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ANALYSIS OF MACHINING PROCESS IN INJECTION MOULDING USING PLC AND PROCESS PARAMETERS

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Abstract—**Injection moulding is most advanced manufacturing technique for the manufacture of plastic parts with high accuracy, complexity and speed is injection moulding. A plastic pallet is heated by a heating element, then a mould cavity is filled with molten metal using a high-pressure injection technique with the help of a screw, and the final component is formed when the plastic has cooled and solidified. The injection moulding process is incredibly flexible and may be used to produce components with intricate geometries and precise tolerances. The layout of moulds, material demand and processing parameters are only a few of the complex factors that move in the complex way of injection moulding. Using PLC we can easily automate the process. In addition to how to improve process parameters and its solution to work efficiently. Industrial automation has become essential. The programmable logic controller (PLC) is a programming system used for automation. It is a user-friendly, specially designed computer with microprocessors that performs various types and complexity of control tasks. The aim is to monitor key process variables and modify operations as needed. PLC is used to automate manufacturing and assembly in the industrial context. The study focuses on the automation of injection moulding machines using PLCs and pneumatic cylinders. There are four cylinders, each representing different tasks. The four steps of this process include the clamping and dissolving of the die, the opening and closing of the die. The injection of plastic materials while they are still melted, and finally the ejection of the components.**

Keywords—**Injection moulding, automation, Programmable Logic Controller (PLC), Process parameters, Quality, efficiency, and optimization.**

I. INTRODUCTION

As the title suggests, we have discussed the whole injection moulding process using some software called "TWINCAT" and also found out the relationship between mould temperatures vs. melting temperatures and injection speed vs. cooling time. Automation is to automate the process with help of new technology to minimize the need for human labour in the creation of mass production. The impact of automation on daily life and the global economy is on the rise. Automation is a technology that employs mechanical, electronic, and computer technologies to run and control production in the industrial setting.

Various process parameters should be in range, which will reduce the cycle time and improve quality, hence the final product must be without any shrinkage, flesh burrs or any type of damage. Yeah, products must be without defect when the inspection process is carried out.

First, we discuss the explanation of the process with diagram and software. Then from the table we will plot graphs and in details process parameters are described. [1]

II. EXPLANATION OF PROCESS

Here, we give complete discuss on how injection moulding works? How different process parameters play vital role to improve, to enhance the machining process of injection moulding process.

So, basically, we have proposed the idea of using ladder logic to explain the whole process with specific parameters. In the machine, different types of pressure sensors, temperature sensors, and, most importantly, timers and controllers are used.

These sensors, timers, and other devices are controlled by a PROGRAMMABLE LOGIC CONTROLLER (PLC). PLC has more advantages like increased reliability, more flexibility, lower cost, and a faster response time. [1]

Many researchers have done research on using some software like Mitsubishi, but here we have used more basic and easier-to-understand software called "TWINCAT" to perform the different ladder logic of the whole process

Process's steps are mentioned below:

1. PB (push button) is pressed, Heater is started.
2. When ideal temperature is reached, alarm is on then and then injection moulding is prepare to be taken into process.
3. Again PB is pressed, there is solenoid that control the motion of cylinder, cylinder moulding in forward direction.

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4. For the specific time of interval cylinder applies the pressure in mold for injecting the material accurately in die.
5. Timer is there for cooling
6. now, sensor detects the temperature of material in the die, according cylinder direction is reversed by solenoid
7. Later on mold is opened, final product is ready for inspection.
8. Mold is closed for another cycle of injection moulding process.

Ladder logic is generated by TWINCAT software, which is implemented in injection moulding machine.
Step by step, PB is pressed, and timers do their job. A total of 5 timers are used for controlling the whole process. So this is an insight into how machines are actually worked with the use of simple software. This is the visitation for a better understanding of the process; it is also generated by TWINCAT software.

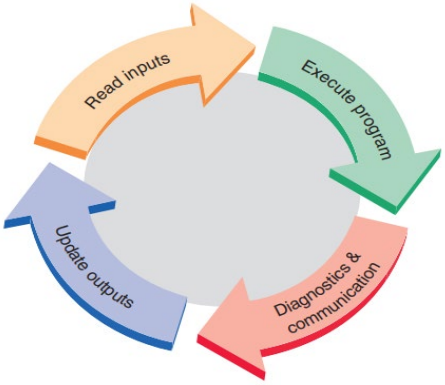

Fig. 1. PLC Working

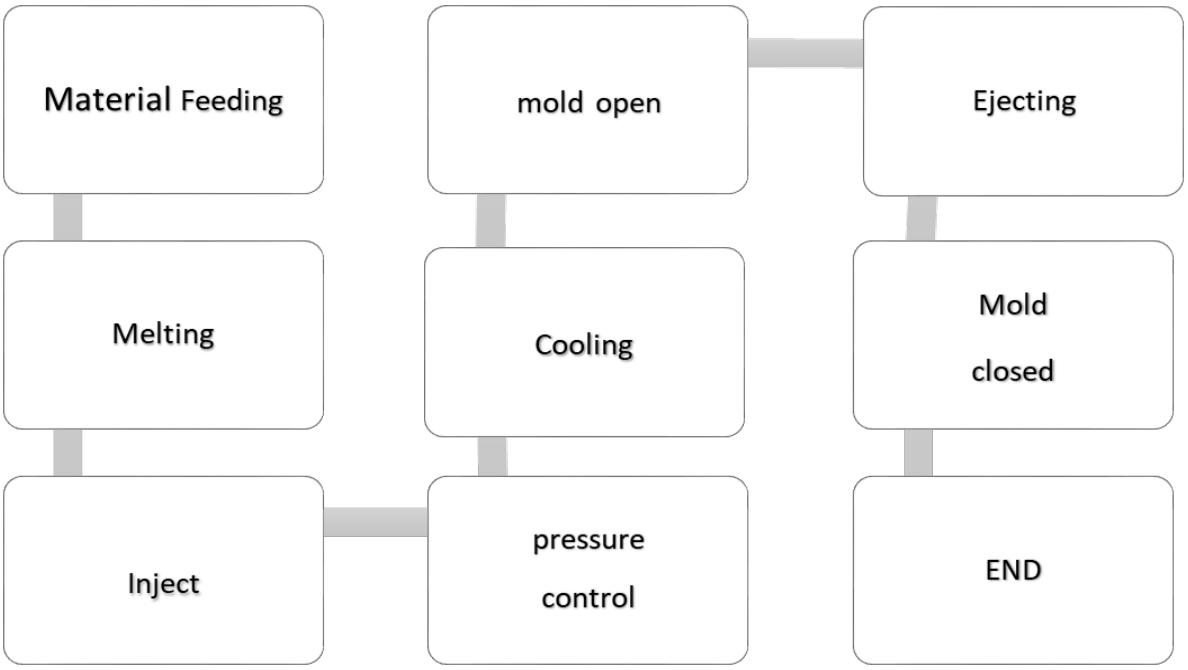

Fig 1 explains the working of whole PLC process, in the chart there is cycle of for different process followed by below:

1) Controller will read inputs whether there is errors or not that confirmed by software.
2) Now program is ready for execution.
3) the sequence in which they happened, the diagnostics-capable modules into the diagnostics buffer.
4) Now it will give updated outputs

Some basics of PLC: these are the main parts of PLC: central processing unit (CPU), the input/output (I/O) section, the power supply, and the programming device. Most PLC systems are in fact proprietary, so you must be sure that any

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generic hardware or software you may use is compatible with your particular PLC. [2]
Sensors: sensors such as pressure as well as temperature sensors happen to be used to indicate the pressure as well as temperature on top of the display that belongs to the injection moulding machine.
Most that belongs to the time, pressure sensors happen to be piezoelectric sensors, as well as that is going to belong to temperature sensors, there happen to be thermocouples mounted on top of the surface.Pressure sensors happen to be used to find the back pressure, holding pressure, etc., whereas temperature sensors happen to be used to find the melting temperature as well as moulding temperature. [3]
Timers: timers happen to be used that is going to belong to melting time that is going to belong to material inside of the die, injecting time, holding time, ejecting time, cooling time, as well as cycle time. Basically, an existing "timer on top of delay" timer happens to be used. [3]

III. ANALYSIS OF LADERLOGIC & PROCESS PARAMETERS

The list of total inputs and outputs are mentioned below:

inputs

- X000 = Button start
- X001 = Contactor
- X002 = Alarm Heater
- X003 = Button stop
- X004 = Alarm motor
- X005 = cylinder reverse
- X006 = cylinder forward

output

- M0 = start
- M1(Y000) =Power Temperature
- M2= Alarm heater
- M3= Heating process
- M4= Temperature reach
- M5= Ready
- M6= Auto process
- M7(Y002)= Cyliner forward
- M8(Y001)= motor for screw
- M9= waiting cooling
- M10= Motor finish
- M11= cooling finish
- M12(Y003)= cylinder reverse

(List of inputs and outputs)

In below images, ladder logic is generated by putting gates in different rungs. There are total 23 rungs, each rung has its own logic and logic must be read by from top left corner to bottom right corner. [5]

The PLC is directly attached to the field input and output devices, and the ladder logic program determines which outputs to activate based on the state of the input signals. Visualizations are also attached for better clarity and

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understating of whole process. Visualizations is also done by this TWINCAT software, as you can see in images.

(Visualizations done in "TWINCAT software")

- Process parameters:

There happen to be various process parameters such as pressure, time, temperature as well as injection speed etc. By changing each parameters final product get may affected.

Inside of brief, on the possibility that we talk about changing inside of time that belongs to injection, its temperature, pressure, holding time during the same time that an existing

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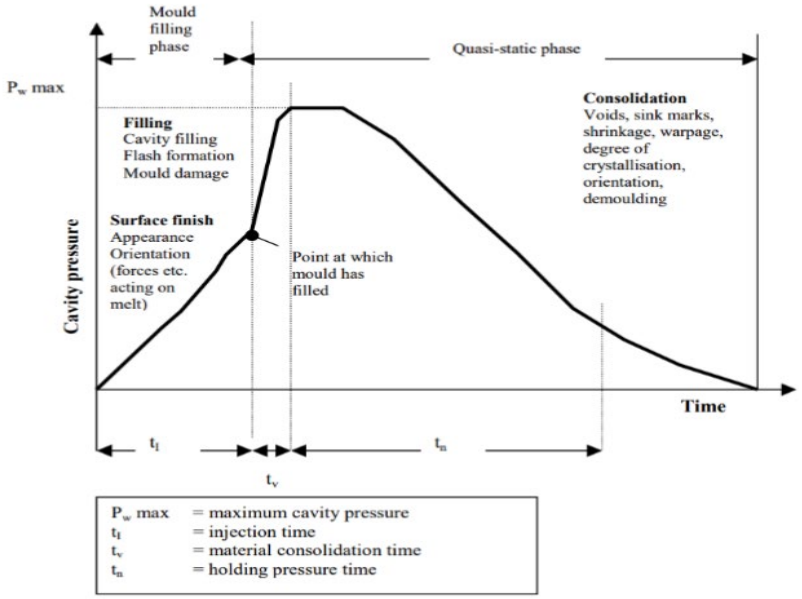
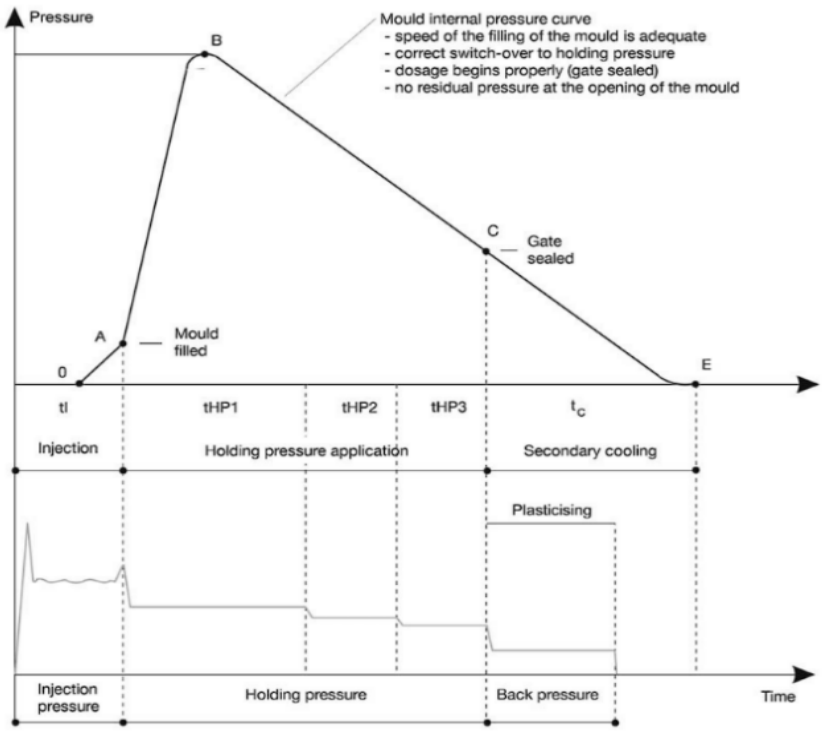
result we have found out that there happens to be rise inside of melting temperature.
There happen to be total three phases melt preparation phase, injection phase as well as holding pressure & time phase.

1) Melt preparation phase:
In this phase, material is being melted at a given temperature. In the above pressure versus time graph, you can see that the pressure in the initial stages is obviously zero, as if not required because the material is not melted. When the timer reaches its preset value, the alarm motor goes on, and the material is ready to pressurize with the use of the cylinder lead screw.
That is going to belong to the most that belongs to material; the melt temperature happens to be always lower than the mould temperature because it gives the quality as well as the most reliable product that is going to belong to the specific cycle time.





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2) Melt preparation phase:

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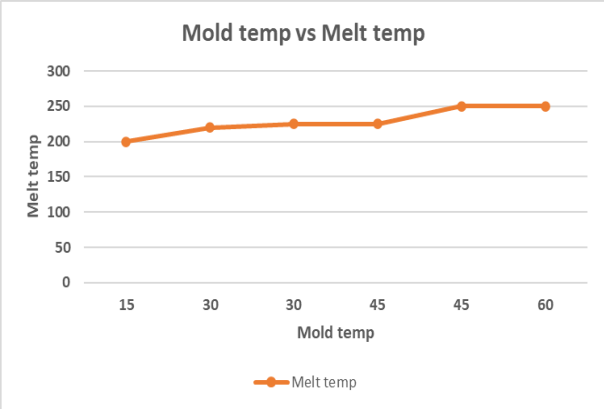
So in this phase, there are also parameters like lead screw speed and back pressure that play an important role. If the lead screw rotates faster than ideal speed, there has to be a chance of a rise in frictional heat, which is not feasible. And if the lead screw rotates slower than ideal speed, there has to be a chance in the die that air holes sucked.

From this graph, on the x-axis is mould temperature and on the y-axis is melt temperature. It is clear from the graph that mould temperature is proportional to melt temperature, and melt temperature is always greater than mould temperature.

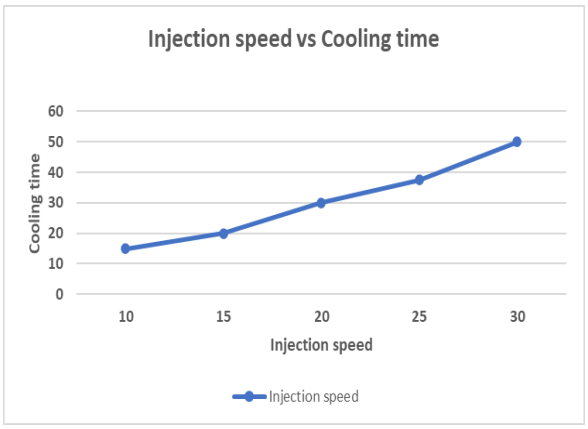


3) Injection phase:

In this phase, as the name suggests injection phase means now our material is ready to inject in the die and for that we need to specify some parameters like pressure, temperature and injection rate.

In increasing with material injection rate, there is found that impact on its energy, in the graph you can see the pressure is decreased after the injection phase has been done and material is fully compressed.

From this graph on x-axis injection speed and on y-axis cooling time. It is clear from graph that injection speed is proportional to cooling time.



- Holding pressure and holding time:

Holding pressure is given to the moulding portion when plastic pallets are heated by heat sources because the only melting necessary is pushed into the cavity to allow the material to shrink thermally and the axial screw speed is low. The material is ready for processing when the predetermined value is reached thanks to PLC timers, which also turn on the alarm motor.

The internal structure of weight, dimensional accuracy, shrinkage, and moulding are all significantly impacted by holding pressures. Shrinkage and the manufacturing of short plastic pieces are also risks of very low holding pressure. Furthermore, an increase in internal residual pressure due to excessive holding pressure damages the mechanical properties. The control pressure must be applied for the same amount of time as it takes the gate to completely freeze or solidify. [8]

- Cooling time & Cycle time:

In injection moulding, cooling time is necessary to cool the plastic material until it has solidified. With the help of a PLC timer, we can control the cooling time. Cooling time depends on the intrinsic material structure. Higher cooling times improve material quality and inner structure. [8]

4) Cycle time is a very important parameter in injection moulding for mass production. It is the time taken to produce a single product in injection moulding. Time taken between machine and mould movement. It's time for the injection unit to move, the mould to open and eject, and the mould to close. Time for residual cooling and time taken in applying pressure Time to inject and plasticity period.

- Screw speed:

5) The requirement for efficient material processing is a variable screw speed. The material determines the ideal screw speed as a parameter. For example, manufacturers will provide the recommended rpm speed for various

polymers, from which the recommended speed for the screw can be calculated. Since the friction is not excessive, there is no need to worry that the melting will be indisputable homogenized or that the plastic will be damaged by heat or mechanical stress.

- Back pressure

The main purpose of the back pressure is to ensure that the melting plasticizes with a sufficiently high degree of uniformity. There must be no air or gas blisters, and there must be an equitable temperature distribution. Due to the growing and more lasting friction effect, back heat increases when back pressure increases, which has an equal and opposite influence on plasticization time and plasticization yield. Overheating also increases the possibility of combined damage. [8]

IV. CONCLUSION

From this paper, we can conclude that for better clarity to understand the whole automation process of any industry 4.0 machine, you need better software to connect the logic of the whole process. With the help of diagrams, simulations, and visualizations, one can easily understand the injection moulding process that we have described above. Using a PC controller, we automate the process and increase its efficiency. If we talk about the process parameters, there are more than two changing variables for one constant variable. For example, mould temperature is varied at the same melt temperature with changing cycle times or holding pressure. It establishes the relationship between three or more process parameters with better clarity. This approach will result in high production rates and great quality, both of which are crucial for a manufacturing unit's existence. Nevertheless, while using current management techniques might greatly improve productivity, they should never be seen as an end in themselves. Instead, research and development should be supported. It’s crucial to have a solid understanding of low-cost automation techniques. Utilizing simple devices like limit switches, relay sensors, actuators of pneumatic and hydraulic systems, and electric control to automate an ordinary injection moulding machine at "low cost" will result in higher productivity, profitability, stability, and growth in small industries. This is achieved at "low cost" by automating existing ordinary injection moulding machines with simple equipment such as limit switches, relay sensors, pneumatic and hydraulic actuators, and electric control. There are many other process parameters like clamping force, mould capacity, delay time for injection, etc., but these above parameters in three phases are more important to establish a quality and reliable final product.

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