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Implementation of Non-Destructive Radiographic Testing for Welding Defect Inspection on Heat Exchanger Project DXXXX at PT XYZ

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Abstract
Welding in the heat exchanger fabrication process is a critical stage that determines structural integrity and operational safety, but internal defects are still often found that cannot be detected visually. This study was conducted to identify the type of welding defect in the Heat Exchanger Project DXXXX and analyze the causative factors based on ASME Section V and VIII standards. The research approach uses a descriptive qualitative method through direct observation of the welding process, Radiography Test documentation, and interviews with Quality Control personnel during field work practice activities. The results showed that out of 279 radiographic films examined at 29 connection points, 31 defects were found consisting of two main types, namely slag inclusion and porosity. Slag inclusion defects are the most dominant finding and are influenced by human factors and work methods, while porosity defects are mainly caused by inaccuracies in methods related to the regulation and use of shielding gas. These findings indicate that inconsistencies in welding procedures, suboptimal material preparation, and inconsistent process control contribute significantly to the occurrence of defects. This study concludes that the Radiography Test is able to provide a comprehensive picture of the quality of weld joints and the defect patterns that occur in heat exchanger fabrication.
Keywords: *welding defect, radiography test, heat exchanger*

Abstrak
Pengelasan pada proses fabrikasi heat exchanger merupakan tahapan kritis yang menentukan integritas struktur dan keselamatan operasi, namun masih sering ditemukan cacat internal yang tidak dapat terdeteksi secara visual. Penelitian ini dilakukan untuk mengidentifikasi jenis welding defect pada Heat Exchanger Project DXXXX serta menganalisis faktor penyebabnya berdasarkan standar ASME Section V dan VIII. Pendekatan penelitian menggunakan metode kualitatif deskriptif melalui observasi langsung pada proses pengelasan, dokumentasi *radiography test*, serta wawancara dengan personel *Quality Control* selama kegiatan praktik kerja lapangan. Hasil penelitian menunjukkan bahwa dari 279 film radiografi yang diperiksa pada 29 titik sambungan, ditemukan 31 cacat yang terdiri dari dua jenis utama, yaitu *slag inclusion* dan *porosity*. Cacat *slag inclusion* merupakan temuan paling dominan dan dipengaruhi oleh faktor manusia dan metode kerja, sedangkan cacat *porosity* terutama disebabkan oleh ketidaktepatan metode terkait pengaturan dan penggunaan *shielding gas*. Temuan ini mengindikasikan bahwa ketidaksesuaian prosedur pengelasan, persiapan material yang kurang optimal, serta kontrol proses yang tidak konsisten berkontribusi signifikan terhadap munculnya *defect*. Penelitian ini menyimpulkan bahwa *Radiography Test* mampu memberikan gambaran komprehensif mengenai kualitas sambungan las serta pola cacat yang terjadi pada fabrikasi *heat exchanger*.
Kata Kunci: *welding defect, radiography test, heat exchanger*

1. Introduction

The welding process is one of the most crucial stages in the metal fabrication industry, especially in pressurized products such as heat exchangers that require very high connection quality to ensure safety and operational performance [1]. PT XYZ as a company with a Make to Order (MTO) production system relies on various welding techniques such as gas tungsten arc welding, plasma arc welding, to submerged arc welding that is tailored to material characteristics and project specifications [2]. The main challenge in the process is the emergence of welding defects that have the potential to reduce the strength of the joints, cause leaks, and pose a risk of pressure failure [3]. Therefore, quality control through Non-Destructive Testing (NDT) methods, especially Radiography Test (RT), is an important step in ensuring that weld joints meet the safety standards set by ASME Section V and Section VIII [4]. However, in practice, various factors such as the connection procedure, operator condition, material preparation, and welding parameters still often lead to the discovery of internal defects that cannot be detected visually [5].

A number of previous studies have examined the different types of welding defects and the effectiveness of the NDT method in detecting joint imperfections [6]. These results show that defects such as porosity, incomplete fusion, and slag inclusion are common findings in pressure vessel fabrication [7]. However, previous studies have tended to focus on one specific type of material, specific welding methods, or simply discuss the characteristics of defects without conducting a comprehensive analysis of the causes of defects based on the interpretation of radiographic results [8]. In addition, some studies have not systematically linked defect findings to ASME standard procedures, so further research is still needed to provide a more holistic picture of welding quality in the context of the large-scale fabrication industry [9]. The novelty of this research lies in the integration between radiographic analysis, defect classification, and tracing of the root cause of defects in Heat Exchanger Project DXXXX, a real research object that has stricter technical standards than common fabrication products. This research also stands out in its application to the direct industrial environment, thus providing a higher practical value than research based on laboratory experiments.

Based on this description, this study aims to (1) identify the types of welding defects in the Heat Exchanger Project DXXXX as a result of the Radiography Test, and (2) analyze the main factors that cause the occurrence of each defect by referring to ASME standards and the actual conditions of the welding process at PT XYZ. The contribution of this research is expected in the form of an in-depth understanding of the defect patterns that appear in pressure vessels, recommendations for continuous improvement for the Quality Control department, and academic contributions related to the application of Radiography Test in the modern fabrication industry. In addition, this study provides a reference for practitioners in designing welding defect mitigation strategies and ensuring that fabricated pressure vessel products can meet international safety standards.

2. Material and Methods

This study uses a descriptive qualitative research design that aims to provide a factual picture of the application of Radiography Test in detecting welding defects in the fabrication process of Heat Exchanger Project DXXXX [10]. The qualitative approach was chosen because the research was carried out directly in an industrial environment through field work practice activities, so that the researcher could observe phenomena naturally without manipulating variables [11]. The research data sources include primary data obtained through direct observation of the welding process and the implementation of the Radiography Test, interviews with Quality Control personnel, and documentation of testing activities available at the company [12]. Data collection techniques are carried out through systematic observation of the workflow in the Quality Control department, recording of radiography processes in the field, informal interviews with operators and inspection officers, and collection of company technical documents such as work procedures, inspection standards, and radiography film interpretation results [13].

The types of data analyzed include qualitative data in the form of weld defect findings, description of joint conditions, and the results of interpretation of radiographic images obtained during field practice [14]. All data were analyzed using descriptive analysis techniques, namely by organizing field data, identifying the categories of defects that appeared, comparing the findings with the requirements of ASME Section V and Section VIII standards, and tracing the causative factors based on the suitability of the procedures and conditions of the welding process in the field [15]. This analysis resulted in a comprehensive understanding of the defect patterns and the root of the problems that occur during heat exchanger fabrication, so that this research method is able to objectively describe the quality of the welding process according to the actual conditions at PT XYZ. The following is also attached the flow of this research.

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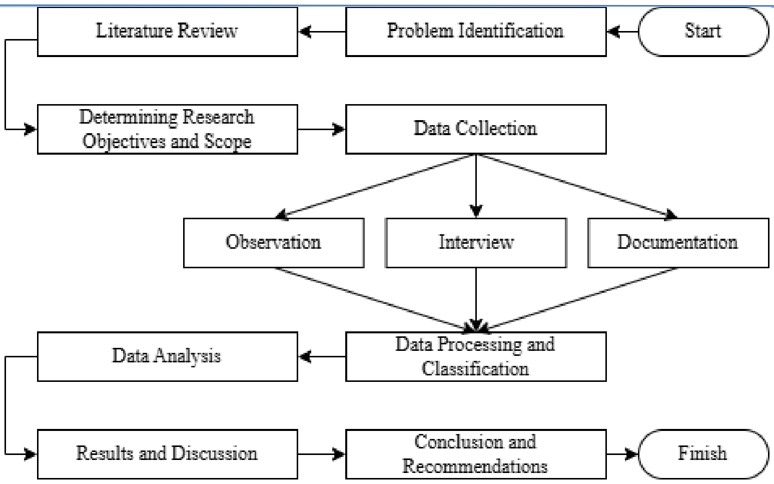

Fig. 1: Research Flow

3. Results and Discussion

Analysis

The results of the radiographic examination on the Heat Exchanger Project DXXXX showed that of the 29 weld connection points with a total of 279 films tested, there were 31 weld defects that required repair and 248 films were declared to be up to standard. These findings provide an overview of the existence of various types of defects in weld joints and form the basis for further analysis regarding the characteristics of defects and their causative factors.

Table 1. Radiography Examination Results of Heat Exchanger Project DXXXX

No	Joint No	Qty Film	Repair	Acc
1	WL.A-1	3	0	3
2	WL.A-2	3	0	3
3	WL.A-3	2	0	2
4	WL.A-4	10	0	10
5	WL.A-5	10	0	10
6	WL.A-6	10	1	9
7	WL.A-7	10	1	9
8	WL.A-8	10	0	10
9	WL.A-12	2	0	2
10	WL.A-13	3	0	3
11	WL.A-14	2	0	2
12	WL.A-17	1	0	1
13	WL.B-1	16	0	16
14	WL.B-2	14	0	14
15	WL.B-3	14	0	14
16	WL.B-4	14	1	13
17	WL.B-5	14	0	14
18	WL.B-6	14	1	13
19	WL.B-7	14	0	14
20	WL.B-8	7	7	0
21	WL.B-11	16	0	16
22	WL.B-12	16	0	16
23	WL.C-1	14	1	13
24	WL.C-2	14	3	11
25	WL.C-3	-	-	-
26	WL.C-4	16	2	14
27	WL.C-5	16	11	5
28	WL.C-6	7	0	7
29	WL.C-7	7	3	4
	Total	**279**	**31**	**248**

Source: Author's Processing Results, 2025

Welding Defect

The results of radiography testing on the Heat Exchanger Project DXXXX weld joint showed 31 welding defects out of a total of 279 films examined. Based on **Table 2**, the most dominant type of defect is Slag Inclusion, found in WL joints. A-6, WL. A-7, WL. B-4, WL. B-6, WL. C-1, WL. C-2, WL. C-4,

Jurnal Serambi Engineering JSE
Volume XI, No.1, Januari 2026 Hal 16844 - 16853 p-ISSN : 2528-3561 e-ISSN : 2541-1934

and WL. C-5, while the Porosity defect type is detected in WL. B-8 and WL. C-7. The radiographic film sample shows the details of each defect, as shown in **Figure 2** (WL. A-6) and **Figure 3** (WL. A-7) showing the Slag Inclusion on the longitudinal shell joint, as well as **Figure 4** (WL. B-4) and **Figure 5** (WL. B-6) which shows a similar defect in the circum shell connection.

Table 2. Welding Defect

	Welding Defect	
Joint No	**QTY Film**	**Jenis**
WL.A-6	1	*Slag Inclusion*
WL.A-7	1	*Slag Inclusion*
WL.B-4	1	*Slag Inclusion*
WL.B-6	1	*Slag Inclusion*
WL.B-8	7	*Porosity*
WL.C-1	1	*Slag Inclusion*
WL.C-2	3	*Slag Inclusion*
WL.C-4	2	*Slag Inclusion*
WL.C-5	11	*Slag Inclusion*
WL.C-7	3	*Porosity*

Source: Author's Processing Results, 2025

The porosity defect is clearly visible in Figure 6 (WL. B-8) and Figure 11 (WL. C-7), are located at the circum shell and flange to pipe joints, respectively. Meanwhile, the Slag Inclusion defect in the other section is shown in Figure 7 (WL. C-1), Figure 8 (WL. C-2), Figure 9 (WL. C-4), and Figure 10 (WL. C-5), which includes flange to channel, channel to tubesheet, and flange to shell connections. Overall, the radiography film data clarifies the distribution and type of weld defects that occur in some critical areas of the Heat Exchanger components.

Fig. 2: WL.A-6
Source: PT XYZ, 2025

. **Fig. 3**: WL.A-7
Source: PT XYZ, 2025

Fig. 4: WL.B-4
Source: PT XYZ, 2025

Fig. 5: WL.B-6
Source: PT XYZ, 2025

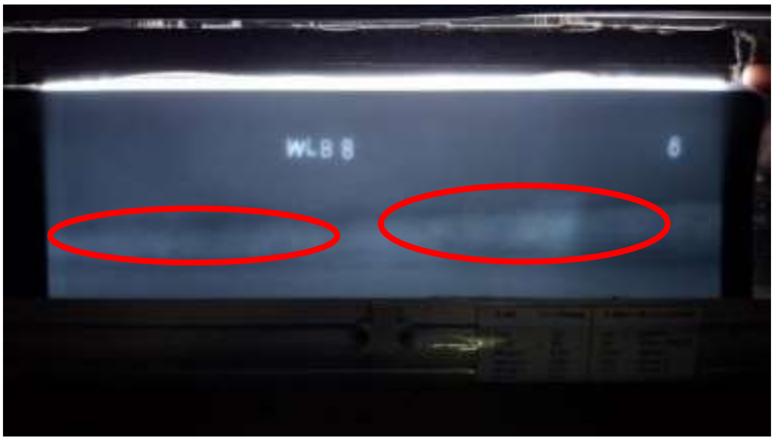

Fig. 6: WL.B-8
Source: PT XYZ, 2025

Jurnal Serambi Engineering JSE
Volume XI, No.1, Januari 2026 Hal 16844 - 16853
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Fig. 7: WL.C-1
Source: PT XYZ, 2025

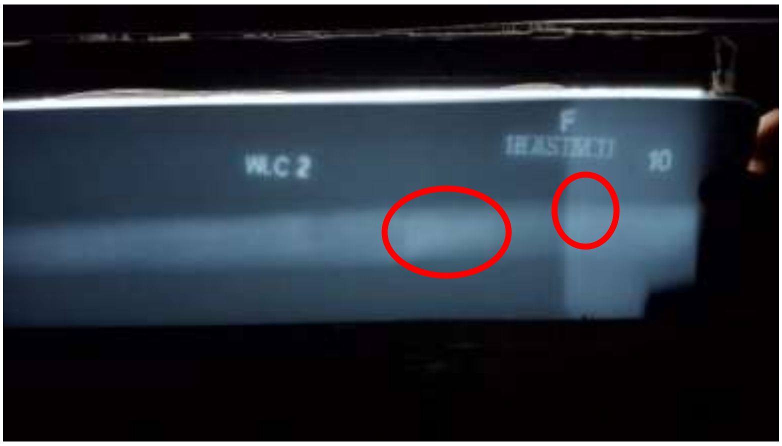

Fig. 8: WL.C-2
Source: PT XYZ, 2025

Fig. 9: WL.C-4
Source: PT XYZ, 2025

Jurnal Serambi JSE Engineering Volume XI, No.1, Januari 2026 Hal 16844 - 16853 p-ISSN : 2528-3561 e-ISSN : 2541-1934

Fig. 10: WL.C-5
Source: PT XYZ, 2025

Fig. 11: WL.C-7
Source: PT XYZ, 2025

Causative Factors of Welding Defect Heat Exchanger Project DXXXX

Based on the results of the analysis using the fishbone diagram on *slag inclusion* defects, as shown in **Figure 12** Fishbone Diagram Slag Inclusion, it is known that this defect can be caused by several main factors. From the Man aspect, the operator is not thorough in cleaning the weld layer so that the remaining slag is left behind and trapped in the weld. From the Machine side, the current instability and the absence of periodic calibration of the welding machine cause the welding quality to be inconsistent. In the Method factor, incorrect adjustment of welding angles also triggers the formation of slag inclusion. From the material factor, flux heating that is not in accordance with the provisions on the manufacturing data sheet makes the flux not work optimally so that residual particles can be left at the joint. Meanwhile, environmental factors such as unclean work areas and the presence of dust or light contaminants also have the potential to enter the welding area and cause these defects.

Jurnal Serambi JSE Engineering Volume XI, No.1, Januari 2026 Hal 16844 - 16853 p-ISSN : 2528-3561 e-ISSN : 2541-1934

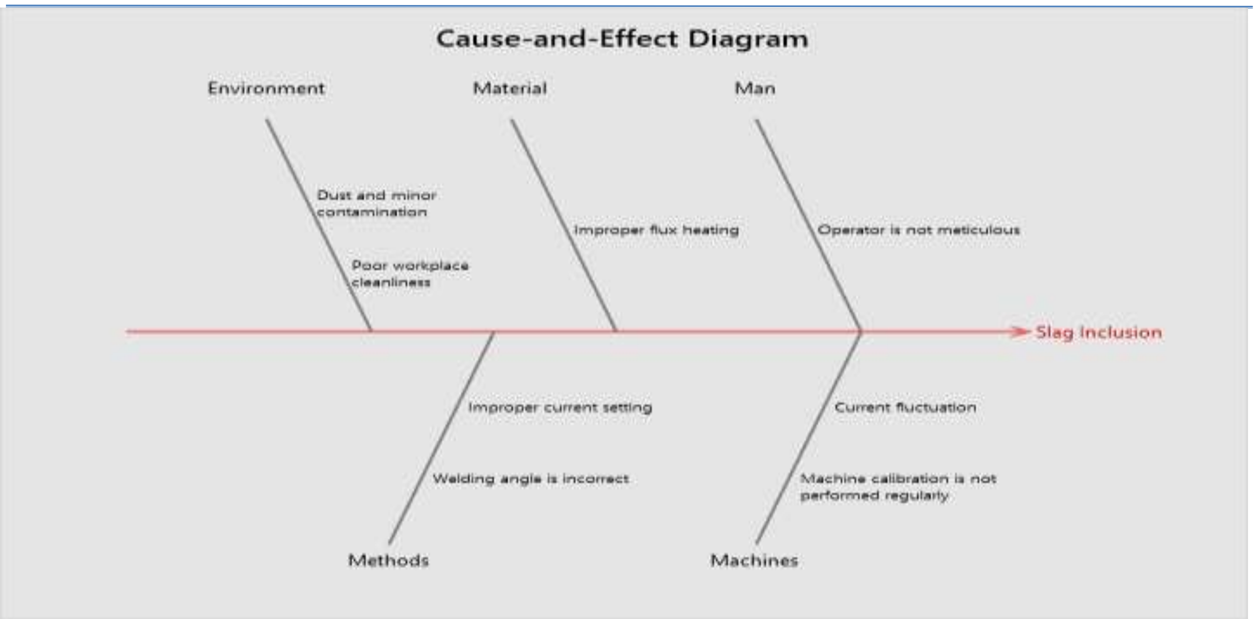

Fig. 12: Fishbone Diagram Slag Inclusion
Source: PT XYZ, 2025

Based on the analysis using fishbone diagrams for porosity defects, as shown in Figure 13 of the Fishbone Porosity Diagram, it is known that these defects are influenced by several main factors. From the Man aspect, the operator is not meticulous in preparing the surface of the material so that the contaminants left behind can release gases when exposed to the welding heat and trapped before the metal freezes. In the Machine factor, unstable gas pressure due to suboptimal regulator settings and inadequate gas cooling systems can increase the temperature and encourage the formation of gases. In terms of method, the use of gas shielding in the GTAW method that is not suitable also triggers the formation of porosity. In the Material aspect, moisture in the base material or electrode and the use of damaged electrodes can produce hydrogen gas during the welding process. Meanwhile, environmental factors such as high air humidity and moisture in the work area can also enter the welding zone, causing small gas cavities to form in the metal that freeze too quickly.

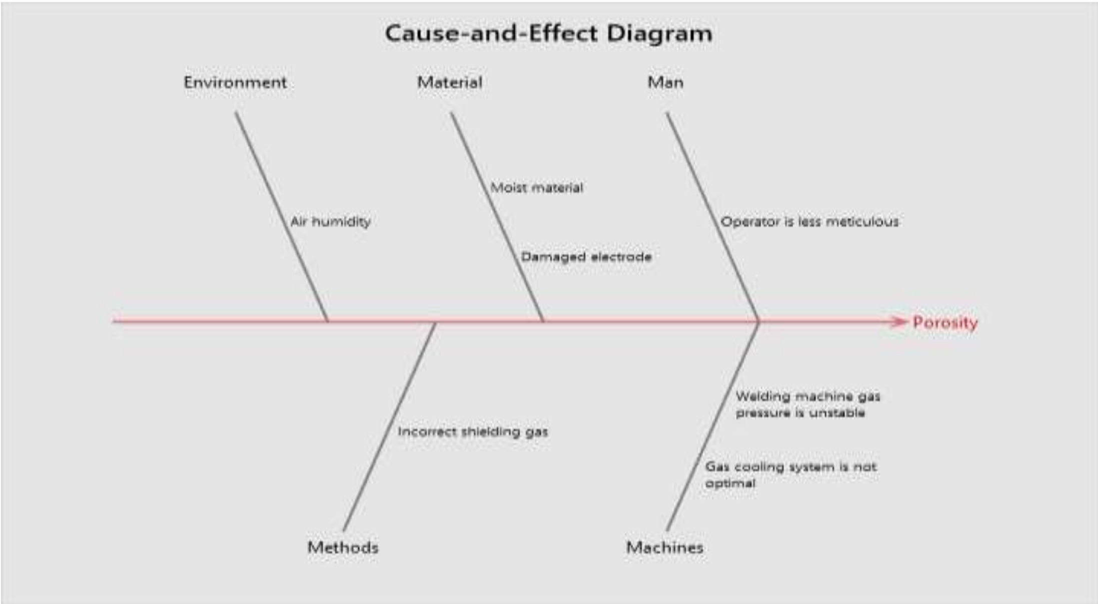

Fig. 13: Fishbone Diagram Porosity
Source: PT XYZ, 2025

After analysis using fishbone diagrams, it was found that the appearance of welding defects that occurred in Heat Exchanger Project DXXXX for slag inclusion defects, and porosity defects are presented in the following table:

Table 3. Causes of the Slag Inclusion Project DXXXX

Slag Inclusion		
No	**Factor**	**Actual Condition**
1	*Man*	Yes
2	*Machine*	No
3	*Method*	Yes
4	*Material*	No
5	*Environment*	No

Source: Author's Processing Results, 2025

Table 4. Causes Porosity Project DXXXX

Porosity		
No	**Factor**	**Actual Condition**
1	*Man*	No
2	*Machine*	No
3	*Method*	Yes
4	*Material*	No
5	*Environment*	Yes

Source: Author's Processing Results, 2025

4. Conclusion

The results showed that the quality of the weld joints in the Heat Exchanger Project DXXXX was still affected by the emergence of two main types of defects, namely *slag inclusion* and *porosity*, with a total of 31 defects from 279 radiographic films examined. This finding answers the purpose of the study that welding defects can be clearly identified through Radiography Test with defect classification referring to ASME Section V and VIII standards. Fishbone analysis revealed that *slag inclusion* was mainly triggered by human factors and improper working methods, while *porosity* was more predominantly caused by method errors related to the use and regulation of gas shielding. Overall, this study confirms that inconsistencies in welding procedures, suboptimal material preparation, and instability of process control contribute significantly to potential defects in heat exchanger connections. To minimize the recurrence of similar defects, it is recommended to improve operator competence through regular training, review of welding procedures according to ASME standards, increased QC supervision at the material preparation stage and welding execution, and the application of periodic calibration to welding equipment. Further research can consider quantitative approaches to measure the relationship between causative factors in a more structured manner and extend the test object to other types of connections to enrich the mapping of defect risk in the fabrication industry.

5. Acknowledgment

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6. References

[1] A. EL Harrak, M. Rhazzaf, and I. Moumene, "Deep Learning Approach for Non-destructive Radiography Testing of Piping Welds," *IAENG Int J Comput Sci*, vol. 51, no. 4, pp. 378–395, 2024.

[2] E. E. Ghandourah, S. A. hanif Hamidi, K. A. M. Salleh, M. N. Wahab, E. M. Banoqitah, and O. A. Fallatah, "Evaluation of Welding Defects with X-ray Digital Laminography for NDT inspection of Carbon Steel Plate," *Res Sq*, vol. 1, no. 1, pp. 1–18, Apr. 2023, doi: 10.21203/rs.3.rs-2692428/v1.

[3] A. V. Prasmoro, "Analisa sistem perawatan pada mesin las MIG dengan metode Failure Mode and Effect Analysis: Studi kasus di PT. TE," *Operations Excellence*, vol. 12, no. 1, pp. 13–27, 2020.

[4] J. Ilmu *et al.*, "Hubungan Antara Ppe, Wps, Bbs Dan Kompetensi Welder Terhadap Penerapan K3 Bidang Pekerjaan Fabrikasi Logam Pada Proses Welding," *Journal of Public Health Sciences)*, vol. 13, no. 2, pp. 251–260, 2024, [Online]. Available: https://jurnal.ikta.ac.id/index.php/kesmas

[5] T. W. Purnomo, F. Danitasari, and D. Handoko, “Weld Defect Detection and Classification based on Deep Learning Method: A Review,” *Jurnal Ilmu Komputer dan Informasi (Journal of Computer Science and Information)*, vol. 16, no. 1, pp. 77–87, 2023, doi: 10.21609/jiki.v16i1.1147.

[6] R. L. Pradana, A. Khumaidi, and R. Andiana, “Identifikasi Penyebab Cacat Pada Hasil Pengelasan Dengan Image Processing Menggunakan Metode YOLO,” *Jurnal Teknik Elektro Dan Komputer Triac*, vol. 9, no. 2, pp. 107–112, 2022, [Online]. Available: https://journal.trunojoyo.ac.id/triac

[7] D. Say, S. Zidi, S. M. Qaisar, and M. Krichen, “Automated Categorization of Multiclass Welding Defects Using the X-ray Image Augmentation and Convolutional Neural Network,” *Sensors*, vol. 23, no. 14, pp. 1–19, Jul. 2023, doi: 10.3390/s23146422.

[8] M. N. Alwahidi, S. Najibah, and B. Afrizal, “Jurnal Mema (Jurnal Mesin dan Manufaktur) Review Pengujian Pengelasan Metode Non-Destructive Test,” *Jurnal Mema (Jurnal Mesin dan Manufaktur)*, vol. 2, no. 1, pp. 30–42, 2025, [Online]. Available: https://memajournal.indiepress.id/index.php/mema/index

[9] Siti Nur Hamidah, Moh. Ayip Fathani, Zulfadlillah Zulfadlillah, and Kardita Kardita, “Peran Quality Engineering dalam Optimasi Proses Produksi (Studi Literatur pada Industri Manufaktur Kontemporer),” *Jural Riset Rumpun Ilmu Teknik*, vol. 3, no. 1, pp. 232–240, Apr. 2024, doi: 10.55606/jurritek.v3i1.4775.

[10] W. Zhang *et al.*, “Deep Learning-Based Automated Detection of Welding Defects in Pressure Pipeline Radiograph,” *Coatings*, vol. 15, no. 7, pp. 1–14, Jul. 2025, doi: 10.3390/coatings15070808.

[11] M. Mahvelatishamsabadi and S. Lee, “Automated Weld Defect Detection in Radiographic Images Using Normalizing Flows,” *Machines*, vol. 13, no. 9, pp. 1–14, Sep. 2025, doi: 10.3390/machines13090836.

[12] Fatmawati, A. Chaerul, and A. Syahid, “Implementasi Planning, Organizing, Leading, Controlling (POLC) Program Pelatihan Pengelasan Untuk Meningkatkan Kesiapan Kerja Peserta Didik Lembaga Kursus dan Pelatihan Nusa Citra Indonesia,” *Jurnal Ilmiah Wahana Pendidikan*, vol. 8, no. 19, pp. 118–126, 2022, doi: 10.5281/zenodo.7162783.

[13] S. A. Pratama, M. Fahreza, and M. K. Hidayat, “Analisis Pengendalian Kualitas Produk Menggunakan Metode SQC Dan Kaizen Pada PT. Laksana Tekhnik Makmur,” *IMTechno: Journal of Industrial Management and Technology*, vol. 6, no. 1, pp. 1–8, 2025, [Online]. Available: http://jurnal.bsi.ac.id/index.php/imtechno

[14] Y. Amalia and S. Rahmatillah, “Analisis Sambungan Las Baja S355 J2 Sebagai Penyusun Welding Procedure Specification di PT Industri Kereta Api,” *JUSTER: Jurnal Sains dan Terapan*, vol. 1, no. 2, pp. 1–6, 2022.

[15] F. Nurrisa, D. Hermina, and Norlaila, “Pendekatan Kualitatif dalam Penelitian: Strategi, Tahapan, dan Analisis Data,” *Jurnal Teknologi Pendidikan Dan Pembelajaran (JTPP)*, vol. 2, no. 3, pp. 793–800, 2025.