



Evaluation of Heater Maintenance on Injection Molding Machine

Final Project

**By:
Jeremi Togito Hutahaean(3222211008)**

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Jeremi Togito Hutahaean



NIM:
3222211008

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By:

Jeremi Togito Hutahaean(3222211008)

Session date: December 24, 2025

Approved by :

Examiner 1



**Muhammad Arifin, S.Si.,
M.Si
NIK: '116161**

Supervisor



**Fitriyanti Nakul, S.Pd., M.Si
NIK: '199004042019032023**

Examiner 2



**Vivin Octowinandi, S.Tr.T.,
M.Sc
NIK: '198310302021211002**

Evaluation of Heater Maintenance on Injection Molding Machine

Jeremi Togito Hutahaean¹, Fitriyanti Nakul^{1*}

¹Jurusan Teknik Elektro, Prodi Teknik Elektronika Manufaktur, Politeknik Negeri Batam, Indonesia

Email: jeremimhutahaean@gmail.com;
Co-Email: fitriyantinakul@polibatam.ac.id

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In the plastic manufacturing industry, the temperature stability of the injection molding machine has an important role in ensuring product quality and production process efficiency. Disturbances in the heater system and temperature instability often occur due to decreased component conditions, residue buildup, and suboptimal implementation of preventive maintenance. These conditions can cause the initial heating time to be longer and increase the potential for product defects. This study aims to evaluate the effectiveness of heater treatment in injection molding machines in improving temperature stability and initial heating performance. The research methods used include visual inspection, cleaning of heater bands and heater nozzles, tightening of electrical terminals, calibration of temperature sensors, and analysis of actual temperature comparisons before and after treatment. The results showed that before treatment, the actual temperature was in the range of 98–136°C and had not reached the specified set temperature. After treatment, the actual temperature increases and is stable in the range of 223–295°C according to the needs of the injection molding process. These results show that heater maintenance is able to improve temperature stability, improve initial heating performance, and support machine reliability during the production process. Thus, the regular application of heater maintenance can improve process efficiency and maintain product quality in injection molding machines.

Keywords: injection molding, heater treatment, temperature stability, maintenance, injection molding machine

I. INTRODUCTION

The plastic manufacturing industry is one of the sectors that is growing rapidly as the demand for plastic products in various fields, such as automotive, electronics, and household needs [1]. One of the most widely used production methods in this industry is the injection molding process, as it is capable of producing large quantities of products with complex shapes and high levels of precision [2]. The success of the injection molding process is highly dependent on the stability of the process parameters, especially the heating temperature of the plastic material.

The heater system is the main component of the injection molding machine that functions to melt the plastic material to the appropriate temperature before it is injected into the mold [3]. If the temperature of the heater is unstable or does not reach the set temperature, then the plastic melting process becomes suboptimal. These conditions can

cause different types of product defects, such as short shot, sink quality and increases material waste.

In field practice, disturbances in the heater system often occur due to degradation of the quality of the heater band, carbon residue buildup, loose electrical terminal connections, and inaccuracies of temperature sensors [4]. This problem generally arises due to engine maintenance that is not carried out regularly and scheduled. Many industries still apply corrective maintenance, which is maintenance carried out after a breakdown, which has the potential to lead to longer machine downtime and greater repair costs.

Unmaintenance of the heater system can cause the actual temperature not to reach the set temperature, the initial heating time to be longer, as well as temperature instability during the production process. This condition has an impact on product quality and the reliability of the injection molding machine. Therefore, an evaluation of heater maintenance is needed to determine the effectiveness of the application of preventive maintenance in improving heater performance and temperature stability. This study evaluated the heater maintenance on Sumitomo brand injection molding machines by comparing the temperature conditions before and after maintenance.

Temperature instability in injection molding machines is generally caused by a decrease in the condition of heating system components, such as heater bands, heater nozzles, loose electrical terminal connections, and inaccuracies in temperature sensors. In addition, the buildup of carbon residue in the heating area can inhibit heat transfer.

This condition causes the actual temperature to be unable to reach the setpoint, the initial warm-up time becomes longer, and the temperature is unstable during the production process. The impact is an increased risk of product defects and a decrease in engine efficiency. Therefore, an evaluation of heater maintenance is needed to determine the effect of maintenance actions on temperature stability and initial heating performance of injection molding machines.

This research is based on the concept of preventive maintenance which aims to prevent equipment failure before damage occurs. In injection molding machines, the heater system functions as the main controller of the melting temperature of plastic materials.

Based on the heat transfer theory, heating efficiency is greatly influenced material flow, which ultimately degrades product by the physical condition of the heater, insulation quality, and temperatur marks, shrinkage, as well as imperfections in sensor accuracy. If one of these components experiences a decrease in performance, the deviation between the actual temperature and the set temperature will increase.

Through the application of heater treatment which includes carbon residue cleaning, tightening of electrical terminals, and calibration of temperature sensors, it is hoped that heat transfer efficiency will increase, temperature deviation will decrease, and the stability of the injection molding process can be achieved. Based on the background of the research, the problems studied in this study are related to the temperature condition of the heater in the injection molding machine before treatment. In addition, this study also examines how the effect of heater maintenance on temperature stability and engine warm-up performance. Another problem is the extent to which heater maintenance is able to reduce temperature deviation so that it can support the optimal performance of injection molding machines. This study aims to evaluate the temperature condition of the heater in the injection molding machine before maintenance. Furthermore, this study aims to analyze the effect of heater maintenance on temperature stability and engine initial heating performance. Another purpose is to determine the effectiveness of heater maintenance in reducing temperature deviation so that it can increase the reliability of the injection molding machine.

II. METHOD

A. Research Flow

The research method used in this study is a quantitative descriptive method, which aims to evaluate the performance of the heater system in injection molding machines through the measurement and comparison of temperature data before and after treatment. This research was carried out by observing the actual condition of the engine, performing heater maintenance, and analyzing temperature changes as an indicator of the effectiveness of maintenance maintenance. To make it easier to understand the stages of the research carried out, the research flow is presented in the form of a flowchart such as shown on Image 1,

Based on the research flow in Figure 1, the stages of research are carried out as follows:

1. Problem Identification

The initial stage of the research was carried out by identifying problems with the heater system of the injection molding machine. Identification is focused on actual temperature conditions that do not reach the set temperature, longer initial warm-up times, as well as temperature instability during the production process.

2. Visual Inspection of Heaters and Cables

After the problem is identified, a visual inspection of the heater components and cables is carried out to determine any physical damage, such as worn cables, loose terminals, or suboptimal heater conditions.

3. Determination of Maintenance Actions

Based on the results of the inspection, it is determined what maintenance actions will be carried out. If physical damage is found to the heater, the heater is replaced with newmaintenance is carried out in the form of maintenance on the heater and cables.

4. Temperature Data Analysis and Comparison

After the maintenance or replacement of the heater is carried out, the actual temperature of the heater is measured during the operation of the machine. Temperature data before and after treatment is then analyzed and compared to determine changes in heater performance and temperature stability.

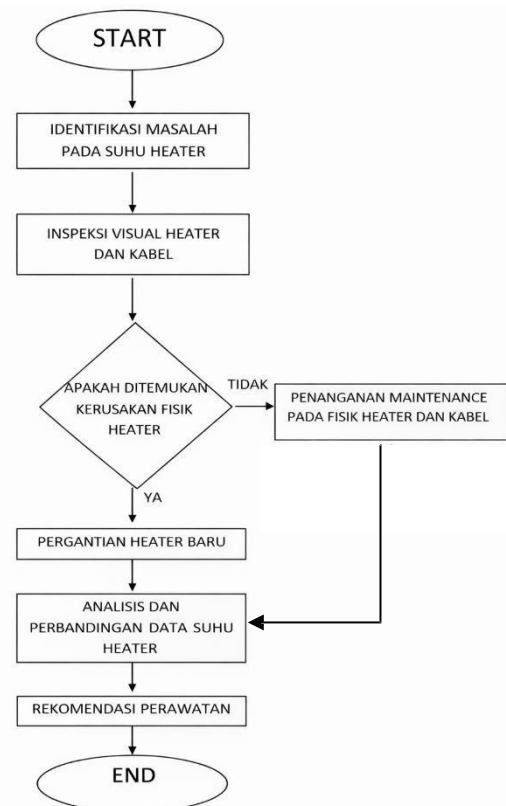


Figure 1. Research Flow

5. Conclusions and Recommendations

The final stage of the study is the drawing of conclusions based on the results of temperature data analysis to assess the effectiveness of heater maintenance. Furthermore, treatment recommendations are given that can be applied to improve the reliability of the heater system in the injection molding machine.

B. Research Tools and Materials

This research focuses on the heating system of injection molding machines, especially in the barrel heater section. For measurement and monitoring purposes, several tools are used, including a digital multimeter to measure current and voltage, as well as a thermocouple as a temperature sensor installed on the heater to ensure that the temperature remains stable. In addition, a temperature controller is used to automatically set

material used in this study is a plastic material used in the injection molding process and is an object of observation during the production process.

In addition to the main data, supporting data was obtained from engine maintenance records, heater breakdown logs, as well as references from technical books and scientific journals that were used as the basis for theories and comparative materials for research results.

C. Research Object and Location

This research was carried out in the injection molding production area of PT Daiho Batam with the object of research in the form of five units of Sumxxxx brand injection molding machines that are actively used in the production process. These machines were chosen because they have the same process characteristics, use a heater system in the barrel as a heating medium for plastic materials, and experience similar problems related to the instability of the heater temperature before maintenance is carried out. The five injection molding machines used in this study consist of several types and capacities, namely machines with the identities SUM-014, SUM-001, and Sumxxxx series machines SE180EV-A, SE220EV-A-HD, and SE450EV-A-

HD. All of these machines operate on the same working principle, where the plastic material is heated in the barrel. Several units of Sumitomo brand injection molding machines used as the object of research are (a) the identity of the SUM-014 machine, (b) the Sumxxxx SE180EV-A machine, (c) the Sumxxxx SE220EV-A-HD machine, and (d) the Sumitomo SE450EV-A-HD machine used in the production process at PT Daiho Batam.

The selection of these five machines aims to obtain more representative data and describe the actual conditions in the field. By using more than one machine, the evaluation of heater maintenance is not only based on one machine unit, but reflects the consistency of the performance of the heater system on several injection molding machines with different capacities. In addition, the use of five machines also allows for a more objective comparison of temperature conditions before and after maintenance maintenance.

The main focus of this research is on the heater barrel system, which includes a heater band, nozzle heater, temperature sensor (thermocouple), and temperature control system (temperature controller). Evaluation was carried out by comparing the actual temperature of the heater before and after maintenance maintenance on each machine. Temperature data is taken when the machine is in normal operating conditions of production.

With five machines as the object of research, the results of the evaluation are expected to be able to show the effectiveness of the heater maintenance as a whole and provide an overview of the increase in temperature stability that occurs in the heating system of the Sumitomo injection molding machine.

D. Mesin Injection Molding Rusco

The RUSCO SO 1800 machine is an automatic injection molding machine used in the process of forming and handling plastic materials for small to medium-sized components, such as electronic components and precision mechanical components. This machine is designed to produce products with

continuously in the mass production process. The advantages of injection molding machines lie in their ability to maintain product dimensional consistency, cycle time efficiency, and stability of process parameters, especially the heating temperature of plastic materials [1][2].

The working system of injection molding machines, including the RUSCO SO 1800, is highly dependent on the performance of the heating system (heater system) which functions to melt plastic materials until they reach the appropriate temperature before the injection process is carried out. Temperature stability in barrel and nozzle becomes

an important factor in ensuring the quality of the print results and minimizing the occurrence of product defects [3].

Injection molding machine is a machine used to produce plastic products by injecting liquid plastic into molds. This process is particularly suitable for mass production because it is able to produce products with complex shapes and precise sizes (Kristanto et al., 2019).

The work process of the injection molding machine begins with inserting plastic material in the form of granules (granules) into the machine. The material is then heated by the heater system until it melts. After the plastic material melts, the plastic is pushed by a screw into the mold at high pressure. Once the mold is fully filled, the plastic material is cooled to harden. Next, the mold is opened and the plastic product is removed from the machine.

The main components of the injection molding machine include a material entry point, a heater system, a driving screw, a mold, and a clamping system. The clamping system serves to keep the mold tightly closed during the injection process.

Injection molding machines are widely used in the industry due to their ability to produce large quantities of plastic products quickly and consistently. However, the stability of the heater temperature must always be maintained so that the material melting process runs properly. If the heater is damaged or the temperature is unstable, the resulting product has the potential to be defective and the production process can be disrupted.

E. Parameter Temperature Heater

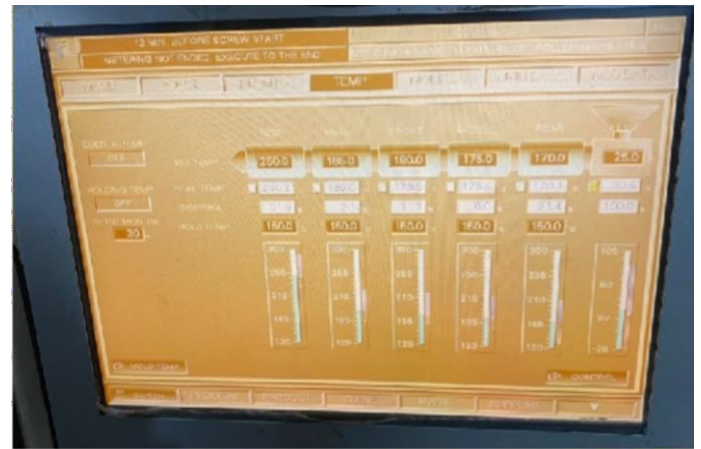


Figure 2. Heater Temperature Parameters

Based on Figure 2, the temperature of the heater in the injection molding machine has a very important role because it directly affects the quality of the plastic products produced. The heater serves to melt the plastic material until it reaches the appropriate temperature before it is injected into the mold. If the temperature is too low, the plastic material

does not melt completely, which can cause product defects, such as short shots (the product is not fully filled) or rough product surfaces. On the other hand, if the temperature is too high, plastic materials can degrade, discolor, and potentially cause damage to the machine (Sidiq et al., 2020). The heater system also needs to be maintained periodically so that it does not suffer premature damage and so that temperature stability remains awake. Regular temperature checks of the heater are essential to ensure that the printing process runs smoothly and the quality of the product is maintained. The temperature setting of the heater must be adjusted to the type of plastic material used.

Here are some important parameters in setting the heater temperature in an injection molding machine:

1. *Temperatur Awal (Start-Up Temperature)*
The initial temperature when the machine starts heating the plastic material. This temperature value must be adjusted to the type of material used so that the heating process takes place optimally.
2. *Operational Temperature Range*
The temperature range that must be maintained during the printing process. Deviations from this range may lead to product defects.
3. *Temperature Uniformity* The temperature must be evenly distributed throughout the heater so that the plastic material melts perfectly and consistently.
4. *Heating Rate*
The heating speed should not be too fast or too slow. Heating too fast can damage the heater, while heating too slowly can hinder the production process.
5. *Temperatur Maksimum (Maximum Temperature)*
6. *Safe highest temperature limit for heaters and plastic materials to prevent component damage and material degradation.*

Material: Plastic	Temperature Barrel (°C)	Temperature Nozzle (°C)
Polypropylene (PP)	180 – 230	190 – 230
Acrylonitrile Butadiene Styrene (ABS)	210 – 260	220 – 260
Polycarbonate (PC)	260 – 320	270 – 320
PC/ABS Blend	230 – 280	240 – 280

Table 1. General Temperature Range of Plastic Materials in the Injection Molding Process

F. Measuring Instruments

In the injection molding process, the measurement of the heater temperature is very important to maintain product quality and the stability of the production process. Therefore, an accurate measuring instrument is needed and capable of displaying temperature data in real-time.

properly and produce accurate data, calibration activities need to be carried out regularly. Calibration aims to ensure that the measurement results remain in accordance with the actual conditions, so that heater maintenance activities can be carried out more precisely and efficiently.


In this study, some of the measuring tools used are as follows:

1. **Multimeter:** Used to measure the temperature, voltage, and electrical resistance of the heater system to determine the electrical condition of the heating components.
2. **Thermocouple:** Used to measure the temperature directly on the barrel or heater so that the actual temperature can be known during the engine's operation.
3. **Infrared Thermometer (Pyrometer):** Used to measure the surface temperature of the heater without direct contact, making it safe and practical to use when the machine is operating.

The regular use of these measuring instruments helps to maintain optimal heater conditions, prevent damage, and ensure that the quality of the products produced remains good.

G. Disability Criteria and Admission Criteria

The following table explains the defect criteria and acceptance criteria for the observed component non-conformity, especially related to the physical condition of the heater, such as burn marks, carbon buildup, and heating temperature instability.

Defective Images	Disability Criteria	Criteria Reception
	<ul style="list-style-type: none"> • Heater The band shows burn marks and the presence of carbon residue buildup. • The actual temperature does not increase or is well below the setpoint. • Uneven heat distribution in the heating area. • Risk of causing overheating or failure during the molding process. 	<p>The actual temperature < 90% of the set temperature. (kbbi)</p> <p>There was an initial warm-up failure. There is damage</p> <p>Physical</p> <p>or residu karbon.</p>


Coplanarity		
	<ul style="list-style-type: none"> Clean and intact band heater with no carbon residue or burn marks. Temperature Actual increase and stabilize close to the set temperature range. Process warm-up takes place normally without alarm. Value resistansi Back be in normal tolerance limits. 	The actual temperature $\geq 90\%$ of the set temperature. Process warm-up runs normally. Conditions Physically clean and no damage.

Table 2. Disability Criteria and Admission Criteria

H. Maintenance Care

Maintenance maintenance is a maintenance activity that is carried out on a scheduled basis to prevent deterioration in component conditions and minimize the risk of heater failure during engine operation. The main objectives of the application of the treatment

The maintenance on the injection molding machine is to ensure the temperature control system, including the heater band and nozzle heater, can operate within acceptable performance limits. Thus, temperature instability, too long initial heating time, and downtime can be avoided.

In contrast to corrective maintenance that is carried out after damage to the heater, maintenance maintenance is carried out regularly so that potential failures can be detected early. The application of this maintenance treatment can reduce the overall repair cost and prevent major disruptions to the production cycle [6].

In Sumitomo injection molding machines, maintenance treatment is focused on several main components of the heating system, namely:

1. Heater band
2. Nozzle heater
3. Sensor temperature
4. Electrical terminal connectors
5. Isolation
6. Wiring harness

These components have an important role in maintaining the stability of the melting temperature of plastic materials. Regular inspections and cleaning allow operators to detect deterioration in physical conditions, carbon residue buildup, loose terminals, and sensor inaccuracies before the machine experiences pre-heating failure or temperature instability during the printing process.

In addition, periodic measurements of electrical resistance, thermostat calibration, and cleaning of accumulated carbon residues can improve heat transfer efficiency and support more precise temperature control [7]. With consistent application of maintenance maintenance, the heater system can operate more efficiently, temperature deviations are reduced, the initial heating time becomes more stable, and unplanned downtime can be minimized. This contributes to the stability of product quality, reduction of material waste, as well as reduction of maintenance costs in the long term. In general, maintenance maintenance plays an important role in maintaining the reliability of the machine and

supporting stable and efficient production performance [8].



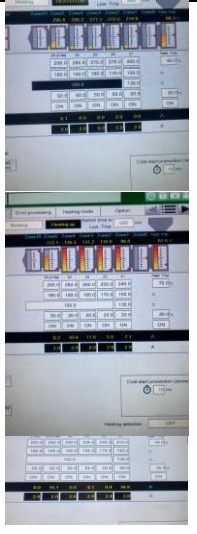
Yes	Steps Care	Key Points	Purpose	Visual Aid
1	Cleaner Nozzle dan heater Strap	Disappearing squirrel Carbon and residues di Around area nozzle	Increase An perpindahan hot and mencegah overheating	
2	Pengencan São terminal Electricity	Ensure Connection terminal strong, safe, and Free corrosion	Mencegah Loss electrical power and chain axis And Heating	
3	Calibration Sensor Temperature	Memverifik Accuracy Sensor through Reading on the panel Control	Ensure Temperature Current Conform With Temperature Set	

Table 3. Machine Maintenance Settings

The procedure carried out on the heater system of the Sum injection molding machine is carried out during routine maintenance to ensure that the heater band, nozzle heater, and temperature sensor can operate normally after cleaning and inspection. Cleaning nozzles and heater bands aims to prevent the buildup of carbon residues that can reduce heat transfer efficiency. Tightening of electrical terminals as well as calibration of temperature sensors is carried out to ensure stable temperature readings and prevent Warm-up failure occurs during engine operation.

If after the maintenance action there are still abnormalities, such as the actual temperature that has not reached the set temperature, then corrective treatment measures are needed. Corrective maintenance can be in the form of replacing a damaged heater band or nozzle heater. Thus, maintenance treatment serves as the first step to reduce the risk of heater failure as well as maintain the stability of temperature control during the injection molding process.

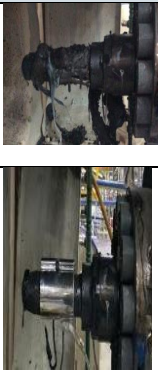


Steps Care	Key Points	Purpose	Visual Aid
Cleaning of heater bands and nozzles	Disappearing an residu karbon Using Brush or cloth	Improves transfer efficiency and Hot mencegah overheating	
Inspection Actual and	Compare Reading Temperature and on panel Control	Verifying Sensor accuracy Temperature	
Testing Performance Heater after Treatment maintenance	Ensure Process Heating Stable and Temperature achieve Value The expected	Ensure System Heater Back Operate normally	

Table 4 shows the maintenance steps for the heating system of the Sumitomo injection molding machine.

Table 4 above describes the steps for implementing maintenance on the heating system of the Sumitomo injection molding machine. These steps are taken when there is an abnormality in the temperature control system, such as the actual temperature that does not reach the set temperature or unstable heating during the initial warm-up process. These abnormalities are generally caused by a decrease in the condition of the heater band, nozzle heater, or loose electrical terminal connections, resulting in longer heating times, inconsistent melting temperatures, and increased risk of production downtime. If temperature instability still occurs after maintenance treatment is carried out, corrective maintenance measures are required in the form of replacing the heater band or nozzle heater. In this study, maintenance treatment was applied to the engine that experienced a disturbance to restore the performance of the heating system, then performance validation was carried out through a comparison of temperatures before and after treatment. The results showed that the actual temperature increased significantly and reached a stable value after heater replacement and maintenance application. The maintenance schedule used in this study is adjusted to the periodic inspection intervals recommended by the manufacturer as well as the company's internal maintenance procedures, so that the implementation of maintenance can be carried out effectively and continuously.

On August 12, 2025, for machine SUM-014, the actual temperature before treatment was in the range of 98 to 145 degrees Celsius. After treatment, the actual temperature increased to 230 to 265 degrees Celsius, and the status was improved. On September 26, 2025, machine SUM-014 recorded an actual temperature before treatment of 98 to 136 degrees Celsius. After treatment, the temperature became 223 to 295 degrees Celsius, and the condition was considered stable. On November 25, 2025, the actual temperature before treatment for machine SUM-014 ranged from 113 to 162 degrees Celsius. After treatment, it increased to 256 to 286 degrees Celsius, with a stable status. Finally, on December 11, 2025, machine SUM-014 had an actual temperature before treatment of 98 to 131 degrees Celsius. After treatment, the temperature reached 259 to 277 degrees Celsius, and the machine condition remained stable.

The table above presents a temperature comparison of the four measurement periods before and after maintenance treatment on a Sumitomo injection molding machine with asset code SUM-014. Prior to treatment, the actual temperature value was consistently below 160°C. After maintenance actions that include cleaning the heater band, retightening the electrical terminal, and calibrating the temperature sensor, the temperature stability has been significantly improved. The operating temperature range after treatment is in the range of 223°C–295°C, according to the needs of the injection molding process. These results show that the performance of the heating system is successfully restored and the temperature variation is significantly reduced, so that the implementation of maintenance treatment can be declared to be running effectively.

I. Percentage Decrease

The percentage reduction formula is used to calculate the magnitude of the decrease in temperature deviation after maintenance treatment is carried out. This calculation aims to determine the level of effectiveness of the treatment measures in stabilizing the actual temperature of the heater [10]. The percentage decrease in temperature deviation is calculated using the following formula:

II. Percentage Decrease

The percentage reduction formula is used to calculate the magnitude of the decrease in temperature deviation after maintenance treatment is carried out. This calculation aims to determine the level of effectiveness of the treatment measures in stabilizing the actual temperature of the heater [10]. The percentage decrease in temperature deviation is calculated using the following formula:

1. The difference between the set temperature and the actual temperature before maintenance treatment is carried out.
2. Temperature deviation after treatment
The difference between the set temperature and the actual temperature after maintenance treatment is performed.
3. Difference in deviation (before – after)
Indicates the magnitude of the decrease in deviation or the rate of improvement that occurs due to the treatment action.
4. Divided by the deviation before treatment
Shows the magnitude of the decline relative to the initial unstable conditions.
5. Multiplied by 100%
Aim to convert the results of the calculation into the form of percentages.

III. RESULTS AND DISCUSSION

A. Data Analysis

Comparison of the actual temperature of the heater before and after maintenance treatment. Pre-treatment data is obtained while the machine is operating, while post-maintenance data. In this comparison, the blue rod represents the temperature value before maintenance treatment, while the orange rod represents the temperature value after the treatment is performed.

Actual Temperature of the Heater Before and After Maintenance Before maintenance treatment, the actual temperature of the heater is in the range of 98°C to 136°C, which indicates that the heating process is not optimal and the temperature is not able to reach the set temperature. This condition indicates the occurrence of initial heating failure and low heat transfer efficiency in the heating system.

After maintenance treatment is performed, the actual temperature of the heater is significantly increased to reach the range of 223°C–295°C, which is the expected operating temperature range. This improvement indicates that the heater band and nozzle heater have been in good working order and that heat transfer efficiency has been successfully restored.

The actual temperature increase proves that the application of maintenance treatment is effective in reducing temperature deviation and improving the performance of initial warm-up. Thus, the potential for product defects due to suboptimal heating and the risk of engine downtime can be minimized.

B. Data Sampling

Data sampling was carried out by focusing research on the Sumxxxxx injection molding machine with the asset code SUM-014, because the machine showed instability in the heating system

before treatment. The selection of this machine unit is based on several criteria that are in accordance with the objectives of maintenance maintenance evaluation, namely:

1. There is a significant deviation between the set temperature and the actual temperature,
2. Longer warm-up time than normal,
3. Operator reports related to heater performance instability during the production process.

This sample selection is in line with the principle of machine maintenance that prioritizes equipment with a high level of risk of performance deviations. Thus, the evaluation carried out is expected to be able to provide a clear picture of the effectiveness of the application of maintenance treatment in improving the performance of the heater system and increasing the reliability of the injection molding machine.

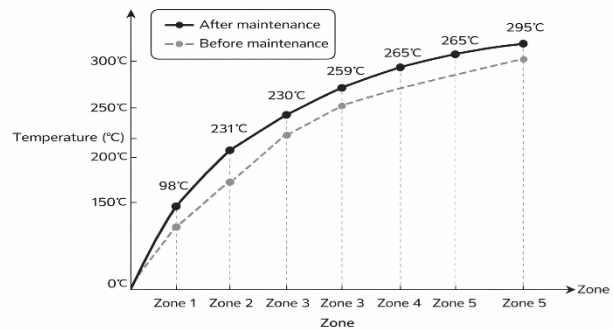


Figure 3. Temperature Deviation Before Maintenance Treatment

Before maintenance treatment, the actual temperature values recorded in Zones 1 to Zone 5 were far below the set temperature. The actual temperature is in the range of 98°C to 136°C, while the set temperature is in the range of 230°C – 265°C. This large temperature deviation indicates that the heater band and nozzle heater are not able to transfer heat effectively to the cylinder (barrel).

The temperature difference indicates several possible problems, such as carbon residue buildup, decreased heater band quality, loose electrical terminal connections, or deteriorating insulation conditions. As a result, the heating system is unable to achieve optimal melting temperatures, leading to heating instability and a longer warm-up time before the production process begins. This condition also increases the risk of product defects, such as materials that do not melt perfectly, imoptimal mold filling, and inconsistencies in product dimensions. Therefore, this condition emphasizes the importance of implementing maintenance maintenance routinely to maintain the performance of the heating system and the quality of production results.

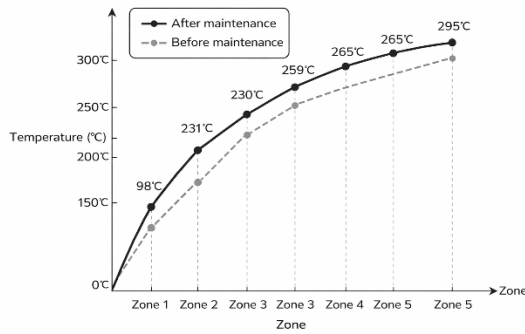


Figure 4. Temperature Performance After Maintenance Treatment.

After maintenance treatment, the actual temperature values in Zone 1 to Zone 5 experienced a significant increase and were able to achieve the targeted set temperature. Based on Figure 8, the actual temperature that was previously in the range of 98°C–136°C increases to 223°C–295°C after treatment.

This shows that the heating system, especially the heater band and nozzle heater, has been functioning effectively after replacement and adjustment. In Zone 1, which previously recorded the lowest temperature deviation, the actual temperature increased from 98°C to 223°C. Zone 2 has increased from 116°C to 272°C. The highest temperature stabilization occurred in Zone 5, where the actual temperature increased from 113°C to 295°C, approaching the set temperature of 255°C. In addition, the feed temperature also increased from 47.8°C to around 60°C, which indicates an increase in the consistency of heat transfer at the material entry point.

Such an increase in actual temperature indicates that:

1. Improved heat transfer efficiency,
2. The resistance value of the heater band returns to normal,
3. The terminal connection and isolation work well,
4. The initial warm-up time becomes shorter. Temperature stability achieved after maintenance treatment show that System Temperature control has been operating close to optimal conditions.

It is capable of Lower Potential occurrence Defects products, improve the quality of material melting, and ensure that the machine can operate continuously without experiencing delayed heating or temperature fluctuations.

Overall, the comparison between the pre- and post-treatment temperature conditions confirms that the maintenance actions including heater replacement, component cleaning, electrical terminal tightening, and sensor recalibration successfully restore the thermal performance of the Sumxxxxx injection molding machine.

Parameter	Before Actual Temp	Set Temp	Deviation (°C)	After Actual Temp	Deviation (°C)	Improvement (%)	Machine
Zone 1	98°C	230°C	132°C	216°C	14°C	89%	SUM-014
Zone 2	113°C	250°C	137°C	259°C	-1°C	99%	SUM-014
Zone 3	131°C	260°C	129°C	273°C	-13°C	90%	SUM-014
Zone 4	160°C	280°C	120°C	286°C	-6°C	95%	SUM-014
Zone 5	136°C	295°C	159°C	295°C	0°C	100%	SUM-014
Feed	41°C	50°C	9°C	61°C	-11°C	78%	SUM-014

Table 5. Temperature Comparison Before and After Maintenance

Treatment Table 4 presents temperature deviation data before and after maintenance treatment on the Sumxxxxx injection molding machine with asset code SUM-014. Prior to treatment, the actual temperature showed a considerable deviation from the set temperature, with the difference being in the range of 98°C to 160°C. This condition indicates that the heating system has not worked optimally.

After maintenance treatment, the temperature deviation decreased significantly, where the actual temperature was able to reach the range of 215°C to 295°C. For example, in Zone 1 the temperature deviation decreased from 132°C to only 14°C, which indicates a rate of improvement of about 89%. In Zone 2, the temperature deviation is reduced from 137°C to -1°C, which indicates that the actual temperature has reached even slightly above the setting temperature.

Overall, the results show that the application of maintenance treatment is able to significantly reduce temperature deviations and improve heater performance in all heating zones. This confirms that maintenance treatment plays an important role in maintaining temperature stability and improving the reliability of the injection molding machine.

Zone	Set Temp (°C)	Actual Before (°C)	Actual After (°C)	Deviation Before (°C)	Deviation After (°C)	Improvement (%)
Zone 1	215	98	216	117	1	89%
Zone 2	230	113	223	117	7	99%
Zone 3	235	131	230	104	5	90%
Zone 4	250	160	229	90	21	95%
Zone 5	255	136	230	119	25	100%
Feed Temp	75	41	60	34	15	78%

Table 6. Comparison of Set Temperature and Actual Temperature Before and After Maintenance

Table 6 shows a comparison of the heater temperature performance before and after maintenance treatment on the Sumxxxxx injection molding machine. Prior to maintenance treatment, the actual temperature in some heating zones was well below the set temperature, with deviations ranging from 90°C to 120°C. This condition shows that heat transfer is not optimal and the efficiency of the heater has decreased.

After maintenance treatment is carried out through tightening of the electrical terminal connector, cleaning of carbon residue buildup, and calibration of the actual temperature sensor temperature has increased and is close to the set temperature. The temperature deviation decreased significantly to be in the range of 1°C to 25°C.

Overall, the improvement in temperature performance reached more than 75% in the entire heating zone. This shows that maintenance treatment successfully restores the normal performance of the heater, stabilizes the *warm-up time*, and minimizes temperature fluctuations during the molding process.

The improvement proves that the maintenance measures are able to:

1. Improves temperature stability,
2. Reduces heat lost
3. Optimizes heater response time,
4. Improve the thermal efficiency of the injection molding process.

V. CONCLUSION

This study shows that the application of maintenance maintenance in Sumitomo injection molding machines, which includes carbon residue cleaning, tightening of electrical terminals, and calibration of temperature sensors, has been proven to be effective in improving heater

performance and temperature stability. Before treatment, the actual temperature of the heater experiences a considerable deviation from the set temperature, while after treatment the temperature deviation decreases significantly and the initial warm-up process becomes more stable. This shows that heater maintenance is able to improve heat transfer efficiency and engine reliability. Thus, the regular application of heater maintenance can support the smooth production process and reduce the risk of operational disruptions in injection molding machines.

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PROPOSAL / FINAL PROJECT REVISION FORM

Name : Jeremi Togito Hutahaean
NIM : 3222211008
Title : Evaluasi Perawatan Heater (Pemanas) Pada Mesin Injection Moulding
Supervisor 1 : Fitriyanti Nakul, S.Pd., M.Si
Supervisor 2 : -
Examiner 1 : Muhammad Arifin, S.Si., M.Si
Examiner 2 : Vivin Octowinandi, S.Tr.T., M.Sc

No.	Reviewer	Comments / Revision Notes	Revisions Made	Supervisor's Initials / Approval Date	Examiner's Initials / Approval Date
1.	Muhammad Arifin, S.Si., M.Si	The research process needs to be clarified by including the cause-and-effect relationship of the problem, the theoretical framework, and the tools or instruments used in the study.	The author added an explanation of the research flow that emphasizes the cause-and-effect relationship of the problem, the theoretical framework applied, and the research tools or instruments in the Introduction section.		
2.	Vivin Octowinandi, S.Tr.T., M.Sc	It is necessary to check the alignment between the problem formulation and the research objectives to ensure consistency with the research focus.	The author added Research Questions and Research Objectives subsections in the Introduction section so that the problem formulation and research objectives are clearly structured and interconnected.		

3.	Vivin Octowinandi, S.Tr.T., M.Sc	The research conclusion needs to be emphasized so that it directly addresses the established research objectives.	The author strengthened the Conclusion section by stating that the research results have addressed the research objectives related to improving temperature stability and warm-up performance through heater maintenance.		
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