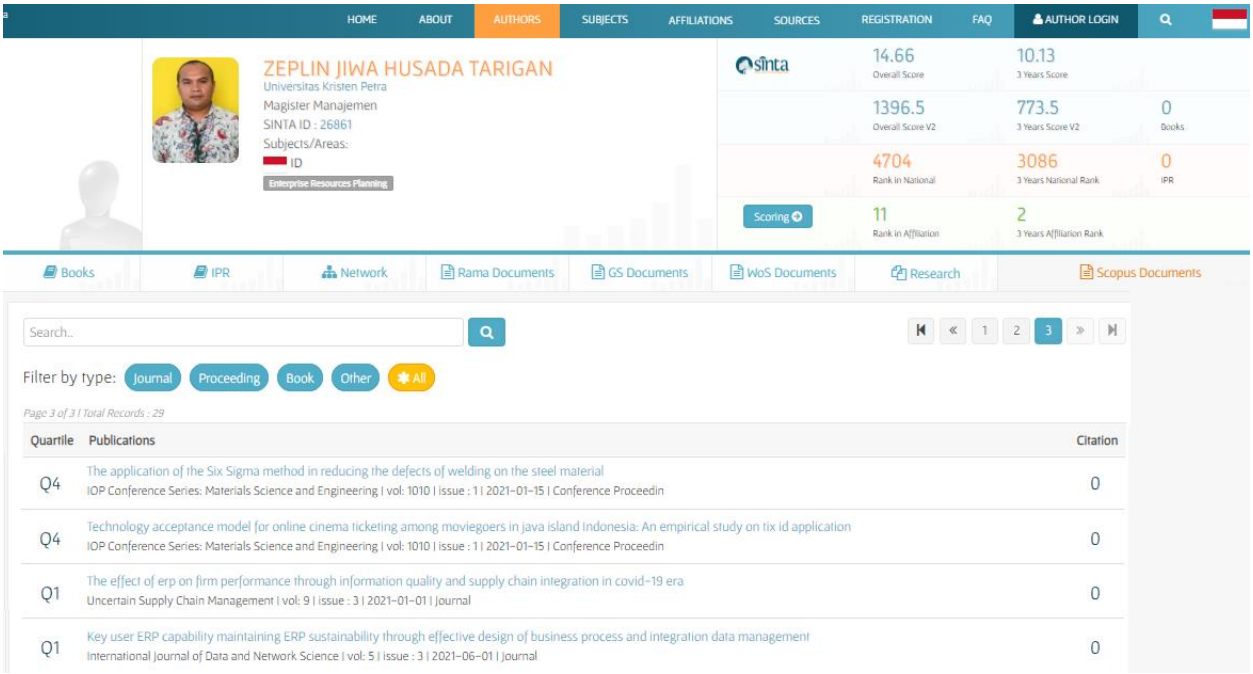

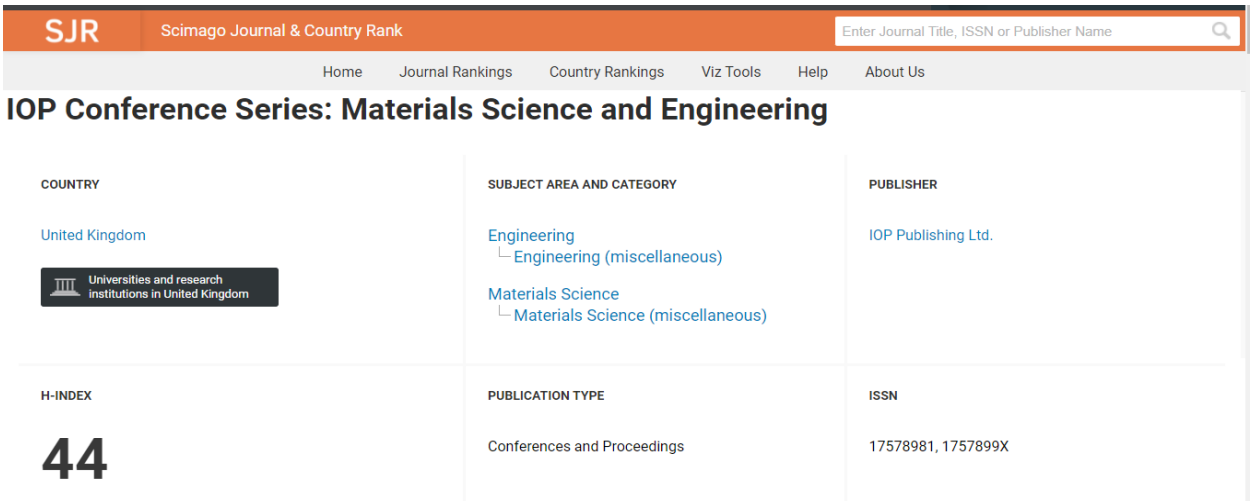

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Preface

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PREFACE

It is with great pleasure that I introduce the proceedings of the **2nd International Conference on Advance Engineering and Technology (ICATECH 2020)** is an international seminar organized by Institut Teknologi Adhi Tama Surabaya (ITATS). ITATS is private university located in Surabaya, East Java, Indonesia. The conference is held on September 26th 2020.

This seminar has the main purpose to bring researcher and scholar to share their knowledge and experience in Material, Metallurgy, Energy, Design, Engineering, Applied Science, Information System and Technology area. The conference serves as an excellent opportunity to meet each other and to exchange ideas with theme of **"Empowering Research and Innovation for Sustainable Technology"**.

The conference is initially planned to be an offline meeting in the venue, but within the outbreak of COVID-19, it is changed into a virtual conference instead of being postponed. The conference is organized through online virtual mode using Internet Communication Technologies (ICT) via Zoom. Authors shared the screen and attendees could discuss their work via online platform. Overall, the conference was held successfully through the platform. Our conference committee and authors were dedicated to support the success of the seminar.

The conference program is consisted of keynote speaker session and oral presentation session. The Distinguished Professor from Taiwan and Korea were invited to be our keynote speaker regarding their latest research in their respective areas of expertise in 45 minutes of presentation. After keynote speaker session was done, it continued to oral presentation session for selected paper. The participants were divided into 3 room of Zoom with respect to topic areas and were given 15 minutes time to present their work, following by questions and answers. One excellent presenter will be chosen among them, depending on the technical merit, presentation file, Language fluency, and application etc for the best paper award. It is worth the option of virtual participation that allows expanding the geography significantly and increasing the number of participants. More than 200 participants participated in the conference and 66 papers from different countries are selected for presentation during the conference sessions.

We thank all of reviewers for their time and effort in reviewing the papers even in the COVID-19 pandemic situation, as well as the authors, who took into account recommendations of reviewers and improved their papers to ensure the publication high quality in IOP Conference Series: Materials Science and Engineering Series.

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Peer review declaration

All papers published in this volume of *IOP Conference Series: Materials Science and Engineering* have been peer reviewed through processes administered by the Editors. Reviews were conducted by expert referees to the professional and scientific standards expected of a proceedings journal published by IOP Publishing.

- **Type of peer review:** Single-blind with two level review system
  - **i.** The conference editor reviewed the submitted papers relevance to the conference topics, checked whether the papers meet the IOP format requirements, and doing similarity check to ensure the percentage of similarity is not greater than 25%.
  - **ii.** The independent reviewers evaluated the submitted papers according to the following criteria as the relevance to meet the substance of study, novelty of work, quality and scientific knowledge, and adequate references etc.
- **Conference submission management system:**

  All the papers were submitted via EasyChair link and conference Email.
- **Number of submissions received:** 73 submissions received
- **Number of submissions sent for review:** 73 submissions were sent for review
- **Number of submissions accepted:** 66 papers accepted
- **Acceptance Rate (Number of Submissions Accepted / Number of Submissions**
- **Received X 100):** 90
- **Average number of reviews per paper:** 2
- **Total number of reviewers involved:** 16
- **Any additional info on review process:** -Nil-
- **Contact person for queries:**

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The application of the Six Sigma method in reducing the defects of welding on the steel material

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References

The application of the Six Sigma method in reducing the defects of welding on the steel material

The application of the Six Sigma method in reducing the defects of welding on the steel material

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Abstract. Quality control is an essential factor in producing products that are following what consumers want. The high quality of the product significantly affects the efficiency of costs incurred during the production process. This study aims to determine the types of defects and their causing factors as well as actions taken to reduce the number of defects to increase the efficiency of production costs. The measurement results obtained the number of productions of 12499 pcs with the number of defects of 2712 pcs of 21.6% with a sigma level of 3.1100 DPMO. Identification of defects in welding is porosity defects of 724 pcs, undercut defect of 613 pcs, slag defect of 435 pcs, crack defect of 491 pcs, and spatter defect of 449 pcs. The actions taken are periodic maintenance and repair of welding machines and connectors, supervising the condition and cleanliness of the material, providing periodic directions to welding operators by explaining reasonable welding procedures and arranging a welding field development program for welding operators through a job training program. Improvements have been implemented and found a reduction of defects up to 15% and a reduction of 6.6%.

1. Introduction

Product quality is a must for industries in producing products following specifications achieved as outputs produced by manufacturing companies. The products produced must meet the requirements stipulated and fall within the quality ranges set by external customers and government regulations (Patel and Desai, 2018) [1]. The quality that is maintained needs to be controlled in such a way as to produce quality products. Quality control is crucial for the company and needs to be realized so that the company can overcome quickly and agile any deviations in the production process [2]. The ability to manufacture companies to detect quality deviations in a short time will reduce defects in the final product so that they can reduce waste and costs incurred by the company [1]. The process systems approach that businesses use to be able to find and eliminate the causes of defects and errors, to reduce product manufacturing cycles and reduce production costs, improve product performance, and provide quality products to customers and better use of company assets is an implementation of six Sigma [3]. Product quality control is a technique and activity, or planned action carried out to achieve, maintain, and improve the quality of a product and service so that it is under predetermined standards and can meet consumer satisfaction [4]. The company uses a statistical approach to control the process quality, product quality, and service quality in a systematic and organized manner as a form of performance improvement [5].

Quality control is to use the Six Sigma method. Six Sigma can be used as a measure of the performance of industrial systems that allows companies to improve performance and be able to reduce complaints from customers because the products produced by the company have met the required quality to reduce defect rates [6]. Six Sigma can also be viewed as a customer-focused industrial process control concerning the company's production process capabilities. Six Sigma that has been used so far is using the DMAIC (Define-Measure-Analyze-Improve-Control) method [7], which in the implementation practice in companies there will be different definitions and approaches according to conditions depending on employee understanding and knowledge transfer from consultants. The implementation of six Sigma in companies will be able to reduce product variations or the results of the production process by determining the process failure rate of 3.4 products per million or two parts per billion of products produced, and analysis is carried out with normal distribution [8]. The six sigma implementation program on project innovation can provide improvements in company performance through increased customer satisfaction for current customers, and incremental innovation [3].

Freitas et al. [9] stated that the company's ability to implement lean six Sigma (LSS) would be able to provide sustainability in the project when the implementation can have an impact on the company's financial profit. Lean Six Sigma for the company is an important thing when the company can increase the competitive advantage of its products and increase the market for the company's products, which are the goals of the company [9,10]. Companies engaged in steel construction is trusted as subcontractors for the larger-scale companies, which is assigned by the Government of Indonesia to build the infrastructure. The suppliers to the main contractor have high standard requirements or specifications, especially for the work specification on bridge construction that requires the welding process with a very high specification. Any defective product that exceeds the tolerance limit will incur higher costs. The total cost will increase, and the selling price will be higher as well. Products will be unable to compete with competitors with lower selling prices and better quality for the same type of product. The application of the Six Sigma method is expected to reduce the level of defective products to the lowest point or even reduce them until the production process runs towards perfection (zero defect) so that the company will be able to increase its profits [3]. Besides, the company can maintain its survival and even improve its market position in the face of hypercompetitive competition. The defective condition of the company during the period of July 2019 to June 2020 is indicated in Table 1

Table 1. Percentage of Defective Products

No.	Month	Product (Pcs)	Rejected Product	Percentage Rejected
1	July 2019	644	154	24%
2	August 2019	1022	194	19%
3	September 2019	974	182	19%
4	October 2019	734	152	21%
5	November 2019	849	156	18%
6	December 2019	1119	215	19 %
7	January 2020	1109	231	21%
8	February 2020	1235	276	22%
9	March 2020	1331	311	23%
10	April 2020	1254	298	24%
11	May 2020	1109	264	24%
12	June 2020	1119	279	25%
	Total	12,499	2,712	22%
	Mean	1,042	226	22%

Initial observations made by researchers at steel construction companies by paying attention to the results of welding products for a year obtained 2712 pieces of defective products and an average of 226 pcs per month, and the percentage of defects obtained at 22%. Based on these data, it is necessary to implement six Sigma in companies to reduce product defects. Based on this result, this research was conducted to measure and make quality improvements in order to reduce defects during the welding process by using DMAIC (define-measure-analyze-improve-control) at the Six Sigma approach.

1.1 Literature Review

The quality of the products that the company produces should focus on customer requirements [2]. Companies should produce quality products by applying the concept of zero defect, or zero error rate as the goal of quality. This concept leads to the lowest possible product error rate, even until there is no error. The quality is the overall characteristics of a product or service that supports the ability to satisfy needs [11]. Quality control can be defined as activities carried out to monitor activities and ensure actual performance [10]. Control and supervision are activities carried out to ensure that production and operation activities carried out per as planned, and if deviations occur, these deviations can be corrected to achieve the expected target. Quality control is an effort to maintain the quality/quality of the goods produced to meet predetermined product specifications [1]. Quality control is a technique and activity, or planned action carried out to achieve, maintain, and improve the quality of a product and service to achieve predetermined standards and can meet consumer satisfaction. The production process needs to be designed to facilitate quality control [12]. Quality control cannot be separated from production control because quality control is part of production control. Production control, both in quality and quantity, is a significant activity in a company.

1.1.1 Six Sigma. Six Sigma has a strategic goal to reduce the occurrence of defects in a production process with the ultimate goal of reducing process variations through special improvement programs and structured methods [13]. The defect is a deviation from predetermined specifications. The sigma quality level is usually also used to describe the output of a process [4]. Six sigma results are associated with a lower level of tolerance given to a product or service through the improvement of the process capability. Six Sigma is a tool or systematic method for process improvement and new product development based on statistical and scientific methods to reduce the number of defects defined by consumers [8]. Six Sigma levels are often associated with process capabilities defined in terms of defects per million opportunities (DPMO). The process of improvement in Six Sigma is known as DMAIC (Define, Measure, Analyze, Improve, Control). DMAIC is a process for continuous improvement towards Six Sigma targets. DMAIC is carried out systematically, based on science and facts. The successful implementation of programs on improving Six Sigma quality is shown through the improvement of process capabilities in producing products towards zero failure rates [7]. The concept of calculating process capability is fundamental to understand and implement the Six Sigma program.

Define is a step determined by the company to determine problem selection and analyze the benefits obtained. Define is the first step in the Six Sigma quality improvement program [6]. At this stage we need to identify several things related to the six sigma project selection criteria, the roles and responsibilities of people who will be involved in the Six Sigma project, training needs for people involved in the six sigma project, the processes involved determine the quality of the product and the specific requirements of the customer. This stage also determines the calculation of the initial sigma level for a particular data period [5]. The measuring stage is carried out with three main issues, firstly, establishing a CTQ (Critical to Quality) which is directly related to the specific needs of the customer which is derived directly from the output and service requirements, secondly investigates and observes to obtain data, the third stage is to set goals setting on output and outcome levels. The Analyze stage is used by analyzing the stability and process capability, determining the performance targets of the key quality characteristics (CTQ) that will be improved in the Six Sigma project, and identifying the root causes of defects or failures [6].

The fifth stage is to improve by making action plans (action plans) regarding the allocation of resources as well as priorities and alternatives to implement the plan. The supervision and efforts through data collection and analysis when implementing a plan must also be planned at this stage, to decide what should be achieved (related to the targets set). The action plan describes the plan in terms of what, where, when, how the action will be implemented. The action plan also indicated how much it would cost and the associated benefits. The last stage is controlling by adjusting the process management and control system so that there is continuous improvement. Designing a process system that may be carried out and maintained so that the system becomes standardized and documented [12].

2. Research Method

This method is a stage of mapping the process by searching, obtaining, collecting, or recording data, both in the form of primary data and secondary data to analyze factors related to the condition of the company [11]. The quality control is performed by checking periodically at each stage of the construction project with the DMAIC stage (Define, Measure, Analyze, Improve, Control) approach [6,7]. This process determines the quality of steel welding under the criteria set by the consumers [7]. The companies are companies that provide physical infrastructure. This study has a flow chart shown in Figure 1.

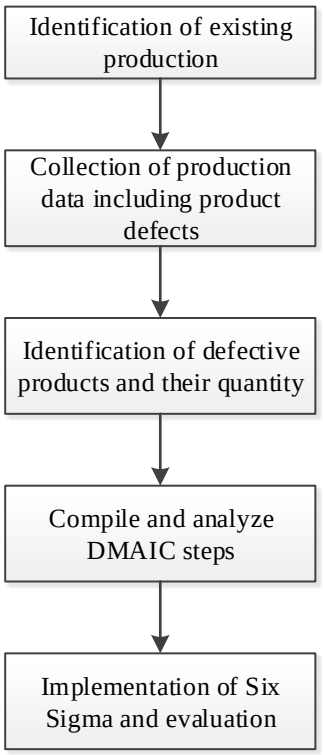

Figure 1. Flowchart of Six Sigma Implementation

3. Six Sigma Project and Discussion

The research analysis uses the six-sigma method, which consists of five stages, namely define, measure, analyze, improve, and control in a welding company

3.1. Define Stage

The stage is the stage of defining quality problems in the welding result. Six Sigma focuses on defects and variations by starting with the identification of the Critical to Quality (CTQ) elements of the product. At this stage, what causes the product to experience a defect is defined as the cause as well. Critical to

quality are the attributes of welding products that are considered essential to customers. The results of observation and analysis of secondary data collection in the welding process identified the five causes of the highest defect products, namely porosity, undercut, slag, crack, and spatter defects. In this stage, the goals and objectives of improving six sigma quality are based on observations by reducing or reducing the defected product from 21.6% to 15%.

3.2. Measuring stage

The measuring is done by creating a check sheet. Check sheets are used for the data collection process and data analysis. Also, it is useful for knowing the problem area based on the frequency of the type or cause and making decisions to make improvements or not. Table 2 shows the cause of the defect in the welding process from June 2019 to June 2020

Table 2. Data of defect type

No	Month	Products (Pcs)	Type of Defect				
			Porosity	Undercut	*Slag*	*Crack*	*Spatter*
1	July 2019	644	51	43	24	31	22
2	August 2019	1022	52	36	29	35	42
3	September 2019	974	43	40	36	32	31
4	October 2019	734	47	26	23	34	22
5	November 2019	849	42	28	26	29	31
6	December 2019	1119	46	37	36	39	39
7	January 2020	1109	61	36	41	52	36
8	February 2020	1235	74	68	45	43	46
9	March 2020	1331	86	79	47	47	52
10	April 2020	1254	81	76	43	49	49
11	May 2020	1109	65	72	38	52	37
12	June 2020	1119	68	74	42	56	39
	Total	12,499	716	615	430	499	446
	Mean	1,042	59.67	51.25	35.83	41.58	37.17

Table 2 demonstrated the biggest flaw in porosity with the number of 716 pcs and followed by the undercut of 615 pcs, slag of 430 pcs 499 pcs, and the crack of the last spatter 44 pcs. The defects were found in the first stage of the process. All pieces passed to the next process have met the criteria. Further processing is carried out by setting the welding result in the sigma value, as shown in Table 3.

Table 3. The setting of six sigma level

Month	Production (Pcs)	Number of Defects (Pcs)	DPMO Value	Sigma Level
July 2019	644	154	59,782.61	3.0566
August 2019	1022	194	47,455.97	3.1700
September 2019	974	182	46,714.58	3.1776
October 2019	734	152	51,771.12	3.1279
November 2019	849	156	45,936.40	3.1856
December 2019	1119	215	48,033.96	3.1642
January 2020	1109	231	52,073.94	3.1251
February 2020	1235	276	55,870.45	3.0904
March 2020	1331	311	58,414.73	3.0682

Month	Production (Pcs)	Number of Defects (Pcs)	DPMO Value	Sigma Level
April 2020	1254	298	59,409.89	3.0597
May 2020	1109	264	59,513.07	3.0589
June 2020	1119	279	62,332.44	3.0355
Average	1,041.58	226	53,942.43	3.1100

From the results of the calculations in Table 3, the production results in welding have a sigma level of 3.1100. This result is, of course, a considerable loss if not handled, because the more welding products are not standard, of course, result in swelling of production costs.

3.3. Analyze stage

Stages The next stage is to determine the stability and capability of the process. Determine the performance targets of the key quality characteristics (CTQ) that will be improved in the Six Sigma project. Identify the root causes of defects or failures. After knowing the types of defects that occur, corrective steps are needed to prevent similar damage. The important thing that must be done and traced is to find the cause of the damage. As a tool to find the cause of the porosity failure, a cause and effect diagram is used and the cause of the defect is found due to the machine is a less standard inverter setting, current connector, defects caused by the material are corrosion, lack of material cleanliness, the welding arc is too long, the welding current is too low, and the travel speed is too high. The cause of the method is the relatively global standard operating procedure, the electrodes used are still damp or exposed to water, and the implementation of the method does not work well. The causes of porosity defect are shown in the fish bone diagram (Figure 2).

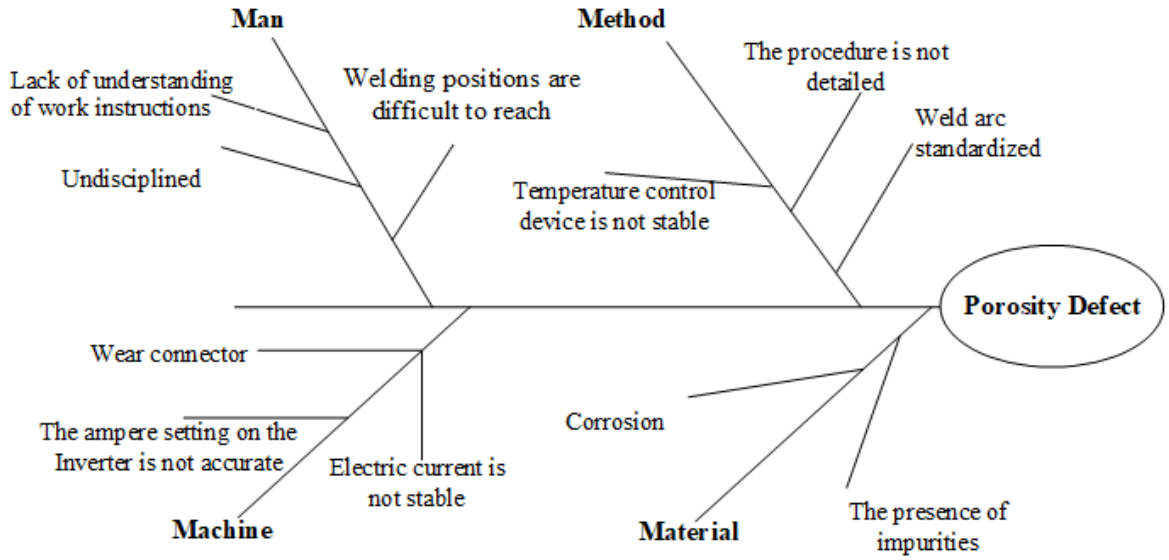

Figure 2. Fish Bone Diagram for Porosity Defect

Undercut defects are caused by several factors, namely the material is too high the electrode, the arc length as the material is too high, the welding current applied by operator is too high, the travel speed/welding speed is too high. The defects caused by the method are the uneven hand swing, the swing time on the side is too fast, and the standard hand restraint needs to be made so that the hand does not shake.

There are two kinds of Crack welding results, Hot Crack defect (hot crack) is a crack in the welding where the crack occurs after the welding process is complete or when the weld metal solidification process. Cold Cracking (cold cracking) is a crack that occurs in the weld area after some time (it takes time, can be 1 minute, 1 hour, or one day); the welding process is complete. Usually, to check for cracks, a test is carried out, namely the Penetrant Test or Magnetic Test. Crack defects of the material are caused by dirty material and the wrong type of electrode, while for machines, the current is too high, and the travel speed is too high. While the spatter defect is caused by the material, the amperage of the instrument is too high, and the travel speed is too high. Meanwhile, what is caused by the method is that the electrodes used are still damp or exposed to water, and the hand swing is too fast. The occurrence of Welding Defect Slag Inclusion is a defect that occurs in the area in the weld. This defect is in the form of slag (melting flux) that is in the weld, which often occurs in the stop and run area (beginning and stopping of the welding process). To see this defect, we must perform radiographic or bending tests.

3.4. Stages Improve

Action plan to implement Six Sigma quality improvement. After knowing the cause of product defects from welding results, a recommendation or recommendation for general corrective action is prepared in an effort to reduce the level of product damage. The porosity failure was carried out by improving the standard operating procedure, replacing the current connector component and setting the inverter according to the standard, and cleaning the material before the welding process. The action plan for undercut defects is carried out by training employees to understand better, establishing work instructions in carrying out work, establishing appropriate standard operating procedures, adjusting welding currents, taking into account standardized amperes, and wrapped in electrodes or WPS (Welding Procedure Specification), setting settings. Re-welding current and welding travel and setting the arc length to be shortened or as high as 1.5 times the electrode diameter.

The action plan for crack defects is to use electrodes that are compatible with WPS or Low Hydrogen which have high tensile properties, conduct heat treatment, set the recommended current to match the standard, travel speed of welding is not too fast concerning WPS, determine the carbon equivalent material above 0.40 must be preheated. Meanwhile, the action plan caused by a spatter defect is that the current is lowered according to the standards set in the work instructions, the electrode is oven according to the handbook (especially low hydrogen welding wire), and the arc length is set at 1.5 times the electrode diameter. Finally, the action on slag defects is that the Ampere quantity is measured in advance and adjusted to the procedure, ensuring that the material is spotless of slag before being carried out before re-welding, and the arc as material needs to be adjusted.

3.5. Control

This stage is the final stage of the Six Sigma project, which emphasizes documenting and disseminating the actions that have been taken. The documentation includes maintaining and repairing welding machines and connectors regularly, monitoring the condition and cleanliness of materials, providing periodic guidance to welding operators with explaining adequate welding procedures, and develop a welding field development program for welding operators through a job training program. With the implementation of the use of the Six Sigma method, the calculation result of the sigma level is 3.1100, where the initial condition of the defect level of the production is 21.6%. Quality control dramatically affects the productivity level of the production process. This result is evidenced by a decrease in the defect rate of the welding products to 15%.

4. Conclusions

The number of welding process results include 5 types of defects, namely 724 pcs porosity defects, 613 undercut defects, 435 pcs slag defects, 491 pcs crack defects, 449 pcs spatter defects. The findings have a sigma level of 3.1100 DPMO. The factors that cause welding defects are due to imperfect standard operating procedures, the welding method used does not follow welding standards, the material is not well controlled, especially the electrodes used when welding, and the lack of maintenance of the welding

machine. The stages of repairs carried out are socializing standard operating procedures, maintaining the cleanliness of raw materials before repeated welding and welding, regular checking of welding equipment and raw materials, and maintaining the workshop in conditions that meet the requirements of the welding process.

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