

Application of Six Sigma Method with DMAI Approach in Railway Manufacturing Company

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Abstract. As one of railway manufacturing company in Southeast Asia, quality is an important factor in maintaining customer satisfaction and one of the key success in business competition. During the railway production, there is problem in the assembly process of car body sub assembly, namely underframe. Defective products have been found which cause the underframe to be repair, so the underframe production is delayed. The type of defect is porosity, which results from the welding process during the assembly process. Therefore, this study uses the Six Sigma method with the Define – Measure – Analyze – Improve (DMAI) approach to give improvements on welding process so the defect - which is porosity will be reduced or may not exist and to maintain the quality. Define phase using Supplier – Input – Process – Output – Customer (SIPOC) diagram and Critical to Quality (CTQ). Measure phase using c-Chart to know the process stability, then Cp and Sigma Level to know the process capability. Fishbone diagram and Failure Mode Effect Analysis (FMEA) are used in the analyze phase. The result of FMEA is the base to design improvements in the improve phase, the improvements are material storage characteristics, workstation design and procedure display.

Introduction

As one of railway manufacturing company in Southeast Asia, quality is an important factor in maintaining customer satisfaction and one of the key success in business competition [1]. Also, this railway manufacturing company has to improve its quality, which is the products that have been produced must be zero defects [2]. The core product of this railway manufacturing company is train. One train consist of two main components, which are *bogie* and *car body*. The components that arrange one car body are shown in the Figure 1. One of car body sub assembly, namely underframe (Figure 2), has its problem. The problem is, defective products have been found which cause the underframe to be repair, so the underframe production is delayed. The production data of underframe is shown in Table 1.

It can be seen from Table 1 that the type of defect is porosity. The identified defects are located in different connections, which are on the side sill connection and the center sill connection. There are 12 joints that need to be inspected on each connection, so the total is 24 joints. Porosity (Figure 3) comes from the welding process during the assembly of underframe' components. The components of underframe (Figure 2) are front end, rear end, side sill, center sill, and cross beam. Therefore, this study uses the Six Sigma method with DMAI approach to give improvements on welding process so the defect - which is porosity will be reduced or may not exist and to maintain the quality.

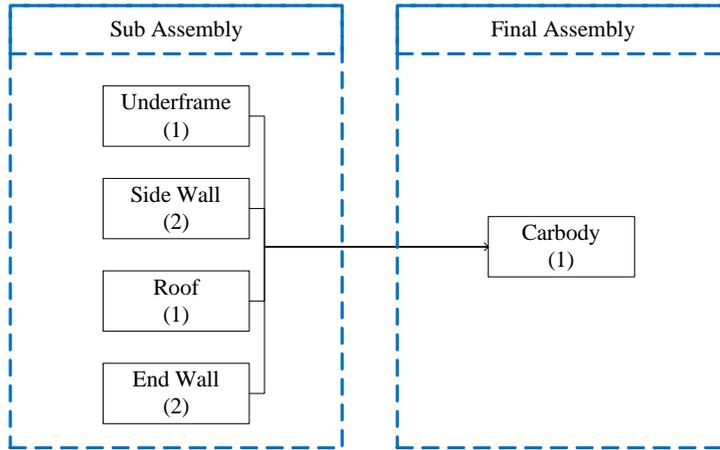


Fig. 1. Carbody's Components

Table 1. Production Data of Underframe

Period [Month/Year/ Week]	Production Target	Production Realization	Amount of Defect Product (unit)	Underframe Number	Defect Detail (joint)		Total of Nonconformities [c = a+b]
					Porosity on Side Sill Connection [a]	Porosity on Center Sill Connection [b]	
Dec 2018 / I	4	2	1	1	8	6	14
Dec 2018 / II	4	2	2	3	6	6	12
				4	8	4	12
Dec 2018 / III	4	2	2	5	8	5	13
				6	5	6	11
Dec 2018 / IV	3	2	1	8	10	7	17
Dec 2018 / V	3	3	2	9	9	7	16
				11	10	7	17
Jan 2019 / I	2	2	1	12	6	9	15
Jan 2019 / II	3	2	1	15	12	8	20
Jan 2019 / III	3	2	1	17	6	9	15
Jan 2019 / IV	3	1	1	18	5	8	13
Feb 2019 / I	3	1	1	19	9	8	17
Feb 2019 / II	3	2	1	20	12	7	19
Feb 2019 / III	3	2	1	23	11	8	19
Feb 2019 / IV	3	2	1	24	8	7	15
Total	41	25	16		133	112	245

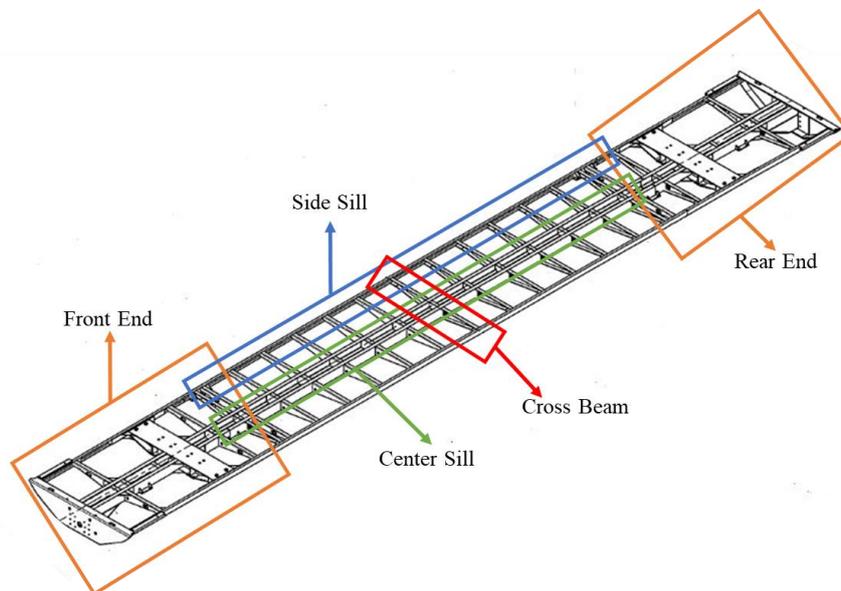


Fig. 2. Underframe and Its Components

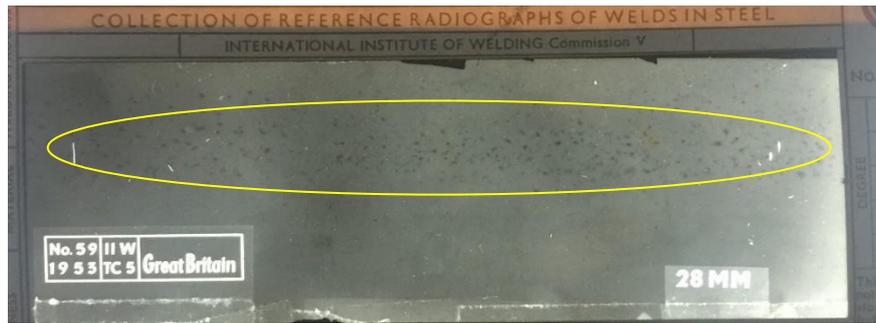


Fig. 3. Porosity (Result of Radiographic Test)

Literature References

Quality. Quality is the suitability of the product to fulfill its use as desired by the customer [3]. There is a framework consisting of eight dimensions to define a quality, namely performance, reliability, durability, serviceability, aesthetics, feature, perceived quality, and conformance to standards [4].

Six Sigma. Six Sigma is a method used to improve quality with ideal results to achieve zero defects. Six Sigma is usually represented by the DMAIC model (Define, Measure, Analyze, Improve, Control) [5].

DMAIC. DMAIC is an iterative process that provides structure and guidance for improving processes in any workplace [6].

SIPOC. SIPOC (Supplier, Input, Process, Output, Customer) is a tool that can be used to make process improvements by presenting a summary from input to output of one or more processes in table form [6].

CTQ. CTQ (Critical to Quality) is a measurable characteristic of a product or process that is determined to ensure customer satisfaction [7]. CTQ helps to ensure that repair activities are in accordance with customer requirements. The intended customer can be an internal or external customer.

c-Control Chart. The c-control chart is one type of attribute map that is used to track the number of nonconformities in a constant-sized sample [4].

Process Capability. Process capability is used to measure the level of nonconformities of a process by showing performance in the form of a single number and involves calculating specification boundary ratios (customer requirements) to process deployment (variation in process) [5].

Welding. Welding is a unification process that produces a combination of materials by heating them at welding temperatures, with or without the application of pressure or by applying pressure only, and with or without the use of metal filler [8].

Porosity. Porosity is a cavity type discontinuity formed by gas entrapment during weld metal compaction [9].

Fishbone Diagram. Fishbone diagram is a visual description of the possible causes of a problem. The impact of the problem is illustrated on the right side and the cause of the problem is illustrated by the shape of the fish bone [7].

FMEA. FMEA (Failure Modes and Effects Analysis) is a step-by-step approach to identify all possible failures in a design, manufacturing or assembly process, or a product or service [5].

Result and Discussion

Define Phase. This phase are using SIPOC Diagram (Figure 4) to identify the production process flow, and CTQ (Table 2) to identify the critical factors that cause the defect. As the explanation on Introduction, porosity comes from welding process during assembling process of A-1 and A-2 (Figure 4), so the focus of this study is on welding process. The welding process uses GMAW (Gas Metal Arc Welding) machine.

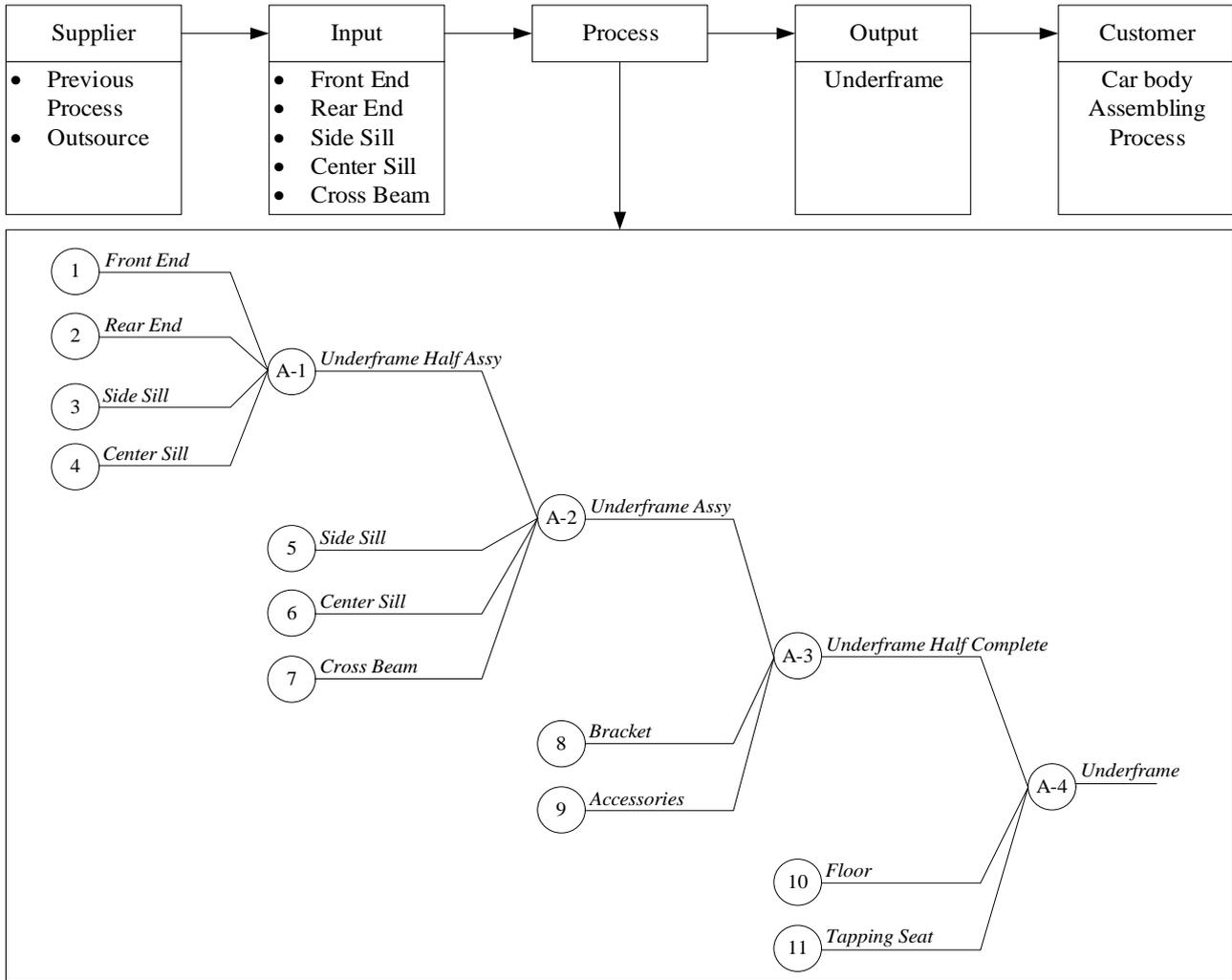


Fig. 4. SIPOC Diagram

Table 2. CTQ

Type of Defect	CTQ	Description
Porosity	Material cleanliness	Material must not rusty, not moist, not wet and not oily.
	Environment condition	There is no outside air contamination.
	Shielding gases flow	Smooth flow of shielding gases during welding process with flow rates of 15-17 liters/minute.
	Connection gap	Gap between the connections must be 2-3 millimeters.
	Chamfer angle' connection	Chamfer angle' connection must be 60°.
	GMAW machine parameters	Suitability of parameter settings based on welding procedure (voltage, current, welding speed).

Measure Phase. This phase using c-Control chart (Figure 5) for process stability measurement. Minitab is used for process capability measurement. It can be seen from Figure 5 that some datas aren't within the control limit, so the next step is eliminate the outlier data then make the new data into the new c-Control chart (Figure 6). It can be seen from Figure 6 that all data is within the control limit, which is not outside of UCL and LCL. It can be concluded that welding process of underframe in a control and stable, so it can be continued with measuring process capability. The process

capability measurement' used Minitab software, so the result is shown on Figure 7. It can be seen from Figure 7 in the column "Comments" explains that if the DPU (Defects per Unit) target is 0, and the process DPU is greater than the target, so it needs to be improved. The probability of producing 1 unit underframe without defect is 0%.

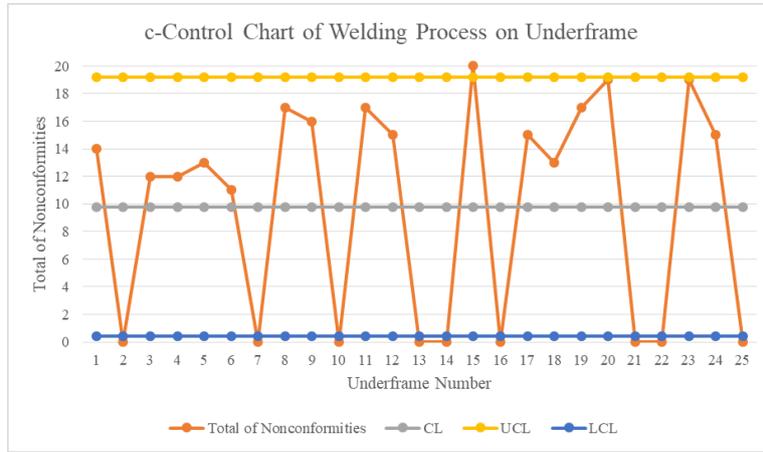


Fig. 5. c-Control Chart of Welding Process on Underframe

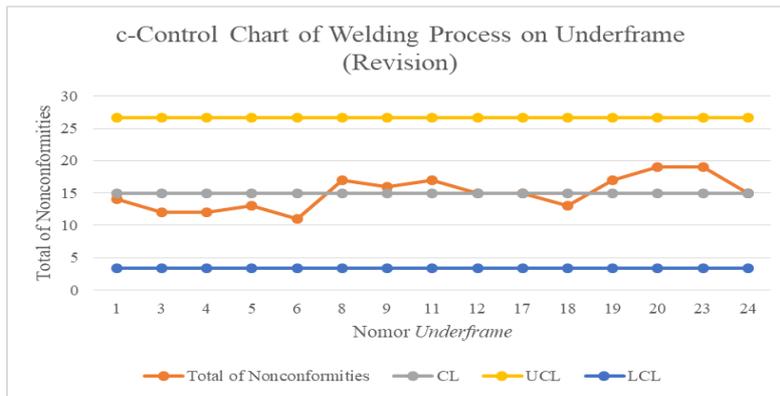


Fig. 6. c-Control Chart of Welding Process on Underframe (Revision)

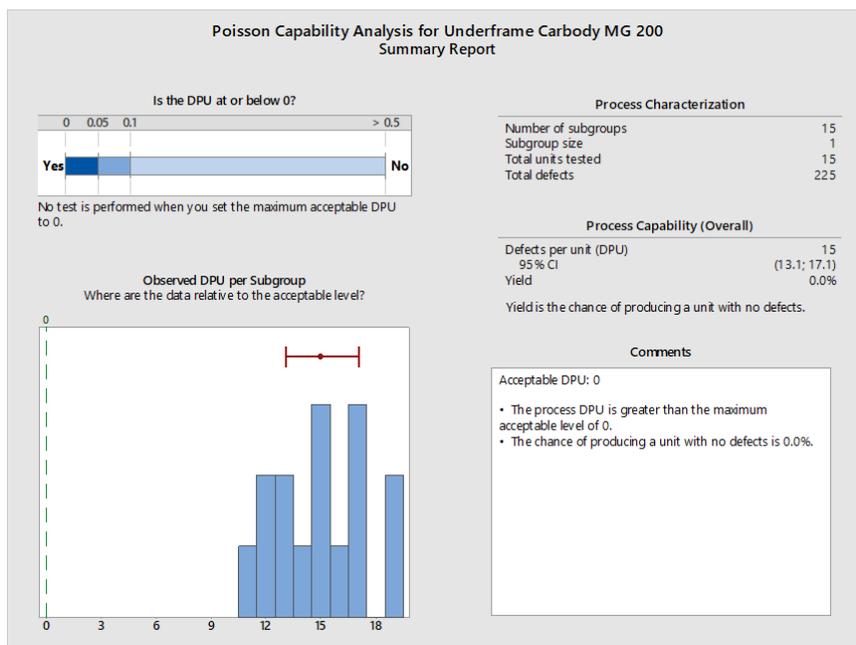


Fig. 7. Process Capability Analysis' Result

Analysis Phase. This phase using fishbone diagram (Figure 8) to identify the root cause of porosity. After that, FMEA (Table 3) is used to know the improvement priority. The result of FMEA have been

discussed, and the discussion' conclusion was all the failure modes will be improved. Therefore, all the failure modes will be the base to design improvements in the next phase, which is improve phase.

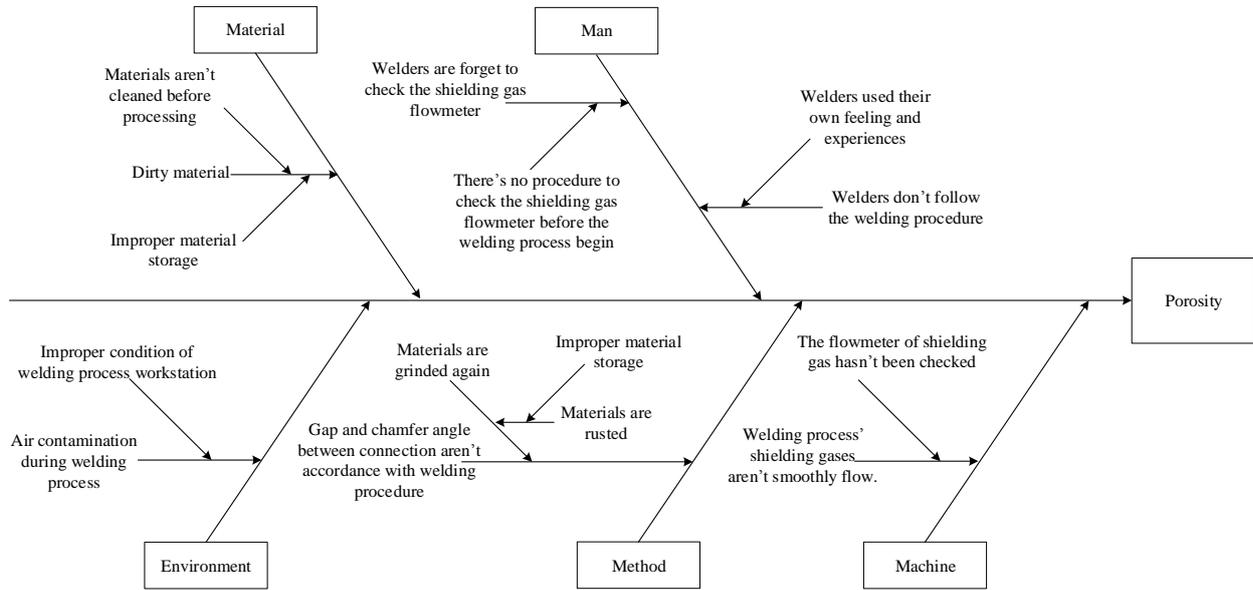


Fig. 8. Fishbone Diagram

Table 3. FMEA

No	Factor	Failure Mode	Effect of Failure	S	Cause of Failure	O	Detection Mode	D	RPN
1	Method	Gap and chamfer angle between connection aren't accordance with welding procedure	Welding results are not good because of the potential for gas contamination which causes gas bubbles on the weld	6	Materials are grinded again because of rust due to poor storage	6	Visual	8	288
2	Machine	Welding process' shielding gases aren't smoothly flow	Shielding gases don't work properly to prevent oxidation during the welding process.	5	Flowmeter of shielding gas hasn't been checked before the welding process begin	6	Visual	8	240
3	Man	Welders are forget to check shielding gas' flowmeter	Shielding gases don't work properly to prevent oxidation during the welding process.	5	There's no procedure to check shielding gas' flowmeter before the welding process begin	6	Visual	8	240
4		Welders don't follow the welding procedure	Welding defect such as porosity because the parameters aren't accordance to welding procedure	8	Standards and tolerance rarely followed by welders, because welders follow their own feeling and experiences	8	Visual	8	512
5	Material	Dirty material	The formation of gas during the welding process	4	Welders forget to clean the material before the welding process, and improper material storage	6	Visual	8	192
6	Environment	Air cantamination during welding process	The gas bubbles are trapped in the weld	3	Improper condition of welding process workstation	3	Visual	9	81

Improve Phase. This phase, the improvements are given in order to reduce or even eliminate the porosity. This improvement recommendations' main concepts are based on some theories [9, 10, 11]. The improvement designs are shown in Table 4.

Table 4. Improvement Designs

Factor	Cause	Improvement	Description
Method	Gap and chamfer angle between connection aren't accordance with welding procedure	Material storage characteristics	The needed characteristics are: it must be in dry place, not having direct contact with water (H ₂ O) and oxygen (O ₂), wrapped in plastic, and cathode protection, which is coating material with Zinc (Zn), or commonly called the use of galvanization.
Environment	Air cantamination during welding process	Workstation design	Screens were added at welding workstation which serves to block air contamination during welding process. In addition, the screen must be able to cover the window, and the fan which are outside the screen. The visual of workstation designed with SketchUp software (Figure 9, 10).
Man	Welders are forget to check shielding gas' flowmeter Welders don't follow the welding procedure	Procedure display	Procedure display (Figure 11) equipped with lamps (in orange color) to attract welders attention, will be displayed near the GMAW machine which contains information about the procedure before and during the welding process, according to welding procedure. The rules for colors and font size have been designed according to ergonomic rules.
Machine	Welding process' shielding gases aren't smoothly flow		
Material	Dirty material		

Conclusion

To maintain the quality, some improvements are given to reduce the defect – which is porosity that comes from welding process. The improvements are material storage characteristics, workstation design and procedure display.

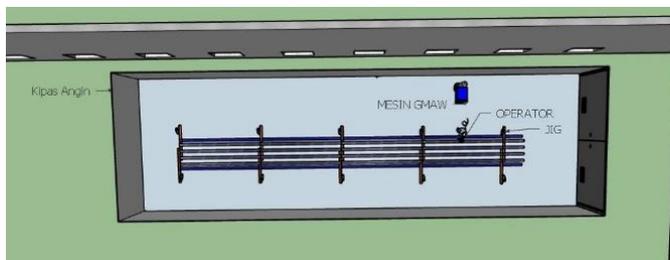


Fig. 9. Workstation Design (Top View)

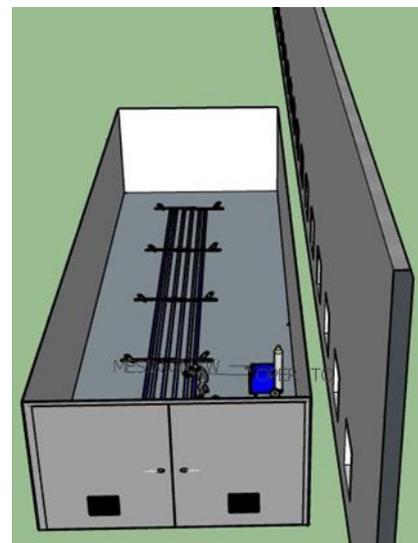


Fig. 10. Workstation Design (Front View)

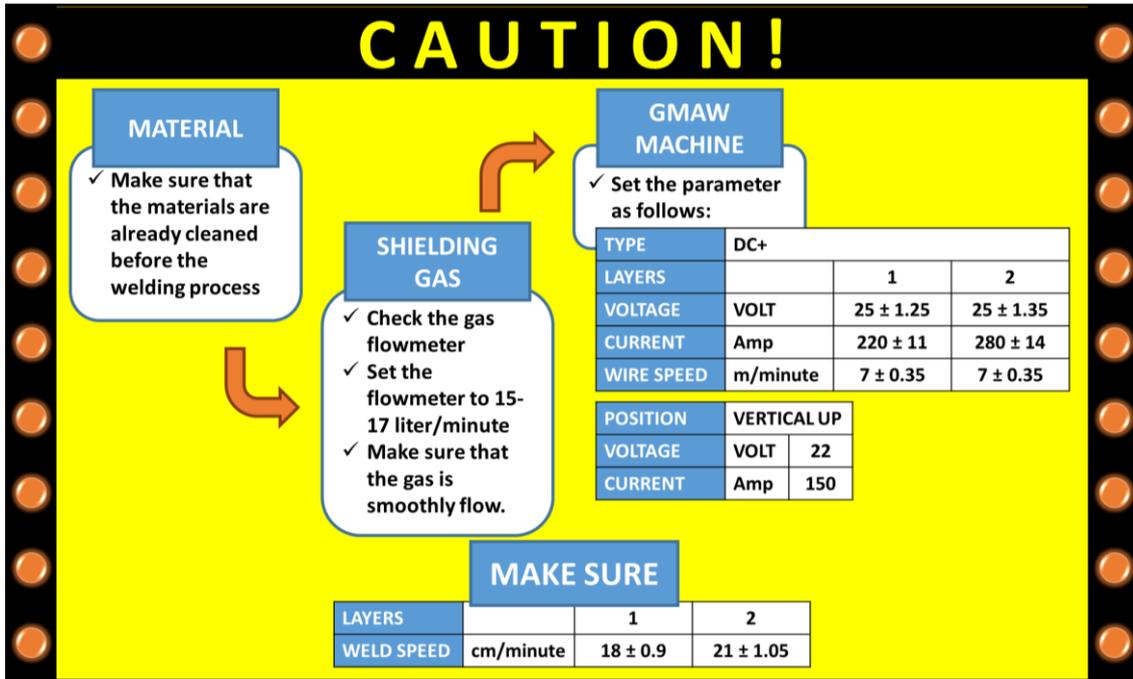


Fig. 11. Procedure Display

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