Control Analysis Of Mini Injection Moulding Machine Based On Microcontroller ATMega128

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Abstract. This research develops a control system for mini injection moulding machines for small industries. The problem in this research is identified by looking at technological developments in Indonesia, one of which is injection moulding machines, whose technology continues to develop rapidly, and the demand for plastic products continues to increase. The current problem is that injection moulding machines require a lot of power for production. This research aims to apply the ATMega128 microcontroller to a mini injection moulding machine driven by a motor. The research method started with making machine mechanics, machine electronics and programming. The results of the research use a control system to control the injection moulding machine, adjusting the character of the stepper and DC motors to produce products using PCL and PLA filaments, which are very suitable because of the low temperature and pressure so they can be used on a small industrial scale.

Keywords: Microcontroller ATMega128, Control System, Injection Moulding Machines.

1 Introduction

The industrial world in the modern era is increasingly experiencing development; various developments in industrial technology are starting to emerge, causing humans to continue to learn to develop and operate control jobs that were initially carried out by humans to become completely automatic (controlled by machines), in its application the control system plays a vital role in technology. As the need for process control is one of the applications that applies to fast injection moulding machines, the first step, in this case, is to design, measure and monitor the process precisely so that the primary process variables can be observed and controlled [1]. This will allow for increased controllability and repeatability of the overall process, possibly reducing unnecessary variations in the process. The injection moulding process includes four main stages: plasticization, injection, cooling and ejection. Between these four stages, cooling takes 50% to 80% of the cycle time [2]. Injection moulding machines are increasingly used in several industrial sectors. Correct and precise parameter settings are essential to achieve high process effectiveness and the desired quality of the products produced. Because injection moulding is a sophisticated process, dealing with all the changes during its implementation is often challenging [3].

Identifying the problem in this research is by looking at technological developments in Indonesia, one of which is injection moulding machines, whose technology continues to develop rapidly. Demand for plastic products increases, but natural energy continues to run low, so alternatives or options are needed to synergize these developments. Here, the

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researcher chose part of developing a mini injection moulding machine towards point saving with the help of a control system using the microcontroller ATMega128 as the engine's brain. Compared to other control systems, the advantages of this microcontroller ATMega128 are that it is cheaper and more efficient.

To keep the injection moulding machine operating correctly, someone is needed who can run the injection moulding machine. Decree of the Minister of Manpower and Transmigration of the Republic of Indonesia, No. 90 of 2014, concerning: "Placement of Indonesian national work competency standards in the main category of processing industry rubber industry, rubber and plastic goods industry business group for plastic goods for packaging", Unit Code: C.222200.007.01 discusses "Operating injection moulding machines" [4]. With this competency, researchers are trying to complement it with additional control system expertise, which leads to analyzing injection moulding machines to control the device well. By understanding the control system, we can answer the need for knowledge in operating injection moulding machines.

2 Literature Review

2.1 Injection Moulding Machine

Injection moulding is a method of thermoplastic materials where a plunger injects the material that melts due to heating into a mould cooled by water, where the fabric will chill and harden to be removed from the mould. Meanwhile, an injection moulding machine makes plastic using an injection moulding system. Injection moulding machines have evolved from the single-stage plunger machine patterned by John Wesley Hyatt in 1872 to the modern reciprocating screw machine developed in 1951 by William H. Willert. The process has been modified, expanded, and refined over the last century. However, the basic concept remained similar to Willert's, except for hydraulics and control systems advances. Reciprocating-screw injection moulding machines are now the most widely used due to their reliable overall performance, such as improved melt rates, closer tolerances on shot size, and better temperature control. The reciprocating-screw injection moulding machine consists of an injection unit, a clamping unit, and a hydraulic unit, as shown schematically in Figure 1.

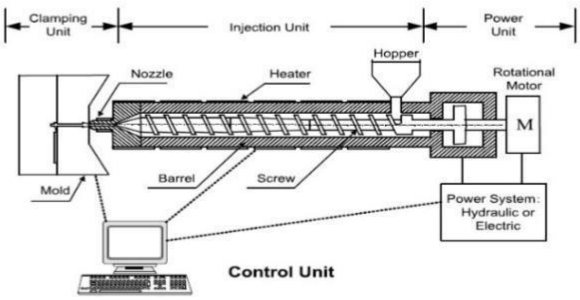

Fig. 1. A simple schematic of a reciprocating-screw injection moulding machine [5]

A simple scheme of a reciprocating screw injection moulding machine. Injection Molding Machine parts generally consist of 4 functional units, namely:

a. Mold clamp unit
b. Injection unit
c. Moulding unit
d. Control system

2.1 Control System

A control system is a reciprocal relationship between components that form a system configuration that provides a desired result. The elements or processes to be regulated can be depicted in a block in Figure 2.

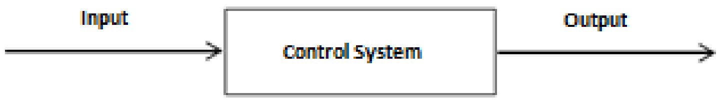

Fig. 2. Control system block diagram

There are two types: an open loop control system (available loop control system) is a system whose output does not influence the control action, and a closed loop control system (close loop control system) is a control system whose output signal has a direct effect on the control action, system. Closed loop control is also a feedback control system, and the block diagram can be seen in the figure below:

a. open loop control system

Fig. 2. Open loop system block diagram

b. close loop control system

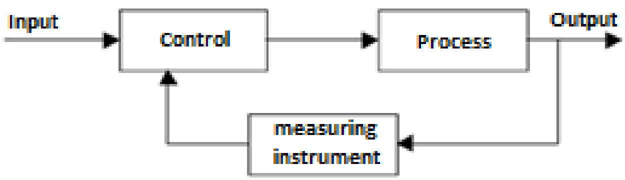

Fig. 3. Close loop system block diagram

Block Diagrams and Signal Flow Graphs [6]

The transfer function compares the Laplace transformation of the output variable and the Laplace change of the input variable. E(s) is the Laplace transform form of the input variable, C(s) is the output variable, and G(s) is the transfer function. One graphic method that shows relationships is a block diagram, as shown in Figure 5(a). For this block diagram, the output equals the transfer function given in the block multiplied by the input. Inputs and outputs are defined by the direction of the arrows, as shown.

$$C(s) = G(s)\,.\,E(s) \tag{1}$$

where;

$C(s)$ = Laplace transform of the system output
$E(s)$ = Laplace transform of system input,
$G(s)$ = Transfer function

$G(s)$ defined by:

$$□(□) = \frac{□(□)}{□(□)} \tag{2}$$

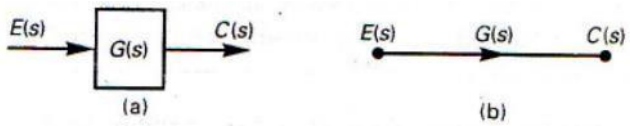

Fig. 5. Block diagram and signal flow graphic elements

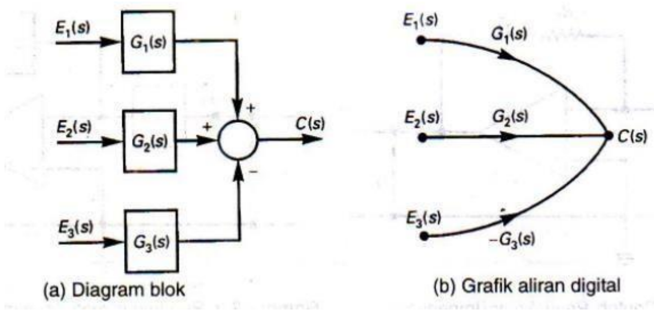

Fig. 6. Equivalent example

3 Methods

Location This research was carried out in the Mechatronics Lab, Department of Mechanical Engineering at the Faculty of Engineering, Medan State University. This research was carried out in the 2022/2023 academic year.

3.1 Research Materials and Tools

a. The materials needed to control the injection moulding machine are Microcontroller ATMega128, DC Motor, Stepper Motor, Electrical Heating Element, and Filament.

b. The tools needed to check the working feasibility of an injection moulding machine are an Oscilloscope, Multitester, Infrared tachometer, Infrared temperature, and AC Power Meter.

3.2 Control System Design Process

The control system design process is carried out in several stages. The design process flow diagram is shown in the following figure:

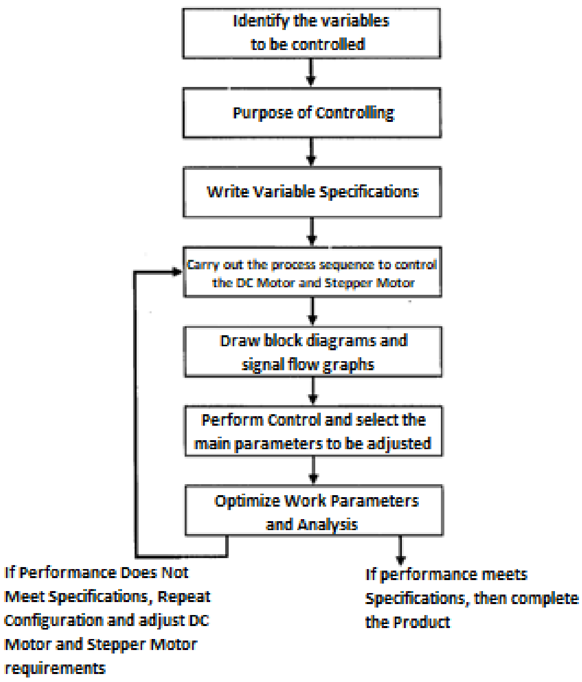

Fig. 7. Control System Design Process Flow Diagram

3.3 Drive on ATMega128-based Injection Molding Machine

There are two drivers for the microcontroller ATMega128-based injection moulding machine, namely:

a. DC motor (Toshiba DC Motor Gearbox DGM-3522-2A) Injection unit drive
b. Stepper motor (Nema23 JK57HS82-3004B Double Shaft) Mould clamp unit driver

3.4 Electronic injection moulding machine

The microcontroller ATMEGA 128 is an AVR family microcontroller with a flash memory capacity of 128KB. AVR (Alf and Vegard's Risc Processor) is a series of 8-bit CMOS microcontrollers made by ATEMEL Inc., based on the RISC (Reduced Instruction Set Computer) architecture [7].

Fig. 8. Electronics with microcontroller ATMega128 control [8] [9]

3.5 Injection moulding machine programming

The injection moulding machine controller in this research uses CodevisionAVR software, which can control the microcontroller ATMega128;

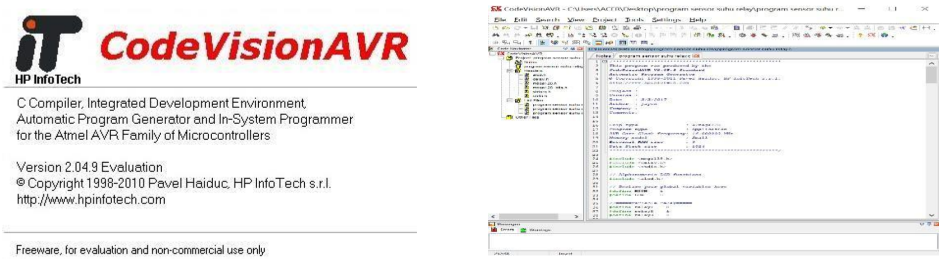

Fig. 9. CodeVisionAVR software controls injection moulding machines [10]

3.6 Initial Process of Injection Moulding Machine Operation and Calibration

a. Starting the Machine
b. Position the Mould in Position 0
c. Heating the Cylinder screw ram
d. Filling the initial ingredients (injecting several times), PLA (Polylactic Acid) and PCL (Polycaprolactone) CodeVisionAVR software controls injection moulding machines).

4 Result and Discussion

Mould testing of product quality after ensuring that the tool used is accurate enough, then the control approach must be thoroughly analyzed and studied to obtain the desired performance of the complete line of the parts. That is, provide temperature – pressure – thickness control, maintain preset parameters, monitor and correct equipment operation.

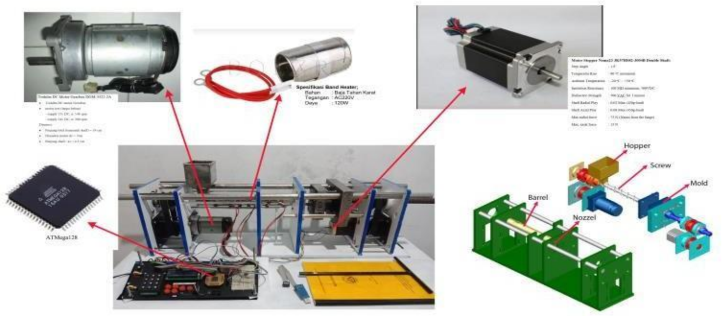

Fig. 10. Mini Injection Moulding Machine Based on Microcontroller ATMega128

a. Using the barrel injection moulding machine temperature control, the schematic of the control loop is illustrated in Figure 11; the controlled variable is the barrel temperature of different zones, the control variable is the power for other heaters, and the disturbances are the ambient temperature, outside airflow, etc.

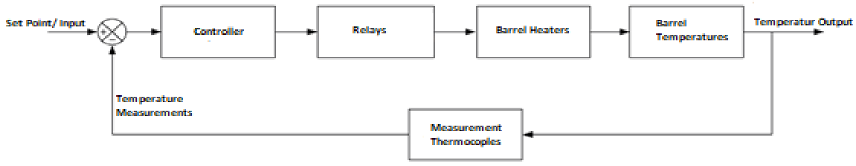

Fig. 11. Block diagram of injection moulding machine barrel temperature control

b. Open loop systems do not use measurements of the controlled variable or any disturbances, and this type of control is only applicable in cases with excellent prior knowledge of the controlled process.

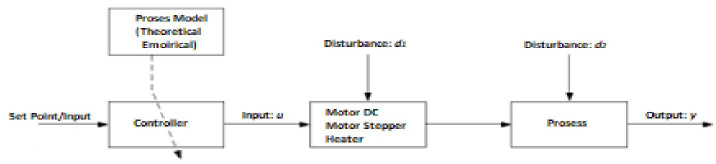

Fig. 12. Block diagram of open-loop injection moulding machine

c. In a closed-loop control, the controller receives a signal from the measuring unit and compares it with the desired value to make a control decision. In a closed-loop control scheme, there is no need for complete and precise knowledge of the controlled process.

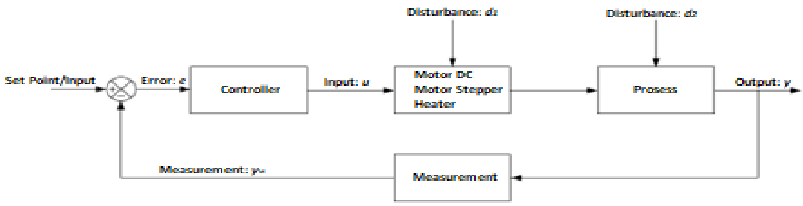

Fig. 13. Closed-loop block diagram of injection moulding machine

Table 1. Results of controlling a mini injection moulding machine based on microcontroller ATMega128

No	Input Stepper Motor	Input DC Motor	Temp. Input Heater 1 (^{O}C)	Temp. Input Heater 2 (^{O}C)	Temp. Input Heater 3 (^{O}C)	Temp. Measurement Results in Cylinders (^{O}C)	Measurement Results (Watt)	Output Stepper Motor	Output DC Motor (Load)
1	30	30	90	90	90	**130**	**491.1**	**30.2**	**0**
2	40	40	100	100	100	**145**	**493.6**	**41.4**	**0**
3	50	50	110	110	110	**160**	**500.7**	**51.5**	**13.5**
4	75	75	120	120	120	**180**	**508.1**	**72.5**	**41.2**
5	100	100	150	150	150	**260**	**509.1**	**93.6**	**55.1**
6	120	120	150	150	150	**260**	**509.5**	**94.6**	**61.5**

5. Conclusion

Based on the research results and discussion referring to the objectives of this research, it can be concluded that 1) The results of this research adjust the character of the motor used by each working principle, where the stepper motor works on a mould that requires accurate positioning and the DC motor works more precisely. For the thread pressing process, which does not require precise positioning of the pressure distance; 2) From research results, Stepper motors and DC motors using PCL Filament and PLA Filament are very suitable because of the low temperature and pressure so that this injection moulding machine can be used on a small industrial scale; 3) It is necessary to add coolers so that the product results are not defective when the cavity and core are separated.

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