World Journal of Advanced Engineering Technology and Sciences

eISSN: 2582-8266

Cross Ref DOI: 10.30574/wjaets

Journal homepage: https://wjaets.com/

(RESEARCH ARTICLE)

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Electro-mechanical lift system for stacking and off-loading of files

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World Journal of Advanced Engineering Technology and Sciences, 2025, 14(03), 140-161

Publication history: Received on 16 January 2025; revised on 24 February 2025; accepted on 27 February 2025

Article DOI: https://doi.org/10.30574/wjaets.2025.14.3.0096

Abstract

In an office environment like the University system, there is always the need to pick, stack and off-load office files on regular basis. Most times, these files are numerous and are stacked at a height, which is cumbersome to perform such work on routine basis. This research work was conceived out of this need to design a machine that can help in the overall performance of such activities. This machine was designed for stacking and offload files with allowable maximum load of 3kg.The machine consists of an AC motor, generating rotatory motion which gets converted to translational motion by the application of a pulley system mechanism installed in a vertical frame up a height of 2.5m which aids the linear movement (up and down) of the cantilever, as it carries the files to the desired height. The production and selection of materials for this research was carried out according to the design analysis and computations done with reference to engineering standards. It was produced and tested and was able to stack and off-load offices files within the design limit.

Keywords: Electro-mechanical; Design; File; Lift; Off-loading; Stacking; System

1. Introduction

There has always been a need to create an artificial aid when it comes to the simple domestic activities needed to be carried out in offices, libraries and other similar places. It is the nature of man to seek for artificial alternatives in carrying out tasks as it makes the total work needed to be done easier and faster in some cases. This need has brought about the significance for the production of artificial aiding machines which can help in performing human tasks as they ranges from simple to complex.

A lift is a transport device used to move goods or people vertically. It is essentially a platform that is either pulled or pushed up by a Mechanical means [1].Common lifting machines are cranes, elevators and forklift etc. These machines work on similar principles and they all work to achieve same goal of carrying load. Similar to these machines and their principles.

The modern day productions and manufacturing processes are filled with height inclined procedures. And all these could not have been possible without the help of an artificial aiding machine to attain the required height as needed. The word 'lift' usually describes a vertical transportation device that moves people or materials between floors in a structure [2]. Imagine conventionally trying to access the terrace of the newly constructed 21 storey office development building located in the central business district of Uyo, which is 108.8m high or lifting a few tons of load vertically up a

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height 40 feets (13.2 m). But these can be achieved easily with the aid of machines operating on programmed and designed mechanisms to lift objects or loads such as the cranes, elevators, forklift etc.

An elevator can be defined as an electric lift which is used as vertical transportation of goods as well as people among the floors in buildings using bins otherwise silos[3]. An elevator is a platform that could either be open or closed and is used for lifting or lowering both people and goods to upper and lower floors. Figure 1 shows a labeled diagram of an elevator.

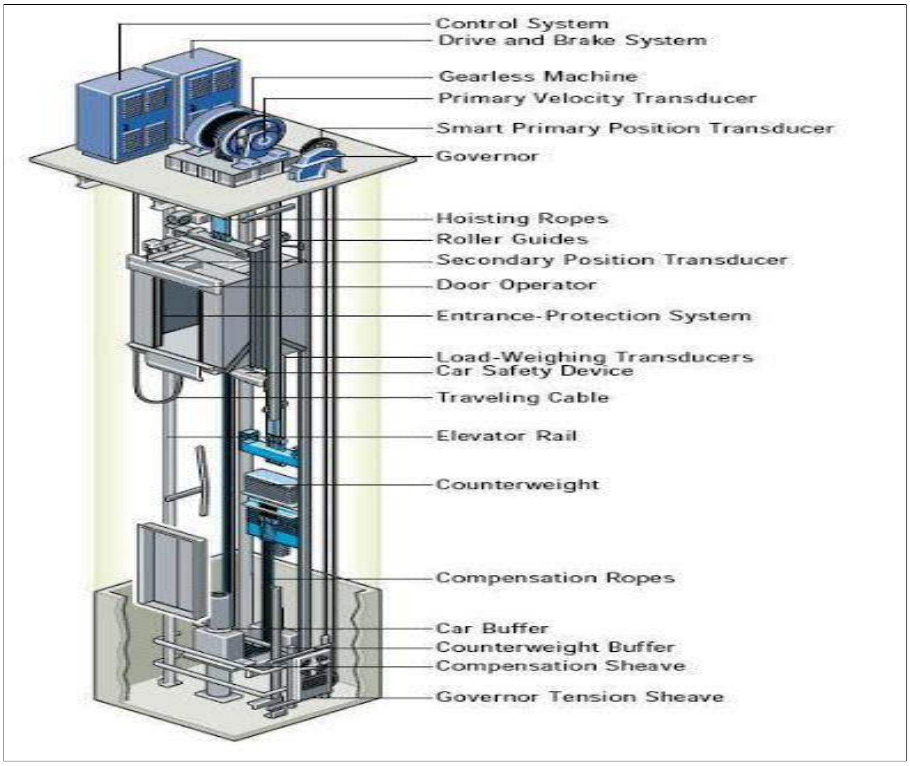

Figure 1 An elevator [4]

A crane is a type of machine, generally equipped with a hoist rope, wire ropes or chains, and sheaves, that can be used both to lift and lower materials and to move them horizontally. It is mainly used for lifting heavy things and transporting them to other places. Figure 2 shows the diagram of a new generation crane.

Figure 2 A new generation crane [5]

Forklifts, just like the cranes, fall under the category of lifting and transport machinery. A forklift has a lifting system for loading packages and a mobile system for moving around, like a truck. According to the data about lift truck sales, acquired by Worldwide Industrial Truck Statistics organization, Europe, North America, Japan and China are some of the biggest players in the market [6]. A forklift truck is a powered industrial truck used to lift and transport materials.

Figure 3 An electric forklift [7]

Office files in offices and libraries are required to be kept in order, arranged and stacked properly for ease of operation. These arrangements which are to be carried out by the office workers may sometimes begin to appear stressful as the operation goes on on a daily basis. Sometimes these files are arranged at heights beyond the reach of an individual considering the facts that human heights varies greatly from person to person, and these will pose a difficulty in stacking and offloading these files. Finally, the time wasted during the conventional method of stacking and unstacking these files especially when large quantities of these files are involved is of a great concern. These form the problem which has brought up the need for this research which has to do with the design and production of a machine that can aid in the stacking and offloading of files in our offices and libraries.

Figure 4 Pack of an office files [8]

The objective of this research is to design and produce an office file stacking and offloading machine.

2. Materials and Methods

2.1. Theory of Operation of the Machine

This machine functions under four major movements which includes an up and down (Vertical motion) and a front and back (horizontal motion). The vertical motion is to lift the engaging member through the translational motion given by the pulley mechanism gotten from the rotational motion from the electric motor, to the desired height of which the file is to be carried while the horizontal motion which is manually controlled engages the member to the file for the stacking and offloading action.

2.2. Design Criteria

It is desired to design a machine that is capable to pick stack and off-load office files in an office. This requires the selection of electric motor that can carry the designed load.

2.3. Design Analysis

Table 1 shows the mechanical properties and standard values for mild steel.

Table 1 Mechanical properties and standard values for mild steel

S/n	Mechanical properties	Metric values
1	Ultimate Tensile strength	440 Mpa
2	Yield Tensile Strength	370 Mpa
3	Modulus of Elasticity	210 Mpa
4	Bulk Modulus	140 Mpa
5	Shear Modulus	80 Mpa

[9]

2.3.1. Design of the Cantilever

The Figure 5 below shows diagrammatical representation of the Cantilever.

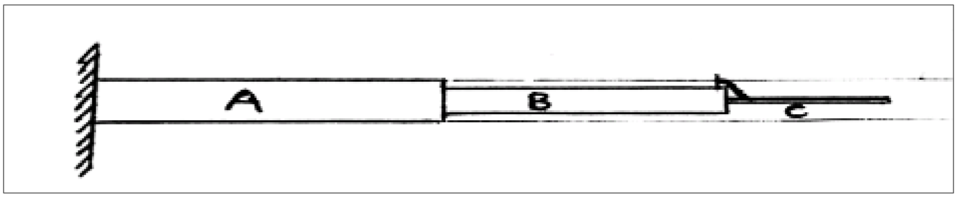

Figure 5 Diagrammatical representation of the Cantilever

For member C,

A decided mass of X kg is to be used as the allowable load for the design of the machine.

where a factor of safety, ç , is to be applied;

X becomes (X × ç) which equals to X' …………………… 1

But F = m' g ……………….. 2

where,
m' is the mass of maximum load = X'

g is the acceleration due to gravity

Therefore,

$$F = X'g \quad \ldots\ldots\ldots\ldots.. \; 3$$

Let's say (X'g) from the Equation 3 be P1

The Figure 6 shows the free body diagram for member C.

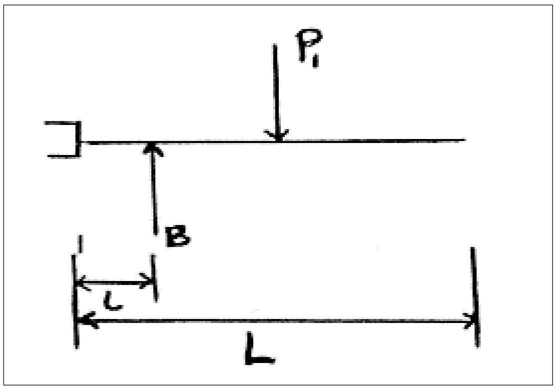

Figure 6 Free body diagram for member C

When Loaded;

Upward force is equal to downward force (for balance and stability)

Therefore,

$$P1 = B \quad \ldots\ldots\ldots\ldots\ldots.. \; 4$$

2.3.2. Analysis for the Upward Motion

When in upward motion, the net force acting on the body is the summation of the force due to the weight of the load and the resisting force due to the state of the body, in motion, which is positive when going up.

where,

$$F1 = P1 + Da \quad \ldots\ldots\ldots\ldots\ldots\ldots \; 5$$

D is the mass of the member C

a is the acceleration of the moving body (member C)

Substituting for the values in Equation 5

$$F1 = (P1 + Da)N \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots..6$$

2.3.3. Analysis for the Downward Motion;

$$F1 = P1 – Da \quad \ldots\ldots\ldots\ldots\ldots \; 7a$$

$$F = (P1 - Da)N \quad \ldots\ldots\ldots\ldots\ldots \; 7b$$

2.3.4. Analysis for the Offloading;

where the bending stress on the spring is σb.

$\sigma b = K \times 32N'/(\pi d^3)$ ……………… 8

where,
K is the Wahl's Stress Factor
N' is the force acting downwards;

N' = P1 + P2 , as shown in Figure 7.

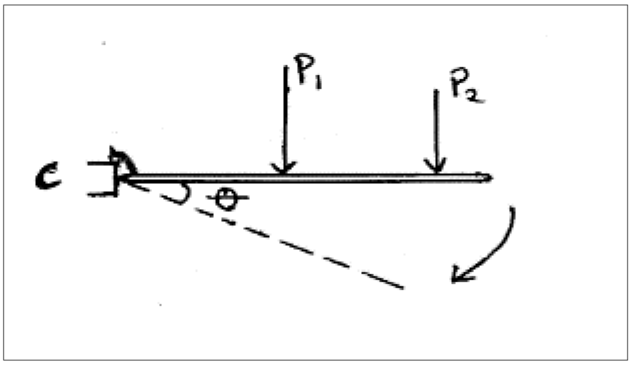

Figure 7 Free body diagram for member C when pulled

P2 = F' + P' …………………… 10

where;

F' is the self-weight of the fork (Member C)

= H × g …………. 11

where;
H is the self-weight of the fork
g is the acceleration due to gravity

Therefore,

F' = (Hg)N 12

P' is the pulling force to tilt the member C, as shown in the figure 3.2 above.

P' = (P')N 13

From Equation 8;

K = 4C - 1/(4C - 4). …………… 14

where;
C, Spring index =D/d 15
D' is the mean diameter of spring coil
d is the diameter of spring wire

Substituting and inputting the values for Equation 13, the value of k can be gotten.

From Equation 8, the bending stress, σb on the spring can be gotten by substituting the values

For the angular deflection of the spring, &

$\& = 64N'D'n / (Ed^4)$ 16

2.3.5. Analysis for the Member B

The free body diagram for the member B is shown Figure 8 a 8b and 8c.

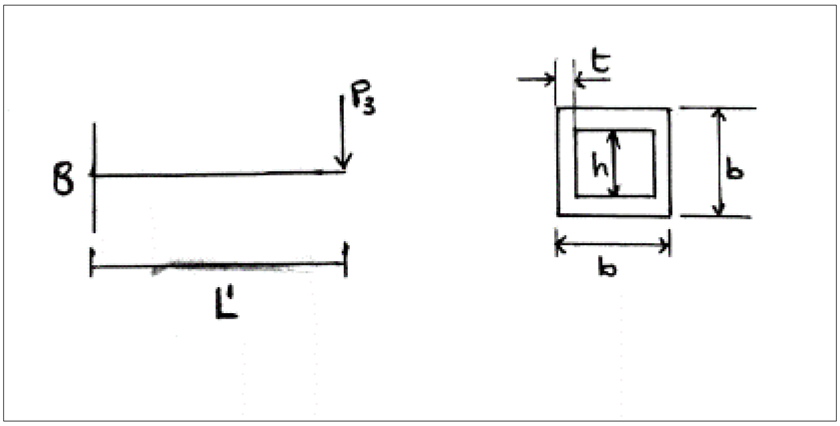

Figure 8a Free body diagram for the member B. Figure 8b :Cross sectional view

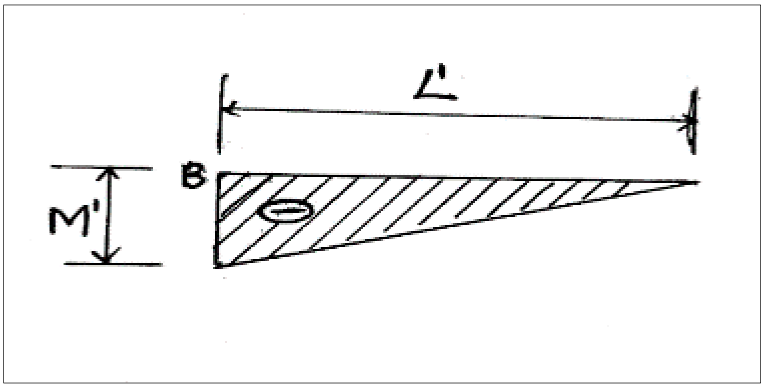

Figure 8c Bending moment diagram

where

P3 = N' 17

And,

b is the breadth

t is the thickness of the member B

h is the length of the hollow part

For the bending moment, M

where,

M' = N' × L' 18

Given

$$(M/I) = (\sigma/y) = (E/R) \qquad \ldots\ldots\ldots\ldots\ldots 19$$

Therefore,

$$M' \times y = E \quad 20$$

where,
E is the Young's Modulus
y is the distance from the neutral axis, b/2 21

And,

b is the length of the breadth

Also, (M'/I) = (E/R) , from Equation 19 22

where,

$$I = (b^4 - h^4) / 12 \quad \ldots\ldots\ldots\ldots\ldots\ldots 23$$

$$R = 0.289\sqrt{(b^2 + h^2)} \quad 24$$

Substituting for I and R in the Equation 23 and 24 simultaneously, the value h can be gotten

Also, thickness,

$$t = b - h \quad \ldots\ldots\ldots\ldots\ldots\ldots 25$$

For the mass of the member B

Solving for the Volume v, for one side,

Given that,

$$v = l \times b \times h' \quad \ldots\ldots\ldots\ldots\ldots\ldots 26$$

where,
l is the length
b is the breadth
h' is the height

Also, For the total volume, V

$$V = 4(v) \quad \ldots\ldots\ldots\ldots\ldots 27$$

$$\text{Weight (mass)}, w' = \text{volume} \times \text{density} \quad \ldots\ldots\ldots 28$$

$$\text{Weight (g)}, w = w' \times g \quad \ldots\ldots\ldots\ldots\ldots 29$$

2.3.6. Analysing for Member A

The free body diagram for the member A are shown in Figures 9a and 9b,

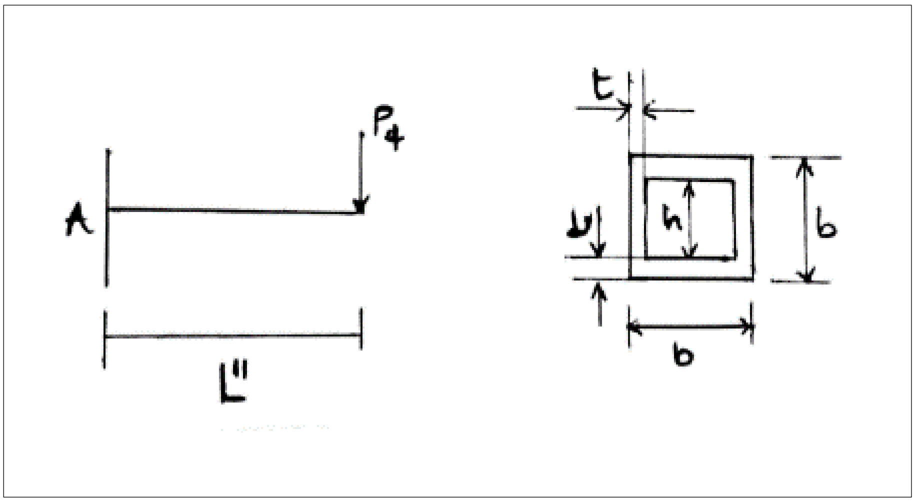

Figure 9a Free body diagram for the member A**. Figure 9 b** Cross sectional view

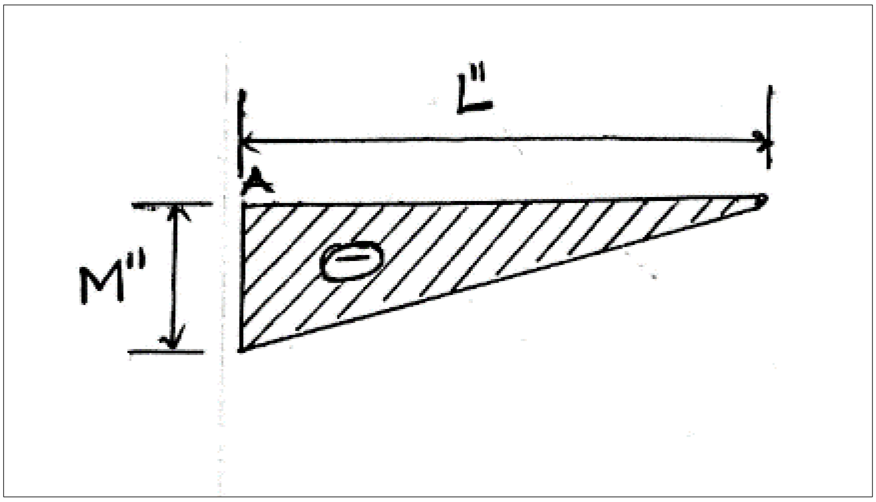

Figure 9 c Bending moment diagram

P4 = P3 + W3 …………..30

where,

W3 is the self weight of member B (refer to Equation 30)

For the bending moment, M

M'' = P4 × L'' ……………31a

Given (M/I) = (σ/y) = (E/R**).[] ……………….** 31b

M'' × y = ……………….32

where,
y is the distance from the neutral axis, b/2

And,

b is the length of the breadth

Also, $(M''/I) = (E/R)$,from Equation 32 …………33

where,

I is the moment of inertia

$$I = (b^4 - h^4) / 12 \quad \text{………………34}$$

Substituting for I in the Equation 31, the value h can be gotten

Also, thickness,

$$t = b - h \quad \text{…………35}$$

For the volume v of member A

Given that,

$$v = l \times b \times h' \quad \text{………………36}$$

where,
l is the length
b is the breadth
h' is the height

Given that volume of one side is v'

Volume of the removed part from member A is v''

Therefore, volume of member A is given as,

$$v = 3(v') + (v-v'') \quad \text{…………..37}$$

And,

$$W' = v \times ¥ \quad \text{…………….38}$$

$$W = W' \times g \quad \text{……………39}$$

where,

W' is the mass of the member A

W is the Weight of the member A

¥ is the Density

2.3.7. Analysis of the Tension in the Rope

Analysing for the maximum tension on the rope which occurs during the upward movement of the Cantilever as shown in the Figure 10.

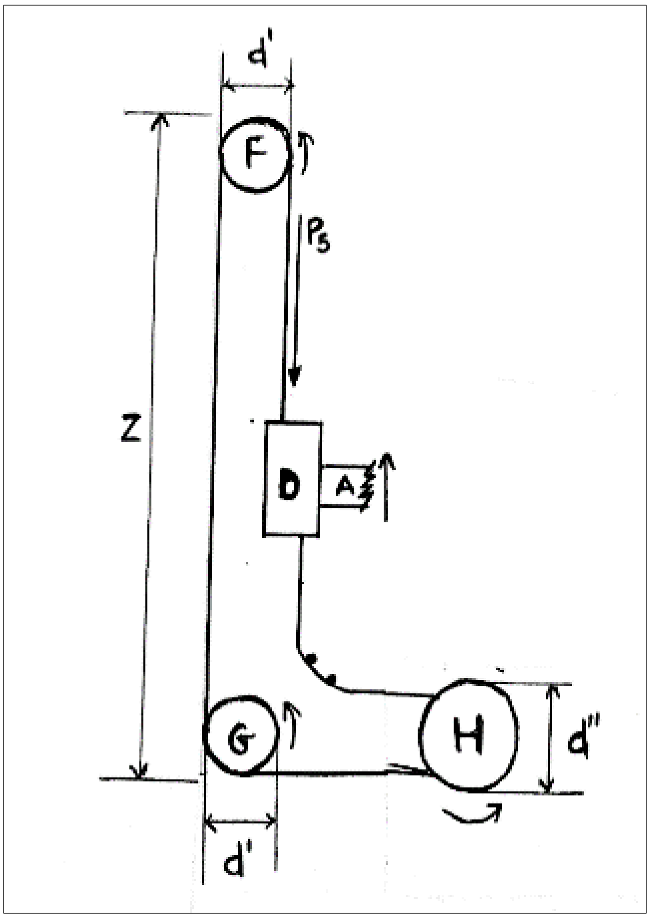

Figure 10 Diagrammatic illustration of the rope on tension due to the cantilever force

Given tension

T = mg + ma …………….40

Where,
m' is mass of the cantilever

= (X + w' + W' + b') ………………41

g is the acceleration due to gravity

a is the acceleration of the moving body (cantilever)

Hence, substituting in equation 3.40, the tension will be gotten

Also, Torque ¶ = (K T D) / 12 [10]. …………….42

Where,
K is the coefficient of friction
D is the nominal diameter (16(r))

Substituting for the values in Equation 42, the torque can be gotten.

Also,

$$P = ¶ \times \Delta \quad \ldots\ldots 43$$

Where,

Δ = angular speed

and,

$$\Delta = (2 \pi n) / 60 \quad \ldots\ldots 44$$

Where,

π = pi

n is in revolutions per minute

Substituting values for P in Equation 37, the power can be gotten.

2.3.8. Analysis of the grip for the member D

The free body diagram for the grip for the member D is shown in Figure 11.

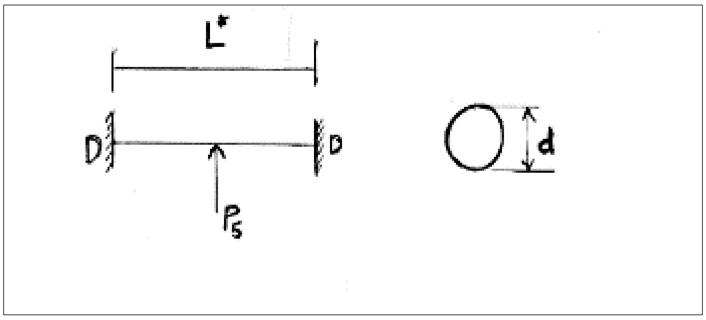

Figure 11(a) Free body diagram for the grip Figure 11(b) Cross sectional view

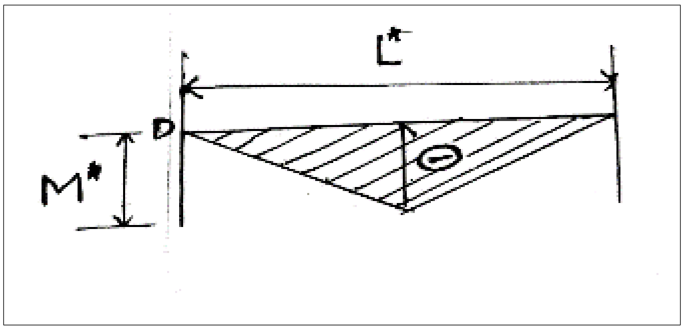

Figure 11 (c) Bending moment diagram

Given Tension

$$T = P5 \quad \ldots\ldots 45$$

Also Maximum bending moment at the grip, M*

Given $M^* = (TL^*)/4$.**[11]** 46

Where,

L* is the length of the grip

Substituting the values for Equation 40, the value M' can be gotten.

Using (M*/I) = Ey (Equation28) …………….47

Where

I is the moment of inertia

$I = (b^4 - h^4) / 12$ …………………48

y is distance from the neutral axis, b/2

b is diameter of the grip

Substituting the values in Equation 41, the value b can be gotten.

Various Techniques by [12],[13],[14],[15],[16],[17],[18],[19], were systematically applied in this research work.

2.4. Design Computation

For the design computation of the Cantilever, where 2.5kg is taken as the decided mass which serves as the allowable load for the design of the machine and applying a factor of safety of 1.2, the mathematical expression can be given as below;

Let,

X = 2.5kg ………………(from 1)

and,

ç = 1.2

Therefore, maximum load, X' = 2.5 × 1.2 (from 2)

X' = 3kg

and,

F = 29.43N …………….(from 4)

When Loaded;

Upward force = downward force (for balance and stability)

Therefore, P1 = B = 29.43N ……………..(from 5)

Figure 12 shows the free body diagram for the member C as gotten from the computation analysis.

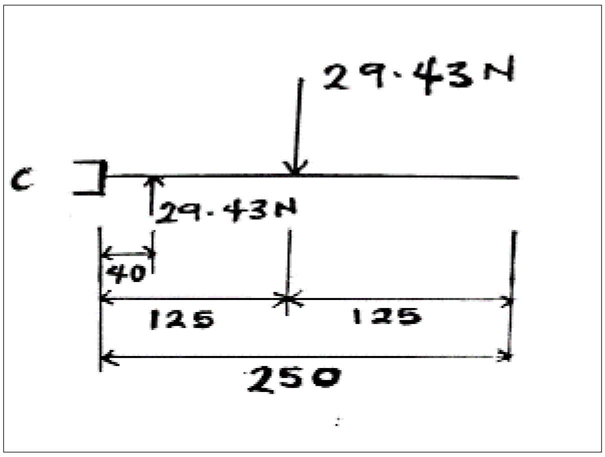

Figure 12 Free body diagram for member C

Computing for the analysis of the upward motion; the net force acting on the body is the summation of the force due to the weight of the load and the resisting force due to the state of the body, in motion, which is positive when going up.

where,

P1 = 29.43N

D = 0.3kg

a = 1.3m/s^2

Therefore,

F1 = 29.82N ……………(from 6)

Computing for the analysis of the downward motion;

where,

P1 =29.43N

D = 0.3kg

a = 1.3m/s^2

Therefore,

F2 = 29.43 - (0.3 × 1.3) ………………(from 8)

Computing for the analysis of the offloading motion;

where the bending stress on the spring is expressed as shown in Equation 9

where,

D' = 14mm

d = 1.5mm

C = 9.33 (from 15)

Substituting in Equation 14,

$$K = 1.09$$

Also,

$$H = 0.3kg$$

$$g = 9.81$$

$$P' = 2.13N$$

Figure 13 shows the free body diagram for the offloading motion

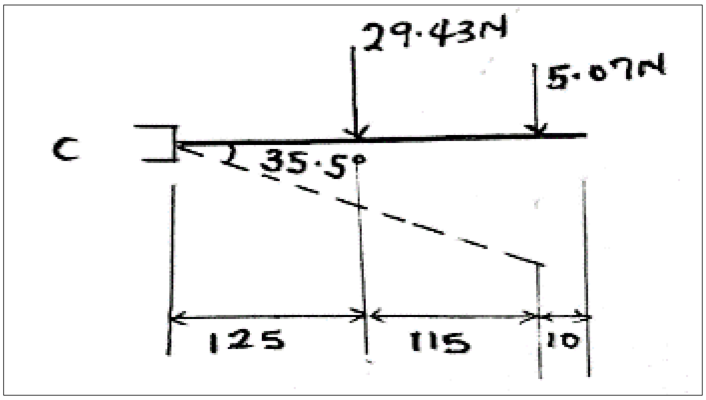

Figure 13 Free body diagram for member C when pulled

Therefore,

F' = 2.94N …………(from12)

P2 = 5.07N …………(from 11)

N' = 34.5N …………..(from 10)

Substituting in the Equation 9, the bending stress σb, can be gotten to be 113.48N/mm^2.

Therefore,

$$\sigma b = 113.48MPa$$

For the angular deflection of the spring &;

Taking E to be 210MPa from the Table1 and substituting other values as given in equation 16, the value of & can be gotten to be 35.5° as shown from below;

where RPM, n = 267

Therefore,

$$\& = 35.5^{\circ}$$

For the computation analysis of the member, B

where,

P3 = 34.5N …………….(from 17)

And the bending moment

M' = 12.08KN-mm ……….(from 18)

Also,

12.08 × y = 210KN-mm………. (from 20)

where,

y = b/2

b = 35mm

Substituting for I and R simultaneously in the Equation 22, we have;

h = 33.33mm

Therefore,

thickness, t = 1.67mm…….. (from 25)

Introducing factor of safety, 1.2

t = 2mm

Figure 14 shows the free body diagram for the member B as gotten from the computation analysis

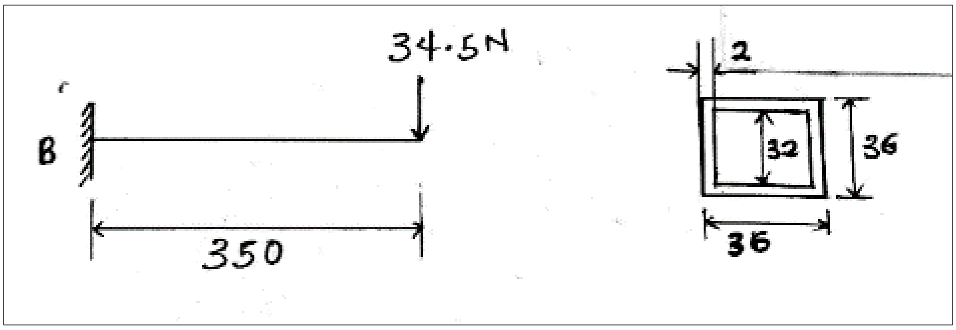

Figure 14(a) Free body diagram for the member B **Figure 14**(b)Cross sectional view

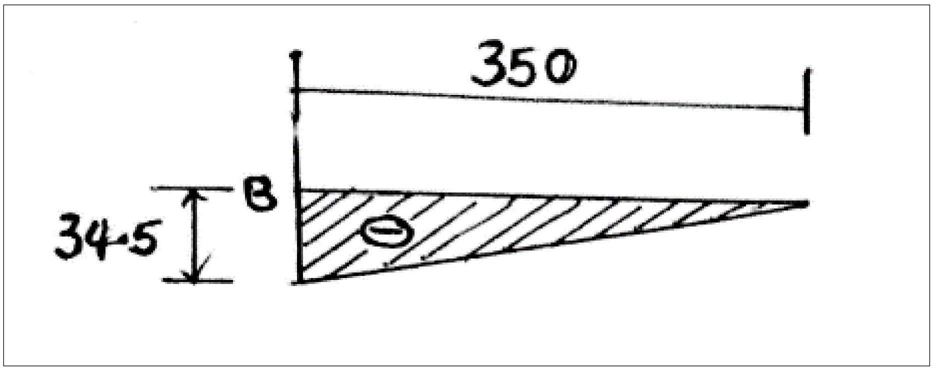

Figure 14(c) Bending moment diagram

For the volume of member B,

Volume v, for one side, = 0.000028m^3……………… (from 26)

Total volume, V == 0.000112m^3 ………….(from 27)

Mass W', of the member B,= = 0.8792Kg …………….(from 28)

Weight = 8.625N …………..(from 29)

Computing for the analysis of the member A,

here,

(from 30)

P4 = 43.125N …………..(from 30)

And the bending moment M'' = 19.4 KN-mm (from18)

Also,

19.4 × y = 210KN-mm …………..(from 31)

where,

y = b/2

b = 43.3mm

Substituting for I and R simultaneously in the Equation 22, we have;

h = 40.8mm

Therefore,

thickness, t = 2.5mm…………. (from 35)

Introducing factor of safety, 1.2

t = 3mm

Figure 15 shows the free body diagram for the member A as gotten from the computation analysis.

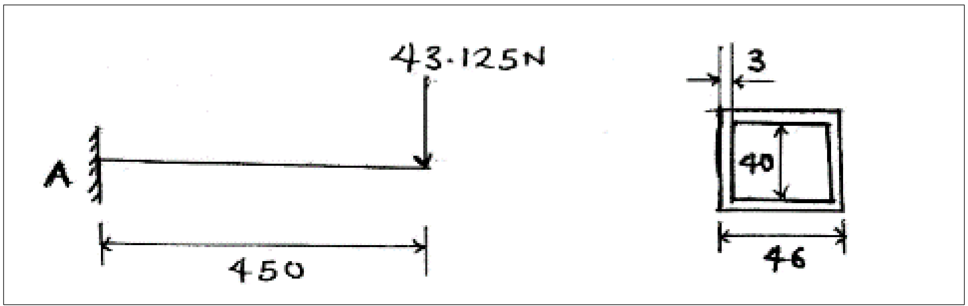

Figure 15(a) Free body diagram for the member A **Figure 15 (b)**:Cross sectional view

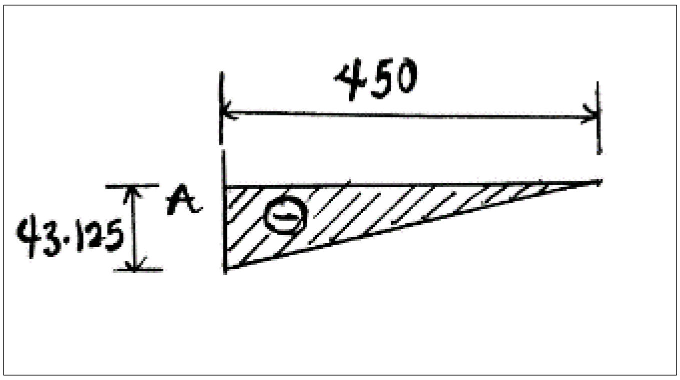

Figure 15(c) Bending moment diagram

For the volume v of member A,

Volume v for one side,= 0.0000654m^3……………. (from 36)

Volume of the removed part, member 2,= = 0.0000204m^3

Total volume of member 1 is therefore, = = 0.000238m^3 …………..(from 37)

Mass of the member A, =1.865kg ……………………..(from 38)

Weight (g) = 18.297N …………….(from 39)

Computing for the analysis of the tension in the rope

where,

m' =5.5442kg …………………(from 41)

a = 1.3m/s^2 (from n = 267 RPM with radius of pulley as 0.08m)

Therefore,

Tension T = 61.596N………….. (from 40)

Figure 16 shows the analysis and tension in the rope as gotten from the computation analysis

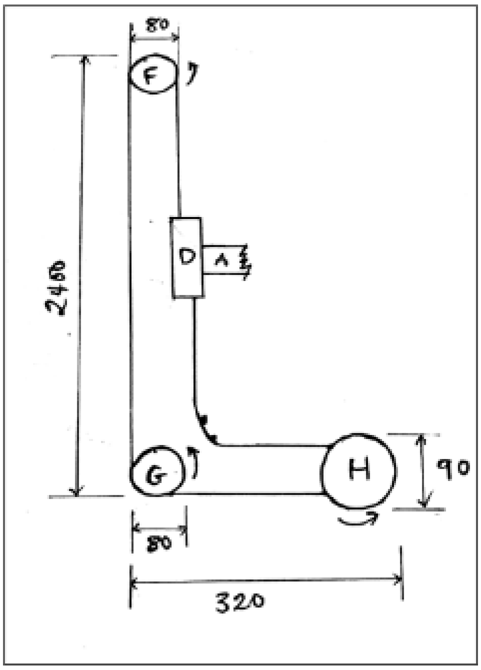

Figure 16 The diagrammatical analysis of the tension in the rope

Also, where;

K = 0.7

D = 0.08 × 16 = 1.28

Therefore,

Torque ¶ =4.6Nm ……………(from 42)

Also, where;

Angular speed Δ =27.9638…………….. (from 44)

Therefore,

Power P=128.63W ……….(from 43)

Putting factor of safety into consideration,

P = 154.272W

Computing for the analysis of the grip for member D

Given that,

Tension T = 61.596N = P5 …………….(from 45)

And the bending moment M* at the grip is given as;

M* ==1.08kN …………….(from 46)

Also, where;

$$I = 1.28 \times 10^{-3}$$

$$y = b/2$$

Therefore,

$$(1.08)/(1.28 \times 10^{-3}) = 210(b/2) \text{ (from 47)}$$

$$b = 8.02\text{mm}$$

Figure 17 shows the free body diagram for the grip of the member D as gotten from the computation analysis.

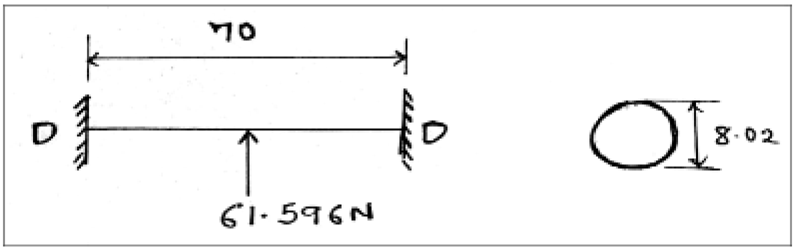

Figure 17(a) Free body diagram for the grip **Figure 17 (b)** Cross sectional view

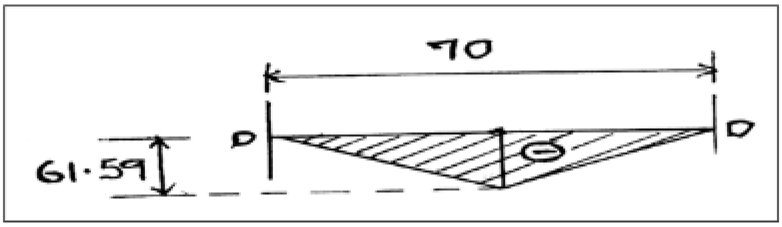

Figure 17 (c) Bending moment diagram

2.5. Materials Selection Based on Computation

Following the results from the analysis based on computations, the appropriate materials for the machine components design were selected.

Considering the value of E, Young's modulus as used in the design of the cantilever which is 210KN-mm, the suitable material is AISI 1018 mild steel. AISI 1018 mild/low carbon steel has excellent weldability, produces a uniform and harder case and it is considered the best steel for carburized parts. AISI 1018 mild/low carbon steel offers a good balance of toughness, strength and ductility[9].

The suitable electric motor as well has to be with the appropriate RPM and power rating as derived from the computation analysis.

3. Results

Figure 18 shows the diagrammatic representation of the file stacking and off-loading machine.

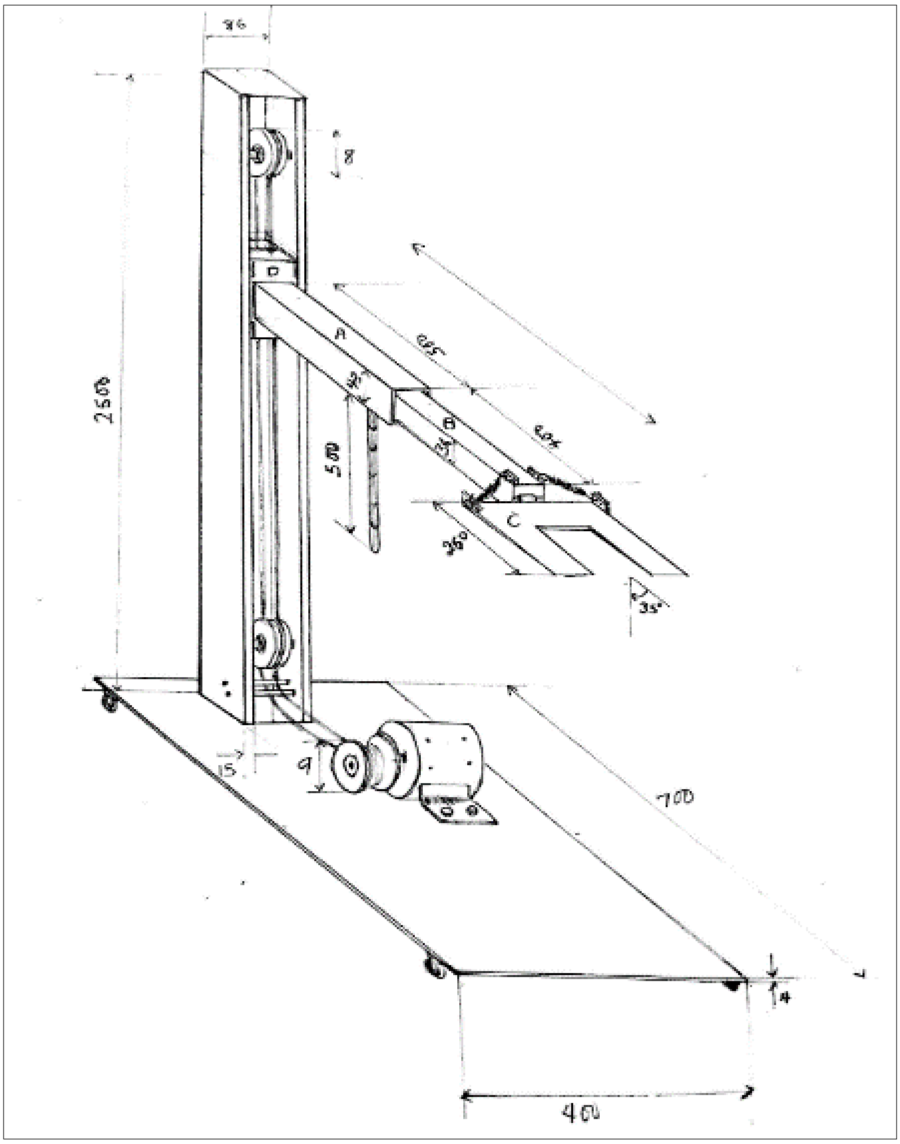

Figure 18 A diagrammatic representation of the office file stacking and offloading machine

4. Discussion

The up and down movement is controlled by an electric motor, the cantliver is used for extension and retraction. Once the desired height is reached, it can be extended to drop and pick a heap of files or upon carriage can be retracted to drop it at the desired position. The machine is designed such that it be manually or electrically operated. It was tested and was able to pick, drop and off-load 2.5kg files at once. The maximum designed load was 3.0kg.

5. Conclusion

The office file stacking and offloading designed and produced was able to pick, drop and off-load files weighing 2.5kg at a height of 2.5m.The machine is effective and will increase the productivity of the clerical and office staff working in the University and allied Institutions.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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