DESIGN OF A COMPACT RETRACTABLE STAIRCASE FOR PUBLIC TRANSPORT BUSES

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ABSTACT

In this case, use of fixed staircase is sometimes impossible depending on the ground level of where the bus has parked. With this problem in mind, we took the challenge and proceeded to design a compact retractable scissor staircase. The design procedure took into account our area of application and the challenges present that should be considered. Here we go through the process and requirements for the construction of the retractable staircase and the mathematical analysis of the mechanism. A double acting pneumatic cylinder by means of the slider and crank mechanism provides the force required for the translational actuation of the mechanism. We have designed an appropriate model for our case study and thus we have presented a practical solution that is simple and applicable.

INTRODUCTION

A staircase is a construction designed to bridge a large vertical distance by dividing it into smaller vertical distances called steps. Special types include ladders, escalators, foldable stairs and retractable scissor stairs.

Problem statement

Moving a body or loads over large vertical elevations requires a lot of energy, which is often insufficient. This method of lifting poses a big risk if dropped. In as much as fixed stairs may be suitable for such applications, specific places do not have enough space for fixed staircase. In a field study done at Mwembe Tiyari bus station, it was distressing to see children, old people and expectant mothers struggle to board and alight buses due to the elevation of the floor platform.

Main objective

Develop a retractable scissor staircase that is efficient and safe in operation.

Specific objectives

1. Design a system that is simple, efficient, functional and with minimum operational cost and good maintenance practices.
2. Develop an appropriate model.

Brief overview of the solution

Design of a retractable scissor staircase that will be used in public transport buses to make it easy and efficient to board, alight or load the buses.

Brief theory

Foldable scissor stairs

Here, scissor like elements formed by a four bar linkage form a foldable stair mechanism. The links are connected using revolute joints. A slider and crank mechanism is used as a load input mechanism, with the crank acting as the input link for the four bar mechanism. The motion of the con rod is transferred to the crank, which pushes the coupler forward causing the vertical links to unfold into vertical and horizontal arrangement, which makes up the staircase steps. This achieved by pneumatic cylinder means.

Pneumatics

Pneumatics involves the use of compressed air in an industrial setting to produce mechanical motion. This process is applied in a retractable scissor staircase with the use of air pressure action on a piston in a pneumatic cylinder to produce linear motion facilitating the folding and unfolding mechanism. The air used here is the already compressed pneumatic breaks air which is channeled through transmission lines i.e. pipes to our double acting cylinder for action. The pneumatic setting consists of mainly the compressor, storage tanks and the regulating valves.

Compact hybrid staircase

The compact hybrid staircase is designed to fold all its steps and stringers flat against the wall it is attached to. They fold sideways unlike other foldable stairs. They have a patent-pending bi-folding handrail that is safely and conveniently folded against the wall when the staircase is folded. It also enables opening and closing from both the lower and the upper floor.

Eclettica spiral staircase

This is a vertical stack of drawers that swivel to become a staircase. It looks like a large cabinet but can effortlessly unfold into a staircase with just a push of a button by mechanism of an electric motor. The drawers in the steps help to utilize space vertically while the closed position of the stair does not block much horizontal space.

Klapster stairs

These stairs optimize the space by swiveling through 90 degrees facilitating a vertical folding towards the wall when not needed. Ones folded up, both stair stringer and steps are on one plane along the wall and extend out from the wall at around 3cm.

Telescoping ladder

A telescoping ladder is operated under the principle of the telescope. It folds down to a compact size, which makes it easy to store and transport. Its height can easily be adjusted to meet the required need.

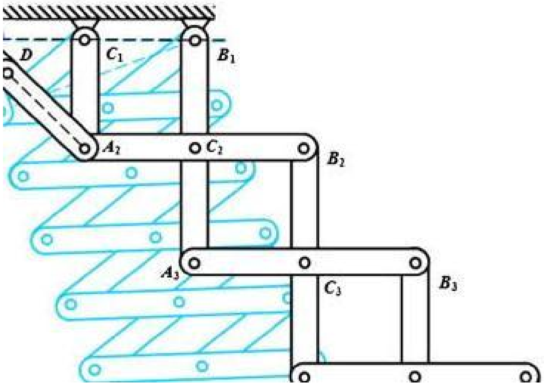
METHODOLOGY

This chapter will analyze project design and fabrication. This will include design of individual parts, material selection and drive system i.e. pneumatic cylinders.

DESIGN THEORY

Pneumatic systems are used to control and Transmit power in a linear direction.
A compressor driven by a prime mover such as an IC engine or electric motor increases the pressure of air, which is in turn stored in a reservoir. Valves control the direction and rate of flow of the compressed air. An actuator (pneumatic cylinder) is used to convert the pressure energy to mechanical power. The amount of output power developed depends upon the flow rate, pressure, the pressure drop in the hoses and actuator and the cylinders' overall efficiency.

MODELLING



Job Specifications

- Minimum load – 100 kg
- Maximum load – 300kg
- Maximum height travel – 5 meters.
- Step width – 1 meter.

Stair Dimensions

- Overall staircase width=1m.
- Tread width=29 cm
- Riser height =18 cm

Link dimensions

- Horizontal link length = 29 cm.
- Horizontal link width = 4 cm.
- Horizontal link breadth = 2 cm.
- Vertical link length = 40 cm.
- Vertical link width = 4cm.
- Vertical link breadth = 2 cm.

Slider and Crank Specifications

- Slider length = 10 cm.
- Slider width = 4 cm.
- Slider breadth = 4 cm.
- Crank length = 22 cm.
- Crank width = 4 cm.
- Crank breadth = 2 cm.

Revolute Joint Specifications

- Pin diameter = 2cm.
- Pin length = 5 cm.
- Hole diameter = 2.05 cm.
- Clearance = 0.05 cm.

Size of the Cylinder Needed

Calculation of the Cylinder Size

Area of cylinder (m^2) $= \frac{Fc}{pressure}$

By considering our area of application i.e. Buses, we decided to utilize the available compressed air used for brakes, for our actuation. The existing bus air brakes require ***830kN/m²*** for stopping. To achieve the desired results, a *pressure regulating valve* is usedtoregulate our actuating pressure, not to exceed the above but practically applicable to our model. We chose to use an estimate value **of 135 kN/m²** in our model.

Pressure=135 kN/m^2

Mass properties

- Mass of the users (mass to be lifted) = 300kg
- Mass of each tread platform = 2.5 kg
- Mass of each horizontal link = 0.595 kg.
- Mass of each vertical link = 0.838 kg
- Mass of each crank = 1.26 kg
- Number of steps/treads = 3
- Number of vertical links needed = 4
    - ✔ Full length vertical links = 2
    - ✔ Cranks = 2
- Number of horizontal links needed = 3
- **Total mass = Total tread mass +**

  2[$\sum(hm + vn + cp)$**]**

- **Total mass = (**3 × 2.5) + 2[(0.592 × 3) + (0.838 ×2) +(1.261 ×2)]

  = 7.5 + 11.948 = 19.448 kg.

Where; h = horizontal link mass

m = number of horizontal links.

v = vertical link mass

n = number of vertical links.

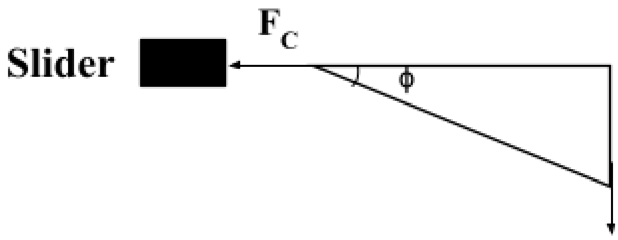
c = mass of the crank

p = number of cranks.

Total load (F) = Total mass × 9.81(gravitational pull).

F = 19.448 × 9.81 = **190.785 N**

Load Experienced at the Pneumatic Cylinders



For each cylinder;

Tan Φ = $\frac{\frac{F}{2}}{Fc}$

F$_c$= $\frac{\frac{F}{2}}{\tan tan\ \Phi}$

Φ =($\frac{18}{26}$) = **34.7 ^{0}**

Taking our formula;

$$F_c = \frac{\frac{190.785\ N}{2}}{\tan 34.7} \ \mathbf{=137.76N}$$

Applying our formulae;

$$A = \frac{137.76}{135 \times 1000} = \mathbf{1.02 \times 10^{-3}\ m^2.}$$

Using the formula;

$$\textbf{Area(circle)} = \pi\frac{d^2}{4}$$

$$d = \sqrt{\left(\frac{4A}{\pi}\right)}$$

$$= \sqrt{\left[\frac{(4 \times 1.02 \times 10^{-3})}{\pi}\right]}$$

$$= \mathbf{0.03605\ m}$$

$$\mathbf{= 36.05\ mm}$$

Note: The cylinder size needs to be greater than the acquired value in order to lift the mechanism.

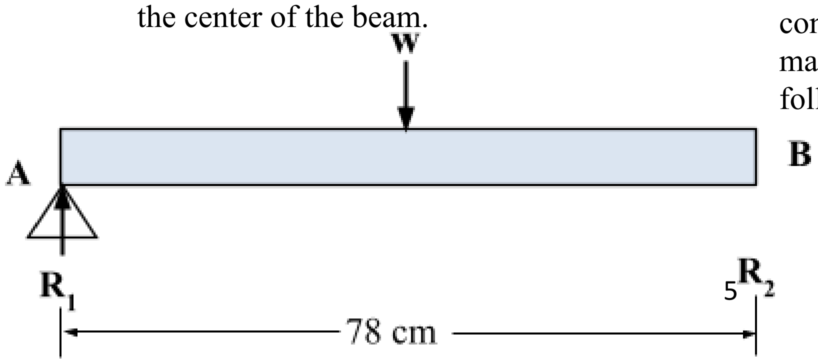
For our model, we recommend a cylinder of **40 mm** diameter.

Bending Moment Analysis

Our model is expressed as a simply

Supported beam with a point load acting at

the center of the beam.



Taking a maximum user mass of 300 kg.

$$\mathbf{W = 300 \times 9.81 = 2943\ N}$$

$$\mathbf{= 2.943\ kN.}$$

Taking our moment about point A;

$$\sum MA = \mathbf{0}$$

$$[(39 \times 10^{-2})\ W] - [(78 \times 10^{-2})\ R2] = 0$$

$$\mathbf{R_2} = \frac{(0.39) \times 2.943}{(78 \times 10-2)}$$

$$\mathbf{= 1.4715\ N}$$

For a point load acting centrally;

$$\mathbf{R_1 = R_2} = \frac{W}{2}$$

Therefore;

$$\mathbf{R1 = 1.4715\ N}$$

$$\mathbf{R_2} = \frac{(0.39) \times 2.943}{(78 \times 10-2)} \mathbf{= 1.4715\ N}$$

COMPONENT MATERIAL

After taking into account the considerations to select the appropriate material for our model, we settled on the following choices for our components;

- Scissor arms – 2014 (T6) Copper aluminum alloy.

- Pneumatic cylinder– Stainless steel.
- Tread platform– Slip mat aluminum plate.
- Slider–Stainless steel.
- Crank– Chrome stainless steel
- Base frame–Stainless steel.

CONCLUSIONS

Having done a thorough study of our design, we arrived at the following conclusions;

This construction is safe for use in variable height conditions since the steps are always parallel to the ground ensuring maximum stability.

The design works perfectly when specifications and measurements in design components are done and selected carefully. Our shear force-bending moment diagrams drawn from our calculations can prove this.

The choice of pneumatic cylinder size depends on the mass of the scissor staircase construction appropriate for the area of application and the load it is designed for.

RECOMMENDATIONS

- Applied load should be within the specified range to prevent deflection and deformation.
- Loads should be applied centrally in the mechanism to ensure uniform distribution of stresses to minimize deflections.
- Proper selection of the specified material in construction of the design.
- Use of the specified pneumatic equipment in the construction of the machine.

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