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Design and Fabrication of IoT based Automatic Riveting Machine

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Abstract - *The aim is to replace the traditional riveting machine with an IoT-based automatic riveting machine. There are several techniques by which the workpiece can be riveted. Existing impact riveting machines use pneumatic, electro-mechanical or hydraulic force to install a rivet. The main drawback is that these machines are manually operated and have a single degree of freedom. Thus, after each riveting operation, the workpiece has to be manually relocated for the next iteration, which involves human error. Some of the key factors that affect human performance in machining shops are stress, fatigue, and temperature in the workplace. In this paper new idea has been proposed to improve the quality and productivity of the riveting machine. An H-bot gantry arrangement with a pneumatic cylinder mounted on the carriage is used for riveting a workpiece in XY axis. Besides, an IoT is implemented using a Node-RED android application to monitor the performance of the machine.*

Key Words: **H-Bot, Pneumatic Cylinder, Stepper motor, Riveting, IoT, Node-RED.**

1. INTRODUCTION

Riveting was a popular method of permanent fastening in the past. Earlier rivets are commonly used in the construction of towers, bridges, and armoured tanks. Nowadays is widely used in applications where lightweight and high strengths are critical, such as in aircraft and automobiles.

In automotive applications, super-speed cars use thin wall components to reduce the overall weight of the vehicle. Pneumatic guns and semi-automatic machines are used for riveting the structure of the vehicle body. The main drawback is that these equipment are manually operated. After riveting every time, the new rivet joint has to be placed on the die in a proper position, and enough squeezing force needs to be given to rivet the workpiece.

Through our design proposal, we developed an IoT-based automatic riveting machine using Raspberry pi. A Pneumatic cylinder mounted on the carriage of the H-Bot mechanism uses a stepper motor to create a motion in dual-axis (XY). Besides, to increase productivity, an IoT system is implemented to monitor and control the workflow process.

2. LITERATURE REVIEW

1) A.S. Aditya Polapragada and K. Sri Varsha: A multipurpose pneumatic punching and riveting machine were developed using 555 timer IC to actuate the direction control valve.

2) Prof. K.G.Sontakke, Prof. R. D. Vaidya, Prof. D.M. Mate: They developed an automatic riveting machine using 3 phase induction motor. It has two sections. In section 1, the drilling spindle is used to drill a hole in the plate, while in section 2, a rotating spindle is used to fasten the rivet the workpiece. Both the spindles are connected to the pulley of induction motor using V belt.

3) Sascha Weikert, Roman Ratnaweera, Oliver Zirn, and Konrad Wegener: Designed and analyzed the H-Bot Kinematic system with alternative kinematics for high productivity, which implies high dynamics at a reduced cost.

4) Amit Kumar Nandi: Developed a 3-axis CNC milling machine using an Arduino microcontroller, Raspberry Pi interfaced with Arduino act as a local server to store and display the data.

3. COMPONENT DESCRIPTION

The components listed below were used to construct the machine. It includes both mechanical and electrical parts.

3.1 POWER SUUPLY

A power supply is an electrical device that supplies electric power to an electrical load. In this circuit, a 12 Volt power supply is used to power the stepper motor and other electronic devices such as Raspberry pi3, electro valve, and stepper motor drive controller.

Fig.3.1 Image of 12V Power supply adapter

3.2 CONVERTER

A buck converter is a DC-to-DC Power converter which steps down the voltage from its input (supply) to its output (load). The LM2596 used in our application has an output voltage

range between 1.5V to 35V and capable of driving a load up to 3A with high efficiency.

Fig.3.2 Pictorial of LM2596 DC Buck converter

3.3 MICROPROCESSOR

Raspberry PI 3 is a development board in the PI series. It can be considered as a single-board computer that works on LINUX operating system. PI board is specifically designed for IoT (Internet of Things) applications. It comes with Broadcom BCM2837 64bit Quad Core Processor and has a built-in Bluetooth V4.1. The operating voltage of the processor is 3.3V, and it has 26 general-purpose input and output pins.

Fig.3.3 Image of Raspberry PI 3

3.4 MOTOR DRIVER IC

Motor drivers act as a bridge between the motors and the control circuits. Motor require high amount of current, whereas the controller circuit works on low current signals. So, the function of motor drivers is to take a low-current control signal and then turn it into a higher-current signal that can drive a motor. LBA-B-V4 CNC Shield equipped with A4988 stepper motor driver used to drive the motor in 5 phase mode.

Fig.3.4 Assembled view of LBA-B-V4 CNC Shield with A4988 stepper motor driver.

3.5 RELAY

Relays are electrically operated switches that open and close the circuits by receiving electrical signals from outside sources. The relay consists of a coil, which receives an electric signal and converts it to a mechanical action and contacts that open and close the electric circuit. A 5V relay module connected between Raspberry Pi and direction control valve receives a control signal from Raspberry Pi to switch the 12V supply to actuate the valve.

Fig.3.5 Image of 5V Relay

3.6 DIRECTION CONTROL VALVES

Directional control valves are one of the most fundamental parts of hydraulic and pneumatic systems. DCVs allow fluid flow into different paths from one or more sources. DCVs will usually consist of a spool inside a cylinder which is mechanically or electrically actuated. In this circuit, a 5/2 solenoid valve is used to control the direction of the pneumatic cylinder.

Fig.3.6 Image of 5/2 Direction control valve

3.7 PNEUMATIC CYLINDER

Pneumatic actuators are mechanical devices that use compressed air acting on a piston inside a cylinder to move a load along a linear path. A Double-acting cylinder has an air port at each end and moves the piston forward and back by alternating the port that receives the high-pressure air. In this project, a rivet tool is fixed at the end of the pneumatic rod.

Fig.3.7 Photo of Double acting cylinder

3.8 H-BOT KINEMATIC SYSTEM

An H-Bot kinematic system is developed using two stepper motors mounted on a linear guide. These two drives are

connected by a single H-shaped circumferential timing belt around two staggered linear axes in a gantry type like configuration.

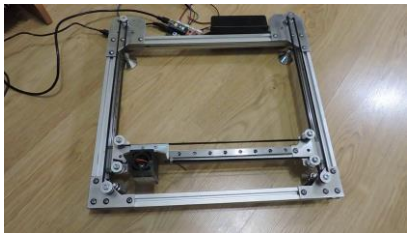

Fig.3.8 Assembled view of H-Bot mechanism

3.9 STEPPER MOTOR

A stepper motor is an electromechanical device it converts electrical power into mechanical power. Also, it is a brushless, synchronous electric motor that can divide a full rotation into an expansive number of steps. The motor's position can be controlled accurately without any feedback mechanism, as long as the motor is carefully sized to the application. The stepper motor uses the theory of operation for magnets to make the motor shaft turn a precise distance when a pulse of electricity is provided.

Fig.3.9 Picture of 12V DC Stepper motor

3.10 LIQUID CRYSTAL DISPLAY

A liquid crystal display is a combination of two states of matter, the solid and the liquid. LCD uses a liquid crystal to produce a visible image. Liquid crystal displays are super-thin technology display screens that are generally used in laptop computer screens, TVs, cell phones, and portable video games. LCD's technologies allow displays to be much thinner when compared to cathode ray technology (CRT) technology. ILI9225 TFT LCD is used to control and monitor the application.

Fig.3.10 ILI9225 TFT LCD

4. DESIGN CALCULATION

Total no of Aluminum alloys sheets to be riveted = 2
Thickness of a sheet = 3mm
The material of Countersunk head rivet is Aluminum.
Total thickness of the sheets(S) =3+3 =6mm

Formula to calculate the diameter of the rivet shank.
D = (1/4) * S
D = diameter of the rivet shank
S = thickness of all plates to be riveted
D = (1/4) * 6
D = 1.5mm

Formula to calculate the length of rivet shank.
L = S + Z
Where,
L = length of the rivet shank
S = thickness of all plates to be riveted
Z = allowance
L = 6 + 2.25
L = 8.25mm

The next size of the rivet length available in the market is **9mm**.

The recommended value for Diameter bore as per design guidelines is **1.6mm**

The squeeze force required to rivet the workpiece is **6KN**.

Formula to calculate required pressure of the cylinder.
D_H = 90mm
P = (F/A)
Where,
P = Gauge Pressure (Pa)
F = Force exerted (N)
A = Full bore area (m^2)

P = (6000)/(pi*0.045^2)
P = 943KPa

The required pressure to set on the gauge is **943KPa**.

But the nearest pressure that can be set on the valve is **950KPa**.

5. SOFTWARE AND CODING

- **Language:**

Python is a powerful programming language that's easy to use (easy to read and write) and, with Raspberry Pi, lets you connect your project to the real world. Python syntax is very clean, with an emphasis on readability, and uses standard English keywords.

- **IoT Platform:**

Node-RED provides developers to connect devices, services, and APIs using a browser-based flow editor. It can run on Raspberry Pi, and further 60,000 modules are accessible to increase its facilities. Node-RED dashboard in smartphone helps to control and monitor the parameters of the machine.

6. WORKING PRINCIPLE

The Pneumatic cylinder mounted on the gantry of the H-Bot initially will be in the home position X0Y0. Once the machine is powered ON, the G-Code and M-Code values are fed to the raspberry pi from ILI9225 TFT display. Initially, the raspberry pi sends the control signal to the motor driver to drive the stepper motor. Once the pneumatic cylinder reaches the riveting position, the gantry is stopped, and a digital pulse is sent to the direction control valve to energize the solenoid. A relay is used between the PI and direction control valve to switch the 12V DC supply from 5V DC.

Once the solenoid is energized, high-pressure air from the compressor flows to one of the ports in the cylinder, exerting the piston rod to rivet the workpiece. After the workpiece is riveted, the solenoid is de-energized, and the piston rod comes to its home position. This cycle is repeated until all the rivets in the workpiece are riveted.

ILI9225 TFT display or the Node-RED android application is used to control and monitor the riveting operation.

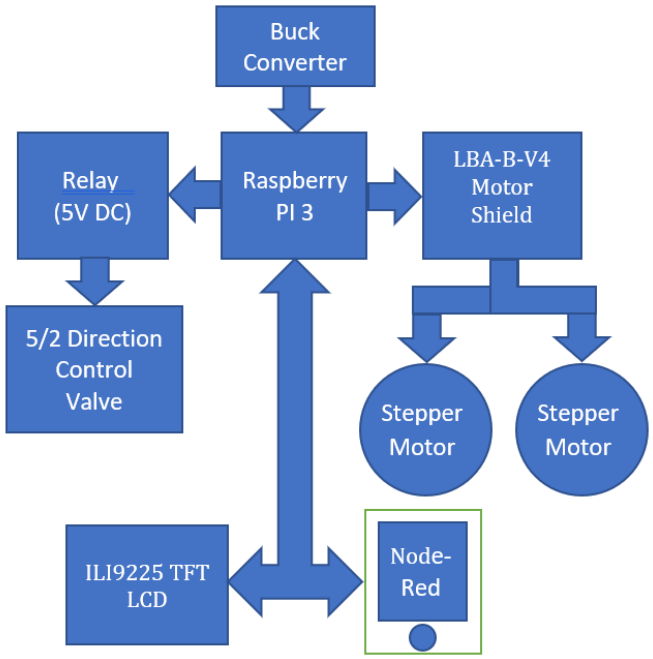

Fig.6.1 Block Diagram

7. CONCLUSION

This project presents an IoT-based automatic riveting machine. Experimental work has been carried out carefully, and the proposed method is verified to be highly beneficial. We can implement this technique in automotive industries, etc.

In the future, the pneumatic system can be replaced using a motor for orbital riveting. Also, machine learning can be utilized with machining processes to improve product quality levels and productivity rates, monitor the health of systems and optimize design and process parameters.

8. REFERENCES

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