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Minimizing Defect of Air Craft Parts Machining Product Using Six Sigma Approach

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ABSTRACT:*Based on ISO 8402-1986, quality defines as the totality of features and characteristics of a product or service that bears its ability to satisfy stated or implied needs. In the other words, quality is a measure of excellence or a state of being free from defects and variations to achieve uniformity in order to keep the loyalties of customer and maintain customer satisfaction in its level.PT.XYZ is a company engaged in aircraft component manufacturing. In the production process, they only processes the raw materials that have been cut in advance from outsourced parties. Several air craft components produced are drive shafts, couplings, actuators and piston. According to company's defect parts per million (DPPM) data in period ofJanuary – July 2018, it was found the number of product outputs that categorized as defective product exceeded thetolerable boundary. The existence of defective products that do not meet the specifications, raises other problems such as an existence of COPQ (cost of poor quality) for the product defects in the form of scrap that can't be reworked and the cost of reworking the defective product. Therefore, this research is conducted usingSix Sigma Approach to minimizenumber of defective product.The problem solving method in six sigma also known as DMAIC. The measurement stage usingp-control chart and for the analysis phase using the Five Why Analysis, Fishbone Diagram and FMEA Analysis.*

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NOMENCLATURE

Symbol	Description
pi	Defect Proportion
Di	Number of defect products for each time period i
ni	Total production over a period of time i
CL	Center Line
UCL	Upper Control Limit
LCL	Lower Control Limit
P	Defect Rate
$DPMO$	Defect per Million Opportunity
DPU	Defect per Unit

I. INTRODUCTION

PT.XYZ is a company engaged in aircraft manufacturing. In the production process, PT. XYZ only processes the raw materials that have been cut in advance from outsourced parties to become aircraft component products such as drive shafts, couplings, actuators and piston. Each product component has a different part number and a different production process. Following figure is the general production process of aircraft components using the SIPOC diagram :

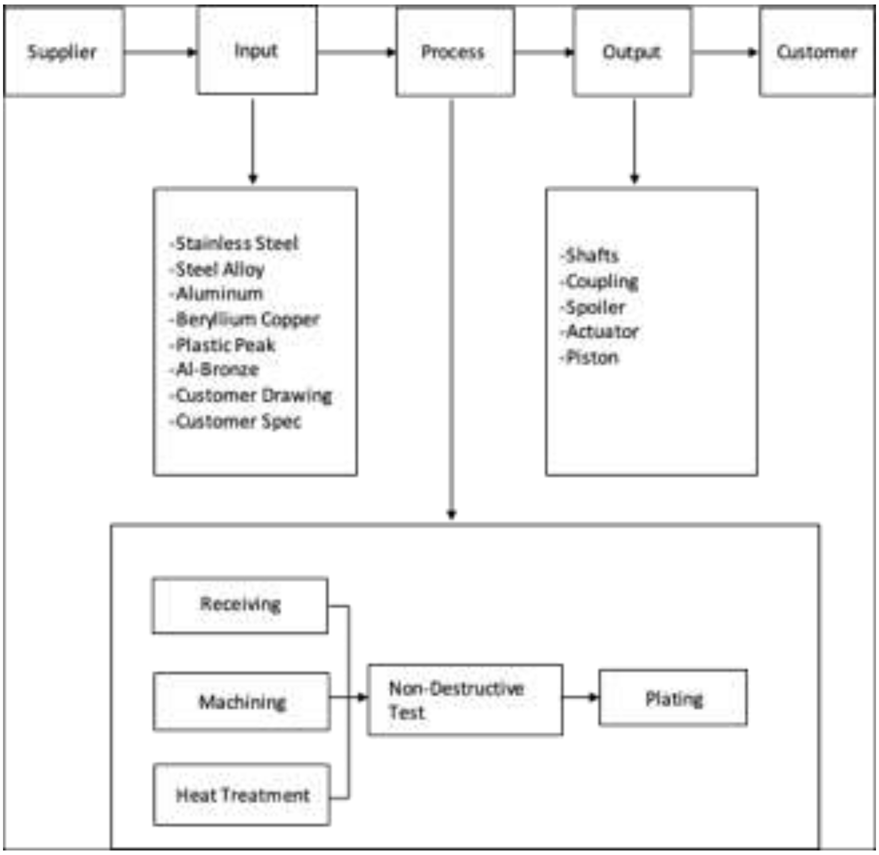

Fig.1 SIPOC Diagram

In every production process that takes place, the product produced is not always in accordance with the specifications provided by the customer. In other words this is often referred as a defect. Defect is a failure in providing customer desires. The existence of a defective product that doesn't meet the specifications also raises another problems, such as the accumulation of air craft component that must be reworked. This indicates a problem with the ongoing process. The following is a table of total production, number of defects and defect targets achieved each month.

Table 1. Target, Total Production Period January – July 2018

Month	Total Production	Total Defect	DPPM	DPPM Target
Jan-18	55598	875	15738	7500
Feb-18	58075	778	13396	7500
Mar-18	45414	829	18254	7500
Apr-18	38394	731	19039	7500
May-18	36750	1271	34585	7500
Jun-18	38127	607	15920	7500
Jul-18	37464	684	18258	7500

Based on table 1.1 it can be seen that the DPPM value per month is still above the DPPM target of 7500 defect parts per million. This is caused by the defective products, so they cannot meet the DPPM target set by the company to maintain the sigma level. The existence of defective products that do not meet the specifications, raises other problems such as an existence of cost of poor quality for the product defects in the form of scrap that can't be reworked and the cost of reworking the defective product. In addition, there will be back orders that cause delays in delivery and impacted on customer satisfaction.

In the case of this production process, defective products are one of the problems occur due to several factorssuch as human factors, machines, methods, measurement, material and environment. The following are types of defects in aircraft components that are available during the period of January to July 2018.

Table 2. Types of Defect Period January to July 2018

Month (2018)	Total Production	Defect Type					Total Defect	% Defect Visual (per-month)	% Defect Dimension (per-month)
		Visual		Dimension					
		Tool Mark	Rusty	Deburring (BW)	Special Process (Plating)	Machining			
Jan-18	55598	290	256	69	137	123	875	62%	38%
Feb-18	58075	303	189	80	61	145	778	63%	37%
Mar-18	45414	327	89	136	98	179	829	50%	50%
Apr-18	38394	385	134	95	45	72	731	71%	29%
May-18	36750	276	458	78	205	254	1271	58%	42%
Jun-18	38127	206	203	32	98	68	607	67%	33%
Jul-18	37464	317	102	29	130	106	684	61%	39%

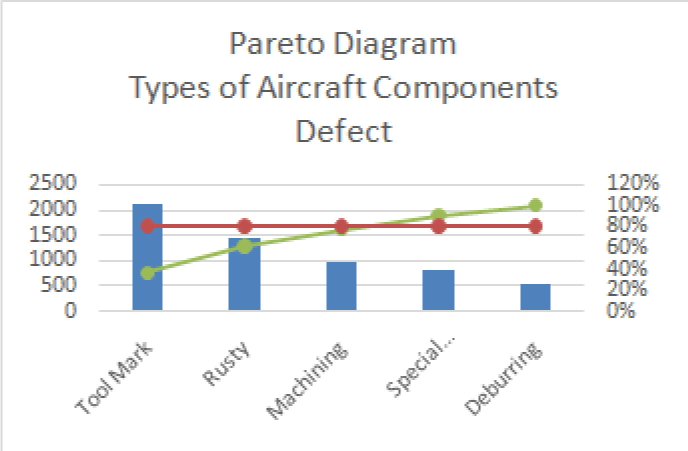

Fig. 2 Pareto Diagram Factor of Components Defect

Based on the problems described above, this research will focus on minimizing the defect type that caused by tool mark and rusty in the production process with six sigma method.

II. LITERATURE STUDY & METHODOLOGY

II.1 Definition of Quality

Quality is a key reference that must be considered by every company. Quality has an important role for customers to select one product or another. Therefore, increasing quality is key to the success and growth of a company. Traditionally, quality is the basis of the views of products and services that meet the requirements or the desire of customers. According to some quality experts it can be interpreted as follows :

1. According to Montgomery [1] quality is a suitability for use, where products and services must meet the requirement of consumers.
2. According to Kotler [2] quality is the overall characteristics and nature of a product that affects its ability to satisfy the stated or implied needs.

Whereas the more well-known quality definition was put forward by Garvin [3] where he distinguished quality into 8 dimensions of assessment; Performance, Reliability, Durability, Serviceability, Aesthetics, Features, Perceived Quality and Conformance to Standards.

II.2 DMAIC

DMAIC stands for Define, Measure, Analyze, Improve and Control. Vincent Gasperz [4] explained DMAIC as a continuous process of quality improvement towards the target of Six Sigma. This process will be applied to real-life problems, such as problems with defect products, problems with the company's targets, or problems with excessive time and costs.

II.3 Control Chart (p-Chart)

Control chart is a tool used to control a production process statistically or better known as Statiscal Process Control (SPC). Control chart is also one of the Seven Tools Quality Control. The initial self-control map was introduced by Dr. Walter Andrew Shewhart. P-control charts are commonly used to map a defect fraction [1]. The use of P control maps is used to measure the proportion of non-conformities of units in the group being inspected. The following is the application of p-control chart :

i. Determine the sample to be taken
ii. Calculate the value of the defect proportion and standard deviation for each sample unit

Di = number of defect products for each time period i.
ni = total production over a period of time i.

iii. Calculate the center line value

k = number of samples

iv. Calculate upper control limit (UCL) and lower control limit (LCL)

$$UCL = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n_i}}$$

$$LCL = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n_i}}$$

v. Plot the data into the control map and do an observation to observe whether the data is within control limits or over the control limits. If the process is within the limit then calculate the process capability. If there is data that is out of bounds, the data is considered as defective.

II.4 Cause and Effect Diagram (Fishbone Diagram)

Fishbone diagram or better known as cause and effect diagram is a diagram used to show the relationship between quality characteristics and factors that cause defective. Shaped like fish bones make this diagram name a fishbone diagram. In its depiction, the right main segment shows the consequences of the problem. In the main branch, indicating the main cause of various factors, and from each of the main branches there is a root cause of a more detailed problem.

II.5 Lean Six Sigma

Six Sigma is a set of concepts and practices that focus on reducing process variation and decreasing product failures or defects. Vincent Gasperz [4]. An important element in Six Sigma is producing only 3.4 defects for every one million opportunities or operations - 3.4 DPMO (Defect Per Million Opportunities). Another source, Franchetti [5] defines Six Sigma as a combination of management philosophy, such as tools for improvement, and methodologies that are combined in a system.From the explanations of these experts we can conclude that the higher the sigma target achieved, the better the performance in the production process.
In Six Sigma there are several terminology used, the following is an explanation of the terminology :

1. Defect rate, is the ratio for the number of defective products to the number of products produced in a certain period or products that do not pass when the inspection process is carried out. Defect rate is usually denoted by the symbol p. The number of inspected defective items in the manufacturing industry is usually called PPM (Parts per Million).

2. DPMO (Defect per Million Opportunity), is the number of defects found in one million production quantities

DPMO = DPO x 1.000.000

3. DPU (Defect per unit), is a product that is categorized as defective because it does not meet the requirements or criteria of the company.

$$DPU = \frac{\sum defect}{\sum Units\ produced}$$

4. DPO is the number of defects found on one occasion.

II.6 5 Why's
The 5 why method is a systematic problem solving technique. This method is done to find the root cause of the problem, by repeating the question until it is found the cause of the problem [6]

II.7 FMEA (Failure Mode and Effect Analysis)
FMEA (Failure Mode and Effect Analysis) is a method to determine the priority of repairs and potential failures. FMEA has 3 main criteria; Severity, Occurrence, and Detectability.

II.8 Conceptual Model
In this research, a framework of thinking is needed to solve structured problem and produce output that is in accordance with the objectives. The following is a framework thinking for minimizing defects in the production of air craft components :

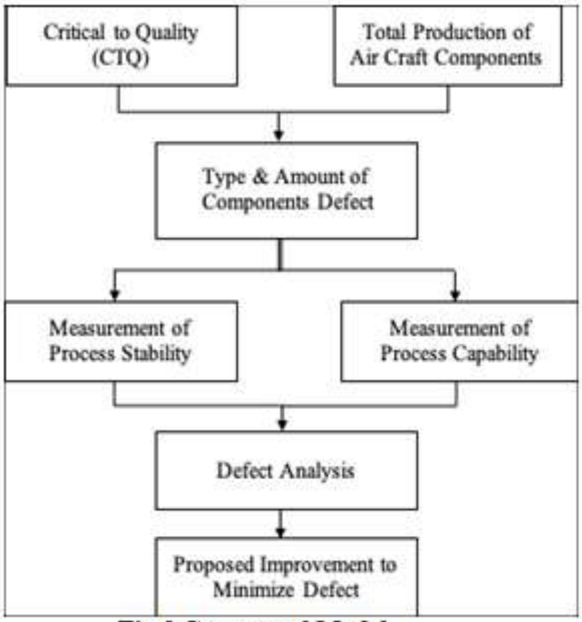

Fig.3 Conceptual Model

III. RESULTS AND ANALYSIS

III.1 Define
The define phase has been explained in introduction and results of the research focus on visual defect (tool mark & rusty) by consideringDPPM targets which had been set by the company, SIPOC diagram and Paretto diagram.

III.2 Measure
III.2.1 Process Stability Measurement
As a tool to measure variations in aircraft components production process, P control chart are used. Stability measurement of this process is carried out based on a predetermined period of January - July 2018. Data used in measuring the stability of this process are data on aircraft component production in period of January – July 2018 and number of visual defects. The following is a calculation of process stability :

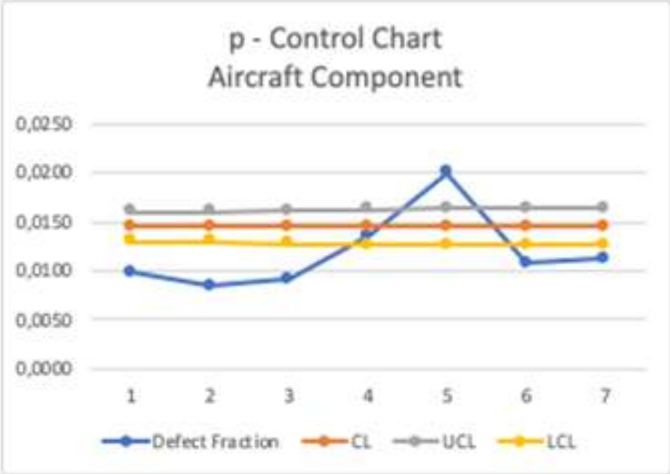

Fig.4 p-Control Chart Aircraft Component

III.2.2 Process Capability Measurement

Process capability is measured by calculating sigma level and DPMO. The process of measuring process capability is by using aircraft component production data in the period of January - July 2018. Table 3 shows the results of the process capability measurement as follows:

Table 3. Capability Process Measurement

Period	Total Production	Total Defect	Total of CTQ Potential	DPU	DPO	DPMO	DPMO Average
Jan-18	55598	669	5	0,0120	0,00241	2406,56	2997,28
Feb-18	58075	637	5	0,0110	0,00219	2193,72	2997,28
Mar-18	45414	595	5	0,0131	0,00262	2620,34	2997,28
Apr-18	38394	591	5	0,0154	0,00308	3078,61	2997,28
May-18	36750	988	5	0,0269	0,00538	5376,87	2997,28
Jun-18	38127	477	5	0,0125	0,00250	2502,16	2997,28
Jul-18	37464	525	5	0,0140	0,00280	2802,69	2997,28

Based on the results of these calculations, the following is a graphic chart of DPMO with an average DPMO from the period of January – July 2018 :

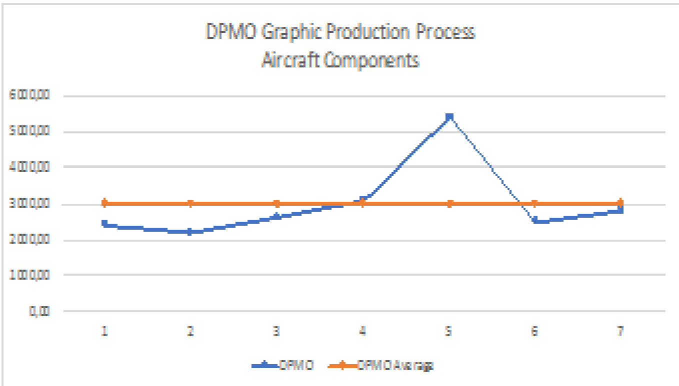

Fig.5 DPMO Graphic Production Process Aircraft Components

From these results it was found that in the period of January to March 2018 the DPMO value was below the average. While in May, the DPMO value was above average. The value of DPMO describes the size that is good for product quality or process because it correlates directly with defects, costs and time wasted. The smaller the DPMO value, the greater the value of sigma level achieved. If the value of sigma level is greater, then the process or quality of the product can be said to be good because the greater the value of the sigma level shows the small number of defects. The following is the DPMO value and its conversion to sigma level for the period of January – July 2018 :

Table 4. DPMO Conversion to Sigma Level

Period	Total Production	Total Defect	DPMO	Sigma Level
Jan-18	55598	669	2407	4,35
Feb-18	58075	637	2194	4,35
Mar-18	45414	595	2620	4,25
Apr-18	38394	591	3079	4,25
May-18	36750	988	5377	4,05
Jun-18	38127	477	2502	4,35
Jul-18	37464	525	2803	4,25

Table 4 shows the results of Sigma Level calculations using conversion tables from DPMO values to sigma levels. Based on the results of the conversion, the following is sigma level chart with an average sigma level for the period of January – July 2018 :

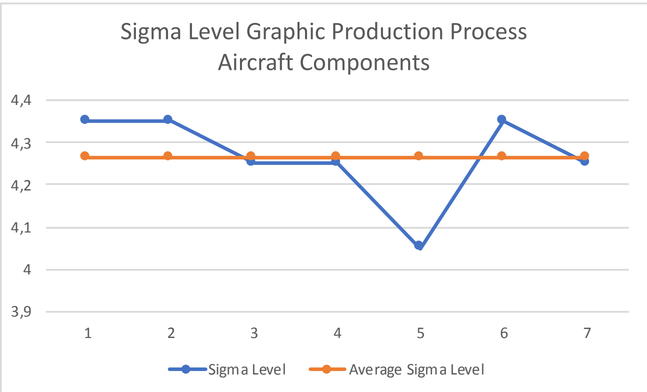

Fig.6 Sigma Level Graphic Production Process Aircraft Components

From the results of the graph it is known that the production process at PT.XYZ is in the range of 4 sigma levels.

III.3 Analyze

III.3.1 Five Why's Analysis

Table 5. Five Why's Analysis

Cause	Sub Cause	Why 1	Why 2
1	2	3	4
Machine	Machine Precision	The machine needs to be set up again for once in a few hours.	Not pay attention to the tool life (still using the same tool even when the tool life is already over) and machine maintenance is not done periodically
Human	Error when setting up the machine	Operator are not well trained to use the machine	Work instruction is not clear enough & caused misunderstanding for the operator
Material	Contaminated with other substances	The mixing of material with other substances results in the electrochemical reaction	Process the components with different materials in one machine

III.3.2 Fishbone Diagram Analysis

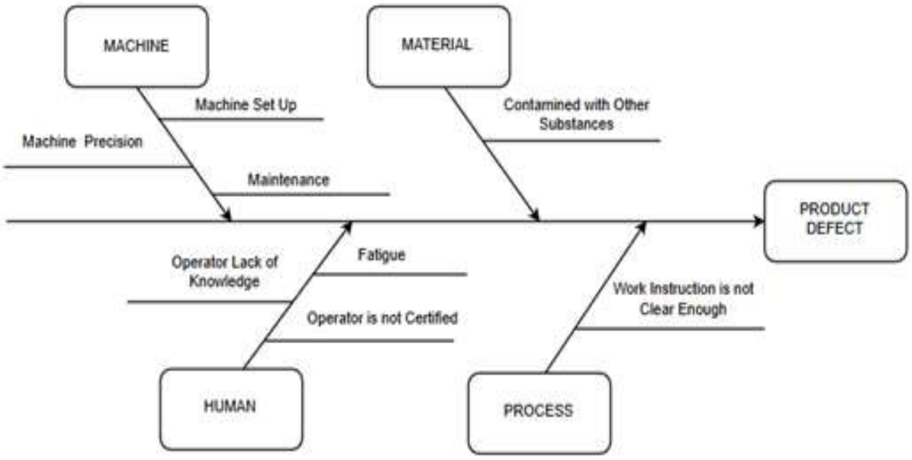

Fig.7 Fishbone Diagram Analysis

III.3.3 FMEA Analysis
In this step, the Risk Priority Number (RPN) will be calculated by using FMEA.

Table 6. FMEA Analysis

No	Factor	Potential Failure Mode	Potential Effect(s) of Failure	Severity	Potential Cause(s) of Failure	Occurences	Current Controls, Detection	Detection	RPN
1	Human	Error when setting up the machine	The product size are not according to the specifications given by the customer (oversized diameter / leaving toolmark)	9	The operator did not understand the work instruction given & not well trained to use the machine	5	Measurement	8	360
2	Machine	Machine precision	The lack of machine precision can leave a tool mark on the components and make the product not according to the specifications given.	9	Not pay attention to the tool life (still using the same tool even when the tool life is already over) and machine maintenance is not done periodically	5	Visual	8	360
3	Material	Contamined with other substances	The mixing of material with other substances results in the electrochemical reaction of Fe2O3H20 so that the product component becomes rusty.	8	Process the components with different materials in one machine & the operator does not understand the work instruction given	5	Visual	7	280

III.4 Improve

After using several tools for analysis, here are the proposal of improvement with their advantages & disadvantages :

Table 7. Tool Life Span in Maintenance

Proposed Improvement	Advantage	Disadvantage
Pay more attention to tool life span in engine maintenance scheduling	By doing maintenance periodically and paying more attention to the span of tool life might reduce the number of defects in product components and reduce the probability of reworking defect products	By changing the tool according to the span of tool life might caused additional stock for tools that have an impact on the cost of purchasing tools

Table 8. Change Work Instruction

Proposed Improvement	Advantage	Disadvantage
Change work instruction and enhance operator's knowledge by conducting training	Facilitate operators in understanding work procedures to reduce the probability of defective product	It is necessary to make adjustments for the new work instructions & the operator might be lazy to follow the new work instructions

Table 9. Separate Machine

Proposed Improvement	Advantage	Disadvantage
Separate machines for the production of components that have different material characteristics	Reducing possibility of the product being rusty because each product that has different material characteristics is processed using a different machine	Differentiate the engine for components that have different materials can lead to the addition of new engine which also has a significant cost and additional time to set up the engine

IV. CONCLUSION

The occurrence of defective product in PT.XYZ are affected by :

1. Machine precision because it frequently needs to be set up for once in a few hours.
2. Error while setting up the machine because work instruction is not clear enough & caused misunderstanding for the operator.
3. The component's material are contaminated by other substances.

As for the proposed improvements to minimize the defect of air craft components as follows :

1. Perform maintenance periodically and replacement of tool according to tool life.
2. Change work instruction.
3. Separate machine for different material characteristics of each component.

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