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Spray Painting Robot with low cost automation

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ABSTRACT: The purpose of this paper is to design, develop, and execute a low-cost automatic spraying operational robot. This contributes to the creation of low-cost spraying robots. Despite developments in robotics and their widespread applications, today's industry demands for automated spray painting are on the rise. Interior and exterior surface spraying operations have had nothing in common in terms of research. Human operators may be exposed to risks such as skin disease and respiratory difficulties as a result of the spraying paints. Furthermore, the nature of the painting method, which necessitates repetitive work and hand rising, makes it tedious, time-consuming, and effort-intensive. When robots are correctly incorporated into jobs, the entire operational process can be better managed, resulting in cost savings in human labour and time. Furthermore, it would provide the opportunity to limit or eliminate human exposure to tough and dangerous situations, resolving the majority of the issues associated with safety when many operations are occurring at the same time. The creation of an automated robotic painting system is motivated by these factors. To emphasise accuracy in system proximity sensors and controller is used in the project.

Keywords :.IR sensor, Spray Painting Robot, Worm and Worm wheel

I. INTRODUCTION

Normally, spray painting is done manually, with spray guns fixed to a stationary base, or with a six-axis robot that follows a complex trajectory that is entirely automated. Robots paint a wide variety of different items at high production rates. For example, some vehicle manufacturers demand finishers to paint all plastic trim elements at the same time in order to achieve better color matching; this is a perfect use for a robot. After the robot has been programmed, it paints millions of pieces with minor differences.

Paint application on the external surfaces is simple and straightforward, regardless of the pipe's huge diameter or length. However, painting the interior walls of the pipe gets more challenging as the pipe lengthens. Because of the length of the pipe, painting is not possible as the inner walls become inaccessible. As a result, a unique device is required to cover the whole inner-wall of the pipe, regardless of its diameter or length. This paper gives design of spray painting robot which easily paint inner wall of object.

II.LITERATURE REVIEW

Kahane et al. [1] and Warszawsky et al. [2] created a robot for interior finishing jobs such as painting, plastering, tiling, and masonry. They employed a typical robot arm with 6 DOF (Degrees of Freedom), 1.7 m reach, and a 30 kg payload.Their robot was mounted on a three-wheeled mobile robot, providing an additional three degrees of freedom. The robot can move between workstations and deploys four stabilising legs at each location. Due to its 500 kg weight, this robot cannot be employed in residential buildings. When compared to human painting, wall painting saves around 70% of the time, and ceiling painting saves an additional 20%.

Andreas Pichler et-al. [3], An automatic spray painting approach for unknown parts has been devised. There are no pre-existing CAD models or other information about the parts included in the system's input. Geometry models from a laser scanning system and customized feature extraction methods are used to completely specify the parts. Previously, only one laser scanner was used to scan the parts. The scanner-visible portions of the surfaces were modeled in a 3D geometry model, which was used to autonomously produce spray gun motions. A collision avoidance mod automatically avoids collisions between the spray cannon and the part and conveyor system.

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BerardoNaticchia et-al. [4]The paper provides information on Robotic spray painting thickness is measured in [µm] by considering different spray painting parameters like paint flow , viscosity, gravity surface tension easily deposition of paint quality measured values.

Sorour et al. [5] proposed a full-scale wall painting robot that was built around a simple two-link manipulator mounted on a mobile base. The system operated, although at a slow rate. Their work was inspired by the fact that the painting arm does not need to be a 6 DOF arm because it is overqualified for the painting job, thus it was substituted with a basic 2 link arm.

Aris et al. [6] proposed a full-scale system for ceiling painting with 3DOF without taking the platform into account and a working envelope of (84x72x122 cm). A 46m2 ceiling was painted in 3.5 hours, which is 1.5 times faster than hand painting.This robot, on the other hand, is large, has a small work space, and is mainly designed to paint the ceiling.

Shigeru Ikemotoa et al.[7]The purpose of his study is to create a learning system for automotive coating and painting operations. The characteristics of professional spray gun handling for vehicle repair painting were investigated and compared in his study. When comparing spray gun handling between specialists and non-experts, the results showed that experts have a longer running length, longer spray time, greater speed, and a narrower spray gun swing range.

A wall painting robot was designed by Pkeerthana et al. [8] using a conveyor belt, shaft, spray gun, and controller unit. Because there were fewer moving parts, it performed as expected.
an autonomous painting robot that comprises of an arm that scans the walls vertically and is mounted on a movable robot base that allows for lateral feed motion to cover the painting surface. To adjust the motion limit and change direction in the room area, ultrasonic sensors are fitted on the arm and mobile base. This effective project proposed by VaniMukundan et al.[9]

III DESIGN OF ROBOT

Design of robot consists of application of scientific principles, technical information and imagination for development of new or improvised machine or mechanism to perform a specific function with maximum economy & efficiency. Hence a careful design approach has to be adopted. The total design work, has been split up into two parts;

- System design
- Mechanical Design.

System design mainly concerns the various physical constraints and ergonomics, space requirements, arrangement of various components on main frame at system, man + machine interactions, No. of controls, position of controls, working environment of machine, chances of failure, safety measures to be provided, servicing aids, ease of maintenance, scope of improvement, weight of machine from ground level, total weight of machine and a lot more.

A. SYSTEM DESIGN

In system design we mainly concentrated on the following parameters: -

1. System Selection Based on Physical Constraints

While selecting any machine it must be checked whether it is going to be used in a large-scale industry or a small-scale industry. In our case it is to be used by a small-scale industry. So space is a major constrain. The system is to be very compact so that it can be adjusted to corner of a room. The mechanical design has direct norms with the system design. Hence the foremost job is to control the physical parameters, so that the distinctions obtained after mechanical design can be well fitted into that.

2. Arrangement of Various Components

Keeping into view the space restrictions the components should be laid such that their easy removal or servicing is possible. More over every component should be easily seen none should be hidden. Every possible space is utilized in component arrangements.

3. Components of System

As already stated the system should be compact enough so that it can be accommodated at a corner of a room. All the moving parts should be well closed & compact. A compact system design gives a high weighted structure which is desired.

4. Man Machine Interaction

The friendliness of a machine with the operator that is operating is an important criteria of design. It is the application of anatomical & psychological principles to solve problems arising from Man – Machine relationship. Following are some of the topics included in this section.

- Design of foot lever
- Energy expenditure in foot & hand operation
- Lighting condition of machine.

5. Chances of Failure

The losses incurred by owner in case of any failure are important criteria of design. Factor safety while doing mechanical design is kept high so that there are less chances of failure. Moreover periodic maintenance is required to keep unit healthy.

6. Servicing Facility

The layout of components should be such that easy servicing is possible. Especially those components which require frequents servicing can be easily disassembled.

7. Scope of Future Improvement

Arrangement should be provided to expand the scope of work in future. Such as to convert the machine motor operated; the system can be easily configured to required one. The die & punch can be changed if required for other shapes of notches.

8. Height of Machine from Ground

For ease and comfort of operator the height of machine should be properly decided so that he may not get tired during operation. The machine should be slightly higher than the waist level, also enough clearance should be provided from the ground for cleaning purpose.

9. Weight of Machine

The total weight depends upon the selection of material components as well as the dimension of components. A higher weighted machine is difficult in transportation & in case of major breakdown, it is difficult to take it to workshop because of more weight.

B.MECHANICAL DESIGN

Mechanical design phase is very important from the view of designer as whole success of the project depends on the correct deign analysis of the problem. Many preliminary alternatives are eliminated during this phase. Designer should have adequate knowledge above physical properties of material, loads stresses, deformation, failure. Theories and wear analysis, He should identify the external and internal forces acting on the machine parts

These forces may be classified as ;

1. Dead weight forces
2. Friction forces
3. Inertia forces
4. Centrifugal forces
5. Forces generated during power transmission etc

- Designer should estimate these forces very accurately by using design equations .If he does not have sufficient information to estimate them he should make certain practical assumptions based on similar conditions
- Which will almost satisfy the functional needs. Assumptions must always be on the safer side.
- Selection of factors of safety to find working or design stress is another important step in design of working dimensions of machine elements. The correction in the theoretical stress values are to be made according in the kind of loads, shape of parts & service requirements.
- Selection of material should be made according to the condition of loading shapes of products environment conditions & desirable properties of material.

Provision should be made to minimize nearly adopting proper lubrications methods. Following are components of system.

Motors with Assembly:

Two DC motors with following specification are used:

Voltage : 12 Volt DC
Power = 50 watt
Speed = 500 rpm
Mounting : Foot mounted

Motor Assembly consist of following parts

- Pinion Shaft : Pinion shaft is mounted at its square end on the worm gear box output side, where as the pinion is held on the other side of the pinion shaft.
- Main shaft: Main shaft is held at one end in ball bearing 6201zz in the main bearing housing which is welded to the base frame. Whereas the side stand is welded at other end of shaft.
- Holder bracket: Holder bracket is an standard forged part which hinges the side stand at one end, and spring arrester pin-1 is welded at the other end. This pin holds one end of the helical tension spring. The holder bracket is welded to the boom.
- Base frame:Base frame comprises of the base plate, boom, motor plate and the gear box plate. These are support members that hold the assembly together.
- DP/DT switch: The DP/DT switch is an electrical direction control switch which changes the direction of rotation of the motor and there by controlling the motion of the side stand.

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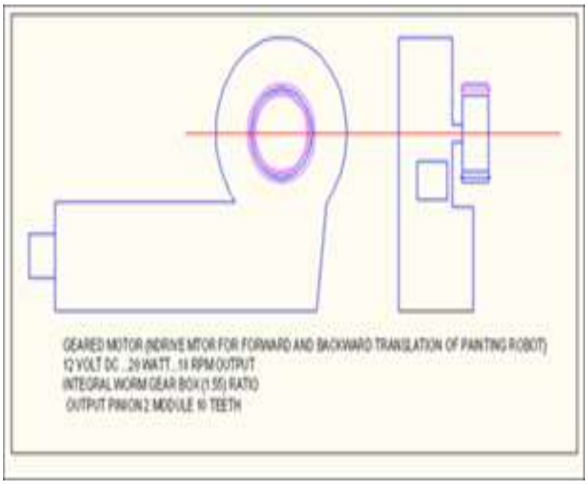

Figure 1 Motor Assembly

IV.CONSTRUCTION & WORKING

1. Base Frame: The Primary base frame is the base element provided with castor wheels, The primary base is made of mild steel square tube and mild steel plate. It supports the entire assembly of the spray paint system robot.

2. Vertical motion system: The vertical motion system comprises of the screw and nut, lifter screw held in two ball bearings and nut connected to the carrier. Rotation of screw is converted to translation of the spray paint system which moves it up or down

3. Paint storage: Paint storage is done in a small tank of 1 to 5 liter capacity mounted on the structure. The compressed air is supplied through the chamber to carry the paint to the spray rotor end.

4. Paint application: Paint application is done by means of a spray gun which is reciprocated in linear guide by crank and connecting rod mechanism operated by motor, for spraying application done by compressed air received from air compressor.

6. Worm and worm wheel: Worm and worm wheel allow horizontal(Left and right) and vertical(Up and Down) motion of spraying gun. The worm is made of case hardened steel 14C6 whereas the worm wheel is made of Cast iron.

7.Control circuit: The paint quality i.e. the thickness of paint will be controlled by the control the speed of the motor so also the speed of the translation of the setup will be controlled by the the speed of translation for controlling position of spray Gun microcontroller is used. The microcontroller used in the controller unit is LPC2148 ARM microcontroller. The microcontroller unit is used to control the two motors and the movement of spray gun fitted on the worm and worm wheel. Microcontroller unit is provided with the 5V signal and as soon as the supply is ON, LCD gets initialized. The controller sets to setting mode and painting distance are given as input to the microcontroller. The microcontroller controls the rotation of DC motor based on the distances given in order to control wheel movement. When IR receiver receives the signal, the worm wheel moves and the spray gun goes to ON condition and if the worm wheel stops, the spray gun goes to OFF condition. It contains relays for the control of forward and backward movement of the stepper motors. When the microcontroller receives the signals from IR sensor, it will be taking a decision to operate the machine. This pulse signal received from IR sensor circuit when there is any object

8. IR sensor

IR sensor is used for this project. IR (Infrared) is the typical light source being used in the sensor for robot to detect opaque object. IR Sensor (IR Receiver and IR Emitter) the basic principle of IR sensor is based on an IR emitter and an IR receiver. IR emitter will emit infrared continuously when power is supplied to it. On the other hand, the IR receiver will be connected and perform the task of a voltage divider. IR receiver can be imagined as a transistor with its base current determined by the intensity of IR light received

9. Castor wheels: Castor wheels with moving platform make robot easy to move towards object. This is base of the machine which enables transportation of the set-up or when applied with motorized motion can enable automatic translation while object painting.

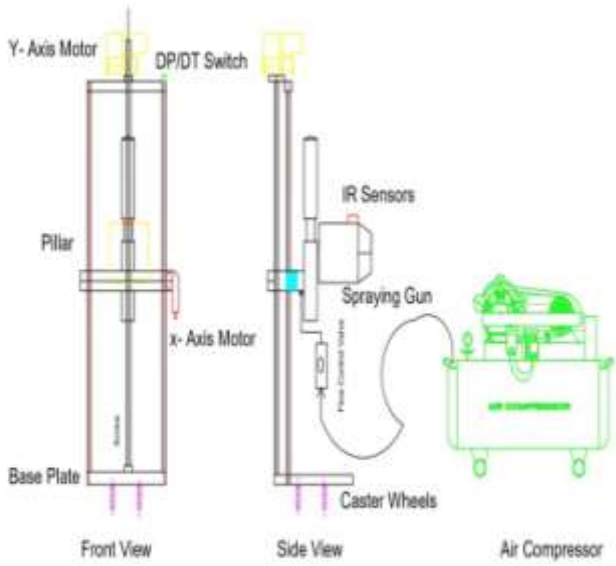

Figure 2.CAD Drawing of Spray Painting Robot

V RESULT

Spray painting robot was design by considering different parameters.Table 1 shows Spray painting robot components with design calculation

Table 1Design calculation of Spray painting Robot components

Sr. No	Component	Assumptions	Results
1	WORM AND WORM WHEEL (WORM GEAR BOX)	The lower value of torque is on the wheel = 1.98×10^6 N-mm	Kw =7.46 Kw As the drive is capable of transmitting 7.46 Kw and we intend to transmit 0.08Kw the drive is safe.
2	GEAR FOR SCREW	Power = 20 watt Speed = 18 rpm,b = 10 m No.of teeth on pinion = 10 No. of teeth on Gear = 30 GEAR DATA No. of teeth on pinion =10 Module = 1.5 mm No. of teeth on gear =30	m=1.35 selecting standard module =1.5 mm

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Sr. No	Component	Assumptions	Results
3	GEAR FOR CRANK	Power = 20 watt Speed = 18 rpm b = 10 m No.of teeth on pinion = 10 No. of teeth on Gear = 82 GEAR DATA No. of teeth on pinion =10 Module = 1.5mm,No. of teeth on gear =82	m=0.6 selecting standard module =1.5 mm
4	GEAR SHAFT	ULTIMATE TENSILE STRENGTH=800 N/mm^2, YEILD STRENGTH=680N/mm^2 Assuming minimum section diameter on input shaft = 21 mm GEAR BORE IS SATANDARD 21MM d = 21 mm	fs act = 17.48 N/mm^2 As fs act < fs all Pinion shaft is safe under torsional load.
5	CRANK PIN	Assuming pin diameter =10mm,Force =318 N TENSILE STRENGTH=800N/mm^2, YEILD STRENGTH=680N/mm^2	Shear stress = 4.04 N/mm^2 Shear stress = 4.04/mm 2 < 144 N/mm^2 Design of crank pin is safe.
6	(SELECTION OF BALL BRG)CRANK	In our case; Radial load FR =318 N L= 4.32 mrev	C = 517.9 N AS; required dynamic of bearing is less than the rated dynamic capacity of bearing;= Bearing is safe.
7	(SELECTION OF BALL BRG)SCREW	In our case; Radial load FR =318 N L= 4.32 mrev	C = 517.9 N AS; required dynamic of bearing is less than the rated dynamic capacity of

Sr. No	Component	Assumptions	Results
			bearing;=Bearing is safe.
8	SLIDER PIN	Force =318 N Assuming pin diameter =10mm MATERIAL SELECTION: TENSILE STRENGTH=800N/mm^2, YEILD STRENGTH=680N/mm^2	Shear stress = 4.04 N/mm^2 Shear stress = 4.04/mm^2< 144 N/mm^2 Design of SLIDER pin is safe.
9	SCREW	Tmotor = 4.7 N-m Torque at screw = 4.7 x 43/12 =16.84 N-m Helix Angle= 5.190, W =5826.9N W = 582.6 kg This is lifting capacity of screw using the motor specifications MATERIAL SELECTION: TENSILE STRENGTH=600N/mm^2, YEILD STRENGTH=380N/mm^2	Direct Tensile or Compressive stress due to an axial load :- a)Compressive stress: f_c act = 16.82 N/mm^2 As f_c act < f_c all ; Screw is safe in compression. b)Torsional shear stress :- f_s act = 9.26 N/mm^2 As f_s act < $f_s$all ; the screw is safe in torsion. C) Bearing Pressure:- Safe bearing pressure=11-17(N/mm^2), n = 4.99 d)Shear stress due to axial load f_s act = 5.88 N/mm^2 As ; f_s act < f_s all , the

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Sr. No	Component	Assumptions	Results
			screw threads are safe in shear. Stresses due to buckling of screw: -W_{cr} =96.21x103 N As, The critical load causing buckling is high as compared to actual compressive load of 5.826KN .
10	NUT	Material Selection: Allowable tensile stress=400N/mm^2, Allowable shear stress=210N/mm^2	n = 5 AS ; n = no of the threads in contact. ln =36 mm Considering length of nut = 36mm 36mm36 mm

VI CONCLUSION

The conceptual design of a Spray painting robot to be used for painting external and interiorparts of objects had been described. The robot uses a roller fed with painting liquid and keeps contact with the parts. By worm and worm wheel mechanism and IR sensor robot can scan both vertically and horizontally the paint objects. The robot can maneuver to adjust itself in front of the object. The criteria for system design had been outlined and the system was implemented and tested. However, there is much scope for system improvement in the future to increase the painting rate and simplify the system design

REFERENCES

[1]. B.Kahane, Y.Rosenfield:"Balencing human-and-robot integration in building task,"Computer-Aided Civil and Infrastructure Engineering,vol.19,2004,pp.394-410

[2]. Y.Warszawsky,Y.Rosenfield:"Robots for interior finishing works in buliding:feasibility analysis,"ASCE Journal of construction Engineering and Management,vol.120(1),1994,pp.132-151

[3]. Andreas Pichler,Markus Vincze Henrik Andersen,Kurt Hausler Profactor"A Method for Automatic Spray Painting of Unknown Parts ",International Symposium on Robotics,october 7-11,2002

[4]. Berardo Naticchia, Alberto Giretti and Alessandro Carbonari, "Setup of an Automated Multi-Colour System for Interior Wall Painting", International Journal of Advanced

Robotic Systems, Vol. 4, No. 4, pp. 407-416, 2007

[5]. M. Sorour, M. Abdellatif, A. Ramadan and A. AboIsmail, "Development of Roller-Based Interior Wall Painting Robot", World Academy of Science, Engineering and Technology Journal, Vol. 59, 2011, pp:1785-1792.

[6]. I. Aris, A. K. Parvez Iqbal, A. R. Ramli and S. Shamsuddin. "Design and development of a programmable painting robot for houses and buildings.," Jurnal Teknologi, Universiti Teknologi Malaysia, vol. 42(A), pp. 27-48, 2005.

[7]. Shigeru Ikemotoa, MengyuanLiaoa, Yuka Takaib,, Akihiko Gotob, Hiroyuki Nishimotoa,HiroyukiHamadaa, "Impact of operator experience on spray gun handling for automobile repair" Procedia Manufacturing 3 (2015) 488 – 494

[8]. P. keerthana et.al, " AUTOMATIC WALL PAINTING ROBOT", International Journal of Innovative Research in Science, Engineering and Technology Vol. 2, Issue 7, July 2013,pp:3009-3023.

[9]. VaniMukundan et al "Automatic Sensor based wall painting robot" International Journal of Advance in Engineering & Scientific research Vol 4, Issue 1 Jan 2017.

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