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# DESIGN AND KINEMATIC ANALYSIS OF GEAR POWERED SCISSOR LIFT

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***Abstract*—In this paper scissor lifts powered by gear mechanism has been introduced. The components of gear powered scissor lift are spur gears, scissor arm, platform, one horse power electric motor. These components are designed and the mechanism is simulated using Automated Dynamic Analysis of Multi Body Dynamics Simulation Solution (ADAMS 2013) software package. A detailed kinematic analysis is performed on the mechanism. For different length to radius ratio, maximum translatory displacement is measured. For different speed of the motor, velocity of the link is studied .Different lift heights can be achieved by varying the number of links .We expect that our design scissor lift will carry a load of around 2000 kilogram with factor of safety equal to 4 and lifting to a height of around 0.5metre.**

*Index Terms*— **ADAMS, Gear train, Lift height, L/R ratio, rpm**.

## I. INTRODUCTION

A scissor liftis a type of platform that can usually move vertically. The mechanism is achieved by the use of linked, folding supports in a criss-cross "X" pattern, known as a pantograph (scissor mechanism). The upward motion is achieved by the application of pressure to the outside of the lowest set of supports, elongating the crossing pattern, and propelling the work platform vertically. The platform may also have an extending "bridge" to allow closer access to the work area.

The contraction of the scissor action can be hydraulic, pneumatic or mechanical via (a lead screw or rack and pinion system). Depending on the power system employed on the lift, it may require no power to enter "descent" mode, but rather a simple release of hydraulic or pneumatic pressure. This is the main reason that these methods of powering the lifts are preferred.

## II. LITERATURE REVIEW

Okolieizunnajude et al described that the conventional method of using rope, ladder, scaffold and even mechanical scissors lift in getting to a height encounter a lot of limitation (time and energy consumption, comfortability, amount of load that can be carried etc), which hydraulic scissors lift is set out to achieve. In this a mobile scissors lift has been designed that will be powered by hydraulic to a height of 3m carrying a maximum load of 300kg [3].

Jaydeep et. al designed as well as analysed a simple aerial scissor lift. Conventionally a scissor lift or jack is used for lifting a vehicle to change a tire, to gain access to go to the underside of the vehicle, to lift the body to appreciable height, and many other applications Also such lifts can be used for various purposes like maintenance and many material handling operations. It can be of mechanical, pneumatic or hydraulic type. The design described in the paper is developed keeping in mind that the lift can be operated by mechanical means so that the overall cost of the scissor lift is reduced. Also such design can make the lift more compact and much suitable for medium scale work. Finally the analysis is also carried out in order to check the compatibility of the design values [4].

Todd J. Bacon designed a belt-driven transportation system including a first set of pulleys rotatable attached to a second member and a second set of pulleys rotatable attached to a second member. The first and second members have relative movement to each other .The system further includes a unitary belt that is guided through a path defined by the first and second sets of pulleys. A plurality of range members maintain a proper positioning of the belt on the pulleys [5].

Arturo Valencia et al designed a lift platform sustained through a double System of support scissors in its lower part, which offers the mechanical, upward and downward motion in a vertical plane and on a base frame. which in its turn is activated by a hydraulic mechanism. The lift platform is characterized because it also includes a hydraulic unit which operates electronically to automatically control the desired position in its upward or downward motion originated by the movement of the mobile arms of the scissors on a track in the horizontal plane [6].

Donald Watkins developed scissor lift mechanism for use on a coil car or the like, the lift having scissor legs connected to each other by a shaft. The lift is raised and lowered by a means for providing a generally vertical force to the shaft. The means may be provided by a hydraulic cylinder and a bell crank mechanism. The bell crank mechanism redirects the force from a hydraulic cylinder to a generally vertical force on a hinge connecting the scissor legs of the lift. The bell crank mechanism allows the strength of the lift to be maximized while retaining a low profile design [7].

Newlin developed a telescopable electro-mechanical actuation arrangement. The actuation arrangement has a contractable and extendable component capable of varying in length and operable to undergo rotation in a first angular direction and translational contraction in length in a first linear direction so as to cause movement of the lift mechanism vertically toward the retracted condition and thereby movement of the work platform toward the lowered position. The telescopable component also is operable to undergo rotation in a second angular direction opposite to the first angular direction and translational extension in length in a second linear direction opposite to the first linear direction so as to cause movement of the lift mechanism vertically toward the expanded condition and thereby movement of the work platform toward the raised position [8].

Mahmood et al studied the aerial platform falls/collapses/ tipovers across all industry classifications. This study showed that approximately two-thirds of fatal and nonfatal incidents involving scissor lifts occurred in the construction industry. Approximately two-thirds were reported at a height range of 3.05 to 8.84 m. One-third of the incidents involving scissor lifts were identified as occurring while there was dynamic movement of the lifts in the horizontal plane as the workers were conducting assigned tasks within the platform and two-thirds of the incidents occurred under static conditions. Understanding the etiology of tip over-related injuries was the primary focus of this study [9].

Dong et al described that the tip-over of scissor lifts in operation has frequently resulted in the death and/or severe injuries of workers. Two series of experiments were performed under possible tip-over scenarios: curb impact and pothole depression. The results suggest that the lift should not be elevated on largely deformable and/or uneven surfaces such as bridged wood board or a soft soil base. The worker on the lift platform should avoid any large continuous periodic movement or forceful action in the horizontal plane, especially when the lift is fully elevated. Besides the tilt angle of the lift, the tilt speed should be monitored to help prevent the tip-over [10].

Richard et al developed a scissor lift apparatus that has three scissor units for supp1ying heavy 1oads. A central Scissor unit has its arms located inwardly of the immediately lower and upper scissor units, and folds into the upper and lower scissor units for storage within a chamber in a mobile chassis The scissor arms of the upper and lower scissor units includes rectangular box beams with a great vertical than horizontal dimension. Hydraulic cylinders are located within and coupled to the opposite two arms of the center scissor unit to expand and collapse the same[11].

## III. PROBLEM FORMULATION

### *A. Air entrapment*

The problem associated with the hydraulic cylinders is the accumulation of air within the cylinder[1]. The presence of this trapped air is undesirable because the entrapped air will, when compressed under load result in bounce of the scissor lift.

### *B. Hose swell*

At high pressure flexible hosing is susceptible to a degree of hose swell when the system pressure is increased[2]. System pressure drops slightly because of this increased hose volume and the scissors table compresses under load. This reduces the lifting capacity of the Scissor lift.

### *C. Belt drive*

The angular velocity ratio is not constant or equal to the ratio of pulley diameters because of belt slip.
These shortcomings can be rectified by these following methods

- Scissor lift with electronic control
- Scissor lift employing telescopable electro-mechanical actuation system.
- Scissor lift powered by gears.

Hence **gear powered scissor lift is** considered to eliminate the above said shortcomings.
In gear powered scissor liftair entrapment and hose swell is not a major issue and angular velocity ratio is always constant in the meshing of two gears.

## IV. METHODOLOGY

In this work kinematic analysis of gear powered scissor lift is performed using ADAMS 13.Gear train is designed for the conversion of rotary motion of the pinion which is coupled with motor shaft to translator motion of the lift. The designed gear train has been validated using ADAMS. The schematic diagram of methodology is given in Fig 1.

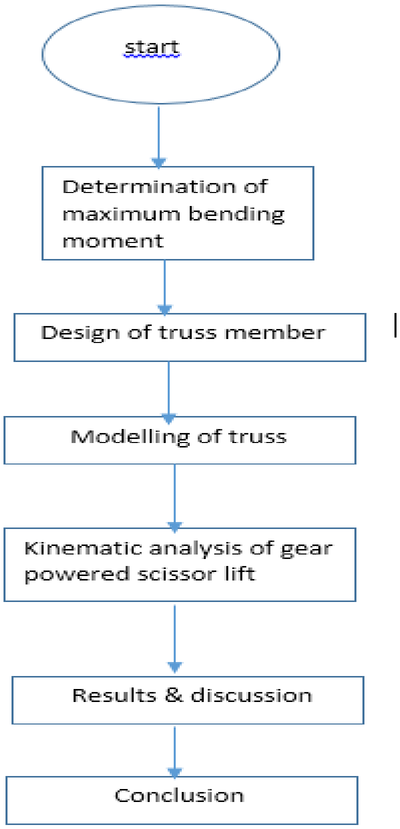


Figure 1 Schematic diagram of methodology

## V. DESIGN CALCULATIONS

The maximum bending moment is determined by considering 2000 kg of maximum load is acted on the platform as uniformly distributed load .The calculated maximum bending moment , maximum shear force is 358.925kNmm and 17.94kN respectively [12], [13].

The forces acting on each member of the truss is determined analytically using method of joints and the maximum force is 14.336 KN
The simple gear train [16] is designed and number of teeth on all gears are 18,63,44,44 and 44 respectively. The gear train assembly is shown in Fig 2.

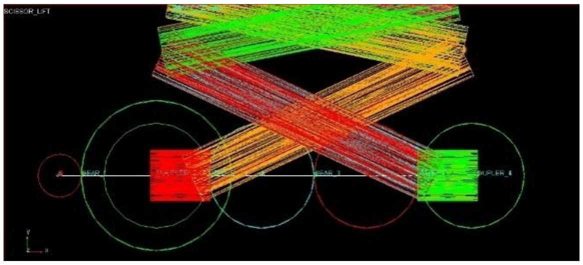

**Figure 2 Gear train assembly**

The member in the truss is considered as hollow pipe [14] and the outer diameter, inner diameter and thickness are 27mm, 20mm, 3.5mm respectively[15], [17].

The material for truss member is considered as low carbon steel (Fe250) and the maximum stress developed in the member is 14.10 $N/mm^2$ which is less than the Fe250 stress of 102.5 $N/mm^2$.

## VI. KINEMATIC ANALYSIS

Based on the design calculations the following model has been simulated using Automated Dynamic Analysis of Multi Body dynamics simulation Solution. The expanded view of the modelled gear powered scissor lift is given in Fig 3.

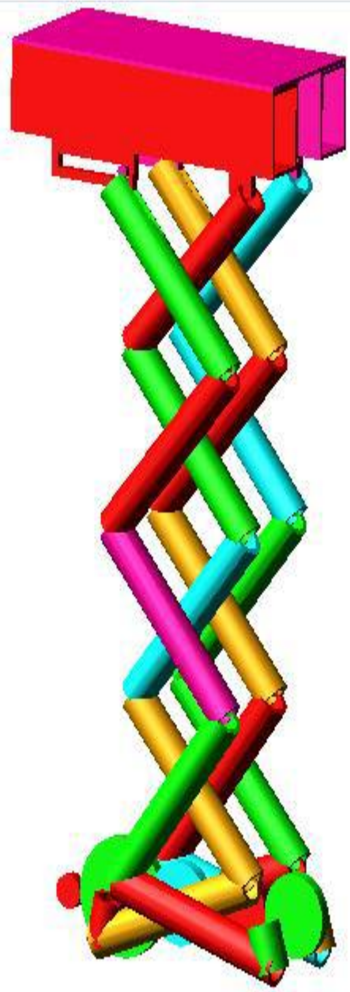

**Figure. 3 Expanded view of Scissor lift.**

The crank and coupler is needed to convert the rotary motion of the gear to translatory motion. The maximum lift height is achieved by linear displacement when is at maximum.To obtain the maximum linear displacement different L/R ((Length of the coupler /Radius of the crank) ratio is considered and the corresponding displacement are given in the table I. The maximum linear displacement is obtained for L=250 mm, R=50 mm and L/R=5.So the L/R ratio 5 is considered.

**Table I Relationship of L/R ratio and linear displacement**

| Sl.No | L (mm) | R (mm) | L/R ratio | Displacement (mm) |
|---|---|---|---|---|
| 1 | 1000 | 300 | 3.33 | 560 |
| 2 | 150 | 30 | 5 | 60 |
| 3 | 200 | 40 | 5 | 80 |
| **4** | **250** | **50** | **5** | **100** |

The analysis is performed for the L/R ratio of 5 with various links and the lift height is predicted and the predicted values are tabulated in table II.

**Table II Lift height varying with respect to number of links**

| Sl.No | L/R ratio | Number of Links | Lift Height (m) |
|---|---|---|---|
| 1 | 5 | 8 | 0.487 |
| 2 | 5 | 6 | 0.353 |
| 3 | 5 | 4 | 0.214 |
| **4** | **5** | **2** | **0.072** |

The table III shows the relationship between rpm and velocity of the link.

**Table III Relationship between input rpm and velocity of the lift**

| Sl.No | Speed (rpm ) | Velocity |
|---|---|---|
| 1 | 700 | 6.162 |
| 2 | 500 | 4.042 |
| 3 | 100 | 0.89 |
| 4 | 50 | 0.44 |
| **5** | **20** | **0.176** |

## VII. RESULTS AND DISCUSSION

As the number of links are increased more than 8, the stability of the system is affected. Hence themaximum lifting height is achieved for considering number of links in the mechanism as 8.

Inorder to reduce vibration in the system and for smooth lifting of the scissor lift we take input rpm= 20 and velocity = 0.176 m/s to achieve a lift height of 0.5m.

Thus a detailed kinematic analysis is performed with the following input parameters.

- L/R ratio= 5
- Length of coupler =250mm
- Radius of crank =50mm
- Number of links =8
- Speed of the motor =20 rpm

The output parameters are the load carrying capacity of the platform of 2000 kilogram to a lifting height of 0.487 m.

From the table I the ratio of coupler length to crank radius (L/R) is increased, the corresponding linear displacement of the link also increased.

From the table III the lifting height of the truss is independent of speed of the deriver and the corresponding velocity of the link. In this work the speed of the truss is taken as 20 rpm.

## VIII. CONCLUSION

Thus the kinematic analysis of gear powered scissor lift is performed with various L/R ratio and number of links for a constant load of 2000 kg.

The following conclusions are identified based on the analysis:

- The lifting height of the truss is independent of the speed of the driver and the corresponding velocity of the link.
- Lifting height is directly proportional to L/R ratio and number of links.
- For a 8 number of links and L/R ratio as 5, the lifting height is obtained for 2000 kg.

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