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Design and Manufacturing of Material Handling Robot Having XY Gantry Mechanism

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Abstract: *In powder coating industry there will be heavy and large number of components for the process. For powder coating process the components need to be taken to three stages. For taking this component to these stages it needs to be lifted. This lifting is time consuming and difficult. We need labors for this and thus it can create accident. Thus, for this purpose we are creating a mechanism that would save our time. For horizontal and vertical movement, we use lead screw. The feed is supplied to the lead screw with DC motor. And for holding the component we use grippers. Today because of developments in technology various industries use robots in material handling to avoid accidents in hazardous chemical industries and for increasing efficiency, accuracy, and safety of workers. So, in this work we are developing XY gantry mechanism for material handling in powder coating. The main aim of our work is to manufacture a robot for material handling purpose. For the material handling operation, the robot will be consisting of rack and pinion arrangement in X and Y directions. While working in X direction rack will be fixed and pinion will be moving and for Y direction rack will be moving and pinion will be stationary. For pick and place operation there will be a gripper. The pick and place operation and all motion will be guided by DC motor.*

Keywords: Robot. Gripper, Gantry, Material Handling

I. INTRODUCTION

An easy way to comply with the conference in modern industries material handling plays an important role to increase the productivity and decrease the cost of product. The material handling can be defined as an integrated system involving such activities as moving, handling, storing, and controlling of materials by means of gravity, manual effort or power activated machinery. Efficient material handling is needed for timely delivery and reduced idle time of machines due to non-availability or accumulations of materials at workstations. Safe handling of materials is important in a plant as it reduces wastages, breakage, loss, and scraps. The last two decades have witnessed a significant advance in the field of robots application. Many more applications are expected to appear in space exploration, battle field and in various actives of daily life in the coming years. A robot is a mechanical device that performs automated tasks and movements, according to either pre-defined program or a set of general guidelines and direct human supervision. These tasks either replace or enhance human work. Robot is an integral part in automating the flexible manufacturing system that one greatly in demand these days. Robots are now more than a machine, as robots have become the solution of the future as cost labour wages and customer's demand. Even though the cost of acquiring robotic system is quite expensive but as today's rapid development and a very high demand in quality with standards human are no longer capable of such demands. Research and development of future robots is moving at a very rapid pace due to the constantly improving and upgrading of the quality standards of products.

II. LITERATURE SURVEY

The last two decades have witnessed a significant advanced in the field of robot applications. A robot is a mechanical device that performs automated tasks and movement according to their set of general guidelines and direct human super vision. The tasks either replace or enhance human work such as in manufacturing or manipulation of heavy and hazardous material handling [1]. In today's competitive global market, industries and manufacturing companies demand adjustable sizes, higher quality, flexibility, and shorter lead time types of products to be manufactured. Companies need to attain customer satisfaction and cost reduction in production operations [2]. A gantry mechanism

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robot low cot with motion in X and Y direction was manufactured. It was an Arduino based project [3] The production processes such as powder coating and dipping processes are done manually which are time-consuming and sometimes hazardous to laborers. There is a need for automation control in doing such processes to reduce labour costs, and time consumption, and increase accuracy. The result has shown that using the gantry mechanism with automation reduces the cost of production and prevents human errors [4]. The use of gantry crane systems for transporting payload is very common in building constructions. However, moving the payload using the crane is not an easy task especially when strict specifications on the swing angle and on the transfer, time need to be satisfied. Various attempts in controlling gantry cranes system based on open- loop and closed-loop control systems were proposed [5]. The objective of the paper was to provide an information of gripping mechanisms for industrial robots. A brief description of a variety of conventional gripping devices used for industrial robots is given [6]. Robot manipulator is an essential motion subsystem component of robotic system for positioning, orientating object so that robot can perform useful task. The main objectives of the work done was to design and implement a 4-DOF pick and place robotic arm. Robot manipulators were designed to execute required movements. The controller used for servo motor actuation is ATmega 16 Development board [7]. The paper presented a design procedure for lead screw design [8]. Pneumatic robots are essential for material handling in chemical industries where electric or hydraulic robots are unsuitable due to fire hazard. 3 axes (3 Degrees of Freedom) articulated pneumatic robotic arm was designed and assembled in this project along with its control system [9]. Material handling system will have various activities like moving, handling, storing, and controlling of materials by means of manual or power actuated machineries. Due to the hazardous materials, different types of robots are used to handle the materials in chemical industries. The work deals with the design and fabrication of robot for material handling applications [10].

III. VARIOUS MATERIAL HANDLING APPLICATIONS

Assembly Pick and place robotic arm used in assembly applications grab incoming parts from one location, such as a conveyor, and place or affix the part on another piece of the item. The two joined parts are then transported to the next assembly area.

Packaging – Pick and place robotic arm is used in the packaging process grab items from an incoming source or designated area and place the items in a packaging container.

Bin picking – Pick and place robotic arm is used in bin picking applications grab parts or items from bins. These pick and place robots typically have advanced vision systems allowing them to distinguish colour, shape and size to pick the right items even from bins containing randomly mixed items. These parts or items are then sent to another location for assembly or packaging.

Inspection – Pick and place robotic arm is used for inspection applications are equipped with advanced vision systems to pick up objects, detect anomalies and remove defective parts or items by placing them in a design at end location.

IV. NEED OF X-Y GANTRY ROBOT

A gantry robot is a modified style of Cartesian robot, using two X (or base) axes rather than the single base axis found in Cartesians. The additional X axis (and sometimes additional Y and Z axes) allows the robot to handle larger loads and forces, making them ideal for pick and place of heavy payloads or parts loading and unloading. Each axis is based on a linear actuator, whether it's a "homemade" actuator assembled by the OEM or integrator, or a pre-assembled actuator from a linear motion company. This means that there are almost limitless options to allow for any combination of high speeds, long strokes, heavy payloads, and high positioning accuracy. Special requirements for harsh environments or low noise are easily incorporated, and if the application requires simultaneous but independent processes to take place, the horizontal axes can be built with linear motors using multiple carriages.

Gantry robots are typically mounted over the working area (hence the common term, "overhead gantry"), but if the part is not suitable for handling from above, as is the case with solar cells and modules, the gantry can be configured to work from below the part. And while gantry robots are typically thought of as very large systems, they are also suitable for smaller, even desktop-sized machines. Because a gantry robot has two X, or base, axes, the moment load presented by the Y and Z axes, as well as the working payload, are resolved as forces on the X axes. This significantly increases the systems stiffness, and in most cases allows the axes to have longer stroke lengths and higher speeds than a similar

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Cartesian robot. When there are two axes in parallel, it is common for only one of them to be driven by the motor, to prevent binding that could result from slightly out-of-sync motion between the two. Instead of driving both axes, a connecting shaft or torque tube is used to transfer motor power to the second axis. And in some cases, the second axis can be an "idler" or follower, consisting of a linear guide to provide support for the load, but no drive mechanism. The decision of whether and how to drive the second axis depends on the distance between the two axes, the rate of acceleration, and the stiffness of the connection between them. Driving only one in a pair of axes also reduces cost and complexity of the system. Sizing a Cartesian or gantry robot is more complicated than sizing a SCARA or articulated robot (which are typically specified with three parameters: reach, speed, and accuracy), but manufacturers have made the process easier over the past several years by introducing pre-configured systems. Cartesian and gantry robot manufacturers, making them easy to integrate into a design or work flow layout, much like SCARA and articulated robots. While articulated and SCARA robots are easily recognized, and Cartesian robots are widely deployed, the gantry design overcomes the limitations in load, speed, reach, and repeatability, with an unmatched level of customization and flexibility.

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V. APPLICATIONS OF GANTRY MECHANISM

Gantry Cranes

Where the load remains beneath the gantry structure, supported from a beam are well suited to lifting massive objects such as ships' engines, as the entire structure can resist the torque created by the load, and counterweights are generally not required. These are often found in shipyards where they are used to move large ship components together for construction. They use a complex system of cables and attachments to support the massive loads undertaken by the full gantry cranes. Some full gantry cranes of note are Samson and Goliath and Taisun. Goliath are two full gantry cranes located in the Harland and Wolff shipyard in Belfast have spans of 140 meters and can lift loads of up to 840 tonnes to a height of 70 meters. In 2008, the world's strongest gantry crane, Taisun, which can lift 20,000 metric tons, was installed in Yantai, China at the. Yantai Raffles Shipyard. In2012, a 22,000-ton capacity crane, the" Honghai Crane" was planned for construction in Qidong City, China.

Rubber tyres gantry cranes in the foreground, ship-to-shore gantries background right, at Port of Shanghai. Smaller gantry cranes are also available running on rubber tyres so that tracks are not needed. Rubber tyres gantry cranes are essential for moving containers from berths throughout the rest of the yard. For this task they come in large sizes, as pictured to the right, that are used for moving to straddle multiple lanes of rail, road, or container storage. They also can lift fully loaded containers to great heights. Smaller rubber tyred gantry cranes come in the form of straddle carriers which are used when moving individual containers or vertical stacks of containers.

Portable gantry crane systems, such as rubber tyred gantry cranes, are in high demand in terminals and ports restricted in size and reliant on maximizing vertical space and not needing to haul containers long distances. This is due to the relatively slow speed yet high reach of rubber tyred gantry cranes when compared to other forms of container terminal equipment.

VI. MECHANICAL DESIGN

Several constraints were considered in the stage of mechanical design. They are Minimal and Maximal Dimensions, Weight, Moving Ability, Motors. Any of these influenced the others and was sometimes in contradiction. We wanted light robot, with high power and torque to move easily and firmly, and it must do material operation easily, these were the main features for the robot we had in mind.

Minimal and Maximal Dimensions

The maximal dimensions of structure are 500mm, total height is 270mm and width is120mm

Weight

Weight is another critical parameter. The total weight of the moving structure is going to come on a rack and pinion arrangement, which we used for motion of the robot. So, we tried to select material and all the components as less as possible in weight and according to required capacity.

Moving ability

The moving ability of the robot was very important parameter because the basic need of the robot is to do material handling operation, so the motion of robot should be in proper manner and required way. We use rack and pinion arrangement for the motion of the robot. For transmission DC motors are used and the arrangement used in X-Y directions. We use guide ways to support and guide moving assembly

Motors

We used three motors. The two DC motors of capacity 12 V, 2Amp and 10rpm used in operation in Y direction and pick and place operation of gripper. We used the 30 rpm motor for X direction motion.

DESIGN CALCULATIONS

Following stresses act on pinion: -

1. Failure due to bending stress.
2. Failure stress due to crushing stress.
3. Failure due to abrasive wear.
4. Failure due to corrosive wear.

1. **Pinion**

Material-Plastic

Ultimate tensile strength (Sut)=40Mpa

No of teeth(z)=18

Bending Stress (σb) = Sut/3= 40/3=13.333

Power (P) = Voltage*current=12*2=24watt Speed (n)=30rpm

Levis form factor(Y) =0.308

Face width (b) =10m

Diameter (d) = mX z=18m

where m = module of pinion

Beam strength

(Sb)=Bending stress x face width x module x Levis form factor= σ_bx b x m x Y

=13.33x10m x m x 0.038

=41.0656 x m^2.   N   …{1}

Velocity(v) = πdn / 60

= (3.142x18mx 30) / (60x1000)

=0.0282m   m/s   …{2}

Tangential force (Pt) = P/v

= (24 x10^(-3)) / 0.0282m

=0.8510/m,   N

Velocity factor (Cv) = 6/ (6+v)

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=6/(6+0.0282m) …{4}

Effective load (Peff) =Cs x Pt /v

= 0.2836 x (6+0.0282m)/m …{5}

FOS=2

Beam strength= FOS x effective load

m2x41.06564=2x0.2836x(6+0.0282m)/m

Solving above equation, we get module as m=0.43628 … {6}

From standard module table of V. B. Bhandari of chapter spur gear of section17.7-pgno.655 module=1mm, m=d/z.

If m increases then diameter increases as a result size of gear increases and other respectively.

2. **Rack**

As pinion is weaker than rack, module=1mm

3. **Motor selection**

Distance travelled in Y direction is 280mm in 30sec Hence we selected10rpm speed of motor

Distance travelled in X direction is 750 mm in 30sec Hence we selected 30 rpm speed motor.

4. **Calculation of diameter for guide ways.**

Material-Mild steel (MS)

Minimum Yield strength =55% of minimum Tensile strength

Tensile strength of MS = 340 N/mm2

Therefore,

Yield strength (Syt)= 0.55 x 340Syt= 187N/mm2

Now according to Maximum shear stress theory Ssy= 0.5x Syt

Permissible shear stress is,

r=Ssy/ FOS

r=0.5 x Syt/FOS =0.5 x187/2.5

r=37.4N/mm2

SFD and BMD Calculations

Load =1Kg

Force = 1x9.81N

Central load of 9.81 N acts on the two guide ways.

Hence, 4.91 N load acts on each.

Reactions at point A and B.

Simply supported beam with point load at centre RA= RB= F/2=2.45N

SFD calculations at each point.

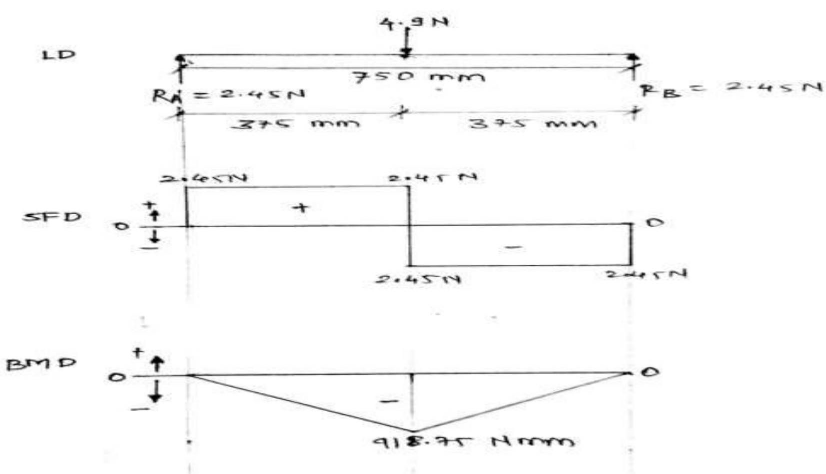

Fig1:SFD & BMD Diagram

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a) Shear force at pt. A.
Vertical upward force of 2.45 NSFA= 2.45N
b) Shear force at section AC, No force
SFAC= 2.45 N
c) Shear force at pt. C.
Vertical downward force of 4.9
NSFA= 2.45-4.9 N=-2.45N
d) Shear force at section CB,
No force SFCB=-2.45 N
e) Shear force at pt .B.
Vertical downward force of 2.45
NSFB= -2.45+2.45N=0

BMD Calculations

a) BM at point A,
M_A= (-4.9x375) +(2.45x750)
M_A= 0

b) BM at point C,
M_A=(2.45x375) =-918.75Nmm…(considering right section CB)

c) BM at point B,
MB= (4.9x 375) -(2.45x 750) =0
Therefore, Maximum Bending Moment is
Mb= 918.75Nmm

Calculation of guide way diameter
r= (16Mb)/(πd3)=(16x 918.75)/(πd3)37.4 =9358.310/d3
Solving above equation, we get d =6.314mm
Hence, we selected standard diameter d =10mm

5. Calculations for Gripping Force.
Gripper type –Screw type gripper Assumption -We have to pick 50g of weight

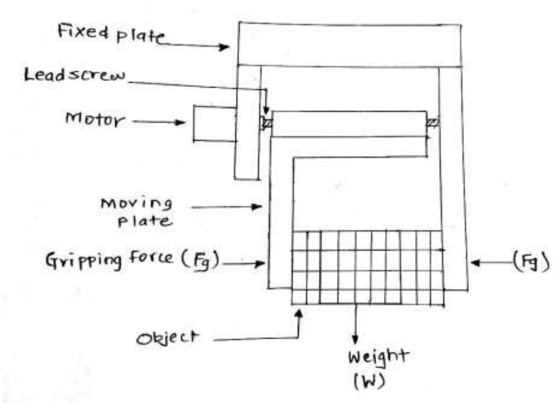

Fig2: Gripper

μx nfxFg= W

0.25 x 2 x Fg = 50 x 9.81Fg= 0.981N

Where,

μ = Coefficient of friction W=Weight of object

nf=Number of fingers of gripper Fg= Gripping force

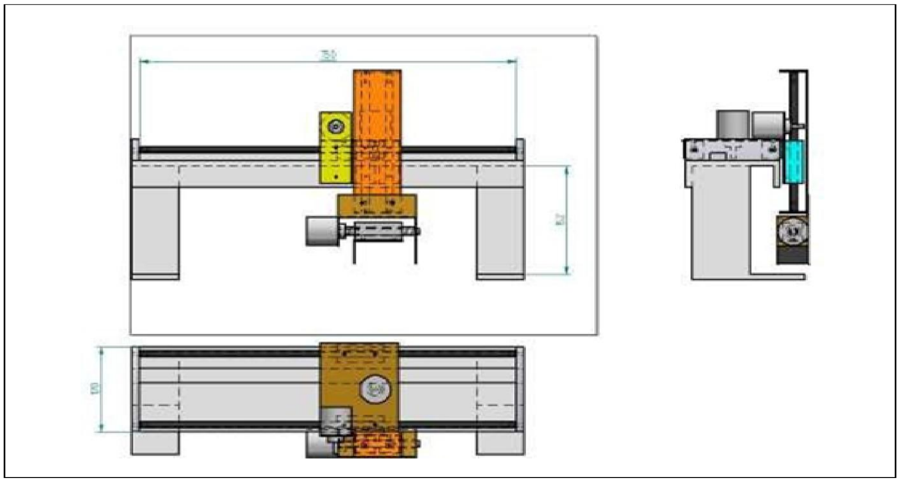

Fig3: CAD Model of the Robot

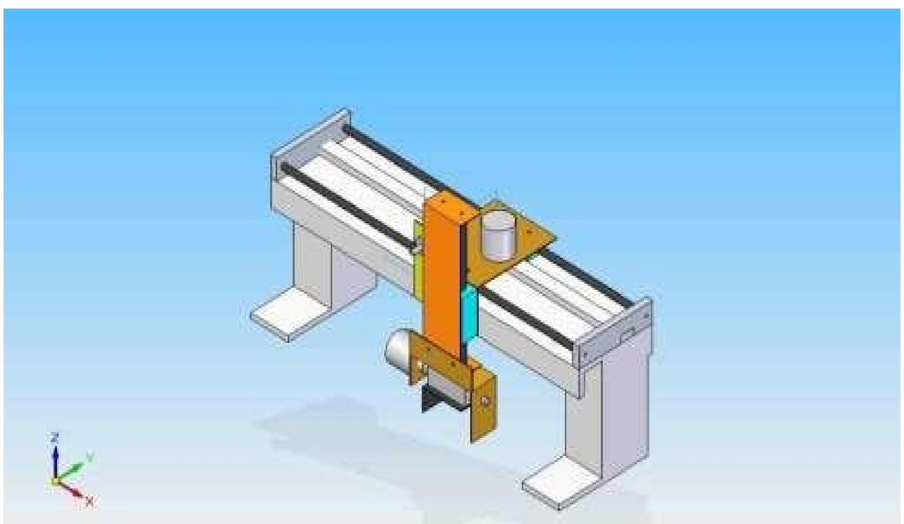

Fig4: CAD Model of the Robot

VII. THE COMPONENTS OF ROBOT

Stepper motor:

Most of the application runs on servomotor, but accuracy cannot be maintained. So, to maintain better accuracy stepper motor is chosen. There are several types of stepper motor, they are hybrid synchronous stepper, variable reluctance stepper, permanent magnet stepper. Main two models are unipolar and bipolar stepper motor. In this paper, 6-wire unipolar hybrid synchronous motor of 1.8-degree step angle is used for better positioning and accuracy. Functioning of motor is based on stepping action. There are several stepping modes. They are full step, half step, micro step. Normally the sequence for motor is A+ A- B+ B-. Main consideration of stepper motor is torque and power rating. Based on the

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torque, load can be used for driving. Two stepper motor is used for x-axis and y-axis movement and their torqueis5kg/cmand10kg/cm

Guiding shaft:
For the movement of solid block structure to move along its path without any shake, guide rod is used. Based on load, material of the guide rod is chosen. There are several materials such as mild steel, EN8, EN19, EN24, aluminium. Mild steel cannot withstand heavy load whereas EN8 and EN24can withstand heavy load. EN8 material is used here.

Limit switch:
It is a switch operated by the motion of a machine part or presence of an object. They are used for control of a machine, as safety interlocks, or to count objects passing a point. It is an electromechanical device that consists of an actuator mechanically linked to a set of contacts. When an object comes into contact with the actuator, the device operates the contacts to make or break an electrical connection.

Aluminium Profile:
Aluminium is preferred than iron due its rust-free nature and good conductivity as well as best heat sink. Based on the manufacturer profile size may vary. Example sizes are 30x30, 40x40 square profile.

Poly Urethane belt:
There are several types of belts made of different material. In this paper, timing belt is used because of its accuracy and positioning. Timing belts are available in rubber, fibber re-in forced in rubber and Poly Urethane material with different circumference sizes such as 550mm, 1100mm are available. If application is based on the oil and water, then poly urethane belt is preferred. If the application is based on the open environment, then fibber re-in forced belt is preferred.

Pulley:
Pulley can be made with different type of material such as plastics, steel, aluminium and nylon block. As compared to other material aluminium gives long life. Pulley parameters are hub, pitch, flange, key lock, inner diameter and outer diameter.

Bearing:
In this paper, linear and ball bearing are used. Linear bearing is used for linear movement in guiding shaft and ball bearing is used for rotational movement in free end pulley support. Based on the outer diameter of guiding shaft, both linear and ball bearing are chosen. Care must be taken that outer diameter of guiding shaft must be equal to inner diameter of bearing.

Nylon block:
Since it is one time machine design, cost is one of the main factors. So, it is best alternative of mild steel material. Drilling can be done in lathe or milling machine. While drilling the through hole for inserting linear bearing, through hole must be greater inner diameter of the linear bearing.

Microcontroller:
To use the microcontroller pins effectively, best controller must be chosen. Pin in it. It is ultra-low power micro controller of 3.5v with inbuilt UART, UCSI in the launch pad. This microcontroller is of Texas Instruments manufacturer.

Lead screw:
For design purpose mechanical analysis of lead screw affected by various parameters like efficiency, torque requirement and load capacity. There are numerous important for successful design of lead screw for drive system. Whenever sliding motion exists in machine, system creates vibration and which severally affects the function of system. In this work the lead screw is slide with the ball screw as system operate. The most common problem for the lead screw

is backlash. The backlashes verily affect the position accuracy of lead screw, hence both design and manufacturing of lead screw may reduce the presence of backlash.

VIII. WORKING MECHANISM

Gantry Robot Systems and Linear Modules For high-speed automation, both gantry and articulated arm robots are widely used throughout industry. Because of the many inherent advantages of the gantry robot, it is rapidly becoming the preferred choice for Parker offers seven standard gantry configurations to solve these and other automation applications. Utilization of these pre-engineered systems enables the user to redirect scarce engineering resources from motion system design to machine or process functionality. HPLA and HLE Linear Drive Modules are the primary building blocks for Parker"s seven standard gantry systems. With six different cross-sectional sizes (60,80,100,120,150, and180mm) and three bearing systems (polyamide or steel rollers, and square rail bearings), these modules can effectively, efficiently, and economically satisfy the widest range of application requirements.

IX. CONCLUSION

We designed manufactured and tested a material handling robot with x-y Gantry mechanism. It is found during testing that it saves time and labor efforts. For horizontal and vertical movement, we use lead screw. The feed is supplied to the lead screw with DC motor. And for holding the component we use grippers. Today because of developments in technology various industries use robots in material handling to avoid accidents in hazardous chemical industries and for increasing efficiency, accuracy, and safety of workers. So, in this work we are developing XY gantry mechanism for material handling in powder coating. The main aim of our work is to manufacture a robot for material handling purpose. For the material handling operation, the robot will be consisting of rack and pinion arrangement in X and Y directions. While working in X direction rack will be fixed and pinion will be moving and for Y direction rack will be moving and pinion will be stationary. For pick and place operation there will be a gripper. The pick and place operation and all motion will be guided by DC motor

REFERENCES

[1]. S. B. Satpal, S. R. Gadilkar, S. M. Gaikwad, P. D. Karande, and U. B. Kare, "Review Paper On Design And Fabrication Of X-Y Gantry Mechanism For Chemical Handling In Chemical Industries," pp. 77–80, 2018.

[2]. L. M and D. S A, "Design and Analysis of Material Handling System," J. Mines, Met. Fuels, vol. 70, pp. 155–163, 2023, doi: 10.18311/jmmf/2022/31220.

[3]. S. Jaygude, M. Kothmire, P. Lobhe, A. Sagel, and P. A. D. Sathe, "Low Cost XY Positioning System using Arduino," no. June, pp. 701–706, 2017.

[4]. H. Farshi and K. Valipour, "Comparative Analysis of Biogeography-Based Optimization and Fuzzy Logic in Load Frequency Control," Int. J. Adv. Res. Electr. Electron. Instrum. Eng. (An ISO Certif. Organ., vol. 3297, no. 1, pp. 6–8, 2007, doi: 10.15662/IJAREEIE.2015.0501001.

[5]. Wahyudi, J. Jalani, R. Muhida, and M. J. E. Salami, "Control strategy for automatic gantry crane systems: A practical and intelligent approach," Int. J. Adv. Robot. Syst., vol. 4, no. 4, pp. 447–456, 2007, doi: 10.5772/5669.

[6]. F. Y. Chen, "Gripping mechanisms for industrial robots. An overview," Mech. Mach. Theory, vol. 17, no. 5, pp. 299–311, 1982, doi: 10.1016/0094-114X(82)90011-8.

[7]. M. Hassan and M. Baqar, "Design and Implementation of a DTMF Based Pick and Place Robotic Arm," vol. 2, no. 1, pp. 232–240, 2020, [Online]. Available: http://arxiv.org/abs/2004.04863

[8]. M. V Gohil and J. Patel, "Design of Lead Screw Mechanism For Vertical Door Wrapping Machine .," vol. 2, no. 04, pp. 185–188, 2014.

[9]. P. Shyam, S. Jaswanth, U. P. Kumar, and V. V. S. S. R. K. Murthy, "International Journal of Research Publication and Reviews Design and Analysis of Turbo Jet Engine," vol. 4, no. 4, pp. 1206–1213, 2023.

[10]. S. Senthilraja, R. Gangadevi, and M. Thirugnanam, "Design and fabrication of three axis robot for material handling in chemical industries," J. Chem. Pharm. Sci., vol. 9, no. 4, pp. 2700–2702, 2016.