International Journal of Electrical and Electronics Engineering, Volume 1, Number 1, 2009

DESIGN AND FABRICATION OF A VACUUM COBWEB CLEANER

Oyawale F. A. and Otesile O. O.
Industrial and Production Engineering Department
University of Ibadan, Ibadan, Oyo State, Nigeria

ABSTRACT

A visit to high rise buildings will show infestations with cobwebs at the walls and ceilings. These buildings could not be cleaned except through the use of scaffolds and long poles with wet cloth or foam rubber attached to the end. The aim of this research is to design a device to do such cleaning efficiently without the inherent dangers in the use of scaffolding. The design of the vacuum cobweb cleaner was based on parameters used in the design of components such as the vacuum cleaner, floor polishers, and floor scrubbers. After the engineering drawing, materials were selected to strike a balance between the cost and quality. The fabrication of the vacuum cobweb cleaner was mainly through the use of basic manufacturing processes such as cutting, joining, machining and drilling. The performance of the vacuum cobweb cleaner was satisfactory. There is need however to improve the suction of sticky webs.
Keywords: Cobweb, Spider, Vacuum Cleaner

INTRODUCTION

The cleaning of cobwebs in tall structures has been one major problem for some time. Though many methods have been employed in the cleaning of cobwebs such as the use of brooms, scaffolds and chemicals in wall paints, little has been achieved to effectively rid the buildings of spider webs due to height of the buildings. Spiders' webs or silk is a fibrous protein that is secreted as a fluid forming a polymer, on being stretched it is resistant to breakage due to its elasticity. There are basically two types of spider webs; the sticky and the non-sticky. It is the sticky ones that dirty the walls when cleaned (Jones, 2006). To clean cobwebs of this type, it will be necessary to get a device that is capable of sucking it effectively. The vacuum cleaner was chosen as the basis for this design. The objective of this project is to design and produce a device that will be able to clean cobwebs effectively and efficiently from the ceilings and edges of buildings with height greater than 3.66 metres. After a lot of pioneering efforts, James Spangler in 1906, invented an electric vacuum cleaner from a fan, a box, and a pillowcase. In addition to suction, Spangler's design incorporated a rotating brush to loosen debris. Spangler patented his rotating-brush design in 1908, and eventually sold the idea to his cousin's "Hoover Harness and Leather Goods Factory". In the United States, Hoover remains one of the leading manufacturers of household goods, including cleaners; and Hoover became very wealthy from the invention. In Britain Hoover has become so associated with vacuum cleaners as to become a generic trademark. The word "Hoover" often is used as a generic term for "vacuum cleaner". [13] The power of the vacuum cleaner's suction depends on a number of factors. Suction will be stronger or weaker depending on: the power of the fan, the good speed of the motor, size of the air passageway, and the size of the opening at the end of the intake port. Since the speed of the vacuum fan is constant, the amount of air passing through the vacuum cleaner per unit of time is also constant. No matter what size you make the intake port, the same number of air particles will have to pass into the vacuum cleaner every second. If you make the port smaller, the individual air particles will have to move much more quickly in order for them all to get through in that amount of time. At the point where the air speed increases, pressure decreases, because of this principle. The drop in pressure translates to a greater suction force at the intake port. Since they create a stronger suction force, narrower vacuum attachments can pick up heavier dirt particles than wider attachments. The moving air particles rub against any loose dust or debris as they move, and if the debris is light enough and the suction is strong enough, the friction carries the material through the inside of the vacuum cleaner. This is the same principle that causes leaves and other debris to float down a stream. [12] Some vacuum designs also have rotating brushes at the intake port, which kick dust and dirt loose from the carpet so it can be picked up by the air stream. The dirt-filled air makes its way to the exhaust port where it passes through the vacuum-cleaner bag. These bags are made of porous woven material (typically cloth or paper), which acts as an air filter. The tiny holes in the bag are large enough to let air particles pass, but too small for most dirt particles. Thus, when the air current streams into the bag, all the air moves on through the material, but the dirt and debris collect in the bag.

MATERIALS AND METHODS

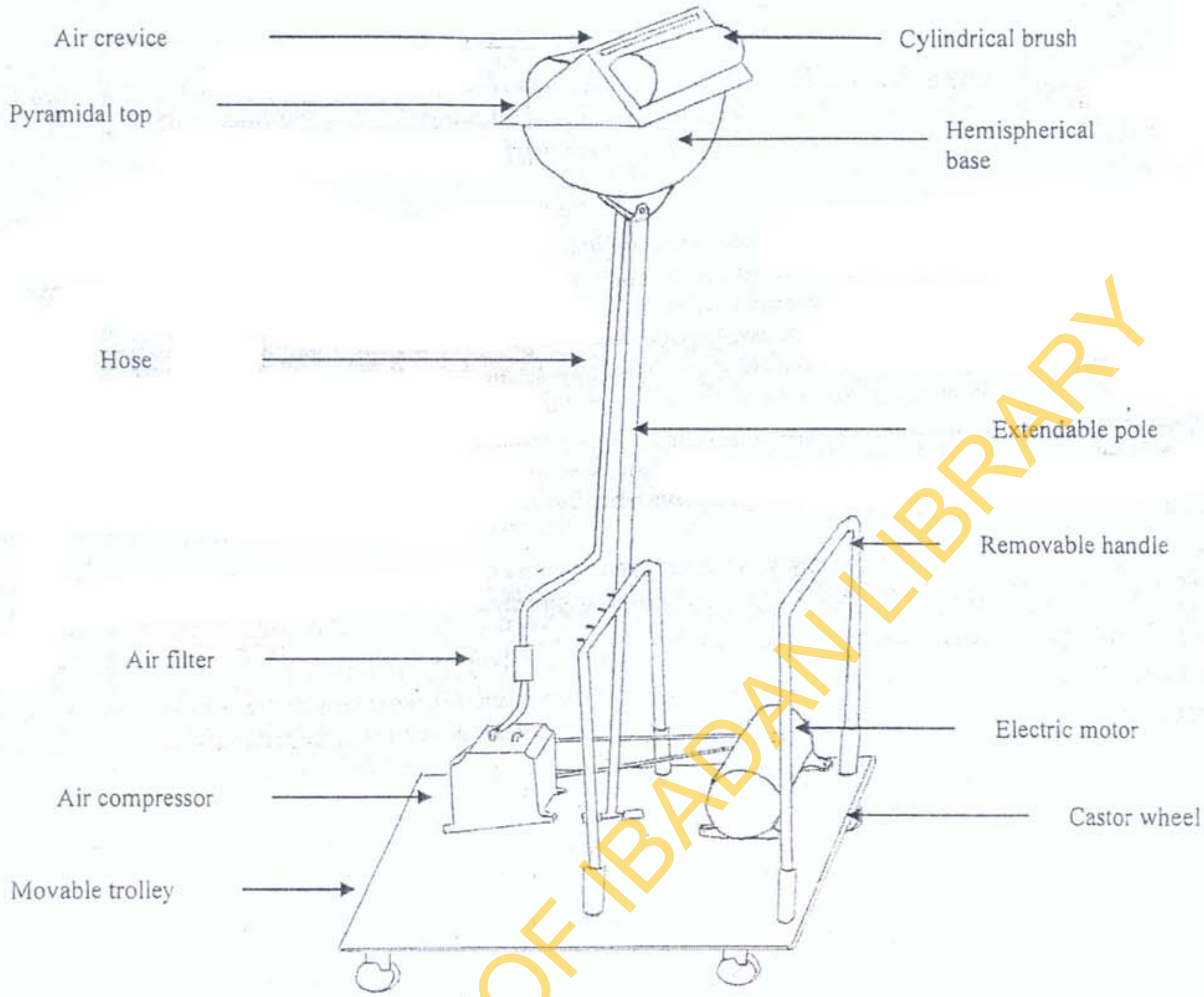


Fig. 1: Schematic diagram of the cobweb cleaner.

Design for pyramidal top of cobweb cleaner

The shape of the pyramidal top is chosen based on the most popular designs of the soffits. The angle of the soffits built in most houses is mostly at 90° which is the basis for the apex of cleaner. The breadth of the top of the cleaner is calculated from the average distance covered by the cobwebs on the wall which is equivalent to 0.2032 metres. The width was calculated to be equivalent to 0.287 metres from Pythagoras rule which makes it only logical for the length to be approximately 0.305metres.

Design of hemispherical base of cleaner

Since the base of the pyramidal top of the cobweb cleaner is like a rectangle, a tolerance of 25mm was given to accommodate the hemispherical base which had a diameter of 254mm. The hemispheric base was designed so that it would be able to rotate up to an angle of 180° on control shaft.

Design of extendable rod

The telescopic rod ranged between 3.66m and 6.096m. The rod is able to support approximately a weight of 10kg. It is sufficiently rigid to withstand the force generated by the rotation of the brushes and the small lectric motor in the housing. The rod is made of high tensile steel and it is resistant to bend during use. [2]

Design for air filter

The air filter is a cubic container made of an aluminium housing which contains a filter bag made of muslin-a type of thin cotton cloth used in curtains. The filter is placed between the pipe from the cobweb cleaner and the air compressor.

Design for trolley

The trolley is made up of light steel frame and heavy steel base of length 762mm and breadth 457.2mm and 6.35mm thick. The steel base is placed on four castor wheels (two movables and two fixed) and the two handles of the trolley will be welded or fitted on it. One of the handles is to support the movable pole to carry the cobweb cleaner. The electric motor and compressor will be mounted on the trolley. The following should be put into consideration when choosing the material for the trolley.

1. Strength of steel plate needed for trolley must be equal to or greater than weight of electric motor plus weight of compressor.
2. Strength of steel plate needed for trolley plus weight of electric motor plus weight of compressor must be equal to or greater than weight of pole plus weight of cobweb cleaner plus vibratory and rotary force(of 2 small 0.134 h.p electric motors and 2 cylindrical brushes).[5,11]

Also, since dimension of trolley is (0.4572m) by (0.762m)

Volume of trolley=0.4572m x 0.762m x 0.005m

$=1.742 \times 10^{-3}$ m^3

Maximum expected mass of cobweb cleaner= 10kg

Expected length of pole=6.096m

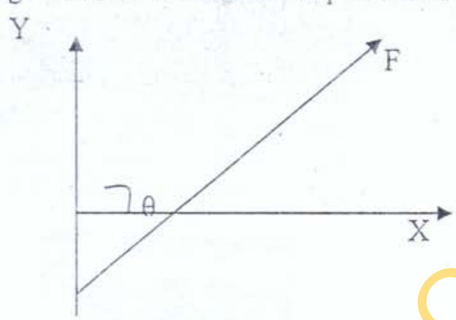
Acceleration due to gravity= 9.8 m/s^2

Maximum expected weight of cobweb cleaner = 10kg x 9.8 m/s^2

= 98kg m/s^2

F = Force generated by weight of cobweb cleaner

θ = angle between the extendable pole and base of trolley.



When θ = 45°,

F = 98kg m/s^2/cos 45°

= 98kg m/s^2 /0.7071

=138.5 kg m/s^2

When θ = 90°,

F= 98 kg m/s^2/sin 90

= 98 kg m/s^2

Therefore, the trolley should be able to support the force generated by the cleaner i.e. at least 98 kg m/s^2 and at most 138.5 kg m/s^2 which implies that the trolley should weigh between 10 kg and 14 kg.

Cylindrical brushes

When a cylinder rolls on a surface the force resisting motion is termed rolling friction. Rolling friction is generally considerably less than sliding friction. Rolling force is

F = f x W/R .... (i)

F = force required to overcome the rolling friction.

M = mass of a cylindrical brush= 0.2kg

g = acceleration due to gravity=0.98 m/s^2

W= weight of the cylinder converted to force, or the force between the cylinder and the flat surface.

R= radius of the cylinder and F is the =0.114 metres

f = the coefficient of rolling friction of hard rubber on concrete = 0.015

W= Mg.......................... (ii)

W = 0.2kg x 0.98 m/s^2

= 1.96 kg m/s^2

F = 0.015 x 1.96 kgm/s^2/0.114

= 2.58 kg m/s^2

Since there are two cylindrical brushes, the total rolling force,

F= 2 x 2.58 kg m/s^2

$= 5.16 kg\ m/s^2$

Sizing of small electric motors in cobweb cleaner: [4]

The electric motor is rated at 100 watts and running at 1440 revolution per minute (r.p.m) and since 746 watts = 1 horse power

100 watts = 1/746 x 100

= 0.134 horse power.

Therefore, the power generated by two small electric motors = (2 x 0.134) horse power

= 0.268 horse power

Sizing of electric motor to power air compressor

The electric motor selected to drive the air compressor is rated 1 horse power running at 1440 rotation per minute because of its availability and cost.

Fabrication of parts

Hemispherical base

The base was initially made by moulding aluminium in a cast. The part was cast by making the pattern which was made of plastic. After which with the help of patterns, the core and the mould was made. The mould was then clamped properly with the cores placed properly in the mould cavity. Then the aluminium to be cast was melted and when it solidified, the casting was removed from the mould. Lastly the casting was cleaned and finished by fettling. The cast had to be disposed of because it was quite heavy and it did not meet the design specification made initially.

Pyramidal top: it is made of aluminium sheet. The aluminium sheet of dimensions 11 inches by 16 inches was bent into two equal parts of dimension 279.4mm by 203.2mm. Two parts of dimensions 228.6mm by 114.3mm and 228.6mm by 6.35mm was cut from the two sides to create allowances from the brush and sucking in of air.

Cylindrical brushes: the core of the brushes was made from very light steel pipe of diameter 17mm and plastic pipe of diameter 15mm.The plastic pipe which has a length of 76.2mm was forced into the light steel pipes of 114.3 mm length when it was cut into two parts. Half an inch of plastic pipe was exposed for the belt to roll on. A ball bearing was welded to the free sides of the steel pipes, which is to be fastened to the cobweb cleaner housing. The bearing has a support on which a hole is drilled on both sides of it. The position of the holes on the supports coincides with holes on the pyramidal top (see Plate 1).

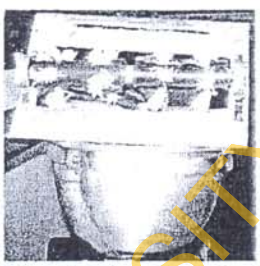


Plate 1: Bowl of the fabricated vacuum cobweb cleaner

Extendable pipe: the pipe is made of steel material and it was cut into two parts; one 1.83 metres and the other 0.9144 metres. At the end of the base of the rod, a hinge is welded to it. The hinge is made from two rods of diameter 8mm and length 50.8mm each, that was cut with a hacksaw. The two cut rods were welded to the base of pipe. Two other small pipes of diameter 10mm and length 50.8mm were cut and welded to the centre of the trolley; they are to act as the hinges for the extendable rod.

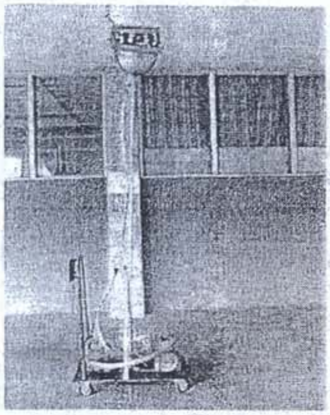
Trolley: the trolley is made up of the following parts:

- The heavy steel base of dimensions 0.4572metres by 0.762 metres.
- Two sets of handles: one for pushing trolley and the other for supporting the extendable pole.
- A set of castor wheels: two fixed and two movable.
- A one horse power electric motor.
- A compressor with leakage test results as [high side- 30 kg/cm^2,low side-14kg/cm^2]

The castor wheels were attached to the trolley with 16 bolts and nuts after 16 holes of diameter 8mm were drilled 1 inch from the edge of the trolley. The electric motor was mounted on the trolley after four holes were drilled some inches from the edge of the trolley. The compressor is mounted on the trolley by first cutting four angle bars 0.1016 metres long and drilling holes of diameter 8mm at 0.0254 metres from the edge of the bar. The end which is 0.0762 metres from the hole drilled is welded to the base of the trolley. After the four bars were welded to the trolley; the compressor was then fastened to the angle plates with the use of 8mm screws and bolts. The handles made on the trolley are removable: four cylindrical pipes were welded to the base of the trolley; the pole bent at two sides was placed into each of the four holes.

Cobweb comb: a thin aluminium plate with vertical cuts made on it is placed in contact with the brush bristles within the cobweb cleaner. It is attached from the side of the vacuum cobweb cleaner.

Air filter: was made by forcing a smaller tube into a larger one and at the junction of intersection, a thin muslin or cotton cloth was used to cover the entrance so that the air being pulled over the compressor is filtered of the cobwebs and dirt so as not to block the passage of air. The assembled machine is shown in Plates 2 and 3.



Plates 2 and 3. Two views of the cobweb cleaner

RESULT AND DISCUSSION

Results

The vacuum cobweb cleaner was designed and fabricated. The cleaner was tested and it works reasonably well. At first testing, the one horse power electric motor powering the air compressor worked well without making much noise. Also, the air compressor worked well as expected; it did not create much vibration and the movable trolley was quite stable. the two 0.134 horse power electric motors in the cobweb cleaner functioned well and rotated the brushes well at very high speeds, only that, then small vee-belts used kept on slipping from the pulley due to the incorrect placement of the pulleys of the electric motors in relation to the mid point of the cylindrical brushes.

DISCUSSION

Most of the parts and components of the vacuum cobweb cleaner were made in such a way that they can be easily assembled and disassembled. The device has been produced for safety, ease of use and mobility. The two cylindrical brushes on the cobweb cleaner are powered by two electric motors running at 0.134 horse power each. The 1 horse power electric motor powers the air compressor. The power of the suction generated by the air compressor was adequate. The trolley (457.2mm by 762 mm) with four castor wheels was able to support the whole device. Most parts of the device are detachable to make for easy storage and transportation.

CONCLUSION

A vacuum cobweb cleaner has been manufactured using locally available materials. This removes the drudgery of cleaning with brooms and dusters. The present cost of ₦40,200 (see appendix 1) is expected to go down with additional research and mass production.

REFERENCES

Clive L. Dym, Patrick Little-Engineering design: a project based introduction.

DeGarmo E. Paul, - "Materials and Processes in Manufacturing" 5th edition. Macmillan publishing (1985)

Hall A.S, A.R. Holowenko and Laughlin H.G., "Schaum's Outline of theory and problems of machine design", SI (metric) Edition, Tata McGraw-Hill publishing company limited (2002)

How stuffs work- vacuum cleaners (www. How stuffs work.com)-(site visited 26/09/2006)

Jackman John J. (2006)"Spiders" (professor and extension entomologist)-cooperative extension work in agriculture and home economics, the Texas A & M university system and united state department of agriculture.(www.texas A&M university system.edu/entomology)- (site visited 11/09/2006)

Jones S. J. (2006) "Spiders in and around the house" - (Ohio state university extension fact sheet-entomology)-ohioline.ag.ohio-state.edu.(site visited 11/09/2006)

Nigel cross -Engineering design methods, strategies for product design (3rd edition).

Norton Robert J.-, "Design of Machinery: An Introduction to the Synthesis and Analysis of Mechanisms and Machines" 2nd Edition, McGraw Hill Series on Mechanical Engineering (1999)

Robert L. Norton -Design of machinery, 2nd edition- an introduction to the synthesis and analysis of mechanism and machines.

Ryder G.H -Strength of Materials(third edition in S.I units)

Ryder G.H, Bennett M.D.-, "Mechanics of machines" ELBS Macmillan (!987)

Sharma P.C -A textbook of production technology (manufacturing processes), s. chand & company limited, 2002. Staple set tufted brush construction and design information (http // www. tanisinc.com /rfq-staple.htm)- (site visited 11/09/2006)

Vacuum cleaners-(www.wikipaedia.org)-(site visited 16/02/2007)

William F. Riley, Leroy Sturges -Engineering mechanics statics (2nd edition).

William Nash -Strength of materials (fourth edition), Schaum's series.

Appendix 1

Cost estimate of the vacuum cobweb cleaner

Part no.	Part name	quantity	Cost in naira	Total cost in naira
1	Hemispherical base	1	3000	3000
2	Pyramidal housing	1	1000	1000
3	Pulleys	4	200	800
4	Cylindrical brushes	2	200	400
5	Cobweb comb	2	100	200
6	Movable handle	1	400	400
7	Extendable pole	1	2000	2000
8	Movable trolley	1	7000	7000
9	Electric motor(1/2 h.p)	1	2000	2000
10	Air compressor	1	5000	5000
11	Rubber pipe	20 ft	1500	1500
12	Electric motor(1 h.p)	1	12000	12000
13	Screws and bolts(Ø 8mm)	20	10	200
14	Washers	20	10	200
15	Labour			4000
16	Transportation			500
	TOTAL COST			40200