U-NET Jurnal Teknik Informatika
Vol. 05, No. 02, Agustus 2021, pp. 67-75
e-ISSN: 2622-8238, p-ISSN: 2722-4287
DOI:

Expert System Detects Boiler Engine Damage Using Certainty Factors

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Info Artikel

Article history:

Received: 19 08 2021
Revised: 11 09 2021
Accepted: 13 09 2021

Kata Kunci:

Expert System, Certainty Factor, Boiler Engine,

Penulis Korespondensi:

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Abstract

The boiler machine is one of the important machinesin the power generation industry which functions to convert water into steam which is then used to drive turbines to produce electrical energy. One of the damages that often occurs in boiler engines is pipe leakage that causes the engineto not operate and the risk of fire. From the danger of the resulting effects, an expert system is needed that can determine the type of damage and how to handle it. The purpose of this study was to analyze the damage to the boilerengine with the Expert System using the Certainty Factor method. The result of this research is the highest percentage of damage on Scale with a confidence level of 83%.

Keywords—Expert System, Certainty Factor, Boiler Engine

Abstrak

Mesin boiler merupakan salah satu mesin penting dalam industri pembangkit listrik yang berfungsi untuk mengubah air menjadi uap yang kemudian digunakan untuk menggerakkan turbin untuk menghasilkan energi listrik. Salah satu kerusakan yang sering terjadi pada mesin boiler adalah kebocoran pipa yang menyebabkan mesin tidak dapat beroperasi dan resiko kebakaran. Dari bahaya efek yang ditimbulkan maka diperlukan sistem pakar yang dapat menentukan jenis kerusakan dan cara penanganannya. Tujuan dari penelitian ini adalah untuk menganalisis kerusakan mesin boiler dengan Sistem Pakar menggunakan metode Certainty Factor. Hasil dari penelitian ini adalah persentase kerusakan tertinggi pada Skala dengan tingkat kepercayaan 83%.

Keywords—Expert System, Certainty Factor, Boiler Engine

1. Introduction

Boiler is one of the important machines in the powergeneration industry. The function of the boiler is converting water into steam which is then used to drive turbines to produce electrical energy. Damage caused by the boiler engine certainly results in great danger. One of the most common damages is pipe leakage which results ina fire hazard and causes the machine to not operate. To reduce the failure and reduce the level of risk to the boiler,a system is needed to detect damage to the boiler engine and prevent such damage.

The use of computer technology is very helpful to humansin managing good information in the field of education[1],health[2] as well as engine damage[3]. Computers help a lot and provide solutions for its users. One computer technology that can manage information is to use an expertsystem. Expert systems are artificial intelligence that mimics human reasoning processes. Solving complex problems can usually only be done by a number of highly trained people, namely an expert.

One of the best expert system methods to diagnose engine damage is to use the Certainty Factor method. Certainty Factor is used to accommodate the uncertainty of thinking (Inexact Reasoning) of an expert. For example, an expert often analyzes existing information with phrases such as "maybe", "most likely", "almost certainly". To accommodate this, Certainty Factor is able to describe the level of expert confidence in the problem that occurred.

2. Related Work

Many expert system studies conducted using certainty factor methods in diagnosing engine damage include research conducted by Juandi Syahputra Simatupang and Erwin Panggabean entitled Expert Systems to Diagnose Canon IR6000 Photocopy Machine Damage Using Certainty Factor Methods. In this research, it can accelerate the handling of photocopy machine damage by operators /users of copy machines which often occur when the copying process is in progress [4].

Next research conducted by Saputra said that an expert system with the Certainty factor method can diagnose engine damage on special matic type motorcycles. Certainty factors will be more accurate if experts enter their knowledge into an application [5].

Furthermore, research conducted by Oktaviani to diagnose GIBEN engine damage. With the existence of an expert system to detect damage to giben machines, one can find out engine damage easily and quickly and report more accurate diagnostic results [6].

Expert systems using factor certainty methods have been widely used in various fields[7][8] of science[9][10]. In the field of health certainty factors used to diagnose children's digestive tract diseases. This study shows that the system has an accuracy of 100% and a confidence level of 80.5%[9]. The certainty factor is also used to diagnose pests and diseases of rice plants. Testing was carried out by35 people with a sample of 12 images of infected rice plants. The test results show the accuracy rate of this system is 73.81%. This means that an expert system with the certainty factor of this method can assist farmers in determining pests or diseases of rice plants[8].

This study aims to analyze the damage to the boiler engine with an expert system using the certainty factor method. The knowledge possessed by an expert will be analyzed using certainty factors to determine the damage that occurs in the boiler engine.

3. Research Methods

Expert system using the Certainty factor method is widely used in various fields both in the field of plants [7], animals[11], [12], health [13] [14][15][16][17] and engine [18,19].

In this study Certainty factor is used to determine boiler engine damage using an expert's knowledge based on the prescribed symptoms. There are some damages that often occur in boiler engines, namely Scale, Corrosion and Carryover. Damage data on the boiler engine is shown in Table I.

Tabel I

Damage Data

Damage Id	Damage Name
K001	Scale
K002	Corrosion
K003	Carryover

Boiler scale is a boiler problem that often occurs both water side and fire side. For fire side is usually called Slag. Both are deposits that have a negative impact on the boiler system. Corrosion problems are boiler problems that oftenoccur. the presence of corrosion problems in the pipecauses a negative impact in the form of reduced pipe thickness, clogging and buildup of deposition of corrosion and broken pipes. Carryover problems can cause problemswith the turbine and equipment thereafter.

All three damage often occurs in boiler engines. In this study the authors will use an expert system to determine the type of damage based on the symptoms that occur on the machine based on the knowledge of the user and expert.Therefore a suitable method to determine the type of damage to the boiler engine is to use the certainty factor method

There are several steps to determine the damage to the boiler engine using an expert system using the Certainty Factor method which is explained in the figure below :

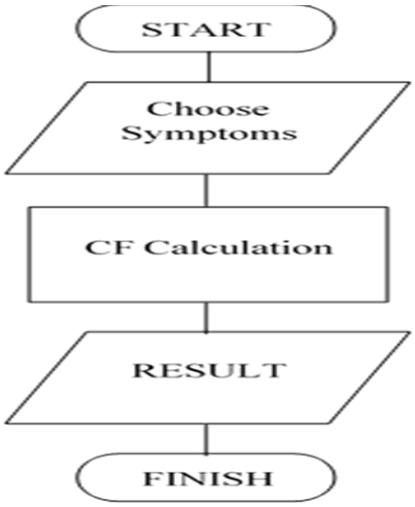

Figure 1. Research Methode

The first step to seeing a boiler engine malfunction is the symptoms that occur in the machine. The symptoms of a machine failure are obtained from an expert on boiler engines. The following is a table of symptoms that have been determined based on the knowledge of an expert

TABLE II.
SYMPTOMS DATA SYMPTOMS OF MACHINERY

Symptom Code	**Name Symptoms**
G001	Unlimited heat transfer (hot spot)
G002	Narrow pipe diameter
G003	High temperature rise and accumulation hardness of water above the maximum limit
G004	Feed water contains Mg and or Ca ions (hard water)
G005	Feed water contains corrosive gases (O2 CO2 and NH3)
G006	Water contains impurities, dissolved solids (TDS), Cadan Mg ions
G007	There is a crust (deposit)
G008	Foam, solid water droplets or corrosive gases carried by steam into the turbine
G009	There is crust on the side of the slag

After the symptoms are chosen next is to start the calculation process using the certainty factor method which is defined as follows:

$$CF\ (HE) = MB\ (HE) - MD\ (HE) \quad (1)$$

Where:

CF (H, E): Certainty factor is obtained based on the

hypothesis H which is influenced by symptoms (evidence)

E. The amount of CF Ranges from -1 to. Value -1 indicatesthe value of absolute mistrust while the value of 1 indicatesabsolute trust.

MB (H, E): measure of increase in confidence (measure of increased belief) of the H hypothesis that is influenced by the symptoms of E.

MD (H, E): measure of increased disbelief of H hypothesisthat is influenced by the symptoms of E.

The certainty factor (CF) shows a network of trust in a hypothesis based on several facts or symptoms. Positive CF means that the facts support the hypothesis because MB> MD. CF = 1 implies that facts prove a hypothesis. CF

= 0 means one of two possibilities, namely first CF = MB

– MD = 0 both MB and MD are zero which means there isno fact. The second possibility is that Md = MB and both are not equal to zero which means that trust is removed or nullified by mistrust.

The basic formula is used if there is no CF value for each symptom that causes disease. The combination of certaintyfactors used to diagnose the disease is:

1. Certainty Factor for rules with the premise / singlesymptom (single premise rules):
   $CF_{symtoms} = CF_{[user]} * CF_{[expert]}$ (2)

2. If there are rules with similar conclusions (similiary concluded rules) or more than one symptom, then the next CF is calculated by the equation:
   $CF_{combine} = CF_{old} + CF_{symptoms} * (1-CF_{old})$ (3)
3. Meanwhile, to calculate the percentage of disease, the equation is used:
   $CF_{percentage} = CF_{combine} * 100$ (4)

To determine the expert belief information, seen fromCFcombine based on the expert confidence factor table in Table II. At the fault diagnosis session, given the choice ofinterpretation, each of which has a CF value as follows:

- Not Sure = 0.0
- Yes) Not Sure = 0.1 –0.3
- (Yes) A Little Sure = 0.4 - 0.5
- (Yes) Pretty Sure = 0.6 - 0.7
- (Yes) Sure = 0.8 - 9.9
- (Yes) Very Sure = 1.0

The process of calculating the percentage of beliefs starts with solving a rule that has multiple symptoms, becomingrules that have a single phenomenon. Then each new rule is calculated by using the CF equation 2. But if there are more than one symptom, the CF disease is calculated usingequation 3.

In the calculation process, an expert's confidence is needed for the process of getting the final value of the certainty factor described in the table below

TABLE III

EXPERT CONFIDENCE

	Certainty Term	CFendern
1	Certainly not	-1.0
2	Almost certainly not	-0.8
3	Most likely no	-0.6
4	Probably not	-0.4
5	Don't Know / Not Sure	-0.2 --- 0.2
6	Maybe	0.4
7	Most likely	0.6
8	Almost certainly	0.8
9	Certainly	1,0

The expert confidence factor is used to assess how much the user's confidence level is 1 to -1.

The value of the Certainty factor is obtained from the levelof expert confidence in a symptom of the type of boiler engine failure. This value weight is used for the calculationprocess in determining the value of certainty factors. Following table weights Certainty Factor damage to boilerengine experts and users.

TABLE IV.

CERTAINTY FACTOR VALUE

G003	0.8	0.4
G004	0.4	0.2
G005	0.8	0.4
G006	0.4	0.6
G007	1.0	0.2
G008	0.6	0.8
G009	0.8	0.2

After getting the value of the expert CF and CF weighting conditions *user* then at this stage the problem is resolved with the provisions and rules of the method*Certainty Factor.* The rules are then calculated by the CF value by multiplying the expert CF by the CF user.

4. Result And Discussion

In this study the method used is Certainty Factor, which is a method of trust or certainty [6] to determine the value ofcertainty

to the expert system of boiler engine damage.

There are 3 damages that often occur in boiler engines, namely scale, corrosion and carryover with the symptoms mentioned in table II. There are three rules for calculating the type of damage based on the symptoms and the damagedata.

Rule I

Calculate the value of CF (H, E) 1-4, i.e. Transfer of hot spots, diameter of narrowed pipes, increase in high temperature and accumulation, water hardness above the maximum limit, Feed water contains Mg ions and or Ca (hard water). By using formulas (1), (2) and (3) to calculatea single premise, we get the results like the table below:

TABLE V

RULE I

	$CF(H)_1 * CF(E)_1$	$CF(H)_2 * CF(E)_2$	$CF_{old}+CF_{gejala}*(1-CF_{old})$	$CF_{combine}* 100$
$CF(H,E)_1$	0.6			
$CF(H,E)_2$		0.32		
$CF(H,E)_3$				
$CF(H,E)_4$				
$CF_{combine}$			0.83	
$CF_{persentase}$				83%

Rule II:

Calculate the value of CF (H, E) 5-7, i.e. Feed water contains corrosive gases (O2 CO2 and NH3), water contains impurities, dissolved solids (TDS), Cadan ions Mg ions, there are deposits (deposits). In the same way theresults obtained as the table below:

TABLE VI
RULE II

	$CF(H)_5 * CF(E)_5$	$CF(H)_6 * CF(E)_6$	$CF(H)_7 * CF(E)_7$	$CF_{old}+CF_{gejala}*(1-CF_{old}$	$CF_{combine}* 100$
$CF(H,E)_5$	0.32				
$CF(H,E)_6$		0.24			
$CF(H,E)_7$			0.2		
$CF_{combine}$				0.64	
$CF_{persentase}$					64%

Rule III:

Calculate the value of CF (H, E) 8-9, i.e. Foam, solid waterdroplets or corrosive gases carried by steam enter the turbine and have slag on the side of the slag In the same way the results obtained as the table below:

TABLE VII

RULE III

	$CF(H)_8 * CF(E)_8$	$CF(H)_9 * CF(E)_9$	$CF_{old}+CF_{gejala}*(1-CF_{old})$	$CF_{combine}* 100$
$CF(H,E)_8$	0.48			
$CF(H,E)_9$		0.16		
$CF_{combine}$			0.61	
$CF_{persentase}$				62%

Based on the rule calculation above, the results of the Certainty Factor calculation can be seen in the following table.

TABLE VIII

THE RESULTS

Rule	Damage	Results *Certainty Factor*	Confidence Level
1	K1	0.83	83%
2	K2	0.64	64%
3	K3	0.62	62%

Based on the diagnostic conclusion table above, the highestpercentage of damage confidence is K1 or Scale with a 83% confidence level.

5. Conclution

Based on certainty factor analysis. The highest confidencedamage percentage is the scale with a confidence level of 83%. Damages that often occur in boiler engines are scale,corrosion and carryover.

The weakness of this research is that it has not used an application to analyze boiler engine damage. With theapplication, users can be more aware of boiler engine damage. In addition, the request is to further use expert systems with other methods so that the expected results aremore accurate.

ACKNOWLEDGMENT

We are grateful to the Universitas Potensi Utama whohas helped in the financial field so that this paper can be published.

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