IMPLEMENTATION OF A WEB-BASED EXPERT SYSTEM FOR MACHINE DAMAGE DIAGNOSIS USING BACKWARD CHAINING AND CERTAINTY FACTOR

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Abstract

PT Hardo Soloplast is a manufacturing company that produces plastic products using various advanced machinery. A recurring issue in the production process is the sudden malfunction of machines, which disrupts operations and increases repair costs. To address this, this study proposes a web-based expert system for machine fault diagnosis using the Backward Chaining reasoning method and Certainty Factor approach. The system is implemented using PHP, HTML, CSS, and JavaScript, and stores knowledge in JSON format. It is accessible via web browser for field technicians. The system covers five main machines: Extruder Starex 1500, Laminating HL-2000, Printing Roto-Gravure, Slitting Rewinder RS-3000, and Blown Film Extrusion Machine. The knowledge base consists of 65 rules and symptoms, collected from interviews and documentation. Backward Chaining was chosen for its efficiency in goal-driven reasoning, while Certainty Factor is applied using the formula CFcombine = CF1 + CF2 × (1 − CF1), with a threshold of 0.75 for reliable results.Testing was conducted by comparing system diagnoses with actual technician assessments, achieving accuracy between 75% and 92.58% . This system contributes to the digitalisation efforts at PT Hardo Soloplast by accelerating diagnosis, improving maintenance response time, and reducing dependence on manual fault identification.

Keywords: *Backward Chaining, Certainty Factor, Fault Diagnosis, Web-based Expert System, Industrial Machines*

1. Introduction

In the modern manufacturing industry, the reliability and operational continuity of machinery are critical factors that directly influence productivity, cost-efficiency, and delivery timelines. PT Hardo Soloplast, a plastic manufacturing company, relies heavily on the stable performance of five major industrial machines: the Extruder Starex 1500, Laminating HL-2000, Printing Roto-Gravure, Slitting Rewinder RS-3000, and the Blown Film Extrusion Machine. Based on internal maintenance records, these machines collectively suffer from approximately three to four breakdown incidents per month. Such disruptions not only result in production delays but also lead to a significant increase in maintenance expenditures, with costs rising by as much as 20% during periods of frequent malfunction [1]. These issues highlight the urgent need for a more reliable and efficient diagnostic system to minimize downtime and optimize production schedules.

Historically, the fault diagnosis process in PT Hardo Soloplast has depended largely on manual inspections carried out by experienced technicians. While this traditional method can be effective, it is inherently time-consuming, heavily reliant on technician availability, and often yields inconsistent results due to human error or subjective judgment. In response to these limitations, various expert systems have been developed in previous research. However, many of these systems are constrained by their focus on diagnosing faults in a single type of machine, lack the capability to quantify diagnostic certainty, and are typically not implemented in a web-based format that allows easy access across multiple departments or users [2], [3]. These constraints make existing systems less practical for comprehensive industrial environments where multiple machines operate simultaneously and where uncertainty in diagnosis is common.

Recent studies emphasize the importance of adopting intelligent systems that combine rule-based inference and probabilistic reasoning to address real-world diagnostic challenges in industrial domains [4], [5]. To bridge these gaps, this study proposes the development of a web-based expert system that is specifically designed to handle fault diagnosis across multiple machines within a single platform. The system integrates two powerful reasoning techniques: Backward Chaining, which allows for logical inference based on observed symptoms, and the Certainty Factor method, which quantifies the level of confidence in a diagnosis by incorporating knowledge from expert technicians. This dual approach enables the system not only to mimic expert reasoning but also to provide transparent and quantifiable diagnostic decisions [6], [7].

The primary objectives of this research are threefold. First, it aims to design and implement a web-based expert system that is capable of diagnosing various types of machine faults across multiple industrial machines used by PT Hardo Soloplast. Second, the research seeks to evaluate the system's ability to measure diagnostic certainty using the Certainty Factor approach, thereby enhancing the trustworthiness and precision of the output. Finally, this study aspires to support PT Hardo Soloplast's broader digital transformation efforts by introducing a modern diagnostic tool that improves the accuracy, consistency, and speed of fault detection in daily operations [8].

2. Method

This chapter outlines the methodology used to develop a web-based expert system for diagnosing machine faults at PT Hardo Soloplast. It covers the research type and approach, research objects, time and location, as well as the process flow. The chapter also explains data collection and analysis techniques using Backward Chaining and Certainty Factor methods. In addition, it describes the system's technical implementation and presents validation results to assess diagnostic accuracy and reliability.

2.1 Type and Research Approach

This study is a type of applied quantitative research with a software engineering approach. The system development follows a structured process involving:

1. Problem identification
2. Data collection (symptoms, rules, faults)
3. Knowledge representation (rule base design)
4. System architecture design
5. System development and coding
6. System validation and evaluation

The reasoning engine is based on the Backward Chaining method, and diagnostic confidence is calculated using the Certainty Factor approach.

2.2 Research Object

The objects of this research are five production machines at PT Hardo Soloplast:

1. Extruder Starex 1500
2. Laminating HL-2000
3. Printing Roto-Gravure
4. Slitting Rewinder RS-3000
5. Blown Film Extrusion Machine

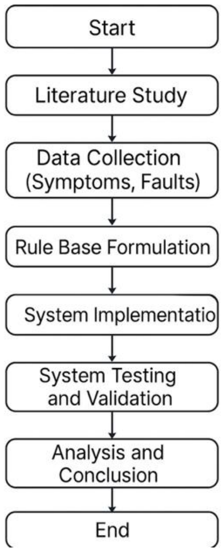
These machines were selected due to their high fault frequency and operational importance in the production process.

2.3 Research Time and Location

The study was conducted at PT Hardo Soloplast, located in Sukoharjo, Central Java, during February to March 2025. The process includes: problem formulation, literature review, system analysis and design, coding, validation, and documentation.[9]

2.4 Research Process Flowchart

The overall process of this research can be visualized in the following steps:



2.5 Data Collection Techniques

Data were collected through interviews and documentation involving field technicians. Collected data include:

1. A list of frequently occurring symptoms
2. Common types of machine faults
3. The relationship between symptoms and specific faults
4. Certainty Factor (CF) values provided by technicians based on experience
5. Total collected data:
   a. 5 machines
   b. 65 symptoms
   c. 65 inference rules

2.6 Data Analysis Techniques

Data were analyzed using two main components:

1. Backward Chaining: Used for tracing logical relationships from a fault hypothesis to supporting symptoms through a structured rule base (IF–THEN rules).

2. Certainty Factor (CF): Used to calculate the diagnostic confidence level.Formula:

   a. $CF(H,E) = MB(H,E) - MD(H,E)$
   b. $CFcombine = CF1 + CF2 \times (1 - CF1)$
   c. Threshold: $CF \geq 0.75$ = valid diagnosis

Example calculation:

If $CF(G1) = 0.8$, $CF(G2) = 0.7 \rightarrow CFcombine = 0.8 + 0.7 \times (1 - 0.8) = 0.8 + 0.14 = 0.94$

3.7 System Implementation (Technical Development)

The system was built as a web-based application using the following technologies:

1. Backend: PHP
2. Frontend: HTML, CSS
3. Client-side scripting: JavaScript
4. Data storage: JSON files (for rules, symptoms, diagnosis records)

All data is processed in structured files to support easy editing and scalability. The system interface was designed to be technician-friendly with checkbox inputs and real-time diagnosis output.

2.8 System Validation

System validation was carried out through:

1. Black-box testing for system logic and input-output validation
2. User-based testing with technicians to compare system output with actual fault cases

Validation Results:

Machine	Total Test Cases	System Accuracy (%)
Extruder Starex 1500	All cases	80.00%
Laminating HL-2000	All cases	75.00%
Printing Roto-Gravure	All cases	78.50%
Slitting Rewinder RS-3000	All cases	82.33%
Blown Film Extrusion Machine	All cases	92.58%

Conclusion: The system consistently produced diagnostic confidence values ≥ 75%, which meets the reliability threshold defined by expert feedback.

3. Result and Discussion

This study presents the results of the implementation and analysis of a web-based expert system for diagnosing faults in five types of industrial machines at PT Hardo Soloplast: Extruder Starex 1500, Laminating HL-2000, Printing Roto-Gravure, Slitting Rewinder RS-3000, and the Blown Film Extrusion Machine. Each of these machines has distinct characteristics and potential failure types, which is why the system was developed with a tailored approach for each machine[10].

The diagnostic process uses the Backward Chaining method along with Certainty Factor (CF) calculations to determine the level of confidence in each diagnosis, based on the symptoms input by technicians. The system generates CF values ranging from 75% to 93%, where the variation reflects the system's confidence in the diagnosis, depending on the clarity and consistency of the symptom data.

For instance, the Blown Film Extrusion Machine achieved the highest CF score at 93%, indicating that the input symptoms were strongly correlated with the diagnosed fault and that the rule base was highly representative. In contrast, machines such as the Laminating HL-2000 had lower CF scores, which may be attributed to overlapping symptoms or more complex fault patterns.

These findings are consistent with the research by Rachman et al. [11], which demonstrated the effectiveness of the Backward Chaining method in machine fault diagnosis systems. However, the system developed in this study goes further by applying this method across five different machines within a single platform. Moreover, the Certainty Factor method, which is effective for managing uncertainty as supported by Prasetyo & Lestari [12], was successfully implemented in this system to provide measurable confidence levels in each diagnostic result.

3.1 Extruder Starex 1500 Machine

Figure 1. Extruder Starex 1500 Machine

The Extruder Starex 1500 machine functions to mold plastic material through a heating and pressing process. Based on observations and interviews with technicians, this machine can experience several malfunction symptoms such as uneven output, unstable temperature, and inconsistent pressure. To analyze these issues, the Backward Chaining method is applied along with Certainty Factor (CF) calculations to determine the level of confidence in the diagnostic results.

3.1.1 Backward Chaining Calculation

The inference rules used in this system were obtained from interviews and direct discussions with experienced technicians at PT Hardo Soloplast. These experts provided insights based on their practical experience in the field regarding the correlation between commonly observed symptoms and types of faults frequently occurring in each machine. These rules are formulated in the form of IF-THEN logic using the Backward Chaining method, enabling the system to trace possible faults based on detected symptoms. The data used in this diagnostic process is presented in Table 2.

Tabel 2. Inference Rules and Symptom Evaluation for Mesin Extruder Starex 1500

Diagnosis Code	Diagnosis Name	Inference Rule	Checked Symptoms	Symptom Conditions	Evaluation Result
D01	Damage to the main motor	IF G01 ∧ G02 ∧ G03 ∧ G06 → D01	G01: Machine won't start → TRUE G02: Barrel temperature doesn't rise → TRUE G03: Thermocontrol not turning on → TRUE G06: Cooling fan not working → TRUE	TRUE	True (D01 is met)
D02	Heater damaged or check cooling system	IF G04 ∧ G07 → D02	G04: No plastic output → TRUE G07: Overheating → FALSE	FALSE	False (D02 is not met)
D03	Electrical system overload	IF G05 → D03	G05: Power drops when machine starts → TRUE	TRUE	True (D03 is met)
D03	Worn bearing or loose components	IF G08 → D03	G08: Unusual noise → FALSE	FALSE	False (D03 is not met)
D04	Incorrect machine position or component balance	IF G09 → D04	G09: Excessive vibration → TRUE	TRUE	True (D04 is met)
D05	Short circuit indication or electrical overload	IF G10 → D05	G10: Blown fuse → FALSE	FALSE	False (D05 is not met)
D06	Control system or panel screen damage	IF G11 → D06	G11: Unresponsive panel → TRUE	TRUE	True (D06 is met)
D07	Cable connection or LED indicator	IF G12 → D07	G12: Indicator light is off → TRUE	TRUE	True (D07 is met)
D08	Motor overloaded or fan damage	IF G13 → D08	G13: Motor is hot → FALSE	FALSE	False (D08 is not met)
D06	Control system or panel screen damage	IF G11 → D06	G11: Unresponsive panel → TRUE	TRUE	True (D06 is met)
D07	Check cable connection or LED indicator	IF G12 → D07	G12: Indicator light is off → TRUE	TRUE	True (D07 is met)
D08	Motor overloaded or fan damage	IF G13 → D08	G13: Motor is hot → FALSE	FALSE	False (D08 is not met)

3.1.2 Backward Chaining Inference Rules

a. IF G01 ∧ G02 ∧ G03 ∧ G06 → D01 (Main motor failure)
b. IF G04 ∧ G07 → D02 (Heater failure or check cooling system)
c. IF G05 → D03 (Electrical system overload)
d. IF G08 → D03 (Worn bearing or loose component)
e. IF G09 → D04 (Improper machine alignment or balance)
f. IF G10 → D05 (Short circuit indication or electrical overload)
g. IF G11 → D06 (Control system or panel screen failure)
h. IF G12 → D07 (Check cable connection or LED indicator)
i. IF G13 → D08 (Motor under excessive load or faulty fan)

3.1.3 Certainty Factor Calculation

The determination of symptoms in this system is based on the direct experience of field technicians. Each symptom is assigned a certainty factor (CF) by experts, reflecting their level of confidence in the symptom's correlation to a specific machine fault.

Table 3. Symptoms and Diagnoses Extruder Starex 1500 Machine

Code	Symptom	Diagnosis Code	Diagnosis Description	MB	MD
G01	Machine won't start	D01	Main motor malfunction	0.8	0.1
G02	Barrel temperature doesn't rise	D01	Main motor malfunction	0.7	0.2
G03	Thermocontrol doesn't turn on	D01	Main motor malfunction	0.6	0.3
G04	Plastic output does not come out	D02	Heater damaged	0.7	0.2
G05	Power drops when machine starts	D03	Electrical system overload	0.65	0.25
G06	Machine does not turn on	D01	Main motor malfunction	0.75	0.1
G07	Overheating	D02	Check cooling system and room temperature	0.8	0.15
G08	Noisy sound	D03	Worn bearing or loose component	0.7	0.25
G09	Excessive vibration	D04	Incorrect component positioning or balance	0.7	0.2
G10	Fuse blown	D05	Indication of short circuit or overload	0.6	0.3
G11	Panel unresponsive	D06	Control system or panel screen malfunction	0.75	0.1
G12	Indicator light off	D07	Check cable connections or LED indicator	0.85	0.1
G13	Motor overheating	D08	Motor overworked or fan damaged	0.6	0.25

Table 4. Certainty Factor Calculation

Symptom	MB (Measure of Belief)	MD (Measure of Disbelief)	CF (Certainty Factor)
G01	0.8	0.1	0.7
G02	0.7	0.2	0.5
G03	0.6	0.3	0.3
G04	0.7	0.2	0.55
G05	0.65	0.25	0.4875
G06	0.75	0.1	0.675
G07	0.8	0.15	0.68
G08	0.7	0.25	0.525
G09	0.7	0.2	0.56
G10	0.6	0.3	0.36
G11	0.75	0.1	0.675
G12	0.85	0.1	0.765
G13	0.6	0.25	0.45

3.1.4 Certainty Factor Calculation

Here are the results of the Certainty Factor calculation based on symptom inputs:

a. CF1 = 0.7
b. CF2 = 0.7 + 0.6 × (1 – 0.7) = 0.88
c. CF3 = 0.88 + 0.65 × (1 – 0.88) = 0.976

Diagnosis Confidence Level:
With a final CF value of 0.976, the system's confidence level in the diagnosis result is 97.6%, indicating a highly accurate diagnosis that can be used as a primary reference.

3.2 Laminating Machine HL-2000

Figure 2. Laminating Machine HL-2000

The Laminating Machine HL-2000 is used to bond two layers of plastic material through a heating process. Common failures include poor adhesion of the laminate, inconsistent roll temperature, and unstable machine speed. These symptoms are analyzed using the Backward Chaining method, and the certainty level is calculated using the Certainty Factor approach.

3.2.1 Backward Chaining Calculation

The inference rules used in this system were obtained from interviews and direct discussions with experienced technicians at PT Hardo Soloplast. Experts provided information based on practical field experience about the relationship between common symptoms and the types of failures that frequently occur in each machine. These rules were formulated into IF-THEN logic using the Backward Chaining method, so the system can trace possible faults based on detected symptoms. The data is shown in Table 5.

Table 5. Inference Rules and Symptom Evaluation for Laminating Machine HL-2000 Fault Diagnosis

Diagnosis Code	Diagnosis Name	Inference Rule	Checked Symptoms	Symptom Conditions	Evaluation Result
D01	Glue heating system malfunction	IF G01 ∧ G03 → D01	G01: Glue doesn't stick properly → TRUE G03: Glue temperature is unstable → TRUE	TRUE	True (D01 is met)
D02	Drive motor malfunction	IF G02 → D02	G02: Roller does not rotate properly → FALSE	FALSE	False (D02 is not met)
D03	Worn bearing / loose components	IF G04 → D03	G04: Unusual noise → FALSE	FALSE	False (D03 is not met)
D04	Machine belt needs tightening	IF G05 → D04	G05: Loose belt → TRUE	TRUE	True (D04 is met)
D05	Sensor does not provide correct input	IF G06 → D05	G06: Damaged sensor → FALSE	FALSE	False (D05 is not met)
D06	Overloaded motor / damaged fan	IF G07 → D06	G07: Motor is hot → TRUE	TRUE	True (D06 is met)
D07	Check temperature and production speed	IF G08 ∧ G03 → D07	G08: Defective production output → FALSE G03: Glue temperature is unstable → TRUE	FALSE	False (D07 is not met)
D08	Incorrect machine position/balance	IF G09 → D08	G09: Excessive vibration → TRUE	TRUE	True (D08 is met)
D09	Check cooling system / room temperature	IF G10 → D09	G10: Overheating → FALSE	FALSE	False (D09 is not met)

3.2.2 Backward Chaining Inference Rules

a. If G01 ∧ G03 → D01 (Heating system problem in the adhesive)
b. If G02 → D02 (Roll drive motor failure)
c. If G04 → D03 (Worn bearing or loose component)
d. If G05 → D04 (Machine belt needs tightening)
e. If G06 → D05 (Sensor does not provide correct input)
f. If G07 → D06 (Motor overload or fan failure)
g. If G08 ∧ G03 → D07 (Check temperature and production speed settings)
h. If G09 → D08 (Machine balance is not correct)
i. If G10 → D09 (Check cooling system and room temperature)

3.2.3 Certainty Factor Calculation

The determination of symptoms in this system is based on direct experience from technicians in the field. Each symptom is assigned a certainty value (CF) by experts according to the degree of confidence related to the machine fault.

Table 6. Symptoms and Diagnosis for Laminating Machine HL-2000

Code	Symptom	Diagnosis Code	Diagnosis Description	MB	MD
G01	Adhesive does not stick well	D01	Fault in the adhesive heating system	0.75	0.2
G02	Roll does not rotate normally	D02	Roll drive motor failure	0.7	0.25
G03	Adhesive temperature unstable	D01	Fault in the adhesive heating system	0.65	0.1
G04	Noisy sound	D03	Worn bearing or loose components	0.6	0.3
G05	Loose belt	D04	Machine belt needs tightening	0.7	0.2
G06	Sensor failure	D05	Sensor does not provide correct input	0.75	0.1
G07	Overheated motor	D06	Motor overload or fan failure	0.65	0.3
G08	Defective production result	D07	Check temperature and production speed settings	0.7	0.2
G09	Excessive vibration	D08	Incorrect positioning or balance of components	0.8	0.15
G10	Overheating	D09	Check cooling system and room temperature	0.75	0.1

Table 7. Certainty Factor Calculation

Symptom	MB (Measure of Belief)	MD (Measure of Disbelief)	CF (Certainty Factor)
G01	0.75	0.2	0.55
G02	0.7	0.25	0.45
G03	0.65	0.1	0.55
G04	0.6	0.3	0.36
G05	0.7	0.2	0.56
G06	0.75	0.1	0.675
G07	0.65	0.3	0.455
G08	0.7	0.2	0.56
G09	0.8	0.15	0.68
G10	0.75	0.1	0.675

3.2.4 Certainty Factor Calculation Example

a. CF1 = 0.5
b. CF2 = 0.5 + 0.6 × (1 – 0.5) = 0.8

Diagnosis Certainty Level:
The final CF value obtained is 0.8, meaning the system has an 80% confidence level regarding the detected fault diagnosis.

3.3 Printing Roto-Gravure Machine

Figure 3. Roto-Gravure Printing Machine

The Roto-Gravure Printing Machine is used to print patterns or designs onto plastic surface materials. Common issues include blurry print results, ink not adhering properly, and misalignment of the printed image. Fault diagnosis is carried out using the Backward Chaining method, and the confidence level is determined through Certainty Factor calculations.

3.3.1 Backward Chaining Calculation

The inference rules used in this system are derived from interviews and direct discussions with experienced technicians at PT Hardo Soloplast. Experts provide information based on practical field experience regarding the relationship between common symptoms and the types of damage that frequently occur in each machine. These rules are formulated in the form of IF-THEN logic using the Backward Chaining method, allowing the system to trace possible faults based on detected symptoms.The related data is presented Table 8.

Table 8. Inference Rules and Symptom Evaluation for Diagnosing Faults in Roto-Gravure Printing Machine

Diagnosis Code	Diagnosis Name	Inference Rule	Checked Symptoms	Symptom Conditions	Evaluation Result
D01	Damage to roll pressure	IF G01 → D01	G01: Uneven print color → TRUE	TRUE	True (D01 is met)
D02	Ink system malfunction	IF G02 → D02	G02: Ink not dispensing → FALSE	FALSE	False (D02 is not met)
D03	Misalignment	IF G03 → D03	G03: Misaligned print result → TRUE	TRUE	True (D03 is met)
D04	Main motor failure	IF G04 → D04	G04: Machine won't start → FALSE	FALSE	False (D04 is not met)
D05	Incorrect temperature and speed settings	IF G05 ∧ G06 → D05	G05: Defective output → TRUE G06: Overheating → TRUE	TRUE	True (D05 is met)
D06	Check cooling system	IF G06 → D06	G06: Overheating → TRUE	TRUE	True (D06 is met)
D07	Worn/damaged motor	IF G07 → D07	G07: Motor jammed → FALSE	FALSE	False (D07 is not met)
D08	Worn gearbox	IF G08 → D08	G08: Worn gears → TRUE	TRUE	True (D08 is met)
D09	Unstable power supply	IF G09 → D09	G09: Power supply unstable → FALSE	FALSE	False (D09 is not met)
D10	Reset or replace sensor	IF G10 → D10	G10: Sensor error → TRUE	TRUE	True (D10 is met)
D11	Damaged cable/connection line	IF G11 → D11	G11: Blown fuse → FALSE	FALSE	False (D11 is not met)
D12	Main cable disconnected	IF G12 → D12	G12: Broken cable → TRUE	TRUE	True (D12 is met)

3.3.2 **Backward Chaining Inference Rules**

a. If G01 → D01 (Roll pressure malfunction)
b. If G02 → D02 (Ink system damage)
c. If G03 → D03 (Alignment imbalance)
d. If G04 → D04 (Main motor malfunction)
e. If G05 ∧ G06 → D05 (Incorrect temperature and speed settings)
f. If G06 → D06 (Check cooling system)
g. If G07 → D07 (Worn/damaged motor)
h. If G08 → D08 (Worn gearbox)
i. If G09 → D09 (Unstable electricity)
j. If G10 → D10 (Reset or replace sensor)
k. If G11 → D11 (Damaged cable/connection line)
l. If G12 → D12 (Main cable disconnected)

3.3.3 **Certainty Factor Calculation**

Symptom determination in this system is based on direct experience from field technicians. Each symptom is assigned a certainty value (CF) by experts based on their level of confidence in its correlation to machine damage.

Table 9. Symptoms and Diagnoses for Roto-Gravure Printing Machine

Code	Symptom	Code	Diagnosis	MB	MD
G01	Uneven print color	D01	Roll pressure malfunction	0.80	0.20
G02	Ink not dispensed	D02	Ink system damage	0.70	0.30
G03	Print misalignment	D03	Alignment imbalance	0.60	0.20
G04	Machine won't start	D04	Main motor malfunction	0.70	0.25

G05	Defective production output	D05	Check temperature and speed settings	0.65	0.30
G06	Overheating	D06	Check cooling system and room temperature	0.75	0.10
G07	Motor jammed	D07	Check motor condition, possibly worn	0.80	0.15
G08	Worn gear	D08	Check gears and gearbox components	0.70	0.20
G09	Unstable electricity	D09	Use stabilizer or check power source	0.75	0.20
G10	Sensor error	D10	Reset or replace the sensor if damaged	0.80	0.15
G11	Blown fuse	D11	Check cable routes and electrical connections	0.70	0.30
G12	Disconnected cable	D12	Check main cable route and connection	0.75	0.10

Table 10. Certainty Factor Calculation

Symptom	MB (Measure of Belief)	MD (Measure of Disbelief)	CF (Certainty Factor)
G01	0.8	0.2	0.6
G02	0.7	0.3	0.4
G03	0.6	0.2	0.4
G04	0.7	0.25	0.525
G05	0.65	0.3	0.455
G06	0.75	0.1	0.675
G07	0.8	0.15	0.68
G08	0.7	0.2	0.56
G09	0.75	0.2	0.6
G10	0.8	0.15	0.68
G11	0.7	0.3	0.49
G12	0.75	0.1	0.675

3.3.4 **Final Certainty Factor Calculation**

a. CF1 = 0.6
b. CF2 = 0.6 + 0.7 × (1 – 0.6) = 0.88
c. CF3 = 0.88 + 0.4 × (1 – 0.88) = 0.928

Diagnosis Confidence Level:

A final CF value of 0.928 is obtained, indicating that the system has a 92.8% confidence level in the detected fault diagnosis of the printing system.

3.4 Slitting Rewinder RS-3000 Machine

Figure 4. Slitting Rewinder RS-3000 Machine

Based on input data from technicians, it was detected that the Slitting Rewinder RS-3000 machine is experiencing issues such as roll tension mismatch, inaccurate sensor readings, and roll movement disturbances. The Slitting Rewinder RS-3000 machine functions to cut and rewind plastic materials into smaller roll sizes. Common problems that arise include uneven cutting results, asymmetrical rolls, or unstable tension. The analysis process was conducted using the Backward Chaining method and reinforced with Certainty Factor calculations.

3.4.1 Backward Chaining Calculation

The inference rules used in this system are derived from interviews and direct discussions with experienced technicians at PT Hardo Soloplast. The experts provided information based on field experience regarding the correlation between common symptoms and frequent machine faults. These rules are formulated into IF-THEN logic using the Backward Chaining method, enabling the system to trace the potential cause of failure based on detected symptoms. The corresponding data is shown in Table 11.

Table 11. Inference Rules and Symptom Evaluation for Slitting Rewinder RS-3000

Diagnosis Code	Diagnosis Name	Inference Rule	Checked Symptoms	Symptom Conditions	Evaluation Result
D01	Roll tension mismatch	IF G01 → D01	G01: Uneven cuts → TRUE	TRUE	True (D01 is met)
D02	Sensor malfunction	IF G02 → D02	G02: Machine frequently stops suddenly → FALSE	FALSE	False (D02 is not met)
D03	Drive system malfunction	IF G03 → D03	G03: Unstable machine speed → TRUE	TRUE	True (D03 is met)
D04	Check temperature and production speed settings	IF G04 ∧ G06 → D04	G04: Defective output → TRUE G06: Overheating → TRUE	TRUE	True (D04 is met)
D05	Worn bearing or unstable machine balance	IF G05 ∧ G13 → D05	G05: Unusual noise → FALSE G13: High vibration → TRUE	FALSE	False (D05 is not met)
D06	Cooling system or room temperature issue	IF G06 → D06	G06: Overheating → TRUE	TRUE	True (D06 is met)
D07	Motor overload or broken fan	IF G07 → D07	G07: Motor is overheating → TRUE	TRUE	True (D07 is met)
D08	Check firmware or panel connection	IF G08 → D08	G08: Control panel error → FALSE	FALSE	False (D08 is not met)
D09	Sensor connection problem	IF G09 → D09	G09: Sensor not active → TRUE	TRUE	True (D09 is met)
D10	Low hydraulic or pneumatic pressure	IF G10 → D10	G10: Low pressure → FALSE	FALSE	False (D10 is not met)
D11	Indication of hydraulic system leakage	IF G11 → D11	G11: Leaking pipe → FALSE	FALSE	False (D11 is not met)
D12	Damage to input/output valve	IF G12 → D12	G12: Damaged valve → TRUE	TRUE	True (D12 is met)
D13	Unstable machine component balance	IF G13 → D13	G13: High vibration → TRUE	TRUE	True (D13 is met)

3.4.2 Backward Chaining Inference Rules

a. IF G01 → D01 (Roll tension mismatch)
b. IF G02 → D02 (Sensor reader malfunction)
c. IF G03 → D03 (Drive system malfunction)
d. IF G04 ∧ G06 → D04 (Check production speed and temperature settings)
e. IF G05 ∧ G13 → D05 (Worn bearing or improper machine balance)
f. IF G06 → D06 (Cooling system or room temperature issues)
g. IF G07 → D07 (Motor under heavy load or broken fan)
h. IF G08 → D08 (Check firmware or panel connection)
i. IF G09 → D09 (Sensor connection error)
j. IF G10 → D10 (Low hydraulic or pneumatic pressure)
k. IF G11 → D11 (Hydraulic system leakage)
l. IF G12 → D12 (Input/output valve malfunction)
m. IF G13 → D13 (Unstable machine component balance)

3.4.3 Certainty Factor Calculation

Symptom determination in this system is based on direct field experience of technicians. Each symptom is assigned a certainty value (CF) by experts based on their confidence in its association with specific machine faults.

Table 12. Symptoms and Diagnoses for Slitting Rewinder RS-3000

Code	Symptom	Diagnosis Code	Diagnosis	MB	MD
G01	Uneven cutting result	D01	Roll tension mismatch	0.8	0.2
G02	Machine stops suddenly	D02	Sensor reader malfunction	0.75	0.25
G03	Unstable machine speed	D03	Drive system malfunction	0.7	0.3
G04	Defective production output	D04	Check speed and temperature settings	0.7	0.3
G05	Unusual noise	D05	Worn bearing or loose component	0.65	0.35
G06	Overheating	D06	Check cooling system and room temperature	0.85	0.15
G07	Overheating motor	D07	Motor overloaded or fan malfunction	0.8	0.2
G08	Control panel error	D08	Check firmware or panel connections	0.9	0.1
G09	Inactive sensor	D09	Check sensor connection	0.75	0.25
G10	Low pressure	D10	Check hydraulic or pneumatic pressure	0.8	0.2
G11	Leaking pipe	D11	Hydraulic system leakage	0.7	0.3
G12	Damaged valve	D12	Check input/output valve	0.7	0.3
G13	High vibration	D13	Check component balance	0.75	0.25

Tabel 13. Certainty Factor Calculation

Symptom	MB (Measure of Belief)	MD (Measure of Disbelief)	CF (Certainty Factor)
G01	0.8	0.2	0.6
G02	0.75	0.25	0.5
G03	0.7	0.3	0.4
G04	0.7	0.3	0.4
G05	0.65	0.35	0.375
G06	0.85	0.15	0.725
G07	0.8	0.2	0.6
G08	0.9	0.1	0.81
G09	0.75	0.25	0.5
G10	0.8	0.2	0.6
G11	0.7	0.3	0.4
G12	0.7	0.3	0.4
G13	0.75	0.25	0.5

3.4.4 Certainty Factor Calculation

a. CF1 = 0.5
b. CF2 = 0.5 + 0.45 × (1 – 0.5) = 0.725
c. CF3 = 0.725 + 0.35 × (1 – 0.725) = 0.858

Diagnosis Confidence Level:
The final CF value of 0.858 indicates the system has 85.8% confidence in the diagnosis result, which is sufficiently high to be used as a basis for corrective action.

3.5 Blown Film Extrusion Machine

Figure 5. Blown Film Extrusion Machine

The Blown Film Extrusion machine is used to produce plastic film in tubular form through a process of heating and air blowing. Common issues encountered include uneven film thickness, excessive air bubbles, and easily torn film. Diagnosis is performed using the Backward Chaining method and is reinforced by Certainty Factor (CF) values.

3.5.1 Backward Chaining Calculation

The inference rules used in this system are obtained from interviews and direct discussions with experienced technicians at PT Hardo Soloplast. Experts provided information based on practical field experience regarding the relationship between common symptoms and types of damage frequently found in each machine. These rules are formulated into IF-THEN logic using the Backward Chaining method, allowing the system to trace possible damages based on detected symptoms. The corresponding data is shown in Table 14.

Table 14. Inference Rules and Symptom Evaluation for Blown Film Extrusion Machine Damage Diagnosis

Diagnosis Code	Diagnosis Name	Inference Rule	Checked Symptoms	Symptom Conditions	Evaluation Result
D01	Main extruder malfunction	IF G01 ∧ G02 → D01	G01: Film does not expand → TRUE G02: Uneven film thickness → TRUE	TRUE	True (D01 is met)
D02	Die temperature imbalance	IF G02 → D02	G02: Uneven film thickness → TRUE	TRUE	True (D02 is met)
D03	Unstable drive motor	IF G03 → D03	G03: Repeated noise → TRUE	TRUE	True (D03 is met)
D04	Check pull roll and cooling system	IF G04 → D04	G04: Wrinkled film output → TRUE	TRUE	True (D04 is met)
D05	Heating malfunction	IF G05 → D05	G05: Unstable heater temperature → TRUE	TRUE	True (D05 is met)
D06	Poor ventilation or excessive load	IF G06 → D06	G06: Motor overheating → TRUE	TRUE	True (D06 is met)
D07	Imbalance or loose shaft	IF G07 → D07	G07: High machine vibration → TRUE	TRUE	True (D07 is met)

3.5.2 Backward Chaining Inference Rules

a. If G01 → D01 (Damage in the main extruder)
b. If G02 → D02 (Die temperature imbalance)
c. If G03 → D03 (Unstable drive motor)
d. If G04 → D04 (Check pulling roll and cooling system)
e. If G05 → D05 (Heater malfunction)
f. If G06 → D06 (Poor ventilation or excessive load)
g. If G07 → D07 (Imbalance or loose shaft)

3.5.3 Certainty Factor Calculation

The identification of symptoms in this system is based on direct experience from field technicians. Each symptom is assigned a certainty value (CF) by experts according to their level of confidence in its relation to machine failure.

Table 15. Symptoms and Diagnoses of the Blown Film Extrusion Machine

Symptom Code	Symptom	Diagnosis Code	Diagnosis	MB	MD
G01	Film does not expand	D01	Damage in the main extruder	0.8	0.2
G02	Uneven film thickness	D02	Die temperature imbalance	0.75	0.25
G03	Repetitive loud noise	D03	Unstable drive motor	0.7	0.3
G04	Wrinkled film output	D04	Check pulling roll and cooling system	0.7	0.3
G05	Unstable heater temperature	D05	Heater malfunction	0.85	0.15
G06	Motor overheating	D06	Poor ventilation or excessive load	0.75	0.25
G07	High machine vibration	D07	Imbalance or loose shaft	0.8	0.2

Table 16. Certainty Factor Calculations

Symptom	MB (Measure of Belief)	MD (Measure of Disbelief)	CF (Certainty Factor)
G01	0.8	0.2	0.6
G02	0.75	0.25	0.5

G03	0.7	0.3	0.4
G04	0.7	0.3	0.4
G05	0.85	0.15	0.725
G06	0.75	0.25	0.5
G07	0.8	0.2	0.6

3.5.4 Certainty Factor Computation

- CF1 = 0.65
- CF2 = 0.65 + 0.5 × (1 – 0.65) = 0.825
- CF3 = 0.825 + 0.6 × (1 – 0.825) = 0.93

Diagnosis Certainty Level:
With a final CF value of 0.93, the system demonstrates a high level of confidence (93%) in the diagnosis provided, making it suitable for use as a quick repair reference.

3.6 Web Application Interface

First, users must log in to the system. Here, they are required to enter a username and password. This ensures that only authorized individuals, such as technicians or administrators, can access the system. After successfully logging in, users are directed to a page where they can select which machine they want to diagnose.

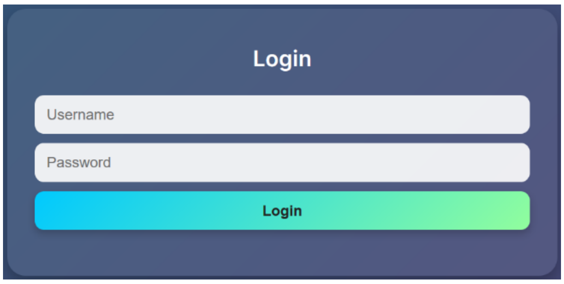


Figure 6. Login Page

After logging in, users will see a list of available machines, such as the Extruder Starex 1500 Machine, Laminating HL-2000 Machine, Printing Roto-Gravure Machine, Slitting Rewinder RS-3000 Machine, and Blown Film Extrusion Machine. Users simply need to click on the machine they want to inspect. On this page, there is also an option to modify symptom data if the user wants to add or edit the existing symptom information.

Figure 7. Machine Selection Page

Once a machine is selected, the system will display a list of symptoms or problems that might occur in that machine. Examples include "machine won't start," "rough engine sound," "overheating," and so on. Users just need to check the symptoms that match the machine's current condition. This data will be used by the system to analyze and detect possible faults.

Figure 8. Fault Diagnosis Page

After selecting all relevant symptoms, the user can click the "Diagnose" button, and the system will immediately analyze the possible faults. The result is presented as an explanation, for example: "The likely fault is in the power supply or the main switch." The system also displays the confidence level of the analysis result, for example 80%. On this page, users can choose to return to the previous menu or log out from the system.

Figure 9. Diagnosis Result Page

There is also an additional feature available for users with access rights, namely "Edit Data." Here, users can modify the list of symptoms available for each machine. The data format is organized in a user-friendly way and can be edited directly, then saved by clicking the "Save" button. This feature is especially useful if new symptoms emerge or adjustments are needed to reflect the latest machine conditions..

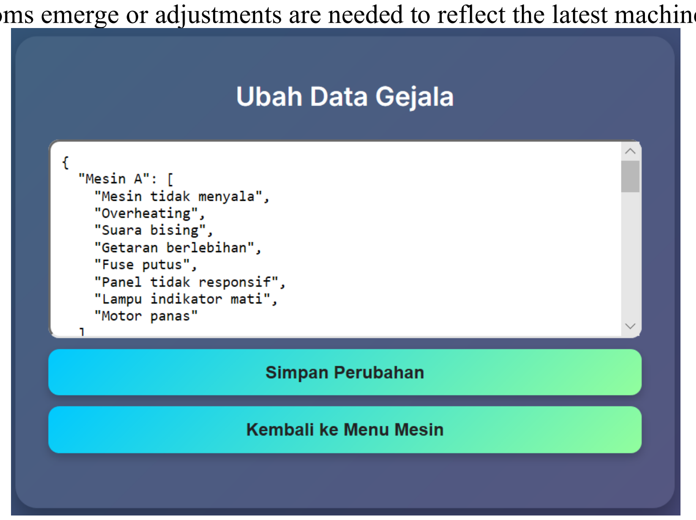


Figure 10. Edit Data Menu Page

4. Conclusion

This study successfully developed a web-based expert system capable of diagnosing faults in multiple industrial machines within a single integrated platform. This multi-machine diagnostic capability highlights the system's unique contribution in supporting comprehensive maintenance operations through one centralized interface. By implementing the Backward Chaining and Certainty Factor methods, the system generates diagnostic results with confidence levels ranging from 75% to 92.58%, which closely align with expert technician evaluations. This CF range indicates a high degree of reliability, showing that the system is capable of handling varying levels of diagnostic certainty while still producing results that reflect expert judgment. The Backward Chaining method is effective for symptom-based reasoning, while the Certainty Factor addresses the uncertainty often present in the diagnostic process. The integration of these two methods results in a robust and practical tool to support technicians in making informed decisions regarding machine failures. In the future, the system could be further enhanced by incorporating machine learning capabilities and expanding its diagnostic coverage to more machines and symptoms

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