Dynamic Analysis of The Hydraulic Scissors Lift Mechanism

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Abstract: ***In this study, model of lifting platform consisting of scissors and hydraulic cylinder is formed. Static state equations have been used for the mathematical model of the mechanism. The weights and mass inertia moments of the platform members and the upper table have been neglected. Vehicle load as a point force, the top of the table is closed at the moment when the mechanism is effective. The sliding in the joints have been neglected.The mechanism is modeled and simulated in order to evaluate several application-specific requirements such as dynamics, position accuracy etc. The system has a 5 degree of freedom. The simulation gives different link lengths of the mechanism over a linear displacement.***

Keywords: Vehicle, Mechanism, Lift, Modeling

1. Introduction

The lift mechanism is a form of construction used in the automotive industry. Infact, they are platform mechanisms that are used in high places that arein accessible because it is a lifting forwarding machine. Scissor-type systems are frequently used as lifting systems in the industry. The systems are mainly preferred to do maintenance, repair, and clean. Lifting systems are generally used for purposes of lifting a load or providing at unreachable heights. Nowadays, many lifting systems are designed to be used for various purposes in industry. These systems can be used in multi-purpose applications and a range of services such as cleaning services, maintenance-repair activities, load lifting and lowering activities. Airports and indoor stadium are examples of these. Lifting systems can be classified as telescopic lifts, articulated lifts, and scissor lifts [1-2].

Scissor lifting mechanism is the first choice for automobiles and industries for elevation work. There are several procedures for deriving dynamic equations of rigid bodies in classical mechanics (i.e. Classic Newton-D'Alembert, Newton- Euler, Lagrange, Hamilton, Kanesto name a few). But these are labor-intensive for large and complicated systems there by error prone. The describes the implementation of general multibody system dynamics on Scissor lift Mechanism (i.e. four bar paralel mechanism) [3].

2. Lift Mechanism and Geometry

The complete system model of the scissor lift mechanism shown Figure1.The parts of this mechanisms are rampa, platform, scissor links, revolute and slider joints, hydraulic cylinder and base port. Techinical datas of lift mechanisms are lifting capacity 3500 kg, lifting height 2000mm , lifting time 50 s, electrical requirement 220 / 380 v, Motor power 2.2 kw

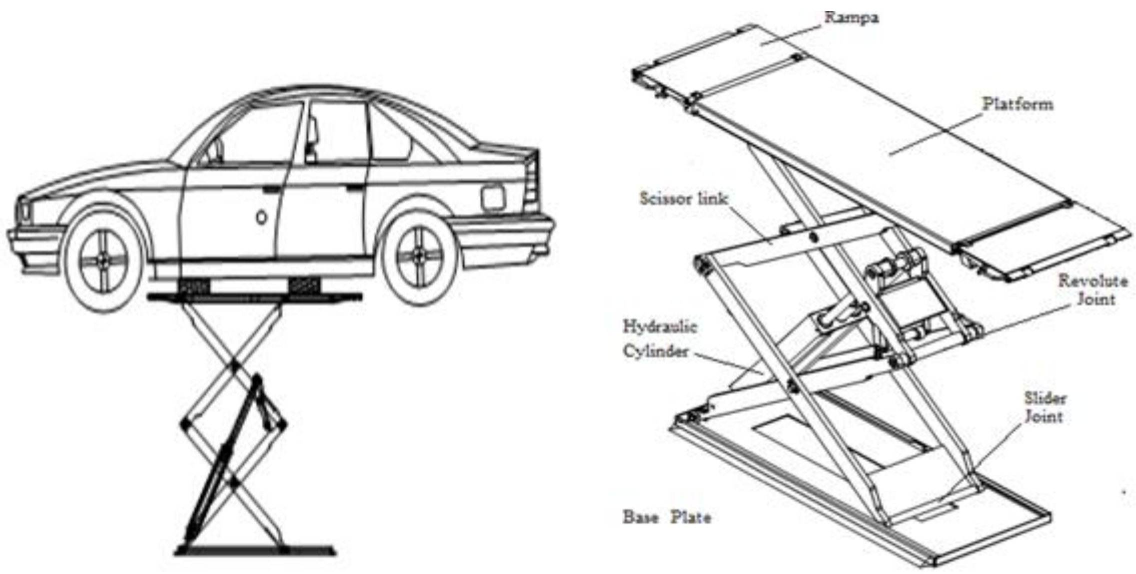

Figure 1: Scissor Lift Mechanism [4]

Figure 2 shown single scissors and single hydraulic cylinders are designed. Scissors are 4 rotational, 2 sliding link as are 5 DOF (Degree of Freedom). The height, θ and β and angles of the hydraulic piston change in the cylinder. Here is the actuator hydraulic cylinder.

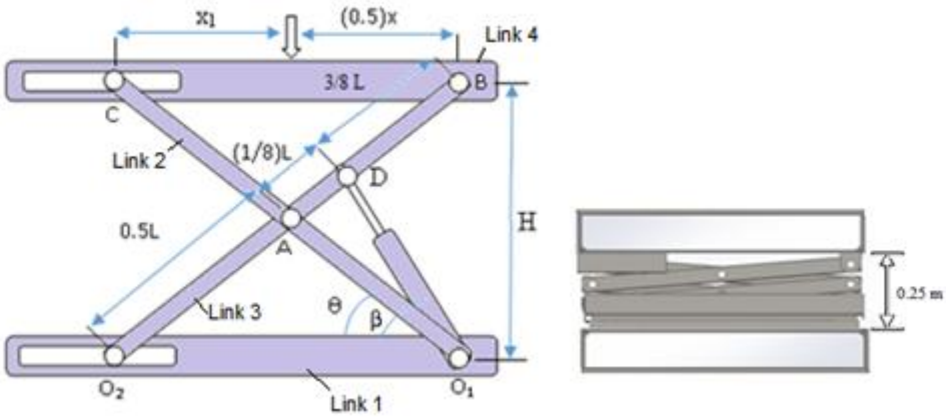

Figure 2: Geometry of Scissor Lift Mechanism [5]

Where L: scissor arm length, H: hydraulic arm height, X: length of upper table in closed condition, X_1: distance between load application point and sliding joint, H: height of mechanism platform, θ: angle between link and horizontal axis, β: hydraulic angle between cylinder and horizontal axis[5].

3. Mathematical Model

The dynamic analysis of the system was carried out with load and reaction forces on the platform (Figure3). There action forces were re-applied to the system despite the force equations (Figure4). In order to obtain the joint forces, free body diagrams of the systems were taken in to consideration. The weights of the system components are neglected. The angle between the link and the base plate was obtained according to the angle β and the total F between the hydraulic plate and the base plate. (1-5) equations are given as analytical solution of thesystem. The forces are shown as F_{ij}^{xy}. The combination of the *i* and *j* links with each other, *x* and *y* show the direction of the forces. F_{ij}^{xy} and F_{ji}^{xy} are the same numerical values. Signs vary from positive to negative. Also, the angles α and β can be calculated for all positions of the platform [6].

3.1. Analytical Calculations

The force analysis of the system was first performed by defining the load and reaction forces on the work platform (Figure 3).

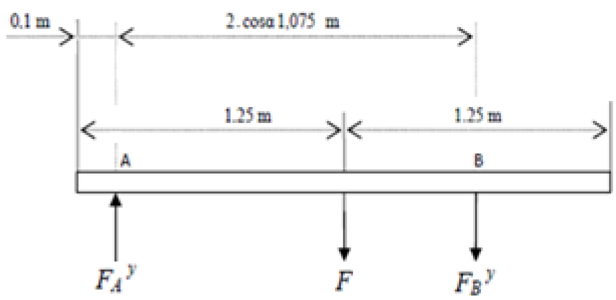

Figure 3: Link4 (Platform) Free Body Diagram

$$\sum F^y = 0 \Longrightarrow F_B^y + F = F_B^y \qquad (1)$$

$$\sum M_b = 0 \Longrightarrow F_A^y.(2.\cos\alpha.1{,}075) = F.(2.\cos\alpha.1{,}075 - 1{,}15) \qquad (2)$$

$$\sum F^x = 0 \Longrightarrow F_{21}^x = F_{41}^x \qquad (3)$$

$$\sum F^y = 0 \Longrightarrow F_{41}^y = F_A^y - F_{21}^y \qquad (4)$$

After the equations related to the forces on the work platform were obtained, the system was started to be solved by applying the reaction forces to the profiles again (Figure 4).

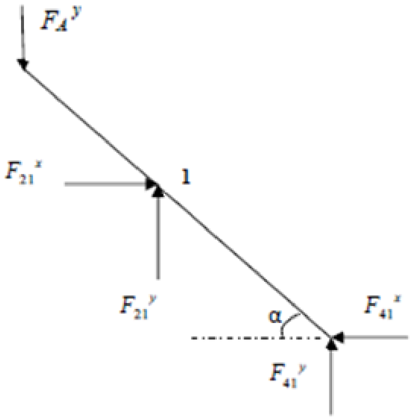

Figure 4: Link 2 Free Body Diagram

At the junction points,

$$\Sigma_M = 0 \text{ (lower point)} \Longrightarrow 2.F_A{}^y.\cos\alpha - F_{21}{}^x.\mathrm{Sin}\alpha - F_{21}{}^y.\cos\alpha = 0 \qquad (5)$$

Piston force is calculated as shown in equation (6) according to analytical calculations.

$$F_{piston} = \frac{[(F_{23}^x - 2.F_{41}^x).\sin\alpha] + [(2.F_{41}^y - F_{23}^y).\cos\alpha] - 2.F_A^y.\cos\alpha + F_B^y.\cos\alpha}{2.(\cos\beta.\sin\alpha - \sin\beta.\cos\alpha)} \qquad (6)$$

By way of example, the piston force is obtained in accordance with the analytical calculations as shown in equation (6). Other forces were obtained in the same way as an equation and transferred to Excel program and numerical values occurred (Table 1).

Table 1: Comparision Experimental and Nümerical Variables

Joint (Angles, Forces)	Nümerical (°, N)	Expermental (°, N)
α	8.35 °	8.35 °
β	22.49 °	22.49 °
F	3386	3382
F_{piston}	31674	31666
$F_A{}^y$	1565.8	1564.7
$F_B{}^y$	-1834	-1833.7
$F_{21}{}^x$	24065	24067

F_{21}^{y}	-280.5	-281
F_{41}^{x}	24056	24061
F_{41}^{y}	1863.1	1863.1
F_{32}^{x}	24081	24082
F_{32}^{y}	1589.7	1589.7
F_{43}^{x}	68556	68560
F_{43}^{y}	268.7	270.8

Mathematical modeling was done with two different classification. These are kinematic and dynamic models.Kinematic equations, according to Fig.2, θ the relation between and β is given in equation (7). The equation (7) is formed by the following procedure [7].

$$(sin\beta)\,L_H + (sin\theta)\left(\frac{3}{8}\right)L = (sin\theta)\,L,$$

$$(sin\beta)\,L_H = \frac{5}{8}(sin\theta)\,L,$$

$$(cos\beta)\,L_H = \frac{3}{8}(cos\theta)\,L$$

$$\beta = \tan^{-1}\left(\frac{5}{3}tan\theta\right) \qquad (7)$$

The relation for distance X_1 is given in equation (8) according to the geometry of platform and order of operation.This state shown in Figure 5.

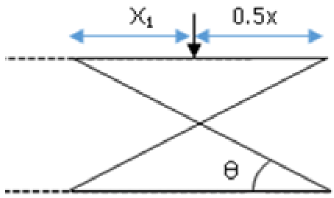

Figure 5: Geometry of Platform

$$x = L.cos(\theta_{min})$$

$$x_1 = x = L.cos(\theta_{min}) \qquad (8)$$

Closed condition in the mechanism: $\theta_{min} = 8°$

$$x_1 = Lcos\theta - 0{,}5x$$

Dynamic equations,The F forces for the Link 2 serbest cisim diyagramında and the M moment equations (9,10,11) are generated according to the geometry in Figure 6 shown below.

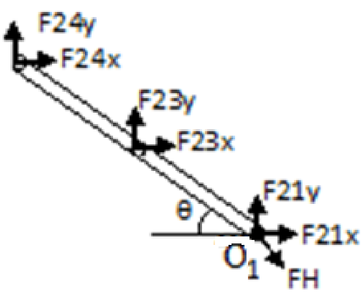

Figure 6: F Forces of Link 2

$$+\!\rightarrow \sum Fx = 0\; F21x + F23x + (cos\beta)FH = 0$$

(9)

$$+\!\rightarrow \sum Fy = 0\; F21y + F23y + F24y + (sin\beta)FH = 0$$

(10)

$$+\circlearrowleft \sum M0_1 = 0\; (-0.5Lsin\theta)F23x + (-0.5Lcos\theta)F23y + (-Lcos\theta)F24y = 0 \qquad (11)$$

The F forces and the M moment equations (12,13,14) are shown in the free body diagram and Figure 7.

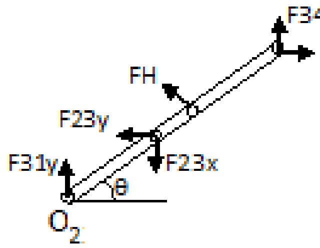

Figure 7: F Forces of Link 3

$$+\!\rightarrow \sum Fx = 0 - F23x + F34x - (cos\beta)FH = 0 \qquad (12)$$

$$+\!\rightarrow \sum Fy = 0\, F31y - F23y + F34y + (sin\beta)FH = 0 \qquad (13)$$

$$+\circlearrowleft \sum M0_2 = 0\; (0.5Lsin\theta)F23x + (-0.5Lcos\theta)F23y + (-Lsin\theta)F34x + (-Lcos\theta)F34y + \left(\frac{5}{8}Lsin\theta\right)cos\beta FH + \left(\frac{5}{8}Lcos\theta\right)sin\beta FH = 0$$

$$+\circlearrowleft \sum M0_2 = 0\; (0.5Lsin\theta)F23x + (-0.5Lcos\theta)F23y + (-Lsin\theta)F34x + (-Lcos\theta)F34y + \frac{5}{8}Lsin(\theta+\beta)FH = 0$$

(14)

The F forces and M moment equations (15, 16, 17) for the Link1were formed according to the geometry and Free Body Diagram (in Figure 8) shown below.

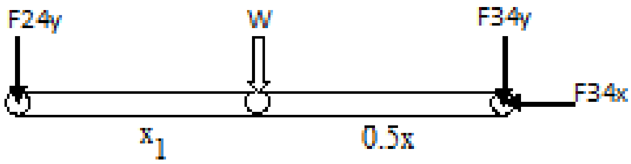

Figure 8: F Forces of Link 1

$$+\!\rightarrow \sum Fx = 0 \quad -F34x = 0 \qquad (15)$$

$$+\!\rightarrow \sum Fy = 0 \quad -F24y - F34y - W = 0 \qquad (16)$$

$$+\circlearrowleft \sum M0_2 = 0\; (x1 + 0.5x)F24y + (0.5x)W = 0 \qquad (17)$$

Because the F_{34x} force is 0, the linear equation set can be formed after being removed from other equations.

Coefficients Matrix:

$$\begin{bmatrix} 1 & 0 & 1 & 0 & 0 & 0 & 0 & cos\beta \\ 0 & 1 & 0 & 1 & 1 & 0 & 0 & sin\beta \\ 0 & 0 & -0.5sin\theta & -0.5cos\theta & -cos\theta & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 & 0 & 0 & 0 & -cos\beta \\ 0 & 0 & 0 & -1 & 0 & 1 & 1 & sin\beta \\ 0 & 0 & 0.5sin\theta & 0.5cos\theta & 0 & 0 & cos\theta & (5/8)sin(\theta+\beta) \\ 0 & 0 & 0 & 0 & -1 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 & x1+0.5x & 0 & 0 & 0 \end{bmatrix} . \begin{bmatrix} F12X \\ F12Y \\ F23X \\ F23Y \\ F24Y \\ F31Y \\ F34Y \\ FH \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ W \\ (0.5X)W \end{bmatrix}$$

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Hydraulic Circuit

The hydraulic circuit of scissor lifting system was created with the help of Fluid-Sim Hydraulic Package Program in Figure 9. The circuit is mainly consisted of a this Figure 9.The systems ends the pressurized oil to the pressure sequencing valve through pressure unit and the filter. The fluid oil open the pressure sequence valve and it sends to directional control valve and hydraulic accumulator under working pressure. After hydraulic accumulator has been charged to a sufficient pressure, hydraulic cylinder move swithc changing the position of the directional control valve. The speed of the hydraulic cylinder can be controlled by a bidirectional flow control valve[8].

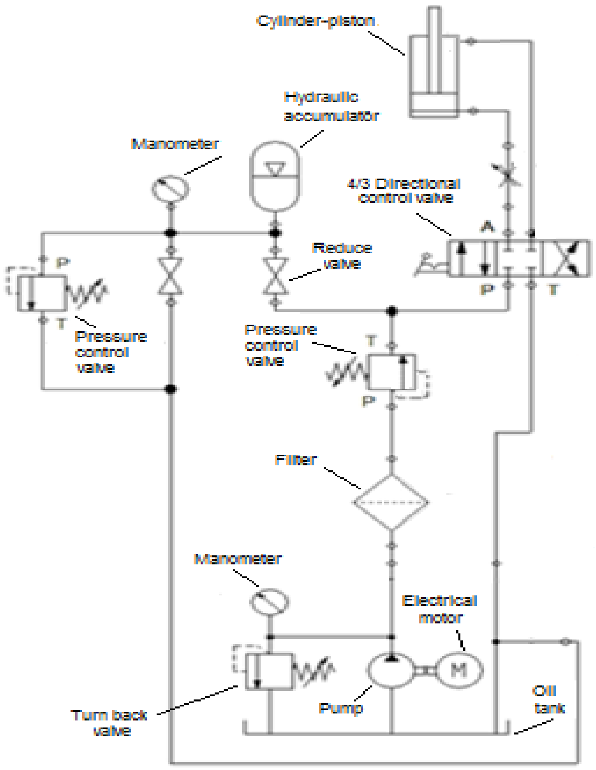

Figure 9: Hydraulic Circuit of Lift Mechanism [8]

4. Conclusion

The study was carried out successfully according to the study plan. The out-come of the hydraulic scissors lift design meets the objective of the study. As a result, the study designed the electro-hydraulic parallelogram lift. The general section described the classification, purpose and technical characteristics of the lift and the mechanism and operation principle of the designed lift. In the design section, the lift calculation is done, where the forces acting in the cylinder and emerging stresses in the system were calculated. A 3D model was created. After completed this study, I have gained some skills and knowledge in this field. I have learnt many things in terms of utilizing engineering mechanisms in a proper manner. Finally, the experience I have obtained through out this Project will certainly help me to be a creative engineer in the future.

5. Acknowledgement

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