Design of Automatic Wall Plastering Machine

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Abstract— This paper proposes a simple approach of designing of wall plastering machine using automation. The construction of building is not more familiar in Research & Development activities in robotics & automation community. Also the construction of building is oldest & biggest in economic sectors, in tensed competition. There is a shortage of skilled labor, increased in the labor cost & technological advances are forcing rapid changes in the construction of buildings. Construction of Buildings is divided into to two large groups. Hence to increase the quality in the construction we needed plastering work. The machine has been developed for plastering work which has very high demand in construction field. The present work highlights the design and developments of the prototype in these area and also the new model is proposed to automate the plastering work. The machine includes microcontroller, display, belt drives, display, fabricated structure, relay, AC/DC motor, etc. The completed model will be validated by the testing of machine using the brick wall and the statistical details of the manual work will also be observed at the different conditions.

Key words: AC/DC motor, Display, Fabricated structure, Robotics & Automation, Microcontroller, Relay

I. Introduction

Now a day’s construction revolution has made the contractors to equip their construction in such a way that, so as to perform the highest output with as minimum building construction cost as possible. In order to have highest output of the parameters such as like accuracy, quality, precision, & cycle time have to be optimized. This optimization is possible either by having a skilled man power or automating the system. In the first case, continuously doing the same kind of work for long time will cause fatigue which will result in lower efficiency. So it will be better to automate the system if work of nature is of same in case of large construction. Hence using the automation it will be also possible to have the higher efficiency, accuracy and quality. The contractors are also concerned with the safety levels of the worker too & the automation also provides the solution of the safety aspects of both the worker & machine. With the constant increase in the demand of the construction, the contractors are forced to increase their construction and also the quality of the construction to remain in this competitive market. The construction industry in most countries amounts upto 10–20% of the GNP [1], making it the largest economic employing sector. It is still labor demand and also most of the work involved is repetitive. The growth of any of the country is dependent on the construction industry hence it is of prime economic significance to many industrial sectors. Due to the Intense competition technological advances are forcing the rapid changes in the construction industry & shortages of skilled labor, thus encouraging its automation in this industry.

The construction of buildings, apartment, shops, complexes & homes are basic requirements of human being. In this Plastering works refers to construction or ornamentation done with plaster [2], such as a layer of plaster done on an interior wall or plaster decorative moldings on ceilings or walls. This is also called plastering. The process of creating plasterwork called plastering. Tools and materials include trowels, floats, hammers, screeds, a hawk, scratching tools, utility knives, laths, lath nails, lime, sand, plaster of Paris, a variety of cements, and various ingredients to form color washes. Plasterers typically divide the room, (especially a large or high-ceilinged wall) into top and bottom. The one working on top will do from the ceiling's edge to about belly height and work off a milk crate for an 8- foot (2.4 m) ceiling, or work off stilts for 12-foot-high rooms. For cathedral ceilings or very high walls, staging is done and one works topside, the others further below.

A. Objectives

Automation is one of the numerous and evolving disciplines among all technologies. The aim of this innovative plan is to render the plasters on walls mechanically. This concept aims in reducing the work of labours. It's possible, light-weight weight, cheap and easy structure scrutiny to the present machine. This innovative method keeps up with the ever ever-changing world of building automation.

- It is the new machine used to reduce human work especially work of plasterers.
- It is the machine, instead of handmade in construction plastering area.
- It is very easy and simple to operate.
- It is not much expensive when comparable to its previous versions.
- Simple structure, light weight, small cubage, easy to operate.
- Saving more than 20% raw material (cement & sand).
- It helps in providing an effective solution to construction applications by using microcontroller operated motor drive for making necessary activity.

II. Plastering technique

Figure 1 shows the trowel operation technique in traditional plastering method. The correct plastering technique is essential with only the trowel being used to apply and finish the skim coat. Achieving a good finish is the combination of firm pressure combined with the correct angle of trowel (how far the leading edge is from the wall). Plastering Technique for applying plaster is initiated by trowel loaded with plaster, and then leading edge of the trowel will be a long way from the wall. The leading edge need to be flattened gradually into the wall. With the next stroke the trowel will be used for flattening out the plaster as just applied. There will be no plaster on trowel and it will be fairly flat - the leading edge will be approximately 10 – 15 mm away from the wall. Firm pressure will push the plaster flat and even. The pressure applied through the trowel is to be considered for the evenness and angle is maintained as required.

If the leading edges is more than 15 mm away from the wall then the trowel will start to scrape plaster off the wall. Close this angle down so that it is 10 - 15 mm away and can push hardly and it will give a nice clean even, hollow free application. This plastering technique is crucial to maintain good consistence at all times. With the correct method speed will then increase very quickly. The stages of plastering is applying the plaster and smoothing out immediately there are many situations that can only be resolved in the stages. It is also not a case of just moving from one stage to the next. Progression through the stages is determined by how quickly the plaster starts to firm up. Move from one stage to the next once the plaster has firmed up and gone tacky. If at any stage do not see any improvement then this does not necessarily mean there is anything wrong with plastering technique but probably that the plaster is too wet. In the early stages the objective is flatness not smoothness. The smoothness will come later, but only if achieved flatness so, always remember the objective of each stage. The setting process of plaster can firm up for two different reasons either, due to the natural setting process or due the moisture being sucked out of the plaster by the backing coat. The single most important aspect to be aware of is suction. If don't have it under control then no matter how good plastering technique will never be able to achieve a good finish. The suction test should always be carried out. If applied skim coat on plasterboard then it need not problem as the suction is controlled. In some instances if the backing coat is very porous the moisture can be sucked out almost instantly. This is clearly not good as by the time to have finished applying plaster to the whole wall, the first application will be totally dry.

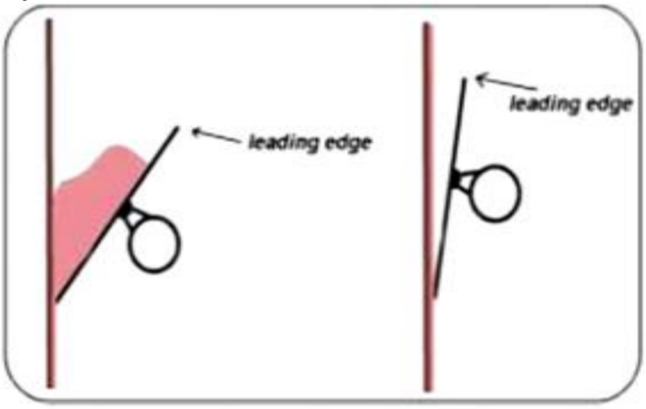

Fig. 1: Trowel Operation Technique

A. *Preplastering Requirements*

The masonry/brick substrate must be installed in strict accordance with the manufacturer's specifications and recommended installation procedures. All pointing shall be flush finished. The manufacturers required curing time must be allowed after placement of the bricks to ensure all of the pointing has completely cured and the walls have stabilized. Failing to allow the pointing to fully cure can lead to excess shrinkage and cracking on the pointing lines after the walls have been plastered [4]. The finished appearance of the wall is highly dependent on the standard of the wall construction. Plastering cannot commence until; all the surfaces that are to be coated are level. There must be no more than a 3mm deviation in the surface alignment over a 1200mm radius. All the necessary waterproofing elements must have been completed and checked and the joinery must be in place. All junctions between the masonry/brick substrate and dissimilar materials must be correctly flashed and sealed with MS Silaflex or another approved equivalent. The MS sealant must be installed in strict accordance with the manufacturer's requirements and must be left to properly cure prior to plastering. Construction Joints must be provided according to the brick manufacturers design criteria. All construction joints must be in place and must be waterproof prior to the commencement of plastering.

III. SHORTAGE OF SKILLED LABOR IN CONSTRUCTION

The Indian industry comprising infrastructure and assets sectors use over twenty six million casual staff and area unit the country's second largest leader once agriculture. The look commission of Republic of India has projected that the development sector would force another forty seven million folks within the manpower over consequent decade (FICCI 2010:13). Despite such significance to the Indian economy, there's no specific policy for ability building within the construction sector. Table below shows the present pool of the development manpower in Republic of India contains principally unskilled workers [3].

Category	Percentage of Employment	Total Employment
Unskilled Workers	83%	25.6 million
Skilled Workers	10%	3.3 million
Engineer	3%	0.8 million
Technician & Foreman	2%	0.6 million
Clerical	2%	0.7 million

Table 1: Current employment details in different industries
Source: Report of Working Group on Construction for the Eleventh Five Year Plan, Planning Commission, Government of India

IV. LITERATURE REVIEW

We have been taken the idea of automatic wall plastering machine with the help of following literatures.

A. *Design and Fabrication of Automatic wall plastering Machine:*

Author Name: Mahesh P.K, Shree Rajendra
Journal Name: IOSR Journal of Mechanical and technology.

This work includes applying the mortar into the wall and additionally pressuring mortar with a creating surface level. The model has been developed and tested with success. With this development the 2 major downside construction industries presently facing are often reduced.

They're consummate labor shortage and Quality within the construction method with less wastage. Through the trials it's noted that the machine is a lot of productive compare to the labor with relevancy the rendering work and additionally the standard achieved is sort of admire the labour.

B. Automatic Plastering Machine:

Author Name: Arivazhagan B.
Journal Name: International Journal of Advanced analysis in physics, Communication & Instrumentation engineering and development.

Machine-driven rendering machine is exclusive and maybe one reasonably machine-driven rendering machinery ideally appropriate for the construction/building business. Machine-driven rendering machine works with typical cement mortar that brings it to a swish, flat end with variable and adjustable thickness to suit every application. Machine-driven rendering machine makes rendering easier, faster, and easy as compare to manual application. This concept also can additional increased by interfacing liquid crystal display & computer keyboard for creating the method while not external supply.

C. Automation in Construction:

Author Name: Pentti Vähä

This paper provides a survey for potential sensor technologies for building construction automation, highlighting their potential Also with contributions from robotics. The paper carries out the survey from the viewpoints of building construction phases.

D. Concept to Position and Enhance Automation Technologies in Emerging Construction Market:

Author Name: Mohan Ramanathan

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

E. Automatic Wall Plastering Machine:

Author Name: Arunkumar Birder
Journal Name: International Journal of Engineering and Technical Research (IJETR) ISSN: 2321-0869 (O) 2454-4698 (P), Volume-4, Issue-1, January 2016

The building construction is time consuming sector because lot of work is labor based there is too much shortage of skilled labor, increase in labor cost and technological advances are forcing rapid change in the building construction. Building construction mainly consists of commercial infrastructure and residential building, but in every sector plastering work is must. We are introducing new machine to automate the plastering work which is very much demand for construction field. The machine consists of AC/DC motor, Gear box, wire rope, pulley, tray mechanism, guide ways, etc. The present work developed model of wall plastering machine.

V. WORKING

Initially, the machine must be placed close to the wall that is to be plastered. The machine needs to be placed in horizontal position. Then the cement mixture that consists of cement and sand within the magnitude relation of roughly around 1:4 is poured into hopper of the receptacle. The machine is raised up with the assistance of lead screw mechanism to lock the machine at one location. The receptacle and hopper assembly is raised with the assistance of motor. The lifting force is given by a rope and machine mechanism.

The linear movement to the assembly is given through a guide manner. Hopper is provided with commixture mechanism to combine and force the mortar to flow in downward direction on the inclined plate. Once the inclined plate moves up with the assistance of guide way's and by keeping 7-8 metric linear unit clearance between inclined plate and wall the mortar gets continue the wall and also the roller mechanism is assembled below the inclined plate that then finishes the plaster done on the wall.

The structures are fabricated by using required necessary components like steel frame, sheet metal, metal bars, power screw, AC/DC motors, different wheels nut and bolts. All these are well assembled as for the requirement. This will be controlled by controller through control components.

The machine consists of a metal frame, sheet metal tray supported by M.S angular, guide ways, thickness adjuster or pressurizer and motor. Initially, the plastering machine has to be placed near the wall which has going to plaster. The machine should be perfectly leveled. Then the cement mixture which consists of cement and sand in the ratio approximately around 1:4 is poured into hopper of the tray. The lifting force is transferred to tray through power screw, which driven by AC motor. The lifting force is given by a belt and pulley mechanism. The linear movement to the tray assembly is given through a guide way. The main part is fixed to vertical column of metal frame and another part of guide way is fixed to tray setup. Using pressurizer setup, this consists of four bar link mechanism. Applying pressure or vary the thickness of plaster is done with these power screws. This activity is controlled by using microcontroller.

VI. DESIGN OF MACHINE COMPONENTS

The Machine design is that the creation of recent and higher machines and up the present ones. A replacement or higher machine is one that is a lot of economical within the overall price of production and operation. The method of design may be a long and time intense one. From the study of existing ideas, a replacement plan must be formed. The concept is then studied keeping in mind its industrial success and given form and type within the variety of drawings. Within the preparation of those drawings, care should be taken of the supply of resources in cash, in men associated in materials needed for the booming completion of the new plan into an actual reality. In planning a machine part, it's necessary to own honest information of the many subjects equivalent to arithmetic, Engineering Mechanics, Strength of Materials, Theory of Machines, Workshop Processes and Engineering Drawing.

A. Classifications of Machine design

The machine design is also classified as follows

1) Accommodative design.

In most cases, the designer's work cares with adaptation of existing designs. This kind of design desires no special information or ability and might be tried by designers of normal technical coaching. The designer solely makes minor alternation or modification within the existing designs of the merchandise.

2) Development design.

This type of design desires goodish scientific coaching and design ability so as to change the present designs into a replacement plan by adopting a replacement material or totally different technique of manufacture. During this case, although the designer starts from the present design, however the ultimate product could dissent quite markedly from the initial product.

3) New design:

This type of design desires ton of analysis, technical ability and artistic thinking. Only those designers UN agency have personal qualities of a sufficiently high order will take up the work of a replacement design.

The designs, relying upon the strategies used are also classified as follows:

a) Rational design.

This type of design depends upon mathematical formulae of principle of mechanics.

b) Empirical design.

This type of design depends upon empirical formulae supported by the observation and past expertise.

(c) Industrial design.

This type of design depends upon the assembly aspects to manufacture any machine part within the trade.

c) Optimum design.

It is the most effective design for the given objective operates beneath the required constraints. It should be achieved by minimizing the undesirable effects. (e) System design.

It is the planning of any advanced system sort of a motor automobile.

d) Element design.

It is the planning of any part of the system like piston, crankshaft, rod, etc.

e) Computer power-assisted design.

This type of design depends upon the utilization of pc systems to help within the creation, modification, analysis and improvement of a design.

B. General concerns in machine design

Following are the overall concerns in planning a machine component:

1) Form of load and stresses caused by the load.

The load, on a machine part, could act in many ways.

2) Motion of the components or mechanics of the machine.

The booming operation of any machine depends for the most part upon the best arrangement of the components which can offer the motion needed. The motion of the components could be:

1) Rectilinear motion which incorporates uni facial and mutual motions.
2) Curved motion which incorporates rotary, oscillating and straightforward harmonic.
3) Constant rate.
4) Constant or variable acceleration.

C. Choice of materials.

It is essential that a designer ought to have intensive information of the properties of the materials and their behavior beneath operating conditions. A number of the vital characteristics of materials are: strength, durability, flexibility, weight, resistance to heat and corrosion, ability to solid, welded or hardened mach inability, electrical physical phenomenon, etc.

D. Form & size of the components.

The form and size are supported judgment. The tiniest practicable cross-sectional is also used, however it should be checked that the stresses elicited within the designed cross-sectional are fairly safe. So as to design any machine half for type and size, it's necessary to grasp the forces that the half should sustain. It's conjointly vital to anticipate any suddenly applied or impact load which can cause failure.

E. Frictional resistance and lubrication.

There is continually a loss of power thanks to resistance and it ought to be noted that the friction of beginning is over that of running friction. It is, therefore, essential that a careful attention should run to the matter of lubrication of all surfaces that move to bear with others, whether or not in rotating, sliding, or rolling bearings.

F. Convenient and economical options.

In planning, the operational options of the machine ought to be rigorously studied. The beginning, dominant and stopping levers ought to be settled on the premise of convenient handling. The adjustment for wear should be provided using the assorted take up devices and arrangement them so the alignment of elements is preserved. If elements are to be modified for various product or replaced on account of damage or breakage, quick access ought to be provided and also the necessity of removing alternative elements to accomplish this could be avoided if attainable. The economical operation of a machine that is to be used for production or for the process of fabric ought to be studied, so as to be told whether or not it\'s the utmost capability in keeping with the assembly of fine work.

G. Use of ordinary elements.

The use of ordinary elements is closely relating to price, as a result of the value of ordinary or stock elements are simply a fraction of the value of comparable elements created to order. The quality or stock elements ought to be used whenever possible; elements that patterns are already living corresponding to gears, pulleys and bearings and elements which can be selected from regular look stock corresponding to screws, barmy and pins. Bolts and studs ought to be as few as attainable to avoid the delay caused by dynamic drills, reamers and faucets and additionally to decrease the amount of wrenches needed.

H. Safety of operation.

Some machines are dangerous to control, particularly those that are speed up to insure production at a most rate. Therefore, and moving a part of a machine that is among the zone of a employee is taken into account an accident hazard and should be the reason behind an injury. It is, therefore, necessary that a designer should offer safety devices for the security of the operator. The security appliances ought to in no approach interfere with operation of the machine.

I. Workshop facilities.

A design engineer ought to be acquainted with the restrictions of his employer's workshop; so as to avoid the requirement of getting work tired another workshop. It's typically necessary to set up and supervise the workshop operations and to draft ways for casting, handling and machining special elements.

J. General Procedure in Machine design

In planning a machine part, there's no rigid rule. The matter is also tried in many ways that. However, the overall procedure to resolve a design drawback is as follows:

1) Recognition of need.
First of all, build an entire statement of the matter, indicating the requirement, aim or purpose that the machine is to be designed.

2) Synthesis (Mechanisms).
Select the attainable mechanism or cluster of mechanisms which can provide the specified motion.

3) Analysis of forces.
Find the forces performing on every member of the machine and also the energy transmitted by every member.

4) Material choice.
Select the fabric best suited to every member of the machine. 5. Design of parts (Size and Stresses).

Find the scale of every member of the machine by considering the force performing on the member and also the permissible stresses for the fabric used. It ought to be unbroken in mind that every member must not deflect or deform than the permissible limit.

5) Modification.
Modify the scale of the member to believe the past expertise and judgment to facilitate manufacture. The modification can also be necessary by thought of producing to cut back overall price.

6) Careful drawing.
Draw the careful drawing of every part and also the assembly of the machine with complete specification for the producing processes prompt.

7) Production.
The part, as per the drawing, is factory-made within the workshop.

K. Design of Hopper

It is a Galvanized iron sheet material hopper to store the mortar into it up to 25kg. We have considered the volume of the hopper.

Amt of material top be filled in the hopper =(Volume * Density of Cement Concrete Material)

$$26Kg = Volume * 1750$$

$$Volume = 0.014745\ m^3$$

Therefore,

Volume of the hopper = 0.014745 m3

We have divided the hopper into four parts according to our drawing and according to consideration of gravitational force.

Therefore,

The hopper is divided into two rectangular and two right angled triangle sections.

First Rectangular Section

$$[Area]_1 = width * breadth$$

$= 290 * 235$

$= 68150\ mm^2$

$$[Volume]_1 = [Area]_1 * depth$$

$= 68150 * 130$

$= 8859500\ mm^3$

Volume of first rectangular section = 8859500 mm3

First Triangular Section

$$[Area]_2 = ½ * a * b$$

$= ½ * 55 * 235$

$= 6462.5\ mm^2$

$[Volume]_2 = [Area]_2 * depth$

$= 6462.5 * 290$

$=1874125\ mm^3$

Volume of first triangular section = $1874125\ mm^3$

Second Triangular Section

$[Area]_3 = ½ * a * b$

$= ½ * 193 * 115$

$= 11097.5\ mm^2$

$$[Volume]_3 = [Area]_3 * depth$$

$= 11097.5 * 290$

$=3218275\ mm^3$

Volume of second triangular section = $3218275\ mm^3$

Second Rectangular Section

$$[Area]_4 = width * breadth$$

$= 48 * 290$

$= 13920\ mm^2$

$$[Volume]_4 = [Area]_4 * depth$$

$= 13920 * 57$

$= 793440\ mm^3$

Volume of second rectangular section = 793440 mm3

$$Total\ Volume = [Volume]_1 + [Volume]_2 + [Volume]_3 + [Volume]_4$$

$$Total\ Volume = 8859500\ mm^3 + 1874125\ mm^3 + 3218275\ mm^3 + 793440\ mm^3$$

Total Volume = $14745340\ mm^3$

Fig. 3: Hopper

L. Design of Upper Shaft

Motor Specification to lift the tray mechanism with the help of rope and pulley
Motor Specification:
Power of Motor = 40 watt
Frequency = 60 Hz
Torque = 120 kg-cm
= 11.77 * 103 N-mm

P=2πNT/60
40=2*3.14*N*11.77/60
N=32.45RPM
N=33RPM
Now,
Material for Shaft Fe360
S_{yt} = 220 N/mm2
S_{ut} = 360 N/mm2
Now According to A.S.M.E Code
$\tau = 0.18 * S_{yt}$
= 0.18*220
=39.6 N/mm^2

$\tau = 0.3 * S_{ut}$
= 0.3*360
=180 N/mm^2
Maximum load consideration = Hopper wt + Motor wt + other wt
= 65 Kg
Load = 65 * 9.81 = 637.65 N

There are two different sides so, weight on single side or load on single side = 637.65/2 = 318.825 N
Now,
Taking reaction of B
$-318.825 * 30 - R_c * 295 + 318.825 * 325 = 0$
$-9564.75 - 295R_c + 103618.125 = 0$
$94053.375 = 295R_c$

R_c = 318.825 N
R_b = 318.825 N

Now, bending moment of both sides is same
$M = R_c * 30$
= 318.825 * 30
= 9564.75 N-mm

Now, we know that

$Te = \sqrt{(K_b * M_b)^2 + (K_t * T)^2}$

$=\sqrt{(1.5 * 9564.75)(1 * 11.77 * 1000)}$

Te = 18557.275 N-mm

$Te = (\pi/16) * d^3 * \tau$

d = 13.363 mm
d = 15 mm
Hence standard diameter for shaft is 15 mm.


Fig. 4: Shaft

M. Design of Lead Screw

Material Used for power screw-Steel 30C8
S_{yt} = 400 N/mm^2
Consider Factor of Safety = 5
Consider weight = 100kg = 100 * 9.81 = 981 N

$\tau = S_{yt}/FOS$
= 400/5
= 80 N/mm^2

Now,
$\sigma = W/(\pi/4) * d_c^2$
$80 = 981/ *(\pi/4)\ d_c^2$
= 3.95 mm
d_c= 4 mm

Nominal diameter is very less which is not available in the market and it is difficult to manufacture, So we assume the Core diameter which is available.
Assume Core Diameter d_c= 20.32 mm
Therefore,
$\sigma_c = W/(\pi/4)d_c^2$
W = 24525 N
Therefore the weight we considered is 2500Kg.
Now,
We Select M24 Screw threaded Power Screw Having Following Property
Pitch = P = 3 mm
Core Diameter = d_c = 20.32 mm
Major Diameter = $_{dm}$ = 24 mm
Depth of the threads = t = 1.840 mm
Nominal Diameter = d = 22.051 mm
Type of thread = V thread
Now,
$d_m = d - 0.5 * P$

= 22.051 – 0.5 * 3

= 20.551 mm

Lead = Number of Start * Pitch
L = 2 * 3

= 6 mm

Now we know that
$\tan\alpha = l/\pi * d_m$

tanα = 0.0929

α = 5.309°

Now,
μ= tanØ

tanØ = 0.15

Ø = 8.53

Since Ø > α Therefore, Screw is self locking.
Torque required lowering the load

M_t = [(W+d_m)/2] * tan (Ø + α)

= (24525 * 20.551/ 2) * tan 13.839

M_t= 62.08068 * 10^3 N-mm

Now
τ = 16 * M_t/(π * d_c^2)

= 16 * 62.08068 * 10^3/(π * 20.320^2)

τ = 37.68 N/mm^2

σ_c= W/[(π/4) * d_c^2

= 24525/[(π/4)* 20.320^2]

= 75.62N/mm^2

Now bending moment is given by
Mb = P * l
P = 0.45*200
P = 90N

M_b = 90 * 230
= 20700 N-mm

σ_b = 32* M_b/ (π * dc^3)

= 32 * 20700/π*20.320^3

= 25.13 N/mm^2

Now, The principal shear stress at the section-XX is given by,
√(σ/b^2)^2 + (τ^2)

= √(25.13/2)^2 + $(37.68)^2$

= 39.72 N/mm^2

Factor of safety
= 0.5 * S_{yt}/τ_{max}
= 0.5 * 400/39.72
= 5.30
Since,(Factor of Safety)Intial < (Factor of Safety)calculated i.e. 5 < 5.30
So, Our Design is safe.

Fig. 5: Lead Screw

Design of Handle
P + l_h = M_t
90 + l_h = 62080.68
l_h = 690 mm

We know that,
σ_b = 32*M_b/(π*d_c^3)
M_b = P * l_h
= 90 *690
= 62100 N-mm * Vg

Now substituting the value in above equation
80 = 32 * 62100/ (π*d_h^3)
d_h = 20 mm
Hence we got diameter of the handle rod as 20 mm.

N. Design of Worm Gear

Consider,
(Sut)worm wheel = 700 N/mm^2 (Case harden steel)
(Sut)gear = 240 N/mm^2(Phosphor bronze)
Assume
Number of teeth on worm wheel = Zw = 3
Number of teeth on Gear = Zg = 18
Therefore, Gear ratio = (Zg/Zw) = (18/3) = 6
Beam strength of worm gear

F_b = $(\sigma_b)_g$ * b * m * Y * Cosλ
Assume q = 10
Tanλ = 3/10
λ = 16.69°

Now, Face width = b = 0.73*dw = 0.73 * m * q = 0.73 * m * 10 = 7.3m
Lewis form factor

Y = 0.484 - 2.87/Zg
= 0.484 – 2.87/18
Y= 0.3245

Bending Stress of gear
$(\sigma_b)_g$ = $(S_{ut})_g$/3
=240/3
= 80 N/mm2
Now substituting all value in beam strength formula

F_b = 80 * m * m * 0.3245 * cos16.69

= 189.508m^2 N
Now calculating wear strength of worm gear
F_w = d_g * b * k

$d_g = m * z_g$
$= 18m$

Face width = b = 10m

Standard wear load factor for phosphor bronze gear
k = 0.83 N/mm^2

$F_w = d_g * b * k$

= 18m * 7.3m * 0.83

= 109.062 m^2 N

Now,

As Fw < Fb Gear pair is weaker in pitting. Hence it is required to design a gear pair against the pitting failure.

Calculate the Effective load on worm gear

$$Feff = (K_a * F_{gt})/k_v$$

Velocity Factor

$K_v = 6/(6+ V_g)$

Velocity of Gear

$Vg = (\pi * d_g * N_g)/ 60000$

$= \pi * 18m * 55/ 60000$

= 0.0518 mm/sec

Therefore Velocity factor

$K_v = 6/(6 + V_g)$

Kv = 6 / (6 + 0.0518m)

Now, Maximum tangential force

We know that

$P_0 = F_{gt} * V_g$

Where, Po = Output Power

Now Efficiency

Efficiency = (P_0/P_i)

Now,

Efficiency = $\tan\lambda/\tan(Ø_v + \lambda)$

Tan $Ø_v = \mu/\cos Ø_n$

= 0.03/14.5

$Ø_v$ = 1.7748

Now,

Efficiency = $\tan\lambda/\tan(Ø_v + \lambda)$

ή = tan 16.69/tan18.4648
= 0.8979

Now, we know that Input power

Input power = $a^{1.7}/34.5(i + 5)$

Where, a = Centre distance and i= gear ratio

P_i = (10.5m)1.7/34.5(6+5)

$P_i = 54.54 * m^{1.7}/ 379.5$

Efficiency = P_o/P_i

$0.8979 = P_o/[54.45(m^{1.7})/379.5]$

$P_o = 48.89(m^{1.7})/379.5$

Assume Input power P_i = 75 watt

Therefore Output Power = (P_i/ Efficiency) = (75/0.8979) = 83.52watt

P_o =83.52watt

$P_o = F_{gt} * V_g$

$83.52 = F_{gt} * 0.0518m$

F_{gt} = 1612.35/m

Now, we know that

$F_{eff} = (Ka * F_{gt})/(K_v)$

109.062 (m^2) = [(1.25 * 1612.35)/m]/[6/(6 + 0.0518m)]

By arranging equation we got,

$109.062m^3 – 17.399m - 2015.4 = 0$

m = 2.66 = 3 mm

m = 3mm

Hence we got module as Module = 3 mm

Dimension of the worm gear are as follow :

Diameter of worm gear = d_g =18m =18 * 3 = 54 mm

Diameter of worm wheel = d_w = m * q = 3 * 10 = 30 mm

Axial pitch = $P_a = \pi * m = \pi * 3$ = 9.42 mm

Face width = 0.73 d_w = 0.73 * 30 = 21.9 mm

Center Distance = C.D = (dw + dg)/2 =30 + 54/2 = 42 mm

Addendum = h_a = 1m = 1 * 3 = 3 mm

Dedendum = h_f = 1.25m = 1. 25 * 3 = 3.75 mm

Length of the worm = $P_a * Z_w$ = 9.42 * 3 = 28.26 mm

Fig. 6: Worm Gear

O. Design of Spur Gear

Consider,
(Sut)pinion = (Sut)gear = 580 N/mm^2 Plain carbon steel 40C8
Number of teeth on Pinion = $Z_p = 15$
Number of teeth on Gear = $Z_g = 45$
Gear ratio = G = dg/dp = 45/15 = 3

Now,

Check whether gear is weaker or pinion is weaker
We know that,

$(\sigma_b)_p = (\sigma_b)_g = (S_{ut})$pinion and gear/a = 580/a
= 193.33 N/mm^2

Lewis Form Factor is,
$Y_p = 0.484 – 2.87/ Z_p$
= 0.484 – 2.87 / 15
$Y_p = 0.2927$

Now when material is same for pinion and gear in such condition always pinion is weaker.
Calculate the beam strength of pinion

$F_b=(\sigma_b)_p * b * m * Y_p$
Face width = b = 10m
$F_b = 193.33 * 10m * m * 0.2927$

$F_b = 565.87\ m^2$ N

Calculate the wear strength of gear pair

$F_w = d_p * b * Q * K$

For external gear pair

$Q = 2 * Z_g/(Z_g + Z_p)$

= 2 * 45/60
= 1.5

Diameter of pinion = dp = Zp * m =15 * m = 15m

Now For steel gear and steel pinion

$K = 0.16 * (BHN/100)^2\ N/mm^2$

$K = 0.16 * (218/100)^2$

$K = 0.76\ N/mm^2$

Wear Strength

$F_w = d_p * b * Q * K$

$F_w = 15m * 10m * 1.5 * 0.76$

$F_w = 171m^2$ N

As, Fw < Fb gear pair is weaker in wear. Hence, it is required to design a gear pair against the wear failure.

Calculate the effective load on gear pair

$F_{eff} = (K_a * K_m * F_t)/K_v$

Now
Velocity factor
$K_v = 6/(6 + V)$

V = (π * dp * Np)/60

V = (π * 15m * 33)/ 60

V = 25.9181m mm/sec

= 0.02591m m/sec

Tangential force
$F_t = P/V$

Where, P = Power = 40 watt
$F_t = 40/ 0.02591m$

$F_t = 1544.40/m$ N
Now
Velocity factor
$K_v = 6/ (6 + V)$

$K_v = 6/(6 + 0.02591m)$
Now,

Effective Load on gear pair

$F_{eff} = (K_a * K_m * F_t)/K_v$

Where $K_a = 1.75$ & $K_m = 1.5$

$F_{eff} = [1.75 * 1.5 * (1544.40/m)]/ [6/ (6 + 0.02591m)]$

$F_{eff} = (4054.05 + 17.499m) / m$

$Fw = FOS * F_{eff}$

$171m^2 = 2[(4054.05 + 17.499m) / m]$

By solving above equations we got,

$171m^3 – 34.98m -8108.1 = 0$
m = 3.63 = 4
m = 4

Module = m = 4 mm
Calculate dimensions of gear pair
Module = m = 4 mm
Face width = b = 10 m = 10 * 4 = 40 mm
Diameter of Pinion = $d_p = m * Z_p$ = 4 *15 = 60 mm
Diameter of Gear = $d_g = m * Z_g$ = 4 * 45 = 180 mm
Center distance = (dp + dg)/2 = (60 + 180)/2 = 120 mm
Addendum = h_a =1m = 1 * 4 = 4 mm
Deddendum = h_f = 1.25 * m = 1. 25 * 4 = 5 mm
Now, calculate the dynamic load by using Buckingham's equation

$$F_d = [21V * (bC + (F_t)_{max})] / [21V + (\sqrt{bC + (F_t)_{max}})]$$

$$(F_t)_{max} = K_a * K_m * F_t$$

But, $F_t = 1544.40/4$ N

Ft = 386.1 N

Therefore,

$(F_t)_{max} = 1.75 * 1.5 * 386.1$

$(F_t)_{max} = 1015.5125$ N

Pitch error for grade 7

$e = 11 + 0.9 [m + 0.25\sqrt{d}]$

Pitch error for Pinion

$e_p = 11 + 0.9[m + 0.25\sqrt{d_p}]$

$e_p = 11 + 0.9[4 + 0.25\sqrt{60}]$

ep = 16.34 μm

Similarly, pitch error for gear is

$e_g = 11 + 0.9[m + 0.25\sqrt{d_g}]$

$e_g = 11 + 0.9 [4 + 0.25\sqrt{180}]$

$e_g = 17.62$ μm

Total pitch error,

$E = e_p + e_g$

e = 16.34 + 17.62

e = 33.95 μm

$e = 33.95 * 10^{-3}$ mm

Deformation Factor

$C = 0.111 * e [(E_p * E_g) / (E_p + E_g)]$

$= 0.111 * 33.95 * 10^{-3} [(207*10^3 * 207 * 10^3) / (207 * 10^3 + 103 * 10^3)]$

= 395.68 N/mm

Velocity,

V = 0.02591m m/s

= 0.02591 * 4

= 0.10364 m/s

The Dynamic load by using Buckingham's Equation,

$$F_d = 21V[bC + (F_t)_{max}] / [21V + \sqrt{bC + (F_t)_{max}}]$$

$F_d = 21 * 0.10364 (40 * 395.68 + 1013.51) / [21 * 0.10364 + \sqrt{(40 * 395.68) + 1013.51}]$

$F_d = 277.67$ N

Calculate the available Factor of Safety

Effective Load

$F_{eff} = (F_t)_{max} + F_d$

$F_{eff} = 1013.51 + 277.67$

$F_{eff} = 1291.18$ N

As gear pair is weaker in pitting

$F_w = FOS * F_{eff}$

$FOS = F_w / F_{eff}$

$F_w = 171 m^2$

$F_w = 171 * 16$

$F_w = 2736$ N

FOS = 2736 \ 1291.18

FOS = 2.11899 > 2

As the available FOS gear pair is higher than the required FOS the design of gear pair is safe.

Fig. 7: (A) Spur Gear

Fig. 7: (B) Spur Pinion

P. Design of Rope

As, Used wire rope is standard so, Specification of wire rope are as below:

Type of Wire Rope = 7 * 19

Material of wire rope is stainless steel wire

Minimum Breaking Stress = 1770MPa

Minimum load capacity = 588 kg

Nominal diameter = 3 mm

Actual load capacity = 65 kg

Weight of wire rope =0.05168 kg

Stresses in wire rope

Direct Stress

$\sigma_d = (W + w) / A$

Where,
W = Load lifted
w = weight of the rope
A =Cross-sectional Area

$\sigma_d = 17.555168 / [(\pi/4) * 3^2]$

$\sigma_d = 2.4830 \text{ N/mm}^2$

Therefore,

The direct stress in the wire is $\sigma_d = 2.4830 \text{ N/mm}^2$

Q. Design of Bearing

Upper Shaft Bearing
Specification of the selected bearing
Designation of the Bearing = 6202
Bore Diameter = d = 15 mm
Outside Diameter = D =35 mm
Width = B = 11 mm
Greece Lubrication = 19000
Oil Lubrication = 24000
Dynamic Load = C = 7800N
Static Load = C_o = 3550N
Now,
Step:1
Calculate Radial load & Axial load
Radial Load = F_r = 318.82 N
Axial Load = F_a = 0 N
Step : 2
Calculate Equivalent dynamic load
Consider X =1 and V =1

$P_e = [(X * V * F_r) + (Y * F_a)]$

$P_e = [(1 * 1 * 318.825) + (1 * 0)]$

$P_e = 318.825$ N

Step:3

Calculate the required dynamic load capacity

$L_{10} = (C_r / P_e)^a$

Consider, Ball bearing a = 3

Assume L_{10} = 8000 hr

$8000 = (C_r / 318.825)^3$

$C_r = 6376.5$ N

Since, Cr < C then selected bearing is suitable.
Selection of bearing for wheel and hopper and rotating handle

Specification of the selected bearing

Designation of the Bearing = 6000

Bore Diameter = d = 10 mm
Outside Diameter = D = 26 mm
Width = B = 8 mm
Greece Lubrication = 30000
Oil Lubrication = 36000
Dynamic Load = C = 4620N
Static Load = C_o = 1960N

Now,

Step:1

Calculate Radial load & Axial load

Radial Load = F_r = 196.2 N
Axial load = F_a = 0 N

Step:2

Calculate Equivalent dynamic load
Consider X =1 and V =1

Step:3

Calculate the required dynamic load capacity

$L_{10} = (C_r / P_e)^a$

Consider, Ball bearing a = 3
Assume L_{10} = 8000 hr

$L_{10} = (Cr / 196.2)^3$

$C_r = 3753.17$ N
Since, Cr < C then selected bearing is suitable.

Fig. 8: Bearing

VII. ADVANTAGES

Negligible maintenance.
Less equipment required.
Heavy loads are lifted & placed easily.
Less man power required.
Handling is required.

VIII. CONCLUSION

The present work includes applying the mortar into the wall and also pressuring mortar with a making surface level. With this development the two major problem construction industries currently facing can be reduced. They are skilled labor shortage and Quality in the construction process with less wastage.

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