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Determination of Standard Time and Man Hours for Welding Process in Barge Repairs

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***Abstract*— Shipyards are facilities that play an important role in building and repairing ships. One common type of repair is replating, which means replacing damaged hull plates with new ones. This process relies heavily on welding, which needs skilled workers and a lot of electrodes. A frequent issue in the field is the challenge of estimating how many electrodes are needed, which often results in wasted materials, increased costs, and delays in completing the work. This study seeks to calculate the electrode needs, the time required for the work, and the man-hours needed for ship replating. The research involved a review of existing literature and a field study. The welding process used the SMAW method with E6013 electrodes, 160A current, and 2G and 3G welding positions. Each welding position involves three stages: root, filler, and capping. The average welding speed data for every 1000 mm is used to calculate the actual welding length in the replating process. The results showed that the average welding time for the 2G position was 39,277.89 minutes, while for the 3G position it was 17,657.54 minutes. The total electrode requirement was 1,619.69 kg, which is equal to 324 boxes, with an estimated cost of Rp. 40,240,800.00. Additionally, the number of workers needed is 27, with a total of 948.924 man-hours over a period of 5 days. In conclusion, organized calculations of electrode needs, time, and man-hours can help improve the efficiency of replating work, reduce waste, and aid in project management planning in shipyards.**

Keywords— Man hours, replating, SMAW welding, electrode requirements.

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I. INTRODUCTION

Ship is a form of construction that can float on water and has the nature of loading in the form of passengers or goods that have a motion force in the form of oars, wind, or engines [10,17]. Because Indonesia is a maritime country which has a sea area ¾ larger than its land area, it is possible that the ratio of ship shipping operations is also large.

The hull is part of a boat or ship that is responsible for providing buoyancy that prevents the sinking of the ship [16]. Ships also have many variations of hull model shapes, one of which is the U and V hull shape. Ships that are often used to transport cargo from one place to another will certainly experience damage with the passage of time, one of the damages that often occurs on ships that are often used is corrosion of materials made of steel which causes frequent contact with sea water so that the quality of the steel material will experience thinning. Therefore, to extend the life of the ship, repairs are needed on a ship. Shipyards have economic value that can make a significant contribution to the economy, thereby potentially supporting the development of marine technology, particularly by making this industry labor-intensive [26]. And also shipyard is an industry in the field of shipping that aims to produce ship products, offshore buildings, floating buildings, and others. While the shipyard is a type of shipyard that is specifically for the manufacture or repair of a ship [20]. Repair dock shipyard is a shipyard that is able to repair all forms of problems on the ship, such as repairing ship engines, ship electricity, ship piping, ship hulls, and others [1]. Repair dock shipyard can do some repairs in a relatively short period of time so that the survival of this shipyard has a strong enough guarantee to survive. Replating is the process of replacing plates on ships that have experienced damage or thinning of the plates by replacing new plates where the installation of new plates on ship replating such as using SMAW and FCAW welding [2,12]. SMAW welding (shielded metal arc welding) or shielded arc welding is a welding method that uses an electric arc as a heat source for the melting of the parent metal. The parent metal will experience melting due to the liquid that arises between the tip of the electrode and the surface of the workpiece [23,25]. Welding is a metal joining technique by melting part of the parent metal and filler metal or without additional metal and producing a continuous connection [3, 4]. There are many types of ships in the maritime world, such as cargo ships, which are ships that transport all of their cargo in trucks using intermodal containers, employing a technique known as containerization [8], and cruise ships, which are ships that serve as a means of recreation and entertainment for their passengers [19]. Barges or pontoon ships are a type of ship characterized by a flat hull or large box that can float. Barges can transport cargo or goods as floating docks [7], such as

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the SPOB (Self-Propelled Oil Barge), which will undergo replating using SMAW welding equipment because it is suitable for both outdoor and indoor use. This issue is certainly not easy to address, given the limited human resources and the welders' ability to complete the replating work on the side shell within the required timeframe. Since there are no established standards for time and man-hours per welding position, it remains challenging to estimate or predict the completion time for welding work at the shipyard. Therefore, to avoid delays, it is necessary to have a standard time and man-hour plan for each welding position. These welding positions include 2G (horizontal) and 3G (vertical), which are due to the large volume in the replating area and will certainly affect the number of man-hours required for these welding positions. This will inevitably affect the supervisor's performance, as they can only estimate how long the replating work will take without a specific timeframe that can be precisely determined, leading to continuous delays. Figure 1.1 shows a graph of the total replating length, where the x-axis represents the total length, and the y-axis represents the welding area and welding position on the ship.

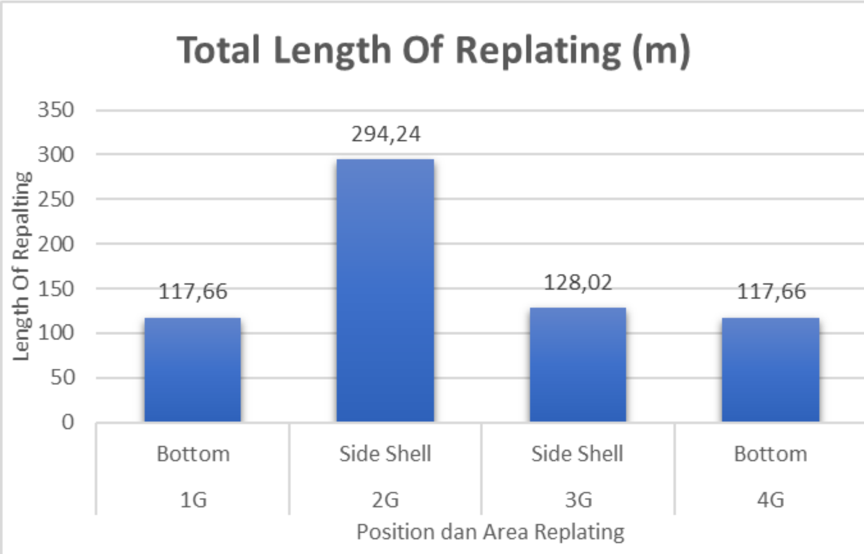

Figure 1.1 Replating Length at Each Welding Position

From the issues mentioned above, the topic to be discussed is Determining the Standard Time and Hours for Welding in Barge Repair. There are three stages of welding: root, filler, and capping. Root refers to the first stage of welding performed by the welder or the initial stage of welding, hence it is called the root pass or root weld [21]. Filler is the next stage after root welding, where the weld is filled up to the top edge of the base material or filled almost completely [9]. Capping is the final stage in welding performed by welders by welding on the top layer of the plate surface or on the final layer of the weld joint [9]. The area used as a reference for calculating the replating time is on the side shell with a welding position of 2G (horizontal) and 3G (vertical) because replating problems are commonly encountered. The purpose of this study is to determine how long welders take to perform replating with their varying skills in each welding position, minimize electrode waste, and assess productivity in the ship repair welding process. The results of this analysis can serve as a reference for companies to establish benchmarks for determining man-hours, electrode requirements, and productivity values in the replating process using SMAW welding equipment.

II. METHOD

The method is a stage that must be passed through first in a regular and structured research process so that there is no confusion in compiling the research. The purpose of the method is to develop the research currently being studied. The following are several methods that must be carried out:

A. Manpower Planning

Manpower planning is a process that explains the development, implementation, and control to ensure that the company has the appropriate number of employees, the right placement of employees, and effective use of time [11,13]. Therefore, this automatically provides more optimal benefits. Thus, manpower planning is a method for companies to organize their work so that it can be completed on time and minimize delays.

Manpower planning must not be overlooked in the industrial world because it is essential for maintaining a company's good reputation in the eyes of its customers. Therefore, manpower planning must be calculated properly. For this reason, work hours can be calculated using the following formula [5]:

J = T x JE x JTK

Total Productivity = M / J

JO = Total Weight (kg) / Produktivity (kg/jo)

Description:

JTK = Total workforce required

JE = Effective hours in working days (hours)

T = Time required to complete the work (days)

J = JTK multiplied by the duration of the work

M = Production capacity (kg/day)

B. Electorde Requirements

A welder is someone who works with any type of welding equipment. The main task of a welder is to join materials made of iron, metal, stainless steel, aluminum, and others [18]. During the plate joining stage, the welding process will be carried out, which requires a large number of electrodes to connect the plates. Welding wire, often referred to as an electrode, is a material used for electric welding that functions as a burner to create an arc [24]. The following is the calculation formula used to estimate electrode requirements, which involves calculating the weight of the welding wire used. The formula for determining electrode requirements according to Faza (2023) is shown in Figure 2.1.

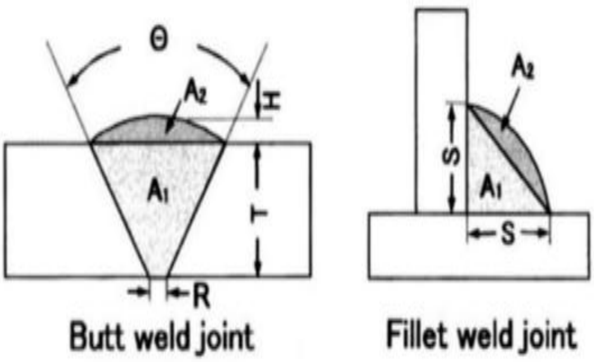

Figure 2.1. Calculation of Butt Joint and Fillet Joint (Source: Farhan Nur Faza, 2023)

Here is the formula:

$$H = \frac{2}{46{,}8} x\, T + 0{,}86$$

$$C = \frac{(A1+A2)xLxG}{E}\, x\, \frac{1}{1000}$$

Description:
C = *Consumption of welding consumables* (kg)
H = Height at area A2
A1 = Area of section A1 weld metal (mm^2)
A2 = Area of section A2 reinforcement (mm^2)
L = Weld Length (m)
G = Specific gravity of weld metal (7,85 g/cm^3)
E = Deposition Efficiency (%)
T = Plate thickness (mm)
With Conditions:
SMAW covered electrodes = 55%
GMAW solid/metal – cored wires = 95%
FCAW flux – cored wires = 90%
SAW solid wires = 100%

C. Standart Time

Standard time is the time required to complete an activity or task by workers under normal conditions [15]. This includes the duration of the activity, the amount of output produced, and the number of workers needed to complete the task. Before determining the standard time, it is necessary to first determine the cycle time used to calculate the average completion time during the measurement of the duration of the work process according to formula 5.6, then calculate the normal time according to formula 5.7. Once these values are obtained, the standard time calculation can be determined according to formula 5.8. All these calculations [22]:

$$Ws = \frac{\sum x}{n}$$

$$Wn = Ws\ x\ \frac{PR}{100\%}$$

$$Wb = Wn\ x\ (\frac{100\%}{100\% - \%allowance})$$

Description:
Ws = Cycle time
X = Number of adjustment times Observed
N = Number of observations made
Wn = Normal Time
PR = *Performance Rating*
Wb = Standart Time
Allowance = Allowance

D. Research Flow Chart

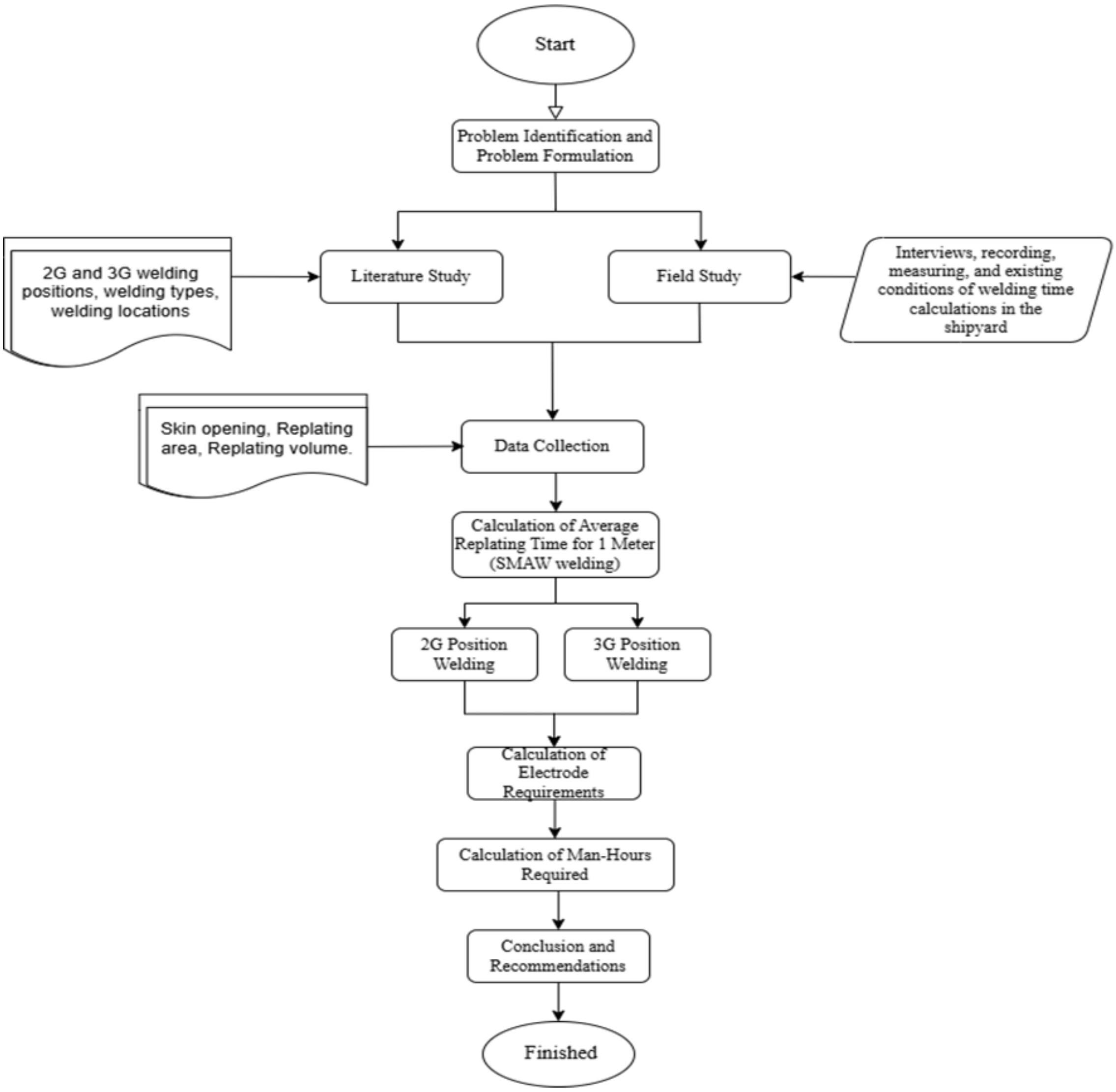

Figure. 2.2. Research Flow Chart

E. Research Stages

1. Problem Identification
   Identify the causes of delays in the replating stage.
2. Literature Study
   A literature study is a stage of activity related to the method of collecting library data, reading, taking notes, and managing research materials. Determine the relationship between each activity.
3. Field Study
   Directly investigating the issues occurring at the on-the-job training site by observing the replating process from start to finish, conducting interviews with employees or subcontractors, and observing existing conditions on-site.
4. Data Collection
   Data on the hull opening of the barge, replating volume, and average time per 1000 mm at welding positions 2G and 3G
5. Average Replating Time Calculation
   Direct observation on-site from when a welder starts welding until completion. The study involved 6 welder samples, where 1 meter or 1000 mm of replating at each 2G and 3G position could be completed in how many minutes of welding
6. Electrode Requirement Calculation
   In the plate joining process, we require electrodes. To minimize excess electrode usage and reduce waste.
7. Calculation of Labor Hours Required
   After obtaining the average welding time for each welding position and the total electrode requirements, the next step is to calculate the total labor hours required.

III. RESULT AND DISCUSSION

This study obtained data on the welding time required to weld 1 meter in the 2G and 3G positions during the root, filler, and capping processes

A. Planning Stage

1. Determination of Welding Time Standards

The time is obtained by recording how many minutes it takes to weld every 1 meter.

TABLE 3. 1
WELDING TIME CALCULATION RESULTS

Welder	*Root* (minute)	*Filler* (minute)	*Capping* (minute)	Welding Length	Welding Position
1	12,32	20,4	23,1	1 meter	2G Welding
2	12,18	21,19	24,7	1 meter	2G Welding
3	13,2	22,1	22,8	1 meter	2G Welding
4	11,04	21,19	24,64	1 meter	2G Welding
5	12,41	23,53	25,8	1 meter	2G Welding
6	11,31	28,31	31,6	1 meter	2G Welding
Averege	12,07	23,19	25,51	1 meter	2G Welding

Welder	*Root* (minute)	*Filler* (minute)	*Capping* (minute)	Welding Length	Welding Position
1	15,04	19,57	26,06	1 meter	3G Welding
2	14,45	22,29	26,16	1 meter	3G Welding
3	15,52	21,37	26,36	1 meter	3G Welding
4	10,5	20,48	28,08	1 meter	3G Welding
5	11,27	26,57	30,18	1 meter	3G Welding
6	12,06	24,18	28,16	1 meter	3G Welding
Averege	13,14	22,41	27,5	1 meter	3G Welding

2. Size of All Replating Parts

Before calculating the average time for replating activities, it is necessary to record all replating area measurements for all parts of the ship being worked on so that once all replating measurements have been obtained, the average replating time can be calculated.

TABLE 3. 2
ALL SIZE REPLATING DATA

No.	Position	Frame	Length (mm)	Wide (mm)	Thick (mm)
1.	*Bottom* (*S*)	Fr. 13-14	1500	1850	12
2.	*Bottom* (*S*)	Fr. 14/15-16/17	3600	1830	12
3.	*Bottom* (*S*)	Fr. 29/30-31/32	2650	1000	12
4.	*Bottom* (*S*)	Fr. 31/32-35/36	6150	1830	12
5.	*Bottom* (*S*)	Fr. 31/32-33/34	1860	2400	12
6.	*Bottom* (*S*)	Fr. 38/39-40/41	1650	1830	12
7.	*Bottom* (*S*)	Fr. 38/39-39/40	2550	1830	12
8.	*Bottom* (*S*)	Fr. 39-40	900	650	12
9.	*Bottom* (*S*)	Fr. 54/55-55/56	2020	1830	14
10.	*Bottom* (*S*)	Fr. 55/56-57/58	3000	1770	14
11.	*Bottom* (*P*)	Fr. 46/47-47/48	950	1350	12
12.	*Bottom* (*P*)	Fr. 30-31/32	1020	1250	12
13.	*Bottom* (*P*)	Fr. 38/39-39/40	1620	1030	12
14.	*Bottom* (*P*)	Fr. 38/39-39/40	1900	1860	12
15.	*Bottom* (*P*)	Fr. 26/27-27/28	1350	1200	12
16.	*Bottom* (*P*)	Fr. 13-14	1150	1450	12
17.	*Side Shell (S)*	Fr. 19/20-20/21	1900	950	12
18.	*Side Shell (S)*	Fr. 20/21-22/23	2800	950	12
19.	*Side Shell (S)*	Fr. 22/23-24/25	2820	950	12
20.	*Side Shell (S)*	Fr. 28/29-29/30	1850	950	12
21.	*Side Shell (S)*	Fr. 29/30-30/31	1850	950	12
22.	*Side Shell (S)*	Fr. 30/31-31/32	1850	950	12
23.	*Side Shell (S)*	Fr. 31/32-32/33	1850	950	12
24.	*Side Shell (S)*	Fr 32/33-33/34	1850	950	12
25.	*Side Shell (S)*	Fr. 38/39-40/41	1650	1830	12
26.	*Side Shell (S)*	Fr. 35-40	7500	1710	12
27.	*Side Shell (S)*	Fr. 42/43-43/44	2500	900	12
28.	*Side Shell (S)*	Fr. 43/44-46/47	4430	1720	12
29.	*Side Shell (S)*	Fr. 44/45-46/47	2250	850	12
30.	*Side Shell (S)*	Fr. 50/51-55/56	7400	1850	12
31.	*Side Shell (S)*	Fr. 50/51-55/56	7400	1660	12

CONTINUED - TABLE 3. 2
ALL SIZE REPLATING DATA

No.	Position	Frame	Length (mm)	Wide (mm)	Thick (mm)
32.	*Side Shell (P)*	Fr. 60-61	1570	600	10
33.	*Side Shell (P)*	Fr. 51/52-55/56	6100	1680	12
34.	*Side Shell (P)*	Fr. 51/52-55/56	6100	1830	12
35.	*Side Shell (P)*	Fr. 50/51-52//53	2530	950	12
36.	*Side Shell (P)*	Fr. 49/50-50/51	2530	950	12
37.	*Side Shell (P)*	Fr. 47/48-49/50	2530	950	12
38.	*Side Shell (P)*	Fr. 46/47-47/48	2530	950	12
39.	*Side Shell (P)*	Fr. 44/45-46/47	2530	950	12
40.	*Side Shell (P)*	Fr. 42/43-44/45	2530	950	12
41.	*Side Shell (P)*	Fr. 44/45-48/49	5600	500	12
42.	*Side Shell (P)*	Fr. 41/42-42/43	1850	950	12
43.	*Side Shell (P)*	Fr. 39/40-41/42	2500	950	12
44.	*Side Shell (P)*	Fr. 38/39-39/40	1900	950	12
45.	*Side Shell (P)*	Fr. 37/38-38/39	1850	950	12
46.	*Side Shell (P)*	Fr. 35/36-37/38	2500	950	12
47.	*Side Shell (P)*	Fr. 33/34-35/36	2500	950	12
48.	*Side Shell (P)*	Fr. 41-41	500	600	12
49.	*Side Shell (P)*	Fr. 37/38-40	3250	1720	12
50.	*Side Shell (P)*	Fr. 32/33-33/34	2370	1150	12
51.	*Side Shell (P)*	Fr. 30/31-32/33	2520	1150	12
52.	*Side Shell (P)*	Fr. 30-31	1100	1650	12
53.	*Side Shell (P)*	Fr. 26/27-27/28	1170	950	12
54.	*Side Shell (P)*	Fr. 25/26-26/27	1800	950	12
55.	*Side Shell (P)*	Fr. 22-23	1400	950	12
56.	*Side Shell (P)*	Fr. 14-15/16	2550	820	12
57.	*Side Shell (P)*	Fr. 13/14-14/15	1260	980	12
58.	*Side Shell (P)*	Fr. 0-2	3100	4700	12
59.	*Fore (S)*	Fr. 62-69	5000	600	10
60.	*Fore (S)*	Fr. 71-73	600	500	10
61.	*Fore (S)*	Fr. 73-74	1350	550	14
62.	*Fore (S)*	Fr. 74-75	1820	1720	14
63.	*Fore (S)*	Fr. 73-75	1700	1200	14
64.	*Fore (S)*	Fr. 73-76	1730	2450	14
65.	*Fore (P)*	Fr. 70-75/76	4600	460	10
66.	*Fore (P)*	Fr. 61-63	2800	1850	10
67.	*Fore (P)*	Fr. 57/58-61/62	5450	1830	12
68.	*Fore (P)*	Fr. 60-61/62	3500	3100	14

3. *Calculation of Average Replating at Each Position*

At this stage, the average replating calculation will be separated at each welding position mentioned in Table 3.5 above. The aim is to make it easier to read and calculate according to the position of each weld. This average replating calculation is focused solely on the welding process itself, following the sequence of welding stages: root, filler, and capping. The following is the result of the calculation table:

TABLE 3.4
RESULTS OF THE WORK TIME CALCULATION

Part Position	Welding Position	Welding Length (m)	Work Time (minutes)
Side Shell and Fore	2G	294,24	32168,26
Side Shell and Fore	3G	128,02	14461,54
Total		657,58	466298,80

4. *Calculating Electrode Requirements*

So, the first step in calculating electrode requirements is to calculate the height at A2 according to formula 2.1 as follows [6].

$$H = \frac{2}{46,8} \, x \, T + 0,86$$

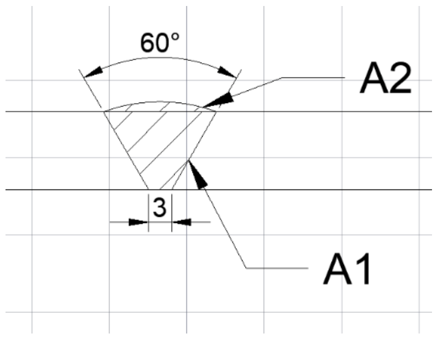

Figure 3. 1 Height at Area A2

After finding the area of section A2 reinforcement (H), the next step is to calculate the electrode consumption in kg according to formula 2.2 and enter the welding length according to the welding length in accordance with the location of each frame. The following is formula 2.2.

$$C = \frac{(A1 + A2) \, x \, L \, x \, G}{E} \, x \, \frac{1}{1000}$$

After obtaining all the C results from each frame, the next step is to enter the C results into the results are obtained from the number of SMAW electrodes (C). All the results obtained from the number of electrodes are then divided by the weight of the welding wire per box, which is 5 kg. Here is the calculation:

$$\frac{(C1 + C2 + C3 + C4)}{5\ kg}$$

= (559,195+559,195+250,6508+250,6508) / 5 kg

= 1619,69 / 5

= 323,93 Box electrode

= 324 Box electrode (rounded up)

5. *Calculation of Planned Man-hours*

The data was collected from the on-the-job training site, where the working hours in a day are 7 hours and there are 5 working days in a week, resulting in a total of 2,100 minutes or 35 working hours per week. The following is the calculation of the planned man-hours required to perform 2G and 3G welding processes in the replating work on barges.

The cycle time was obtained through direct observation by recording the welding work time for the barge replating. The following cycle time was obtained from the average calculation of the replating work/

TABLE 3.5
CYCLE TIME

Part Position	Welding Postion	Welding length (m)	Work Time (minutes)
Side Shell and Fore	2G	294,24	32168,26
Side Shell and Fore	3G	128,02	14461,54
Total		657,58	466298,80

Normal time is the length of time it takes a welder to complete a job under normal conditions and with average skill. Calculating normal time requires adjustment factors, the values of which are taken from direct observation in the field. Normal time is the length of time it takes a welder to complete a job under normal conditions and with average skill. Calculating normal time requires adjustment factors, the values of which are taken from direct observation in the field.

TABLE 3.6
PERFORMANCE RATING

Factor	Assessment	Adjustment
Skills	*Good*	0,06
Effort	*Good*	0,02
Working Condition	*Good*	0,02
Consistency	*Good*	0,01
Total		0,11

So, the total performance rating of the welder is

=100% + (total factor x 100%)
=100% + (0,11 x 100%)
=111%

This means that the welder can work with a performance rating 11% above normal time. So, after obtaining the performance rating results, the normal time can be calculated as shown in Table 3.7.

TABLE 3.7
NORMAL TIME CALCULATION

Position	Works Time (minutes)	*Performance Rating*	Normal Time (minutes)
2G	32168,26	1,11	35707,17
3G	14461,54	1,11	16052,31
Total	32168,26	1,11	35706,77

In calculating the slack factor in Table 4.32, adjustments were first made to account for the addition of personal time and time for relaxation. In this study, the slack factor value was determined based on the length of time for each factor in a day for each welder sample, as shown in Table 4.32 below, at 10%. The details are as follows, in accordance with Table 3.11.

TABLE 3.8
AVERAGE ALLOWANCE FACTORS FOR EACH WELDEr

Factor	Welder 1(menit)	Welder 2(menit)	Welder 3(menit)	Total (menit)
Personal Needs	20	15	23	22
Eliminating Fatigue	21	20	25	22

After obtaining the average result for each factor, the next step is to calculate the allowance factor. Allowance refers to giving workers the opportunity to perform activities that should be done so that the standard time can be considered complete work time data [14]. Therefore, the method of calculation is to determine the total percentage of the allowance factor obtained from the average time each welder spends on personal needs and resting, divided by the total working time in one day, multiplied by 100%, as shown in Table 3.12..

TABEL 3.9
ALLOWANCE FACTOR

Faktor	Nilai	Keterangan
Personal Needs	$\frac{22\ menit}{420\ menit} x\ 100\%$	The duration of personal leave is 22 minutes.
Relieving Fatigue	$\frac{22\ menit}{420\ menit} x\ 100\%$	The length of time allowed for fatigue relief is 22 minutes.
Total Allowance	10%	Change value

The total standard time is calculated by multiplying the cycle time by the allowance of 10%, which then gives the standard time for each welding position. See Table 3.13 for more details

TABEL 3.10
STANDARD TIME

Welding Position	Cycle Time (minutes)	*Allowance %*	$\frac{100\%}{100\% - Allowance\%}$	Standart Time (minutes)
Side Shell 2G	35707,17	10%	1,1	39277,89
Side Shell 3G	16052,31	10%	1,1	17657,54
Total				56935,43

The number of hours required to perform replating work on positions 1G, 2G, 3G, and 4G on barges in Lamongan is obtained from the calculation of standard time divided by the total number of working hours in a week or 5 working days. The calculation is as follows:

$$\text{Labor} = \frac{\text{Total Standart Time}}{\textit{Working Time}}$$

$$= \frac{56935{,}43}{2100}$$

$$= 27{,}11 \text{ Workers}$$

Man Hour = T x JE x JTK
= 5 x 7 hour x 27,11
= 948,924 JO

IV. CONCLUSION

After calculating the results and discussing them, the following conclusions can be drawn in accordance with the problem formulation that has been established:

1. The average time required to achieve 1000 mm of welding in the 2G external position is 12.07 minutes for root, 26.19 minutes for filler, and 25.51 minutes for capping. The calculated welding time for the side shell in the 2G position is 35,707.17 minutes or 595.12 hours. Meanwhile, in the 3G position, the root takes 13.14 minutes, the filler takes 22.41 minutes, and the capping takes 27.05 minutes. The calculated welding time for the side shell in the 3G position is 17,657.54 minutes or 294.29 hours.
2. Therefore, the total amount of electrodes required during the replating process on the barge in Lamongan at the 2G outer position is 559.195 kg, and at the 2G inner position is 559.195 kg, resulting in a total of 1,118.39 kg of electrodes required for the 2G position. For the 3G Outer position, the required electrode quantity is 250.6508 kg, and for the 3G Inner position, it is also 250.6508 kg, resulting in a total of 501.30 kg of electrodes needed for the 3G position. Therefore, the total amount of electrodes required for replating the barge at the Lamongan shipyard is 1,619.69 kg or 324 boxes of electrodes, with a total cost of Rp. 40,240,800.00
3. The results of the man-hour analysis for the replating of the barge hull in Lamongan estimated the replating work time to be 5 days and the number of workers required to be 27.11, which was rounded up to 27, and the total man-hours to be 948.924 man-hours.

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