ISSN 2087-3336 (Print) | 2721-4729 (Online)

TEKNOSAINS: Jurnal Sains, Teknologi dan Informatika
Vol. 11, No. 02, July 2024, page. 257-267
http://jurnal.sttmcileungsi.ac.id/index.php/tekno
DOI: 10.37373

Analysis of reject pinhole hardfacing process for stellite alloy metal motorcycle engine valves

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Submitted: 14/01/2024 Revised: 08/03/2024 Accepted: 11/03/2024

ABSTRACT

If businesses wish to compete in the industrial world, they must produce quality and process results. No matter how big or little, some goods will always fail to generate or be rejected in a production process. In this case, companies in the automobile sector have noticed an increase in the number of pinholes that have been returned during the past three months. The company established a maximum reject rate of 0.9% each month based on the rejected data; from May to July, the average reject rate was 0.23%. Finding the factors causing the surge in pinhole rejects that occurred between May and July is the aim of this investigation. The analysis showed that the increase in pinhole rejects was caused by a variety of variables, including machine, process, and human factors. Further examination disclosed alterations to the device's configuration and software, along with the operator's persistent incapacity to comprehend the process. As operations become less efficient, repair components build up in the manufacturing line area. As a result, an improvement plan is needed, which is put into action by giving operator training and rearranging the machine and its software according to process requirements. Operators with a greater understanding of the process yield better results and higher productivity. As a result, operator confidence will rise along with performance. It was discovered that after developments in the field of human resource development, the number of rejections had dropped. Before the repair was finished, the average reject from May to July 2023 was 0.23%; following the repair, the average reject from August to October 2023 was 0.09%.

Keywords: Fishbone schematic; PDCA; hardfacing; stellite; 5W+1H.

1. INTRODUCTION

Businesses that wish to compete in the industrial world must improve the quality and outcomes of their processes. There is no doubt that every business has quality requirements, and minimizing rejects during the production process is a top concern to save costs and boost customer confidence [1].

One of the manufacturers of internal combustion engine valves for a range of cars and motorcycles. The company always conducts research and develops new technologies to modify the engine valves or valves it manufactures. Companies must constantly maintain and improve the quality of their products in addition to innovating by reducing the number of product rejects [2].

Motorcycle engine valve manufacture is an extremely vital step since it increases the valve's hardness [3]. The hardening procedure in the seating face area (valve edge) is one component of the engine valve [4]. By adding stellite alloy metal material during the welding process, the valve edges are hardened [5].

Because there is always a chance that a product will be rejected during the production process, rejects are an aspect that needs to be managed by each department [6]. Every month, we encounter a variety of rejected goods in the hardfacing process, representing a range of reject categories. The

hardfacing of the stellite alloy on the seating face area results in reject pinholes. Hardfacing is a welding procedure that is typically applied to workpieces that need a high level of wear resistance. It adds material to the surface of other welding materials or workpieces [7].

When the air gets trapped in the hardfacing process, a reject pinhole form. This causes the item's quality status to be declared "NG" because it can weaken the valve itself and have potentially fatal consequences if it is installed on an engine. Deformation or rupture will also occur during the engine process [8]. The reject pinhole's form is depicted in Figure 1.

Figure 1. Reject pinholes.

Every month, a variety of rejected items with a range of reject types go through the hardfacing procedure. But during the past three months, there has been a noticeable rise in the quantity of pinhole rejects.

In light of these issues, businesses must use quality control measures to reduce the quantity of rejections to meet the designated rejection targets [9]. The PDCA cycle and the fishbone diagram are two fundamental quality control tools that can be used in quality control operations (Plan Do, Check, Action) [10].

2. METHOD

A research study's truth is sought through a sequence of activity steps known as research techniques [11]. This section on methods describes how to gather the necessary data and handle the acquired data.

2.1 Flowchart

Figure 2 displays the research flow diagram along with the stages that were completed:

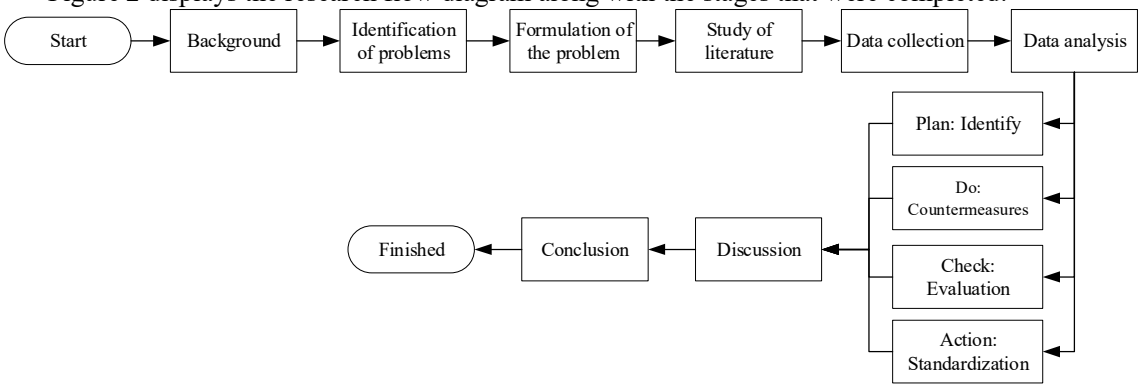

Figure 2. Research flow diagram.

2.2 Types of research

Verbal sentences from the study object are used in descriptive analysis, which is produced by qualitative research, a method based on views of a phenomenon with a data approach [12]. In quantitative research, logical patterns and nomothetic principles are strictly applied during the ideation and concept-formation process. This is a scientific research method [13].

Descriptive research is the type of study that is conducted with the goal of methodically and factually resolving current issues. The research samples included in this study came from motorcycle engine valve production reject data collected between May and July of 2023.

2.3 Types of data and information

The details and kinds of data required to complete this study. Both qualitative and quantitative data were employed in this study; qualitative data took the form of details regarding the flow of production processes for products [14]. On the other hand, quantitative data are those that are based on numbers and may be utilized to compare production results [15]. The data used in this study is secondary data, meaning that it was gathered via supporting documentation for product standards rather than directly from the research item.

3 RESULTS AND DISCUSSION

Several preliminary steps, such as setting up the machine and the materials to be processed, precede the actual production process. The production method used relates to outcomes that meet business requirements [16]. In addition, time efficiency needs to be taken into account to meet production goals. The production flow is depicted in Figure 3.

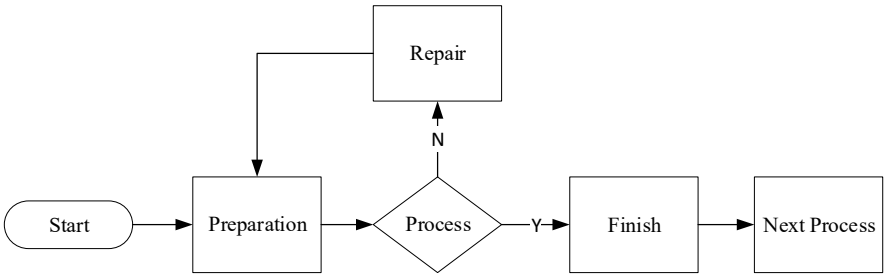

Figure 3. Hardfacing process flow.

The engine valve edge area is subjected to a hardfacing procedure that involves fusing stellite material to boost hardness [17]. Every month, a variety of goods are rejected throughout the hardfacing process; but, between May and July of 2023, there was a noticeable increase in the quantity of pinhole rejects. Table 1 contains information on the quantity of production and production rejections based on observations of the production process.

Table 1. Production reject data.

Month	Production Data (pcs)	Data Reject (pcs)	Reject Percentage
January	553.000	553	0.10%
Februari	615.103	677	0.11%
Maret	564.226	508	0.09%
April	375.000	563	0.15%
Mei	375.000	940	0.25%
Juni	464.000	975	0.21%
Juli	471.000	1130	0.24%

Production data from January to July 2023 is displayed in Table 1, with varying reject numbers for each month. In the past three months, there has been a noticeable rise in the number of rejections.

3.1 Data Processing and Analysis

The planning stage of the PDCA cycle is the initial step that seeks to identify the primary causes of production process issues. To identify the root cause of the issue, several strategies need to be decided upon.

Figure 4 shows the reject data graph for production from January to July 2023. It shows that there was an average 0.23% increase in rejects from May to July 2023. This percentage is much higher than the company's monthly rejection target of approximately 0.9%.

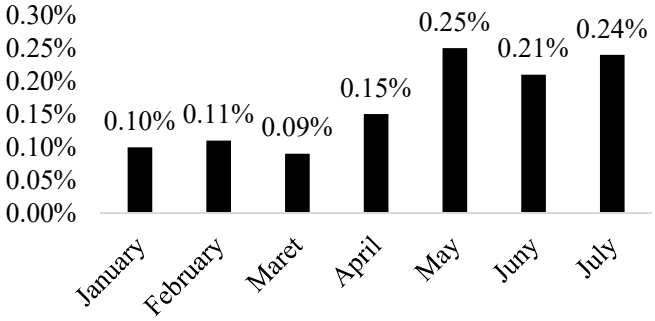

Figure 4. Grafik rejects pinhole.

As for calculating the average increase in rejects in the period May – July

$$Average\ Reject = \frac{Number\ of\ rejects\ May-July}{Amount\ Data} \times 100\% \quad (1)$$

The acquired data is then examined in light of the current circumstances to determine the issues causing the rise in rejects [18]. Table 2 displays the outcomes of the discussion the researcher had with several relevant employees to analyze the actual scenario and determine the current circumstances.

Table 2. Analysis of existing conditions

Factor	Findings
Machine	The barber angle slope is not standard
Machine	The inclination angle of the stellite bar is not standard
Machine	The results of the blasting process are not clean
Method	The results of the process contain small holes
Method	Gas pressure is unstable
Method	The result of the process is a step in the underhead area
Man	Operator skills vary

The discussion's conclusions indicate that machine issues, process factors, and human factors are the three primary causes of the pinhole reject issue [19].

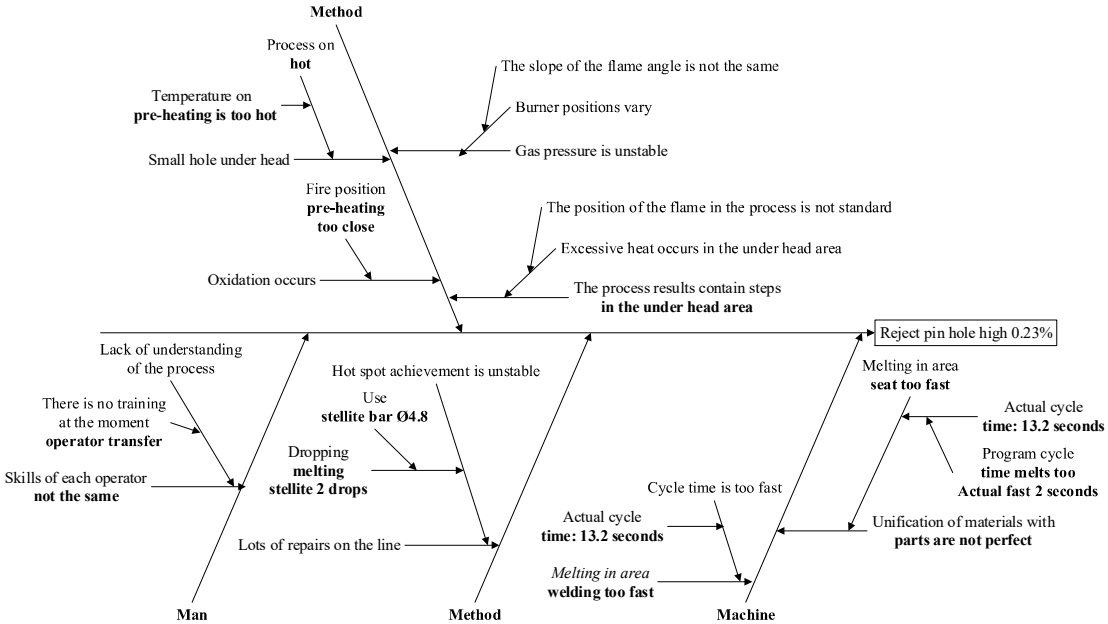

Figure 5. Cause and effect diagram.

Three key components were discovered to have the most influence on the pinhole reject problem based on the study from the cause and effect diagram.

a. Engine factor: The device that hardfaces the stellite alloy on motorcycle engine valves or valve edge areas is known as the engine factor. There are two issues. The first is that the melting cycle time program is set too quickly, which causes the melting in the seat area to occur too quickly. This results in a less than ideal fusion of the stellite material and the valve material. Furthermore, it was discovered that the excessively rapid cycle time was the reason behind the excessive melting in the welding area.
b. Method factor: The number of pieces mended in a row, various findings, and the process method used in the stellite alloy hardfacing process make up the method factor. Oxidation-prone parts go through several steps in the process, which ends with unstable gas pressure.
c. Human factors: Processes are impacted by operator skill differences, frequent operator turnover, and inadequate training of new operators, which results in operators not understanding each process's protocols.

Using the 5W + 1H approach (What, Who, Where, When, Why, and How), table 3 should be used to build remedies against pinhole rejects.

Table 3. Mitigation plan.

Faktor	What	Who	Where	When	Why	How
Machine	Melting time is too fast	Production team	In the production process	July 2023	There is still air trapped in the material	Trial adding stirring time after the stellite material drips
Machine	Cycle time is too fast	Production team	In the production process	July 2023	There is still air trapped in the material	The addition of melting time affects the overall total time, the cycle time is increased
Method	Use of stellite bar material no. 6 Ø4.8	Production team	In the production section	July 2023	Lots of repairs on the line	Replacing the use of stellite bar no. 6 Ø6.0
Method	The position of the pre-heating flame is too close to the seat area	Production team	In the production section	July 2023	Oxidation occurs in the seat area	Change the position of the fire according to the standard, namely in the middle between the embankment and the straight line of steam
Method	The pre-heating temperature is too hot, the temperature reaches 1100 ºC	Production team	In the production section	July 2023	There were small holes	Lower the pre-heating temperature according to the process visual.

Method	The burner angle in the welding process is not the same	Production team	In the production section	July 2023	Fire pressure varies	A standard angle is made that is suitable for the welding process stage
Method	Fire position number 4 is too forward	Production team	In the production section	July 2023	Steps occur	Fire position number 4 is lowered to a fire position right in the middle of the seating area
Man	Frequent operator changes occur	Production team	In the production section	July 2023	Operator skills are not the same, problem handlers have low response	Operator training before entering the line and operator rolling is carried out annually

In determining targets, use the SMART method as follows:

a. Specific; Reduces reject pinhole.
b. Measurable: Reject fell from 0.23% to 0.09%.
c. Attainable: Targets can be achieved by maximizing member abilities and skills.
d. Realistic: Targets are by management's decisions regarding quality.
e. Timelines: The problem resolution target is 3 months.

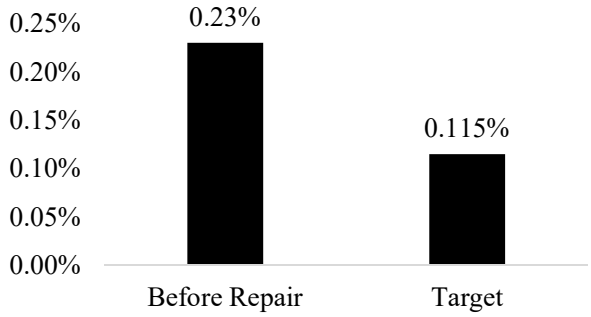

Figure 6. Reject reduction target.

Determining targets that are realistic and have a set time, and improvement progress that can be measured. Figure 6. The target after improvements have been made decreases with a target of 0.115%.

3.2 Do Phase (Implementation)

Table 4: plan stage, next stage of implementation (do) as a problem handling stage using the 5W + 1H method.

Table 4. Implementation of problem management with 5W + 1H.

Factor	What		Who	Where	When	Why	How
	Cause	Repair					
Machine	Melting time is too fast Melting: 2 seconds	Increase melting time Melting: 3 seconds	Production team	In the production section	July 2023	Visual formation is easier, the process results in no air bubbles on the valve surface	Program settings

Machine	Cycle time is too fast, namely 13.2 seconds	Changing the drip program will change the overall cycle time, countermeasure 1 as well as countermeasure 2	Production team	In the production section	July 2023	Cycle time increases to 13.7 seconds	Program settings
Method	The use of stellite material no. 6 Ø 4.8 to cover the entire area must go through 2x dripping	Replacing the material stellite no. 6 Ø 4.8 to stellite no. 6 Ø 6.0 Before: 2x drops	Production team	In the production section	July 2023	The process results are better with 1x drop immediately covering the entire seat area After: 1x drop	Experiment with materials with different diameters
Method	Flame position number 2 (pre-heating) is too close to the seat area	Fire number 2 (pre-heating) was moved to the embankment area	Production team	In the production section	July 2023	The heat of the fire in the seat area is reduced and the heat spreads more evenly from the neck area to the seat area	Machine settings
Method	The pre-heating temperature is too hot, the temperature reaches 1100 ºC	The temperature is lowered until you get the best visuals 1. 1050º 2. 1000º 3. 950º	Production team	In the production section	July 2023	1. During the welding process, the droplets immediately flow to the full seat area. 2. During the welding process, the droplets only cover 2/3 of the seat area. 3. During the welding process, only half of the seat area is filled. d. Standard set: 1050º ± 30º	Program settings

Method	The burner flame angles 3 and 4 are not the same Flame angle 3: 13º Flame angle 4: 9º	Experiment with burner angles until you get the best results for the process 1. 8º ± 2º 2. 11º ± 2º 1.3. 14º ± 2º	Production team	In the production section	July 2023	From the trial results, new rejects emerged 1. The melting seat is too low 2. OK, good 3. Too above the window seat. Stand: 11º ± 2º	Machine settings
Method	Fire position number 4 is too forward	Set position number 4 in the middle of the seat area	Production team	In the production section	July 2023	The seat area is all filled and the results are smooth	Machine settings
Man	There is often a change in operator/process with a replacement operator	Training by leaders and foreman on understanding the process, types of rejects and their handling	Production team	In the production section	July 2023	Operators understand more about the process, understand abnormalities and how to deal with them	Conduct training to operators

3.2 Check stage

The third step in the PDCA process is called the check stage [20]. At this point, data before and after the repair are compared to evaluate the changes made once the improvement implementation operations have been finished. Evaluation of results**, t**able 5 below shows production and reject data from August to October.

Table 5. Production and reject data for August – October.

No.	Type	Production	Reject	%
1	August	510.574	562	0.11
2	September	517.217	467	0.09
3	October	434.997	305	0.07

Table 5 production and reject statistics are then re-presented graphically to illustrate the monthly drop in rejects. A graph of the decrease in pinhole rejects is presented in Figure 7.

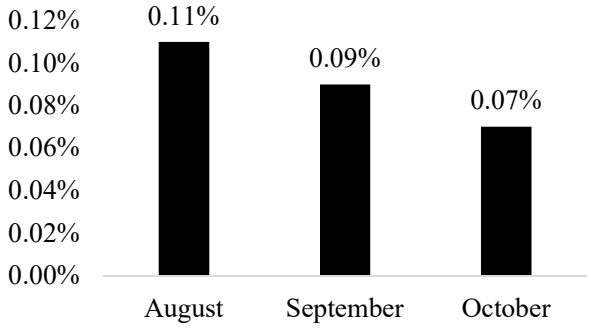

Figure 7. Evaluation of reject pinhole results.

Comparison of results, The results that have been obtained are compared before and after the repair. Figure 8 shows a comparison before and after improvement.

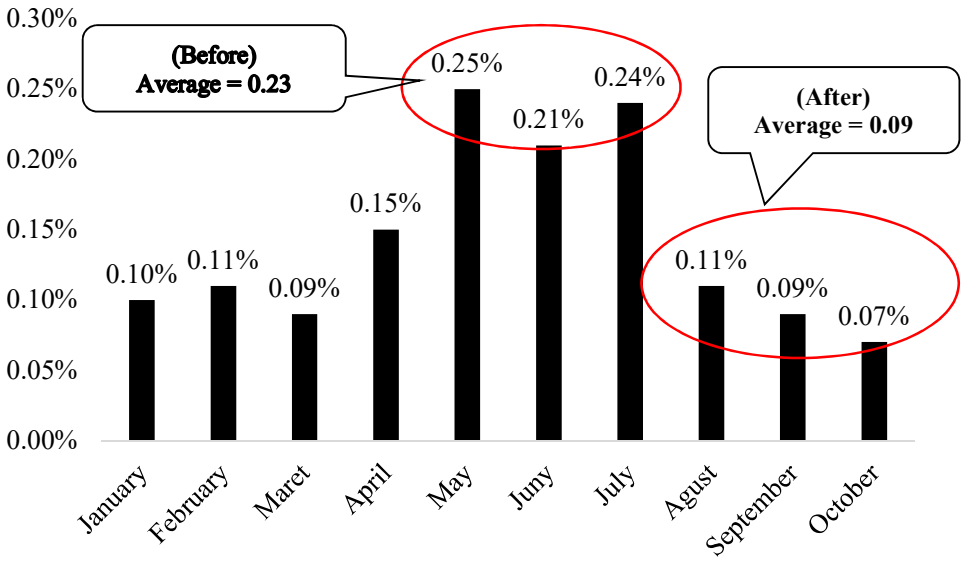

Figure 8. Comparison graph of repair results.

Figure 8 illustrates how rejects fell in August, with an average reject of 0.11% through October. In addition to decreasing rejects, the improvement outcomes have other advantages. The average reject rate is 0.07%. Advantages in terms of QCDSMPE (environment, productivity, morale, safety, cost, delivery, and quality):

1) Quality: The effects of enhancements lead to higher-quality production outcomes based on the quality. It is known that the KJ ex type's NG valve was at 0.23% before repair; following repair, which involved resetting the engine and software, the NG was discovered to be at 0.09%.
2) Cost: The expenses a business bears when conducting business.
3) Delivery: Delivery entails moving items on to the subsequent step. Delivery of goods to the following process increases as a result of a decrease in the reject number, and it also occurs more smoothly.
4) Safety: The study's main goal is to minimize returned items so that it won't affect safety.
5) Morale: A happier workplace is produced by operators feeling more confidence as a result of less rejection.
6) Productivity: Production volume will inevitably rise as rejects decline.
7) Environment: The state of having an impact on the environment is the environment. Because there are fewer rejected pinholes, fewer things are thrown away, resulting in fewer waste products.

The action stage is the last phase in the PDCA process. With the intention of managing the standardization of the product process, the action stage comes next. Table 6 provides an initial reference for process settings in the basic manufacturing process configuration.

Table 6. Standardization of evaluation results.

	Basic set up proses	
Acuan	**Before repairs**	**After repair**
Temperature	1100ºC	1050ºC
Burner angle	13º	11º
Cycle time	13.2 seconds	13.7 seconds
Material	Ø4.8	Ø6.0

After then, the evaluation's findings are standardized to ensure that the production process keeps moving forward in line with its goals. Several standard points, such as temperature, burner angle, cycle time, and material, have been altered in table 7 since they have a significant impact on the process.

4 CONCLUSION

It can be inferred as follows based on the outcomes of the processing and analysis that has been done: 1) Based on the analysis's findings, it was discovered that a number of variables, including machine, process, and human factors, contribute to pinhole rejects. 2) The machine's program and settings are the main causes of pinhole rejects, according to the results of data processing using the PDCA method, as these two factors are directly related to the manufacturing process. Because of this, process standardization—which involves both machine program changes and resets—is implemented to reduce the likelihood of rejects. Following re-standardization, operators undergo additional training to help them comprehend the process better, recognize irregularities, and know how to handle them. 3) It was discovered that the reject rate had dropped after the repairs were completed. The average reject from May to July was 0.23% before the repairs, but from August to October, the average reject was just 0.09%.

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