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Development of a Delphi Based Ultrasonic Testing Expert System

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ABSTRACT

A person who has the expertise to operate ultrasonic testing in the field of ultrasonic called experts. Currently very difficult to obtain an ultrasonic expert in an industry. For the expert knowledge of ultrasonic testing is adopted in the computer system. This system called Expert System Type of Disability Determination Using Ultrasonic Welding The Delphi Program. This expert system is used to determine the classification of weld defects in determining the acceptance / rejection of defective welds. In the expert system can also be used to determine the type of weld defects based on defect indications obtained. In addition to the expert system there is an explanation of ultrasonic, calibration procedures and procedures for ultrasonic inspection. In the expert system is the input data that shows an ultrasonic flaw manually entered into the computer. In building an expert system software to use Delphi 7 and Inno Compiler Set Up the installer. Expert systems can be used by people who are just learning the ultrasonic as a tool to determine the acceptance / rejection of defective welds. The results showed that the Expert System Determining the type of defect indications welding able to identify all the defective welds of the inspection. Acceptance of material is observed in accordance with AWS D1.1 acceptance standards.

Keywords: *Expert System, Classification, Ultrasonic.*

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INTRODUCTION

The increasing number of requests a particular item in the mining industry and shipping (Deng dkk., 2020). So as to produce a high quality industrial goods and high-efficient, it is necessary to do an inspection to determine the quality of industrial goods (Darwish dkk., 2019). One of the inspections that can be used for this inspection are Non Destructive Testing (NDT) (Marcantonio dkk., 2019). Therefore we need a Human Resources (HR) is involved in the inspection, either as an inspector, checker, and maintenance who qualified (Jiang dkk., 2020). That inspection is mostly done to

determine the connection between the presence of defects in welds and defective welds whether it can be accepted or rejected (Ramdani dkk., 2019). For testing it is necessary for NDT either at the fabrication of components, construction and maintenance.

A person who has the expertise to operate ultrasonic testing in the field of ultrasonic called experts (Sadowski dkk., 2019). Currently very difficult to obtain an ultrasonic expert in an industry. For this reason the expert knowledge of ultrasonic testing is adopted in the computer system (Jasiūnienė dkk., 2019). This system called Expert System Type of Disability Determination Using Ultrasonic Lasan The Delphi Program (Agustanti & Astuti, 2022). The system is built using the Delphi program. In the expert system is the input data that shows an ultrasonic flaw manually entered into the computer (Balia dkk., 2021). The input data will be processed to determine the type of weld defects and weld defect classification (Amiri dkk., 2020). The expert system is equipped with a calibration procedure, which will facilitate the operation for starting a new ultrasonic inspection.

THEORETICAL STUDIES

Expert System

Expert systems are computer-based application that is used to resolve problems in accordance with the thinking of experts (Lopez dkk., 2019). Experts are people who have special expertise that can solve problems that can not be solved by people in general.

Architecture of a typical expert system is shown in Figure 1 (Fadli, 2003).

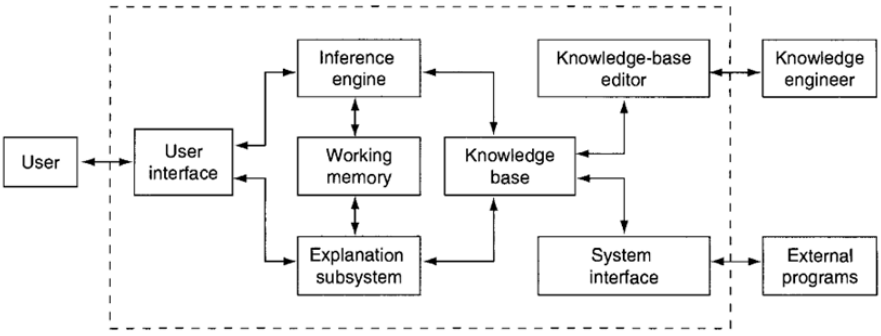

Figure 1. Architecture of Expert System

where the explanation of each part is as follows:

1. A knowledge base is the core of an expert system, namely the representation of expert knowledge. The knowledge base consists of facts and rules. Facts are information about an object, event, or situation. Rules are a way to generate new facts from already known facts.
2. The inference engine acts as the brain of the expert system. The inference engine functions to guide the condition reasoning process, based on the available knowledge base.

3. A working memory used to storing data, a statement of purpose, and the results of which form the current state of the inference process.
4. An explanation subsystem provides an explanation of the reasoning process of the system and the justification for the actions of the system and conclusions.
5. A user interface is used as a communication intermediary between users and interface system designs, including frequently asked questions, display menus, programming languages, graphic displays and help both offline and online.
6. A knowledge-base editor is the window where the knowledge engineer (the person who removed an expert knowledge into a computer system).
7. A system interface to connect expert system with external programs and information resources.

Knowledge Representation Technique

Knowledge Representation is a technique for representing the acquired knowledge base into a schematic/diagram that is known to relate/connect between the data and other data. This technique helps knowledge engineers understand the knowledge structure that will become an expert system. There are several knowledge representation techniques that are commonly used in expert system development, namely: (Fadli, 2003).

1. Knowledge Based Rules
   In rule-based reasoning, knowledge is represented using rules of the form: IF-THEN. This form is used when we have expert knowledge about a particular issue, and experts can solve the problem sequentially. Apart from that, this form is also used where it is necessary to explain the traces (steps) of achieving a solution.
2. Case-Base Reasoning
   In the reasoning-based case, the knowledge base will contain solutions that have been reached previously, and will then derive solutions for the current situation (facts). This form is used when the user wants to know more about almost the same (similar) cases. Apart from that, this form is also used when we already have a number of situations or certain cases in the knowledge base.

Delphi

Delphi is an IDE Compiler for the Pascal programming language and software development environment (Hoang & Kang, 2019). This product was developed by Code Gear as Embarcadero's software development division, a division previously owned by Borland (Kadir, 2014).

Ultrasonic Testing

The basic principle of this test is to transmit ultrasonic waves into the material being examined (Marco dkk., 2021). Ultrasonic wave will propagate into the material and will be reflected when the direction of propagation found an air cavity (King dkk., 2020). The reflected wave will be welcomed back by the probe (transducer) in the form of a pulse on the CRT screen which is a pulse or pulses disabled Backwall.

Acceptance Rejection Criteria of Weld Defect Using Ultrasonic Method

Used AWS D1.1 which refers to Table 6.2 for Statically Loaded Nontubular Connection and Table 6.3 for Cyclically Loaded Nontubular Connection (Blodget, 2000). Testing using the probe angle (shear) aims to obtain the length of the indication (Ayaz dkk., 2019). The length indication shall be determined by measuring the distance between the centerline location where the effects of amplitude indication tranducer rating down (drop) 50% [6 Db] under a disability rating for the appropriate classification (Yu dkk., 2020). This length should direcord in the "discontinuity length" in the test report.

By calculating the value of indication rating, it can be an indication of the defect is known classification into Class A, Class B, Class C or Class D. To find a value indication rating "d" in AWS D1.1 test using the following formula(Blodget, 2000):

$$d = a – b – c$$

with

d = Indication rating, describing the calculation of decibel difference between the indication level and reference level with correction for attenuation

a = Indication level, the decibel reading of the instrument at the time of maximum attainable indication of a defect that produces a horizontal reference level trace detection on display.

b = Zero reference level, the decibel readings on the instrument as an indication of the maximum of the first back reflection reaches 50 to 75% screen height (height of the screen) (Fathi dkk., 2020). Where the measurement is done tranducer set to gain a position on the IIW block (at the time of calibration).

c = attenuation factor, which is obtained by subtracting 1 inch (25 mm) of distance soundpath and multiply the remainder by 2. These factors should be rounded to the nearest dB.

$$c = ((SP/25) -1) \times 2 \text{……..(2.2)}$$

with sp is soundpath distance..

Weld Defect

Weld defects can be divided into two, namely (Wiryosumarto & Okumura, 2000):

1. Continues defects such as undercut surface, intermittent undercut, incomplete penetration, etc.
2. Internal defects such as distributed porosity, slag inclusion, wormhole, incomplete fusion, crack (longitudinal / transverse), etc.

Welding Techniques

In general, welding technique that is known 5 types (Minwalla, 2003):

1. Shielded Metal Arc Welding (SMAW)
2. Gas Metal Arc Welding (GMAW)
3. Flux Core Arc Welding (FCAW)
4. Submerged Arc Welding (SAW)
5. Gas Tungsten Arc Welding (GTAW)
6.

RESEARCH METHODOLOGY

Input Requirement

There are two kinds of input requirements (Giannakis dkk., 2021). The first material data in the form of materials (D. Y. Zhang dkk., 2020), welding technique and material dimensions (thick material) (Virkkunen dkk., 2021). The second data indicative of a form of ultrasonic defect, the location indication defect, a flaw in the screen display pulse UT flaw detector (Shah dkk., 2020), the zero reference level, the level indication, soundpath value, value and visual indication rating disabilities.

Process Requirement

Inference Engines

To the needs of the input data as output data as input into output using the technique of reasoning trace Forward (Forward Chaining) (Fadli, 2003), the input is processed through three stages:

1. Phase I Design Creating a Program Flowchart
   In making the flowchart authors limit the materials to be used as a display as well as information that can be accepted by users. At the design stage is also the input (data ultrasonic material and data) and output (the presence and type of weld defects, material acceptance, the solution to the existing defects) were collected and grouped according to the criteria.
2. Phase II Development
   At this stage of the criteria that have been grouped, made into a database which is then processed into a program.
3. Phase III Testing
   At the last stage is a program that will process the input is matched to the output according to the criteria.

Output Requirement

To the requirement of output data showing the conclusion of the classification and type of defects in the welds are obtained, the cause of the disability and appropriate solutions (Wu dkk., 2020). These conclusions were obtained through the execution of the program by entering the inputs that have been stored in the database.

Requirement of Software and Hardware

The software used in developing an expert system program is the Embarcadero Delphi 7, AlphaLite its components (Du dkk., 2019), and software Inno compiler set up (K. Zhang dkk., 2020). While the hardware needs to follow the requirements of software.

Formulation Knowledge Base and Inference Machines

Material Data and Ultrasonic Data are grouped, arranged into a decision table and decision trees.

The design of the Main Window Interface

The design of the main window interface is shown in figure2 .

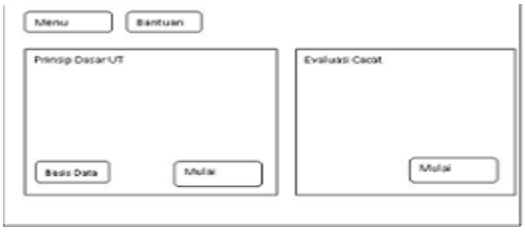

Figure 2. Interface Design of first Page

Figure 3. Interface Design of Database Page

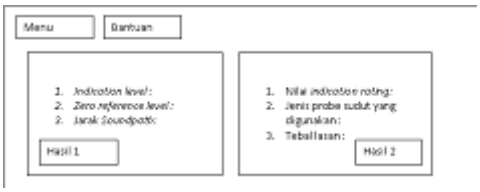

Figure 4. Interface design of evaluation defect classification Page

Program Algorithm

Algorithm program classification expert system for evaluation of weld defects and defect type is shown in the following figure 5. Flowchart evaluation of defect classification.

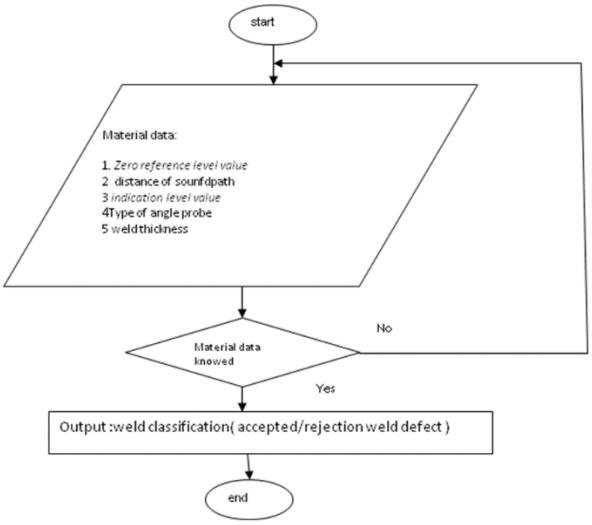

Figure 5. Flowchart of classification defect evaluation

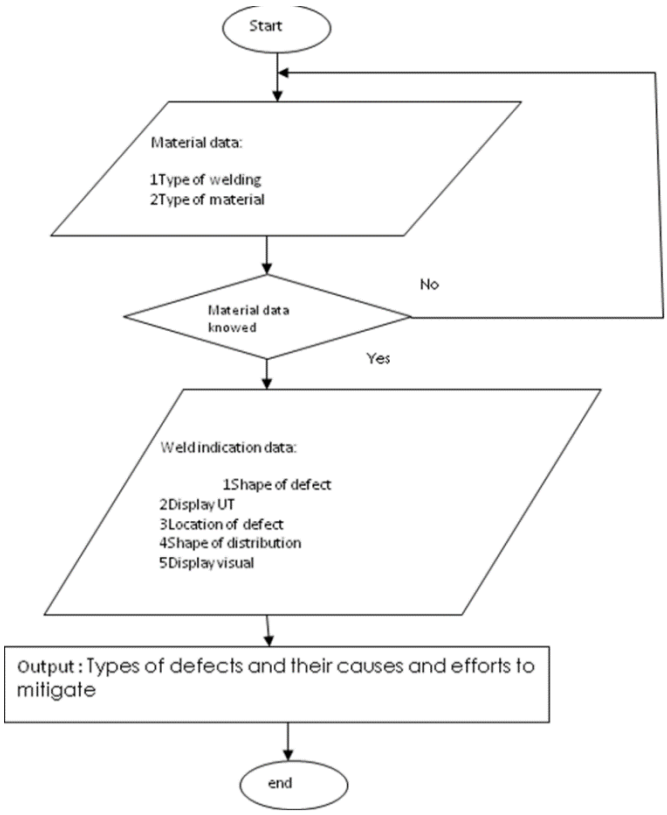

Figure 6. Flowchart of defect type evaluation

RESULTS AND DISCUSSION

Implementation Program

Implementation is the stage where the program is ready to operate on a real stage (Majhi dkk., 2020), so it will be known whether the program made can actually produce the desired goal (Saeedifar dkk., 2019). This stage is done by running the program with the results as shown below.

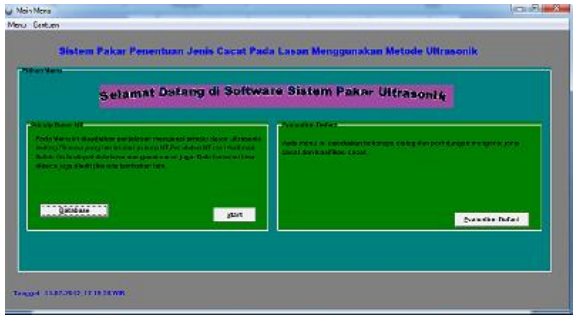

Figure 7. Display of main window

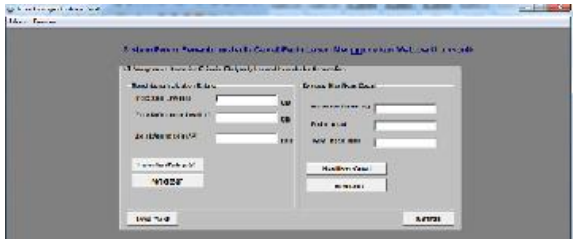

Figure 8. Display of defect classification evaluation window

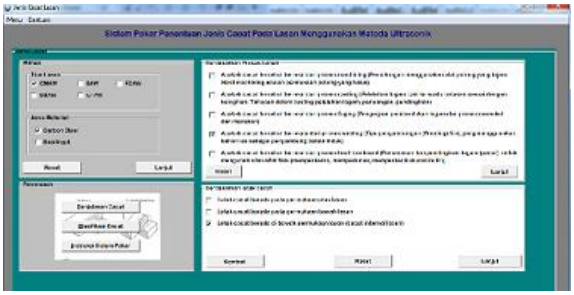

Figure 9. Display of defect type classification evaluation window

Testing Program

Testing of the weld defect evaluation

Testing of the weld defect evaluation is divided into two, namely the evaluation of the weld defect classification to determine whether these defects can be accepted or rejected (Iglesias-Pradas dkk., 2021). While the second evaluation is the evaluation of the weld defect types.

In the test below is a test to determine the classification of weld defects:

In the testing of the weld defect classification is the user entering the data material (Gaffney dkk., 2019), data and data of ultrasonic flaw indications are:

1. Material data:

The data included material is thick welds (mm)

2. Indicative of defects data:

Data included indications of defects is the indication level, zero level referrence, distance soundpath

3. Ultrasonic data:

Data is entered ultrasonic probe angle used during the implementation of inspection.

By entering the zero reference level, the level and range indication will be obtained soundpath attenuation value and indication rating. The results obtained using the formula.

c=((sp/25)-1) x 2

d=a-b-c

With :

d = Indication rating, a = Indication level, b = Zero reference level, c = Attenuation factor, sp= Soundpath distance

Where the indication rating should be rounded to the nearest number.

After knowing the value of the indication rating by looking at Table 6.2 for statically Loaded NonTubular Connection and Table 6.3 for Cylically Loaded Nontubular Connection (Ayaz dkk., 2019), it will be known to the classification of weld defects. Of classification will be known whether the defective weld is accepted or rejected (Baumann & Cabassa, 2020). To test this UT inspection test data used in PT PAL when I do the Job Training (KP) in PT PAL.

1. Oyong Extension Platform Inspection
   Date : July 27th ,2011

Criteria : AWS D 1.1
Drawing No. : 9810-90-02-201
Material Type : Carbon Steel (CS)
Place : Plat Construction workshop II (Oyong Project)
Surface Condition: smooth
Surface preparation: As Welded
Flaw Detector: SIUI CTS-9005
Calibration Block: IIW Block V1,V2
DB Reff (b) : 81,5
Couplant : CMC + Water
Probe : probe : CB MWS 700 4MHz 8x9
Test results on the platform on July 27th, 2011 Table 1 looks like the following:

Table 1 Data Observations On Platform 1

NO	JOINT NO	T (mm)	L (mm)	Acceptance Criteria			Sound path (mm)	Length of discontinuity (mm)	Depth (mm)	RESULT	Jenis Cacat
				Indication level (a)	Attenuation factor (c)	Indication rating (d)					
1	J.100	8 + 10	150	87,5	0	6	23	15	5-7	Acc	-
2	J.122	8	150	80,5	0	-1	20	126	5-7	Rep	Pl
3	J.128	8	120	80,5	0	-1	20	120	5-7	Rep	Pl
4	J.129	8	120	80,5	0	-1	20	120	6-7	Rep	Pl
5	J.130	8 +10	150	80,5	0	-1	20	130	5-7	Rep	Pl
6	J.130 A	8 +10	150	80,5	0	-1	20	130	5-7	Rep	Pl

After knowing the data is the data is entered on the expert system program to determine the indication rating and classification of weld defects (Ai dkk., 2020). By entering the data into the defect classification evaluation form, the obtained results of the comparison between the indication rating is calculated using a formula and a calculation program as in the table below.

1. Date : July 27th,2011
   Criteria : AWS D 1.1
   Drawing No. : 9810-90-02-201
   Material Type : Carbon Steel (CS)
   Place : Plat Construction workshop II (Oyong Project)
   DB Reff (b) : 81,5
   Probe : probe : CB MWS 700 4MHz 8x9

Differences in the indication rating is calculated using formulas and programs as in Table 2 below:

Table 2. Difference indication rating value from formula and program

NO	JOINT NO	T (mm)	Acceptance Criteria					error percentage	Length of discontinuity (mm)	Depth (mm)	Class	Result	Type of Defect
			Indication level (a)	Attenuation factor (c)	Sound path (mm)	Indication rating (formula)	Indication rating (program)						
1	J.10	8	87,5	0	23	6	6	0	15	5-7	B	Ac	-

	0	+10										c	
2	J.122	8	80,5	0	20	-1	-1	0	126	5-7	A	Rep	Pl
3	J.128	8	80,5	0	20	-1	-1	0	120	5-7	A	Rep	Pl
4	J.129	8	80,5	0	20	-1	-1	0	120	6-7	A	Rep	Pl
5	J.130	8 +10	80,5	0	20	-1	-1	0	130	5-7	A	Rep	Pl
6	J.130 A	8 +10	80,5	0	20	-1	-1	0	130	5-7	A	Rep	Pl

From table above can be known differences in the indication rating formulas and calculations in the program did not experience the difference (error percentage = 0%). Thus it can be said to be an expert system program has been successful in calculating the value of the rating and classification indication correctly. By knowing the value indication, it will be known classification rating. So that the classification will be known whether these defects can be accepted (Acc) or rejected (Rep). UT inspection on the implementation of Table 6.2 is used to statically Loaded Nontubular Connection. This is because the welded joints on Platform Extension Oyong a static connection.

At this evaluation can only be known classification of weld defects that would be useful to know the acceptance of weld defects. While to know the type of weld defects, the user can enter into a form that contains a defect type dialog box question. Dialog box contains questions related to the question of data indicative of defective welds that must be answered by the user to know the type of weld defects. After knowing the types of weld defects, the user can find an explanation of the types of defects in the form explanation of the weld defect types. On this form we are difficult to obtain data related to the indication of weld defects that can be identified using ultrasonic methods. Because so far only used for the ultrasonic inspection kedalalaman find its classification in the determination of disability and receipt of weld defects. So the questions that exist in this dialog box only contains data that can be an indication of weld defects using ultrasonic identification of ultrasonic appearance, the effect of changing the position transducer of high amplitude and visual appearance.

To test this type of weld defects obtained the following data:

1. The first flaw testing

   UT display

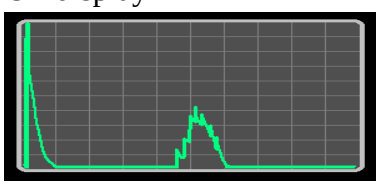

Figure 10. UT Display

Changes in transducer position shift does not affect the amplitude changes

The defects are internal weld defects

Visual display: Presence of dirt / non-metal particles in the weld metal

So by entering data into the dialog box type of expert system will be obtained weld defects. When the above data is inserted into the expert system program such as displayed the image around the following:

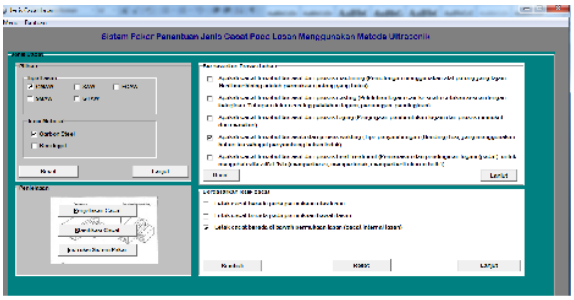

Figure 11. Display dialog box

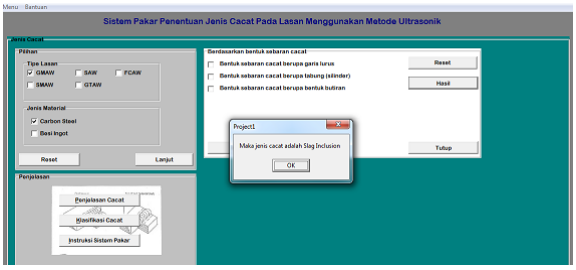

Figure 12. The results obtained by the type of program execution is slag inclusion

From the data obtained indicate that the defect can be estimated is the type of slag inclusion defects. Because the defective weld slag inclusions is caused by the dirt on the surface of the weld. And because the volume of slag inclusions are deformed so that the shift in position did not affect the amplitude of the transducer on the screen UT Flaw Detector. With data is the use of decision tables and decision trees of this expert system the obtained types of defects are slag inclusions. And when included in the executable program and obtained the result type of weld slag inclusion defects.

From the above tests can be concluded that this expert system program can know what type of weld defects to incorporate some indication of defect. Where the type of defect is based on decision tables and decision trees expert system.

CONCLUSION

Based on the discussion in the previous chapters can be deduced as follows: Program has created an expert system for weld defects by ultrasonic evaluation as a tool in evaluating weld defects. This software can be installed and executed on computers using Windows 97 or above generation, with a minimum capacity required on the hard drive is 5.7 Mb.

The ability of this expert system are: (1) Expert systems are able to evaluate accurately the indication rating, classification and type of weld defect indications that are indicative of defects in an ultrasonic inspection; and (2) Expert systems also provide an explanation on the definition and causes of weld defects, acceptance of material as well as efforts to cope with the occurrence of weld defects.

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