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DESIGN OPTIMIZATION OF TWO COMBINED FOUR-BAR MECHANISMS USING THE PRINCIPLES OF AXIOMATIC DESIGN

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ABSTRACT

Two combined four-bar mechanisms have two functions: lift and collapse. In the current design, high effort was found for the collapse function. Axiomatic Design was used to analyze and optimize the current design. The customer domain was mapped into the functional domain by specifying customer needs in terms of functional requirements (FRs) and constraints (Cs). Design parameters (DPs) were identified in the physical domain for each functional requirement. Design matrices were then defined to characterize the product design [1].

The two combined four-bar mechanisms have two functional requirements at the highest level: lift and collapse. The corresponding DPs are lift four-bar linkage and collapse four-bar linkage. Through zigzagging to decompose to the next level, the design was found to be coupled. At this level, a torsion spring was selected as the DP for minimizing the lift effort. However, this DP was also found to affect three next level FRs for the collapse: the front leg rotation, the rear leg rotation and the float link rolling. This coupling greatly increased the collapse operation effort because the spring was useful for the lift function but was a hindrance for the collapse function.

The design was de-coupled by adding two locks, which are called floating link lock and front leg lock, and an extra plate which is called locking plate. The new modified design can improve customer satisfaction because when the rear lock and the floating link lock are released, the torsion spring will assist the lift, and when front lock and front leg lock are released, the torsion spring will not resist the collapse.

Keywords: Axiomatic Design, Design Optimization, Four bar Mechanism

1 INTRODUCTION

Two combined four-bar mechanisms are composed of front leg, rear leg, ground link, float link, retract link, six hinges, torsion spring, front lock, and rear lock. Lift and collapse functions are required. In the lift mode, the front leg is a fixed link; when the rear lock is released, the float link, the retract link, and the rear leg can be lifted; the torsion spring is used to assist the lift. In the collapse mode, the ground link is a fixed link; the front leg, the float link, and the rear leg can be collapsed. Figure 1(a) (b) (c) shows the two combined four-bar mechanisms and how the lift mode and the collapse mode work.

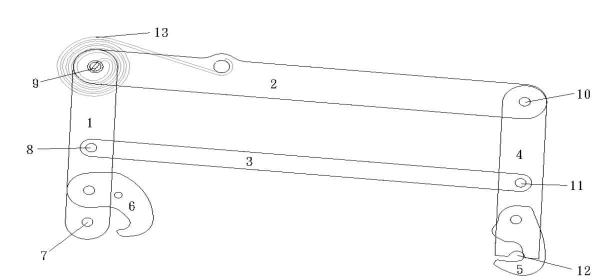

Figure 1 (a) Two Combined Four-Bar Mechanisms in Design Position

Here,

(1) Front leg
(2) Float link
(3) Retract link
(4) Rear leg
(5) Rear lock
(6) Front lock
(7) Front lower hinge
(8) Front middle hinge
(9) Front upper hinge
(10) Rear upper hinge

(11) Rear middle hinge
(12) Rear lower hinge
(13) Torsion spring

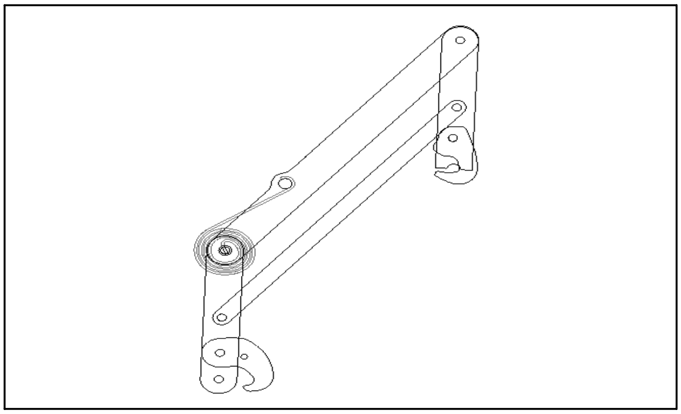

Figure 1 (b) Two Combined Four-Bar Mechanisms in Lift Mode

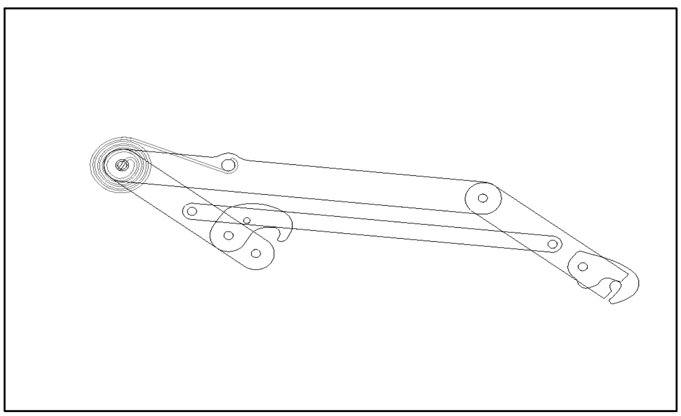

Figure 1 (c) Two Combined Four-Bar Mechanisms in Collapse Mode

2 DESIGN ANALYSIS USING THE INDEPENDENCE AXIOM

The two combined four-bar mechanisms were treated as one system. Two functional requirements at the highest level were identified in this system:

FR1 = Lift
FR2 = Collapse

The corresponding design parameters to satisfy these functional requirements are:

DP1 = Lift four-bar linkage
DP2 = Collapse four-bar linkage

The design equation may be written as:

$$\begin{Bmatrix} FR1 \\ FR2 \end{Bmatrix} = \begin{bmatrix} X & 0 \\ 0 & X \end{bmatrix} \begin{Bmatrix} DP1 \\ DP2 \end{Bmatrix} \qquad (1)$$

FR1 may be decomposed as:

FR11 = Release rear lock
FR12 = Float link rotation
FR13 = Retract link rotation
FR14 = Rear leg rolling
FR15 = Minimize lift effort

FR2 may be decomposed as:

FR21 = Release front lock
FR22 = Front leg rotation
FR23 = Rear leg rotation
FR24 = Float link rolling

The design parameters at this level are:

DP11 = Rear lock
DP12 = Front upper hinge
DP13 = Front middle hinge
DP14 = Moving/fix centrode set 1
DP15 = Torsion spring

DP21 = Front lock
DP22 = Front lower hinge
DP23 = Rear lower hinge
DP24 = Moving/fix centrode set 2

The overall design matrix for this second level is:

	DP 11	**DP 12**	**DP 13**	**DP 14**	**DP 15**	**DP 21**	**DP 22**	**DP 23**	**DP 24**
FR11	X								
FR12		X			X				
FR13			X		X				
FR14				X					
FR15					X				
FR21						X			
FR22					X		X		
FR23					X			X	
FR24					X				X

To realize the design expressed by Equation (1), DP1x's should not affect FR2x's, and similarly, DP2x's should not affect FR1x's. However, in this design, DP15, which was selected to minimize the lift effort, does affect FR22, FR23, and FR24 because the torsion spring was helpful for the lift function but was a hindrance for the collapse function.

3 IMPROVED DESIGN USING DE-COUPLING

The coupled design can be de-coupled by adding a floating link lock, a front leg lock and a locking plate as shown in Figure 2. The new modified design can improve customer satisfaction by reducing high operation effort for the collapse mode. When the rear lock and the float link lock are released, the torsion spring for the lift effort will assist the lift since front leg lock locks the torsion spring and lock plate into the front leg. When the front lock and the front leg lock are released, the torsion spring will not resist the collapse since the torsion spring and the lock plate will be locked on the floating link.

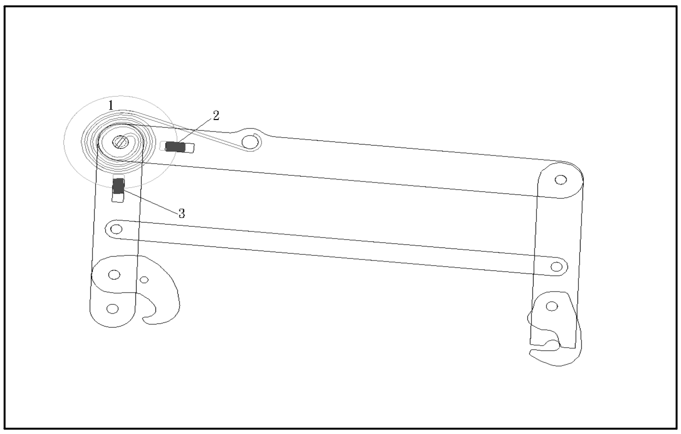

Figure 2 Locking Plate, Floating Link Lock and Front Leg Lock in the New Design

Here,

(1) Lock Plate
(2) Floating Link Lock
(3) Front Leg Lock

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4 REFERENCES

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