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Analysis of Porosity and Undercut Defects in Structural Steel Grade S355JR Fabrication

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Abstract: *This study aimed to identify the dominant causes of porosity and undercut defects and evaluate the effectiveness of welding defect control measures applied during the fabrication of S355JR Structural Steel in an E-house project at PT.X Batam. A descriptive qualitative approach supported by quantitative data was employed through field observations, semi-structured interviews, documentation, and Pareto and fishbone analyses. The results indicated that welding defects were predominantly caused by welding method (10 joints; 34.5%), followed by environmental factors (7 joints; 24.1%), machine conditions (5 joints; 17.2%), material conditions (4 joints; 13.8%), and welder skill (3 joints; 10.3%). The findings showed that improper welding parameters, unstable shielding gas due to wind exposure, inadequate equipment condition, contaminated material surfaces, and inconsistent implementation of the Welding Procedure Specification (WPS) were the principal contributors to defect occurrence. Corrective measures, including material surface cleaning, dry electrode usage, rod oven storage, welding parameter control, and welding habitat protection, effectively reduced the occurrence of porosity and undercut defects. The novelty of this study lies in the integrated evaluation of technical and operational factors affecting welding quality under actual EPC fabrication conditions. The findings provide practical guidance for improving welding quality control and reducing production losses in structural steel fabrication.*

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INTRODUCTION

S355JR Structural Steel is a structural carbon steel widely used in construction and fabrication industries because of its high strength, excellent weldability, and good formability. Owing to these characteristics, the material is extensively applied in bridges, industrial platforms, offshore structures, and E-house fabrication projects. Despite its favorable welding characteristics, welded joints in S355JR steel remain susceptible to various welding defects that may reduce mechanical performance, structural integrity, and service life. Among these defects, porosity and undercut are the most frequently encountered because they directly affect weld strength and may initiate crack propagation under cyclic loading (Almeida et al., 2022; Dzioba & Lipiec, 2019; Huang et al., 2022; Rahmatia et al., 2025).

The increasing demand for large-scale infrastructure and industrial facilities has intensified the need for high-quality welding in the Engineering, Procurement, and Construction (EPC) industry. Since welded joints serve as the primary load-transferring components in fabricated steel structures, maintaining weld quality has become an essential requirement to ensure safety, reliability, and compliance with international fabrication standards. Consequently, identifying the causes of welding defects and implementing effective control measures are important aspects of quality assurance throughout the fabrication process (Barnaby boby et al., 2022; Dewi et al., 2017; indriani, 2025; Pérez-Ruiz & Serrano-Guzmán, 2020; Sholikhah et al., 2024; Triemiaty, Maarif, et al., 2019).

Porosity and undercut are among the most critical welding defects encountered in structural steel fabrication. Porosity is caused by gas entrapment during weld metal solidification, producing

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internal cavities that reduce weld density and fatigue resistance. Undercut is characterized by a groove formed along the weld toe due to excessive melting of the base metal without sufficient filler metal deposition, resulting in stress concentration and reduced load-carrying capacity. Previous studies have identified several contributing factors, including improper welding parameters, unsuitable electrode selection, contaminated material surfaces, inadequate welder skills, and unfavorable environmental conditions (Adnyana, 2022; Govinda & Aziz, 2019; Irawan et al., 2024; Sutanto et al., 2025; Wari et al., 2020). These findings indicate that welding defects are influenced by multiple interrelated factors rather than a single technical variable.

Several previous studies have investigated welding defects by emphasizing individual technical variables such as welding current, voltage, travel speed, shielding gas flow rate, and electrode type (Aditya et al., 2021; Assagaf et al., 2025; Hussin & Lah, 2020; saputra, Setiawan, et al., 2025; Sasongko et al., 2025). other studies have evaluated the influence of material properties or welding procedures under controlled laboratory conditions. although these studies provide valuable knowledge regarding defect formation mechanisms, their findings are difficult to generalize to actual fabrication projects because industrial environments involve additional operational complexities such as fluctuating weather conditions, production schedules, material handling, equipment maintenance, and variations in welder performance. As a result, limited studies have comprehensively analyzed the interaction between technical and non-technical factors affecting welding defects under real EPC fabrication conditions.

Field observations conducted during the fabrication of an E-house project at PT.X Batam revealed recurring porosity and undercut defects in welded joints of S355JR Structural Steel. Preliminary investigations indicated that these defects were associated not only with improper welding parameters but also with unstable shielding gas flow, contaminated material surfaces, inconsistent electrode handling, and environmental exposure such as wind during outdoor fabrication. These observations demonstrate that welding quality is influenced by a combination of technical practices and workplace conditions that are often overlooked in laboratory-based investigations.

The novelty of this research lies in its comprehensive evaluation of welding defects under actual industrial fabrication conditions by integrating technical factors, including welding parameters, material condition, and electrode handling, with non-technical factors such as environmental conditions and workplace operational practices. Unlike previous studies that primarily focused on isolated technical variables or laboratory experiments, this study investigates the interaction of these factors in a real EPC fabrication project. Furthermore, Pareto analysis and fishbone diagram analysis are employed to identify the dominant causes of welding defects and support the development of practical quality control strategies for industrial applications.

Therefore, this study aims to analyze the causes of porosity and undercut defects in S355JR Structural Steel during the fabrication process of an E-house project at PT.X Batam and to evaluate the effectiveness of the defect control measures implemented. The findings are expected to provide practical recommendations for improving welding quality management, reducing defect occurrence, and enhancing the reliability of welded structures in EPC fabrication projects.

RESEARCH METHOD

This study employed a descriptive qualitative approach supported by quantitative data using a simple mixed-method approach. The study aimed to analyze the causes of welding defects in the form of porosity and undercut, as well as the control efforts implemented during the fabrication process of S355JR Structural Steel. This approach was selected because it enabled comprehensive analysis of actual field conditions while quantitative data were used to strengthen qualitative findings and determine the priority of defect causes.

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The research was conducted over a three-month period, from February to April 2026, at PT.X Batam, a company operating in the Engineering, Procurement, and Construction (EPC) sector, particularly in E-house fabrication projects. A case study design was adopted because it allowed an in-depth investigation of welding defect phenomena occurring in an actual industrial environment.

The population in this study consisted of all welding activities and welded joints produced during the E-house fabrication process using S355JR Structural Steel at PT.X Batam. The research sample included welded joints exhibiting porosity and undercut defects during the observation period, as well as personnel directly involved in welding activities, including welders, welding inspectors, and QC engineers. A total of 30 respondents participated in this study, consisting of personnel involved in welding production and quality inspection activities.

The sampling technique employed was purposive sampling, whereby samples were intentionally selected based on criteria relevant to the research objectives. These criteria included welded joints identified as having welding defects and respondents who possessed direct experience in welding, inspection, and welding quality control.

The data sources consisted of primary and secondary data. Primary data were collected through direct field observations, semi-structured interviews, and welding inspection documentation. Secondary data were obtained from company documents, including Welding Procedure Specifications (WPS), inspection reports, Welder Qualification Test (WQT) records, and relevant literature concerning welding defects and welding quality control.

Data collection techniques were conducted through the following methods:

1. Direct observation to identify welding process conditions and potential causes of defects.
2. Semi-structured interviews with welders, welding inspectors, and QC engineers to obtain in-depth information regarding welding defects and control measures.
3. Documentation studies to analyze historical welding defect data and inspection records.

The research instruments included observation sheets, interview guidelines, welding inspection checklists, and documentation forms.

The welding inspection process referred to the company's Welding Procedure Specification (WPS) and applicable welding inspection standards implemented by PT.X during fabrication activities. Visual inspection was performed to identify surface defects such as porosity and undercut on welded joints. The observed welding parameters included welding current, voltage, welding speed, shielding gas flow rate, electrode condition, material surface cleanliness, and environmental conditions during welding. The variables analyzed in this study were the frequency of porosity and undercut defects together with their contributing factors.

The qualitative and quantitative data were integrated during the analysis stage. Qualitative findings obtained from observations and interviews were used to identify the root causes of welding defects, while quantitative data in the form of defect frequencies were analyzed to determine the dominant causes and prioritize corrective actions. This integration enabled a more comprehensive understanding of welding defect phenomena under actual industrial conditions.

Data analysis was conducted using interactive qualitative analysis consisting of three stages:

1. Data reduction, by simplifying and classifying data based on defect types and causal factors.
2. Data presentation, using tables, Pareto diagrams, and fishbone diagrams to facilitate interpretation of dominant defect causes.
3. Conclusion drawing, by identifying the dominant factors causing welding defects and determining appropriate corrective actions.

Fishbone analysis was selected because it systematically identifies the root causes of welding defects from multiple perspectives, including material, method, machine, manpower, and environmental factors. Meanwhile, Pareto analysis was employed to prioritize the most significant

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defect causes based on the Pareto Principle (80/20), enabling improvement efforts to focus on factors contributing the greatest proportion of welding defects.

To ensure data validity, source triangulation and method triangulation were applied by comparing the results of observations, interviews, and documentation studies. Data reliability was strengthened by referring to company standard procedures, including Welding Procedure Specifications (WPS) and Welder Qualification Test (WQT) records.

The use of a qualitative approach supported by quantitative data enabled this study to examine the interaction between technical and non-technical factors influencing welding quality under actual industrial conditions. Consequently, the findings are expected to provide both theoretical contributions to welding defect studies and practical recommendations for improving welding quality control in EPC fabrication projects.

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LIST OF QUALIFIED WELDER & WELDING OPERATOR (STRUCTURAL WELDER)

Update: 7-Oct-24

NO	WELDER/WELDING OPERATOR		CODE/ SPEC	WELDING				TEST MATERIAL					RANGE QUALIFIED							
	NAME	STAMP		PROCESS	POS	CONSUMABLE (SFA/AWS Class)	F No.	MATERIAL SPEC	P or S No./ Group	PLATE THK	PIPE DIA	PIPE SCH	Position	THICKNESS MIN	THICKNESS MAX	DIAMETER MIN	DIAMETER MAX	MATERIAL GROUP NO.	FILLER (F No.)	BACKING
268	YOSEP BENYAMIN	B3240	AWS D1.1	SMAW/ FCAW-GS	6G	SFA5.1- A5.20 (E7016,E7018, E71T-1C)	F4 (SMAW)	API 5L XS2	Group II	-	NPS 8	SCH 80	All (Except TKY joint)	5 mm	Unlimited	≥4"	Unlimited	All	F1-F3 with backing, F4 with/without backing	SMAW: with or without backing. FCAW: with backing/ back welding
269	ACHMAD CHOIRUDIN	B3292	AWS D1.1	FCAW-GS	3G & 4G	SFA5.20 (E71T-1C)	N/A	A36	Group II	25mm	-	-	All (Except TKY joint)	3 mm	Unlimited	≥24"	Unlimited	All	N/A	with backing/ back welding
270	CHANDRA HAIDIR	B3211	AWS D1.1	FCAW-GS	3G & 4G	SFA5.20 (E71T-1C)	N/A	A36	Group II	25mm	-	-	All (Except TKY joint)	3 mm	Unlimited	≥24"	Unlimited	All	N/A	with backing/ back welding
271	SAPARIN SIREGAR	B2364	AWS D1.1	FCAW-GS	3G & 4G	SFA5.20 (E71T-1C)	N/A	EH36	Group II	25mm	-	-	All (Except TKY joint)	3 mm	Unlimited	≥24"	Unlimited	All	N/A	with backing/ back welding
272	ROHAIZAT	B2333	AWS D1.1	FCAW-GS	3G & 4G	SFA5.20 (E71T-1C)	N/A	EH36	Group II	25mm	-	-	All (Except TKY joint)	3 mm	Unlimited	≥24"	Unlimited	All	N/A	with backing/ back welding

Figure 1. Welder Qualification Test (WQT)

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LIST OF pWPS for STRUCTURAL welding - PART 1
FOR SAIPEM H&G IES PROJECT

Rev.No : 2
Date: 31-Oct-24

No.	WPS No.	PQR No.	CODE / STD	STRUCTURAL TYPE	PROCEDURE QUALIFICATION TEST MATRIX										QUALIFIED RANGE				
					WELDING				BASE METAL				BACKING/ GOUGING	CVN					
					WELD PROCESS	FILLER METAL (SFA /Class)	BRAND	WELD POSITION	BEVEL TYPE	MATERIAL GRADE	DIA-Sch	THK/WT (mm)			WELD PROCESS	WELD POSITION	MATERIAL GRADE	DIAMETER	BASE METAL THICKNESS (mm)
10	pWPS-W-483	PQR-W-483	AWS D1.1	Primary & Secondary	FCAW-G	A5.20 E71T-1C	KOBE DW-100	6G	Butt Joint Single Vee	S275J0 vs S275JR	250mm OD (Rolled Plate)	5.9mm (machined from 12mm)	Yes	Yes @ 20°C	FCAW-G	ALL, except (T-K-Y)	S275J0 vs S275JR	≥ 250mm OD	3mm to 11.8mm (with or without CVN)
11	pWPS-W-484	PQR-W-484	AWS D1.1	Secondary	FCAW-G	A5.20 E71T-1C	KOBE DW-100	6G	Butt Joint Single Vee	275J0 vs S275J0	250mm OD (Rolled Plate)	5.9mm (machined from 12mm)	Yes	Yes @ 20°C	FCAW-G	ALL, except (T-K-Y)	275J0 vs S275J0	≥ 250mm OD	3mm to 11.8mm (with or without CVN)

WPS MATRIX

No	Material 1	Material 2	PRODUCTION RANGE (mm)			
			THK MIN	THK MAX	DIAM MIN	DIAM MAX
1	S355JR	S355JR	5.3mm	33mm	beam	
2	S355JR	S275JR	5mm	8mm	Plate, beam, channel	
3	S275JR	S275JR	5mm	8mm	Plate, channel	
4	S355JR	SS316L	5mm	10mm	Fillet only for earthing boss	
5	S275JR	STUD WELD	5mm	8mm	For hanging the Rockwall	
6	S275J0	S355JR	5mm	10mm	Plate, channel	

	Prepared By:	checked By
SIGN		
NAME	ATAMIK B	RUDI PUTERA
DATE	31-Oct-24	31-Oct-24

Figure 2. Welder Procedure Specification (WPS)

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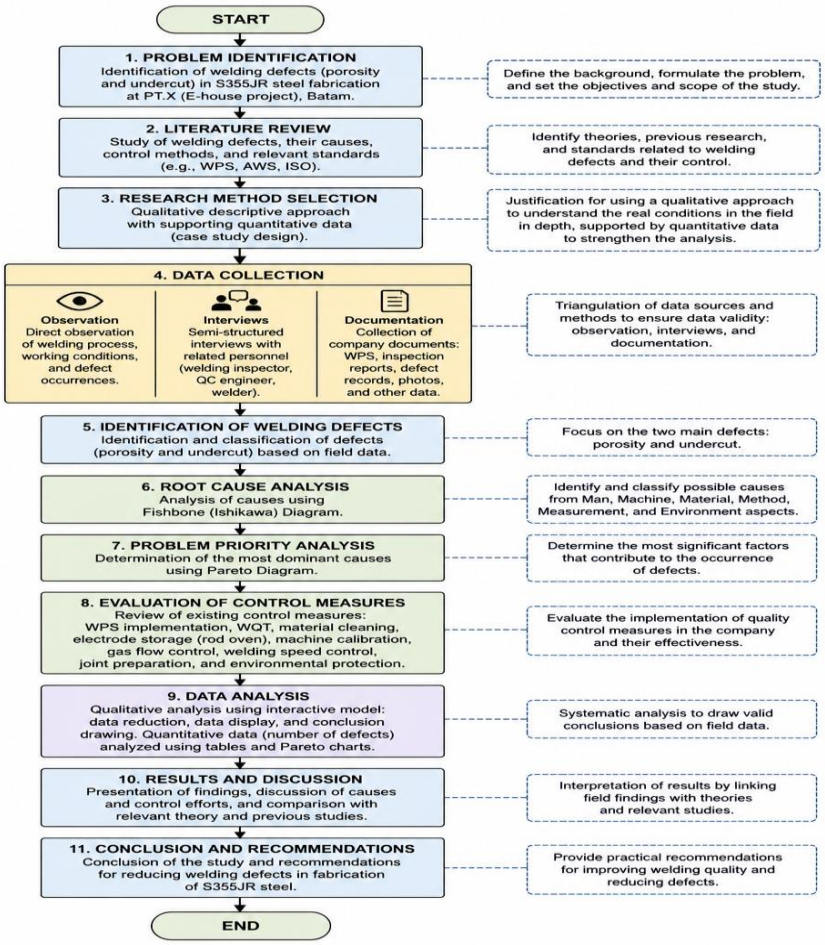

Figure 3. Research methodology flowchart

RESULTS AND DISCUSSION

Identification results of welding defects

Inspection results obtained during the E-house fabrication process at PT.X identified several welding discontinuities on S355JR Structural Steel. Based on visual inspection and quality control records, the two most dominant defects were porosity and undercut, representing the highest frequency among all observed welding defects. Porosity appeared as small cavities caused by entrapped gases within the weld metal, while undercut was observed as grooves along the weld toe that reduced the effective thickness of the base material.

The occurrence of these defects indicates that welding quality was influenced more by operational practices than by the inherent characteristics of S355JR Structural Steel. Although S355JR possesses good weldability according to EN 10025, its relatively higher yield strength and carbon equivalent compared with ordinary low-carbon steel require stricter control of welding parameters. Inadequate heat input, unstable shielding gas protection, and poor surface preparation were frequently observed during field inspections and were associated with defect formation

These findings suggest that compliance with the Welding Procedure Specification (WPS) is essential to maintain weld integrity during fabrication.

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Figure 4. Defect weld porosity

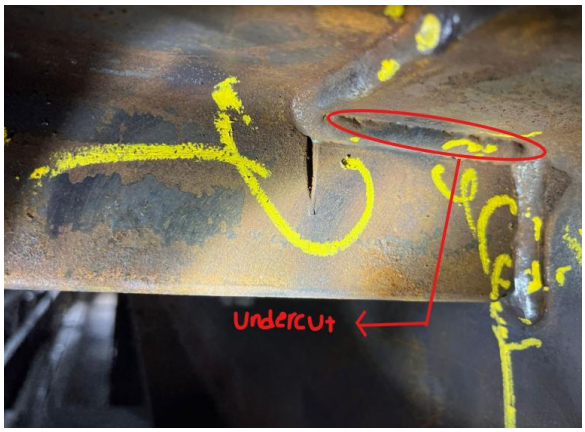

Figure 5. Defect weld undercut

Analysis of defect causes

The Fishbone (Ishikawa) analysis classified the causes of porosity and undercut defects into five major categories: material, method, machine, environment, and manpower:

- Material factor
  Field observations showed that contaminated joint surfaces containing rust, oil, paint, and moisture contributed significantly to porosity formation by preventing proper fusion and promoting gas entrapment. Moisture on electrodes or base metal surfaces also increased the possibility of hydrogen contamination during welding. these findings are consistent with previous studies reporting that inadequate surface preparation is one of the primary contributors to porosity in carbon steel welding because contaminants interfere with shielding gas protection and molten metal solidification.

- Method factor
  Method-related factors represented one of the dominant causes of welding defects. Excessive welding current (amperage), welding speeds exceeding WPS recommendations, unstable arc length, improper electrode angle, and inconsistent weaving techniques frequently resulted in undercut and excessive spatter. In several observations, welders also deviated from the prescribed WPS parameters during production activities. the results indicate that parameter control has a direct influence on weld bead geometry. Excessive heat input increased melting along the weld toe without allowing sufficient filler deposition, thereby producing undercut defects.

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- Machine factor
  Several welding machines were found to have unstable current and voltage outputs because calibration had not been performed according to schedule. This instability reduced arc consistency and affected heat input distribution, increasing the probability of weld discontinuities. Although machine-related factors were not the dominant cause, they contributed to inconsistent welding quality when combined with inappropriate welding parameters.

- Environment factor
  Environmental conditions were identified as one of the most influential external factors. Most fabrication activities were conducted in open working areas where wind disrupted shielding gas coverage and allowed atmospheric gases to contaminate the weld pool, thereby increasing porosity occurrence. unlike laboratory studies conducted under controlled environments, actual fabrication conditions expose welding operations to continuously changing environmental variables. This finding highlights the importance of environmental protection during industrial welding operations.

- Manpower factor
  Welder competency significantly affected welding quality. Defects were more frequently observed during vertical and overhead welding positions because these positions required greater skill in controlling molten metal against gravity. Field observations also revealed that work pressure, physical fatigue, and inconsistent compliance with supervisory instructions reduced concentration during welding. interestingly, several experienced welders tended to rely on personal experience rather than strictly following WPS requirements. This finding indicates that practical experience alone cannot guarantee consistent welding quality without procedural compliance.

Problem priority analysis

The Pareto analysis demonstrated that only a limited number of factors contributed to the majority of welding defects. The highest contributions originated from welding parameters that did not comply with WPS requirements, contaminated material surfaces, and improper welding techniques.

These results indicate that corrective actions should primarily focus on improving parameter control, strengthening material preparation procedures, and increasing welder compliance with established welding standards. Concentrating improvement efforts on these dominant factors is expected to significantly reduce the occurrence of porosity and undercut defects

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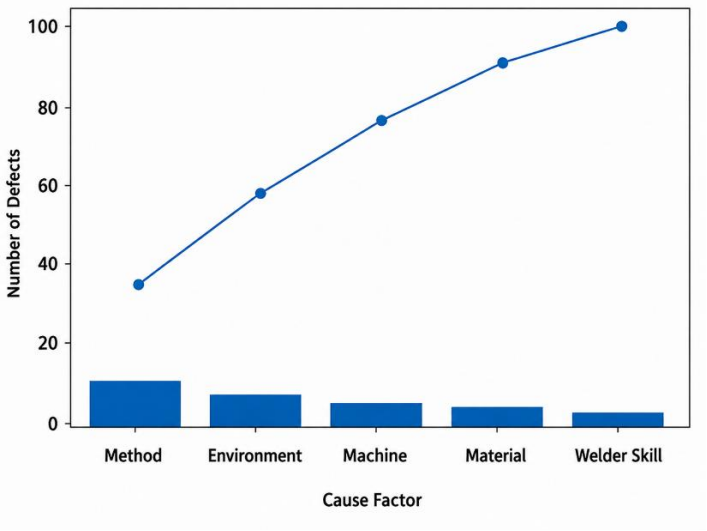

Figure 6. Pareto diagram analysis

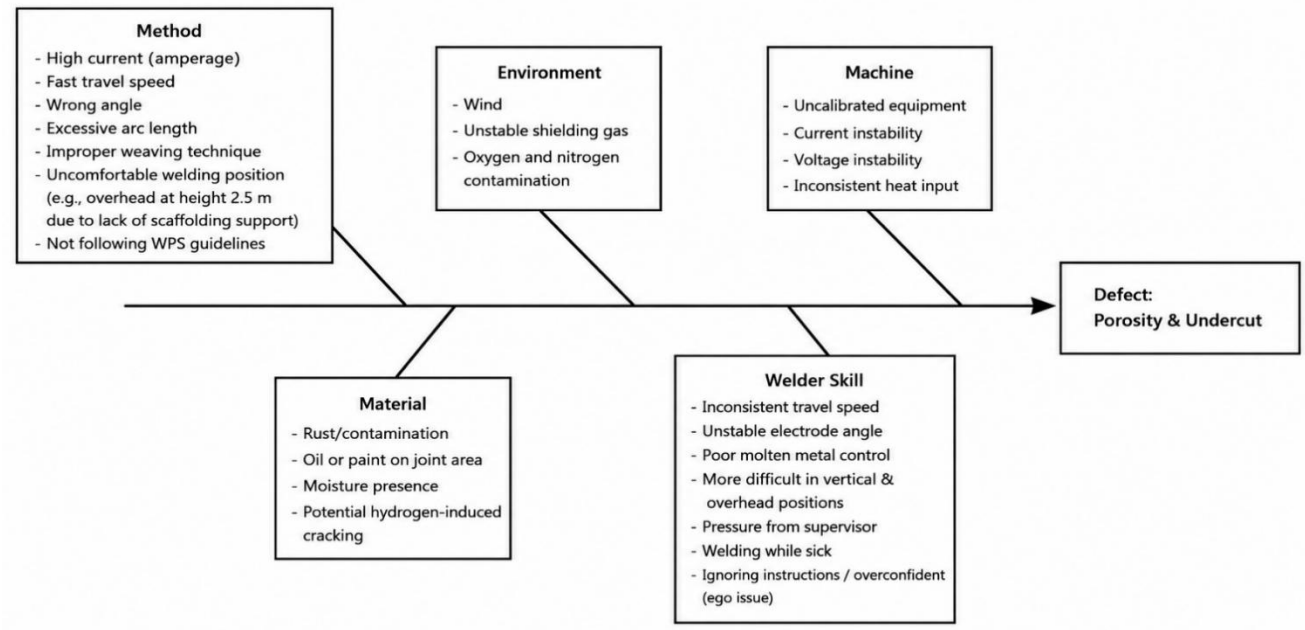

Figure 7. Fishbone diagram analysis

Evaluation of control efforts

Based on the identified root causes, PT.X implemented several corrective and preventive measures to improve welding quality. Technical improvements included cleaning joint surfaces until bright metal conditions were achieved, using properly dried E7018 electrodes, storing electrodes in rod ovens at 250–350°C, applying welding habitats in outdoor working areas, adjusting welding current according to WPS requirements, controlling travel speed, maintaining proper electrode angle, and performing preheating at a minimum temperature of 65°C to minimize moisture.

In addition to technical improvements, organizational measures were also introduced. These included refresher training for welders, performance-based reward programs, coordination with the

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scaffolding team to improve working access, motivational briefings before work, and encouraging supervisors to apply constructive communication during quality control activities.

The combination of technical and organizational controls reflects a comprehensive approach to welding quality management because defect occurrence is influenced by both engineering and human factors.

Figure 8. Control interpass weld

Figure 9. Control ampare

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Figure 10. Control voltage

Discussion

The present study demonstrates that porosity and undercut defects are generated through interactions among material, welding method, equipment condition, environmental exposure, and human performance rather than by a single isolated factor. Among these variables, welding parameter deviations and inadequate procedural compliance were identified as the most influential contributors.

These findings agree with previous welding studies that identify inappropriate heat input, contaminated base metal, unstable shielding gas protection, and welder competency as the principal causes of porosity and undercut in structural steel fabrication. However, this study extends previous research by demonstrating that organizational factors—including work pressure, supervisor communication, and inadequate working access—also indirectly influence welding quality by affecting welder performance in actual EPC fabrication environments.

Another important finding is the significant contribution of environmental conditions. Wind exposure in open fabrication areas reduced shielding gas effectiveness and increased porosity formation. This observation emphasizes that welding quality obtained under industrial production conditions may differ considerably from laboratory-scale investigations where environmental variables are carefully controlled.

From an industrial perspective, welding defects have consequences beyond technical quality. Repair welding increases production costs, material consumption, labor hours, and project duration while reducing fabrication productivity. More importantly, defects that remain undetected may compromise structural integrity, increase safety risks, reduce client confidence, and potentially affect the company's compliance with contractual and quality certification requirements.

Therefore, improving welding quality requires an integrated quality management approach involving strict WPS implementation, preventive equipment maintenance, proper material handling, environmental protection during welding, and continuous competency development for welders. These integrated control measures provide practical guidance for reducing porosity and undercut defects in S355JR Structural Steel fabrication within EPC industries.

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CONCLUSION

This study investigated the causes of porosity and undercut defects during the fabrication of S355JR Structural Steel in an EPC company using field observations, interviews, documentation, Fishbone analysis, and Pareto analysis. The inspection results showed that porosity and undercut were the most frequently identified welding defects, indicating that these discontinuities remain critical quality issues during fabrication.

The results demonstrated that welding defects were not caused by the characteristics of S355JR Structural Steel alone but by the interaction of five main factors: material, method, machine, environment, and manpower. Pareto analysis further identified that deviations from the Welding Procedure Specification (WPS), contaminated joint surfaces, and inadequate welding techniques were the dominant contributors to defect occurrence. These findings indicate that welding quality depends primarily on consistent process control rather than on the weldability of the material itself.

The implementation of corrective and preventive actions—including proper material surface preparation, the use of dry electrodes stored in rod ovens, compliance with WPS parameters, welding habitat protection in open working areas, equipment maintenance, and continuous welder competency development—provides an effective strategy for minimizing porosity and undercut defects during fabrication.

This study contributes to the existing literature by demonstrating that, in actual EPC fabrication environments, organizational and environmental conditions such as work pressure, accessibility of the welding area, and wind exposure can significantly influence welding quality in addition to conventional technical factors. These findings provide practical guidance for fabrication companies seeking to improve welding quality, reduce repair and rework costs, enhance productivity, maintain structural reliability, and strengthen client confidence through more effective welding quality management.

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REFERENCES

Aditya, Z., Hidayat, T., & Yuwita, P. E. (2021). Studi pengaruh gas flow rate terhadap kekuatan tarik, kekerasan dan cacat pada pengelasan MAG baja ASTM A 53. *Media Bina Ilmiah*, *16*(5), 6835–6844.

Adnyana, D. N. (2022). Fatigue failure in a longitudinal welded elbow of a processing vessel. *Metalurgi*, *36*(3), 93–100. https://doi.org/10.14203/metalurgi.v36i3.609

Almeida, E., Pedro, P., Martins, P., & Silva, C. (2022). Evaluation of different types of steel under high loading rates for short circuit applications. *Journal of Energy - Energija*, *63*(1–4), 82–94. https://doi.org/10.37798/2014631-4166

Assagaf, I. P. A., Ariyanto, A., Prasetyo, A. B., & Fitrah, M. A. (2025). Analisis cacat las SMAW dengan elektroda berbeda posisi 2G pada baja ST 37 metode FTA. *IRA Jurnal Teknik Mesin dan Aplikasinya (IRAJTMA)*, *4*(3), 143–152. https://doi.org/10.56862/irajtma.v4i3.334

Copyright © 2026, the author(s). This is an open access article under the CC-BY-SA License.

Barnaby, M. B., Poernomo, I., & Sahadi, S. (2022). Analisis faktor risiko yang mempengaruhi kesuksesan proyek di Indonesia dengan metode structural equation modeling (SEM). *Rancang Bangun Teknik Sipil*, *8*(2), 57–72.

Dewi, D., & Lumbanraja, S. M. (2017). Rantai pasok industri baja untuk pembangunan PLTN di Indonesia. *Jurnal Pengembangan Energi Nuklir*, *19*(1), 51–60.

Dzioba, I., & Lipiec, S. (2019). Evolution of the mechanical fields and fracture process of S355JR steel. *Procedia Structural Integrity*, *16*, 97–104. https://doi.org/10.1016/j.prostr.2019.07.027

Gómez, E. R., Buitrago, J. V., Ruiz, D. D. P., & Guzmán, M. F. S. (2019). Identification of risks in contract of building construction. *Dimensión Empresarial*, *17*(1), 45–58.

Govinda, K., & Aziz, A. (2019). Effect of cutting speed, feed-rate and depth of cut on the surface roughness level of ST-37 steel in shaping process. *Teknomekanik*, *2*(1), 1–6. https://doi.org/10.24036/tm.v2i2.2372

Huang, B., Fang, Z., Yang, J., Zheng, J., & Wang, S. (2022). Numerical simulation of S355JR-316L dissimilar metal welding. *Welding in the World*, *66*(2), 287–299. https://doi.org/10.1007/s40194-021-01200-5

Hussin, M. H., & Lah, N. A. C. (2020). Weld bead surface defects formation and its implications: A review. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, *72*, 41–55. https://doi.org/10.37934/ARFMTS.72.2.4155

Indriani, S. N., & Wirdianto, A. (2025). Analisis variance pada penerapan lean construction terhadap waktu produksi proyek EPC. *Jejak Digital: Jurnal Ilmiah Multidisiplin*, *1*(5), 3095–3113.

Irawan, A., Finali, A., Prasetya, I. G. N. A. S., Yudha, D., Umar, M. L., & Utomo, R. E. P. (2024). Analisa cacat hasil pengelasan SMAW pada baja karbon ST 41 dengan variasi pendingin. *Journal of Scientech Research and Development*, *6*(1), 1440–1452.

Rahmatia, Mawarani, L. J., & Apriandi, R. (2025). Numerical study on the material strength of a microcar chassis under static and dynamic loads. *Scientific Journal of Mechanical Engineering Kinematika*, *10*(2), 228–241. https://doi.org/10.20527/sjmekinematika.v10i2.757

Saputra, J. S. D., Samhuddin, S., Aminur, A., & Setiawan, R. (2025). Analisa pengaruh media pendingin air dan air garam terhadap sifat mekanis sambungan lap joint menggunakan las SMAW baja karbon rendah. *Enthalpy: Jurnal Ilmiah Mahasiswa Teknik Mesin*, *10*(4), 278–308.

Sasongko, K. E., Kurniyanto, H. B., & Wibowo, A. T. (2025). Analisis multiple repair pada pengelasan material HARDOX 400 menggunakan proses FCAW terhadap sifat mekanik dan struktur mikro. *Jurnal Teknik Mesin*, *22*(2), 51–66. https://doi.org/10.9744/jtm.22.2.51-66

Sholikhah, M., Ridwan, R., Prabowo, A. R., Ghanbari-Ghazijahani, T., Yaningsih, I., Muhayat, N., Tjahjana, D. D. D. P., Adiputra, R., & Sohn, J. M. (2024). Strength assessment of stiffened-panel structures against buckling loads: FE benchmarking and analysis. *Civil Engineering Journal*, *10*(4), 1034–1050. https://doi.org/10.28991/CEJ-2024-010-04-03

Sutanto, J., Iswanto, I., Sumirat, I., Pramutadi Andi Mustari, A., & Permana, S. (2025). Development of standard test specimens for competency improvement of non-destructive test (NDT) personnel—Industrial radiography. *JMPM (Jurnal Material dan Proses Manufaktur)*, *9*(2), 116–124. https://doi.org/10.18196/jmpm.v9i2.26290

Triemiaty, T., Maarif, M. S., Affandi, M. J., & Pawenary, P. (2019). Strategi peningkatan kinerja karyawan. *Benefit: Jurnal Manajemen dan Bisnis*, *4*(1), 54–68.

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Wari, A., Nurdin, H., & Ya, K. Z. (2020). Porosity defect analysis in ST 37 steel welding joints using the dye penetrant method. *Teknomekanik*, *3*(1), 1–8. https://doi.org/10.24036/tm.v3i1.5272

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