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Preliminary Design of a New Mechanism for Sheep Shearing Device

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Abstract
A sheep hair shearing device is a mechanized device used to cut the woolen fleece of sheep. The mechanical device is currently being imported to India at high costs, making it unaffordable for rural people [1]. The inability of the Indian manufacturing industry to produce such devices lied in the fact that the mechanism being used in the commercial device was patented by a foreign manufacturing company. Therefore, there is a demanding need for the development of a new, novel mechanism for the purpose which can be used to manufacture low-cost, affordable shearing devices in India itself. This research paper is a step towards the development of such a mechanism, and it talks about the synthesis of the mechanism from scratch as well as its kinematic and dynamic analyses, carried out in a simulated environment, using commercial software, Recurdyn. The research started with review of the kinematic and dynamic analyses of the already existing sheep shearing mechanism and search for various new plausible candidate mechanisms that might have similar input-output kinematic characteristics. This search culminated in the 3-link R-Sp-R mechanism (Revolute_Sphere-plane_Revolute) (see Figure 1), which fulfilled all the basic kinematic requirements. Figure 1 shows the initial position of two rigid bodies grounded via rotational pairs and connected together by a sphere-plane pair.

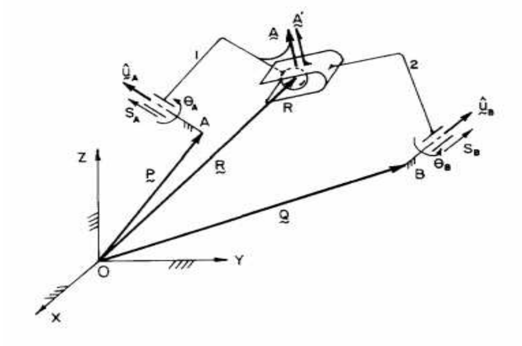


Figure 1: Schematic of R-Sp-R Mechanism [2]

Some of the vector and scalar quantities shown in above figure are explained below:
$\mathbf{S_B}$ - translation of link 2 along axis $\mathbf{U_B}$ (Zero for revolute). Define $\mathbf{K = R - P}$ and $\mathbf{L = R - Q}$
Using loop closure equation and motion constraint equation for Sp joint, kinematic relation obtained is as follows [2]

$$\tan\frac{\Theta_{Bj}}{2} = \frac{-b \pm \sqrt{(b^2 - c(c-2a))}}{c-2a} \quad (1)$$

where
$a = (-\mathbf{U}_{BL} \cdot \mathbf{A}) - (\mathbf{S}_j \cdot \mathbf{U}_{BA})$; $b = (\mathbf{U_B} \times \mathbf{L}) \cdot \mathbf{A} - \mathbf{S}_j \cdot (\mathbf{U_B} \times \mathbf{A})$; $c = -(\mathbf{S}_j \cdot \mathbf{A})$; $\mathbf{S}_j = (\cos\Theta_{Aj} - 1)\,\mathbf{U}_{AK} + \sin\Theta_{Aj}\,(\mathbf{U_A} \times \mathbf{K})$
wherein,
$\mathbf{U_{CD} = (U_C \times D) \times U_C}$, for any vectors $\mathbf{U_C}$ and **D.**
K and **L** are related to the lengths and orientation of the two rotating links, $\mathbf{U_A}$, $\mathbf{U_B}$, and **A** depict the initial orientation of joints.
The formula in equation (1) gives us the relation between input rotatory angle Θ_A and output angle Θ_B in terms of $\mathbf{U_A}$, $\mathbf{U_B}$, **A**, **K** and **L**. Equation (1) was used to carry out kinematic synthesis of the mechanism for the following required input-output relations: (a) output link should approximately oscillate 15 degrees for 360 degrees of continuous rotatory input, (b) the input and output axes should be intersecting and orthogonal. The results of kinematic synthesis of the R-Sp-R mechanism, using MATLAB, are as follows: $\mathbf{U_A} = [1,0,0]$; $\mathbf{U_B} = [0,1,0]$; $\mathbf{A} = [0,0,1]$; $\mathbf{K} = [7,0,.5]$; $\mathbf{L} = [-4,0,.5]$. For the mentioned set of

parameters, an output oscillation of 14.72 degrees for a 360-degree rotatory input was obtained by trial and error method. Using the above synthesized dimensions of the mechanism, a CAD model of the same is prepared (Figure 2).

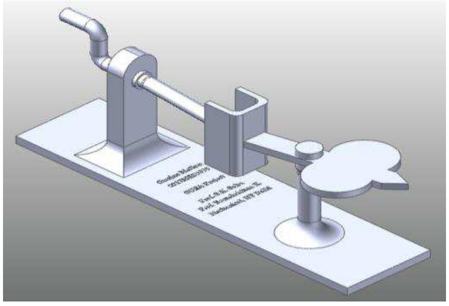
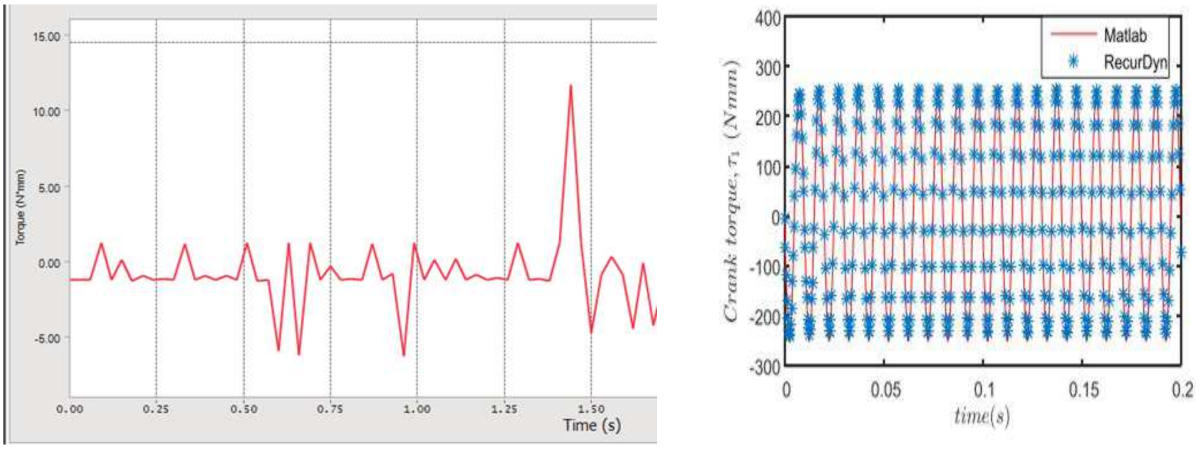


Figure 2: CAD model of the synthesized mechanism

Kinematic and Dynamic analysis of the modelled mechanism is performed using Recurdyn. Dynamic analysis (Figure 3a) carried out was purely inertial; no external forces/torques were taken into account. The irregularities in the curve shown in Fig. 3a can be explained by the clearance provided between the sphere and plane in the CAD model.



a.) b.)

Figure 3: Torque(N*mm) vs Time(s) curve for: a.) Synthesized mechanism b.) Existing mechanism [1]

These results make more sense when we compare them with similar analyses already carried out for the existing mechanism. The existing 4-link mechanism oscillates with an amplitude of 15 degrees for 360 degrees rotatory input [1]. Also, its inertial Dynamic analysis results show an input torque requirement of around 250 N*mm (Figure 3b) for input rotatory speed of 3000 rpm, which is very high as compared to the Torque-requirement in the new mechanism developed [1]. An important point to be noted is that the masses of the crank, fork (output oscillatory link) and ball (sphere in Sp joint) used for analysis are comparable for both the mechanims; therefore it is fair to compare the results of the two. The results of this research work suggest that the R-Sp-R mechanism can potentially be used in a sheep hair shearing device and has proven to be better than the existing one so far. This argument can be further strengthened by carrying out a more rigorous dynamic analysis, taking into account all the external forces and torques. Therefore, this paper sets a strong base to the development of a novel mechanism that might trigger a new segment of the production industry in the Indian market.

References

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[2] Sandor, G.N.; Kohli, D.; Hernandez, M. Jr.; Ghosal, A.: Kinematic Analysis of three-link Spatial Mechanisms containing Sphere-Plane and Sphere-Groove pairs. Mechanism and Machine Theory, Vol.19, No. 1, pp 129-138, 1984.