Injection Molding Machine Remote Control

Background

An **Injection molding machine**, also known as an **injection press**, is a machine for manufacturing plastic products by the injection molding process.

The machine consists of three main components:

- Feeding and heating module: this component consists of a feed hopper followed with a heater that heats the material so that it melts and then feed to mold.
- Injection module: This is a pneumatic system with a needle valve to control the input pressure. A manual directional valve is connected to a handle, which helps in moving the piston horizontally left and right. This is used in feeding the molten material into the mold when extending.
- Mold clamp: This is the part that holds the mold in place and helps align the nozzle to the mouth of the mold. The mold clamp has two screws, the vertical one helps secure the mold in place while the horizontal screw is to adjust the mold inlet to the nozzle opening.

It also features a front panel, which consist of temperature and pressure control as will as meters for both parameters, and a power indication light.

The initial examination of the machine reviled that the energy distribution unit was faulty and hence the machine heater was not powering on. The mold nozzle had broken out and was filled with a lot of plastic material, which prevented it from being attached to the heater.

Figure 1 The physical system

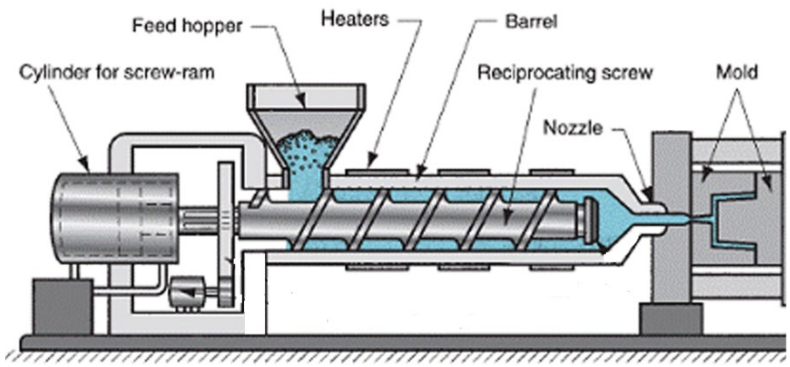

Figure 2 The schematic of the physical system

Objectives

The objectives of the study include (1) develop a web-based User interface and host the server so that anyone in the network can access the interface and control the equipment, (2) integrate the webserver to Arduino microcontroller through serial communication which in turn controls the equipment, and (3) interface real-time video surveillance of the equipment to the user interface.

System Design

The proposed design aims to fully automate the original physical system to enable remote control capability. The physical system change includes:

- The piston position manual control will be replaced by a solenoid valve.
- The mold clamp will be replaced by a screw-rod that is driven by a stepper motor.
- Pressure control knob and meter are replaced by an electronic pressure regulator, which also has the analog output of the pressure reading.
- Temperature close loop control is automated by a set of relays and thermal couple.

After the modification, all the control signals and sensing inputs are connected electronically to an Arduino microcontroller, which in turn connects to a computer (webserver). The server serves as both control system as well as the host of the web-based graphic user interface (GUI).

The proposed software architecture is a python flask library-based webserver that is hosted and accessible to anyone in the network.

The webserver also accesses video streams from two cameras on the system to give real-time video feedback.

Hardware

Overview

The structure of the physical system is summarized in Figure 3.

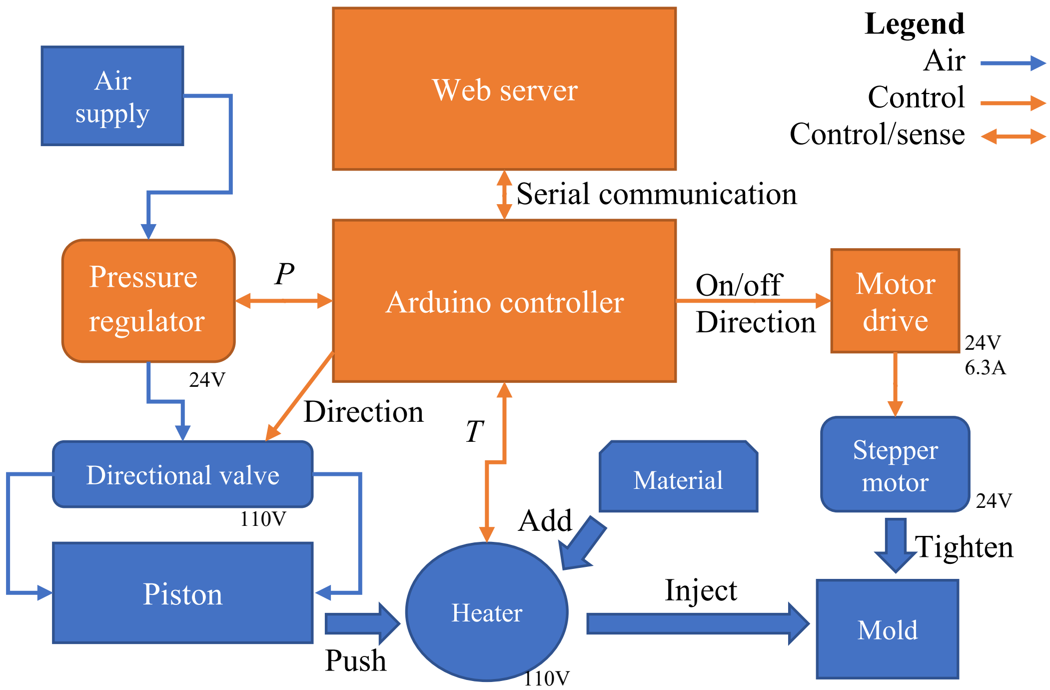

Figure 3. Remote Injection Molding Machine System Architecture

The air supply is firstly connected to the pressure control valve, which sends pressure reading to as well as accepts settings from Arduino. The regulated compressed air is then sent to directional valve's inlet, which is controlled by the Arduino again to decide if to extend or retract the piston.

The heater is also controlled in the same fashion as the pressure regular, except this time it is the temperature that is been regulated.

The motorized clamp is driven by a stepper through a motor drive.

The Arduino itself has two-way communication with the web server.

The details of each of the components are detailed below.

Actuators

To enable remote control capacity, the following actuators are added to or substituted in the original physical system components in order to automate the process.

Motorized mold clamp

a heavy-duty stepper motor is added to replace the manual mold clamp. It is mounted directly to the original screw rod's top, using shaft coupler, so the motor's shaft can turn it, results in moving up and down. A slider fixture is installed to prevent the motor itself to rotate.

The motor is controlled by Arduino controller through a high power (6.3A, 24V) driver. The driver is in the electrical box alongside the Arduino.

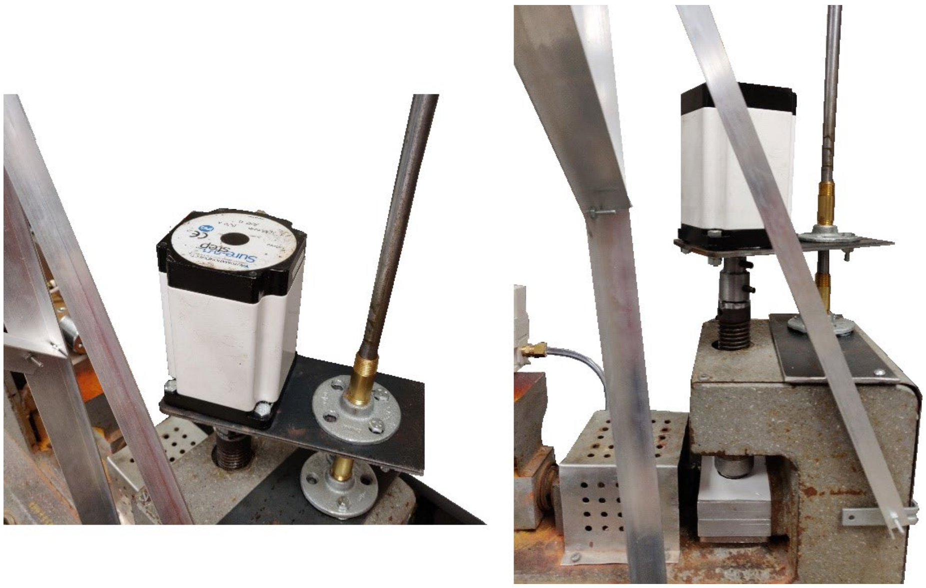

Figure 3 Stepper motor, threaded rod and fixture for mold clamp

Solenoid directional valve

To direct the compressed air to the piston for extending (for material injection) and retracting automatically, the old manual directional valve is replaced with a solenoid one.

Figure 4 Original manual directional valve

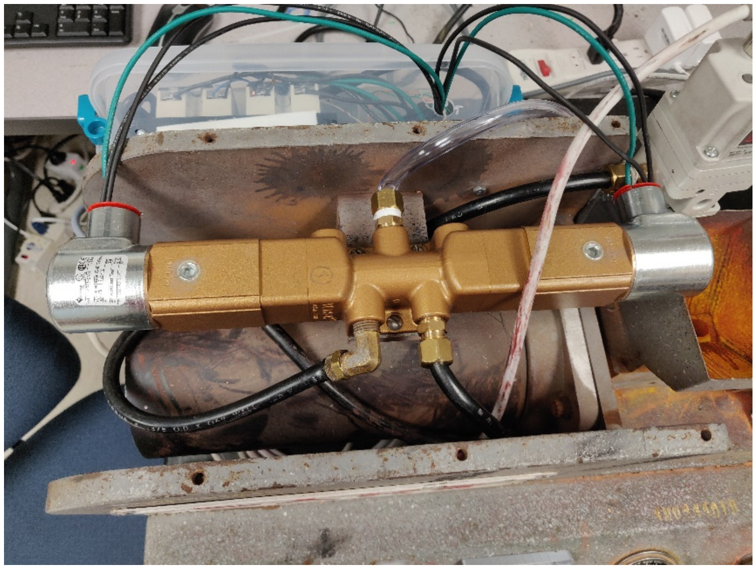

Figure 5 New solenoid directional valve

The solenoid directional valve has three positions, outlet A on, all closed, and outlet B on. It has two 110V AC solenoids that are mounted to both end of the valve to move the spool inside of the valve to change the positions. When the left one is energized, outlet A is connected to the compressed air supply (and B to the exhaust hole), thus retracts the position. When the right one is energized, it extends the piston instead. When both are deenergized, both outlets are blocked, and the piston chamber can retain its pressure, so piston retains its current position.

Electro-Pneumatic Regulator

A proportional electro-pneumatic regulator from SMC is used to regulate the air pressure, replacing the original manual pressure valve.

The valve is operating on 24V. It has four pins: +24V, GND, input signal and monitoring output.

It controls the output pressure to the injection cylinder based on the PWM input signal from the Arduino. It can also report the current readings of the output pressure on its monitoring output pin, which also connects to the Arduino.

The valve also features a small LED screen to show the current pressure.

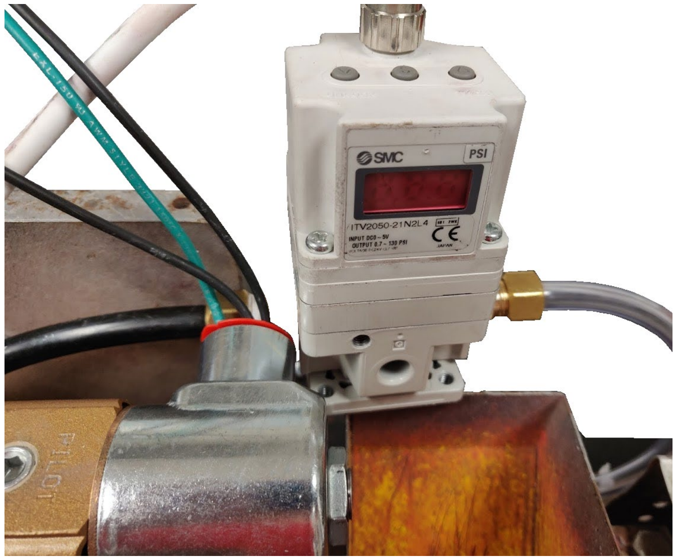

Figure 6 Electro-pneumatic regulator

Other internal modifications

There are several other modifications that are done inside of the equipment for control and sensing purposes.

K-type thermocouple instrumentation amplifier: the original thermal couple of the system is kept. But instead of connecting to the gauge, an amplifier is added to amplify the mV signal from the thermocouple and gives output in V range so that Arduino can read it and give proper output to the web-based UI.

Solid state Relays: a total of four relays are used to control multiple AC-powered components. It includes: the main power, two solenoid valves, and the heater. The input low-voltage control signals (5V) are from Arduino, and the driven sides are all the 110V (hot).

Power supply: an additional power adapter is added to the system to provide 24V to the proportional pressure control valve and motor drive board.

Camera setup

Two cameras are added for real-time video feed of the system from different angles (front and top views, respectively).

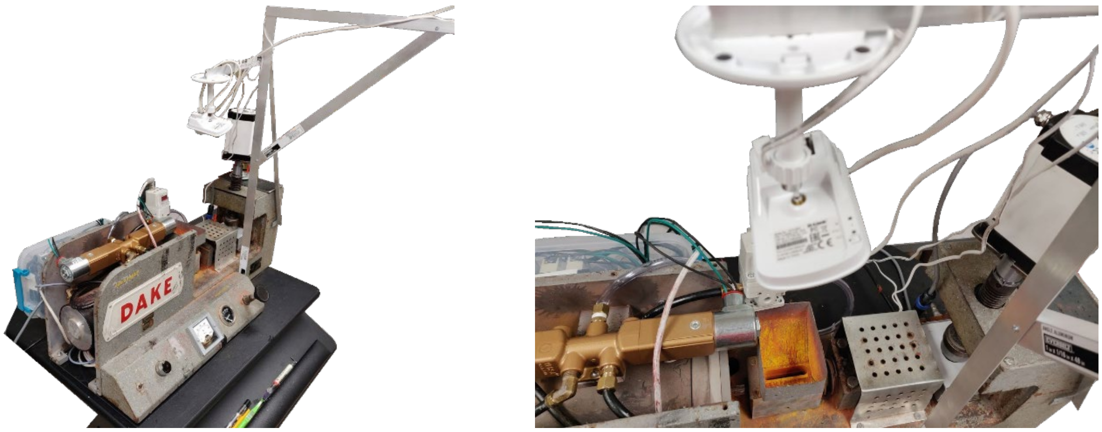

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Figure 7 Top camera and its field of view

The top view camera is setup to monitor the material feeder and piston extension, and the current position of mold clamp.

Figure 8 Front camera and its field of view

The front view camera is setup to look at the front panel and the overview of the whole system. It can show the indication light, gauges on front panel, and readings on pressure sensors.

An example capture results of the cameras are shown below.

Figure 9 Camera image capture examples

Control system

An Arduino Mega microcontroller is adopted as the core of the physical control system. Arduino is an open-source electronics platform based on easy-to-use hardware and software. The Arduino software is a C-like language, available for extension by experienced programmers. The language can be expanded through libraries [1].

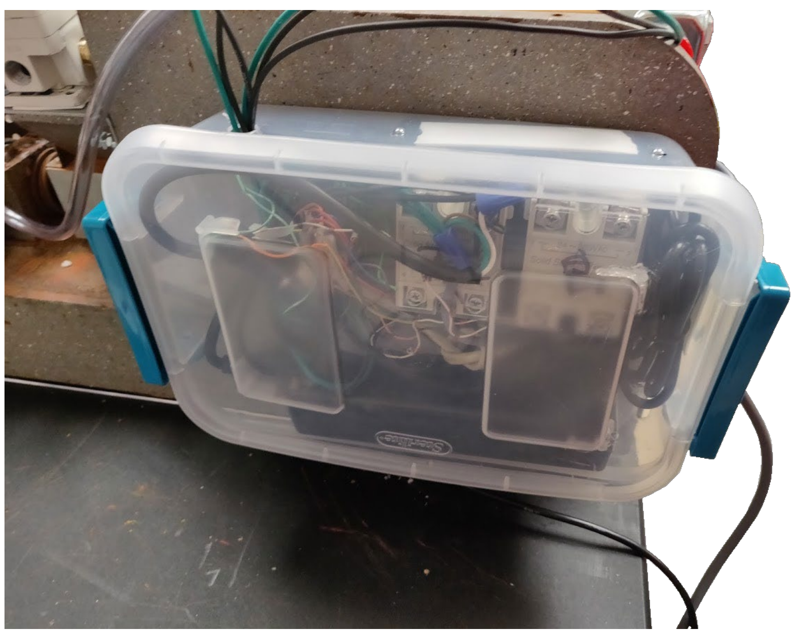

Figure 10 Control system box, featuring Arduino, motor drive, power adapter and two relays

In the proposed system, the Arduino controller is in charge of all the low-level controls. Including receiving the input signals from two sensors, sending out signals to the actuators.

The Arduino itself is communicated to the web server through serial port (USB on computer side). A two-way serial communication between the two is used to bring the high-level control from the server to the Arduino, as well as to pass the sensory readings and system status to the server.

Software Design

The diagram in Figure 12 shows the interaction between user, server, and hardware.

The web server can be described as two parts, backend and frontend (interface). It also has a small datafile used for storage. The Arduino is used to interact with the machine directly as a proxy of the web server. The camera system is a separate standalone system running on their own. Only their video/image streams will be incorporated into the final UI.

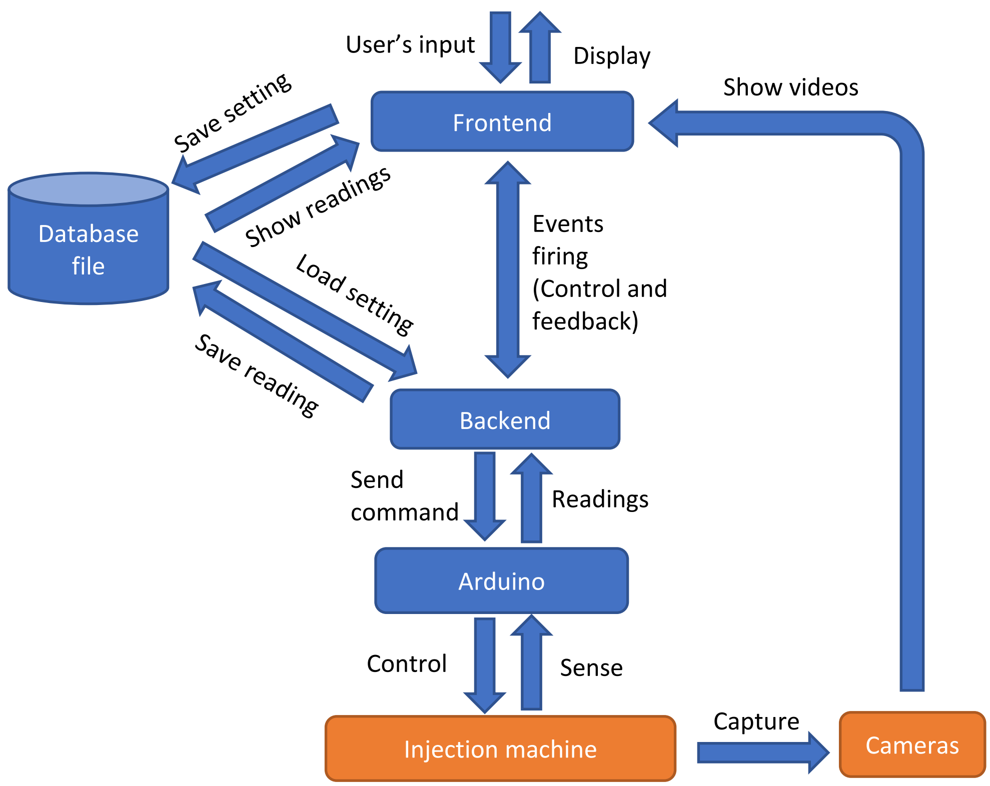

Figure 12 Software architecture

User interface

The user interface (frontend) of the application is a single-page app built using Jinja template engine and rendered by the Flask. The event handling on frontend is handled by Socket IO JavaScript module. A CSS grid design is adopted to have better flexibility on the layouts. It makes arranging and aligning elements much easier, as well as that it can fit into varying screen size. Figure 12 shows the final design of user interface.

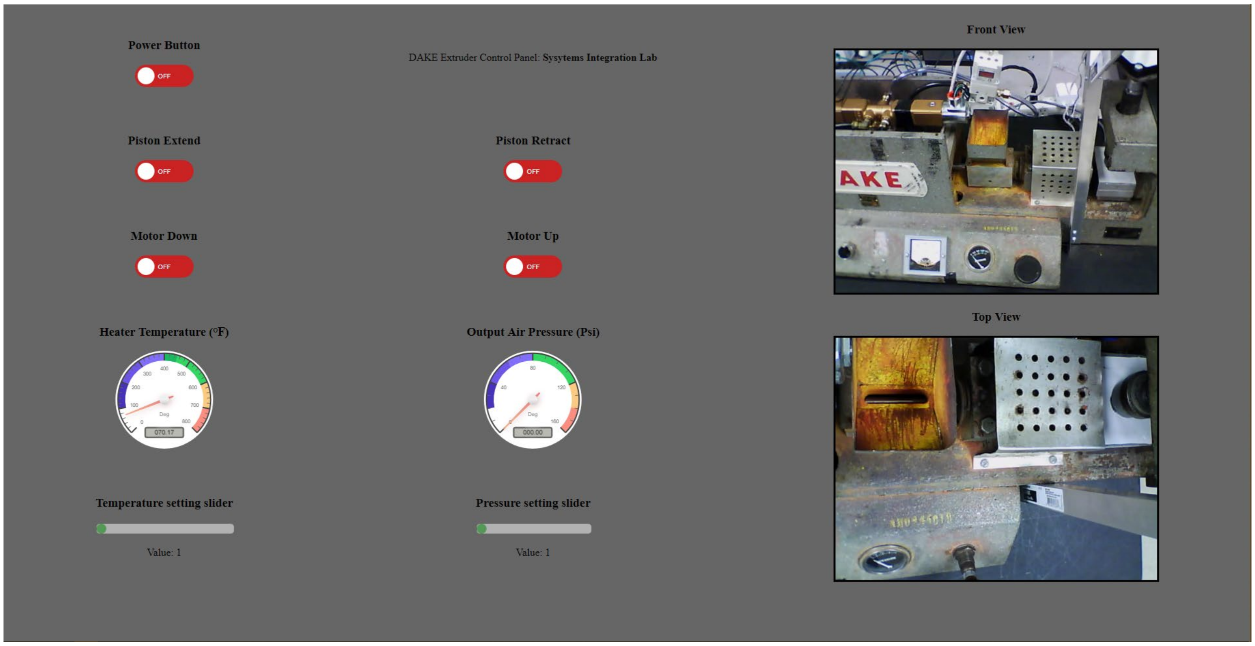

Figure 12. Graphic User Interface of the Remote-control System

The user interface features several control switches for power, piston, and motor, along with temperature and pressure monitoring displayed in an analog-like dial similar to the actual physical gauge. There are also sliders to control the temperature and pressure of the equipment remotely. The views from cameras are also inserted into the page.

This layout was chosen to make the user interface as identical to the physical equipment as possible. The analog gauges give the exact feel of that on the machine.

From top to bottom, on the left side:

- Power button
- Piston control buttons, extend and retract
- Mold clamp motor buttons, up and down
- Heater temperature gauge and air pressure gauge
- Heater temperature control slider and pressure setting slider.

On the right, there are two camera views for visual feedback on what is happening and will help in assisting the user.

Available user operations

- The user can power on and off the main power of the equipment.
- User has control over two sets of the actuators: a pair of solenoid valves to control the piston, as we as the control of the motor to tighten and untighten the mold.

- User also has control over the pressure output and the temperature output which can be done using the corresponding sliders. The current temperature and pressure are shown on the analog gauges.
- User gets a real-time remote video monitoring of the equipment on the interface.

Conclusions

This project upgraded an existing injection molding machine. The equipment can now be remote accessed and controlled by user. The enhancements enable remote study through the equipment saving time and enabling resource sharing.