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Reduce the Risk of Failure of The Automotive Part Manufacturing Process using PFMEA AIAG-VDA: Case Study of Automotive Motorcycle Supplier in Indonesia

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A B S T R A C T

Competition in the automotive industry, especially in Indonesia, is quite tight. Automotive OEMs require their suppliers, both Tier-1 and Tier-2, to supply quality products consistently. One of the indicators of supplier evaluation is the quality performance with abnormal product quality detection parameters from supplier to automotive OEM, and even to end-user if this happens on motorcycles. For this reason, this research aims to analyze and improve supplier performance level, mainly the manufacture of OEM motorcycle spare parts, by looking at the risk of production process failure. The method analyses for this research use AIAG-VDA PFMEA to analyze this starting from the closest case or the occurrence of abnormal violations on the assembly of OEMs and even end-users of motorcycles. The results showed that one of the suppliers processing with the lowest value, the Cap Camshaft product, in the casting process, there was a crack failure on the product. The cause of cracking by analyzing the casting process found that was due to bile on the casting and the instability of the bolting assembly area caused cracking on the camshaft cover. The repaired item standardizes the Nozzle Spray Die on Dies' lubrication direction and increases the level of abnormal detection, especially cracks with color detector inspection items. The Purpose of improvement proposals is to analyze the process with risk forecasting patterns and avoid process failures and even flow to customers..

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1. INTRODUCTION

The automotive industry plays an essential role in the development of other companies that become suppliers. The opportunity to become a leading supplier of Motorcycle automotive OEM (Original Equipment Manufacturer) to have been a potential supplier in Indonesia is still open (AISI, 2019), that condition stated (Trimarjoko et al., 2019) showed the automotive sales 2019 was increased by 3.6%,

and (Syah, 2019) stated in Indonesian.

From that condition, the supply chain for both motorcycles and automobiles makes factories distribute the distribution of vehicle unit parts before being assembled into motorcycles or automobiles, which selected suppliers had significant. Research by (Rozak et al., 2020) stated to win the competition, each automotive company includes supplier potential or existing and must increase their quality and productivity. Meanwhile, in Indonesia stated (Syah, 2019), the government also assists local supplier companies with capital investment, marketing, and human resources development in improving supplier performance capabilities, if enhancing the abilities of suppliers represented by tier-1 and tier-2 companies important role in economic development. Based on Gaikindo data in 2018, Indonesia has 500 tier-1 supplier companies and 1,000 tier-2 and tier-3 floor suppliers because not all suppliers are trusted to produce significant engine parts. Only companies from the OEM group are authorized to supply this particular part (engine), while non-group suppliers are allowed to supply support parts other than the main engine parts.

Fig. 1 is performance quality data from the worse 10 Tier-2 automotive suppliers (Parts and services), with ratings conducted by Tier-1. The Tier-2 or Tier-3 supplier quality performance expressed based on a ppm index (pieces per million shipments) means the number of abnormal products detected per one million shipments during receipt or subsequent processing at Tier-1 or OEM. The index specified in the KPI measure (key performance index) indicates that the product should not be detected abnormality until the Motorcycle's end user. The market also uses the case of each case of abnormal detection failure. With a performance appraisal index based on tracking findings on customers, in this case, Tier-2 customers are Tier-1, for Tier-1 customers are major automotive OEM manufacturers, and customers for major automotive OEM manufacturers are consumers or automotive users. Evaluation subjects assigned to Level-2 based on abnormal delivery and tracking of subsequent customers. From Table 1, it could that only eight companies can achieve the maximum target of 3 ppm with a value of B, which means 80% of companies do not reach the target. The remaining 20% get the target.

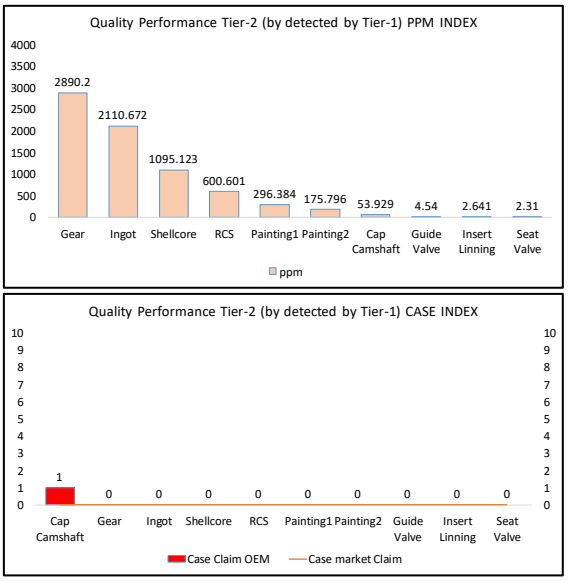

Fig.1. Tier-2 Supplier quality performance results (Tier-1 Automotive OEM evaluations)

Table 1. Remark Level of Quality Performance

	Detection (Average per Month)		
	Tier 1	OEM Main Customer	Claim Market user
LEVEL	Rage ppm	Case	Case
A	0 ppm	0 Case	0
B	1 ppm - 3 ppm	1 Case	No Level
C	4 ppm - 30 ppm	2 Case	
D	31 ppm - 60 ppm	3 Case	
E	> 60 ppm	4 Case	1

Source: Tier-1 OEM Motorcycle in Indonesia

This problem is a problem raised in this study; it could tighten the competition in the automotive industry, and competitive solutions should found as a supplier or prospective automotive supplier. See a strict target of automotive customer instructions with instructions for the risk of product failure. Until delivered to the customer, it must be zero.

Some researches manufacturing strategy by QFD method to had solution in overcoming quality problem to had reduced of reject ratio in process manufacturing Automotive (Jaqin et al., 2020) with study emphasizes between process determination and customer needs. A method often used in the manufacture of automotive spare parts is FMEA, as described

(Rozak et al., 2020; Febriana et al., 2020) by combining DMAIC and FMEA methods to increase the productivity of automotive companies and (Ramly & Atan, 2018), which solves problems in-company workshops.

According to that references, it should be additional process improvement had concluded effectively. Suppose we want to solve automotive process problems. In that case, The PFMEA tool is a mandatory reference because the effect of a process failure is not only on Tier-1 automotive suppliers but also on the following process to OEMs and end-users must also be used. In this study, the FMEA method will also be used, with the latest version of the PFMEA approach, namely the PFMEA AIAG-VDA. With the study sample taken from the quality performance background data of Tier-2 and Tier-1 suppliers, the Purpose to improve the root cause of that case

2. LITERATURE REVIEW

We can directly see the problem-solving measures taken when referring to AIAG-VDA PFMEA in previous references in problem-solving by looking at previous research analysis sources such as (Ershadi et al., 2018), (Chokkalingam et al., 2017), (Mondal et al., 2018), (Jayaprasad et al., 2018), (Luo et al., 2018), (Dobrusskin, 2016), who conducted research exploring the causes of cases in the industry using Ishikawa diagrams or fish bones and developments mind as a source of data analysis. Without reference to production process audits and brainstorming processes, the analysis will not be effective, and this situation is also expressed by (Jumbad & Chel, 2018); The Audit Control Plan document is very helpful in taking standard reference from the initial plan of the process, with the help of members who come from the production department who are experienced and experts in their field and have supervisory positions at their respective levels.

Results of direct evaluation and discussion of the germination of ideas from previous audits. The result of this process is expected to solve the root of the problem, which can then be solved effectively. Automotive suppliers cannot do their analysis; but requires cooperation between suppliers and customers as stated (Esa & Yusof, 2017) because the effects arising from process failures and the effects of products supplied by suppliers will affect the process in customers, abnormal historical inputs that have existed before or are predicted will affecting customer processes due to failures in production processes from suppliers finding a way out to the root of the problem aims to facilitate analysis in the PFMEA method to be suitable for applications as already presented (Ramly & Atan, 2018), (Pourgol-Mohammad et al., 2017), (Yule, 2013), (S. Parsana & T. Patel, 2014), (Ng et al., 2017), (Arabsheybani et al., 2018), explain the effectiveness of production system risk analysis with a process approach that is expected to obtain the optimal design in preventing production system failure risk. By getting input from experts' experience, history of previous problems, both in the company's internal processes and in subsequent operations, even the customer Tier-1 or OEM must impact the effect that has occurred and the predictive nature of the framework all contained in the FMEA.

FMEA AIAG-VDA version 2019 is the latest version of the specified FMEA (AIAG, 2019), consisting of two discussions, namely FMEA Design (DFMEA) related to new product development FMEA process related to the manufacturing process, and explained by the disclosure (Diagnosis, 2020). Several changes are included in this format, such as determining the cause of the failure mode, and the cause of the failure analyzed in 4M + E (Human, Machine, Material, Method) and Environment.

The weighted values of the priority scale that are very important to be resolved or called AP PFMEA (Action Priority PFMEA) are taken from the relationship between severity, occurrence, and detection values with the standard matrix. Research by Tanaka et al., (2020) apply AIAG-VDA FMEA analysis and fault tree to create a safety analysis artifact framework and possible failures and expectations. Still, its approach is only related to design, or DFMEA has not yet shown a study in terms of the manufacturing process or PFMEA.

3. RESEARCH METHOD

The methodology used can be seen in Fig. 2. The methods used combine DMAIC, Root Cause Analysis, and PFMEA AIAG-VDA. To measure to solve the problem carefully, DMAIC had used. At the same time, root cause analysis and PFMEA AIAG-VDA are already a reference in this latest version of FMEA to find the effects caused and caused by process failure, the root cause of the problem that occurs with the help of Expected 5W + 1H. Ishikawa Diagram can find the root cause of the problem so that it will be easier to determine the mode of failure and the cause of failure (from the analysis) as input looking for Risk Analysis and optimization as the objective of this study.

DEFINE is a step in the initial determination to identify the problem or phenomenon of the problem. Quality performance index data is required to find the subjects of company determination taken from 10 suppliers, with the lowest value taken by one supplier with a lower value than the others. The object of the study is the main problem of selected suppliers by considering the effect of the breakthrough problem on the Motorcycle's critical function (the Motorcycle (the general function of the Motorcycle cannot function).

Further, the MEASURE step is a comparison between the phenomenon of the problem that occurs with the product standard and the standard of the manufacturing process so that the deviation of the main problem that occurs can be found. Here we will determine whether to evaluate based on the setting of product standards (design) or production process standards and quality assurance.

ANALYZE step enters the AIAG-VDA PFMEA development step by determining the Failure Mode and Failure Cause items seeking improvement suggestions from the process with the highest Action Priority (AP). The proposed level of process design process and quality gate system design is presented at the OPTIMIZATION step so that it is expected that the level of risk from AP can be reduced.

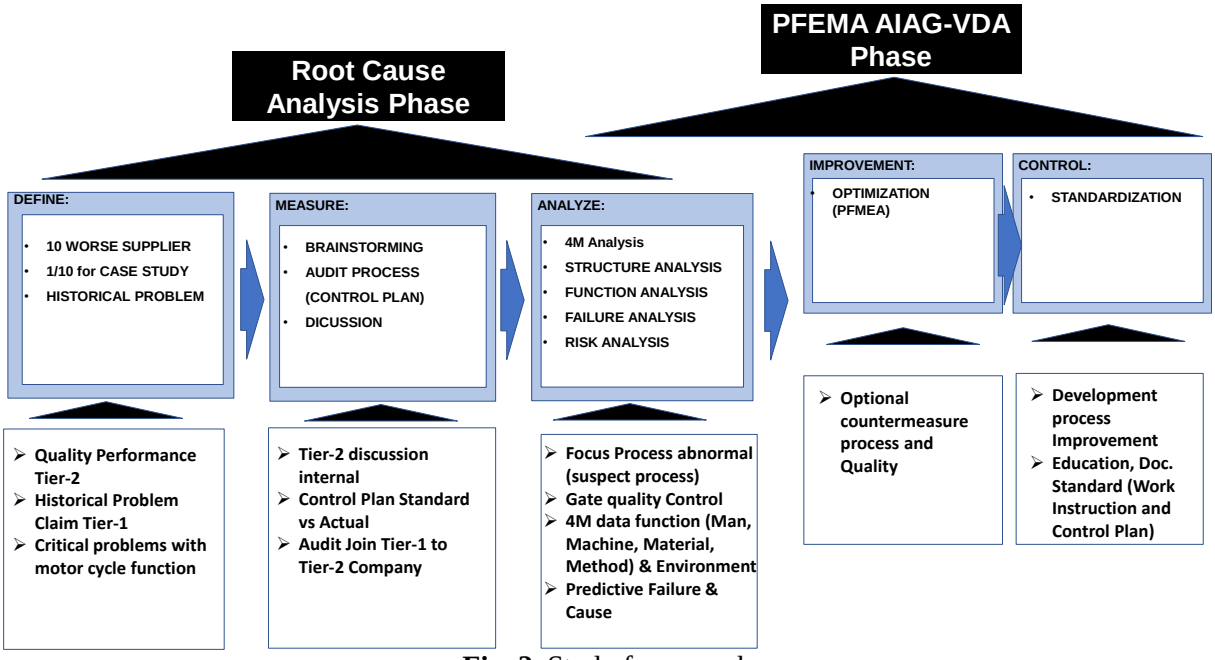

Fig. 2. Study framework

4. RESULT AND DISCUSSION

From Table 1, it can be seen that the Tier-2 Parts/ Process abnormal breakdown index with the worst abnormal supplier whose evaluation result is Gear. But for abnormal damage on automotive OEMs from the Tier-2 supplier is the Camshaft Cap parts supplier. Against this background is Supplier Cap camshaft as a case study and application of PFMEA AIAG-VDA. For reference, see Figure 2: The Camshaft Cap

Part is a sub-assembly part of the Cylinder Head. The function of the Camshaft Cap is as a guide for the rotating camshaft intake, which will then move the valve to open the gasoline to the combustion chamber and the exhaust valve to open the remaining combustion port to the motor exhaust. Camshaft mounting cover uses bolt flange with a torque of 12 Nm +/- 2 Nm. After installing the cylinder head, the machining process of the shaft hole is carried out with the target roundness, the cylinder according to the drawing specifications. A sign of the desired function is that the camshaft rotation does not drag or touch tightly with the cylinder head and camshaft cover. If this happens, the Motorcycle will not get a fuel supply, and while driving, it can STOP. The history problems in Tier-1 records by detecting abnormal are acceptance of the quality of products supplied by Tier-2 in 2018 and 2019 are shown in Table 2. From the Table 2, it is the most numerous and recurring problem is shrinkage or porosity. But the problem category is still at the appearance level. It does not affect the assembly and engine function of the Motorcycle. For 2018, there is a critical problem at the function level, i.e., dowel pin depth is lower than standard. There is a problem affecting function in 2019, i.e., cracking when bolting torque assembly with cap camshaft.

Table 2. History of problems Tier-2 about 2018-2019

No	Phenomena	Detected Area	Case No	Years	Effect
1	Porosity/ Shrinkage	Receiving Check Tier-1	7	2018	Appearance
2	Handling Mark	Receiving Check Tier-1	5	2018	Appearance
3	Rusty	Receiving Check Tier-1	1	2018	Appearance
4	Depth Pin Dowel lower from Std.	Assy Line OEM	1	2018	Function
5	Porosity/ Shrinkage	Receiving Check Tier-1	3	2019	Appearance
6	Crack after Bolting	Assy Line Tier -1	1	2019	Function

Source: Motorcycle Tier-1 Report Quality Performance for Supplier Tier-2 (2018-2019)

Of the two functional problems, the sample in this study is a crack problem due to the installation of bolts on the cylinder head. If this problem happens to the OEM, the OEM may not detect it directly, and the crack effect is felt while the Motorcycle is running or when it is used for a certain period by the end-user (motorcyclist). This situation would undoubtedly have a detrimental effect on customer confidence if it happened. In Fig. 4, cracking problems are detected during the camshaft cover assembly process or bolting with the cylinder head. This phenomenon leads to the separation of the entire product stock both in Tier-1 and in Tier-2. The results of the Tier-2 internal analysis showed that the process was abnormal due to an abnormal casting process. Tier-1 confirmed the suspected product; by examining the microstructure, it was concluded that there was potential a "galling" due to non-optimal compaction freezing or cooling faster before perfect compaction.

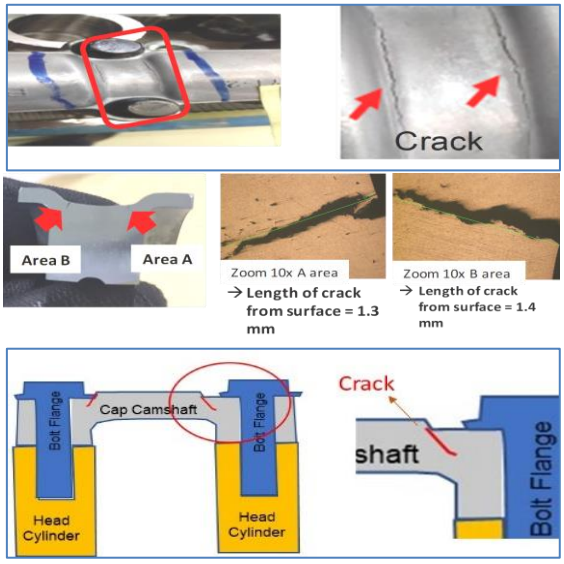

Fig. 3. Crack phenomenon on the camshaft cover

Analysis of suspected cracking products is performed by the microstructure and technical mechanics of casting formation as a first step

in determining the details of the casting process be analyzed in 4M factors. From Fig. 4, it can be seen that the differences in the microstructure of the camshaft cover material by comparing the products are not cracked, and cracking is suspected.

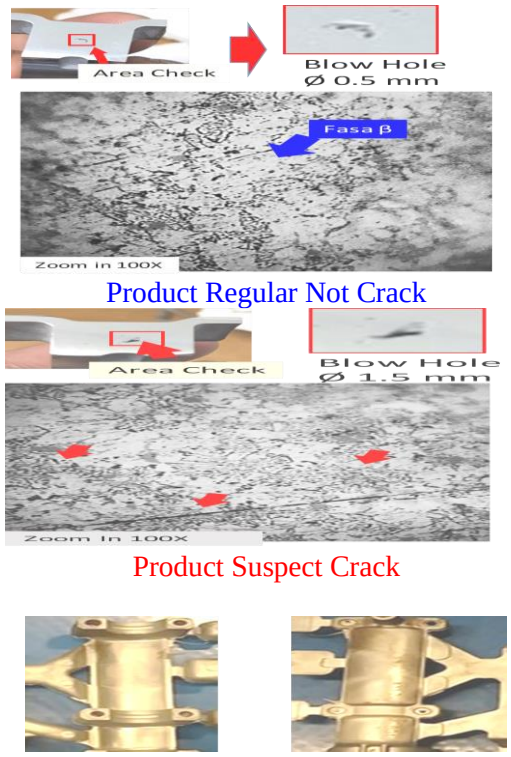

Fig. 4. Comparative analysis of cracks and no cracking phenomenon

It is seen that for suspect cracking, there is a blowing hole in the middle of the 1.5 mm aluminum casting entrance area. This situation is reinforced by microstructure analysis of solidification material. There is camshaft element density of cover material where the product does not crack tighter than the suspected crack product. One of the factors causing the density of the material is due to the compaction of the molten metal material to solidify faster than the target, or the regular product does not crack. So that an examination of the suitability of the control plane with the actual process is potential, examine the process in the Control Plan illustrated in Fig. 5 while analyzing possible abnormalities in the casting core process and abnormalities until it reaches the customer because visual detection is unclear. Only cracks detected after bolts or camshaft cover profile instability against bolting camshaft torque load with the cylinder head.

The suspect analysis by the level of supervision and supervisor of the camshaft cap casting process. The final inspection was not detected casting process failure by visual inspection because of the camshaft cap process design already running and mass production. So that product quality analysis and process assurance are required. As a result of the discussion and inspection of the process, analysis was made on 4M (Man, Machine, Material, Method) analysis to find the leading cause of the cracking problem, as shown in Fig. 5 and Table 3.

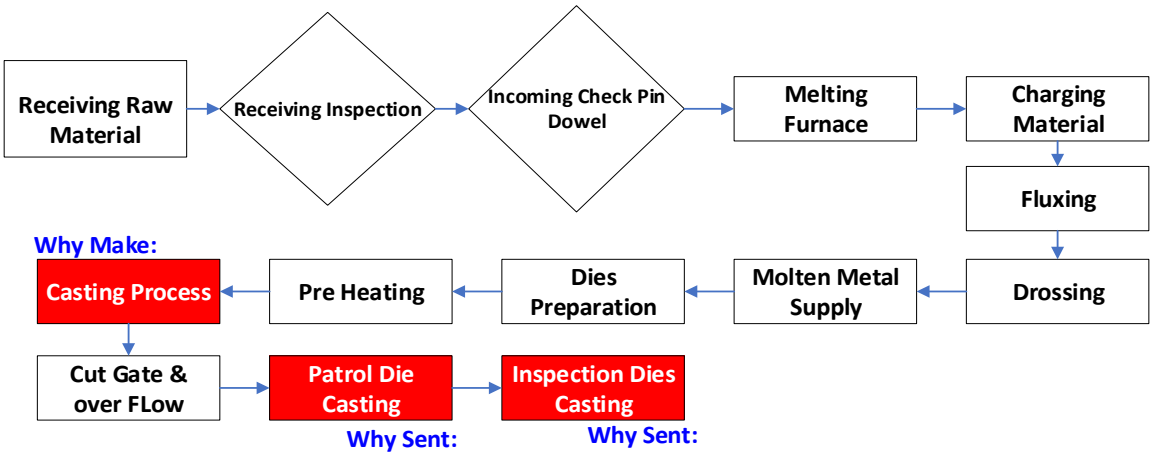

Fig 5. Flow process casting
Source: Control plan process cap camshaft

Table 3. Structure analysis & function analysis- casting suspect process cap camshaft

STRUCTURE ANALYSIS (Step 2)			FUNCTION ANALYSIS (Step 3)		
1. Process Item System, Subsystem, Part Element or Name of Process	**2. Process Step Station No. and Name of Focus Element**	**3. Process Work Element 4M Type**	**1. Function of the Process Item Function of System, Subsystem, Part Element of Process**	**2. Function of the process Step and Product Characteristic (Quantitative value is optional)**	**3. Function of the Process Work Element and Process Characteristic**
Casting Process	Casting Process	Machine : Dies Cast, Dies	*Your Plant*: Startup Product Formation *Ship to Plant)*: Match the unit to the Cylinder head and Camshaft Cap *End User*: The motor engine can work	Cap Camshaft product shape formation	Machine: molten metal mold, according to mold dimensions (die), wear occurs on the Cavity pins and the bushing is not centered
		Method: Visual Check, Colour Check			Method: detect product appearance, handling marks, porosity, cracks, etc.
Casting Process	Patrol Die Casting	Measurement: Visual & Colour Check	*Your Plant:* Startup Product Formation *Ship to Plant):* Match the unit to the Cylinder head and Camshaft Cap *End User:* The motor engine can work	Sampling Check the product quality of the cap camshaft to avoid many abnormal products, which can be eliminated by stopping if there are any abnormalities	Measurement: detect appearance visually
		Environment:-			Environment:

Source: Brainstorming and control plan

Failure analysis has affected the customer if a process failure occurs and is unfollowed up. The abnormal casting process, the dimensions, and the camshaft cover material, and the solidification effect affect the product's main function as an assembly with other parts in the customer. In this case, the material structure of the cap camshaft is not strong when locking with the cylinder head. If this happens, the camshaft cover will lock the camshaft and cannot rotate optimally and even stop rotating.

Table 4. Failure analysis & risk a- casting suspect process cap camshaft

FAILURE ANALYSIS (Step 4)				RISK ANALYSIS (Step 5)						
1.Failure Effects (FE) to The Next Higher Level Element and/ or End User	**Severity (S) of FE**	**2. Failure Mode (FM) of the Focus Element**	**3. Failure Cause (FC) of the work element (Root Causes Analisis)**	**Current Prevention Control (PC) of FC**	**Occurrence (O) of FC**	**Current Detection Controls (DC) of FC or FM**	**Detection (D) of FC/ FM**	**P FMEA AP**	**Special Characteristic**	**Filler Code (Optional)**
The bolt does not lock when the assy is stamped by the camshaft	8	the temperature is not reached and the cooling system is not optimal	The spray cooling direction is not fixed according to the entire mold area	100% visual inspection	6	spray and visual cooling	6	H		
	7	Not detected of problem handling marks, shaft, camshaft cap cracked	Important rules for routine education are not present in the regular operator education schedule	100% visual inspection	6	visual	6	H		
The bolt does not lock when the assy is stamped by the camshaft	7	over judgment, and lower judgment	Visual inspection is not optimal because visual inspection tools are not provided	100% visual inspection	6	visual	6	H		
		-								

Source: Brainstorming and Control Plan.

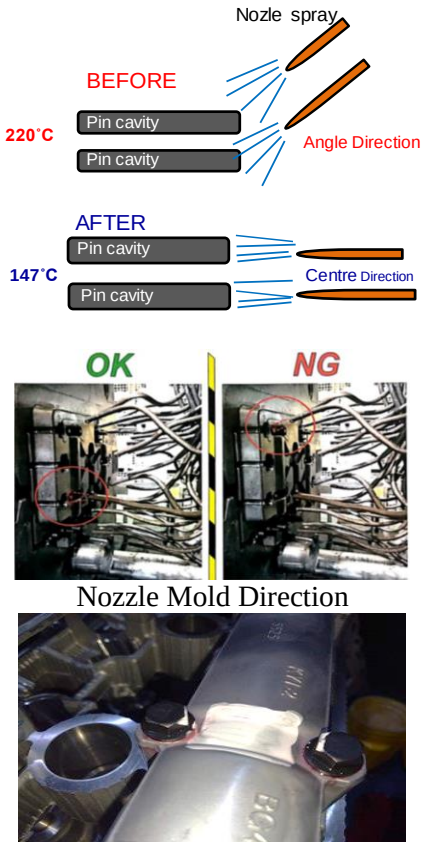

Fig 6. Improvement direction nozzle spray mold & color detector

If this problem is anticipated in the initial design, the likelihood of failure of the camshaft cap casting process is reduced. Like the directional preparation of dies lubrication nozzles, cooling equalization to all dead areas becomes the target process. For now, the Nozzle direction process is only an improvement. However, the Nozzle direction changing is still possible, requiring additional assurance of quality inspection as recommended by the customer using the Color detector.

The root of the problem obtained in the analysis of the camshaft cap casting process is looking at the AP value of PFMEA with H (High), which means the main priority scale. Table 4 is the result of the causes and precautions taken on the 4M parameter. For machines, spare parts had been replaced for Pin Cavity and Bushing. For measurements, additional inspections (Color detector) had performed. That can be seen improvement results show in Figure 6 (Optimization). By obtaining the root cause of the problem from the Dies cooling process, where the Nozzle direction is unevenly divided into all cooling areas, it is corrected with the die direction of the Nozzle cooling and standardized. Then, to reduce the risk of process failure that still can occur with other phenomena, red and white color detector checks had added that can detect cracking and shrinkage or another defect casting. That can be seen results show in Table 5.

Table 5. Optimization and improvement

RISK ANALYSIS (Step 5)							OPTIMIZATION (Step 6)									
Current Prevention Control (PC) of FC	Occurrence (O) of FC	Current Detection Controls (DC) of FC or FM	Detection (D) of FC/ FM	P FMEA AP	Special Characteristic	Filler Code (Optional)	Prevention Action	Detection Action	Responsible Person Name	Target Completion Date	Status	Severity (S)	Occurrence (O)	Detection (D)	PFMEA AP	Special Characteristic
100% visual inspection	6	spray and visual cooling	6	H			Make Direction standard Nozzle Cooling Mold, and change Pin & Bushing Cavity	Temperature Dies Monitoring	> Rudiana > Nurdiana > Madi	Dec'20	Closed	8	4	6	M	
100% visual inspection	6	visual	6	H			BY Regular Process	Check the color detector and cut product (the problem areas of the product suspect) for visual inspection	> Rudiana > Nurdiana > Madi	Dec'20	Open	8	4	6	M	
100% visual inspection	6	visual	6	H			BY Regular Process	Check the color detector and cut product (the problem areas of the product suspect) for visual inspection	> Rudiana > Nurdiana > Madi	Dec'20	Open	8	4	6	M	

Source: Brainstorming and control plan

5. CONCLUSION

From the study results, it can be seen that the presentation and direction of PFMEA AIAG-VDA get 4M variable factors (Human, Machine, Material, Method, & Environment) narrows the analysis based on process, process function, and effect of process failure on the customer. This result is directly proportional to the PFMEA directive with the Severity value unchanged because the failure effect still has a significant impact on the customer, but increasing the Detection and Incident value changes the repair priority scale value due to reduced quality assurance with control tool measurement detector.

This point of improvement is considered relatively late because the phenomenon of problems has occurred. Anticipating possible other process failures still has to be distinguished, such as details of molten metal temperature parameters. The material composition of machine instability and measurements is also considered to be developed in automotive supplier enterprises. The value of loss felt due to this problem is quite significant, especially if there is a failure on the end-user. The value of money spent to produce motorcycle products and trust from end-users and customer loyalty will be reduced and even lost. Because they no longer trust motorcycle products sold by motorcycle OEMs.

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