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DESIGN AND ANALYSIS OF 2-AXIS AUTOMATIC WALL PLASTERING MACHINE

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Abstract- *At every construction site there is a requirement of plastering. For plastering process, skilled workers are needed and a lot of time. To reduce man power and time, automated plaster spraying machine is used instead. Automated plaster spraying machine has some negative factors of its own. To rectify this problems, in this dissertation design of 2-axis plaster spraying machine is done. An attempt has been made to solve problems faced in initial design of this machine. New machine will be working on 2 axis movement instead of old one capable of only 1 axis movement. The new design will be better and free of problems faced by old design. A comparison of both will be shown by conducting analysis on both the designs. Also more variations and ideas will be looked upon on this concept.*

Keywords- *Automation, Plaster Spraying Machine, Automatic Rendering Machine, Plastering, Design and Analysis*

I. INTRODUCTION

India is one of the fastest growing developing countries in the world. One of the many traits of any developing countries is the continuous construction of buildings in smart cities. Hence, a need of automation is needed in civil engineering industry. Most important part of construction of building is the plastering process. The plastering process in India is still being done manually. This has to change by introducing Automatic Wall Plastering machine in the industry. There is already a Plastering Machine available in market. But, it is still not developed enough to be used in the Industry. So, in this paper an attempt has been made to rectify all the mistakes in the available machine and introducing a machine that is better and can be utilized in market for plastering the walls.

1.1. Manual Plastering Process

The first step of plastering is cleaning. After the masonry wall is prepared it is first cleaned properly with brushes and trowels. This step of cleaning the wall is taken so that there are no irregularities on the surface of the wall. It is an important step since it provides the wall to be smooth. After that scaffolds are prepared. Scaffolds are a structure that is used by the workers to plaster the walls which are at more height. Scaffold is provided to the labor for him to stand and perform the plastering process effectively and safely. The materials required for the plastering process is transported to the performing site as soon as possible. This process is to be done before the plastering process starts.

Next step is preparing the cement mortar. The ratio specified for the mortar mix is 1:4. That is 1 unit volume of cement and 4 unit volume of sand is mixed properly. That is the best mortar mix. The normal cement bag is 50kg in mass. Recron fibre is added to the mixer because it helps in avoiding cracks in plaster. 125gm of fibre is used for 1 bag of cement. As per IS standards, 0.025m^3 water is added to 1 bag of cement. But it may be changed according to workability requirements. The mortar mix has an initial setting time of 45 minutes. Chicken mesh is used at the joints of the wall to avoid the cracks in plaster in the future. After that level pads are made. Level pads are made to maintain thickness of the plaster on the wall. D1 is the distance of wall form reference line. And D2 is distance between reference line and level pad's surface. And therefore thickness of the plaster is D1-D2. Plumb Bob is used to check whether the plaster is in straight line in horizontal direction. And then using a masonry trowel plastering is done by the worker. Sometimes a hair is used to provide better adhesion of the whole layer.

The basic steps included in manual plastering process:
Step 1: Application of plaster to the walls
Step 2: Formation of plain surface by leveling the plaster which had been applied to the walls
Step 3: Finishing the surface in order to meet the given tolerances.

1.2. Brief of Automatic Wall Plastering Machine

A basic model of automatic plastering machine consists of a plaster spraying mechanism, mounted on two guide rods so that it can move vertically upwards and downwards on the path of guide ways. The spraying assembly includes a container secured to a frame assembly means capable of vertical movement to hold and to apply cement-sand mortar plaster on to the planar structure. The plastering machine is mounted onto a fixed set of wheels and a set of hydraulically mounted roller wheels and the base frame can be raised above ground level.

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The workings of the machine and other features of the machine will be described now. The machine is moved towards the wall or structure to be plastered and positioned in a manner such that the container is adjusted and parallel to the plane of wall or the structure. The rail is positioned parallel to the plane of the wall or structure and is preferably fixed in the selected position by driving of nails or screws provided along the length of the rail. The desired thickness of the plaster to be applied is determined. The desired distance of the container from the wall is correspondingly determined and fixed in the position. Cement plaster is introduced into the container manually. There are vibrators rods present behind the trowel which are energized and the container is moved vertically upwards in a controlled manner. The cement mortar is compacted onto the wall, ensuring that the mortar flows downwards by gravitational force. As the container is raised upwards, an even layer of plaster is compacted onto the wall structure. The trowel ensures that the mortar is smoothened out to produce an even and smooth plastered wall.

1.3. The New Concept

Our main aim of performing this dissertation is to introduce a new concept to the already existing automatic plastering machine. This new concept is 2-axis movement of the spraying assembly of the machine. The research that has been done up to now on this topic has always been 1-axis movement possible. We have a new concept that can change the idea of plastering in a good way and bring a revolution in this industry. There has never been a machine that can plaster the wall in horizontal as well as vertical direction. But by the use of 2-axis spraying mechanism that we are developing, spraying of plaster in both directions will be possible. We will be using 2 screw barrels on which the mechanism will be able to move in horizontal and vertical direction. There will be 3 motors used. 2 motors will be performing the task of giving the motion to screw barrels and the third motor will have the task of spraying the plaster on to the wall. Another important point that we will take into consideration is the weight of the whole mechanism. It will be light in weight. This is how our new concept will play a key role in giving a new branch to the concept of automatic plastering machine. This concept will work without affecting the already possible advantages of the machine.

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II. LITERATURE REVIEW

Sr. No.	Paper Title	Name of Author	Findings
1	Automatic Wall Plastering Machine[1]	Arunkumar Biradar, Vaibhav Shejwal, Akshay Barate, Sameer Barate	- The development trade in most countries amounts to 10-20% of the total nationwide product, creating it the biggest economic using sector. - It's still labour that are jointly the majority of work that is concerned wirh the cycle. - The expansion of any country depends on the development trade therefore it is of prime economic significance to several industrial sectors.
2	Design and Fabrication of Automatic Plastering Machine Prototype[2]	Mahesha P.K., Sree Rajendra	- Experimented the trowel operation procedure which is customary plastering method. The exact plastering procedure is dependent on how the trowel is being used and apply coat of mortar on wall. - The foremost edge will be approximately 10mm - 15mm away apart from the wall.
3	Design and Fabrication of Automatic Wall Plastering Machine[3]	Harshal C. Kuttarmare, Dhanashri Dagwar, Sagar V. Bhoyar, Sujata Gothe	- Mix Plastering material is put on slope of middle section. Vertical guide rail moves up the head. - Middle section holds the plaster temporarily. - Aluminum sheet to evenly smudge the wall. - Analysis of manual vs. machine is done. - Plastering by Machine – 0.6560m^2 in 10kg material in 34 seconds - Plastering Manually – 0.45m^2 in 13Kg Material in 34 seconds
4	Design of Automatic Wall Plastering Machine[4]	Ankush N. Askar, Laukik P. Raut	- The right troweling technique is essential with exclusively the trowel getting used to use and end the skim coat. - The brick structure should be developed in proper manner, with the manufacturer's condition and suggested installation procedure. - Components need to be fabricated for the machine are ceiling bean, resist board, supporting bar, hydraulic base, hydraulic handle, hydraulic pedal, rollers, gear, pulleys etc.
5	Automatic Plastering Machine[5]	Arivazhagan. B.	- This paper explained the mechanical design of the machine which consists of the motor pump to push cement mix, Funnel to load the cement mix, flexible pipe to bear the cement blend to hopper, vertical bar to guide plastering unit to move up and down. - Automatic plastering machine is exclusive and maybe one type of automated plastering machinery suitable for construction industry.
6	"Design and Analysis of Lead Screw For Fixture" [6]	Aman B. Kotwal, Mangesh N. Gavhane, Sachin S. kushare	Finite Element Analysis of Lead screw is done in Ansys Software. After calculating the lead screw dimensions by analytical method, it verifies by the finite element model.

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III. DESIGN

3.1. Design Calculation

Plastering Width - 0.50 m

Plastering Height - 1 m

Layer Thickness - 10 mm

Density of Standard Mortar (Sand + Cement) = 2162 Kg/m^3

Volume of mortar - 0.5 X 1.0 X 0.01

- 0.005 m^3

Mass of Mortar = Volume of Mortar X Density

= 0.005 X 2162

= 11 Kg

Load of Mortar = 11 X 9.81

= 107.91 N ----------A

Mass of Plastering Assembly = 6.38 X 9.81

= 62.58 N ----------B

Mass of Motor = 147.15 N ----------C

Total Load = A + B + C

= 107.91 + 62.58 + 147.15

= 317.64 N

Total Load = 317.64 / 9.81

= 32 Kg

3.1.1. AC Motor

Power of Motor = 0.5 hp

= 470watt

Torque = 48 Kg. cm

= 4.7X10^3 Nm

Frequency = 50Hz

Power = 2πNT/60

N = 750 rpm

Weight = 32 pound

= 14.5 = 15kg

- Velocity of vertical Movement

V = 0.31 m/s

- Velocity of Horizontal Movement

V = 0.31 m/s

3.1.2. Lead Screw

Material for Screw = SS316

S_{yt} (Yield Strength) =290 N/mm^2

S_{ut} (Ultimate Tensile Strength) = 580 N/mm^2

Distance from point of load = 1000 mm

According to ASME,

Shear Stress, $\tau = 0.18 \times S_{yt}$

$= 0.18 \times 290$

$= 52.2$ N/mm^2

Also , $\tau = 0.3 \times S_{ut}$

$= 0.3 \times 580$

$= 174$ N/mm^2

Total Load = 32k = 317.64 N

Distance from Load application = 147mm

Bending Moment at that point

M = 317.64 x 147

= 46693.08 Nmm

So, Twisting Moment,

$(T_e) = \sqrt{((km\ X\ M)^2 + (kc\ X\ T)^2)}$

= 73889.53 Nmm

Now, Torsional Equation,

$T_e/J = \tau \backslash r$

$T_e = 10.24d^3$

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d = 19.32 = 20mm

Weight of Lead Screw

h = 1000mm
D = 20mm
P = 8 g/cm^3 = 8000 kg/m^3
V = $\pi r^2 h$ = 0.000314m^3
Mass = 0.000314 X 8000
= 2.512 kg

3.1.3. Vertical Guide Rod

L = 1000mm
Material = AISI 1018 Mild / Low Carbon Steel
Density (ρ) = 7.85 g/cm^3 = 7850 kg/m^3
Diameter = 20mm
V = $\pi r^2 h$
= 0.000314 m^3
Mass = V X P
= 2.46 kg

3.1.4. Top Plate

Material = AISI 1018 Mild / Low Carbon Steel
Density (ρ) = 7.85 g/cm^3 = 7850 kg/m^3
V = 127 X 203.2 X 3
= 0.0000773 m^3
Mass = 0.0000773 X 7850
= 0.607 kg

3.1.5. Top Side Plate

Material = AISI 1018 Mild / Low Carbon Steel
Density (ρ) = 7.85 g/cm^3 = 7850 kg/m^3
V = 150 X 205 X 5
= 1.53 X 10^{-4} = 0.000153
Mass = V x P
= 1.2069 kg

3.1.6. Bottom Plate

Material = AISI 1018 Mild / Low Carbon Steel
Density (ρ) = 7.85 g/cm^3 = 7850 kg/m^3
V = 203.2 X 203.2 X 5
= 2.64 X 10^{-4}
= 0.000264
Mass = V X P
= 2.07 kg

3.1.7. Fins of Plaster Spraying Unit

V = W X L X H
= 8 X 50 X 2
= 0.0000008 m^3
Total Fins = 13
Volume delivered by,
13 fins = 0.0000104 m^3
Mass = ρ V
= 0.0000104 X 2162 kg / m^3
= 0.022 kg
Force = 0.022 X 9.81
= 0.22 N

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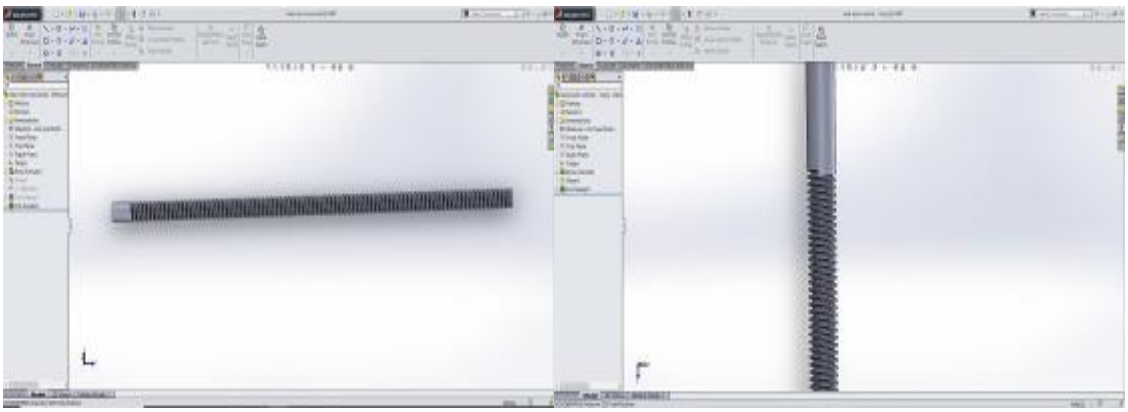
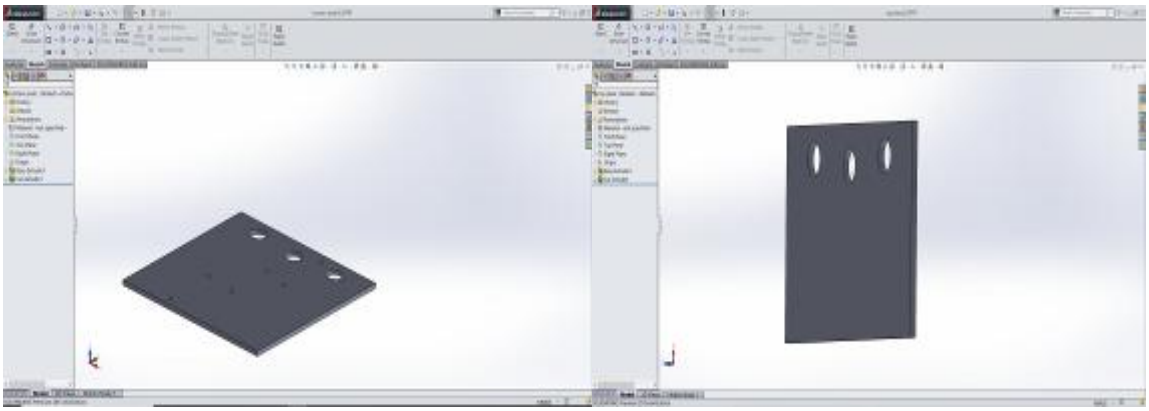
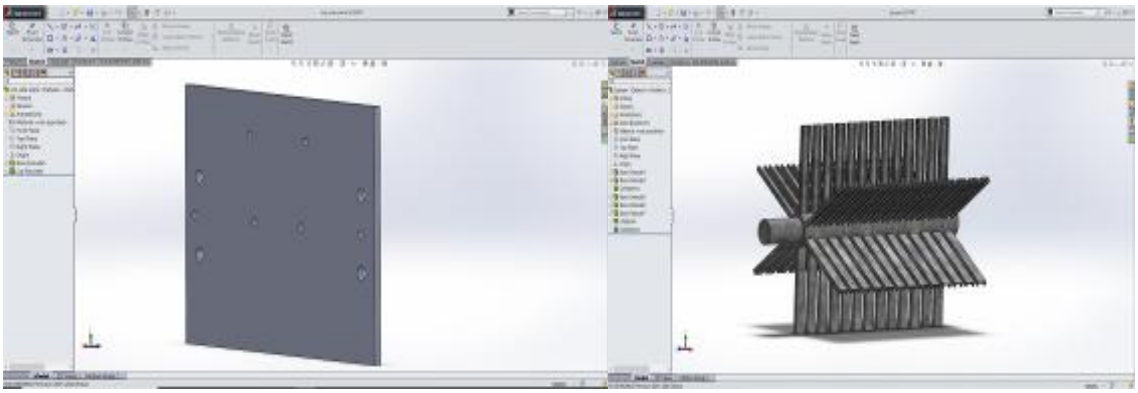
3.2. Modelling in SolidWorks Software



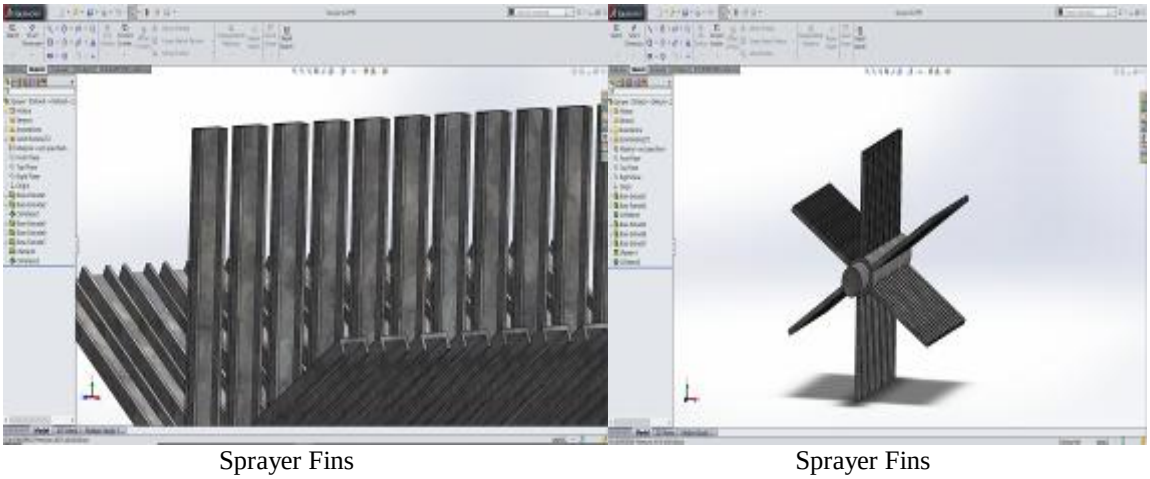
Horizontal Lead Screw Vertical Lead Screw



Bottom Plate Top Plate



Top Side Plate Sprayer Fins



Sprayer Fins Sprayer Fins

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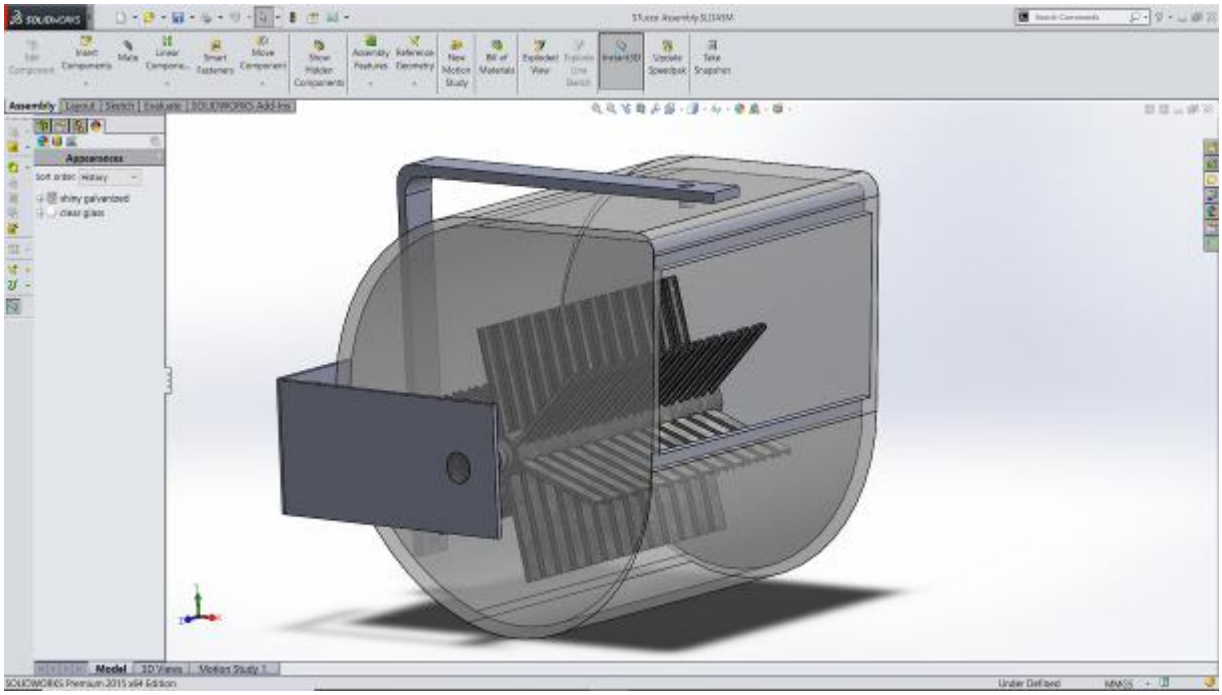
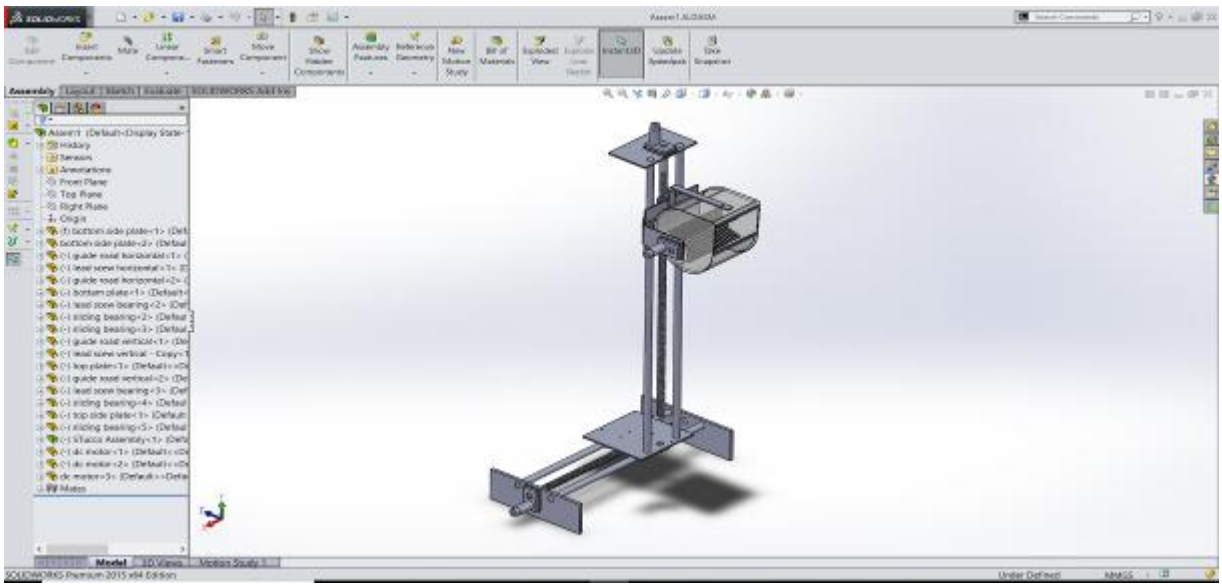
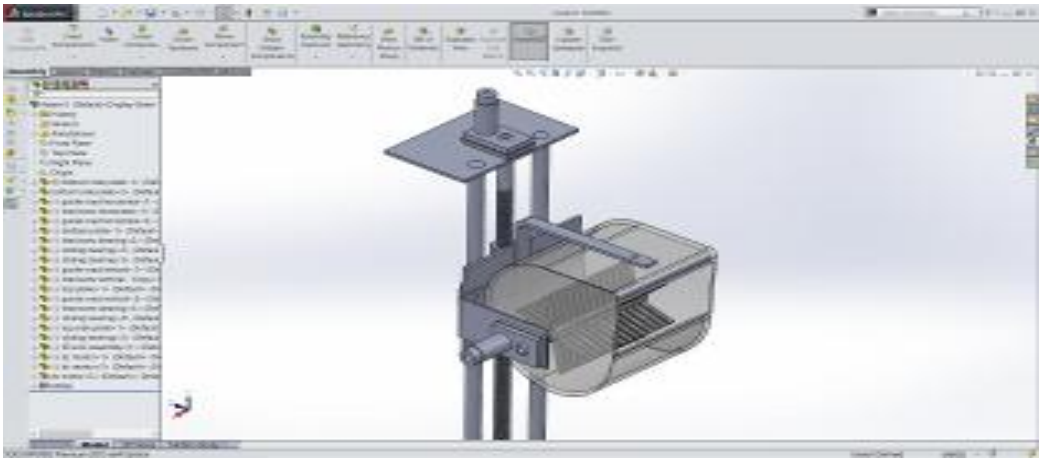
3.2.1. Stucco Spraying Assembly



3.2.2. Final Assembly





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IV. ANALYSIS

4.1. Material Properties

MATERIAL PROPERTIES OF STAINLESS STEEL	VALUE	UNIT
DENSITY	7750	Kg m^{-3}
YOUNG'S MODULUS	1.93E+11	Pa
POISSON'S RATIO	0.31	
BULK MODULUS	1.693E+11	Pa
SHEAR MODULUS	7.3664E+10	Pa
TENSILE YIELD STRENGTH	2.07E+08	Pa
COMPRESSIVE YIELD STRENGTH	2.07E+08	Pa
TENSILE ULTIMATE STRENGTH	5.86E+08	Pa
COMPRESSIVE ULTIMATE STRENGTH	0	Pa

MATERIAL PROPERTIES OF STRUCTURAL STEEL	VALUE	UNIT
DENSITY	7850	Kg m^-3
YOUNG'S MODULUS	2E+11	Pa
POISSON'S RATIO	0.3	
BULK MODULUS	1.6667E+11	Pa
SHEAR MODULUS	7.6923E+10	Pa
TENSILE YIELD STRENGTH	2.5E+08	Pa
COMPRESSIVE YIELD STRENGTH	2.5E+08	Pa
TENSILE ULTIMATE STRENGTH	4.6E+08	Pa
COMPRESSIVE ULTIMATE STRENGTH	0	Pa

MATERIAL PROPERTIES OF GALVANIZED STEEL	VALUE	UNIT
DENSITY	8050	Kg m^{-3}
YOUNG'S MODULUS	2.0E+11	Pa
POISSON'S RATIO	0.26	
BULK MODULUS	1.3889E+11	Pa
SHEAR MODULUS	7.9365E+10	Pa
TENSILE YIELD STRENGTH	3.3E+08	Pa
COMPRESSIVE YIELD STRENGTH	4.06E+08	Pa
TENSILE ULTIMATE STRENGTH	5.71E+08	Pa
COMPRESSIVE ULTIMATE STRENGTH	6.0E+8	Pa

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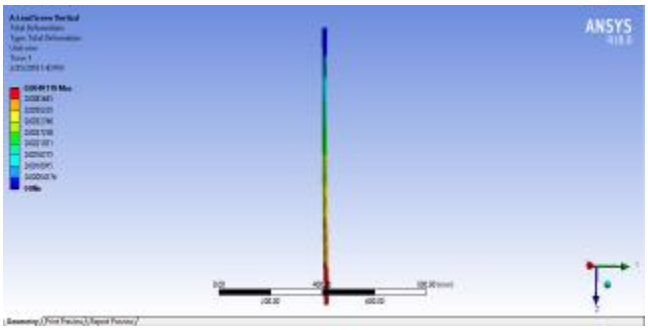
4.2. Vertical Lead Screw

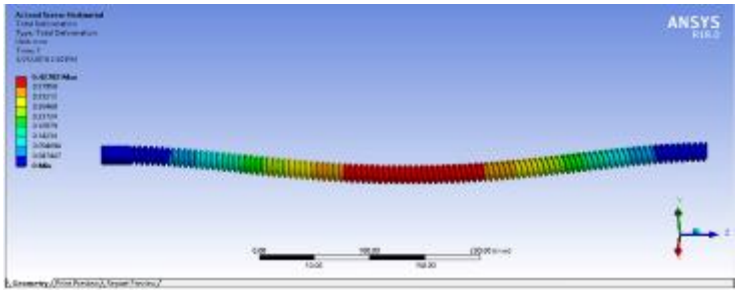
4.2.1. Results



Total Deformation is 0.0049mm. Hence Design is safe.

4.3. Horizontal Lead Screw

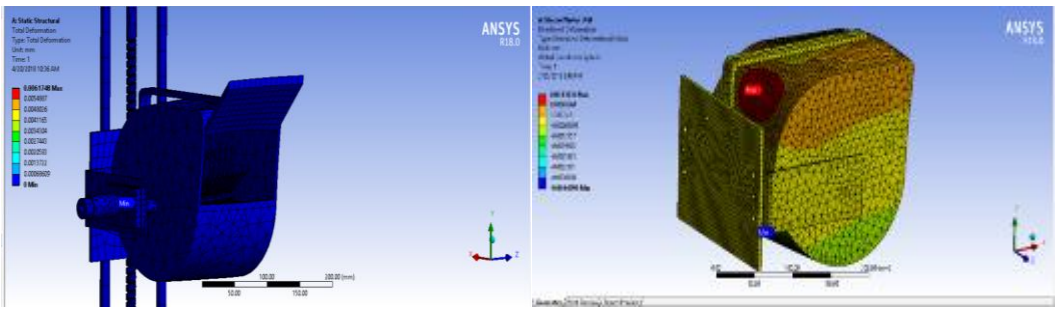
4.3.1. Results



Maximum Deformation is 0.42mm. Hence, Design is safe.

4.4. Plaster Spraying Unit

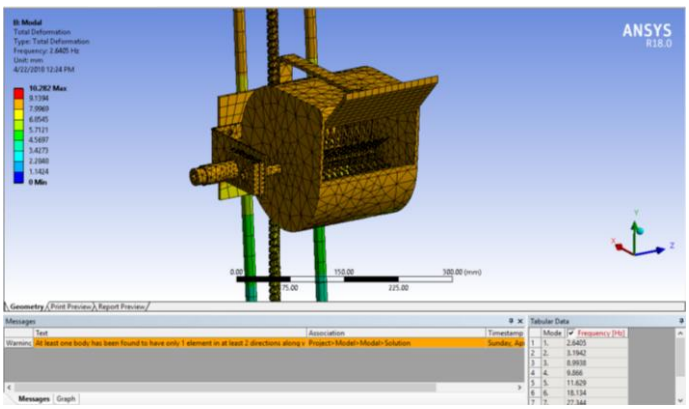
4.4.1. Results



Total Deformation is 0.01mm Total Deformation in X direction is 0.001mm

4.5. Deflection

4.5.1. Results



Max. Deflection is 10 mm

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V. CONCLUSION

5.1. Comparison

	Manual	Single Axis Wall Plastering Machine	2-Axis Wall Plastering Machine
Plastering Thickness	12mm	5-10mm	8-10mm
Plastering Speed	1.25m^2/Hr	45m^2/Hr	30m^2/Hr
Surface Smoothness	Great Finishing	Second Layer will be applied (2-3mm)	Manual finishing is required
Plastering Time for 1m^2	Skilled Labour – 5-7 min	2-3 min	2-3 min
Capital Cost	Less	More	More
Operating Cost	More	Less	Less
Operating Resource Cost	More	Less	Less
Operating Time Required	More	Moderate	Less
Wastage of Material	More	No Wastage	No Wastage
Set Up Time	2-10 minutes	4-8 minutes	3-6 minutes
Labour Requirement	In direct variation with the completion speed required (Required Speed ∞ Number of labors)	2	2

5.2. Conclusion

We can conclude from above analysis of machine in Ansys software that the machine is structurally stable and will be able to withstand large amount of force and vibrations that will be created while its operation. Also, the above comparison proves that both the machines single axis and 2-axis are better than manual operation of plastering.
This machine will help us in faster operation of plastering than both manual as well as single axis machine. The machine is far less complex and easy in transportation than single axis machine. As far as the quality of plastering is considered, there is still a lot of work and research to be done. But this research done will be helpful in building a far more superior machine than the existing one.

So, we can say that there is a possibility of future work to be done on this machine. And the application of this machine to plaster is limited on flat surfaces. Future work on this machine can be done to make the machine such that it can be applied on slant walls also. Such research will be helpful in building the machine such that it can be used for complicated plastering in complex high-rise buildings completely automated without any manual labour necessary. This is still not possible as of now, but future work on this topic may lead to such wonders in our country.

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