DESIGN AND FABRICATION OF BLOCK LAYING ROBOT

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Abstract— This project deals with an attempt of developing automated equipment to lay blocks or bags one after the other in a rows and one above the other in layers. This equipment can also be used in laying bags of food grains, fertilizers, cement bags, etc. The basic idea of this equipment is to lay bricks in constructing a wall. An analysis may lead to help all communities in the construction fields as well as in inventory or store room for stacking.

According to the recent development of industrial robots about their functions and workability which are studied and came to a conclusion that most robots are considered to do appropriate work so that it can be able to decide by itself how many blocks or bags are to be laid in rows so that the spaces are evenly left between the blocks and an accurate type of lifting for next layers of block is done. Determining the correct angle of each individual block has been difficult and exclusively without any imitating pattern visible. It also reduces chance of the accident happening during construction works. Developed Robot found to consistent in laying the blocks.

Index Terms— DC motors, IR sensor, Robot,

I. INTRODUCTION

Automatic block laying robot is basically a robot designed to keep blocks in a sequence one after other to build wall. It moves along a straight path. In order to sense the block an Infra-Red (IR) sensor is used and sensor work for the particular range. The choice of this sensor would be dependent upon the sensing accuracy and flexibility required. From the industrial point of view, automatic block laying robot can be implemented in semi to fully automotive construction works. In this environment, these robots functions as block and cement carrier from one end to another end for faster wall construction without the help of any labour for this type of machinery no worker is required to carry cement and blocks. This robot has the capabilities to sense the number of blocks to be laid during construction process. To add on to the complexity of the problem, sensor positioning also plays a role in optimizing the robots performance for the tasks mentioned earlier.

Line-following robots with pick and place capabilities are commonly used in manufacturing plants. These move on a specified path to pick the components from specified locations and place them on desired locations. Basically, automatic block laying robot is a self-operating robot that detects blocks in series and laid in proper sequence maintaining the gap for keeping cement and follows a path which is parallel to wall. The control system used in this robot will provide feedback for correcting the wrong moves of the gripper and conveyer.

Industrial robots are found in a variety of locations including the automobile and manufacturing industries. Robots cut and shape fabricated parts, assemble machinery and inspect manufactured parts. Some types of jobs robots do: load blocks, die cast, drill, fasten, forge, make glass, grind, heat treat, load/unload machines, machine parts, handle parts, measure, monitor radiation, run nuts, sort parts, clean parts, profile objects, perform quality control, rivet, sand blast, change tools and weld.

II. LITERATURE REVIEW

J. Heintze et all[1] explained about design of brick laying robot and discussed about the tight performance claims which have been imposed by the task specification, constitute the basis for the research on control of hydraulically driven manipulators.

Mamta B. Rajgor et all[2] studied about Building and construction industries are one of the major industries around the world. In which Construction industry is a labour intensive.

Masonry G. Pritschow et all[3] explained about design of robot control system. The dramatic shortage of skilled workers and a strong need of improving productivity and efficiency characterize the situation of masonry construction in Germany today.

Carlos Balaguer[4] discussed about the open issues and the main barriers to introducing automation in the construction industry are analyzed. This paper explained about the possibilities in automating the construction.

G. Pritschowa et all[5] here report is given about the progress in research and development of a mobile bricklaying robot for use on the construction site.

Seung-Nam Y et all[6] explained about the brick handling in construction road paving site or building construction site is traditionally performed by the handwork of humans.

A.W. Hendry[7] explained about contemporary masonry wall construction beginning with a brief statement of the applications and advantages of this form of construction.

Carlos Balaguer[8] discussed about the EU Future Home project is focusing in the development of new modular building construction with several important features: high quality, variety of designs, mass production, reasonable cost, and etc.

B. Kahane and Y. Rosenfeld[9] explained about comparison of various ways to use a robotic system for building a wall.

Yukio Hasegawa[10] explained about the Construction automation and robotization effort was started in around 1980 as ISACR and IAARC promising great progress by promoted technologies in the 21st century.

Drawback of manual construction:

Working for 24×7 in the construction field is difficult.

Rate of construction is very less.

It is hard for labour to work in the construction and there may be chance that the block may fall on the worker head.

Investigator is required to check the constant work of labours.

Costing for labour is also high

This project would be able to overcome these drawbacks and provide a better and a more fool proof system. Thus the aim of this project is “To design and fabricate a mechanism or structure which will lay the block during the construction work and overcomes the limitations seen in the labour work”

Before going into the design stages of this system, let us first see the different components that form the building blocks of the project.

DESCRIPTION OF COMPONENTS

This block laying robot is basically divided into 3 parts

1. Top part
2. Middle part
3. Bottom part(base part)

TOP PART: This Part is as shown in fig.1 and consist of wooden block with bearing it supports the screw rods for the free rotation of rod so that the platform can easily move up and down on the screw rods and it act as a shield which protect the gripper and base part from the environment. The dimension of this top part is 390×360×15 mm as per design discussed in next section.

Fig.1: Top Plate

MIDDLE PART: Middle part shown in fig 2 is main part of the robot, as it consists of platform with Conveyer and Gripper.

CONVEYER: Conveyer mounted on the platform as shown in fig. 3 is fitted parallel to platform so that block can be easily gripped by gripper. Here 3 Rubber belts are used which are allowed to rotate on 2 small plastic pipes which are attached to the shaft of 2 DC motor of 10 rpm as speed of conveyor should be slow so that block can be easily picked by gripper. Both the DC motors are fitted to platform; length of conveyer is 19 cm because of the space constraint on platform. The blocks are directly placed on conveyer and from conveyor Blocks are moved to a position where gripper can pick the block. For correct positioning of the block an IR sensor is used, sensor is programmed to sense block as it senses it stops the conveyor and then gripper will pick the block from conveyer.

Fig.2 Middle part

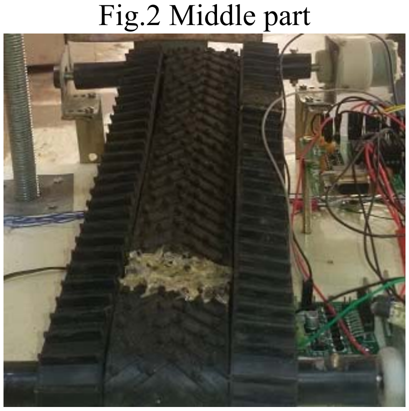

Fig. 3: Conveyer

GRIPPER: Gripper is the main part of robot and function of this gripper is to pick the block from conveyer and place it at accurate position to build wall. Here gripper used is made up of plastic material and has standard specification i.e. it can lift maximum 200 grams and maximum opening of gripper jaws is 3.5 cm. Opening and closing of jaws is controlled by servo motor for this purpose a 10 kg torque servo motor is used according to design of gripper. The block here used is of scaled model of brick hence width of block is taken as 5 cm and of gripper opening was 3.5 cm, opening of gripper was extended by attaching mild steel plates of 1 mm thickness (available standard size in market) to extend opening of the jaws and 3 layers of rubber pads are glued to these plates to provide rough surface to grip or hold the blocks.

Then this gripper is mounted to a mild steel plate of length 14 cm here this length is selected because length of block is 12 cm (scaled down) and 1 cm tolerance is given on both sides so that block can be easily picked and placed and at the edges this plate is bent so that it can be attached to the gripper arm with nut and bolt in order to get swaying motion so that while gripper is moving to and fro the gripper should remain in the same position in whole gripper assembly. Gripper and assembly is as shown in fig. 4 (a) (b) and (c).

The arm length of gripper is 200 mm (space constrain on platform) material used for this arm is mild steel and to the one end of the arm clamp is attached which contains gripper, to the other end a DC motor is attached with torque 38 kg-cm and 60 rpm. This specific motor is selected because gripper has to pick and place block fast. The mechanism used for the motion of the whole gripper is explained below.

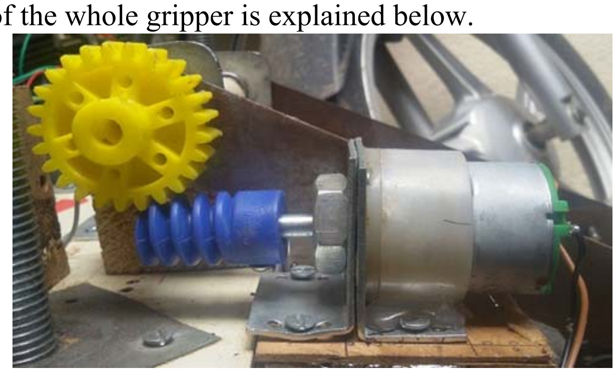

Fig.4: (a) worm drive with motor

Fig.4: (b) Gripper

Fig.4: (c) gripper with arm

BOTTOM PART (BASE): This is the part on which all the other components (middle part, top part) are mounted. The base is of 390×360×15 mm dimensions (as per design). Material used for the base is Nylon, 4 holes of different diameter are drilled at a distance of 50 mm from both the edge. A bore hole of diameter 2.7 cm top and 1cm depth are drilled to fit bearings (Standard available in market) in that holes and then screw rod are fitted into it and at the center a DC motor of torque 38 kg – cm is fitted and a sprocket is fitted to shaft of DC motor with pin. Sprockets are mounted to screw rod with grub screw a chain is connected to all the sprockets .As the motor rotate it will rotate the chain as a result all rods will rotate and platform move up and down. Assembled components are as shown in figures 5 and 6.

Fig. 5: Base, platform, top plate assembly

Fig.6: Nylon base with screw rods, wheels, platform and gripper

ELECTRONIC COMPONENT DESCRIPTION

8051 MICROCONTROLLERS: The 8051 is a low-power, high-performance CMOS 8-bit microcontroller with 4K bytes of Programmable flash Memory and Erasable Read Only Memory (PEROM). The device is manufactured using Atmel's high-density nonvolatile memory technology and is compatible with the industry-standard MCS-51 instruction set and pin out. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer. By combining a versatile 8-bit CPU with Flash on a monolithic chip, the Atmel 8051 is a powerful microcontroller which provides a highly-flexible and cost-effective solution to many embedded control applications.

Digital Display and key Board: Digital display and Key board is used to enter the number of blocks and to enter the number of layers. as soon as power is supplied digital display will show to enter the number of blocks after entering the number of blocks it will show to enter the number of layers to be laid, then robot starts working. Digital display and Key board is as shown in fig. 7. With the help of keyboard maximum number of blocks and maximum number of layers to be laid is 16, depending on the number of block and layers required we can enter number of blocks and layers.

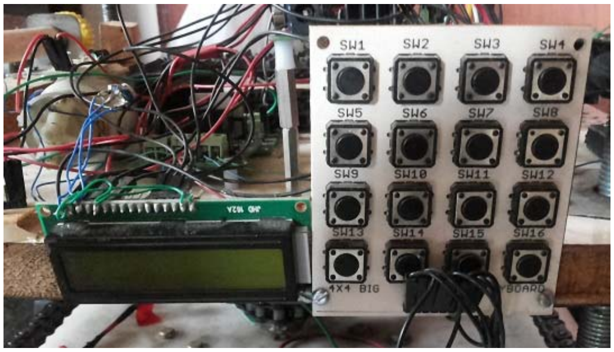

Fig.7 : Digital Display and keyboard

IR SENSORS: An Infra-Red sensor shown in fig.8, detects Infra-Red light/white light from a particular object/line and then converts light energy to electrical energy. An IR sensor pair consists of an emitter and a detector. The emitter is blue in color and the detector can be grey, black or white in color**.**

Fig. 8: IR sensor

DC MOTORS: These are very commonly used in robotics. DC motors shown in fig.9 can rotate in both directions depending upon the polarity of current through the motor. These motors have free running torque and current ideally zero. These motors have high speed which can be reduced with the help of gears and traded off for torque. Speed Control of DC motors is done through Pulse Width Modulation techniques, i.e. sending the current in intermittent bursts. PWM can be generated by 555 timer IC with adjusted duty cycle. Varying current through the motor varies the torque.

Fig. 9: DC MOTOR

TRACK WHEEL: Track wheel shown in fig.10 is a circular wheel with rubber grip fastened on DC motor shaft by screw. Track wheel provide help in movement of robot in any direction.

Fig. 10: Track wheel

RELAY: A relay is an electrically operated switch as shown in fig.11. Many relays use an electromagnet to mechanically operate a switch but other operating principles are also used, such as solid- state relays. Relays are used where it is necessary to control a circuit by a low power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal, the first relays were used a long distance telegraph circuits as amplifiers they repeated the signal coming in from one circuit and re–transmitted it on another circuit. Relays were used extensively in telephone exchanges and early computers to perform logical operations.

A type of relay that can handle the high power required to directly control an electric motor or other loads called a conductor. Solid –state relays control power circuits with no moving parts, instead using a semiconductor device to perform switching, Relays with calibrated operating characteristics and sometimes multiple operating coils are used to protect electrical circuits from overload or faults.

Fig.11: Relay

MOTOR DRIVER: A motor driver is a device or group of devices that serves to govern in some predetermined manner the performance of an electric motor. A motor controller might include a manual or automatic means for starting and stopping the motor, selecting forward or reverse rotation, selecting and regulating the speed, regulating or limiting the torque, and protecting against overloads. Motor driver is as shown in fig.12

It is an electronic circuit which enables a voltage to be applied across a load in either direction. It allows a circuit full control over a standard electric DC motor. That is, with an H-bridge, a microcontroller, logic chip, or remote control can electronically command the motor to go forward, reverse, brake, and coast. H-bridges are available as integrated circuits, or can be built from discrete components. A "double pole double throw" relay can generally achieve the same electrical functionality as an H-bridge, but an H-bridge would be preferable where a smaller physical size is needed, high speed switching, low driving voltage, or where the wearing out of mechanical parts is undesirable.

Fig.12: Motor Driver

DESIGN AND SPECIFICATION OF GRIPPER:

Maximum mass the gripper can lift = 200×10^{-3} kg

Mass of Wooden Block to be lifted = 70×10^{-3} kg

Total mass of the gripper including arm = 491×10^{-3} kg

Torque = Force × Perpendicular Distance

$=4.816 \times 200 \times 10^{-3} = 0.9632$ N-m

Force required to grip the block = $70\times 10^{-3}\times 9.81 = 0.6867$ N

Motors Specification:

Servo motor: Torque = 0.981 N-m, Angle = 180^0

DC geared motor: Torque = 3.727 N-m, Speed = 60 rpm

DESIGN AND SPECIFICATION OF SCREWROD: Screw rod is used for up and down movement of the middle plate form.

Material : Mild Steel

Yield stress : 324 N/mm^2

Assumed FOS : 4

Allowable Stress = 81 N/mm^2

Allowable Shear Stress = 40.5 N/mm^2

General Torsion equation:

$$\frac{T}{J} = \frac{G\theta}{l} = \frac{\tau}{r} \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where T = Torque (N-m)

J = Polar Moment Of Inertia = (π/32) d^4 (mm^4)

τ = Shear Stress (N/mm^2)

r = Radius of Screw Rod (mm) = 6 mm

J = (π/32) 12^4 = 2035.75 N/mm^4

T =13741.31 N-mm = 13.741 N-m

Motor specification:

DC geared Motor: Torque = 3.727 N-m, Speed = 60 rpm

DESIGN AND SPECIFICATION OF BASE: This part is made up of nylon sheet. Which carry all the load of the top part. Even it provides support to the screw rod for the free rotation over the bearing. Bottom part consists of chain sprocket bearing motor.

Material : NYLON

Density : 1330 kg/m^3

Tensile Strength: 48 N/mm^2

Young's Module: 3.4 GN/mm^2

Total mass acting on the Base: M = 15 Kg

Total force acting on the Base: F = M×g = 147.15 N Where g = Acceleration due to gravity (9.81 m/Sec^2)

Maximum Stress: $\sigma_{max} = (B_{max} \text{ X } D_{max})/ I$

Where B_{max} =Maximum Bending Moment (N-m)

D_{max} =Maximum Deflection (m)

I = Moment Of Inertia (m^4)

B_{max} =FL/4 = 14.347 N-m

Where L= Length of the Base (m)

D_{max}=h/2 = = 0.0075 m

Where h = Height of the Base (m)

I = $(bh^3)/12 = 1.0125\text{x}10^{-7}\text{m}^4$

Where b = Breadth of the Base (m)

Therefore σ_{max} = 1062740 N/m^2

Assuming base as a simply supported beam. The maximum deflection of simply supported Beam is given by the fallowing expression

$D_{max} = (FL^3) / (48EI) = 0.0005129$ m

DESIGN AND SPECIFICATION OF CHAIN AND SPROCKET:

Pitch of Chain: $P \leq 10\times[60.67/n_1]^{2/3}$

Where n1 = Speed of Motor = 60 rpm

$P \leq 154.4$ mm = 15.4 cm

From Design Data Hand Book (k . Balaveera Reddy)

P =101.60 (Chain Number = 232A)

Breaking Load = 169.07 KN, Measuring Load = 2000.56 N.

Number of teeth on the sprocket $(n_1/n_2) = 1$. (As the speed is constant: $n_1 = n_2$)

$(n_1/n_2) = (z_1/z_2) = 1$

where Z_1 = Number of teeth on sprocket 1

Z_2 = Number of teeth on Sprocket 2

$Z_1 = Z_2$

Pitch Diameter: D= P/sin(180/z)= 499.89 mm = 49.9 cm

Velocity: v= (Pz_1n_1)/(60x1000) = 2.566×10^{-3} m/sec

Tangential force: F= (1000xP)/v = 4687.5 N

Where p = Power (kW)

Allowable Force: Fa = Fu/ (FOS x Ks) = 3898.75 N 3.89 KN

Where Fu= Ultimate strength of the chain N/strand

Ks= Service factor

Number of Strands i: Tangential force/Allowable force = 1.201(approx.) = 1

PROCESS CARRIED OUT DURING FABRICATION: different processes carried out to finish the fabrication.

Planning and marking: This is the first process which is carried to fabricate the robot. This process basically consists of Design of Base on which whole assembly is mounted .Once the design was completed next material required for fabrication was selected for each part .Then according to the design dimension markings were made on each part according to the plan .

Cutting: This is the second process where the parts on which marks were made according to design were cut .for cutting purpose cutting machine was used for cutting big parts and smaller one were cut by using hack saw blade. Rods were cut in Lathe machine by fixing one side of the rod in the wise of the lathe.

Filing: In this process the components which were cut in the previous process were filed. This process was carried out to get all parts with accurate measurements and good finish at the cut edges. This filling process is carried out by using file. Rough file was done using rectangular file. Finishing was done using triangular and round file.

Welding: After filling process welding is done for the required components. During fabrication it was required to rotate the screw rod in the holes which were drilled in the platform in that holes M16 nut were fitted but these nut were not tightly fitted in that platform .They were continuously coming out .For the tight fit the nuts were welded to a 1mm thickness mild steel plates and then steel plates were fitted to platform with screws. Welding was also done between bearing and clamps of the gripper.

Painting: This was the last stage where all the dust and rust was removed and the parts were painted .metal paint is used. Painting was done to avoid rust and effects from the Environment.

Assembly: Once all the parts which were required to be painted is done next all the parts were assembled to perform the required task. First the wheels were fitted to the base , then bearing were fitted in the holes which were made the base in that screw rods were fitted, sprockets were tightly locked to the screw rod with the grab screw then at the center a high torque dc motor was fixed. Chain is fitted to the motor and to the sprockets.

Platform is fitted into four rods and brought down to certain height by rotating all the rods with the help of motor. Then according to the design conveyer is mounted on the platform. The conveyer was made to run by using 2 DC motors then a tray is fixed on to the platform according to the design for free movement of blocks to drop on to the conveyer. Then the gripper is mounted on to the platform so that it can correctly pick the block from platform and place it.

Top plate is fitted at the other end of the rod in order to provide support for the rotation of rod so that platform can easily move up and down to perform the operation.

After the Assembly was completed programming was carried out for functioning of all parts to get the required task, for this Microcontroller 8051 was used the program was fed to the microcontroller so that robot can perform the task according to the program.

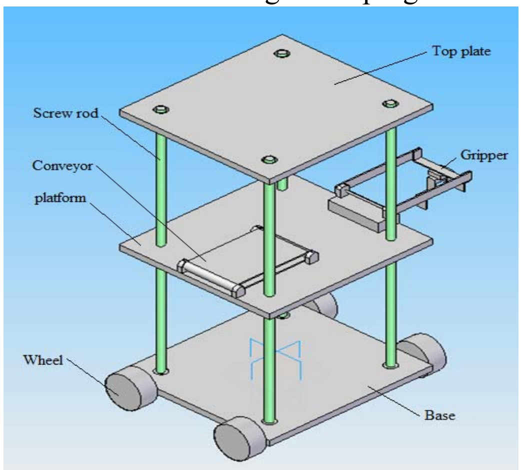

Fig. 13. Isometric view of model

WORKING OF ROBOT: Here as per the design robot is fabricated and programmed. Flow chart of programming is as shown in fig. 15, Once the power is supplied according to the program digital display asks to enter number of blocks after entering number of block it will asks to enter the number of layers to be laid once number of layers are entered, The conveyer belt which is driven by DC motor will start running when block is placed on conveyor block will move from one end of conveyor towards other end where gripper will pick it, At the other end of conveyor an IR sensor is used. It is programed to sense block so that as soon as sensor sense block according to program conveyor will stop moving and gripper will stars to move towards conveyor to pick block as it reaches the conveyor jaws of gripper will be in open condition and it will easily picks block from conveyor here a DC motor which is attached to gripper arm drives the gripper then the gripper will start moving and its take 87 degree to rotate in the clockwise direction after reaching near to the block according to the delay timing of the DC motor of the gripper will catch the block then again the DC motor rotates through angle 134 degree and place the block

After placing one block in appropriate position the wheels will start moving in the forward direction which is attached to the base part. The distance moved by the robot is to be 125 mm .Then again gripper will pick blocks and place according to how much number of blocks to be laid were entered at the beginning of operation in digital display, after blocks are laid platform will be lifted by one layer that is 25 mm height of the block then again it will start laying bricks from that position only robot will work like this until it completes all the entered number of layers are laid. Once the operation is completed digital display will shows that operation is completed and according to program robot will come to its initial position i.e. during operation how much number of layers of blocks it laid after completion of operation platform has to be lowered to that numbers of layers. Here platform is raised layer by layer by using DC motor which is connected to 4 screw rods with help of chain and sprocket. The final working model of block laying robot is as shown in fig. 14.

Fig.14: Final assembled Block Laying Robot

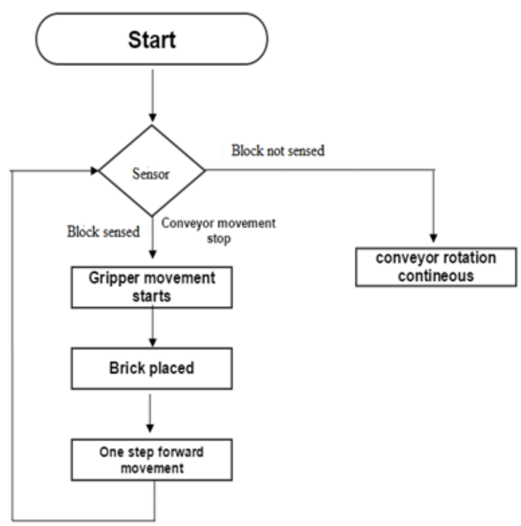

Fig. 15: Flow chart of programming

RESULTS:In order to determine the performance of the robot trials were conducted. From these trials we got that as per the program robot is working and as we enter the inputs i.e. number of blocks and number of layers following results were obtained.

The time taken by the gripper to pick one block from conveyor and place it in appropriate position is 22 seconds.

The time taken to lift the platform by one layer to lay next layer of blocks of thickness 25 mm is 13 seconds.

The time taken by robot to move in forward and backward direction to lay blocks one after other is 1 seconds.

8 trials were conducted in order to check the accuracy, for that a combination of 3 bricks 1 layer is used and the following graph was plotted.

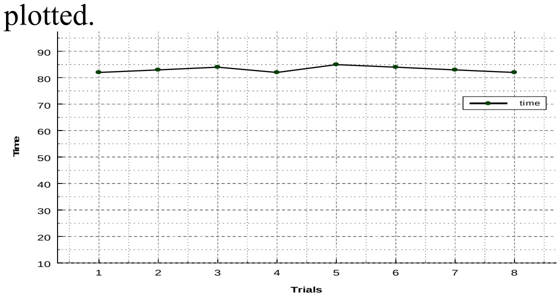

Fig.16 : Graph Time vs. Trials

From graph fig.16 we can see that for trial with a combination of 3 bricks and 1 layer the time taken by robot to lay the blocks varying between 82 sec to 85 sec. So an average of 83 seconds is taking to lay 3 blocks with 1 layer. This can be verified as below.

Time taken for one block = 22 sec

Time taken for three blocks = 66 sec

Time to move one block distance is = 1 sec

For three blocks = 3 sec

Time taken to lift platform by one layer is = 13 sec

Therefore total time taken for 3 bricks 1 layer is = 66+3+13 = 82 sec

CONCLUSIONS: As per the design robot is fabricated, programmed to lay the blocks and is working as programmed.

One of the constrain of this robot is that it will start laying block only after 200 mm above ground level and at topmost height it cannot build completely because of gripper arm length as it may touches the ceiling because the gripper is mounted on certain height at the top end of arm due to the length of arm it may touch ceiling. Hence in future new methods should be used to remove this constrain.

In order to make the gripper to pick blocks accurately from conveyor, spacers can be provided so that gap present between blocks will help the gripper to pick block without interfering next block which is on conveyor.

As we know in today's world masonry construction remains non-automatized. Hence instead of block if we use brick results in avoiding the following constraints.

Working for 24×7 in the construction field is difficult for labours as they became tired but this robot has the capacity to work continuously without getting tired.

Rate of construction is very less by labour because of human fatigue, but robot can work without any fatigue.

While working in construction area chances of getting injured to labour is quite common, this can be avoided by using robot.

Always any machinery will reduce the total cost of work; this robot also follows the same concept. But initial cost of machinery may be high. In long run working with machinery surely reduces the total cost of work.

While constructing the wall there will be wastage of masonry (mixture of mortar) and it is undesirable but by using this robot this wastage can be reduced. (This particular concept is mentioned in future scope).

From fig.16 we can conclude that for 8 trials of laying of blocks the average time taken by robot is 82 seconds with ± 3 seconds.

FUTURE SCOPE: As per the design the robot is fabricated. A few improvements in the robot can increase the efficiency.

Some of the improvements to be made in robot are as follows.

This robot is only laying the blocks but to build wall masonry some improvement are to be done. Hence a steel container of some weight that the robot can take it along with it is be placed by extending the base. A pump which can supply masonry from the container to the block can be used. Before laying the bricks, a layer of masonry is to be laid and for this purpose a nozzle is used which can provide a layer of masonry from Container. One important thing to be considered that the nozzle should be on the both sides of gripper because the robot is programmed to move in such a way that when the robot start to lay bricks from right to left as per the program. When one layer is completed robot will lift the platform to height of the block with some plus or minus tolerance and from there (left) it will start laying bricks. Hence if nozzles are at the edge of platform it is a better option.

During constructing a wall when block is laid, some amount of force has to be applied on the block so that it should strongly form bond with masonry. As our designed robot is not applying any force so a roller which is having some weight can be used. This roller should be attached on both sides of robot because of the above reason. The roller should be attached to such a position that after laying the block from the gripper it should apply some force on to block so that it can strongly form bond with masonry. The gap between block and roller should be of very small distance.

Sensors should be attached to check the quality of block and proportion of water, cement and sand which results to a good masonry mixture so that a strong wall can be built and no damages are done.

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