Robust Design of Automatic Sheet Fixing System for Metal Roofing

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Abstract. Metal roofs overtaken the conventional roofing system in the recent days due to its reliability, it can withstand over 100 years without any damage. The assembler provides 50 years of warranty because it has better stability. The fixing of sheets over prefixed frame is a tedious process at greater heights. Due to the slippery nature of the polished sheets, it is quite difficult to fix the sheets by manually at highest building roofs. Hence, automation in this process reduces the accidents and reduces the processing time. To overcome this problem, a system is proposed to automate the process to fixing the metal roofs in the building roofs, which must be designed in flexible manner to the operator. To design and fabricate a low cost automatic sheet fixing system, contemplations of economy of the system, flexibility, easy handling etc., should be analyzed. A machine is fabricated to automate the sheet fixing process with effective features were inbuilt like pneumatic cylinders for linear movement and drilling machine. The system is provided with rollers to accommodate its movement above the sheets in the desirable path with the help of 5/3 DCV valve. In addition, the horizontal cylinders are also used for retraction and the drilling machine is fixed to drills the screw at the fixed positions and the process will be repeated for several times based on the inputs. The inputs for drill positions are given in the wireless console by the way drilling process is controlled automatically.

Keywords: metal roof fixing system, autonomous bot, wireless controllers, pneumatic cylinders

1. Introduction
Metal can sustain over 100 years, by giving 50 year warranty. Overall metal roofs are cheaper than the asphalt shingles [1]. It has high percentage of recycled material sometimes it becomes 100%. It brings the air gap between plywood roof and metal [2]. Light colored metals are reflective in nature as compare to dark colors, re-sealing and encasing air ducts in attic will reduce money [3, 4]. Metal roofing’s are usually light in weight it produces low stress value on the load bearing. Due to its lightweight it can be easily installed in top of the existing roof [5]. It is highly useful for the large structured buildings, old structures reason behind is light weight and also it provides resistance towards wind on compared with other than metal roofing [6]. It has interlocking panel. The fixing of these sheets over prefixed frame is a tedious process when the height is higher. It shows the unsafe method of sheet fixing [7].
The problems in the fixing process are

- Slippery nature of the coated sheets there is a huge chances of slippage
- Wind speed will be more in the greater heights which may even make the person to lose their control
- Very skilled and experienced labor must be employed in this tedious process.

According to the study, nearly a quarter of roofers were died on sheet fixing process at height buildings as per statics. Mostly ¾ of the fatalities accounted only due to slippage on the roofs while making very giant buildings [8]. The metal roof buildings are highly wanted in industries to avoid the cost of making huge size buildings [9, 10]. The risk is very high in the existing system as shown in the Figure 1.

If commits serious injuries, the result is sobering. This happens mainly due to the slippery nature of the polished sheets used [11]. Hence automating this process reduces the accidents and leads the following advantages [12]:

- Increases the safety of the labor
- Reduces the process time
- Make system flexible to the operator

Hence the objective of the paper is to eliminate the difficulties and complications involved in existing safety features in the sheet fixing process with low cost. The main intention of the work is to design an automatic sheet fixing system/bot in roofing to reduce the time of fixing process as well as to reduce the human risk within the labor cost. To implement the proposed work, an autonomous system is designed with linear actuators where driller setup is fixed and the entire system is controlled through smart devices.

2. Frameworks of Automated Sheet Fixing System

2.1 Design of the Proposed System

Embodying grade manufacturing shingles are in successive development in roofing which carried by newly designed frame having wheel assembly mounted on the air driven motors. This motor helps to enable the apparatus to move in a vertical motion. The hopper claps the shingles and then the shuffle bar changes simultaneously shingles placing one other shingle forthwith instantly in to forks. Where the forks hop move downwards towards roof then shingles are set out in designated area by using pneumatic nailer the roof is fastened.
Thereafter shingles are fastened subsequently where forks tug out from shingle and then return back to its initial state to renew the upcoming shingle to get fastened down. Henceforth forks start to shift from the top of the roof in an upright motion apparatus. Once reached its destination the operation come to an end. Where shingle equipment is connected with nylon belts hereinafter tends to move forward to the top of the roof by the support of linear motion. All movements are achieved by the help of micro processing system and numerous sensor [13]. After installation it requires little attention. The operator simply retains the pneumatic guns filled with fasteners and hopper filled with shingles [14, 15].

**Existing System**

A labor loads the metal sheets over the prefixed frame and moves near the area where the sheets intersect with the rod in the frame. Then, labor will load the roofing screw in the sheets and continues the feeding until the screw fixes the metal roof over the frame. Then the same procedure will repeat for further locations. This makes the process as too slow in the existing system of sheet fixing with metal roofs. The drawbacks of the existing system are processing time is very high and slippery nature of the sheets may cause accidents [15-17].

**Proposed System**

In the proposed work, the distance between the center pipe and parallel pipes are noted when the frame is fixed. Then, these values are loaded into microcontroller which automatically moves the system to the required location and fixes the screw in the sheet. The movement and drilling machine feed are achieved by pneumatic cylinders. This complete system will act as a fixing bot with wireless operating conditions [11, 18].

3. **Principle of Operation of the proposed System**

The fabricated bot is fixed in the center frame thus the sheet locations will be identified and input is given by the Arduino (microcontroller). In the fabricated bot, two sections will be placed, one is fixed in the center rod and next drilling will move for required position. When horizontal cylinder retracts movement takes place to the given position by the use of 5/3 DCV where positioning of the drilling setup is done. Encoders are mounted in the slotted wheels to track the position and provide the feedback to the controller. The setup is provided with rollers to indulge its movement in extended space above the sheets. The other section has two vertical cylinders. The extension drilling machine will be placed in top of the rest position on retraction the drill bit feed into sheets. This section has a linear electric actuator which has a DC motor attached with a rack and pinion. This is used for loading screws into drill bit. After positioning is done, the linear actuators are retracted with screw at the end the vertical cylinders are retracted with drilling machine in off condition where the drill bit has the magnet which picks up the screw and holds the screw, and then vertical cylinders are retracted. When drilling machine is switched on it holds the screw and vertical cylinders are retracted. Hence, that air pressure acts as feed and it fixes the screw over the sheets. For real time implementation telescopic cylinders can be used in place of normal pneumatic cylinders, so that lengthier sheets can be fixed.

4. **Feasibility and Specifications**

**Economic Feasibility**

The proposed paper is economically feasible, all the components are within easy reach and mainly it is onetime cost which would lesser then the overall labor cost. So coming to cost wise, it is economically feasible and components involved in paper are very cheap reason behind low cost is they are readily available as a product in the industries.

**Operational Feasibility**

Thus the paper possess only a simple additional programming in Arduino, there is no complex process involved in these operation. As fixing operation happens automatic and the human intervention is
needed only when loading and fixing the setup over the central frame. Although it is a simple process, even a unskilled labor can do this process very efficiently.

**Design Specifications and Calculations**
The essential components and their descriptions are given below.
- Universal Motor: 220V, 7Nm
- Relay Module: 5V DC, 230V AC
- Solenoid DCV: 5/3 230V AC
- Solenoid DCV: 5/2 230V AC
- Microcontroller ATmega 328P
- Electric actuator (DC motor): 12V
- Rotary Encoder Direction of rotation of rear axle
- Pneumatic Cylinders Double acting
- Flow Control Valves to regulate the pneumatic pressure
- LED Indicators for process identification
- Pneumatic Hoses

**Universal Motor**
Universal motors are used to run single phase AC supply or DC. They are commonly series wound motor and it produces high starting torque. It is used to run at a peak speed of 3500 RPM. It runs on AC and DC voltage. An Electromagnetic field is produced when current flows takes place. The same current is flows from armature. Where the mechanical force is experienced when the conductor is placed in an electromagnetic field. Due to its mechanical force rotor rotates. These kind of motors are mainly based upon Fleming's left hand rule. When AC power supply is given it rises the unidirectional torque. In series connection both field and armature winding are in same phase with each other. The directions of both armature current and magnetic field are back in such a way that direction of force are expertise by armature conductors which always remains constant. The universal motor works by DC series motor. It is commonly used in portable drilling machines.

**Micro Controller**
Microcontroller is an integral circuit connection consists the processor core along with the input and output programming and also memory. Thus the program memory in a form of OTP ROM or NOR flashes are added in the chip and also small amount of RAM is included. These are commonly used in personal computer for general purpose application and it also shows an ATMEGA 328P microcontroller. Atmel is the leading company among the manufactures. This paper utilizes an ATMEGA328 microcontroller, with the ARDUINO platform, 28 pin IC. It is used to control devices and products likewise implantable medical devices, remote controls, automobile engine control systems, power tools and also some other embedded systems.

**Linear Actuator**
Linear actuator generates in a straight line. These actuators are mostly involved in computer peripherals and in the industrial machine tools. Linear motions are done with the help of Lead-screw or screw. Thus the screw rotates either in clockwise or in anticlockwise and this rotation leads the shaft movement. In the linear actuator we use DC motor at the rate of 12volt is mostly used.

**Double-Acting Cylinder**
Double acting cylinder is the type of cylinder here the working involves movement on both sides of piston. The sequence of connecting piston in a double-acting cylinder by the external mechanism in the path of crank shaft where the hole will be in one end of the cylinder need for piston
rod and these are fitted with a gland to avert escape of working fluid. These cylinders are frequently using in steam engines but not in other engines. A lot of pneumatic cylinders and hydraulic cylinders are usually used to achieve force on dual directions. It has a port on each end, hydraulic fluid is supplied on each port for extension and retraction movement of piston. These cylinders are commonly used where the necessity of high force to moves in both directions.

**Direction Control Valve**

Directional control valves (DCVs) usually relied as one of the most fundamental parts of hydraulic circuits and machinery as well as pneumatic systems. DCVs allows fluid to flow into certain pathways from one or multiple sources henceforth as the name suggests it is used to control the direction of fluids. DCVs basic configuration relies on spool inside a cylinder where the movement of the spool is achieved by means of actuating force to reverse the flow direction and extend/retract the cylinder. A glimpse on working of 5/2 DCV is briefly explained. A 5/2 DCV consists of five ports and two spool positions which are used for controlling double acting pneumatic cylinders. Electrical solenoid is a power operated device where high current is used for initial pull and lower current to sustain the electrical signal thereby to trigger the valve opening or closing with low pressure. At first solenoid valve which allows flow of air by the help of air flow it performs pneumatic valve. A 5/3 single solenoid valve closed in mid-position which is capable of functioning the bidirectional way by the use of solenoid in addition of pneumatic piloting and then winding. Mid-22 the positions are manually done in both the directions. The working of 5/3 solenoid valve is shown below Figure 2.

**Rotary Encoder**

Rotary encoder is an electro-mechanical device which transform the motion of the shaft. Where the rotary encoder gives two different pulses based on the direction of rotation. If clockwise one set of pulses are generated, if anticlockwise another set of pulses are generated. It is used in wide range application which requires monitoring or control.

**Pneumatic Hoses**

Pneumatic tubes are used to convey pressurized air by means of tubes to actuators, valves and other devices of a system. Flexible hoses are used in pneumatic systems intended to distribute in solid objects which are chiefly used for the transportation of fluids.

**Design Calculation**

- Mass of the components:
  - Material = Mild steel
  - Density = 7.85x10^-6 Kg/mm^3
  - Frame = 9Kg
• Drilling machine mass = 2kg
• Pneumatic Cylinders = 2.13kg
• DCV= 0.5kg

Hence total mass \( W \) = 13.63 kg ~ 14kg

✓ Motor Specification
• Motor Type: Universal motor
• Power \( = 2 \times 3.14 \times nT/60 \)
• Torque: 7Nm
• Speed: 2600RPM
• Voltage/Current: 220V/7A

✓ Microcontroller Specification
• Manufacturer: ATMEAL
• Model no: ATMEGA38P
• Memory: 32k bytes (flash)
• I/O ports: 28
• RAM: 2k bytes
• Timers: Two 8bit and One 16 bit

✓ Electronic Relay Specification
• Type: Single point relay
• Coil voltage: 5 V/DC
• Operating voltage: 250 VAC/10A---28VDC/10A

5. Working Model
The CAD model of the design shown in Figure 3 which clarifies the structure of the proposed model. The mechanical section comprises of integrated mechanical components and pneumatic components. It includes a frame or chassis assists as a system base meanwhile it acts as a provision for electronics system. Horizontal compound is fixed and the chassis co-opt vertical cylinders of incorporated plate wherein the drilling machine remains to be fixed. The slotted wheels are located in the frame where the vertical cylinders remain to be fixed. The linear actuator is placed within the frame. Separate horizontal arrangement is intended to integrate with the electronic setup. The complete fabricated setup is shown in Figure 4.

Advantages of Proposed Work
In many ways, the proposed paper makes different kind of automation in a new form of increasing to ensure the safety of labors leads. This safety is highly required in the construction sector, where worker faces critical issues.

The advantages are:
• The proposed paper is economically feasible as it reduces the process parameters especially time, where the position values are loaded for a single time as a result the system continuously fixes the screw independent of human.
• The technical part of the system possesses simple controls and henceforth there is no need of skilled labors.
6. Conclusion
The proposed system reduces accidents and reduces process to a greater extent and increases safety to the sheet fixing process. Thus, the greater accuracy and control over the process can be achieved. Thereby real time implementation may require some changes in design according to the need of the customer. This system is completely wireless so no need of human intervention, their part is loading the setup and sheets. If it is replaced the Telescopic linear actuator in the place of Pneumatic cylinder, could achieve greater positioning accuracy and repeatability over all there is no need of pneumatic supply.
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