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Design And Construction Of A Dust Extractor Machine

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***Abstract*—The essence of this study is to develop a low cost dust extractor device that will be of immeasurable value to our local industries. This device, the dust extractor machine will eliminate dust and other similar solid pollutants of related sizes form enclosures. The effect would be the purification of the surrounding air. Both past and recent developments have been taken into consideration. The outstanding features in these extractor devices have been weighed against problems that limit their usage. And in our design, the experience and efforts of past inventors have been brought to bear vis-à-vis our research efforts. The design of the dust extractor machine is based on engineering laws, principles and theory. The machine was fabricated in accordance with the specification and although this is a research model, the specification was strictly adhered to. An industrial scale would simple be in line with dimensional analysis. The materials used in construction were locally sourced and economic was employed without compromising quality in the cost analysis. Aesthetics, ergonomics and safety of usage were equally taken into account in the design and construction of this device. The machine has been designed for safe operation and easy maintainability.**

Keywords—design, construction dust, extractor, fan, ergonomics

INTRODUCTION

The ability to envisage a better way to solving the problems of his society has always been a trait of the engineer. Engineers employ their creative ingenuity in proffering solutions to the problems of mankind. Man was joyful on the advent of industrial revolution but man would have to contend with problems brought about by that revolution. One of such problems is pollution brought about by the effluence from certain industrial machineries and processes (1).

And specifically is the issue of dust pollution. Industrial processes such as those involving asphalt or cement productions, for instance, releases dust effluents to the atmosphere, which if left uncontrolled could lead to serious health problems for those working in such plants or people living in the environment.

There is therefore the need to design a device, machine or process that would extract the dust from the air before the air is released to the atmosphere, and such a device must be inexpensive but very effective to enable small scale business owners have access to it. Hence the design and construction of the "Dust Extractor Machine".

BACKGROUND OF STUDY

Pollution is a serous problem in modem civilization. It is the contamination of a system or the environment by harmful substances. The environment we live-in has continued to experience pollution from different types of contaminants as a result of human activities. Environmental pollution can be categorized into three major groups depending on the part of the environment being contaminated. These are: Air pollution, soil (land) pollution and water pollution. These can further be classified according to the type and nature of the contaminants into; Gas pollution, solid pollution, liquid pollution and radioactive pollution. The solid pollution is sometimes referred to as dust pollution (2).

Dust pollution in our environment is mainly brought about by human activities such as earth movement (involving road construction), solid mineral processing, wood processing, grains and cereals processing, flour milling, just to mention a few. In the past, serious attention was not paid to environmental dust pollution. However since the harmful effects of pollution to our health and environment have become a matter of concern, environmental laws and regulations have been promulgated to curtail the act of indiscriminate pollution of our environment.

Different methods and devices are now available for controlling dust emissions to the atmosphere. However these means are only available to the large-scale entrepreneurs that can afford them. Many smaller production outfits continue to produce and emit dust particles to the environment since they cannot afford the available controlling device. In order to provide solution to the problem, it is necessary to have an inexpensive device that will be affordable and at the same time efficient. It is in the light of this that the design and construction of a cost and effective dust extractor machine is being undertaken.

AIMS AND OBJECTIVES

The purpose of this research are to

i. design and construct a simple machine that would capture and purify the air within a production room.
ii. To test and evaluate the designed machine.

SIGNIFICANCE OF THE STUDY

This device is targeted at solving the problem of dust pollution occurring from small scale business ventures where dust is generated such as solid mineral processing factories, wood processing factories, grain milling and threshing and other such similar ventures or activities where dust is readily and openly released to the atmosphere or the environment. Indigenous extractor devices are not common; this research will be an indigenous design of a dust extractor machine.

LITERATURE REVIEW

Historical Development

Environmental Management and Pollution control pose a major concern to all. Over the years, different techniques have been developed to either suppress the dust at the source before it is generated or control the dust after being generated. So that it doesn't get access to the atmosphere. It is pertinent that we take these two alternatives into consideration even though we are much concerned about the second alternative. The former is a recent development spanning for about a decade now and is based on advanced technology techniques. Kaveri developed these dust suppression systems in 1981. The second option is to extract the already generated dust or pollutant by way of reduction or total elimination (3).

The application of existing and new technology has resulted in the development of many air pollution control devices to this effect (4). In the last two dozen intervening years, much of these equipments has reached the end of their useful life, the original process parameters have changed rendering these equipment less effective, and historical failure modes and equipment limitations have been identified (5).

The major controlling performance parameters are:

Particle size, weight, shape., Particle velocity, Gas temperature / density, Solubility and Ph, System pressure drop and mass transfer conditions, Particle size distribution, Gas viscosity, Humidity level, Chemical Stoichiometry and Residence Time.

DESIGN METHODOLOGY

Design Concept and Operating Principles

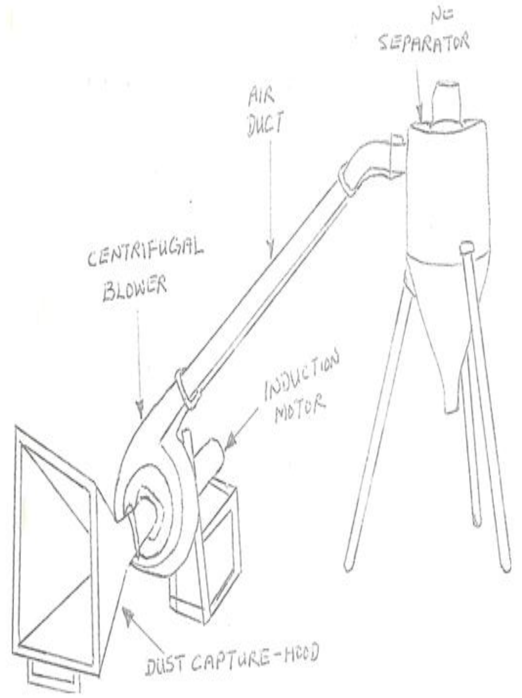


Fig 1: Diagram of Dust Extractor Machine

The Concept consists of the following

1. Dust capture-hood
2. centrifugal blower
3. Air duct
4. Cyclone Separator

Principle of Operation

The dust capture-hood is normally positioned in the dust laden air, environment. The end of it is connected to the blower inlet by means of a short air conduit pipe. The blower is connected to an induction motor. Power is switched on, and this causes the motor to rotate which in turn causes the blower to rotate. As the blower rotates, dust-laden air is sucked from the environment into the dust capture-hood and into the blower. In the blower, the motion of the dust-laden air is accelerated. It is then channeled through the air duct into the cyclone separator. Inside the cyclone separator, the dust — laden air follows the circular profile and spins round the cyclone in a decreasing order in terms of circular diameter. This action causes the dust particles to settle down to the bottom of the cyclone, The air, which is now clean, escapes through the vortex finder to the atmosphere. The accumulated dust however drops down through the opening at the cyclone base (6).

3.1.2. Machine Components

1. Capture-hood
2. Centrifugal blower
3. Air duct
4. Cyclone Separator

3.2 DESIGN SPECIFICATIONS OF COMPONENT PARTS

Area of capture - hood	150mm X 150mm
Speed of blower	2750rpm

Blade diameter	200mm
Blade angle	90°
Prime mover type	Single phase induction motor
Cyclone diameter	300mm
Cyclone length	820mm
Air-duct length	600mm
Air duct cross-sectional area	80mm X 80mm

DESIGN PARAMETERS

(i) Torque developed by the blower in moving the air,
(ii) Theoretical power required to move ah*.
(iii) Pressure head (H) developed by the fan.
(iv) Pressure developed
(v) Volume flow rate of air through the conduit
(vi) Pressure loss in pipe.

Preliminary Design Calculations

Torque developed by the blower in moving the air

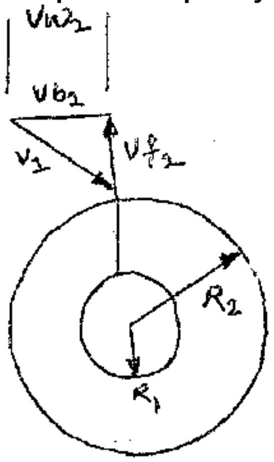


Fig. 2 Velocity diagram of the air flow

Referring to figure 2 above, the velocity diagram of the air flow consists of the following:

Vb_2 = Outlet blade velocity

Vw2=Exit velocity (whirl velocity) of dust-laden air.

Vw2 = Vb_2, This is because it is the blade that impacts the angular motion to the dust laden air.

Considering figure 2, the dimensions of the impeller blade is given by the following parameters: m, R_1 R_2 and w

Where

m = mass of air flowing through the impeller in Kg/s

R! = Internal radius of the impeller - 50mm

R_2 - External radius of the impeller = 200rnm

w = Angular velocity of the impeller. The angular velocity w of the impeller is given by:

$$W = \frac{2\pi N}{60} \qquad (1)$$

From the design specification, N = 2750rpm

$$W = \frac{2X3.142X2750}{60}$$

= 288.017

Thus W=288.02 rad/s

The angular momentum of dust laden air entering the impeller per second is given by:

Angular momentum (entry) = mVw_1R_1
(2)

Where R_1 = internal radius of impeller

m = mass flow rate of dust laden air (in Kg/s)
=

Vw_1 = entry velocity of dust laden air.

Similarly the angular momentum of dust laden air leaving the impeller per second is given by:

Angular momentum (exit) — mVw_2R_2

Where m = mass flow rate of dust laden air (in Kg/s)

Vw2 = exit velocity of dust laden air

R_2 = external radius of the impeller

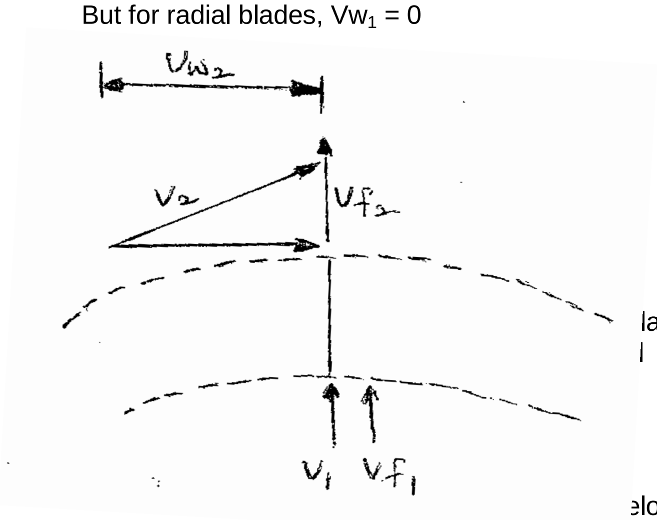
According the principle of conservation of angular momentum, the angular momentum about an axis of a given rotating body or system of bodies is constant, if no external toque acts about that axis.

Thus: $mVw_2R_2 = mVw_1R_1$

i.e. $mVw_2R_2 - mVw_1R_1$ - 0

Or $m(Vw_2R_2 - Vw_1R_1)$-0

But for radial blades, $Vw_1 = 0$



lade
l
elocity

Now for straight or radial blades (i.e. blade angle = 90°) at inlet the absolute velocity Vi is in-line with Vfi (considering fig 3)

That is, $V_1 - Vf_1$

And $V_1 - Vf_1 = 0$

Thus $Vw_1 = V_1 - Vf_1 = 0$

From figure 3.2, we recall that $Vw_2 = Vb_2$

Hence $Vw_2\text{-}Vb_2 = \frac{\pi D_2 N}{60}$

$= \frac{3.142X0.2X2750}{60}$

$= \frac{1728.1}{60}$ = 28.80

= 29m/s

Similarly we have that;

Q- $\pi D_2 b_2 Vf_2$

Where Q = flow rate (m7s)

D_2= External diameter of impeller = $2R_2$ = 200mm

b_2 =

Width of impeller at outlet = 150mm

Vf_2 = radial velocity of flow at outlet = 15m/s /.

∴Q = 3.142 X 0.2 X 0.15 X 15

= 1.4m^3/s

Also,

$m = \rho_a \times Q$
(6)

ρ_a = density of air (1.2Kg/m^3)

m=1.2X1.4
= 1.68Kg/s
Hence toque = 1.68 (29 X 0.1)
= 4.87 Nm

Power required to move air

The power required to move air is given by:
P = Tw
Where
T = Toque developed (Nm)
w = angular speed of the blade (rad/s)
.'. Power = 4.87 x 288.02
= 1403.23W = 1.40323KW
IHp= 0.746KW
xHp = 1.40323KW, xp = 1.88
Thus p = 1.88Hp say 2Hp.

MATERIAL SELECTION

The selection of working materials is based on:
(i) Functionality of component parts.
(il) Cost of the materials,
(iii) Availability of the materials

Table 1 Parts, Materials and Selection Criteria

S/N	PART	MATERIAL	CRITERIA
1	Cyclone Separator	1mm thick mild steel sheet	Lightness, cheap, readily available and easy to fabricate
2	Conduit pipe	1mm thick mild steel plate	Light weight and easy to fabricate
3	Fan Blade	3mm thick mild steel plate	Strength and stability after weld
4	Fan Housing	1mm thick steel metal	Light weight and easy to fabricate
5	motor mounting	1 inch angle bar	Rigidity and low costing
6	Blower frame	1 Inch angle	Rigidity and low costing

TEST / RESULT

The machine is meant to capture dust-laden air emanating from processing operations such as limestone, crushing, cement production, corn and cassava flour milling.

This test was carried out by allowing 5kg of dust particles of size range between 0.05mm and 1.5mm to entrain into the capture-hood while the device was on.

During the test, dust particles were deposited by the cyclone separator. The weight of the dust particles deposited was then measured. The result is tabulated below:

Table 2 Test Result of dust entrained into Device

Test	Particle Size range	Weight of dust entrained	Weight of dust deposited
1.	0.05 -	3kg	2.6kg

Capture efficiency $\eta_c = \frac{2.6}{3} \times 100$
$= 86\%$

PERFORMANCE EVALUATION

From the capture efficiency obtained (i.e. 86%) for a single test; the machine can be said to have high capture efficiency for the range of particle sizes used for the test.

The test carried out on the machine showed efficient performance. The machine operation was observed to be very smooth with low vibration and noise level. This will guarantee the reliability of the machine in service.

CONCLUSION

The construction and testing of the machine has been achieved. The design was done in accordance with standard design specification.

Test carried out on the machine indicated a high level of efficiency and that the machine would conveniently address the problem, it was designed to solve, that is, extracting dust.

RECOMMENDATION

For a more cost effective way of producing this device, mass production is recommended, as it would enable the product to be available at a low price. It is also recommended that money be spent in the design and development of automatic machines that will produce the major components, to make them available in large numbers.

It is further recommended that in subsequent construction of this device, standard parts be made use of as the cost of standard is only a fraction of the cost of similar parts made to order.

The sizes of machine members may be modified in order to facilitate manufacture or reduce overall cost. And finally, regular maintenance is recommended to extend the life span of the machine. The machine however has been designed for easy maintainability.

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