows the references used in this work, which are mentioned at the end of this paper.