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DEVELOPMENT AND PERFORMANCE EVALUATION OF CATTLE SHED CLEANING SPRAYER

RAGHAVENDRA VEERAMMANAVARA[1*], PRAKASH K.V[2]., SIDDESH MARIHONNAPPANAVARA[3], H. MANJUNATH [4], MAREPPA H.[5] MURALI M.[5], SANTOSH[6] SREEDHARA J. N.[7] AND VINAYAKA NIRANJAN[8]

[1,2,4]Department of Renewable Energy Engineering, College of Agricultural Engineering, Raichur, India
[3]Farm Machinery Testing Centre, CAE, Raichur, Karnataka, India
[5]Department of Farm Machinery and Power Engineering, College of Agricultural Engineering, Raichur, Karnataka, India
[7]Department of Animal Science, CAE, UAS, Raichur, Karnataka, India
[8]K.H. Patil, KVK, Hulkoti, Karnataka, India

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ABSTRACT

Cleaning is the important operation in the cattle shed to maintain hygiene to avoid infectious diseases to the cattle and it has to be carried out daily twice to keep the floor clean. Manual cleaning of the dung floor is very tedious, time consuming and labour intensive. In order to solve these problems a cleaning sprayer is designed and developed. The developed spryer is powered by 3 HP HTP pump. The sprayer was evaluated for discharge, fuel consumption and field efficiency. The maximum discharge was observed 291.6l/h at 20kg/cm^2, when the flat fan nozzle is used. The maximum fuel consumed is 2.91l/h at 20kg/cm^2 when flat fan nozzle is used on the concrete floor. The maximum field efficiency of the machine is 89% on the tile floor when flat fan nozzle is used at 20kg/cm^2 pressure. The cost of operation was 86.76 Rs/h.

KEY WORDS : Cattle shed cleaning sprayer, HTP pump, Discharge, Fuel consumption and cleaning efficiency

INTRODUCTION

India has transformed into the world's largest producer of milk, producing a bulk volume of 187.7 million tonnes in the year 2019, accounting for 17.4% of the total global output (Faye, B 2012). India is the top country by the number of cattle and buffaloes in the world accounting for 33.33% of the world number of cattle and buffaloes possessing 305.4 Million animals (World data Atlas, 2021).

Cleaning is an essential and unavoidable part of life and cleaning animal shed waste is a time consuming activity that may be better spent on something more productive (Manazir, *et al.*, 2016). Reducing the contamination of the farm will improve the quality of milk and milk products and also reduce the mortality and morbidity percentage of animals in farm and increase the reproductive performance and fertility. Dung and urine harbors microorganisms and ticks and fleas (Vlkovai *et al.*, 2008 and Gurucharan *et al.*, 2018).

The bacterial causes were laminitis due to wet surface, mastitis that is highly economical as more than 80 percentage of the farm income from milk production, *Salmonella*, *E. Coli* and viral infections includes Foot and mouth disease (transmitted by food and water), pseudo cowpox and fungal diseases of Aflatoxicosis, Aspergillosis and tick by Boophilussp. and fleas deteriorate the normal health of animal and causes economic loss like tick infestation causes depreciation of the value of hide and skin and reduction of milk yield by mastitis and

([1*]Assistant Prof., [2]Prof., [3]Testing Engineer, [4]Senior Research fellow, [5]Assistant Prof., [6]Ph.D Scholar, [7]Assistant Prof., [8]Subject Matter Specialist)

reduction in reproduction efficiency by uterine infections (Manazir, 2016). The cost for treatment of infection or disease also accounts for economic loss. The main disadvantage of cleaning the cattle shed is labour scarcity, which is caused by employees dislike of picking and collecting animal dung manually (Haslam *et al.*, 1999).

Non availability of suitable cattle shed cleaning machine and high cost of the existing machine (M, Ranjith Kumar, 2015). In cattle fields cleaning is an unavoidable task as the cow dung is accumulated and there a necessity to clean it regularly. Manual cleaning is done with the use of tools like shovel, scraper, spade, wheel barrow and water *etc* (Manreet Kaur and Preeti Abrol, 2014). Traditionally cow dung has been used as a fertilizer, though today dung is collected and used to produce bio gas and many application. These days farmers are having hard time in maintaining the cow shed because of less time and lack of man power (Dinesh *et al.,* 2013). By using the tools the work may become easier but as everything in nowadays is automated there is a need in a cleaning machine particularly used for Animal shed (Prakash Singh *et al.,* 2019). There are many cleaning machines available in the market but they are not capable of cleaning the floor and collecting the waste at same time. Hence, in view of above said problems, there is need to develop suitable cattle shed cleaning machine.

MATERIALS AND METHODS

Location: The experiment was conducted at the Cattle shed of the University of Agricultural Sciences, Raichur, Karnataka.

General Description of Cattle Shed Cleaning Sprayer: Cattle shed cleaning sprayer consists of set of four high pressure Nozzles which are installed on the main boom and the boom is made up of the GI pipe which is closed at both the ends. The main boom is connected to another GI pipe in the perpendicular direction, which is considered as a handle to which hose pipe is connected. The other end of hose pipe is connected to the HTP pump. The HTP pump is used to uplift the water from the water reservoir and to generate the high pressure of 20-40 kg/cm^2 for spraying through the nozzles. The suction pipe or football is connected to the pump to suck the water from the reservoir. All the components are mounted through screw threaded ends and clamps. Cattle shed cleaning sprayer is presented in Fig. 1.

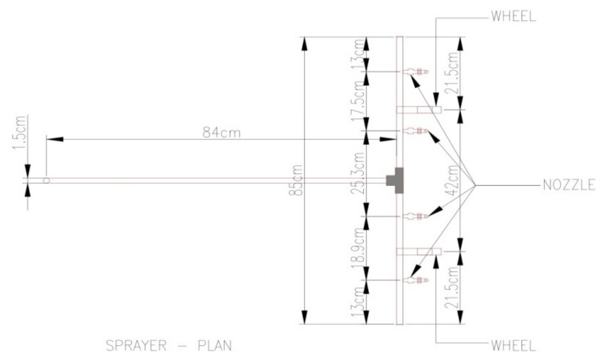

Fig. 1. Cattle shed cleaning sprayer

Power Generation System

High pressure water spraying is required to clean the floor filled with dung and other waste material. Hence the HTP pump is used to create high pressure and low volume. The power is generated in the pump by using the petrol which is a main source of energy as an input to the pump which converts chemical energy into mechanical energy. The input of pump is connected to the water reservoir. As the pump gets drive from the motor which runs at 500-800 revolution per minute (rpm) through which suction pressure is generated in the suction pipe which lifts the water to the main unit of the sprayer and water is sprayed with required pressure.

HTP Pump: HTP Sprayer pump is a heavy-duty sprayer used for agricultural, horticultural, and cleaning purpose as it creates high pressure. The pump is of 3 HP which runs at 500-800 rpm and it produces the discharge of 17-27 l/min and the pressure created range is between 20-40 kg/cm^2.

Engine: It gives the drive to the pump through the pulleys, which are connected through the belts. The fuel used is petrol which coverts chemical energy to mechanical energy, and has specific fuel consumption (SFC) of 348 g/kWh. The output power of the engine is 2.90 KW and runs at 3600 rpm.

Fuel tank: The fuel tank capacity of the engine is 3.6 l.

Pressure gauge: It is designed to measure the pressure of media in a system, which is located on the main frame. Pressure gauge helps in changing the variant pressures accordingly.

Main frame: Frame is the main supporting unit to the pump and engine.

Suction pipe: The Suction pipe is the pipe which is connected to the pump of its one end and the other end is placed in the water in which it creates the suction pressure in the pipe with the help of foot valve.

Hose pipe: The Hose pipe is of 50 meters. The one end of hose pipe is connected to the pump and the other end is connected to the handle of the sprayer. The hose pipe is used to transfer the water from the reservoir to the spraying unit.

Main handle: Handle is made up of Galvanised Iron (GI) pipe. The hose pipe is connected to the main handle with the help of clamps. The other end of handle is connected to the boom of the sprayer with the screw threaded end.

Boom: The boom can be considered as main part of the sprayer. It is made up of GI pipe. The boom gets attached to the main handle with the help of screw thread, exactly at the mid-point of the boom.

Nozzles: The nozzles were attached to the boom of the sprayer for uniform spraying action. The NTM triple action nozzles were used in this sprayer. These nozzles help in changing the spray patterns.

Transport Wheels: The two wheels were fitted to the main frame. These wheels help in carrying the machine from one place to another place.

Performance evaluation of cattle shed cleaning sprayer

Field experiment was carried out for evaluating the developed cattle shed cleaning sprayer at Dairy unit, University of Agricultural Sciences in Raichur (UASR), Karnataka. The independent and dependent parameters were selected as shown in Table 1.

Speed of travel: Measure out a distance of 20 metres on the ground to be sprayed and mark the start and finish positions with pegs. Measure how many seconds it takes to travel 20 metres with the cattle shed cleaning sprayer (Dahab *et al.*, 2010 and Vijayakumar *et al.*, 2015).

$$\text{Speed of travel} = \frac{\text{Distance (m)}}{\text{Time (min)}} \quad .. (1)$$

Discharge rate: The discharge rate of the cattle shed cleaning sprayer was evaluated for different operating pressure. The discharge rate was measured by collecting the discharge fluid (v) for a unit time at one minute (t) in a measuring jar (Lal *et al.* 2022 and Ferguson *et al.*, 2016) and it was calculated as

$$\text{Discharge rate(q)} = \frac{\text{Volume collected (L)}}{\text{Time(m)}} \quad .. (2)$$

Cleaning efficiency: cleaning efficiency is calculated by taking the initial weight of the dung on the floor before cleaning and final weight of the dung left on the floor after cleaning. (Manazir *et al.* 2016 and Imaekhai, 2012)

$$\text{Cleaning Efficiency (\%)} = \frac{\text{Initial weight} - \text{Final Weight}}{\text{Initial Weight}} \times 100 \quad .. (3)$$

Theoretical Field Capacity: It is the rate of floor coverage of cattle shed cleaning sprayer that would be obtained if the cleaning machine were performing its function 100% of the time at the rated forward speed and always covered 100% of its swath width. (Vijaykumar *et al.*, 2015)

$$\text{T.F.C.} = \frac{W \times S}{10} \quad .. (4)$$

Where,
W= Swath width of the machine (m)
S= Speed of travel (km/h)

Effective Field Capacity: It is the actual average rate of coverage by the cattle shed cleaning sprayer machine. It is expressed as ha/hr. (Vijaykumar *et al*. 2015)

$$\text{Effective field capacity(C)} = \frac{W \times S}{10 \times Er} \quad .. (5)$$

Where
C= Effective Field Capacity, ha/hr
W=Rated width of implement, m
S=Speed of travel, Km/hr
Ef=Field Efficiency, %

Field efficiency: It is the ratio of effective field capacity to theoretical field capacity, in %. It includes the effect of time lost during operation and failure to utilize the full width of the cattle shed

Table 1. Experimental design

SI No.	Dependent Variable	Levels	Dependent parameter
1	Operating pressure	3 (10, 15 and 20 kg/cm^2)	Discharge rate (L/h)
2	Type of nozzle	2 (Flat fan and hollow cone)	Cleaning efficiency (%)
3	Type of floor	2 (concrete and tile)	Fuel consumption (Lh^{-1})
			Field efficiency (%)

cleaning sprayer. (Mehtha *et al*. 2005)

Fuel consumption: It is measured by refill method where the fuel tank is completely filled before starting the experiment and should be refilled again by measuring the fuel in the measuring cylinder. From above method we can conclude that fuel taken in the measuring cylinder to refill the fuel tank, that is the fuel consumed in the before reading. (Goyal *et al.* 2010)

Cost of operation: The costs of cleaning with developed cleaning sprayer is classified into two categories; such as fixed cost and variable cost. (Sandeep *et al.*, 2014)

Fixed costs: The fixed cost is the cost which is involved irrespective of whether the machine is used or not. These costs includes depreciation, interest and tax and insurance

Depreciation: Depreciation is the reduction in the value of a machine with the passage of time. Depreciation cost was calculated by straight line method.

$$\text{Depreciation} = \frac{(P - S)}{L \times H} \quad .. (6)$$

Where,

P=Purchase price, Rs

S=Salvage value, Rs

L=Useful life, y

H=Annual usage, h

Interest: Interest on the investment on a farm machine is a legitimate cost, since money spent in buying a machine cannot be used for other productive enterprises. Interest on investment was calculated by Straight Line method.

$$\text{Interest} = \frac{(P + S)}{2} \times \frac{i}{H} \quad .. (7)$$

Where,

P=Purchase price, Rs

S=Salvage value, Rs

i=Interest rate, %

H= Annual usage, h

Tax and Insurance It is taken as 3% of purchase price.

Total fixed cost: TFC = Depreciation + Interest + Tax and Insurance….. (8)

Variable Costs: Variable cost includes Fuel, Lubrication, Labour, Repair and Maintenance costs, Lubrication cost = 10% of fuel

$$\text{Labour cost} = \frac{\text{(Average labour wage)}}{\text{Working hours}} \ \text{Rs/h} \quad .. (9)$$

Repair and Maintenance cost = 1% of principal value.

Total Variable Costs = Lubrication cost +Labour cost + Repair and maintenance cost.

Total cost of operation: Total cost = Total fixed cost + Total variable cost + Overhead charges.

Overhead charges = 20% (Total fixed cost +Total variable cost).

RESULTS AND DISCUSSION

The machine and operating parameters plays very important role in development of cattle shed cleaning sprayer. The cattle shed cleaning sprayer was developed based on the optimized machine parameters. The performance evaluation of the cattle shed cleaning sprayer was carried out at three operating pressure (10, 15 and 20 kg/cm^2), two types of nozzles (Flat fan and hollow cone nozzle) and two different types of floors (Concrete floor and Tile floor). The cost of operation was also calculated based on the optimized machine and operating parameters. Effect of operating pressure, type of nozzle on discharge, fuel consumption and cleaning efficiency on concrete floor is shown in Table 2. Effect of operating pressure, type of nozzle on discharge, fuel consumption and cleaning efficiency on tile floor is shown in Table 3.

Effect of operating pressure on discharge by using

Table 2. Effect of operating pressure, type of nozzle on discharge, fuel consumption and cleaning efficiency on concrete floor

Concrete floor		Pressure (kg/cm^2)		
Type of nozzles	Parameter	10.00	15.00	20.00
Flat fan	Discharge (l/h)	171.0	259.20	291.60
	Fuel consumption (l/h)	2.10	2.49	2.91
	Cleaning efficiency (%)	72.00	75.00	79.00
Hollow cone	Discharge (l/h)	169.20	201.60	219.60
	Fuel consumption (l/h)	1.95	2.16	2.49
	Cleaning efficiency (%)	69.00	71.00	77.00

flat fan nozzle on the concrete floor

The discharge rate was increased from 171 to 291.6 l/h with increase in operating pressure from 10 to 20 kg/cm^2. As the pressure and discharge are directly proportional, the maximum discharge was at 20 kg/cm^2. But change in nozzle type produced minute change in discharge rate.

Effect of operating pressure on fuel consumption by using flat fan nozzle on concrete floor

The fuel consumption was increased from 2.1 to 2.91 l/h with increase in operating pressure from 10 to 20 kg/cm^2, as the pressure increases, engine power requirement was increased, hence fuel consumption increased. The maximum fuel consumption was observed at 20 kg/cm^2. Change in nozzle type had lower effect on fuel consumption.

Effect of operating pressure on cleaning efficiency by using flat fan nozzle on concrete floor

Field efficiency was increased from 72 % to 79 % with increase in operating pressure from 10 to 20 kg/cm^2. As the pressure increased, the swath of cleaning also increased and hence, cleaning efficiency also increased. The maximum field efficiency was observed at 20 kg/cm^2. Change in nozzle type produced minor change in field efficiency.

Effect of operating pressure on discharge by using hollow cone nozzle on the concrete floor

The discharge rate was increased from 169.2 to 219.6 l/h, with increase in operating pressure from 10 to 20 kg/cm^2. As the pressure increased, discharge also increased due to the fact that at higher pressure, rate of flow of water increases. The maximum discharge was observed at 20 kg/cm^2.

Effect of operating pressure on fuel consumption by using hollow cone nozzle on concrete floor

The fuel consumption was increased from 1.95 to 2.49 l/h, with increase in operating pressure from 10 to 20 kg/cm^2. As the pressure increased, engine power requirement also increased hence, fuel consumption increased. The maximum fuel consumption was observed at 20 kg/cm^2 operating pressure.

Effect of operating pressure on field efficiency by using hollow cone nozzle on concrete floor

Field efficiency was increased from 69 % to 77 % with increase in operating pressure from 10 to 20 kg/cm^2. As the pressure increased the swath of cleaning increased hence, cleaning efficiency also increased. The maximum field efficiency was observed at 20 kg/cm^2 operating pressure.

Effect of operating pressure on discharge by using flat fan nozzle on the tile floor

Discharge rate is increased from 171 to 291.6 l/h with increase in operating pressure from 10 to 20 kg/cm^2. As the pressure increased discharge also increased due to the fact that at higher pressure rate of flow of water increases. Hence, the maximum discharge was observed at 20kg/cm^2 operating pressure.

Effect of operating pressure on fuel consumption by using flat fan nozzle on the tile floor

Fuel consumption was increased from 1.89 to 2.49 l/h with increase in operating pressure from 10 to 20 kg/cm^2. As the pressure increased, engine power required is also increased and hence, fuel consumption increased. The maximum fuel consumption was observed at 20kg/cm^2 operating pressure. But change in nozzle type produced a minute change in fuel consumption.

Effect of operating pressure on field efficiency by using flat fan nozzle on the tile floor

Field efficiency was increased from 81% to 88% with increase in operating pressure from 10 to 20 kg/cm^2. As the pressure increased the swath width of cleaning increased and hence cleaning efficiency

Table 3. Effect of operating pressure, type of nozzle on discharge, fuel consumption and cleaning efficiency on tile floor

Tile floor		Pressure (kg/cm^2)		
Type of nozzles	Parameter	10.00	15.00	20.00
Flat fan	Discharge (l/h)	171.00	259.20	291.60
	Fuel consumption (l/h)	1.89	2.22	2.49
	Cleaning efficiency (%)	81.00	86.00	89.00
Hollow cone	Discharge (l/h)	169.20	201.60	219.60
	Fuel consumption (l/h)	1.86	2.08	2.10
	Cleaning efficiency (%)	86.00	88.00	88.00

also increased. The maximum field efficiency was recorded at 20 kg/cm^2. Change in nozzle type had lower effect on field efficiency.

Effect of operating pressure on discharge by using hollow cone nozzle on the tile floor

The discharge rate was increased from 169.2 to 219.6 l/h, with increase in operating pressure from 10 to 20 kg/cm^2. As the pressure increased discharge also increased due to the fact that at higher pressure, rate of flow of water increases. The maximum discharge was observed at 20kg/cm^2 operating pressure.

Effect of operating pressure on fuel consumption by using hollow cone nozzle on the tile floor

Fuel consumption was increased from 1.86 to 2.1 l/h, with increase in operating pressure from 10 to 20 kg/cm^2. As the pressure increased, engine power requirement was also increased and therefore, fuel consumption increased. The maximum fuel consumption was observed at 20 kg/cm^2 operating pressure.

Effect of operating pressure on field efficiency by using hollow cone nozzle on the tile floor

Field efficiency was increased from 86% to 89% with increase in operating pressure from 10 to 20 kg/cm^2. As the pressure increased the swath width of cleaning increased and hence cleaning efficiency also increased. The maximum field efficiency was at 20 kg/cm^2. The overall cleaning efficiency was good on the tile floor when flat fan nozzle was used compared to the concrete floor.

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