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# Visual Inspection of Welding Joints: Analysis of the Causes of Welding Defects and Solutions for Repair

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**Abstract**

The development of technology in the increasingly advanced construction sector cannot be separated from welding, because it has an important role in metal engineering and repair.. There are several factors that affect the quality of welding results, including welding procedures, materials, electrodes, and types of welds used. Inspection of welding results can be done in several ways, one of which is by visual inspection. The TWI Acceptance Criteria standard is used as a reference in determining the quality of welding results in this study. The results of the study showed that four out of five welding defects did not pass the test. This indicates the importance of mastering welding techniques and quality control in the production process. A welder must have competencies that are in accordance with the specifications of his work. Routine inspections and the use of reference standards such as the TWI Acceptance Criteria should be applied to ensure the quality of welding results, both on an educational, training, and industrial scale.

**Keywords**: *Inspection; Visual; Welding; Defect*

***Abstrak***

*Perkembangan teknologi di bidang konstruksi yang semakin maju tidak lepas dari pengelasan, karena memiliki peranan penting dalam rekayasa dan perbaikan logam. Ada beberapa faktor yang mempengaruhi kualitas hasil pengelasan, antara lain prosedur pengelasan, material, elektroda, dan jenis las yang digunakan. Pemeriksaan hasil pengelasan dapat dilakukan dengan beberapa cara, salah satunya dengan inspeksi visual. Standar TWI Acceptance Criteria digunakan sebagai acuan dalam menentukan kualitas hasil pengelasan pada penelitian ini. Hasil penelitian menunjukkan bahwa empat dari lima cacat las tidak lolos uji. Hal ini menunjukkan pentingnya penguasaan teknik pengelasan dan pengendalian kualitas dalam proses produksi. Seorang welder harus memiliki kompetensi yang sesuai dengan spesifikasi pekerjaannya. Inspeksi rutin dan penggunaan standar acuan seperti TWI Acceptance Criteria harus diterapkan untuk menjamin kualitas hasil pengelasan, baik dalam skala pendidikan, pelatihan, maupun industri.*

***Kata kunci***: *Inspeksi; Visual; Pengelasan; Cacat*

## 1. Introduction

The development of increasingly advanced technology in the construction sector cannot be separated from welding, because it has an important role in metal engineering and repair **[1].** In addition, the welding process also has an important role in the manufacturing sector, such as machine manufacturing, shipbuilding, water maintenance, aerospace, offshore drilling, electronic technology, and other fields **[2].** Human resources must be balanced with the knowledge of currently developing technology in the field of welding **[3].** A worker in the welding field (welder) must have standard industrial work competencies, considering the high risk of accidents, he must meet the minimum requirements that must be met as a welder **[4].**

There are several factors that influence the quality of welding results, including the welding procedure, materials, electrodes and type of weld used[4]. Welding results inspection can be done through two methods, one of which is the Non Destructive Testing (NDT) method. The NDT method is an inspection of an object to find out if there are defects, cracks, or other discontinuities without damaging the object we are testing or inspecting **[5].** NDT methods include visual inspection, magnetic particle testing, ultrasonic, radiography, and liquid penetration. Research in the field of welding testing is very important. The quality of welding results is a very important aspect to ensure safety, considering that the application of this joining technique is most widely used in the construction and manufacturing sectors. Visual inspection is the most common inspection technique used in manufacturing, including welding technology. Almost any specimen can be visually inspected to check for manufacturing accuracy. Visual inspection is usually used as a first step to ensure that the part is manufactured to specified work standards **[6].**

Politeknik Negeri Subang as one of 43 state polytechnics in Indonesia, as well as the only first state university in Subang Regency, has a strategic role in national development by producing graduates who are ready to work in various fields of expertise, one of which is in the field of welding technology. This study aims to identify problems that occur in welding practicum specimens/workpieces and their repairs based on the problems found using non-destructive testing methods, namely visual inspection of welding joints. Welding results do not always meet the expected standards, so various aspects must be considered carefully. A welder must master the welding procedure well in order to minimize the risk of defects in the welding results.

## 2. Method

### 2.1. Time and Place of Reaserch

he research was conducted at the Material Testing Laboratory, Department of Mechanical Engineering, Politeknik Negeri Subang. Starting from the data collection stage, testing welding results, to compiling analysis reports. The welding process itself was carried out at the Fabrication Laboratory, Department of Mechanical Engineering, Politeknik Negeri Subang. The specimens tested were the results of student competency tests in the Welding Work Practice course.

### 2.2. Research Tools and Materials

Preparation of tools and materials used to conduct this research can be seen in **Table 1**.

**Table 1.** Research Tools and Materials

| No | Name | | Specification | Note |
|---|---|---|---|---|
| 1. | Tools | | | |
| | a. | Welding gauge | Standart | - |
| | b. | specimen las | Plat butt joint / grove | Metal / carbon steel medium |
| | d. | PPE visual test | Standart | Mask, glove, safety glass |
| | e. | Testing tools | Standart | brush, flashlight, rag, etc |
| | f. | Ruler | Min 30 mm | - |
| 2. | Material | | | |
| | a. | WPS | WPS grove | - |
| | b. | Welder certificate | SMAW Plat 3G | - |
| | c. | Acceptence citeria | TWI standart | - |
| | d. | SOP and IK | Visual test | - |

### 2.3. Welding Process

The term welding according to DIN (Deutsche Industrie Norman) is a metallurgical bond at the joint of metal or alloy metals carried out in a melted or liquid state. In other words, welding can be interpreted as the process of joining two metals to the point of metal recrystallization, with or without the use of additional materials and using heat energy as a melter for the welded material. The use of additional materials or electrodes in the welding process can increase the strength of the weld joint as desired. The strength of the weld joint can be influenced by several factors, including the welding procedure, materials, electrodes and the type of weld used [4].

The welding carried out in this study uses the SMAW (Shield Metal Arc Welding) method.

This welding is carried out using electrode wire wrapped in flux. The heat from the arc metal will cause the parent metal and the tip of the electrode to melt and form grains that are carried by the electric current that occurs during the welding process [7].

### 2.4. Testing Process

2.4.1. Visual Inspection

Testing of welding results in this study used the visual inspection method. Visual inspection is a method of testing welding results by observing directly using vision without special tools, so that only the outer part of the weld is checked. There are several important aspects that must be considered, including:

1. The appearance of the weld is generally seen in the weld bead section. If the appearance is not neat or attractive, this can raise doubts about the quality of the weld joint.
2. For single-sided penetration welding, the appearance of the weld result is crucial as a quality indicator.
3. In addition to being able to check defects on the weld surface using liquid or magnetic particle penetration methods, defects can also be observed directly with the eye (visual inspection).
4. Post-welding processes such as slag cleaning, spatter refining and other treatments need to ensure cleanliness through visual observation.

2.4.2. Visual Inspection Stages

Visual inspection is done by observing directly using the eyes, so that only the outer part of the weld joint can be inspected. This method has limitations, namely depending on the sharpness of the inspector's vision. The welding inspection process is generally divided into two stages, namely:

1. Quality Control (QC)

   The purpose of the QC is to assess and control the quality of the welded joint and ensure that the welding process complies with the specified requirements. The QC steps in visual inspection include:

   a. Visual inspection and dimensional measurement to detect any deviations or defects on the weld surface.

b. Determine whether the welding results can be accepted or rejected based on the criteria listed in the reference standard.

c. If necessary, further testing is carried out to detect the presence, size, number and position of internal defects (which are not directly visible).

d. Based on the results, it is decided whether the defect is still within the tolerance limit or must be repaired according to applicable standards.

2. Quality Assurance (QA)

The purpose of the QA is to ensure that the QC is carried out correctly by the implementer. By carrying out the QA, it indirectly provides a guarantee that the QC is in accordance with the established technical specifications.

### 2.5. Health, Safety, and Environment (HSE)

One thing that should not be forgotten after conducting a visual inspection of the welded joints in the laboratory is to ensure that the HSE aspects are carried out correctly. There are several aspects related to HSE in visual inspection, namely:

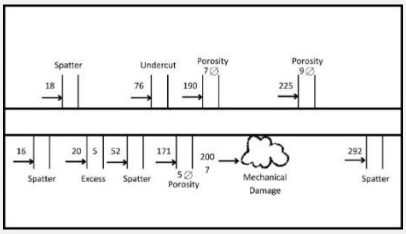
1. Check the condition of the laboratory where the visual inspection is carried out to ensure that there is no dirt or liquid.
2. Wear standard testing PPE during visual inspection.
3. Clean up the tools that have been used after testing and clean the tools properly.

## 3. Results and Discussion

### 3.1. Research Result

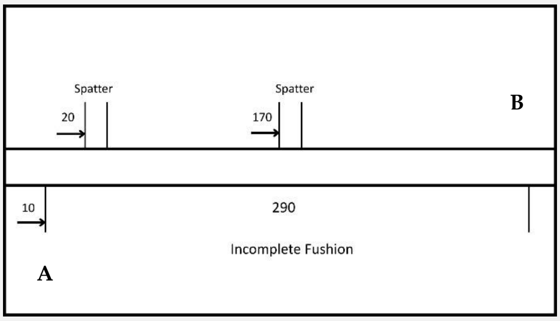
The results of visual inspection of the test specimens can generally be seen in **Table 2.**

**Table 2.** Visual Inspection Results

| No | Visualization | |
|---|---|---|
| | Specimen | Sketch |
| 1 | Weld Face | |
| |  | <br>B |



A

| No | Visualization | |
|---|---|---|
| | Specimen | Sketch |
| | | |
| 2 | Weld Root | |
| |  |  |

Based on the table data above, there are several findings of welding defects from the specimens from the examination results. Welding defects were found both on the weld face and weld root. Welding defects found in the welding results include porosity, spatter, undercut, excess weld metal, mechanical deformation, and incomplete root fusion. The details of the welding defects can be seen in **Table 3**.

**Table 3.** Details of Visual Inspection Results

| No | Defects | Result |
|---|---|---|
| 1 | Porosity | Diameter 5, 7, 9 mm |
| 2 | Undercut | Length 6 mm |
| 3 | Mechanical Damage | Height 7 mm, width 7 mm |
| 4 | Excess Weld Meta | Height max 5 mm |
| 5 | Incomplate Root Fusion | Length 290 mm |

### 3.2. Discussion

The results of the visual inspection of the specimen of the welded object above, there are several welding defects. These welding defects can be caused by several factors, depending on the type of welding defect. Based on the acceptance criteria for plate and pipe welding, of the five types of welding defects found, four of them did not meet the criteria or did not pass the test. While spatter is a welding defect, it is not included in the category required by the acceptance criteria. The comparison of welding results with acceptance criteria is **Table 4.**

**Table 4.** Comparison of Welding Results with Acceptance Criteria

| No | Defects | Result | Acceptance Criteria | Not |
|---|---|---|---|---|
| 1 | *Porosity* | Diameter 5, 7, 9 mm | Individual pores ≤ 1.5 max. Cluster porosity maximum 50²mm total area. Elongated, piping or wormholes 15mm max. L continuous or intermittent. | NG |
| 2 | *Undercut* | Length 6 mm | No sharp indications Smooth blend required. The length of any undercut shall not exceed 50mm continuous or intermittent. Accumulative totals shall not exceed 50mm. Max D = 1mm for the cap weld metal. Root undercut not permitted. | Acceptance |
| 3 | *Mechanical Damage* | Height 7 mm, Widht 7 mm | No stray tack welds permitted Parent material must be smoothly blended General corrosion permitted. Max. D = 1.5mm. Only 1 location allowed | NG |
| 4 | *Excess Weld Meta* | Height max 5 mm | Excess weld metal will not exceed H = 2mm in any area on the parent material, showing smooth transition at weld toes. | NG |
| 5 | *Incomplate Root Fusion* | Length 290 mm | Lack of root fusion, not to exceed 50mm total continuous or accumulative. | NG |

As for the defects that occur in the welding results, they can be caused by several factors. The explanation related to the causes of the welding defects is as follows:

1. Porosity, which are small holes or cavities in the weld seam. Caused by trapped gas during the solidification of the weld metal.
2. Spatter, which are small splashes of molten metal that are thrown during welding and stick to the surface of the weld specimen around the weld bead.
3. Undercut, which is a groove in the parent metal along the edge of the weld. This is caused by too high welding current, too low welding speed, wrong electrode angle, poor welding technique.

4. Excess Weld Metal, which is a defect that occurs when the amount of metal added exceeds the needs or specifications of the joint. This is caused by the welding current being too low, the welding speed being too slow, the electrode size or filler wire being too large.
5. Mechanical Damage, which is a defect that refers to physical damage to the parent metal or weld metal due to external factors other than the welding process. This is caused by impact or friction of the tool.
6. Incomplete Root Fusion, which is a defect that occurs due to the weld metal not merging properly with the parent metal. This is caused by insufficient input heat, dirty or oxidized surfaces, incorrect electrode angles, and poor welding techniques.

Welding improvement efforts can be done starting from the welding process preparation stage until the end of the welding process. There are several solutions to prevent welding defects, including:: use proper welding parameters, prepare the surface properly, pay attention to welding techniques and positions, choose appropriate equipment and materials, and handle and clean with care.

## 4. Conclusion

Based on the results of visual inspection of the welding results, several types of welding defects were found, including:

1. Porosity, Undercut, Spatter, and Excess Weld Metal, caused by inappropriate welding parameters.
2. Mechanical Damage, due to careless handling.
3. Incomplete Fusion, as a result of lack of heat or poor welding technique.

There are a total of five types of welding defects found in the workpiece specimen. Based on the five defects, there are four welding defects that do not meet the TWI Acceptance Criteria. This indicates the importance of mastering welding techniques and quality control in the production process. Errors in parameters and work techniques greatly affect the quality of welding results in the construction and manufacturing fields.

A welder must have the competency that is in accordance with the specifications of his work. A welder's understanding of the TWI Acceptance Criteria is very important to detect welding defects early on. Routine inspections and the use of reference standards such as the TWI

Acceptance Criteria should be implemented to ensure the quality of welding results, both on an educational, training, and industrial scale.

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