Visual inspection on shielded metal arc welding products of Asian welding contestants in Yogyakarta province

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Abstract. This research aims to determine the quality of 3F blunt connection (T-Joint) and 2G shielded metal arc welding (butt joint) of the welding products of the regional selection contestants of ASEAN Skill Contest-Vocational High School (ASC-VHS) in Yogyakarta province. This study was implemented using a discrete approach. The data in this research were collected using a check list for the quality assessment of welding engineering students through a visual inspection and measuring tool for welding gauge. This research was conducted in the fabrication workshop, Department of Mechanical Engineering, Faculty of Engineering, Yogyakarta State University. The population of this study was all contestants of the 2019 ASEAN Skill Contest (ASC) regional selection in welding in the Yogyakarta Special Region. The results of this research show that the quality of the student competencies is still below The Welding Institute (TWI) standard. The aspect that becomes the weakness of contestants in the implementation of the ASC-VHS regional selection for welding includes a lack of understanding and knowledge in determining the welding requirements especially in identifying the welding code, selecting the current Welding, recognizing the type of metal material, recognizing the type of shielded metal arc welding electrodes, and knowing the function of occupational safety and health. Also, welding defects were found in the welding products.

1. Introduction

Welding is the most efficient way of joining metal, so that it plays a key role in the manufacturing and production processes in industry [1]. In general, the shielded metal arc welding (SMAW) process is commonly used in industry because it employs low cost fillers. In addition, SMAW can be more easily performed than other welding techniques [2-3]. However, the welding filler is a determining factor for the microstructure and mechanical properties of the welds.

SMAW is one of the common welding processes used in engineering industries especially in industries dealing with piping and structural applications [4]. SMAW uses the heat produced by an arc created between metal specimen and flux that coated with consumable electrode to weld metals. Slag formed during welding process is required to be removed after weldments is cooled. Electrode arc, tip, weld puddle and heated work piece are shielded from contamination of gas. Gas contamination comes from atmospheric gases produced by electrode combustion and decomposition. Besides, SMAW equipment is inexpensive and the operator only needs a little training. The ability of this type of welding to weld without external gas used causes it is possible to conduct onsite welding of metals where the other methods are not possible [5].
To obtain quality welding connections and meet the standard requirements, we need qualified welding personnel who have welding competency certificates that are recognized by national certification bodies such as National Professional Certification. The qualifications of welding personnel are generally divided into welders or welding operators, inspectors, supervisors, and engineers. Because welding involves the melting, metallurgical, and metal freezing processes, in-depth knowledge is needed to be able to produce quality welded joints and to meet the requirements in terms of visual, strength, and economical aspects. In the SMAW process, welding is an important thing that must be considered in detail because it is very influential on the construction strength of a tool, and not only the strength but also the visuals of the welding products must also meet the standards according to The Welding Institute (TWI) or Welding Procedure Specification (WPS). Graduates’ competencies in accordance with the job requirements are highly expected by educational institutions [6].

Welding profession or a welder plays an important role in the welding process. Almost all industries in doing their projects require a welder, including the process of creating tools using metal. This work is dominated by welding, so the role of a welder is crucial in the progress of the project, cost, and time delivery of a metal work done. If the project is carried out by a welder who is inexperienced or has low capability, the quality of the construction product will be low and cost overruns occur. Vocational secondary education also prioritizes the development of student ability to carry out certain types of work. Two basic things in preparing vocational secondary education graduates are the demands of professional attitude on a particular job and the welding expertise which is very important for a welder involved in the construction of a tool or in an industry using metal as the main material [7]. This study compares the welding products made by the vocational students in Yogyakarta Special Region in the regional selection for the ASEAN Skill Contest (ASC) based on a visual perspective.

2. Methods
In this study, researchers used a descriptive approach. Descriptive research aims to systematically and accurately describe characteristics about the population or a particular field. This study tries to describe a situation or an event. The data generated were descriptive, so it is not intended to provide explanations, test hypotheses, make predictions, or study the implications. This is in line with the Wagiran statement which stated that descriptive research is conducted to describe the facts or events systematically and accurately, regarding the nature of the population. It does not tend to search for or explain the relationship between variables and test hypotheses [8].

This research was conducted at the Fabrication Workshop of the Department of Mechanical Engineering Education, Faculty of Engineering, Yogyakarta State University. The data were collected from the vocational students of the Welding Engineering program in the ASC Regional Selection. The study was conducted on April 22-24, 2019.

The population is defined in a variety of description. According to [9], population is a generalization area consisting of objects or subjects that have certain qualities and characteristics determined by researchers to be studied and then drawn the conclusions. In this study, the population was 10 vocational students as the contestants of the 2019 ASEAN Skill Contest (ASC) Regional Selection in Yogyakarta as who make the welding products.

The data were collected using a check list to assess the quality of the students’ welding products with a visual test and a measuring instrument welding gauge. The welding engineering instrument of the TWI (The Welding Institute) industry standard was used in this study, which can be seen in table 1.
Table 1. The instrument of 3F and 2G position for shielded metal arc welding based on TWI standard

| Defect No. | Type of defect                                  | Allowed max. size | Score if no defect | Defect No. | Type of defect                                  | Allowed max. size | Score if no defect |
|------------|------------------------------------------------|-------------------|--------------------|------------|------------------------------------------------|-------------------|--------------------|
| 1          | Cracks                                         | not allowed       | 10                 | 1          | Cracks                                         | not allowed       | 10                 |
| 2          | Worm holes                                     | 1 mm              | 10                 | 2          | Porosities/worm holes                          | 1 mm              | 10                 |
| 3          | Overlap                                        | accumulative total: 20 mm | 10 | 3          | Overlap                                        | accumulative total: max 20 mm | 10 |
| 4          | Lack of side wall fusion                       | accumulative total: 20 mm | 10 | 4          | Lack of side wall fusion                       | accumulative total: max 20 mm | 10 |
| 5          | Slag inclusion, trapped slag, spatter etc.     | spatter not allowed | 10 | 5          | Lack of root fusion/incomplete root penetration | accumulative total: max 20 mm | 10 |
| 6          | Undercut                                       | trapped slag width 3 mm 10 % from length, with max depth of 1 mm | 10 | 6          | Slag inclusion, trapped slag, spatter etc.      | length 12 mm, width 3 mm total max 15 mm | 10 |
| 7          | Underfill/incompletely filled groove/lack of fill | not allowed       | 10 | 8          | Undercut                                       | 10 % from length, with max depth of 1 mm | 10 |
| 8          | Arc strikes/stray arc                          | scratches due to arc | 10 | 9          | Root concavity                                 | max -1 mm         | 10                 |
| 9          | Mechanical damage                              | not allowed       | 10 | 10         | Underfill/incompletely filled groove/lack of fill | not allowed       | 10                 |
| 10         | Angular misalignment                           | angular misalignment 3° | 10 | 11         | Linear misalignment                            | maximum: p: < 10 mm t: 1 mm; p: < 10 mm t: 1.5 mm | 10 |
| 11         | Star/stop welded joint                         | 1 mm              | 10 | 12         | Arc strikes/stray arc                          | not allowed       | 10                 |
| 12         | Height of reinforcement                        | max. 8 – 10 mm    | 10 | 13         | Mechanical damage                              | depends on the depth and type | 10 |
|            |                                                 |                   | 14 | 14         | Angular misalignment                           | angular misalignment 3° | 10 |
|            |                                                 |                   | 15 | 15         | Height of reinforcement/cover                   | max. 2 mm         | 10                 |
|            |                                                 |                   | 16 | 16         | Height of penetration                           | max. 1.5 mm       | 10                 |

Max. score 120
Max. score 160

3. Results and Discussion
The research findings are data on the results of the Regional Selection of ASC- VHS in Yogyakarta Special Region of welding program which include welding theory assessment sheets, and 3F and 2G
position welding products. In the implementation of the 2019 ASC Vocational High School Regional Selection for the welding program in Yogyakarta, 10 participants came from vocational schools throughout the Yogyakarta Province. The contest consists of theoretical knowledge about SMAW, personal protective equipment of welding, and welding positions. The task is to make a 3F vertical position blunt connection T-joint and the 2G Horizontal connection of V groove butt join.

The standard of TWI is used to assess the welding products of the contestants. It is done by assessing the welding products with the welding positions of 3F and 2G. The following is the assessment result of the 2019 ASC Regional Selection. The ASC-VHS Regional Selection in Yogyakarta is implemented by conducting welding practices with the T-Join 3F position carried out by the 10 students.

**Table 2. ASC-VHS score results for 3F position**

| Contester No. | Scoring instrument based on TWI standard* (defect no.) | Total Score (TS) | Final Score= (TS/12) *10 |
|---------------|--------------------------------------------------------|----------------|--------------------------|
| 1             | 0 0 0 0 0 0 0 0 10 0 0 0 10 0 0 10 0 0 0 0 0 0 0 | 30             | 25                       |
| 2             | 10 0 0 0 0 0 0 0 10 0 0 0 10 0 0 10 0 0 10 0 10 0 10 0 0 | 40             | 33.3                     |
| 3             | 10 0 0 10 0 0 0 10 0 10 0 10 0 10 0 10 0 10 0 10 0 0 0 0 | 50             | 41.6                     |
| 4             | 10 0 10 10 0 0 10 0 10 10 0 10 10 0 10 0 10 0 10 0 10 0 10 0 | 90             | 75                       |
| 5             | 10 0 0 0 0 10 0 0 10 0 10 10 0 10 10 0 10 10 0 10 10 0 0 0 0 | 60             | 50                       |
| 6             | 10 0 0 0 0 0 0 0 10 0 10 0 10 10 0 10 0 10 0 10 0 0 0 0 0 0 0 | 40             | 33.3                     |
| 7             | 10 0 0 10 0 0 0 0 0 10 0 10 0 10 10 0 10 0 0 0 0 0 0 0 0 0 0 | 70             | 58.3                     |
| 8             | 10 0 10 0 0 0 0 0 0 10 0 10 10 0 10 10 0 10 10 0 10 0 0 0 0 0 | 70             | 58.3                     |
| 9             | 10 0 10 10 0 0 0 0 10 0 10 10 0 10 10 0 10 10 0 10 0 0 0 0 0 0 | 70             | 58.3                     |
| 10            | 10 0 10 10 0 0 0 0 10 0 10 10 0 10 10 0 10 10 0 10 0 0 0 0 0 0 | 70             | 58.3                     |

Not defect qty. : 10 0 5 6 3 2 8 6 8 9 0 2  Averag e score 49.14

*Note: Score of 10 means that the contestant did not cause the defect
The assessment based on the TWI standard shows that the welding products of 3F Fillet position of almost all contestants have not passed the industry standard where the passing grade is 75% or 75 final score (table 2). There are 12 items of visual test assessment instruments that become a reference in assessing the 3F position connection welds. The number of contestant that caused the defect is summarized in figure 1. It can be seen from figure 1 that the highest defect is defect number 2 (porosities/worm holes) that reached 100%, where all contestant could not avoid this defect. Porosities is caused by filler is contaminated by water, paint, oil, etc. so that when the metal heated, the fluid release the gas causes air entrapped in welded metal. Porosity could also be caused by no preheat process before welding the materials. Porosity is greatly reduced at higher preheat temperature [10].

Figure 1. Diagram of defect found form ASC-VHS contestants of 3F position

Table 3. ASC-VHS score results for 2G position

| Contestant No. | Scoring instrument based on TWI standard* (defect no.) | Total Score (TS) | Final Score= (TS/16)*10 |
|----------------|---------------------------------------------------|-----------------|-------------------------|
| 1              | 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 0 0 140 |                | 87.5                    |
| 2              | 10 10 10 10 10 10 0 0 10 10 10 0 0 0 0 0 100 |                | 62.5                    |
| 3              | 10 10 10 10 10 10 10 10 10 10 10 10 0 0 0 0 130 |                | 81.25                   |
| 4              | 10 0 10 10 10 0 0 10 10 10 0 10 10 0 10 110   |                | 68.75                   |
| 5              | 10 0 10 10 10 10 0 10 10 10 0 10 10 0 10 120   |                | 75                      |
| Not defect     | 5 3 5 5 5 5 2 3 5 5 3 4 2 1 2 Average    |                | 75                      |

*Note: Score of 10 means that the contestant did not cause the defect

The assessment based on welding products of 2G position of all contestants is presented in table 3. There are 16 items of visual test assessment instruments that become a reference in assessing the 2G
position connection welds. There is only 5 contestants who follow this competition. From the table, it could be seen that only 2 contestants that outcome the 75% passing grade. The number of contestant that caused the defect in 2G position SMAW is summarized in figure 2. It can be seen from figure 2 that the highest defect is defect number 15 (height or reinforcement/ cover), where 80% contestant could not avoid this defect. Excessive reinforcement is a weld products that is too big or has too much convexity. This is caused by low travel speeds or incorrect procedures [11]. The low reinforcement (1 mm) increased the fatigue strength [12].

![Diagram of defect found from ASC-VHS contestants of 2G position](image)

**Figure 2.** Diagram of defect found form ASC-VHS contestants of 2G position

Hot crack is a crack in welding that occurs after the welding process is complete or during the metal solidification process. The causes are the wrong electrode selection and the heat treatment that is not conducted. Cold Cracking is a crack that occurs in the weld area after some time (taking time, can be 1 minute, 1 hour, or 1 day) or after the welding process is complete. The risk of the welding defects (cracks) is the reduced strength of the welding joint. If applied to an oil or gas pipeline it can cause damage and very large losses due to the leak. If a comparative test is carried out, a fracture occurs at the welding connection [13].

Underfill welding defects are caused by the welding amperes that are too low, so that they do not fill the sides of the weld groove. Also, the dirty side becomes a factor causing underfill defects, so that the swing angle of the electrode cannot melt the groove mouth and the electrode angle when welding is not accordingly; therefore the direction of the metal and electrode fluids do not stick perfectly. The risks that occur if underfill welding defects occur is the reduced strength of the metal welding. This causes cracks or leaks if the welding is applied to pressurized oil or gas pipes. Therefore, the welding connection does not pass the test [14].

Slag is a type of welding defect that is often found in the 2019 ASC-VHS Regional Selection in Yogyakarta. The cause is the in-optimum cleansing in the previous welding, and it can also be caused by rust on metals, so that electrons cannot stick to the dirty metals. Undercut and porosity are the welding defects that are always present in the preliminary round to the final round in the Regional Selection. The cause of undercut is the too large welding amperes, slow electrode movements, small amperes, and too fast electrode movements. Porosity can be caused due to inappropriate cleaning in the previous welding and in the welding preparation process. When the work piece cleaning is not done properly, oil attached is still found. Also, it can be caused by the misuse of electrodes that should be put into oven, but it will
pass through the oven process [15]. The defects (porosity, slag, undercut) of contestants welding products could be seen in figure 3.

![Welding defects](image)

**Figure 3.** Welding defects: slag, porosity, and undercut of 3F position

Start-stop welding is caused by the electrode movement when connecting, which is not in accordance with the path to be joined. The welding height is caused by the movement and the wrong angle of the electrode being too long at the welding center, and the absence of gap on the sides of the welding. The width of the weld bead is caused by the instability in the welding; it does not see the previous path, so that the welding product becomes narrow and unstraight. It can be seen in figures 5 and 6.

![Welding defects](image)

**Figure 4.** Welding defects: porosity of 2G position (ASC-VHS competition)
Figure 5. Welding defects (stop-start, welding bead, and reinforcement in 3F Position)

Figure 6. Welding defects: start/stop root in 2G Position

4. Conclusions
Based on the results and discussion it can be concluded that the average score of the final assessment in the 2019 ASC Vocational High School in Yogyakarta Province shows that the competency of vocational students in Yogyakarta who take welding engineering program is still below the criteria of the industry standard assessment when assessed using TWI. Referring to the analysis of the final score of 2019 ASC-VHS, the median obtained is 12, while the mode value is 7. Based on the analysis results of the 2G position SMAW with TWI industry standard, the weaknesses of participants are some of the errors that occur, so that it they could not read perfect points. The welding defects are in the form of slag; spatter; arc stray; beads of irregular welding products, so that the product is not neat; incomplete penetration; root of fusion porosity; stop-start on cover surface pass and root pass; underfill; defects (reinforcement
height) that exceed the tolerance or provisions of the standard determined by TWI (2 mm). Regarding the welding defects above, the ability of the ASC-VHS Regional Selection participants in Yogyakarta to make 2G welding is still low because the students have not passed the industry standard (TWI).

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