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Design and Development of Warehouse Spraying System

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ABSTRACT

India is agricultural country; Most of the grains produced in Indian farm are stored in warehouses for the periodof a few weeks to a few years as per the market demands. The stored grains are chiefly subjected to attack of insects, rats and micro-organisms. To avoid the increasing population of insects the toxic chemicals are spread on stored grains. The spraying of pesticides, insecticides or fumigants on stored grains is purely done by human workers using traditional equipment's likes hand operated sprayer and portable spraying pumps. Toxic chemicals may be swallowed by human worker at the time of spraying operation. Toxic pesticides are very hazardous and harmful to human life and they cause some health effects like eye irritation, skin irritation. Some of chemicals are commonly used have been associated with birth defects, mutations and cancers. To avoid direct human contact during the spraying of toxic chemicals on stored grains in warehouse the unmanned manually operated Warehouse Spraying System is proposed. This paper presents the design and development of unmanned manually operated Warehouse Spraying System. This system having remote control battery operated mobile platform and telescopic boom with flat fan type nozzles. This system is used to spray the toxic chemicals on stored grains without direct contact of human during spraying operation. This system is capable to spray the chemicals in congested areas which are generally found in warehouses. Warehouse Spraying System is efficiently spraying the chemicals on stored and stacked grains bags at height up to 14 feet's.

Keywords- **Warehouse, Grains, Insects, Toxic Chemicals, Warehouse Spraying System**

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I. INTRODUCTION

India is agricultural country; main business of Indian people is farming. The grains produced in farm are stored in warehouses for periods of a few weeks to a few years before they are fed or processed as per market demand. The grains bins are stacked in warehouse at up to 14 feet height. The stored grains, Seeds are chiefly subjected to attack of insects, rats and micro-organisms. Regular spray of insecticide &pesticides is helping to clean up lingering infestations and prevent increasing population of stored-grain insects.

Pesticides are intentionally toxic substances. It causes skin irritation, eye irritation and allergic skin reactions. Some of chemicals are commonly used have been associated with birth defects, mutations, adverse reproductive effects, and cancer in laboratory animals [1].To avoid direct human interference during spraying of toxic chemicals in warehouses the unmanned manually operated Warehouse Spraying System is proposed. This system is very useful to spray any kinds of liquid chemicals like pesticides, insecticide or a fumigant on stored grains.

Unmanned Warehouse Spraying System is manually operated by using remote controlunit or programmed computer interface. Warehouse Spraying System consist of two Lithium-ionbatteries, two BLDC motors for drive, two powered wheel at rear, one caster wheel at front, spring suspension system, liquid tank with pump and vertical telescopic boom with flat fan type nozzles.This system can be used in rough terrain which is generally observed in warehouse.

Warehouse Spraying System is able spray chemicals at height up to 14 feet's. This system is capable for very safe and efficient work in warehouse.

II. LITERATURE REVIEW

a Indian Agriculture is facing the major challenges with respect to ever growing population to feed, shrinking natural resources, increasing global competitiveness, lack of scientific storage facilities, and changing food habits of consumers and above all, uncertainties of the monsoon and changing climate. Moreover, absence of scientific storage system leads to post harvest losses, wastage and quality deterioration. The small farmers do not have the financial strength to retain the produce with them and are unable to get better off season prices of their agricultural produce. They have to resort to distress sale of their produce during the peak marketing season when there is glut in the market. Various committees have suggested measures for Agricultural reforms.

The warehousing plays a very vital role in promoting agricultural marketing, rural banking and financing and ensuring food security in the county. It enables the markets to ease the pressure during the harvest season and to maintain uninterrupted supply of agricultural commodities during the off season. Hence, it solves the problems of glut and scarcity, which are the usual problems in agricultural marketing.

The warehousing capacity available in India, in public, cooperative and private sector is about 108.75 million MTs. The storage capacity available with the FCI and a part of the warehousing capacity available with the CWC and the SWCs are used for the storage of food grains procured by the Government agencies for the Central Pool.

The storage space available in the country is not sufficient to cater to the procured stocks. As a result, a substantial quantity of food grains (wheat and paddy) is stored in Covered and Plinth (CAP), an open storage system.

S. N.	**Name of organization / Sector**	**Storage capacity in million MTs**
1	Food Corporation of India (FCI)	32.05
2	Central Warehousing corporation (CWC)	10.07
3	State Warehousing corporations (SWCs)	21.29
4	State Civil Supplies Departments	11.30
5	Cooperative Sector	15.07
6	Private Sector	18.97
	Total	108.75

Table.1 - Warehousing Capacity in India

A. Grain Storage

The stored grains, Seeds are chiefly subjected to attack of insects, rats and micro-organisms. The insects feed on grains produce the heating and deterioration. Regular spray of pesticide or insecticide is helping to clean up lingering infestations and prevent increasing population of stored-grain insects. Residual sprays also create a barrier or insects that may migrate into a storage area from outside. A pesticide is any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest.

Pests can be insects and insect-like organisms, mice and other vertebrate animals, unwanted plants (weeds), or fungi, bacteria and viruses that cause plant diseases. Though often misunderstood to refer only to insecticides, the term pesticide also applies to herbicides, fungicides, and various other substances used to control pests. Applying an insecticide or a fumigant in an empty bin can supplement physical clean-up efforts. Need to be applying an insecticide to the walls, ceiling, roof, and floor of all bins that will be used to store grain formore than a few weeks during warm weather. And also applying a residual spray is 2 to 3 weeks before new grain will be stored in the bin.

Traditional Spraying system of Pesticides, insecticide or a fumigant is purely done by Human workers. In warehouse workers load pesticides in 10 to 15 litre tank and spray chemicals on grains bags which are stacking up to 14 feet height. Spraying is often a three-man operation: one worker sprays, a second person walks behind him with the pesticide mixture, and a third person mixes the next batch of pesticide powder with water. Numbers of workers are increased with size and numbers of warehouses.

Fig.1Traditional Manual Spraying system

B. Symptoms of Pesticide and insecticide

People exposed to pesticides may experience a number of health symptoms. Most of the pesticides are designed to harm or kill pests. Because some pests have systems similar to the human system, some pesticides also can harm or kill humans. Hazard is the risk of harmful effects from pesticides. Hazard depends on the toxicity of the pesticide and the exposure a human will receive in any situation [9].

Pesticides are intentionally toxic substances. It may be fatal if swallowed. Causes skin irritation. Harmful if absorbed through skin or inhaled. Causes moderate eye irritation and allergic skin reactions. Some of chemicals Are commonly used have been associated with birth defects, mutations, adverse reproductive effects, and cancer in laboratory animals [10].

Pesticides are composed of active ingredients and inert ingredients. Some inert ingredients may be more toxic than active ingredients and can comprise 90% to 95% of the product. Some inert ingredients are suspected carcinogens, while others have been linked to central nervous system disorders, liver and kidney damage, birth defects, and some short-term health effects [1].

C. Problem Identification

All grains and food stored in warehouse, and they are chiefly subjected to attack of insects, rats and micro-organisms. Regular spray of insecticide or pesticides on stored grains is helping to clean up lingering infestations and prevent increasing population of stored-grain insects.But spray of insecticide or pesticides affects on humans because of toxicity of chemicals and the direct contact of human during chemical spray. Human error has a negative effect on safety, efficiency, and quality. There is need of such system which can spray the toxic chemicals without the direct contact of human.

To avoid direct human contact during spraying of chemicals in warehouse the Unmanned manually operated Warehouse Spraying System (WSS) is proposed. This system will be very useful to all types of warehouses for spraying any kind of liquid chemicals likes Pesticides, insecticide or a fumigant on stored Grains in warehouses.

III. WAREHOUSE SPRAYING SYSTEM

Warehouse Spraying System (WSS)is used for spraying chemicals in warehouses for clean-up lingering infestations and prevent increasing population of stored-grain insects. Unmanned Warehouse Spraying System can be operated or controlled from distance location by using remote control unit or programmed computer interface. This system can be used in rough terrain which is generally observed in warehouse. It can be able spray chemicals at height up to 14 feet's.

A. Design of Warehouse spraying system

For designing of Warehouse spraying system some standard parts are purchased as per requirement, like BLDC Motors, Battery, Wheels, Nozzles, Valves, Pump, Tank, Bearings, etc. Structural parts are designed as per design requirement and standard parts fitting, like Base plate, Top plate, links, wheel shafts, pillars, mountings, Telescopic boom and side covers.

CAD design of warehouse spraying system mobile platform is shown in fig.2.

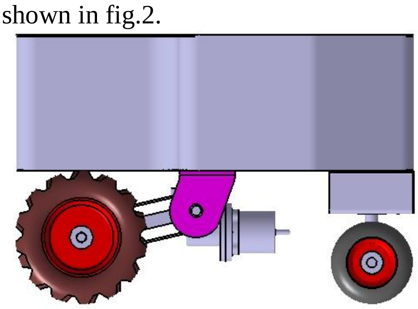


Fig.2 Warehousespraying system mobile platform

1) *Motor calculation:*

Data for calculation
Total mass of system = M =160 Kg (30 % overload)
Velocity of system = v = 1.5 m/sec.
Acceleration = A = 0.1 m/sec2
Wheel radius = r = 0.1 meter
To calculate the torque of the system
Torque = Force x Distance
Torque = M. a. r = 160X9.81X 0.1X0.1= 14.12 Nm
Torque required at each wheel= 14.12/2=7.06 Nm (min)

Type= BLDC Motor with gear head (Drive motor)
Speed = 144 rpm (at output shaft)
Reduction Ratio = 1:10
Torque = 8.5 Nm
Weight = 2.20 kg
Power = 120 watt(24 V, 5 amp)

Type of Motor = Steeper motor
Min Rotation angle = 0.18 Degree.
Reduction ratio = 1:5
Torque = 5 Nm
Power = 100 Watt (24 V, 4 Amp)

1)

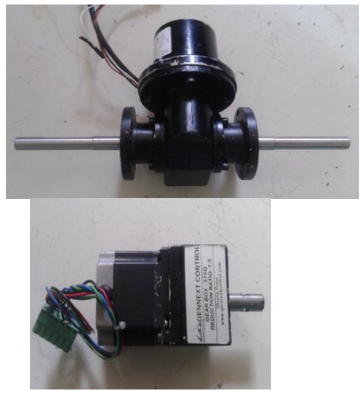


Fig.3 BLDC& Stepper motor

Battery Details
Type of battery= Lithium-ion
Voltage and current = 24 V, 17 Ah.
Size =158 X 182 X 166 mm

2) *Suspension spring calculation:*

Spring materials=Stainless steel (AISI316, ASTM A313)
Ultimate tensile strength of material=1476N/mm2
Permissible shear stress=0.5σut
τ=738 N/mm2
Spring index = C=6

Wahl's Factor = K= $\frac{4c}{4c} + \frac{0.6}{c}$C=1.2545

Shear Modulus,

$$=K\left(\frac{8\times618.03}{\pi d^2}\right)$$

$$738=1.2545\left(\frac{8\times618.03}{\pi d^2}\right)$$

Wire Diameter d=8 mm

Mean coil diameter (D) = C x d = 6 x 8 = 48
Numbers of active coils (N)

$$\delta = \frac{8\times P\times D^3}{GD^4} = 100 = \frac{8\times618.03\times48^3}{10\times10^3\times8^4}$$

N = 6

Spring has square & ground ends
(N) TotalNo of Coils = N+ 2= 6+ 2= 8
[2].

Fig.4 Suspension system

3) Shaft calculation:

For load (P1) and (P2)

P1 = P2 = = $\frac{1}{}$=48 kg

Where,w= Distributed weight at 3 wheels.

According to F=mg

P1 = P2 =48 9.81 = 470.88 N

Bending moment about point A,

ΣM at A=0

-P1 31.5+Rf 277 – P2 245.5=0

-470.88 31.5+Rf 277- 470.88 245.5=0

Rf=470.88 N

ΣF at V=0

RAV+RFV – P1 – P2=0

RAV+470.88-470.88-470.88=0

RAV=470.88 N

Bending moment at point C and D ,

M at D= - RF 84.5+ P2 53=0

=-470.88 84.5+470.88 53

M at D= - 14832.72Nmm

M at C= - RA 84.5+ P1 53

M at C= - 14832.72Nmm

Maximum Bending Moment,

M max = (Mc2 + Md2) (1/2)

= [(- 14832.72)2 + (-14832.72)2] (1/2)

Mmax= 20976.63Nmm

Equivalent Torque calculation for shaft material (plain carbon steel),

According to ASME Code,

Kb= Combinedshock andfatigue factor for bending= 1.5

Kt= Combinedshock andfatigue factor for tension= 1

Te= [(Kb Mmax)2 + (Kt T)2](1/2)

Te = [(1.5 20976.63)2 + (1 8.5 102)2] (1/2))

Te = 32592.83 Nmm

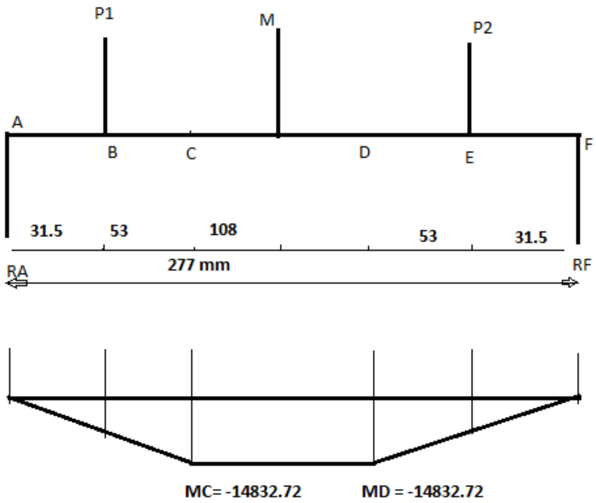


Fig.5Bending moment diagram

According to maximum shear stress theory for shaft material,

Plain carbon steel, Grade40C8

Sut= 580 N/mm2, BHN=217

Syt= 380 N/mm2

Carbon %= 0.4

Manganese %=0.8

For Allowable Shear Stress for Shaft,

Grade 40C8

τ allow= 0.18 Sut =0.18 580 = 104.4 N/mm2

τ allow=0.3 Syt = 0.3 380=114 N/mm2

Take smaller τ allow,τ allow=104.4 N/mm2

τ allowable = $\frac{16 \times}{\pi \times}$= 104.4 = $\frac{16 \times 32592.}{\pi \times d3}$

d = 11.67 mm ....Calculated.

Fromstandard shaft diameter with 1.2 factor of safety,

d =15 mm........Standard.[2].

4) Bearing selection:

For Shaft diameter = d=15mm

Load Factor ka= 1.1

For ball bearing a=3

Expected life of bearing Lh10=16000 hrs

Radial Face,

Fr= $\sqrt{(RH)2 + (RV}$

= $\sqrt{(470.88)^\wedge 2 + (470.88)}$

Fr=665.924

Basic static capacity = CO=6.55kw

Basic dynamic capacity =C=11.2kw

Equivalent dynamic load

Pe=Fr.Kg=665.924 1.1=732.5164N

L10= $\frac{Lh10\times 60}{10\wedge 6}$= $\frac{16000\times 60\times 14}{10\wedge 6}$=( ) ^2

1382.4=($\frac{c}{732.51}$) 2

C=8160.095 W

C=8.16kw < 11kW
Selected Bearing = SKF series 6005
Bearing size=d D B = 15 24 5 mm.

5) Base plate design & Top Plate design:

Base plate size= 3X400X600 mm
Top Plate = 3X400X600 mm
Material = Stainless steel 304/316

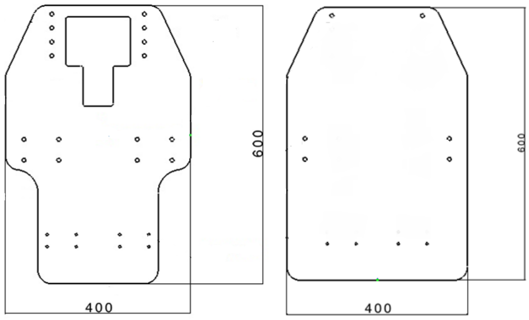


Fig.6Sizes of Base plate& Top plate

Base plate & Top plate as shown in fig. 6 are modelled in Catia V5 and then analysed by using Ansys software, analysis images are shown in fig. 7, 8, 09&10.

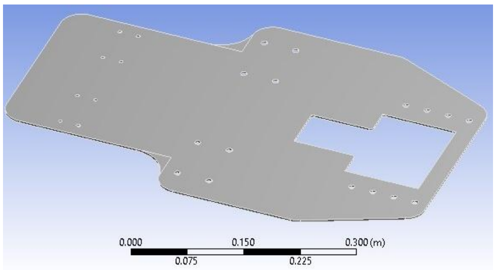


Fig.7Geometry of Base plate

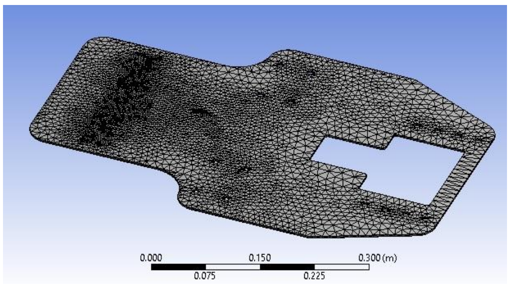


Fig.8Meshed model of Base plate

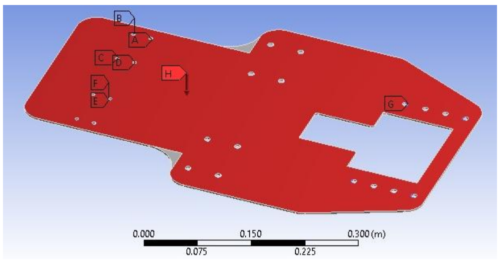


Fig.9loading of Base plate

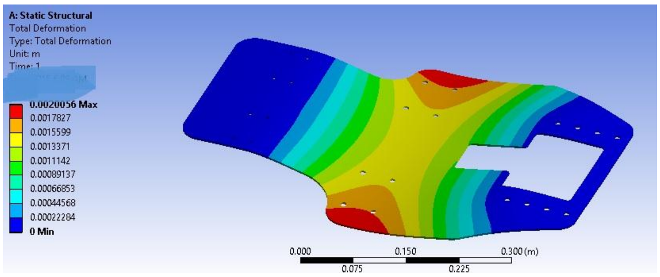


Fig.10Total deflection

6) Nozzle selection:

According to application120° flat-fan nozzle are selected. The standard flat-fan nozzle normally operates between 30 pounds per square inch (psi) and 60 psi, with an ideal range of 30–40 psi. The even flat-fan nozzles apply uniform coverage across the entire width of the nozzle's spray pattern. Smaller droplets improve coverage.[11].

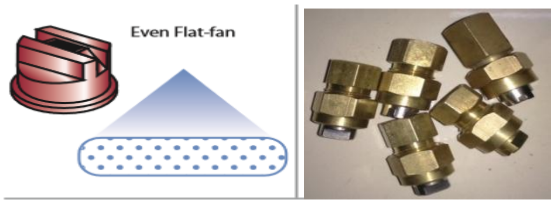
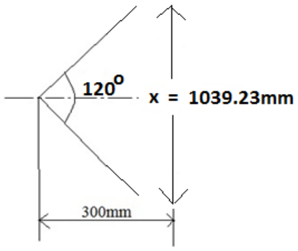


Fig.11120° Flat-fan nozzles

- Sizing of Nozzles on telescopic boom,
- By using four 120° flat-fan nozzles cover the vertical distance up to 14 feet from ground.



7) Pump & Tank selection:

Tank capacity – 16 litres
Pump – Electric sprayer 12 volt 2.7 LPM Viton pumps
Working pressure- 30 PSIto 40 PSI
Discharge - 840 ml/min - 30 PSI
Flat fen nozzle -910 ml/min - 40 PSI
L×W×H (in mm) = 335×140×470
Flow rate - 910 ml/min
Maximum head – 3267.2mm

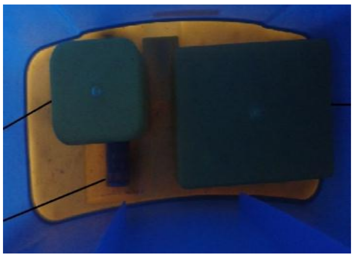


Fig.12Pump-Electric sprayer

B. Working of Warehouse spraying system

Warehouse spraying system is operated on 24V battery power. Two BLDC geared motors and two powered wheels are used for locomotion. These two wheels have independent suspension system. Chain driven mechanism is used to transmit power from motor to wheel. One wheel is mounted on front which is steered by steeper motor. A 12 feet long telescopic boom is used for mounting the 4 to 5 nozzles for spraying the chemicals on grains bags. Flat fan type nozzles are connected with solenoid valves having parallel pipe connection from Chemical tank. Chemical tank of 16 litre capacity with electric pump sprayer is mounted on system.

User can control and guide the Warehouse spraying system from distance location near about 300 meters away from system.

Users cancontrolling the system by using wireless remote control, and sending appropriate signals to system according to signals and results coming from system and path of lane in which spray is required. User can monitor the system through display unit and accordingly control the system in desired environment [8]. System should travels between two rows of stored grains bags; the area available for movement is near about 60 to 80 cm, which is very congested for movement, so system should be design according to the available space. Warehouse spraying system working environment is shown in Fig. 13.

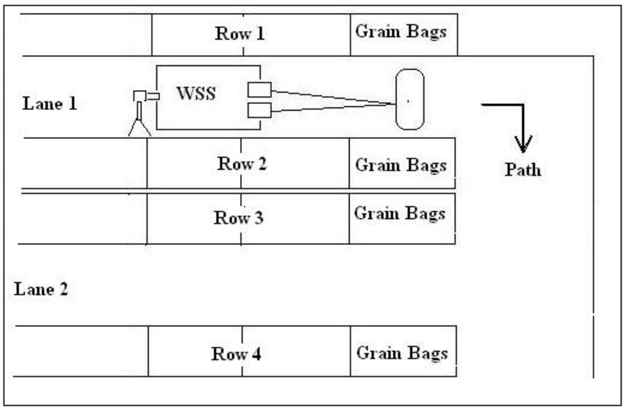


Fig.13 Warehouse spraying system working environment

Complete warehouse spraying system is shown in fig.14.

Fig.14 Complete Warehouse spraying system

IV.CONCLUSION

aWarehouse spraying system is very helpful in warehouse to spray the toxic chemicals on stored grain bags without direct human contact with toxic chemicals.Warehouse spraying system can spray chemicals very safely and efficiently at height up to 16 feet's. There is very large scope seen to add autonomous intelligence in Warehouse spraying system

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