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# Process Assurance Capability Analysis Based on Capability Process, Detection Process Capabilities and Irregular Condition Actions in Automotive Industry

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*Abstract* - **Rail roof side is an automotive product with high quality specifications. In the manufacturing process, there are unstable process issues that cause variations in size. On the other hand, the process abnormality detection system occurs at the end of the production process, so potential defects cannot be detected during the process. This study aims to ensure stable process quality so that defective products can be detected during the manufacturing process. The quality assurance process uses an approach based on process stability score, known as Cpk. The capability of process detection devices derived from the quality control technology used, and the ability to address irregular conditions identified through human capability to take action when process abnormalities occur. Based on the calculation of process quality assurance capability, a rank value of 1.70 indicates that the quality assurance system has been achieved. This means that the process assurance status is capable of preventing and detecting process variation issues and defects from the start of the process.**

***Keywords*** – *Assurance, Capability, Defect, Detection, Variation.*

## INTRODUCTION

New products reach consumers through the product development stage and mass production stage. Successful product development begins with the process of designing product quality, implementing and verifying the stability of the production process. Problems in the product development stage include variations and discrepancies of up to 75% compared to variations during mass production [1]. In the automotive manufacturing industry, the development stage of car body parts experiences instability during the component manufacturing and assembly processes, requiring improvements to tooling and machine parameter [2].

Metal sheet body parts are unique products that require precise specification [3]. This is because the parts are assembled to form a vehicle unit. Body parts with low dimensional accuracy cannot be assembled with other components. The industry will suffer losses in the form of high production costs because defective products cannot be repaired and Tier 1 companies as consumers will be dissatisfied because the products do not meet specifications. The Tier 1 company verifies and selects subcontractors and distributes purchase orders to subcontractors. The Tier 1 company is also responsible for raw material preparation mixed with product specifications [4].

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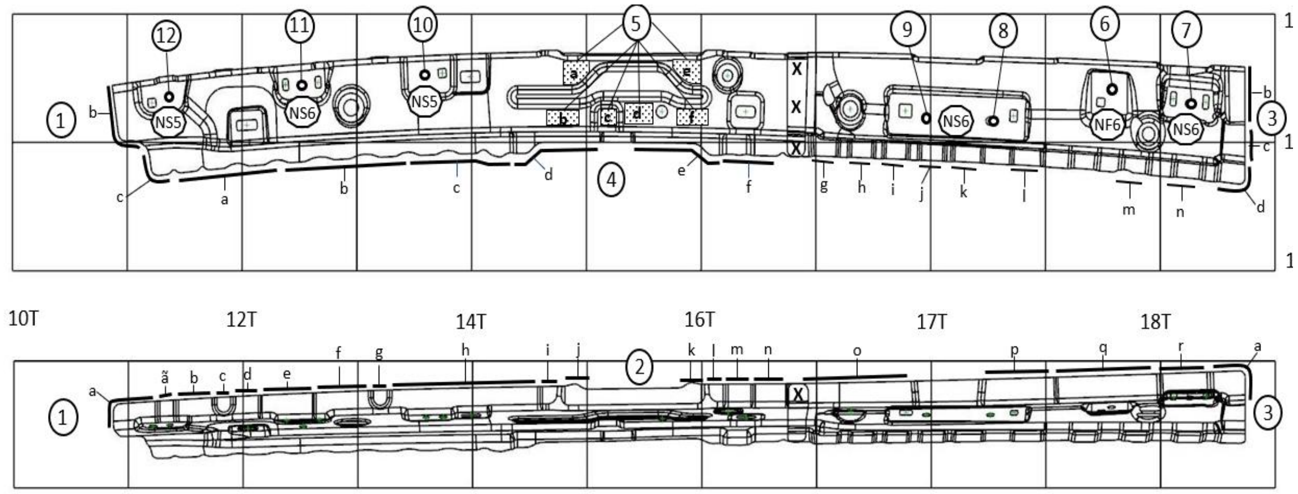

Figure 1. Inspection Point Rail Roof Side

The data used in this study is the development process of the rail roof product, which is the upper part of the car frame in figure 1. The inspection point is the part that requires high dimensional accuracy and no variation [5]. The production process complies with IATF 16949 Quality management systems requirements for automotive production and relevant service part organisations [6]. Manufacturing process capability is measured using process capability values that describe manufacturing performance [7]. Process capability indicates the level of consistency in the manufacturing process in producing components and specifications. Process capability over a certain period of time is measured using the process capability index. The capability index consists of capability (Cp) and Performance (Cpk) as measurement tools to determine the current product development process conditions [8].

Process stability measurements indicate inspection points where the process is unstable, as indicated by a Cpk value < 1.33. This value indicates variation in the pressing and welding processes caused by tooling dies that are unable to form components in accordance with specifications [2]. An unstable process causes defects and reduces customer satisfaction. Additionally, it disrupts production scheduling, potentially leading to product delivery delays. From an environmental perspective, defective body parts generate waste, resulting in material and energy wastage.

One phase of product prototype development involves product testing using either manual methods or automated equipment. Process abnormalities can be detected using sensor devices. In the development of the Rail Roof product, specification dimension testing is carried out after the production process is complete, so it cannot be done in real time during the process. The detection process faces the challenge of minimising anomalies in testing. Additionally, providing a real-time process accuracy detection system and minimising anomalies can reduce time and energy during product production [9]. Quality assurance system tools that determine the quality of the design process for electric vehicles include product consistency, compliance with standards, prevention of defects, economic efficiency, customer satisfaction (consumer properties), continuous improvement, supplier quality management, lean manufacturing [10].

This study is a continuation of the previous study by Abid et al [8] which designed a framework for verifying process assurance capabilities. This study aims to improve quality by verifying process assurance capabilities using the summation technique to measure production process stability. The process assurance verification process aims to prevent recurring issues and defects by classifying quality assurance status based on a systematic verification process of process assurance, detection capabilities and control of irregular conditions.

## METHOD

**Design, Place and Time**

The design, place and time are explained sequentially in paragraphs. The method of this research is quantitative research, namely conducting an analysis of the quality assurance capabilities of the automotive manufacturing process using variable capability index, process capability detection, and irregular condition actions. Data collection was conducted at a metal sheet stamping company that manufactures car bodies located in Karawang, Indonesia.

**Research Stages**

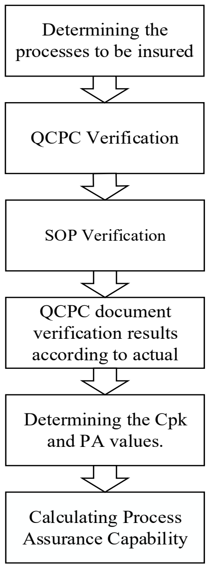


Figure 2. Quality Assurance Verification Process Flowchart

The quality assurance verification research for the manufacturing process in figure 2 consists of six stages [8], The first stage of this research determines the product items to be verified and sets a target rank to ensure that all processes are in place and none are overlooked. The second stage is the verification of the Quality Control Process Chart (QCPC), which involves comparing the actual process with the one documented in the QCPC. The third stage involves verifying the Standard Operating Procedures (SOP) of the process, which is reviewed by all department heads to ensure the process flow, executors and the details of the activities are in compliance. The fourth stage is the verification of actual processes at the QA verification stage to ensure that operations can be carried out in accordance with the applicable SOPs and the actions taken when irregular conditions occur. The fifth stage is calculating process capability in the form of the process stability index (Cpk). The final stage is calculating the process assurance value by summing the process stability index value, the process detection capability value, and the irregular condition action capability value.

**Data Processing and Analysis**

Process capability analysis is a tool for determining product conditions during development. The capability process index consists of capability and performance. The CP value indicates the value of the process that is within control of the specification control limits [11]. The ability of a process to produce products is measured statistically. In addition, the Cpk index measurement value is based on international standards. The process capability criteria are as follows [4], poor and incapable quality when Cpk is =< 1.00, fair quality when Cpk is < 1.67 and > 1.00, excellent and capable quality when Cpk is > 1.67, very excellent (6σ) when Cpk is equal to 1.67.

The automotive industry has methods for inspecting and detecting defects during the process. According to Abid et al [8], visual inspections are carried out during operations with a score of 0.8 and upon completion of operations with a score of 1.1. Inspections using manual checking tools are carried out during operations with a score of 1.0 and upon completion of operations with a score of 1.2. Inspections use quality assurance machine detection that functions as a warning during the work operation at a score of 1.0 and after the work operation at a score of 1.3. Inspections use quality assurance machine detection that functions as an interlock during the work operation at a score of 1.4 and after the work operation at a score of 1.4.

Confirmation points that operators must follow when irregular conditions occur [8], (1) Do not take action based on your own decision but follow the instructions of a leader who provides training. (2) Perform work operations based on clear procedures at all times. (3) Perform work operations based on the work sequence following procedures until 1 unit is completed. (4) Understand the issue first before reporting it to the leader. (5) Do not forcefully tighten and report immediately when there is an issue. (6) When asked to speed up work, report immediately to the leader/staff. (7) If there is an irregular issue, perform quality checks at the same level as usual operations. (8) If there is an abnormality in the jig/tool, report it immediately and use a normal tool. (9) If components are incomplete, perform a quality/specification check. (10) If a part falls and cannot be retrieved, report it immediately and record it in the inspection log. If irregular control measures are achieved, the score is 1. If not achieved, the score is 0.

Based on the mathematical model of Cpk value, the ranking of Process Assurance capability is obtained using the following formula (1) [8].

Rank Value = Cpk * K1a * K1b * K2 (1)

Rank Value : Quality Assurance
Cpk : Process stability score
K1a : Detection score during operation
K1b : Detection score after operation
K2 : Irregular condition action score

The target rank S process assurance has a value of 2.00, meaning it is achieved. Target rank A has a value of 1.50–1.99, meaning it is achieved. Target rank B has a value of 1.20–1.49, meaning it is not achieved. Target rank C has a value of 0.00–1.19.

## RESULTS AND DISCUSSION

### Determining The Processes to be Insured

Table 1 explains the classification of target items that must be carried out in the assembly welding process for rail roof products. The control items for this process are the system area surface with a standard specification of 5±0.5 mm. The determination of the process to be assured takes into account several considerations, including the identification of critical processes, process mapping and documentation, the establishment of standards and tolerances, the implementation of a quality assurance system and continuous improvement.

The rail roof has a critical process in the surface area, the specifications of which have an impact on vehicle quality. A surface size of 5±0.5 mm will facilitate the assembly process with other components. Conversely, sizes outside this tolerance range affect the welding quality of the curved rail roof product, as gaps between parts cause the two parts to pull against each other. Therefore, the forming of metal sheet stamping in the bending process is a priority process that must be guaranteed. An efficient stamping process design must include an inspection scheme through, (1) proactive diagnostic routines to monitor process performance while inspecting the product, (2) focusing on error detection rather than defect detection routines and (3) utilising closed-loop, feedback communications [12].

Table 1. Classification of Target Item

| Engineering drawing | Critical | Standard Inspection | Actual inspection | Past problems |
|---|---|---|---|---|
| Stamping process Part Rail Roof | Surface area | >5±0,5 mm | 5±0,5 mm | Request point check part adjust tolerance to control stability part.<br>Before : 5.0 +1.0 -0.<br>After : 5.5 ± 0.5 |

### QCPC Verification

Table 2. Quality Control Process Chart Verification

| Check Item | Purpose / Aim | Result |
|---|---|---|
| With or without Process Quality Control Table 1 | -Check if there is form (Process Quality Control Table 1) that has stated process design.<br>-If form is not completed, confirm that process design can be checked in other method. | O |
| Process design (Series) | -Check that process flow / assurance system are made so that problem will not occur easily.<br>-Check that assurance system of process are made so that problem can be detected when it occur. | O |
| With or without Process Quality Control Table II | -Check if there is form (Process Quality Control Table II) that can check control item and points along process flow.<br>-If the form not completed, confirm whether control item and points can be checked in other method. | O |
| Control item | -Whether control items and points are surely reflected to Process Quality Control Table. | O |
| Standard value | -Whether standard value is surely reflected to Process Quality Control Table by the value or in alternate way. | O |
| Check method | -Whether the check method (visual / sensory / jigs & tools, etc.) are specified clearly. | O |

| Check Item | Purpose / Aim | Result |
|---|---|---|
| Check frequency | -Whether check frequency (100% / each LOT / daily, etc.) are specified clearly. | O |
| Contents of past trouble | -Check that countermeasure for reoccurrence is added based on past troubles of its process and other similar process. | O |

Table 2 explains the quality control process chart verification, which consists of eight items that are controlled, namely QCPC I to ensure that the flowchart contains detailed information on the identity of the parts being produced, the process flow that explains the stages of the process from raw materials in the warehouse to the delivery of finished products to consumers. Additionally, it explains the bill of materials for the product. The process design is reviewed to ensure quality assurance is available at every stage to detect any issues that may arise. Verification of QCPC II is conducted to ensure the availability of standard values used to control each production process. The stages controlled in this process are product quality and machine parameters [13].

The results of the QCPC verification process show that 'O' indicates available and 'x' indicates unavailable. The verification process results show that in QCPC I, it was verified that the rail roof product consists of front roof and rear components and 6 mm flange nuts. It is known that the critical processes are forming, bending and piercing, which affect the quality of the surface dimensions. In this process, a process guarantee must be provided to prevent significant process variations. In QCPC II, the quality assurance process stages for product appearance, profile and machine parameters must comply with work instructions, engineering drawings, inspection checklists and machine parameter setting checklists. Each operator must visually confirm the process results for the stamping machine with start, middle and end checks at each production stage. Meanwhile, the assembly quality assurance process must have sensors on the jig to detect the process [14].

Table 3 explains the verification of SOPs using operation instruction documents that contain product dimension specifications, material types and critical inspection areas. This verification ensures that the stamping and welding processes meet consumer requirements. The processes at each work station are verified and adjusted to the actual process flow [15]. This stage also identifies potential process errors that could hinder production. Additionally, it improves the quality of the SOP to make it clearer, easier to understand and more effectively implementable. The final verification stage requires approval from the highest authority to ensure that every step in the SOP is accountable.

Table 3. Verify Operation Standards Based on Operation Instruction

| Check Item | Source process |
|---|---|
| With or without operation standards | O |
| Contents of problem TOP events | O |
| Quality characteristics / criteria | O |
| Operation point | O |
| Operation sequence | O |
| Jigs and tools used | O |
| Specified protector | O |
| Operation environment / difficulty | O |
| Derivation is switched | O |
| Re-check of forms | O |
| Equipment regular check | O |
| Contents of past trouble | O |

These SOPs have been verified by production, quality, engineering and the manufacturing director. The results of the verification of major issues in the process have been addressed with corrective actions in the FMEA. The manufacturing company has an RPN FMEA assessment standard, where an RPN value of 100 or higher (RPN $\geq$ 100) requires corrective actions to be taken for the root causes of the issues [16][17]. The SOP also includes quality standards in accordance with specifications. During the verification of operational points, it was determined that the operational methods can maintain control items/quality standards and the operational points have been concretely defined. The verification results of the operational procedure sequence have been established in an easy manner. This aims to anticipate issues that may arise if the procedures are not followed. Verification of jig and process equipment usage shows that the jigs/tools used have been determined, thus preventing misuse. Additionally, the frequency of inspections/routine replacements is appropriate. The method used for replacing tool components has also been determined accordingly.

Protector verification indicates statements that guide the use of specified protectors so that protectors are not used incorrectly during operations [18]. Operation constraint verification indicates that operations (processes) are completed within a specified time. In addition, operations can be carried out continuously for hours (one working hour per day). Verification of actions when the operation model is changed indicates that it has been determined. Furthermore, verify whether forms such as standard operating procedures are revised when there are changes or on a regular basis. Additionally, verify that inspection items, inspection frequencies, and inspection criteria are established in the pre-operational inspection table and the routine equipment and jig inspection table. Verify problem solving actions for the future.

**QCPC Document Verification Results According to Actual**

Table 4 explains the results of verifying standard operating procedures with actual processes to ensure that inspection methods/frequencies/measurement results are recorded and signed. The verification results for problem understanding indicate that operators can identify major problems/events occurring in the process and are able to take action. Quality criteria verification shows that control items and standard values have been measured/controlled. Verification of operating points and their understanding shows that operators have performed actual operations in accordance with process specifications and that operators understand the operating points. Verification of the sequence of operations shows that operators have complied with the operating procedures specified in the process specifications. Additionally, the operator has understood the issues that are expected to occur if the procedures are not followed. Verification of the tools or equipment used in the operation shows that the operator has used the assigned tools/equipment correctly. Additionally, regular inspections/ replacements of tools have been carried out at the specified frequency.

Table 4. Verify Actual Operation Based on Operation Standards

| Check Item | Source process |
|---|---|
| Check frequency of operation standard: | O |
| Understanding of problem | O |
| Quality characteristics / criteria | O |
| Operation point and its understanding | O |
| Operation sequence | O |
| Jigs / Tools used | O |
| Specified protector | O |
| Operation environment / difficulty | O |
| Preoperational check equipment | O |
| Check process (next step) | O |
| History of quality problem | O |
| Derivation is switched | O |
| Re-check of forms | X |
| Contents of past troubles | O |

The verification process uses protective equipment in the form of sensors that detect welding nut failure. Operators must be able to identify the sensor's detection results if there are unfavourable conditions. Figure 3 explains how this sensor works to detect potential nut missing, nut not installed, insufficient number of nuts, and loose nuts. If there is a potential failure, the sensor will give a warning signal.

Figure 3. Sensor Assembly Welding

Pre-operational inspection by routinely checking equipment/jigs in accordance with the standard inspection table and equipment and jig operating frequency. Equipment inspections are carried out every 3 months.

**Determining the Cpk and PA Values**

Figure 4 shows the level of process stability at the Rail Roof Side product inspection point, where one inspection point is unstable due to process variation. The factors causing this inspection point to be unstable are influenced by material variation, equipment and machine variation, work method variation, operator skill variation during operation, and work environment variation. Process control measures to reduce variations in the Rail Roof Side production process include [2]. (1) Updating machine stamping setup parameters, particularly Die Height (DH) and Stamp End Block [19]. (2) Analysing die tooling design using 3D simulation to identify tooling areas causing process instability. The results of 3D simulation can show die formation damage, thereby assisting in proposing improvements to punch parameter settings [20]. (3) Ensuring the accuracy and precision of measurements using Measurement System Analysis (4) Conducting real-time or periodic process monitoring [21].

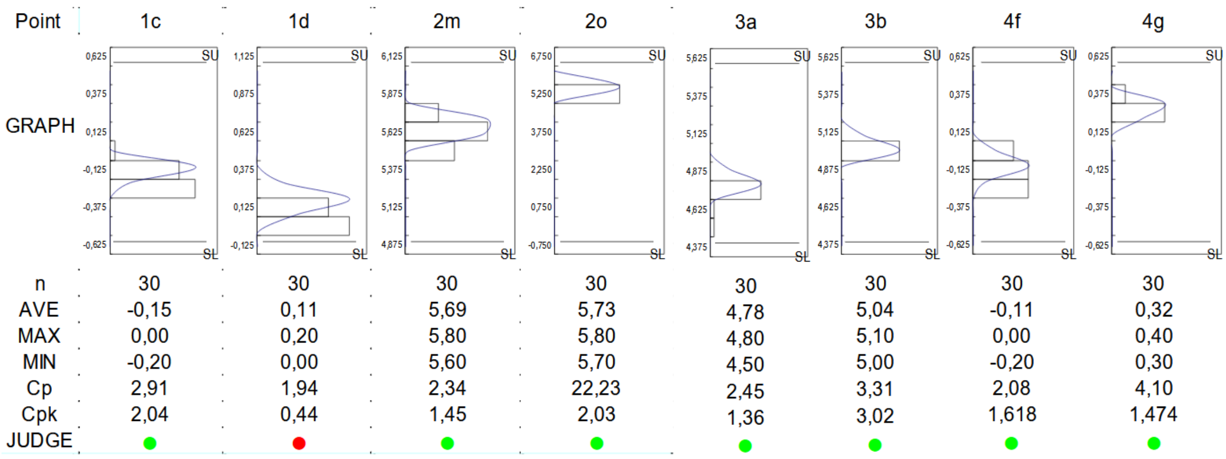

Figure 4. Capability Index

The simulation results show that the moulds at stations 3 and 4 are not fully filled and there is significant damage to the bearing surface (flange) area. The cracks are caused by high stress concentration during the forming process at station 3 because the punch corners do not have a radius (rounding).

**Process Capability Detection (K1)**

The welding robot used in the Rail Roof Side assembly process is equipped with sensors that can detect process errors. The sensors will provide notifications if there are process errors such as component positioning errors, incorrect component installation and incorrect component quantities during operation.

Figure 2 QA sensor detects position and size errors of nuts during installation. Welding nuts is one of the critical processes in the Rail Roof Side manufacturing process. The detection process works by providing warnings to operators in case of abnormal conditions. This non-destructive detection method uses a sensor device with a detection capability of 1.0 during operation. The continuous monitoring method based on non-destructive tests meets the requirements for a reliable and high-quality automotive manufacturing process [22]. Monitoring and detection processes consist of detection change points and alarms based on performance evaluations derived from maintenance history records. This detection method is highly suitable for manufacturing process scenarios because the parameter model can be set without requiring predefined control parameters [23],[24].

**Irregular Condition Actions**

Table 5 explains the results of verifying the operator's ability to handle irregular process conditions in the assembly process by confirming that the regulations regarding irregular conditions have been implemented. Next, confirmation is carried out during actual conditions.

Table 5. Verification of Irregular Condition Action

| Check Item | Source process |
|---|---|
| Product model change settings | O |
| Equipment inspection/adjustment/teaching | O |
| Equipment problem | O |
| Jig CHG / template CHG | O |
| Tip replacement / sharpening | O |
| Modification and introduction of new engines | O |
| Employee changes (new/job rotation/replacement) | O |
| Offline operations | O |
| Hand operation for machines with automated procedures | O |
| Urgent operation | O |

The results of the verification of irregular conditions are shown in table 5. The repair capability value in irregular conditions is 1.0, indicating that all irregular items are fulfilled. Operators are able to operate the robot welding machine for Rail Roof Side assembly, having previously operated other part processes. During the operator training phase, operators are provided with an understanding of standard operating procedures and part characteristics, particularly critical process components. Potential operational issues that may arise with the equipment include worn cup tips, misalignment/off-centre positioning, which can cause welding joints to come loose. Detection processes involve setting parameters at the start of each process, using the Okamochi system and performing preventive maintenance on the gun tip. Operators conduct checks at the beginning, middle and end of each process and perform regular dressing on the cup tip. In urgent situations where the welding robot is not operational due to issues, operators can use manual gun equipment for part assembly operations. Potential issues with manual guns include misaligned spot welds due to improper gun positioning. Operators can address this by controlling part surface accuracy, conducting visual inspections, and performing checks at the beginning, middle and end of the process.

**Calculating Process Assurance Capability**

Based on the mathematical model of process assurance capability, the ranking is obtained using the following formula (2).

$$\text{Rank Value} = 1{,}7 * 1{,}0 * 1 = 1{,}70 \quad (2)$$

The calculation consists of rank values and priority categories based on process stability, detection capabilities, and control capabilities for irregular conditions. The calculation results in a rank value of 1.70 for the Rail Roof Side 1 production process assurance capability, with a target rank of A. This rank value indicates that the quality assurance system has been achieved. This means that the process assurance status is capable of preventing recurring problems and variations in the process. Good Manufacturing Practice regulations ensure that automotive products meet high quality standards during the manufacturing process. The meticulous nature of GMP regulations mandates that each step in the manufacturing process is precisely defined, documented, and controlled [25].

## CONCLUSION

The quality assurance of the Rail Roof Side car body production process has been achieved and meets the requirements to prevent recurring problems and unstable process failures. This is influenced by the stable stamping part and assembly welding processes, the detection capabilities of operations that already use QA machines, and the operators' ability to handle irregular conditions in accordance with regulations. This quality assurance process has an effectiveness rating of A, indicating that the quality assurance system is sufficient to mitigate the risk of quality issues and that operations can continue as usual. The key strength of this quality assurance system lies in its ability to handle irregular conditions, which must be met. If any of these conditions are not met, the system will receive a score of 0, rendering it unable to prevent recurring issues and mitigate quality risks.

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