Improvement of cooling time performance in TAD® 20t mixing vessel using root cause analysis and PDCA cycle in TAD® 20t mixing vessel product maturity

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Abstract. The process of continuous improvement in product design portfolios uses the PDCA cycle, while the iteration process is carried out to obtain optimal and validated results and to increase the level of maturity of the product. Eliminating defects in TAD® installed at PT. YYY is able to improve the “cooling time” performance. Improved cooling time performance also resolves problems that occur in the production of Hair Care at PT. YYY and improve global product efficiency. On the other hand this also completes the "Problem Resolution Customer System" ticket on behalf of PT. YYY The solution produced has been through several discussions ranging from brainstorming all parameters that cause problems, the process of gathering RCA (Root Cause Analysis) to look for the potential impact of all parameters found during the brainstorming process through Fish Bond Diagram analysis techniques to obtain potential solutions. In terms of product portfolio management also minimizes the impact of this happening again in the future which can have negative effects related to the company’s name, additional costs for product repairs that increase problems and minimize losses from customers. Keywords: root cause analysis, PDCA, cooling time, maturity, and performance

1. Introduction

1.1 Research Background
On this occasion the author will discuss improvements to the company PT. XXX with his address in Jakarta. The intended product is a vacuum mixing with Patent Brand TAD® Mixing Vessel. Where the type to be reviewed is the 20T capacity TAD®. Product Maturity is a product design journey that is enhanced by a continuous improvement system based on findings or issues raised related to product design from the TAD® Mixing Vessel. Product design has several design criteria ranging from process design, mechanical design, electrical & automation design and system installation.

Complaint was found by one of the customers regarding the cooling time performance produced by the 20T TAD® Mixing Vessel. Where the cooling time needed for production with a maximum capacity of 20T exceeds the required cooling time limit. This is the result of a comparison between the design parameter requirements requested by customers of PT. YYY is made as the basic design requirements in project implementation. Complaints from PT. YYY as a customer, related to the TAD® 20T cooling time performance that they use is a design defect that will be eliminated. This is
also one of the agendas of PT. XXX as the owner of TAD® Product Design to always make continuous improvements related design of TAD®.

1.2 Research Purposes
Based on the background of this research, this research was compiled to obtain solutions related to:
- How to improve the Cooling Time performance of the 20T TAD® Mixing Vessel
- How is the implementation of Defect Elimination in the TAD® Product Mixing Vessel Design in the Continues Improvement Product Maturity.

Through the implementation of continuous improvement using the PDCA cycle in the TAD® product design to eliminate defects that occur related to cooling time performance. This is also a solution to the problems experienced by PT. YYY in using TAD® 20T with an increase in Cooling Time performance as expected by PT. YYY.

1.3 PDCA (Plan Do Check Act)
There is a problem-solving concept that can be applied in our company, namely by using the P-D-C-A approach as the process of solving problems. In the language of quality control, P-D-C-A can be interpreted as a process of completion and control. To summarize the PDCA process can be explained into several stages, namely:

a. P (Plan)
   It means to plan GOAL (GOAL = OBJECTIVE) and what PROCESS is needed to determine the results that are synchronous with the SPECIFICATIONS of the objectives set.

b. D (Do)
   This means DOING PROCESS planning that has been previously determined. The measurements of this process have also been determined in the PLAN stage.

c. C (Check)
   It means evaluating TARGETS & PROCESSES and reporting the results. We double check what we have done, is it according to the standard or there are still shortcomings.

d. A (Act)
   It means conducting a total evaluation of the TARGET and PROCESS results and following up through improvements. If there are still deficiencies in the process, immediately take corrective action.

1.4 Root Cause Analysis
Root Cause Analysis (RCA) is one of the continuous improvements and problem-solving tools used to find identification of the root problems that arise in systems and processes. RCA is a structured approach in identifying various factors from past events to find the causes of problems that can be fixed to prevent the same problem from happening again. RCA is done in 5 steps to find the answer why a specific problem can arise in the process, the steps are as follows:

a. Define the Problem
   Define the Problem In the initial process, identification of problems that arise and needs to be resolved.

b. Collect Data
   In this process, representatives from each of the departments involved (from expert staff to vanguard staff) need to be gathered, who understand the situation in order to be effective.

c. Identify possible causes
   At this stage, identify as many causes of the problem as you can think of. Many tools can be used to help find crucial factors of an issue, such as:
“5-Whys” analysis. This is will creating basic question goes to the problem to understand deeper what the real problem from the several perspectives.

- Appreciation – Describe all fact that happened and all possibilities and asked why it’s happened and not happened, Cause and Effect Diagram (Fishbone Diagram).

d. Identification of Root Causes (Root Causes)
To get the root of the problem use the same tool used in step 3 to find the root of each factor. This process will find answers to questions related to the root of the problem

e. Propose and Implement a Solution
Analyse the cause-effect identification process and look for the need for changes in other systems. One way to do this is to use the FMEA (Failure Mode and Effects Analysis) tool. [5]

1.5 Brainstorming
Alex Faickney Osborn in 1953 in his book Applied Imagination popularized the Brainstorming Method. Groups can multiply their creative work by brainstorming. Brainstorming works by focusing on the problem, then freely will emerge as many solutions as possible to be developed as far as possible, according to Osborn.

1.6 Risk Management
Risk management is a process that identifies exposure exposures faced by an organization and chooses the most appropriate technique for treating such exposures (McNamara, Michael, Rejda, George E. 2016). Definition of risk (Jhon C. hull, 2018).

2. Research Method

2.1 Review & Implementation of PDCA to eliminate defects in the TAD® Product maturity design
PDCA (Plan, Do, Check, Act), is an iterative four-step problem solving process that is commonly used in quality control. PDCA is known as the "Shewhart cycle". PDCA is a useful tool for continuous improvement without stopping. In this phase defects were found in the TAD® 20T mixing vessel product, which is the cooling time performance below the customer's minimum design requirements so this needs to be done several ways separately to avoid & avoid similar things happening in the next design.

a. P (Plan)
The purpose of this study is to improve the cooling time performance of the TAD® 20T Mixing Vessel and the implementation of continuous improvement in all Product Maturity designs. The process used in analysing problems is root cause analysis (RCA), brainstorming and fish bond diagrams.

- Reviewing all the factors that have an impact on actual cooling time performance ranging from Mechanical Design to jacketed pressure vessels, Process heat transfer design to pressurized vessels using a system jacket, fabrication process or mechanical pressure vessel construction, Processes installation site for the development of the TAD® 20T Mixing skid system
- Improvement on the product design Maturity TAD® Mixing through the stages of Analysis of all implemented designs that already exist in the customer.

b. D (Do)
Perform activities that have been made at the Plan stage effectively and efficiently to increase the potential for success and minimize the deviation between the plan & actual implementation.

- Conduct desktop reviews with all stakeholders related to design, manufacturing, site installation and commissioning.
- An actual review of data for current production at PT. YYY and compare with the standard performance parameters.

c. C (Check)
   Evaluate the implementation of the plan to achieve the research objectives and stages of the implementation of the recommendations and review the recommendations.

d. A (Act)
   The existence of the results of the joint review with customers, if still found deviations on the performance of Cooling Time or the implementation of this improvement has another impact on the operating process that will be followed up again.

If the results meet the research objectives, all improvement activities will be recorded and made into a new standard parameter for all future TAD® designs so that similar problems are not repeated later. Report the results to the Customer Issue Resolution to close the issue item by obtaining approval from the customer of PT. YYY

2.2 Record and Identify Customer Complaints (PT. YYY)
Customer complaints at PT. YYY is the actual cooling time performance when production is lower than the minimum requirement. Where the standard cooling time for TAD® 20T is 205 minutes for one batch of production where the actual Cooling Time achieved is 389 minutes, 366 minutes, 370 minutes, 365 minutes. With this condition, the Customer submits the issue to PT. XXX and are followed up by Portfolio Products as TAD® Product Owners.

2.3 Review customer production data and identify problems related to Defect TAD®
Based on production data which is explained in the Customer Issue Resolution System ticket on behalf of PT. YYY is explained in Table 1, Table 2.

| No | Formulation / Batch | Cooling time, minutes |
|----|----------------------|-----------------------|
|    |                      | 21-Mar-14  | 24-Mar-14  | 26-Mar-14  | 28-Mar-14  |
| 1  | Hair Care Formula 1  | 389        |            |            |            |
| 2  | Hair Care Formula 2  |            | 366        | 370        |            |
| 3  | Hair Care Formula 3  |            |            |            | 365        |

Table 2. Comparison of Actual Cooling Time with Standard Cooling Time

| Production Date | Actual | Standard | Remark         |
|-----------------|--------|----------|----------------|
| 21-Mar-14       | 389    | 205      | Hair Care Formula 1 |
| 24-Mar-14       | 366    | 205      | Hair Care Formula 2 |
| 26-Mar-14       | 370    | 205      | Hair Care Formula 3 |
| 28-Mar-14       | 365    | 205      |                |

In the graph found a very significant deviation related to cooling performance. Cooling Time performance for 20T capacity is 205 minutes. So that deviation occurs. average actual cooling time is (389; 366; 370; 365) minutes = 372.5 minutes. The deviation from the average performance is 81.7% (167.5 minutes).

- Cooling water temperature = 7 °C (standard requirement min 8 °C)
- Cooling water supply pressure = 3.1 bar (standard requirement is 2.5 bar min)
- Cooling water flow rate = 64 m³/hours (minimum requirement is 60 m³/hours).
2.4 Analyse potential impacts related to decreasing cooling time in Engineering Design, Manufacturing, and Installation.

The Root Cause Analysis (RCA) technique in the problem-solving process is a technique that is intended to help the team in your work area find and understand the main causes of the problem, with the aim of eliminating these causes again in the future so that preventive action can be taken. These included:

a. Pressure mechanical design or construction design for pressure vessels and jacket systems.
   - The thickness of the jacket wall which can accommodate steam pressure and cooling water pressure \( t = 12 \text{ mm} \) (Nominal)
   - The thickness of the jacket wall which is able to accommodate the working pressure in both vacuum and pressurized. \( t = 12 \text{ mm} \) (Nominal)
   - Pressure in the Jacket is 3.3 bar and Pressure in the pressure vessel is 2.2 bar.
   - To accommodate fluctuations in production volume, Jackets are divided into 2 Zones, namely the down jacket zone and the upper jacket zone.

b. The Process Heat Transfer design uses pressurized vessels using the system jacket
   - Process Cooling temperature starts from 80\(^\circ\)C to 25\(^\circ\)C
   - Cooling water temperature used is a minimum of 8\(^\circ\)C
   - The cooling water flow rate needed to achieve minimum performance is 60 m\(^3\)/hours
   - Working capacity is 20T, the minimum cooling time performance of 205 minutes at working capacity is 20T, The pipeline size in the cooling water distribution is 4 inches

c. Process Manufacturing or construction of pressure vessels
   The manufacturing process is an activity of making TAD\(^\text{®}\) 20T based on Original design, specific methodology, material design and time provided: Certificate of material used (plates and coils and critical consumables such as welding wire)
   - Data of personnel carrying out the manufacturing process, because all relevant personnel are required to have pressure vessel certification and pass the qualification during implementation
   - ITP (Inspection Testing Procedure) report that reports all inspection results starting from preparation, assembly and final inspection. Non-destructive Radiographic or X-Ray testing (NDT) Test, Hydrotest and QC final inspection test
   - Design Calculation validated against the actual design done by the QC team and all stakeholders in the Joint Inspection (internal test)
   - FAT (factory Acceptant Test) report is a test which is carried out where the Customer and Third Part (External Test)

d. Process Site Installing the TAD\(^\text{®}\) 20T Mixing Vessel Mixing Skid System construction.
   The TAD\(^\text{®}\) 20T Mixing Vessel piping and construction installation is in accordance with the installation drawing which has been validated also by the Commissioning Engineer and Customer representative proven by the certificate installation Completion.

e. Commissioning Process TAD\(^\text{®}\) 20T Mixing
   The commissioning is the last stage for the last inspection until the machine is declared ready for commercial production. Where in this test all the initial tests of the installation and functions will be validated and witnessed by the customer, this process is carried out at PT. YYY (Mexico City).

From the results of the commission, it was obtained that the cooling time achieved to cool the 20T Vessel from 80 to 25 \(^\circ\)C took 378 minutes, whereas the design standard was 205 minutes. Perform Risk management processes to minimize the negative impacts that may arise from the implementation of recommendations and increase the positive impact on eliminating TAD\(^\text{®}\) defects, especially on cooling time performance. Activities to be carried out in the risk assessment are:
a. Identification that will be generated
b. Conduct a Qualitative Analysis of all those that have been identified by giving priority scale to each. Scoring is done by analysing the probability (level of likelihood) and the impact that will occur. Where Priority Value is obtained by multiplying the likelihood with impact. Priority = Probability x Impact.
c. Perform Qualitative Risk Analysis and quantify all the risk to be cost to perform.
d. Prepared Risk Respond Plan. Prepared counter measure to all risk already identified to minimized or eliminate all potentially risk and enhance possibility for opportunity

e. Implemented Planning in Risk Respond Plan while this is part of DO (Phase) in process Improvement PDCA product Design Maturity TAD® as Grand Master Plan.
f. Control and monitor all action plan and prepared also fall-back action if one of those planning does not perform as per expectation.

3. Analysis and Result
From the results of the methodology and framework can be described several related to elimination defect and continuous improvement.

3.1 Integrate the results of the analysis and carry out the Brainstorming & Root Cause Analysis (RCA) & Risk Management process
This study the PDCA cycle process is chosen to implement iterative continuous improvement in accordance with the conditions and needs at a certain time. There are complaints regarding the performance defect from PT. YYY triggers TAD® product Owners to carry out the PDCA cycle to be able to eliminate Defect and find permanent solutions that can be implemented on all products. Following are the risk management activities undertaken by the product owner regarding PDCA implementation:

a. Risk Identification
   • Defect performance is found by customers in the customer's factory during production.
   • Durability issues related to mechanical design
   • The company's reputation is due to issues with TAD® performance
   • Unplanned costs that occur because of repair activities on the customer site
b. Analysis and Quantization Based on Probability & Impact.
   • Defect performance is found by customers in the customer's factory during production. At this risk the probability is medium with very high impact. Because the costs that will be incurred to solve this problem are very high.
   • Durability issues related to mechanical design. At this risk the probability is low with very high impact.
   • The company's reputation is due to issues with TAD® performance. At this risk the probability is low with catastrophic impact because the issue that can cause the company's reputation to go down is very high and requires enormous costs to restore the atmosphere.
c. Preparing a Risk Response Plan
   • Perform CAPA (Corrective Action Preventive Action) for defects that occur in the engineering and manufacturing phases where this phase is still in the corporate environment.
   • Implementing continuous improvement through the PDCA cycle
d. Implementation of Respondent Risk Plans
   • Implementation of the PDCA Cycle in the case of the performance of the TAD® 20T issue in PT. YYY
   • Standardize the results of evaluation of recommendations
e. Risk Monitoring and Control
• Evaluate the results of implementing recommendations and validate the results data to improve TAD® performance
• Evaluate Start Variations and include them in the product life cycle.

3.2 Analysis of Mechanical Design or construction Design and Process Heat Transfer.
Theoretically Performance Cooling Time is significantly influenced by the speed of heat transfer from hot media (Product) to cold media (Cooling Water). The heat transfer speed itself is influenced by:

a. Temperature of cooling fluid minimum as per basic calculation is 8 °C and the actual fluid is 7 °C, it means in term of potential energy that carrier by the cold fluid is sufficient.
b. Total energy that need to be delivery are affected by Delta temperature, Mass flow rate of the cooling fluid and the heat capacity of that fluid. Heat balance can be express on equation 1.

\[
Q = M \times C_p \times \Delta Temp
\]  
(1)
Where Q is energy and M is the number of times.
c. Type and thickness of heat conducting media. Where thickness is an obstacle to energy transfer. Types of products with variations in density and viscosity also affect the speed of energy transfer.

3.3 Analysis of Equipment Design (Mechanical Design & Heat Transfer)
The flow rate requirement for cooling water in the jacket has been adjusted in volume so that it can be passed with cooling water with a capacity of 60 m³/hours in both the upper and lower jacket zones. Differences in pressure drop in the lower and upper zone jackets cannot be avoided because of differences in the volume level of the product that follows the position of the agitator and the presence of different hydrostatic pressures due to different heights. From the heat transfer process parameters, especially in the piping:

• The existence of the lower zone jacket and the upper zone connection pipeline is divided into two lines so there is a possibility of an unbalanced flow rate in both.
• Adding a pressure drop to the lower zone jacket is the solution by providing flow rate limitation to the lower zone pipeline. With the right physics calculation, the pressure drop values in the upper and lower zone jackets.
• The diameter of the orifice is calculated precisely so that the desired pressure drop can produce a certain cooling water flow rate.
• The purpose of adding orifice is to ensure that the flowrate in the upper and lower zone jackets matches the volume portion of the zone jacket itself.

3.4 Manufacturing Process Analysis
In the manufacturing process the highest potential that causes the cooling time defect performance is:

• The dimensions of the jacket and tank do not match the original image that was done in the design phase.
• There is a malfunction caused by mechanical errors such as a leak in the jacket.

3.5 Site Process Installation Analysis
The installation process is a process of reassembling the TAD® 20T Mixing Vessel after undergoing the process of shipping by ship from Indonesia to Mexico City on the site of PT. YYY Some possible causes of the defect in this installation phase are:

• Damage occurs when shipping at sea, resulting in changes in geometry that affect the function of the Cooling System
• Damage occurred during re-assembly where the use of heavy equipment such as cranes allowed the wrong handling to occur so that the tank fell and changed.
Errors in re-assembly pipelines where in this case errors could occur from the drawing of the assembly guide or there was a human error in reading so that there is a different orientation.

3.6 Operational Process Analysis (Production at the Customer)
The concern on the customer’s side is the actual utility supply because of the good quality of supply utility that can produce optimal production performance. Search results and checking the cooling water supply temperature needed is 8 °C with the actual temperature supply is 7 °C.

3.7 Summary of the Analysis of Defect Analysis and Risk Management.
This process begins with Brainstorming, which aims to find out as many possibilities as possible with the specific performance of cooling time.

Found critical slices of parameters closely related to Cooling Performance:
- Process design requires a minimum cooling water flow rate of 60 m³/hr
- The process requires the system jacket to be divided into 2 zones, the lower zone and the upper zone, this is to accommodate if the working volume is 100% where it is 20T and if the volume is 30 -50% where it is only 5 or 10T.
- The piping part must design the pipe so that the flowrate of both has a different cooling load and flow rate, where the beginning is not realized by all stakeholders.
- By reviewing together, they understand each other and understand the needs of each and his colleagues to achieve the value of mutual optimization.

After finding several action plans as a recommendation to eliminate Defect in this TAD® Mixing Vessel. Continue to do management to minimize the negative impacts that might be caused by this recommendation. Stages in management.

a. Risk Identification
   - Finding arising from the activity Recommendation example, Limitation of flowrate due to this Orifice will increase the pressure inside the jacket which can damage the durability of the jacket and change the geometric structure of the jacket.
   - Increased electricity consumption on the customer side due to giving greater pressure.
   - Customers do not allow the implementation of recommendations because of customer uncertainty

b. Analysis and Quantization Based on Probability & Impact.
   Measure potential impact on all by multiplying probability with its impact

c. Prepare the Risk Respond Plan
   - There is a safety that is installed in the jacket to avoid excessive pressure. Make sure the security is installed well in the field and the technical specifications are the same as what is needed.
   - Provide an explanation related to the implementation plan of this recommendation starting from the basis of supporting theory, the benefits that will be obtained to detail planning. Prepare the right team to implement the recommendations.

d. Implementation of Respondent Risk Plans
   - Make sure the security is installed well in the field and the technical specifications are the same as what is needed.
   - Ensuring an experienced team related to this problem so that the purpose and objectives of implementing recommendations can be on target.

e. Risk Monitoring and Control
   - Observe and evaluate the implementation of the Risk Respond Plan and measure the success of the risk mitigation plan.
• Observe increased pressure in the jacket because of implementing recommendations and evaluating whether the safety equipment prepared is working properly. Evaluate customer responses to the results.

3.8 Recommendations for Improvement of TAD® at PT. YYY

The addition of Orifice with hole size with diameter X according to the design calculation gives a proportional pressure drop condition between the upper and lower zone jackets. The results of implementing the addition of the orifice in the lower zone jacket line result in improved following are the Implementation Recommendations for adding Orifice to the lower zone jacket on the TAD® 20T. Significant performance improvement with a proportional flow rate in each jacket zone. Cooling time that can be achieved after improvement is 199.23 minutes on average.

3.9 Implementation of recommendations for continuous improvement of TAD® at PT. YYY

Implementation of the Recommendation data validation process is also carried out by recording the production data of PT. YYY after the Implementation of Recommendations.

Here is the Cooling Time after doing the Improvement.

• Production of "Hair Care Formula 2" total cooling time is 198.6 minutes, Standard cooling time = 205 minutes
• The production of "Hair Care Formula 3" total cooling time is 193.8 minutes, Standard cooling time = 205 minutes

3.10 Implementation and Review Improvement of the TAD® Mixing Vessel's Product Design life cycle to Product Maturity through the PDCA process.

Improved cooling time performance at PT. YYY which has been through the validation process related to the new TAD® design where the addition of the Orifice system in the lower zone jacket provides proportional equalization effect of the flow rate of cooling water so as to speed up cooling time. Data that has been validated on the PT. This YYY will be used as a Design update where in the future all TAD® Designs will consider the improvement points that have been made.

4. Conclusion

The result of implementation of the addition of measured Orifice in the take zone jacket produces re-commissioning cooling time data to 205 minutes before 378 minutes before. The results of the data validation use production data after the cooling time recommendations are down to 198.6 minutes and 193.8 minutes where the average time is 196.2 minutes. Validated improvement results are recorded and standardized for all new TAD® Mixing Vessel designs and become a check list parameter in the system design. A new design parameter update and as built drawing were done to prevent the same thing from happening again. The PDCA cycle will continue if there are new requirements regarding the portfolio’s product performance & reliability.

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