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Modelling and Fabrication of Automatic Wall Plastering Machine

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Abstract

The building construction is a time-consuming sector because a lot of work is labor-based, there is too much shortage of skilled labor, and an increase in labor cost and technological advancement are forcing rapid change in the building construction. The aim of this research is to modeling and fabrication an Automatic Wall Plastering Machine (AWPM). This paper carries a specific objective which is to examine for plastering a wall with a good finishing surface of uniform thickness with the help of a trowel mechanism. Different types of mechanical machine elements such as- pulley systems are used for lifting mechanisms, a chain-sprocket mechanism for power transmission, and conveyor mechanism for feeding mortar towards the wall. The main power source of this machine is AC and the wiper motor was used for dc power with the help of SMPS. The modeled and fabricated AWPM experimental result shows that it saves manpower, raw material, cycle time, and cost as compared to manual plastering. Additionally, this AWPM can be used as a finishing technology for both interior and exterior walls made from bricks like masonry bricks, thermal bricks, and other bricks. This plastering machine experimentally shows that labor cost can be saved up to 80%, productivity can be increased by 4 times, and quality finishing in less time. Eventually, the AWPM could play a significant role in overall construction projects to reduce project net accomplishing time and increases the net profits.

Keywords: *AWPM, Modeling, Fabrication, Efficiency analysis.*

1. Introduction

Now a day's construction revolution has made the contractors perform their construction in such a way that to obtain the highest output with the minimum construction cost as possible. To obtain the highest output, parameters like accuracy, precision, quality, and cycle time have to be optimized. This optimization is possible either by having skilled manpower or by automating the system. In the first case, continuously doing the same

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kind of work for a long time will cause fatigue resulting in lower efficiency. So, it would be better to automate the system if the work nature is of the same as in case of a large construction. With automation, it is also possible to have higher efficiency, accuracy, and quality.

The existing technique for plastering the walls is manual i.e. the labors are used to plaster the walls with their hand by using some instruments like flat board or other flat surface objects which are made by metal, wood, or plastic. In this process, the mortar which is the mixture of cement and sand has been spread on the wall which is to be plaster with the help of these objects. After dispersal the mortar the labors need to concentrate to make a skinny film of mortar on the wall, which has been smooth and has a good surface finish. Due to which labor needs to work repeatedly until they get the required surface finish [1].

This process takes a long time and consumes additional human power. So due to this slow process, the labor cost has also been increasing as the laborers are working daily basis. Also, if the labor is not a skilled person then there has been a low-quality work as well as the wastage of material. Ultimately the manual plastering technique has some downsides like high cost, more time, material wastage, and low-quality work due to unskilled labors.

This paper is a new innovative concept of plastering to an alternative for the manual method. The research relates to the modelling and fabrication of an automatic wall plastering machine, which will not only provide an alternative to the manual method but also provide high efficiency and portability.

1.1 Problem Statement

In the manual plastering technique, the crucial factor is skilled labor because of which plastering has been done on the walls, but presently there is a lack of skilled laborers due to which it is very inconvenient to complete this process. Labor requires more time to finish the process which increases their wages and hence the total plastering or labor cost increases.

1.2 Objectives

General objective of this work is to model and fabricate the automatic wall plastering machine. But its specific objective is to test the performance as well.

2. Literature Review

According to Yehiel Rosenfeld et al, technological developments form a basis for more reliable feasibility studies of robotic applications in construction. By comparing the cost, the productivity and the speed of robotic versus manual execution of interior finishing tasks, it is possible to determine whether, and under what conditions, the employment of robots on construction sites is feasible or desirable. All the applications presented here requires a considerable amount of human intervention, which could be reduced. To achieve economy and efficiency, people should be assigned with tasks that the robot has difficulties to cope with such as marking, initial calibration, complex maneuvering, etc., while the robot should be mainly utilized with routine well-structured programmable tasks. As the robotic and mainly intelligent artificial sensing will develop, more and more tasks can be assigned to robots, releasing the human operator for only supervisory duties [2].

According to Johan Forsberg et al., it is possible to use an autonomous mobile robot for plastering entire rooms. The accuracy is more than sufficient assuming that the calibration and mechanical problems are solved using a mechanical construction. Many interesting extensions are possible and the autonomy of the robot can be increased by adding further sensing capabilities. On line measurements of the spray pattern using a sheet-of-light range camera would make the system considerably more robust and flexible. Using the full power of the

navigation system could allow the robot to autonomously work on an entire level of an apartment building rather than one room at a time [3].

Debasish Tripathy et al. proposed the construction industry is labor-intensive and conducted in dangerous situations. Therefore, the importance of construction robotics has been realized and is grown rapidly. Applications and activities of robotics and automation in this construction industry started in the early 90's aiming to optimize equipment operations, improve safety, enhance the perception of workspace and ensure a quality environment for building occupants. After this, the advances in the robotics and automation in the construction industry has grown rapidly [4].

Mahesha P.K and Sree Rajendra developed the model of the automatic wall plastering machine and tested it successfully. The project includes applying mortar into the wall and pressuring mortar to create a surface level. With the development of this, two major problems which construction industries are currently facing were reduced namely, labor shortage and quality in the construction process along with the less wastage of the mortar. During the trials, they found that the machine was more productive compared to labor concerning the plastering work, and also the quality achieved was almost equivalent to the labor [5].

Arivazhagan B. shows that the machine-driven rendering machine is exclusive and is ideally appropriate for the construction and building sector. This machine-driven rendering machine includes cement mortar that is brought to a swish which includes a flat end of variable and adjustable thickness to suit every application. It makes rendering easier, faster, and easy compared with the manual applications [6].

According to S.M.S. Elattar, Robots are progressively concerned in construction operations to take care of extremely correct actions and to scale back venturous risks by achieving improved management and safety. Machine-driven constructions are often developed to include design, engineering, and maintenance of the existing and planned structures. Several analysis works result in an extremely autonomous robotic system for better performance. The "Sense-and-Act" could become a reality with the development of advanced robotic systems for construction applications. Efforts should be made to persuade professionals in building management to integrate AI and building automation which enhances the standard of services of contemporary intelligent buildings. However, many of the problems in construction engineering cannot be addressed through improvement and computation [7].

The paper prepared by Pentti Vähä provides a survey for potential sensor technologies used for the automation of building construction and highlighting their potential with the contributions from robotics. The paper surveys the viewpoints of building construction phases [8].

According to Arunkumar Biradar et al., building construction is a time-consuming sector because a lot of work is labor-based and there is too much shortage of skilled labor which tends to increase the labor cost. They had introduced a new machine to automate the plastering work which is in very much demand for the construction field. The machine consists of AC/DC motor, Gearbox, wire rope, pulley, tray mechanism, guideways, etc [9].

According to Mohan Ramanathan, Automation has been an indicator of the technological and developmental progress of the construction industry. The objectives of any automation have to improve the quality of work, productivity, and higher safety for both workers and the public through developing machines for dangerous jobs, uniform quality of work with higher accuracy. Improving work environment as conventional manual work is reduced to the minimum so workers are relieved from dangerous work, but the disadvantage of automation is high cost, less knowledge to the worker, high maintenance cost, etc [10].

3. Methodology

3.1 Construction of Prototype of Wall Plastering Machine

The prototype consists of three main parts that are Base, Top& sliding box. The sliding box consists of two sliders that are mounted in the box, which slides vertically on a hollow square bar. It consists of a DC motor which drives the shaft through the chain sprocket mechanism. The shaft consists of two grooved nylon bar that supports the rope for lifting mechanism through pulleys, mounted on the top. And also help for driving the conveyor belt. A trowel is mounted at the front of the machine that plasters the walls.



Figure 1. Fabricated Prototype of machine

3.2 Working of the Prototype

Initially, the machine should be brought close to the wall which is to be plastered and positioned according to the need. Then, the mortar which is roughly in the proportion of 1:4 is poured into the hopper-tray and is lifted employing a rope that is coupled to the motor through the pulley. Then the conveyor belt which is coupled with the same motor through the chain-sprocket transports the mortar towards the wall. The mortar flows downwards due to gravitational force and the trowel applies pressure to the cement mixture so that the cement adheres to the wall. The clearance between the wall and machine can be adjusted as per the thickness of the plaster needed. When the sliding box containing mortar moves upward, the mortar gets applied to the wall, and during the downward movement, the finished plaster surface is obtained.

3.3 Mechanisms involved in Automatic Wall Plastering Machine Prototype

3.3.1 Chain and sprocket mechanism

A sprocket is a toothed wheel that is used to transmit motion and torque from one shaft to another. Chains that are used to transmit motion and force from one sprocket to another are called power transmission chains. Unlike gears that have to mesh to transmit motion and torque from one gear to another, sprockets may be positioned far apart. Sprockets are connected by a chain. A sprocket with a hole that matches the diameter of the shaft is chosen and slid onto the shaft. The sprocket is then rotated until the keyways in the sprocket and shaft line up. A rectangular piece of steel bar called a key is slid into the keyways to prevent the sprocket from spinning on the shaft.

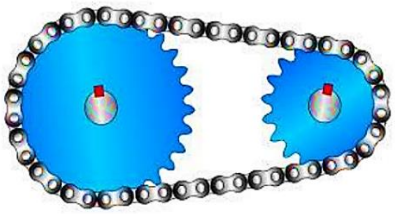


Figure 2. Chain and Sprocket

Chain and sprocket mechanisms perform the same task as a belt and pulley system, i.e. they transfer motion and force from one shaft to another. A belt can slip on a pulley but the teeth on the sprocket prevent the chain from slipping.

3.3.2 Conveyor mechanism

A conveyor mechanism is a common piece of mechanical handling equipment that moves materials from one location to another. Conveyors are especially useful in an application involving the transportation of heavy or bulk materials. Conveyors system allows efficient transportation for a wide variety of materials, which make them very popular in the material handling and packaging industries many kinds of conveying system are available and are used according to the various needs of different industries.

During experimental tests, the conveyor belt performs feeding of mortar to the trowel. It is also driven by a motor of 80 rpm.



Figure 3. Conveyor Belt

3.3.3 Lifting mechanism

Lifting mechanism in the mechanical process in which the weight is raised or lowered to a certain height application of force. Lifting is especially useful in an application involving the transportation of heavy or bulk materials to a certain height. In this paper, the pulley is used to lift the sliding box driven by a motor for plastering on the wall.

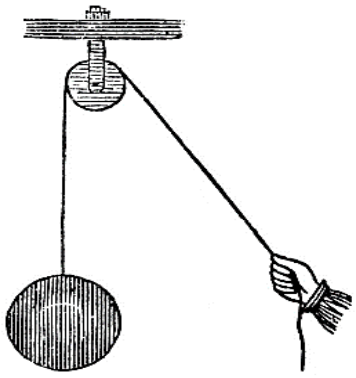


Figure 4. Pulley

4. Modelling and Fabrication of AWPM

4.1 CAD Model

This AWPM has been designed with the help of Solid Works Software.

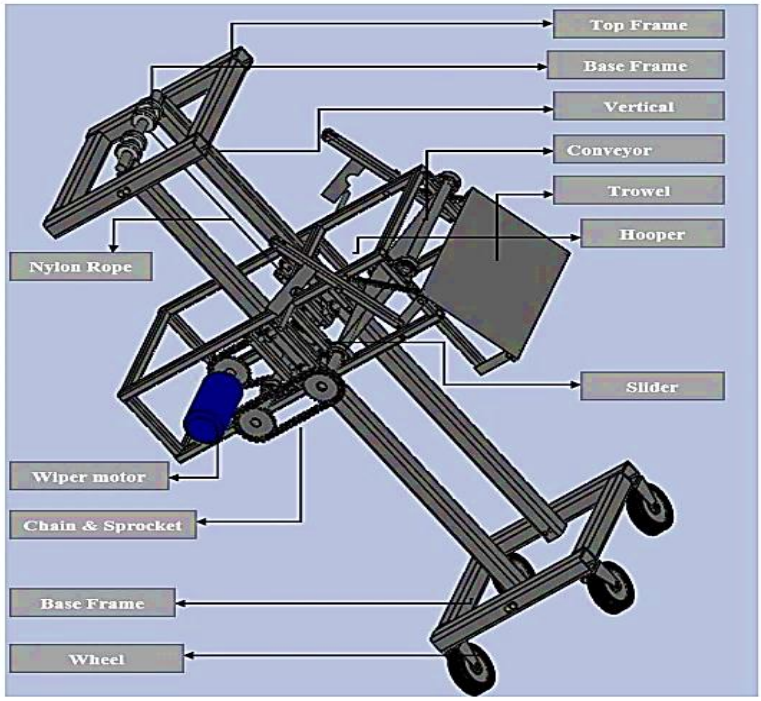


Figure 5. CAD Model of Prototype

Modelling Numerical Calculation

(i) Loads on Hopper

Plastering Width = 0.305m
Plastering height = 1.15m
Plastering thickness = 1m = 0.01m
Mortar mixing proportions:
1:4 (normally)
Density of wet mortar, $\rho = 2400\ kg/m^3$
Plastering Volume, V = 0.305 x 1.15 x 0.01
$V = 3.5075 \times 10^{-3}\ m^3$
Mass, m= ρxV

$$M = 2400 \times 3.507 \times 10^{-3} = 8.42\ kg$$

Mass of hopper excluding mortar, M = 13 kg
Total weight on hopper including cement mixture, (M+m) = 21.42Kg
Maximum force acting on rope is

$$F = (M+m) \times g$$
$$F = 21.42 \times 9.81 = 210\ N$$

(ii) Rope Design

Approximate weight on hopper = 21.42kg
Axial load acting on rope = 21.42Kg
Select rope material as polypropylene wire.
Take F.O.S. for polypropylene wire (for lifting) = 10
Nominal breaking strength of the rope

σ_{break} = 850 N/mm^2
Allowable Stress,
$\sigma_{allowable} = \sigma_{break}$ / F.O.S. = 850/10 = 85
As,
F = 210 N
$\sigma_{allowable} = \frac{F}{A}$, where A= $\left(\frac{\prod d^2}{4}\right)$
$\sigma_{allowable} \geq \frac{F}{\left(\frac{\prod d^2}{4}\right)}$
$\frac{\prod d^2}{4} \geq \frac{210}{85}$
$d^2 \geq \frac{210 \times 4}{85 \times \prod}$
$d^2 \geq 3.1456$
$d \geq 1.773$ mm
Hence, for safe design, take d = 2mm.

(iii) Gear Design

Motor used = 12V, 50W DC
For motor,
Motor speed (N_1) = 75 rpm
Teeth on sprocket 1 (T_1) = 20
For shaft,
Teeth on sprocket 2 (T_2) = 36
Speed of shaft (N_2) = ?
Also,
$\frac{N_2}{N_1} = \frac{T_1}{T_2}$
$N_2 = \frac{20 \times 75}{36}$
N_2 = 42 rpm

(iv) Efficiency of AWPM

The efficiency of AWPM ($\eta_{machine}$) = $\frac{\text{Area Plastered by machine}}{\text{Area plastered by machine + Area plastered by manually}} \times 100\%$

4.3 Fabrication of the AWPM

4.3.1 Base and Top

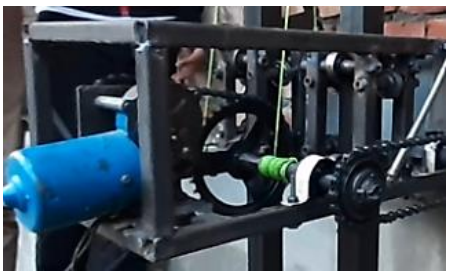


Figure 6. Base and top view

The base and top of the machine are made up of a hollow square pipe (cross-section area of 4x4 cm and thickness of 2cm) of iron. A long pipe is cut in pieces with power hacksaw and made a rectangular base of 40x30cm through the welding process.

4.3.2 Vertical Column



Figure 7. Vertical column

The long square pipe is cut in two pieces of 120 cm by hacksawing. Both the stands were attached in the top and base frame through nut-bolt.

4.3.3 Slider



Figure 8. Slider

The slider consists of eight shafts and eight bearings. The shaft diameter is decreased to 13mm in the machining section through lathe operation and the bearing is fitted in that shaft. The shafts consisting of the bearing are welded on a square pipe of a cross-section of 2 cm.

4.3.4 Pulley



Figure 9. Pulley

Pulley was made up of cast iron with lathe operation. It has a diameter of 5cm and a groove depth of 2cm.

4.3.5 Conveyor

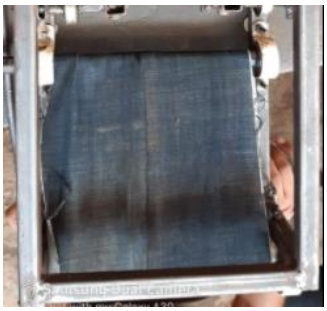


Figure 10. Conveyor

The conveyor is connected with the help of two shafts mounted on the sliding box. The conveyor belt is made up of jeans of dimension 24x18 cm.

4.3.6 Trowel



Figure 11. Trowel

The trowel is made up of an iron metal sheet of dimension 32 x 15 x 0.2 cm. It is attached to the slider box with the pin joint and spring.

4.3.7 Sliding box



Figure 12. Sliding box

All the above-fabricated slider, trowel, and conveyor are fitted in this box.

4.4 Assembly and testing

After the fabrication of components, these components were assembled by different mechanisms such as the welding process, nut-bolts assembly, chain-sprocket, and pulley mechanism. After the assembly process was completed, all the electric connections were checked to configure the motor coupling via chain and sprocket. Double Pole Double Throw (DPDT) switches were checked to test the polarity. The individual mechanism testing was done to configure each mechanism operation. At first, testing was done without putting any load in to check the proper working of the system. Hence, repeating the above process accordingly for the load, preliminary testing was done.

4. Results

After performing experimental tests, the following results were obtained which are tabulated in Table 1 during experimental tests

Table 1. *Experimental results*

S.N.	Time(min)	Plastering Area(m^2)	
		By machine	By manually
1.	3	1.05	0.25
2.	5	1.75	0.42
3.	8	2.8	0.67
4.	10	3.5	0.85

Hence, from the above experimental observations, it is seen that the plastering done by machine is nearly 4 times faster than manual plastering. Time taken for lifting the box is 1 min 10 sec and for lifting down was 1 min 5 sec, and the efficiency of the AWPM was found to be 80%.

6. Conclusion and Recommendations

6.1 Conclusions

The model of the automatic wall plastering machine had been developed and tested successfully. From the results, it is noted that the machine is nearly 4 times more productive than the labor, and also the quality achieved is almost equivalent to the labor. Hence, it is concluded that the machine could overcome the major problems facing by the construction industries i.e., shortage of skilled labor and quality of the plaster along with the less wastage of the mortar.

6.2 Recommendations

The prototype is capable of plastering the vertical wall with a good surface finish. Certain recommendations are suggested

- A hydraulic lift can be employed for rigidly fixing the machine with the ceiling.
- Lasers can be used for adjusting the gap between the trowel and vertical wall.
- Different types of tools and techniques can be employed for plastering in curved areas and ceiling.
- Sensors can be used for mortar control.

If all these steps in fabricating and recommendations are to be followed, the commercialization of wall plastering is no hard job. In the future, this system can be used as one of the best alternatives to reduce the problems regarding plastering.

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