DEVELOPMENT OF STANDARD PROCEDURE FOR SHAMPOO PRODUCTION

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จักรพันธ์ บุญกิตติพร : การจัดทำมาตรฐานในกระบวนการผลิตแชมพู. (DEVELOPMENT OF STANDARD PROCEDURE FOR SHAMPOO PRODUCTION) อ. ที่ปรึกษาวิทยานิพนธ์หลัก : ผศ. ประเสริฐ อัครประถมพงศ์ , 105 หน้า.

งานวิจัยนี้มีวัตถุประสงค์เพื่อศึกษาการจัดทำมาตรฐานสำหรับกระบวนการผลิตแชมพูในโรงงานเครื่องสำอางเพื่อการปรับปรุงประสิทธิภาพในเรื่องของ Right First Time ขอบข่ายของการวิจัยจะเน้นถึงกระบวนการผลิตแชมพูในกลุ่มเพื่อให้ผมนุ่มสวย ซึ่งเป็นกลุ่มที่มีการผลิตมากที่สุดของบริษัทที่เป็นกรณีศึกษา โดยจะเริ่มตั้งแต่กระบวนการเตรียมวัตถุดิบจนกระทั่งถึงการถ่ายผลิตภัณฑ์ไปยังถังเก็บ

การวิเคราะห์ลักษณะข้อบกพร่องและผลกระทบ (Failure Mode and Effect Analysis, FMEA) และ แผนภูมิการวิเคราะห์เหตุและผล (Cause and Effect diagram) ได้ถูกนำมาใช้ในการวิเคราะห์และระบุถึงปัญหาในกระบวนการผลิตแชมพู จากการศึกษามีการพบว่ามีปัญหาหลักๆที่ส่งผลถึงเรื่อง Right First Time อยู่ 4 ประการ ซึ่งก็คือ 1.คุณภาพของวัตถุดิบในการผลิต 2.ความบกพร่องของวิธีการทำงาน 3. ความไม่เที่ยงตรงของเครื่องวัดน้ำหนักในหม้อผสม 4.ความผิดพลาดจากคน ปัญหาเหล่านี้ได้นำไปสู่ปัญหาในเรื่องของ Right First Time และ ระยะเวลาในการผลิต ซึ่งส่งผลกระทบต่อประสิทธิภาพของการผลิต จากผลการวิเคราะห์นำไปสู่การจัดทำขั้นตอนมาตรฐานซึ่งเปรียบเสมือนเป็นตัวควบคุมคุณภาพในกระบวนการผลิตแชมพู ผลจากการทำขั้นตอนมาตรฐานนี้ได้ช่วยให้เรื่องของ Right First Time ในการผลิตปรับปรุงจาก 60.12 เปอร์เซ็นต์ไปเป็น 78.24 เปอร์เซ็นต์ และระยะเวลาในการผลิตลดลงจาก 151 นาทีเป็น 116 นาทีซึ่งคิดเป็นการลดลง 23.18 เปอร์เซ็นต์

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The purpose of this study is to develop standard procedure for Shampoo Products in Cosmetic manufacturing for the performance improvement in term of Right First Time. The scope of this study focuses on beauty shampoo production, which is the most volume shampoo production of the case study company that starts from raw material preparation step until discharging to storage tank.

Failure Mode and Effect Analysis (FMEA) and Cause and Effect diagram are used as quality tools for problem identification and analysis in shampoo production. Based on the study, it is found that there are 4 major problems that impact to production Right First Time. They include 1. Quality of raw material 2. Standard procedure deficiency 3. Inaccuracy of load cell in main mixer 4. Human error. These problems lead to Right First Time and production batch time problem which affect to production performance. The result of analysis leads to the creation of standard procedures which serve as quality control for shampoo production. This implementation can help improve Right First Time and production batch time in the shampoo production. Based on the result, Right First Time can improve from 60.12% to 78.24%. Moreover, production batch time also reduce from 151 minutes to 116 minutes which is 23.18% batch time reduction.

The Regional Centre for Manufacturing Systems Engineering Student's Signature.....
Field of study : Engineering Management Principal Advisor's Signature.....
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CHAPTER 1

Introduction

1.1 Background of the Research

At present, the competition in many businesses is very intense. Companies have to find the way to gain more market share and profits to stay in the business. Manufacturing efficiency improving including production cost reducing play vital part on any industries. Cosmetic industry is also one of them that can not survive without efficient production management. Since we live in global village now, process improvement is even more significant important. China and India are fast developing country and they have quite low cost on labor and many resources to develop their businesses. As a result, companies in Thailand need to develop their competition edge to compete with international competitors and also the local one.

Failure Mode and Effect Analysis (FMEA) is studied in this thesis as a tool to help developing process standard in cosmetic manufacturing to improve production performance in terms of quality, cost and time. Production process will be analyzed to identify potential failures that affect to the product quality and process performance. Cause and effect of that failure including process control will also be identified and evaluated. Data collection will be considered and apply to achieve process standard of production. Process of FMEA will be illustrated in figure 1.1.

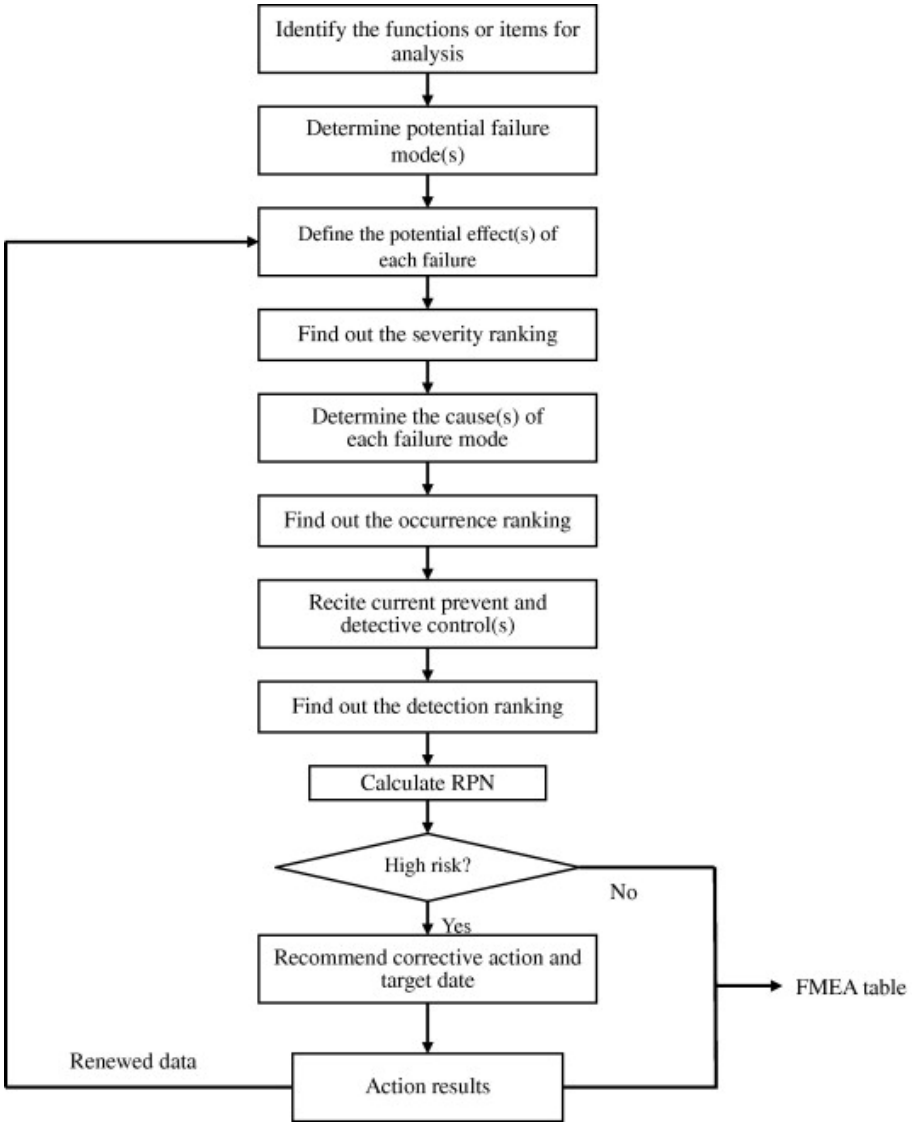


Figure 1.1: Process of FMEA (Chao-Ton Su and Chia-Jen Chou, 2007)

After FMEA discussion, Design of Experiment (DOE) will be used for analyzing several factors that affect to the problem and find the suitable way to solve that problem. Design of experiment (DOE) is a powerful technique for discovering a set of process variables which are most important to the process and then assisting experimenters to determine at what levels these variables should be set to optimize performance.

1.2 Company Background

The case study company is the international consumer products manufacturer and was established in Thailand since 1932. The company products can be divided into 4 categories.

- Personal Care
- Skin Care and Cleansing
- Home Care
- Ice Refreshment and Foods

The company is presented with GMP (Good Manufacturing Practice) certification in 1995 and receives ISO 9001 and ISO 9002 quality standards certification in the year after. One year later, it is granted ISO 14001 standards accreditation.

Production Process in Cosmetic plant

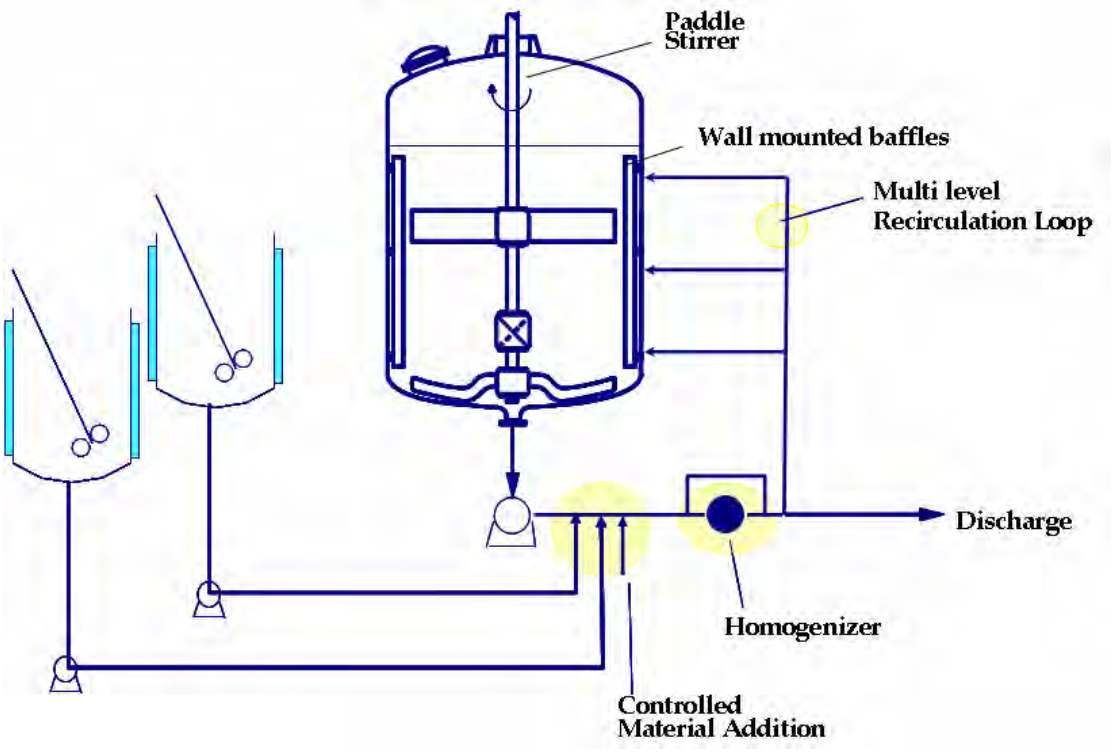


Figure 1.2: Cosmetic plant's mixer

Cosmetic plant is main plant of the case study company producing many quality products to the market. Because of that, process improvement in this plant has a huge benefit to the company.

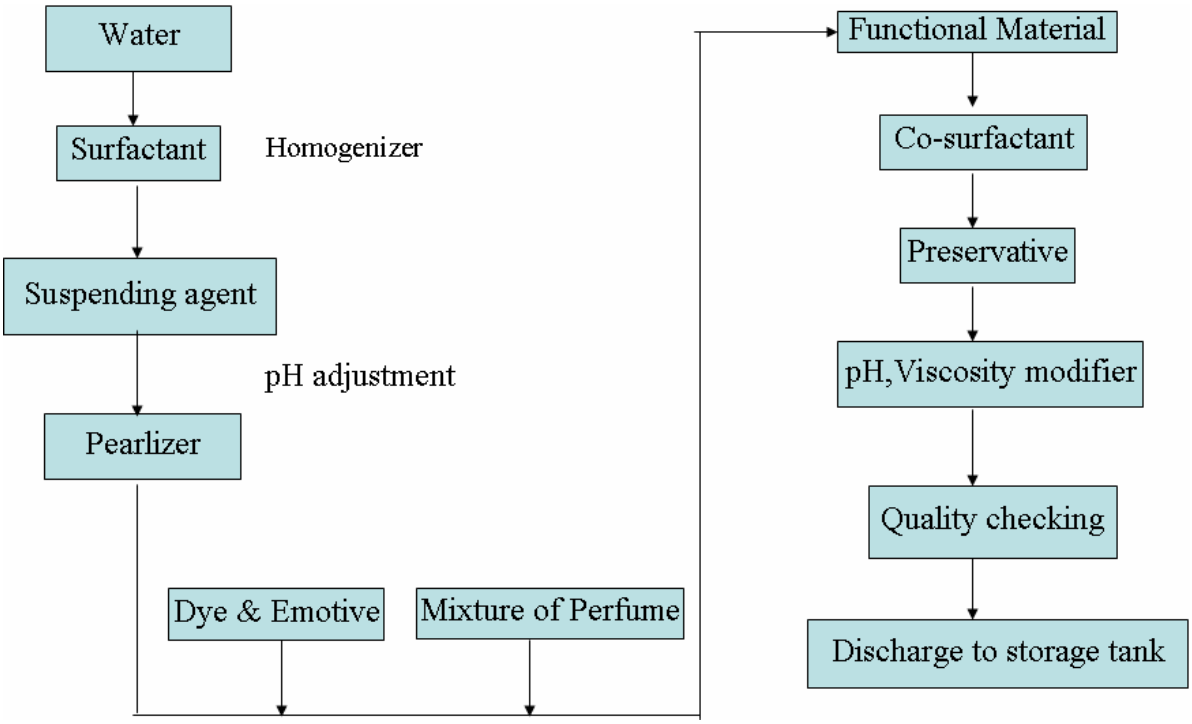


Figure 1.3: Raw material step for shampoo products

1.3 Statement of the Problem

From cosmetic plant data, it can achieve the Right First Time only 60.12% for Shampoo products which is relatively low. Right First Time is calculated from No. of shampoo batches that have already got the right specification and there is no need for further quality adjustment in QC step per No. of total batch. Viscosity, pH, %AI, density, color standard are product parameters that must be controlled to get the right product quality and they have to be adjusted several time before getting the right specification. This also affect to the production batch time since it takes a lot of time per each adjustment. Consequently, it impacts to the productivity and efficiency of Cosmetic plant.

Table 1.1: % Right First Time of Shampoo products in 2007

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Summary
No. of batch	104	91	76	103	130	122	99	115	840
RFT (Batch)	59	45	46	59	69	82	69	76	505
%RFT	56.7	49.5	60.5	57.3	53.1	67.2	69.7	66.1	60.12

Production batch time of shampoo products should be improved as well since Shampoo is the main product of this plant. Batch time reduction can be a huge benefit to the factory. Energy cost such as electricity, water and steam will also reduce as batch time reduces as well. Loss of material is also this Cosmetic plant's problem. Higher overhead cost from loss of material and labor will lead to the higher manufacturing cost as well. In addition, high manufacturing cost will have influence to competitive power of company in competing with the competitors in the market. The company which has low manufacturing cost will get higher profit in price-war business as present time. When price-reduction campaign has been launched, company can still get reasonable margin because of low cost manufacturing. Among fierce competition today in the consumer product, the company with high manufacturing cost will have risk to lose their market share and may not survive in the business.

Production batch time and material loss of Shampoo products will be shown in table 1.2 and 1.3, respectively.

Table 1.2: Production batch time of Shampoo Products

Year 2007	Jan	Feb	Mar	Apr	May	Jun	Jul	Avg.
Mixing time	80	77	67	70	71	79	74	74
QC time	42	48	56	64	56	52	53	53
Discharge time	25	24	23	26	27	23	23	24
Total time	147	149	146	160	154	154	150	151

Table 1.3: Cost of material loss of Shampoo Products in 2007

Material	Cost of material loss (Thousand Baht)							
	Jan	Feb	Mar	Apr	May	June	Jul	Aug
Surfactant	67	-	-	-	-	-	-	-
Co-surfactant	50	59	66	80	104	147	137	-
Silicone	7	96	-	-	-	-	-	-
Anti dandruff agent	4	18	17	48	35	49	30	-
Other raw material	29	143	100	116	132	167	189	213
R/M received from other plant	-	-	12	24	32	25	24	29
Total	157	316	195	268	303	388	380	242

Since Right-First-Time problem can affect to the other two problems, it should be the focus improvement of this research. In addition, there are other problems occurred in the Cosmetic plant such as machine break down. However, it does not influence too much on the factory.

Standard procedure is needed to be created for control raw material specification and mixing process of shampoo production to improve this production Right First Time.

1.4 Objective of the Research

The objective of this research is to develop standard procedure for Shampoo Products in Cosmetic manufacturing for the performance improvement in term of Right-First-Time.

1.5 Scope of the Research

This study will be conducted based on beauty shampoo production which covers around 70% of overall manufacturing in Cosmetic plant from raw material preparation step until discharging to storage tank.

1.6 Expected Benefits

The expected benefits of this research are as follow:

1. Standard procedure of the Shampoo processing in Cosmetic plant
2. Higher percentage of Right-First-Time in Shampoo mixing
3. Process batch time reduction
4. Cost of material loss reduction
5. Guideline to the similar plant in the same industry

1.7 Research Procedure

1. Review the literatures and related studies.
2. Collect data of existing problems in Shampoo manufacturing from Cosmetic plant.
3. Set up FMEA team which consists of members from process development, production, engineering and quality assurance.
4. Brainstorm and identify possible causes and effects of problem by Fishbone diagram including discuss the estimation of severity, occurrence, and detection.
5. Propose potential solutions by using Design of Experiment (DOE) for the improvement.
6. Review and test the improvement in pilot plant including implement in Cosmetic plant.

7. Create standard procedure for Shampoo products in Cosmetic plant.
8. Compare production data before and after improvement.
9. Summarize the thesis.
10. Prepare thesis report and final examination.

1.8 Research Schedule

Procedure	2008						
	Mar	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
1. Review the literatures and related studies							
2. Collect data from Shampoo manufacturing							
3. Set up FMEA team							
4. Brainstorm to identify cause and effects and discuss estimation of severity, occurrence and detection							
5. Propose potential solution for the improvement							
6. Review the improvement							
7. Create standard procedure for Shampoo Products in Cosmetic plant							
8. Compare production data before and after improvement							
9. Summarize the thesis							
10. Prepare thesis report and final examination							

CHAPTER 2

Theory and Literature Survey

2.1 Definition of FMEA

Failure mode and effects analysis (FMEA) first emerged in 1963 from studies done by NASA and then expand into automotive industry. FMEA method is based on systematic brainstorming to examine the possible failure that may happen in a process system and explore the impact of the failure on product design and process planning.

According to Teng and Ho (1996), FMEA is a technique that identifies

1. "The potential failure modes of a product during its life cycle
2. The effects of these failures
3. The criticality of these failure effects in product functionality"

FMEA is a popular tool for reliability and failure mode analysis since it would cover the activities both design and process operations. It is also useful in quality planning and reliability prediction. Although FMEA may be applied at any stage of design, development, or production, it is most suitably applied at the design stage to identify and eliminate causes because its main purpose is to prevent failure. FMEA would offer basic information to product and process design. It would help finding potential problems in the earlier stage and prevent costly change at later stage such as production stage. FMEA can be classified as "bottom up" approach as it functions by means of the identification of a particular cause or failure mode within a system in a fashion that traces forward the logical sequence of this condition through the system to the final effect (R. Mcdermott, R. Mikulak and M. Beauregard, 1996)

According to Napassavong, benefits of FMEA can be identified as below.

- “Minimize failures due to product and process
- Provide focus on where to improve the design and process
- Reduce late design changes
- Serve as document and support idea exchange across functions
- Used as knowledge base for other similar parts”

Type of FMEA

There are several types of FMEA: design FMEA, process FMEA, equipment FMEA, maintenance FMEA, concept FMEA, service FMEA, system FMEA, environmental FMEA, and other. However, for all intents and purposes, all of the types can be broadly categorized under either design FMEA or process FMEA (Besterfield et al, 2003)

1. *Design FMEA*

It is used to analyze designs before they are released to production. The most leverage of the Design FMEA is when the failure modes are proactively identified in the early stages of the project when it is still on paper. During design process, design FMEA will help identifying known and foreseeable failure modes and then ranking failure according to relevant impact on the product.

This would help FMEA team in

- Estimating the effects on all customer segments
- Assessing and selecting design alternatives
- Prioritizing the list of corrective actions using strategies such as mitigation, ignoring, transferring or preventing the failure modes
- Identifying the potential special design parameters in terms of failure

- Reducing development time and cost of manufacturing processes by eliminating many potential failure modes prior to operation step

- Documenting the findings for future reference

2. *Process FMEA*

It is used to analyze manufacturing, assembly or any other processes. It will help identifying potential process failure modes by ranking failures and helping to establish priorities according to the relevant impact on both internal and external customer.

This would help FMEA team in

- Identifying potential manufacturing/assembly or production process causes in order to establish controls on increasing detection and reducing occurrence

- Prioritizing the list of corrective actions using strategies such as mitigation, ignoring, transferring or preventing the failure modes

- Documenting the results of their production processes

- Identifying the special potential process variables from a failure standpoint which need special controls

Some of the other types beside design FMEA and process FMEA will be described as below.

Maintenance FMEA

This is slightly modified version of process FMEA. It is used to diagnose a problem on assembly line or test the potential failure of prospective equipment before making final purchase.

Environmental FMEA

It is similar to maintenance FMEA since it is also slight modification of process FMEA. Environmental FMEA can be used to evaluate the environmental impact or correct the impact of production.

Service FMEA

Since most types of services can be considered processes, service FMEA can be modified from standard process FMEA. Processes within service industry could be evaluated prior to customers seeing them to prevent any initial loss of business that may occur. For example, service FMEA can be used to analyze the way a company is servicing its customer.

When to use the FMEA

Straker (1995) has identified when to use FMEA as follows:

- Use it when designing products or processes, to identify and avoid failure-prone designs.
- Use it when investigating why existing systems have failed, to help identify possible causes and remedies.
- Use it when investigating possible solutions, to help select one with an acceptable risk for the known benefit of implementing it.
- Use it when planning actions, in order to identify risks in the plan and hence identify countermeasures.

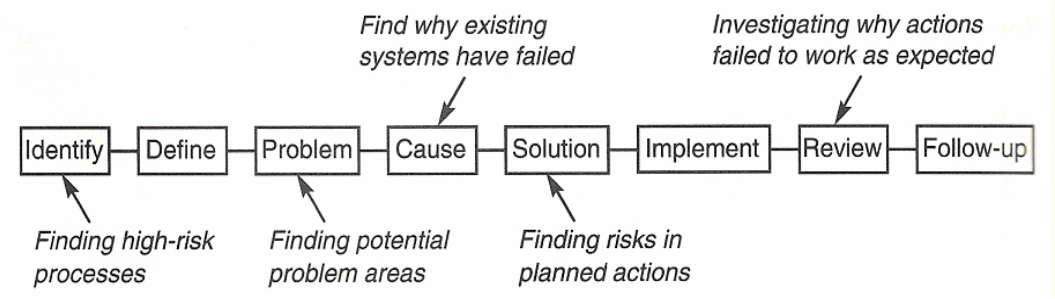


Figure 2.1: Possible uses in improvement project framework

2.2 Process of FMEA (Methodology)

1. **Define the process boundaries**

Constructing the project processes boundary as bounded by the process structure. The FMEA can maximize its design quality by preventing all manufacturing, assembly and production failures. The boundary of process will need to be clearly defined. If the team needs to go beyond this boundary, the process should also be clarified. Process flow chart is applicable for process FMEA and it can help FMEA team in identifying failure mode and relevant information throughout the FMEA process. This flow chart will provide overview of the complete production processes for the product. It should show the sequence of each production operation and how these functions create the required product characteristic.

2. **Select the FMEA team**

FMEA is “team approach”. It can not be done properly on individual basis. FMEA input should come from a multi-disciplinary team. The team should consist of knowledgeable individuals with appropriate expertise e.g. design, manufacturing, assembly, service and quality. The responsible engineer typically leads the FMEA

team. Members and leadership may vary as the system, product, and process designs mature. Teamwork is critical to the success of the FMEA process. Therefore, all members must be ensured that they willing to contribute to the team. As a result, all required information would be used to develop an effective FMEA report.

3. Brainstorm Potential Failure Modes

The team will begin to brainstorm the process failure modes after they understand the process and its boundaries. Brainstorming sessions and cause and effect diagrams which are basic tools can be used to determine the relationship between potential failure modes, their effects and the cause leading to them for each function that is analyzed. Focusing on each component will result in more through potential failure mode list. All possible failure modes of the product's components, sub-assemblies, final assembly and its manufacturing processes should be listed. Cause and effect diagram is also useful tool in grouping failure modes into each category such as man, material, method, etc.

4. List the potential effects

After each failure mode is identified, the FMEA team would determine all significant effects that may be manifested and set down the effects that each mode of failure would have on the function of the product or system. The effect is the outcome to question like "what is an undesirable result of the identified failure mode? It can be simplified by using a standard list of effects. For example, difficult to close, will not close, etc. The failure may impact to other components in the system, process and lead to other failures. It could affect customer whether it is internal or external customer.

5. Identify the potential cause of each failure

All the possible causes of each failure mode will be listed. This is also important part of the FMEA process. This information is crucial for the improvement effort since it provides insight into probability of failure and guides the team toward suitable corrective action later.

6. **List the current control**

For each potential cause of failure, list the current or intended control that will detect either the cause or the failure mode such as some testing or inspection.

7. **Evaluate the severity, occurrence and detection**

The team would assess numerically on severity, occurrence and detection. Experience and reliability data should be used, together with judgment, to determine the value. Team should develop their own standardized ranking on both scale and criteria to suit their failures.

8. **Calculate and prioritize the "risk"**

To evaluate the criticality of a cause of possible defect, the risk priority number (RPN) for the failure is calculated as the product of 3 indexes: the severity index "S", reflecting how serious the failure is, the occurrence index "O", reflecting the likelihood of the failure occurring, and the detection index "D", reflecting the likelihood of a possible flaw not being detected. This will indicate the relative priority of each mode in the failure prevention activities. When the risk priority number has been calculated, the failures may be ranked accordingly. It is usually advisable therefore to determine the value of RPN for each failure mode before completing the last columns. In this way the action required against each item can be judged in the light of the ranked severity and the resources available (Oakland, 1993).

RPN = Severity x Occurrence x Detection

9. Determine corrective action

Having obtained the RPN, a ranking of the causes of the failure is showed up and corrective action is taken by the involve department beginning with the riskiest as shown by the RPN. Responsible department or person should be assigned in the FMEA worksheet together with the expected completion date. This make responsibility clear-cut and facilitates tracking.

In reducing the risk, Ammerman (1998) proposes an order of priorities that must be followed to decide corrective action as the following.

1. 1) *Eliminate the cause of the failure*. The design of a part might be changed, for example, so that another piece that is similar and easily mistaken for it is not incorrectly assembled.
2. (2) *Reduce the frequency or likelihood of occurrence*. Instead of trying to eliminate the root cause of the failure, the system is strengthened so it can "resist".
3. (3) *Reduce the severity of the failure*. This can only be achieved with failure-free design or by using redundant systems.
4. (4) *Increase the likelihood of detection*. By increasing controls or designing an improvement of the existing controls.

10. Review the FMEA

After actions have been taken, re-assess the severity, occurrence and detection and review the revised RPN to see whether there are any further actions required. The FMEA is a living document and should be reviewed and managed on an ongoing basis. As the design or process changes, the assessment changes or new information becomes known, FMEA should be updated since these changes often introduce new failure modes.

According to Crow (2002), it is important to review and/or update FMEA when:

- A new product or process is being initiated (at the beginning of the cycle)
- Changes are made to the operating conditions the product or process is expected to function in.
- A change is made to either the product or process design. The product and process are inter-related. When the product design is changed the process is impacted and vice-versa
- New regulations are instituted
- Customer feedback indicates problems in the product or process

2.3 Component (Element) of FMEA

Table 2.1: Example of Process FMEA Document

FAILURE MODE AND EFFECT ANALYSIS
(PROCESS FMEA)

FMEA Number _____

Page _____ of _____

Item _____ Process Responsibility _____ Prepared By _____

Model Number/Year _____ Key Date _____ FMEA Date (Orig.) _____ (Rev.) _____

Core Team _____

Process Function Requirements	Potential Failure Mode	Potential Effect(s) of Failure	S	CLASS	Potential Cause(s)/ Mechanism(s) of Failure	O	Current Process Controls	D	RPN	Recommended Actions	Responsibility and Target Completion Dates	Action Results				
												Actions Taken	SEV	OCC	DET	RPN

FMEA document's form depends on FMEA team to choose to suit their process. However, it usually consists of:

- Process Function/ Requirements

It is the description of the process being analyzed. It should be given as completely and concisely as possible. Each operation should be listed separately along with its description, if that process involves more than one operation.

- Potential Failure Mode

It is the manner in which the process could potentially fail to meet the process requirements. Each potential failure mode for the particular operation may have more than one level. Aspect of viewing what is not acceptable come from the side of customer whether internal or external.

- Potential Effect of Failure

It is the consequence of the failure as experienced by the customer, whether internal or external. The effects of failure must be described in terms of what the customer notices or perceives. It can also be stated whether the failure will impact health or safety issues.

- Severity

It is subjective measure of “how bad” or “serious” the effect of the failure mode is. The severity applies only to the effect of failure.

- Potential Cause of Failure

It is defined as how the failure could occur, described in terms of something that can be corrected or controlled. Many causes are not mutually exclusive, and to correct or control the cause, design of experiments may be considered to determine which root causes are major contributors and which can be controlled.

- Occurrence

It is subjective measure of how frequently the failure cause/ mechanism are projected to occur.

- Current Process Controls

It is list of current controls that either prevent the failure mode from occurring or detect the failure mode if it should occur.

- Detection

It is an assessment corresponding to the likelihood that the current process control will detect a potential weakness or subsequent failure mode before the component leaves the production operation or assembly location.

- Risk Priority Number (RPN)

Risk Priority Number is the product of Severity (S), Occurrence (O) and Detection (D) values as shown below:

$$RPN = (S) \times (O) \times (D)$$

- Recommended Actions

Team should begin to examine the corrective action that may be employed after giving a risk priority number. The purpose of the recommended actions is to reduce one or more of the criteria that constitute the risk priority number. It is worth mention that entering “None” if there are no recommended actions available to reduce any of those criteria is also important, so future users of the document will know the concern has been considered.

- Responsibility and Target Completion Dates

This part is for individual or group responsible for the recommended actions. The target completion date should be entered as reference for future users.

- Action taken

A brief description of the actual action and its effective date should be entered after an action has been implemented to ensure that future users may track the progress of the plan.

2.4 Literature Survey

There are many studies and literatures showing FMEA has been used successfully in many different industries. Examples of these studies are:

Intira Laosrimongkol (2004) showed that FMEA is useful tool to reduce defects in cast iron products and to evaluate the return on quality investment. Brainstorming on other related factors and applying cause and effect matrix, why-why analysis, and FMEA would help to define root cause of the problem.

Sunya Sirichanyakul (2004) showed that the application of FMEA technique could solve the breakage problem in the production of PP bands in the oven in the stretching process. FMEA team was formed from various departments to identify all possible causes that could potentially lead to PP-band breakage problems. Detailed process flowchart and fishbone diagram could be used to aid this brainstorming. The experiment was designed to analyze the real cause of breakage. The corrective action was implemented to eliminate the problem after the cause was found.

Piyawat Rattanasupar (2002) explained developing the standard procedure for color control in tinted products in paint manufacturing by means of FMEA technique. FMEA and Cause and Effect Diagram were used as the quality tools for analyzing the potential failure modes and their effects in tinted alkyd products in a systematic way. The result has lead to the establishment of the quality assurance system for tinted alkyd products which include standard work instruction, check sheet and preventive maintenance plan. After the implementation, color adjustment and process time had improved.

Ching-Chow Yang, Wen-Tsaan Lin, Ming-Yi Lin and Jui-Tang Huang (2006) showed that a systematic evaluation and improvement mechanism could be establish via failure mode and effects analysis (FMEA) to locate the risk priority number (RPN) of implementation items for semiconductor related industries in Taiwan while

introducing ERP. A standardized system introduced performance matrix based on the performance evaluation matrix (PEM) will be established in accordance with the locations of severity (S), occurrence (O) and detection (D) and the three RPN indices, in the PEM. Performance levels will be assessed and the performance improvement strategy introduced by the system will be formulated. Finally, items falling within the non-appropriate performance zone will be specified through the quality function development (QFD) method.

Sheng-Hsien Teng and Shin-Yann Ho (1996) discussed the implementation of FMEA for both product design and process control in airbag inflator. It was implemented in two ways to make sure that the reliability requirements were met for the production. Design FMEA is performed to generate a process control plan, visual aids, and a process verification list. Design and process FMEA were integrated through reliability prediction and supplier PPM reports. The supplier PPM reports contain the information that can be employed to update the probabilities used in design FMEA. The results of reliability predictions were fed back to eliminate the design weakness. Demonstrates the integrated procedure of the FMEA approach and discusses the relationships among useful tools.

S. Gary Teng, S. Michael Ho, Debra Shumar and Paul C. Liu (2006) explained the implementation of FMEA in a Collaborative environment, the issues occurred in the implementation process, and a tool that can be used by all parties in a collaborative environment for FMEA process. The discussion included the procedure of an integrated FMEA approach, how to implement the procedure in a supply chain, and the common problems happened in its implementation in automotive industry under a collaborative environment.

G. Cassanelli, G. Mura, F. Fantini, M. Vanzi and B. Plano (2006) showed that ordinary FMEA was applied during the design phase of an electric motor control system for vehicle HVAC (Heating/Ventilation/Air Conditioning). The corrective actions, planned on the basis of the sole failure mode, as usual in FMEA, proved to be inadequate and Failure Analysis was performed to understand the failure mechanism

of the indicted component and integrate. New proper corrective actions were devised and successfully implemented.

2.5 Related Studies

Woraphoom Jatuworaphat (2004) provided the new packaging design and concept that reduces freight cost and packaging cost by Six-Sigma methodology. Both macro and micro level of packaging problem were analyzed to find an appropriate quality improvement process. Then, the factors that were related to the problem had been prioritized and the factors that have most impact to objective will be selected for improve and analyze. As a result, the new concept packaging from the research had been totally changed from the original design that was designed for group packaging to be the transport packaging. New packaging was also implemented as the pilot run to assess the negative impact to the quality that may be happened from packaging cost reduction.

M.C. Eti, S.O.T. Ogaji and S.D. Probert (2006) explained a methodology for the development of PM using the modern approaches of FMEA, root-cause analysis, and fault-tree analysis was presented. Applying PM leaded to cost reduction in maintenance and less overall energy expenditure.

S.M. Seyed-Hosseini, N. Safaei and M.J. Asgharpour (2005) explained that an effective methodology related to decision making field had been developed for reprioritization of failure modes in a system FMEA for corrective actions. The proposed method called Decision Making Trial and Evaluation Laboratory (DEMATEL) is an effective approach for analyzing relation between components of a system in respect to its type (direct/indirect) and severity. The main advantages of DEMATEL were involving indirect relations in analyze, allocating as possible as unique ranks to alternatives and clustering alternatives in large systems.

B. Almannai, R. Greenough and J. Kay (2007) showed integrated approach, both the quality function deployment (QFD) and FMEA, developed for supporting management in addressing technology, organization, and people at the earliest stages of manufacturing automation decision making. The principal concepts of both applications were merged together to form a decision tool; QFD in its ability to identify the most suitable manufacturing automation alternative and FMEA in its ability to identify the associated risk with that option to be addressed in the manufacturing system design and implementation phases.

Nune Ravi Sankar and Bantwal S. Prabhu (2001) discussed a technique for prioritizing failures for corrective actions in FMEA. This technique extended the risk prioritization beyond the conventional risk priority number (RPN) method. A new scale had been defined. The ranks 1 through 1,000 were used to represent the increasing risk of the 1,000 possible severity-occurrence-detection combinations, called risk priority ranks (RPRs).

Seung J. Rhee and Kosuke Ishii (2003) explained that FMEA was a design tool that mitigates risks during the design phase before they occur. Risk was measured in terms of Risk Priority Number (RPN) that was a product of occurrence, severity, and detection difficulty. The authors introduced Life Cost-Based FMEA which measures risk in terms of cost. It was useful for comparing and selecting design alternatives that can reduce the overall life cycle cost of a particular system. Monte Carlo simulation was applied to the Cost-Based FMEA to account for the uncertainties in: detection time, fixing time, occurrence, delay time, down time, and model complex scenarios.

Ching-Liang Chang, Ping-Hung Liu and Chiu-Chi Wei (2001) explained that conventional FMEA determines a risk priority number by multiplying the scores of three factors. However, the scores were obtained from subjective linguistic assessment, and the relative importance of factors was not considered. This study applied the grey theory to the FMEA to improve the effectiveness. It could enhance product reliability and process stability by discovering potential problems during the stages of the product design and process planning.

Jiju Antony, Tzu-Tao Chou and Sid Ghosh (2003) explained that Design of experiment (DOE) was a powerful technique for discovering a set of process or design variables which are most important to the process/product/system and then assisting experimenters to determine at what levels these variables should be set / kept to optimize performance. In order to demonstrate the power of designed experiments over the traditional one-factor-at-a-time (OFAT) approach, the authors used a simple catapult experiment. They suggested that such an experiment could act as a powerful weapon in the training of engineers and managers who might be intimidated by a more “up front” statistical approach.

Shad Dowlatshahi (2004) showed using design of experiment (DOE) to identify causes of defects associated with plastic injection molding processes at the early phases of designing processes and operations. A detailed eight-phase methodology was offered through which an identification of defects and effective solutions for their removal could be done. The author also showed how the parameters of the problem could be established and how DOE could be applied to achieve the stated objectives by using the results of only 18 and ten DOE test runs. The results of the initial experiments were subjected to a verification procedure to determine their viability and accuracy. As a result of this experiment, the company was able to make the changes needed to reduce the cycle time required to produce products and thus, increase productivity while maintaining high quality standards.

CHAPTER 3

Research Methodology

This chapter is about research methodology to reduce the Right First Time problem in the Shampoo production line of the case study company and to identify the potential causes of this problem which affect to production performance and production cost. The Failure Mode and Effect Analysis (FMEA) is employed to achieve the objective of this thesis since it is a analysis tool used to identify and eliminate potential failures that affect to product quality and process performance. Moreover, Cause and Effect diagram is also applied in the FMEA process to identify root causes of the problem. Information on Right First Time problem was collected in the case study company and beauty shampoo production line which covers 70% of overall manufacturing in Cosmetic plant was selected for this study.

3.1 Failure Mode and Effects Analysis in Shampoo Production

3.1.1 Data Collection

The data regarding Right First Time problem in the case study company includes data of the amount of batch mixed and batch achieved Right First Time in year 2007 as shown in table 3.1:

Table 3.1: Data of Right First Time problem in the study line

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Summary
No. of batch	104	91	76	103	130	122	99	115	840
RFT (Batch)	59	45	46	59	69	82	69	76	505
%RFT	56.7	49.5	60.5	57.3	53.1	67.2	69.7	66.1	60.12

3.1.2 Process Boundary

Process boundary or scope of the FMEA discussion need to be clearly defined to all FMEA team members. The scope of FMEA in this thesis will study from raw material preparation step until discharging step to storage tank as explained below:

1. Charge Chlorinated water in the main mixer as shown in figure 3.1 and start agitator at low speed.

Figure 3.1: Main mixer

2. Feed Surfactant into the mixer pass through Homogenizer.

Figure 3.2: Homogenizer

3. Charge Suspending agent from stock tank into main mixer. Then, neutralize with pH modifier to make it functional.

Figure 3.3: Suspending agent solution stock tank

4. Prepare mixture of emotive and perfume in side pot separately and transfer the mixture into main mixer.

Figure 3.4: Mixture of Emotive preparation side pot

Figure 3.5: Mixture of Perfume preparation side pot

5. Add Pearlizer and Functional material via top of the mixer as figure 3.6

Figure 3.6: Adding material on top of mixer

6. Add preservative and Co-surfactant into the mixer.

7. Charge Viscosity modifier for viscosity adjustment in the main mixer, stir at high speed to make it homogeneous.

Figure 3.7: Viscosity modifier tank

8. Quality inspection and adjustment step to control product parameters to be within product specification.

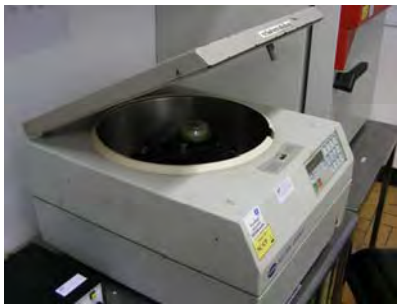



Figure 3.8: QC instruments on quality measurement

9. When all controlled parameters are within specification, then it will be discharged to storage tank.

Figure 3.9: Finished Goods storage tank

3.1.3 FMEA team set up

The FMEA concept is “team approach”. The team must be cross-functional and they must be willing to contribute to the project. The FMEA team in this study consists of production engineer, process development supervisor, product development supervisor and quality assurance supervisor. Below is the detail of the team members.

1. Team Chief	: The author
2. Production Engineer	: Bachelor degree in Chemistry, working experience 3 years
3. Process Development Supervisor	: Bachelor degree in Polymer Science, working experience 2 years
4. Product Development Supervisor	: Bachelor Degree in Chemistry, working experience 4 years
5. Manufacturing	: Diploma degree in Electronic, working experience 15 years
6. Quality Assurance Supervisor	: Master degree in Product Development, working experience 1 year

3.1.4 Process of conducting FMEA

Process FMEA is applied to eliminate or minimize all possible causes that have impact to Right First Time problem in Shampoo production. Process FMEA Table (See Appendix A) will be used in documentation and facilitating the FMEA process.

FMEA team members will brainstorm all potential causes of failure for each process step of shampoo production process that affect to Right First Time problem. This process will be facilitated by using process flow chart of shampoo production. Cause and Effect diagram technique will be used to categorize the team's ideas. The ideas would be classified into 5 categories of cause and effect diagram – material, man, measurement, method and machine as exhibited in figure 3.10. The information from this analysis will be used to fill in the columns of the process FMEA table in relationship to the potential effects of failure and current process control. Recommended actions need to be filled in process FMEA table. Responsibility and Target Completion Date is also important when assigning to appropriate team member.

Since the case study company has their own evaluation criteria about the score of severity, occurrence and detection, the author will use those criteria (See Appendix B, C and D) in rating the score in order to prevent the confusion when implement this FMEA process to the case study company. The RPN (Risk Priority Number) which is the risk degree will be calculated from Severity (S), Occurrence (O) and Detection (D) as below.

$$RPN = S * O * D$$

RPN value will be used to rank the concerns n the shampoo production process. The failure that has higher RPN value should be focused more since it has higher risk.

The FMEA team agrees to pursue failures on RPN value > 18 based on maximum score for the RPN is 125 (5*5*5 from severity, occurrence and detection). In addition, RPN score at 18 come from acceptable level of severity at 2, occurrence at 3, detection at 3. It means that the RPN of failure that has higher score than 18 must be addressed and taken into consideration to find solution and improvement.

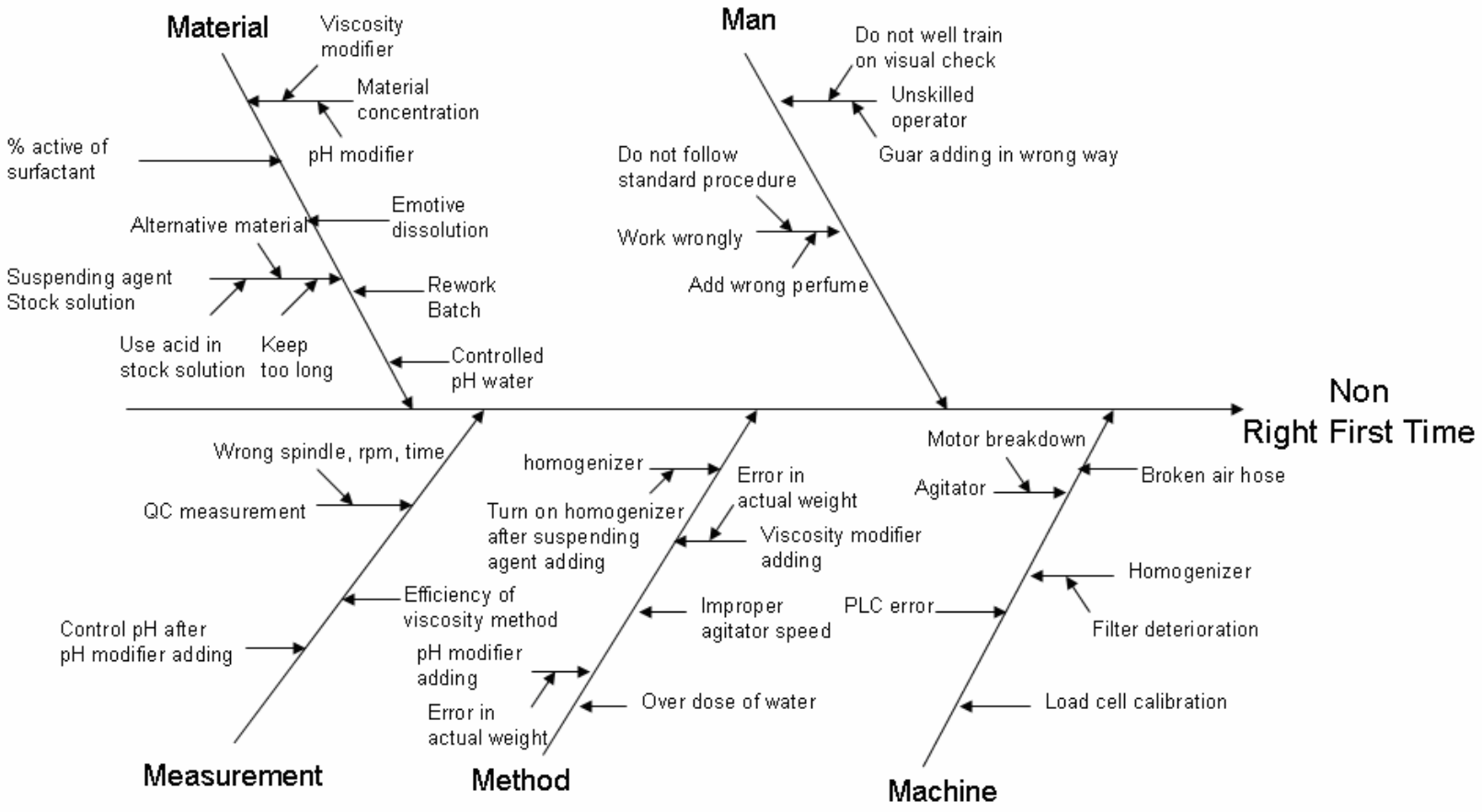
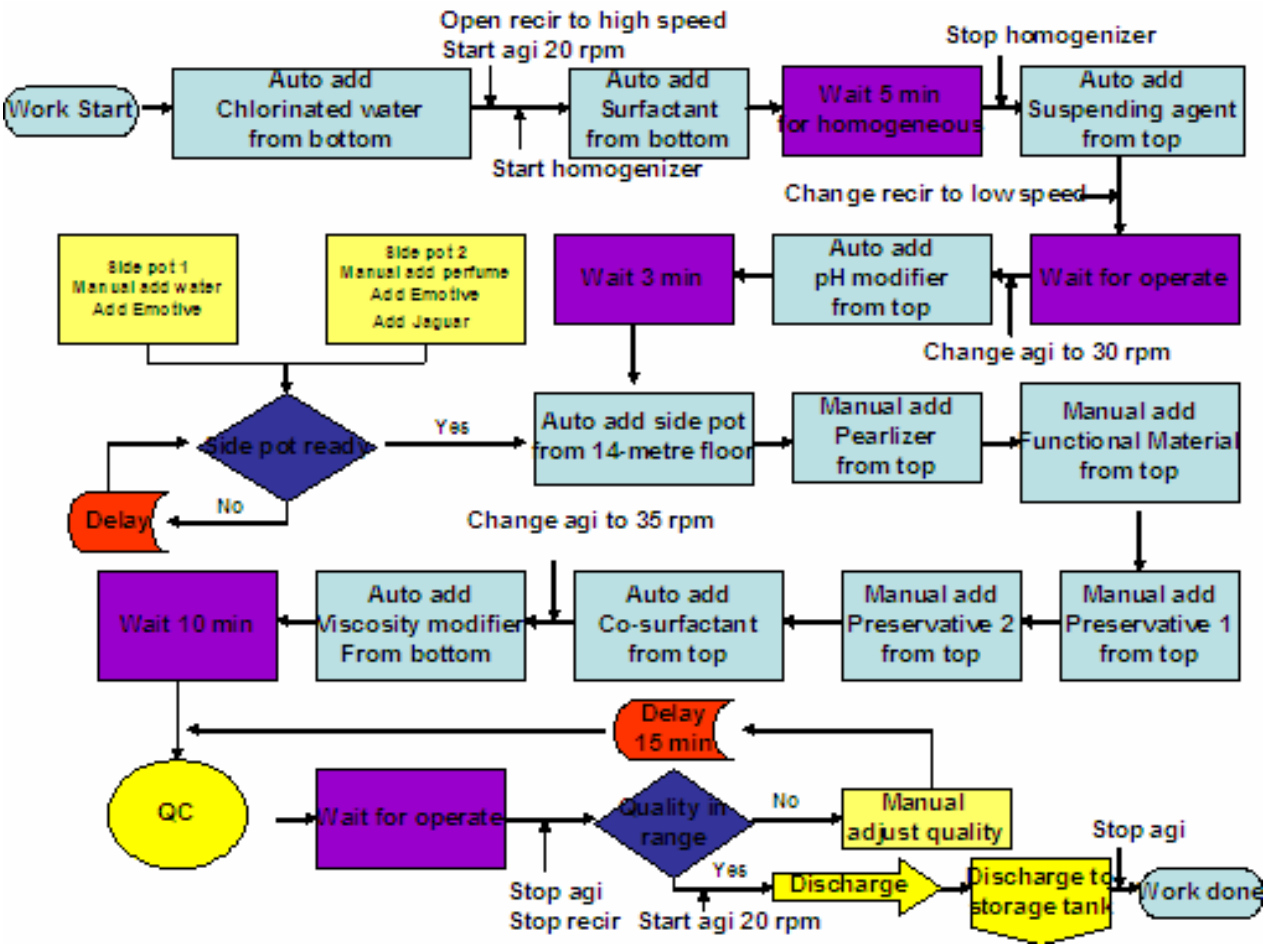


Figure 3.10: Cause and Effect Diagram

3.1.5 Shampoo production process flow chart



3.1.6 Process FMEA at shampoo production

The FMEA team has ranked the score of severity, occurrence and detection of each failure in shampoo production based on Evaluation criteria (See Appendix B, C and D). Process FMEA will be illustrated in table 3.2

Table 3.2: Process FMEA of shampoo production

Process FMEA (Failure Mode and Effects Analysis)

Product Name :	Shampoo product									FMEA Number :	PP-001			
Project :	FMEA									FMEA Date (orig.) :	Apr 30, 08			
Prepared by :	Jakkaphan B.									FMEA Date (Rev.) :	May 14, 08			
Key date :	May 14, 08									Page 1 of 5				
Team :	Team chief, production engineer, process development supervisor, product development supervisor, manufacturing, quality assurance supervisor													

Process Function and Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential Cause(s) of Failure	O	Current Process Control	D	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Results: Action taken	S	O	D	RPN
Chlorinated water	Product pH will out of spec	pH will out of spec.	4	pH water is out of controlled at 5.5-8.0	1	Probe controller /alarm	1	4							
Surfactant	Lump of surfactant	Cleansing performance	4	Surfactant is not completely dissolved	3	Visual check	3	36	Set up work instruction to ensure surfactant dissolution	Process Develoment (June 24, 08)					
	Low %AI of product	Cleansing performance	4	Lower dosage of Surfactant on%active	4	Control via PLC and weighing system	3	48	Set up work instruction for surfactant concentration	Production, QA (June 27, 08)					
Surfactant adding	Surfactant is not homogeneous	Cleansing performance	4	Too high rate of Surfactant adding	1	Control recir rate at high during Surfactant adding	1	4							
Machine system	Error on agitator	Non-homogeneous of Product	4	Agitator speed is not proper	2	Process specification	1	8							
		Can not mix at all	4	Agitator motor breakdown	2	Visual inspection	2	16							
	Error on weighing system/ balance	Loss/gain of material	4	Wrong weighing system/ balance calibration	3	Visual inspection	2	24	Set up preventive maintenance	Production, QA (June 24, 08)					
	Error on PLC	Can not mix properly	4	PLC error	2	Visual inspection	3	24	Set up preventive maintenance	Production, QA (June 24, 08)					

(continued)

Process FMEA (Failure Mode and Effects Analysis)

Product Name :	Shampoo product	FMEA Number :	PP-001
Project :	FMEA	FMEA Date (orig.) :	Apr 30, 08
Prepared by :	Jakkaphan B.	FMEA Date (Rev.) :	May 14, 08
Key date :	May 14, 08	Page 2 of 5	
Team :	Team chief, production engineer, process development supervisor, product development supervisor, manufacturing, quality assurance supervisor		

Process Function and Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential Cause(s) of Failure	O	Current Process Control	D	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Results: Action taken	S	O	D	RPN
Homogenizer during the process	Product generates a lot of bubble	Filling line cannot fill	3	Introduce the homogenizer after Surfactant dissolution	2	Identify in the batch sheet	2	12							
	Error on homogenizer	Product is not homogeneous	4	Filter deterioration in homoginizer	2	Visual inspection	2	16							
Preparation of Suspending agent's solution	Suspending agent solution get lumping	Product become lumping	4	Speed and time are not properly to disperse the Suspending agent	2	Mixing procedure and visual check	2	16							
			4	Keep Suspending agent solution over than 2 hr. before use	1	Identify in the process batch sheet	2	8							
			4	Use alternative material for Suspending agent	5	Visual check	1	20	Revise work instruction for preparing stock solution of suspending agent	Process Development (June 24, 08)					
	Suspending agent solution is more viscous	Stock solution get lump	2	Use less acid in stock solution	2	Control %acid	1	4							
Suspending agent adding	Broken structure of Suspending agent	Low viscosity	4	Introduce high shear (Homoginizer) after Suspending agent swelling	2	Mixing procedure	1	8							

(continued)

Process FMEA (Failure Mode and Effects Analysis)

Product Name :	Shampoo product											FMEA Number :	PP-001						
Project :	FMEA											FMEA Date (orig.) :	Apr 30, 08						
Prepared by :	Jakkaphan B.											FMEA Date (Rev.) :	May 14, 08						
Key date :	May 14, 08											Page 3 of 5							
Team :	Team chief, production engineer, process development supervisor, product development supervisor, manufacturing, quality assurance supervisor																		

Process Function and Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential Cause(s) of Failure	O	Current Process Control	D	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Results: Action taken	S	O	D	RPN
pH modifier	Uncontrolled pH modifier concentration	Lower or upper on F/G pH	4	Improper pH modifier concentration	4	No control	3	48	Set up work instruction for pH modifier concentration	QA (June 27, 08)					
pH modifier adding	Product pH will out of spec	Long lead time for manufacturing line (pH adjustment)	3	Improper dosage of pH modifier	3	Control via weighing system	2	18							
	Product pH inconsistent	Lower or upper on F/G pH	4	The actual weight of pH modifier is error	3	Use orific in pH modifier valve/ Use the PLC and weighing system	2	24	Check dosing system/ reduce size of pH modifier tube	Production (June 16, 08)					
	pH measurement on neutralization step	pH will out of spec	4	Uncontrol of product pH after pH modifier adding	3	Define amount of pH modifier in neutralization phase	2	24	Extend measurement step of neutralization phase	Process Development (June 16,08)					
Perfume adding	Different odour from the standard	Product write off/ give away fill	4	Add wrong perfume	2	Match with product standard	2	16							
		Odour differentiate	4	Weight wrong amount of the perfume	2	Barcode system	3	24	Set up preventive maintenance	Production (June 24, 08)					
	Viscosity error	High product solution's viscosity at that immediate step	1	Perfume effect	5	Visual check	2	10							

(continued)

Process FMEA (Failure Mode and Effects Analysis)

Product Name :	Shampoo product										FMEA Number :	PP-001				
Project :	FMEA										FMEA Date (orig.) :	Apr 30, 08				
Prepared by :	Jakkaphan B.										FMEA Date (Rev.) :	May 14, 08				
Key date :	May 14, 08										Page 4 of 5					
Team :	Team chief, production engineer, process development supervisor, product development supervisor, manufacturing, quality assurance supervisor															

Process Function and Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential Cause(s) of Failure	O	Current Process Control	D	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Results				
											Action taken	S	O	D	RPN
Mixture of guar in perfume	Guar get lumping during mixture preparation	Less conditioning effect	4	Long dispersion time and leave product longer than 30 min	2	Mixing procedure	2	16							
		Solution gets lump	3	There is some water left over in the vessel	3	Visual check	1	9							
Mixture of soluble emotive solution preparation	Mica setting/ agglomerate	Effect on film appearance (less shiny)	3	Mica is not well dispersed and leave for 30 min without stirring	1	Mixing procedure	2	6							
		Broken structure of Mica/ less shiny	3	Homogenizer after Mica adding	1	Process specification	1	3							
Adding from side pot	Error on air hose	Can not discharge material/ add via inline instead of discharge	3	Broken air hose	2	Visual inspection	2	12							
Pearlizer	Low %AI of product	Low %AI from pearlizer	2	Surfactant in pearlizer	1	R/M specification	1	2							
Functional material system	Incorrect dosage of Functional material	Less conditioning effect	4	The Functional material is not charged at the right dosage	4	Control via weighing system	2	32	Set up work instruction for functional material adding	Production (June 16, 08)					
Viscosity modifier	Viscosity modifier preparation	Viscosity out of spec	4	Improper Viscosity modifier Concentration	4	Mixing procedure	4	64	Revise mixing procedure/ set up work instruction	Production, QA (June 27, 08)					

(continued)

Process FMEA (Failure Mode and Effects Analysis)

Product Name :	Shampoo product	FMEA Number :	PP-001
Project :	FMEA	FMEA Date (orig.) :	Apr 30, 08
Prepared by :	Jakkaphan B.	FMEA Date (Rev.) :	May 14, 08
Key date :	May 14, 08	Page 5 of 5	
Team :	Team chief, production engineer, process development supervisor, product development supervisor, manufacturing, quality assurance supervisor		

Process Function and Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential Cause(s) of Failure	O	Current Process Control	D	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Results: Action taken	S	O	D	RPN
Viscosity modifier adding	Product viscosity inconsistent	Long lead time for quality adjustment	3	The actual weight of Viscosity modifier is error	4	Control via weighing system	2	24	Develop own equipment/install new equipment with high accuracy						
Amount of water	%AI is out of spec	Cleansing performance	4	Amount of water is not match with batch size	5	Control via weighing system	1	20	Set up work instruction for suitable level of water	Production (June 24, 08)					
QC	Measurement error	Get different product viscosity	3	Inefficient viscosity method	5	Standard global method	1	15							
		Defect of F/G	4	Wrong QC measurement	1	Measurement procedure	1	4							
	Operation skill of operator	Defect of F/G	4	Operators do not well trained on visual check	3	No control	4	48	Specific trainning	Production (June 27, 08)					
	Operator discipline	Defect of F/G	4	Operators do not follow work instruction	3	Process specification	3	36	Mixing instruction training	Production (June 27, 08)					
pH of finished goods	The pH cannot achieve the Right First Time	Long lead time for manufacturing line (pH adjustment)	3	The dosage of pH modifier is error	3	Use the PLC and weighing system/ control the pH after charge the pH modifier	2	18							

For organizing the process FMEA into section based on Right First Time problem, the process FMEA will be organized by each parameter and also the RPN value from highest to lowest as shown in table 3.3-3.6.

Table 3.3: Process FMEA of shampoo production ranked from highest to lowest score by %AI parameter

Process FMEA (Failure Mode and Effects Analysis)															
Product Name :	Shampoo product									FMEA Number :	PP-001				
Project :	FMEA									FMEA Date (orig.) :	Apr 30, 08				
Prepared by :	Jakkaphan B.									FMEA Date (Rev.) :	May 14, 08				
Key date :	May 14, 08									Page 1 of 5					
Team :	Team chief, production engineer, process development supervisor, product development supervisor, manufacturing, quality assurance supervisor														
Process Function and Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential Cause(s) of Failure	O	Current Process Control	D	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Results Action taken	S	O	D	RPN
	Non-conformance on %AI														
Surfactant	Low %AI of product	Cleansing performance	4	Lower dosage of Surfactant on%active	4	Control via PLC and weighing system	3	48	Set up work instruction for surfactant concentration	Production, QA (June 27, 08)					
	Lump of surfactant	Cleansing performance	4	Surfactant is not completely dissolved	3	Visual check	3	36	Set up work instruction to ensure surfactant dissolution	Process Develoment (June 24, 08)					
Amount of water	%AI is out of spec	Cleansing performance	4	Amount of water is not match with batch size	5	Control via weighing system	1	20	Set up work instruction for suitable level of water	Production (June 24, 08)					
Surfactant adding	Surfactant is not homogeneous	Cleansing performance	4	Too high rate of Surfactant adding	1	Control recir rate at high during Surfactant adding	1	4							
Pearlizer	Low %AI of product	Low %AI from pearlizer	2	Surfactant in pearlizer	1	R/M specification	1	2							

Table 3.4: Process FMEA of shampoo production ranked from highest to lowest score by %Viscosity parameter

Process FMEA (Failure Mode and Effects Analysis)

Product Name :	Shampoo product								FMEA Number :	PP-001		
Project :	FMEA								FMEA Date (orig.) :	Apr 30, 08		
Prepared by :	Jakkaphan B.								FMEA Date (Rev.) :	May 14, 08		
Key date :	May 14, 08								Page 2 of 5			
Team :	Team chief, production engineer, process development supervisor, product development supervisor, manufacturing, quality assurance supervisor											

Process Function and Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential Cause(s) of Failure	O	Current Process Control	D	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Results: Action taken	S	O	D	RPN
	Non-conformance on viscosity														
Viscosity modifier	Viscosity modifier preparation	Viscosity out of spec	4	Improper Viscosity modifier Concentration	4	Mixing procedure	4	**64**	Revise mixing procedure/ set up work instruction	Production, QA (June 27, 08)					
Viscosity modifier adding	Product viscosity inconsistent	Long lead time for quality adjustment	3	The actual weight of Viscosity modifier is error	4	Control via weighing system	2	**24**	Develop own equipment/install new equipment with high accuracy						
Preparation of Suspending agent	Suspending agent solution get lumping	Product become lumping	4	Use alternative material for Suspending agent	5	Visual check	1	**20**	Revise work instruction for preparing stock solution of suspending agent	Process Development (June 24, 08)					
			4	Speed and time are not properly to disperse the Suspending agent	2	Mixing procedure and visual check	2	16							
Dosage of Viscosity modifier	Over/Under dosage of Viscosity modifier	Get different product viscosity	3	Inefficient viscosity method	5	Standard global method	1	15							
		High product solution's viscosity at that immediate step	1	Perfume effect	5	Visual check	2	10							
Preparation of Suspending agent's solution	Broken structure of Suspending agent	Low viscosity	4	Introduce high shear (Homogenizer) after Suspending agent swelling	2	Mixing procedure	1	8							
	Suspending agent solution get lumping	Product become lumping	4	Keep Suspending agent solution over than 2 hr. before use	1	Identify in the process batch sheet	2	8							
	Suspending agent solution is more viscous	Stock solution get lump	2	Use less acid in stock solution	2	Control %acid	1	4							

Table 3.5: Process FMEA of shampoo production ranked from highest to lowest score by %Density and pH parameter

Process FMEA (Failure Mode and Effects Analysis)

Product Name :	Shampoo product										FMEA Number :	PP-001				
Project :	FMEA										FMEA Date (orig.) :	Apr 30, 08				
Prepared by :	Jakkaphan B.										FMEA Date (Rev.) :	May 14, 08				
Key date :	May 14, 08										Page 3 of 5					
Team :	Team chief, production engineer, process development supervisor, product development supervisor, manufacturing, quality assurance supervisor															
Process Function and Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential Cause(s) of Failure	O	Current Process Control	D	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Results					
											Action taken	S	O	D	RPN	
	Non-conformance on Density															
Homogenizer during the process	Product generates a lot of bubble	Filling line cannot fill	3	Introduce the homogenizer after Surfactant dissolution	2	Identify in the batch sheet	2	12								
	Non-conformance on pH															
pH modifier	Uncontrolled pH modifier concentration	Lower or upper on F/G pH	4	Improper pH modifier concentration	4	No control	3	**48**	Set up work instruction for pH modifier concentration	QA (June 27, 08)						
pH modifier adding	Product pH inconsistent	Lower or upper on F/G pH	4	The actual weight of pH modifier is error	3	Use orific in pH modifier valve/ Use the PLC and weighing system	2	**24**	Check dosing system/ reduce size of pH modifier tube	Production (June 16, 08)						
	pH measurement on neutralization step	pH will out of spec	4	Uncontrol of product pH after pH modifier adding	3	Define amount of pH modifier in neutralization phase	2	**24**	Extend measurement step of neutralization phase	Process Development (June 16,08)						
	Product pH will out of spec	Long lead time for manufacturing line (pH adjustment)	3	Improper dosage of pH modifier	3	Control via weighing system	2	18								
pH of finished goods	The pH cannot achieve the Right First Time	Long lead time for manufacturing line (pH adjustment)	3	The dosage of pH modifier is error	3	Use the PLC and weighing systeml/ control the pH after charge the pH modifier	2	18								
		pH will out of spec.	4	pH water is out of controlled at 5.5-8.0	1	Probe controller /alarm	1	4								

Table 3.6: Process FMEA of shampoo production ranked from highest to lowest score by product appearance/ other

Process FMEA (Failure Mode and Effects Analysis)																
Product Name :	Shampoo product										FMEA Number :	PP-001				
Project :	FMEA										FMEA Date (orig.) :	Apr 30, 08				
Prepared by :	Jakkaphan B.										FMEA Date (Rev.) :	May 14, 08				
Key date :	May 14, 08										Page 4 of 5					
Team :	Team chief, production engineer, process development supervisor, product development supervisor, manufacturing, quality assurance supervisor															
Process Function and Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential Cause(s) of Failure	O	Current Process Control	D	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Results Action taken	S	O	D	RPN	
	Non-conformance on product appearance / other															
QC	Operation skill of operator	Defect of F/G	4	Operators do not well trained on visual check	3	No control	4	**48**	Specific trainning	Production (June 27, 08)						
	Operator discipline	Defect of F/G	4	Operators do not follow work instruction	3	Process specification	3	**36**	Mixing instruction training	Production (June 27, 08)						
Functional material system	Incorrect dosage of Functional material	Less conditioning effect	4	The Functional material is not charged at the right dosage	4	Control via weighing system	2	**32**	Set up work instruction for functional material adding	Production (June 16, 08)						
Perfume adding	Different odour from the standard	Odour differentiate	4	Weight wrong amount of the perfume	2	Barcode system	3	**24**	Set up preventive maintenance	Production (June 24, 08)						
Machine system	Error on PLC	Can not mix properly	4	PLC error	2	Visual inspection	3	**24**	Set up preventive maintenance	Production (June 24, 08)						
	Error on weighing system/ balance	Loss/gain of material	4	Wrong weighing system/ balance calibration	3	Visual inspection	2	**24**	Set up preventive maintenance	Production (June 24, 08)						

(continued)

Process FMEA (Failure Mode and Effects Analysis)

Product Name :	Shampoo product	FMEA Number :	PP-001
Project :	FMEA	FMEA Date (orig.) :	Apr 30, 08
Prepared by :	Jakkaphan B.	FMEA Date (Rev.) :	May 14, 08
Key date :	May 14, 08	Page 5 of 5	
Team :	Team chief, production engineer, process development supervisor, product development supervisor, manufacturing, quality assurance supervisor		

Process Function and Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential Cause(s) of Failure	O	Current Process Control	D	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Results Action taken	S	O	D	RPN
	Error on agitator	Can not mix at all	4	Agitator motor breakdown	2	Visual inspection	2	16							
	Error on homogenizer	Product is not homogeneous	4	Filter deterioration in homogenizer	2	Visual inspection	2	16							
Perfume adding	Different odour from the standard	Product write off/ give away fill	4	Add wrong perfume	2	Match with product standard	2	16							
Mixture of guar in perfume	Guar get lumping during mixture preparation	Less conditioning effect	4	Long dispersion time and leave product longer than 30 min	2	Mixing procedure	2	16							
Machine system	Error on air hose	Can not discharge material/ add via inline instead of discharge	3	Broken air hose	2	Visual inspection	2	12							
Mixture of guar in perfume	Guar get lumping during mixture preparation	Solution gets lump	3	There is some water left over in the vessel	3	Visual check	1	9							
Machine system	Error on agitator	Non-homogeneous of product	4	Agitator speed is not proper	2	Process specification	1	8							
Mixture of soluble emotive solution preparation	Mica setting/ agglomerate	Effect on film appearance (less shiny)	3	Mica is not well dispersed and leave for 30 min without stirring	1	Mixing procedure	2	6							
QC	Measurement error	Defect of F/G	4	Wrong QC measurement	1	Measurement procedure	1	4							
Mixture of soluble emotive solution preparation	Mica setting/ agglomerate	Broken structure of Mica/ less shiny	3	Homogenizer after Mica adding	1	Process specification	1	3							

Some examples will be explained the way to rank the score of severity, occurrence and detection in this study.

3.1.6.1 Right First Time in term of %active (%AI)

In term of %Active (%AI), the main critical failure mode come from surfactant. That surfactant is completely dissolved is very important to the %AI of Shampoo. Therefore, it is ranked the severity score at 4 since it affect a lot to consumer satisfaction and cause quite huge performance failure. In terms of occurrence and detection, they are rated the score at 3 since it has moderate chance to occur and also detect.

3.1.6.2 Right First Time in term of viscosity

The concentration of viscosity modifier in shampoo process is troublesome for the Right First Time problem. This failure has not only high severity but also high occurrence and detection. This problem happens a lot to this shampoo production and there is no formal procedure to control the failure. As a result, the RPN score is 4*4*4 = 64, which is very high RPN since it leads to several quality adjustment very often.

3.1.6.3 Right First Time in term of appearance/other

Adding wrong perfume into mixer is also crucial to shampoo production. It is rated severity at 4 since it has not serious safety for this “error” shampoo for the score at 5. But the company has to write off that “error” shampoo since it is not allow to sell such product and that cause lose to the company. While occurrence and detection are rated at 2 since this failure is rarely occur and the production has standard product to compare with. The company also has some test to cover this kind of problem.

Table 3.7: Summary of process FMEA that the RPN value is higher than 18

Item	Potential Failure Mode	Potential cause (s) of Failure	RPN
1	Lump of surfactant	Surfactant is not completely dissolved	36
2	Low %AI of product	Lower dosage of Surfactant on %active	48
3	Error on weighing system/balance	Wrong weighing system/ balance calibration	24
4	Error on PLC	PLC error	24
5	Suspending agent solution get lumping	Use alternative material for Suspending agent	20
6	Uncontrolled pH modifier concentration	Improper pH modifier concentration	48
7	Product pH inconsistent	The actual weight of pH modifier is error	24
8	pH measurement on neutralization step	Uncontrol of product pH after pH modifier adding	24
9	Different odour from the standard	Weight wrong amount of the perfume	24
10	Incorrect dosage of Functional material	The Functional material is not charged at the right dosage	32
11	Viscosity modifier preparation	Improper Viscosity modifier concentration	64
12	Product viscosity inconsistent	The actual weight of Viscosity modifier is error	24
13	%AI is out of spec	Amount of water is not match with batch size	20
14	Operation skill of operator	Operators do not well trained on visual check	48
15	Operator discipline	Operators do not follow work instruction	36

It was found that amount and concentration of key raw material such as viscosity modifier, surfactant and pH modifier show high score in the process FMEA since they get the RPN score at 64, 48 and 48 respectively. Therefore, they should be taken care first since they have significant effect to Right First Time problem.

The FMEA team has discussed to generate action plan to reduce each failure in the process FMEA as the following table.

Table 3.8: The summary action for FMEA project

Production

Topic	Due Date	Remark	Item	Standard Procedure
Set up work instruction				
- Set up work instruction for water for flush	June 24, 08	To control amount of water in the batch	13	Document No.7
- Set up working procedure for preparing	June 27, 08	To control quality of viscosity modifier	11	Document No.6
viscosity modifier				
- Set up work instruction for functional	June 16, 08	To control conditioning effect of	10	Document No.8
material adding		Finished Goods		
Set up preventive maintenance plan				
- Set up preventive maintenance plan for	June 24, 08	To ensure the accuracy of perfume	3,9	
balance calibration		during weighing		
- Set up preventive maintenance plan for weighing	June 24,08	To prevent the error from weighing	3,7,12	
system		system		
- Set up preventive maintenance plan for PLC	June 24, 08	To prevent the error from PLC	4	
Miscellaneous				
- Develop own equipment/ install new	TBC	To ensure the weight of Surfactant	3,7,12	
equipment with high accuracy		and viscosity modifier		
- Check dosing system of pH modifier in buffer	May 23, 08	To ensure that orifice is installed	7	
tank		properly		
- Reduce size of pH modifier tube	June 16, 08	To reduce risk of error dosing of	7	
		pH modifier		
Training				
- Train operators about visual check	June 27, 08		14	
- Train operators about mixing instruction	June 27, 08		15	

Quality Assurance

Topic	Due Date	Remark	Item	Standard Procedure
Set up work instruction				
- Set up work instruction for surfactant	June 27, 08	To control surfactant specification	2	Document No.3
concentration		before using in production		
- Set up work instruction for viscosity modifier	June 27, 08	To control viscosity modifier	11	Document No.5
concentration		specification before using in production		
- Set up work instruction for pH modifier	June 27, 08	To control pH modifier specification	6	Document No.4
concentration		before using in production		

Process Development

Topic	Due Date	Remark	Item	Standard Procedure
Set up work instruction				
- Set up work instruction in form of agitator,	June 24, 08	To ensure that surfactant is	1	Document No.2
recir speed of surfactant dissolution		completely dissolved		
- Revise work instruction for preparing stock	June 24, 08	To ensure that alternative material of	5	Document No.1
solution of suspending agent		suspending agent will not cause lump		
Miscellaneous				
- Extend measurement step of neutralization	June 16, 08	Reduce problem about out of pH	8	
phase in batch sheet		specification in Finished Goods		

From Summary of process FMEA that the RPN value is higher than 18 (Table 3.7), 15 items of high-risk area are addressed. Therefore, the FMEA team can have meeting to take proper actions to find the solutions for those failures. At last, the action plan is created for each related department. In addition, item and standard procedure column of action plan in table 3.8 are represented as the action to improve the failures in table 3.7 and standard procedure generated to solve the problems respectively. Detail of each standard procedure will be shown in chapter 6.

After the recommended actions are finished, the FMEA team implements them in shampoo production. The team collects the data of Right First Time problem in shampoo production and compares with before implement the improvement.

CHAPTER 4

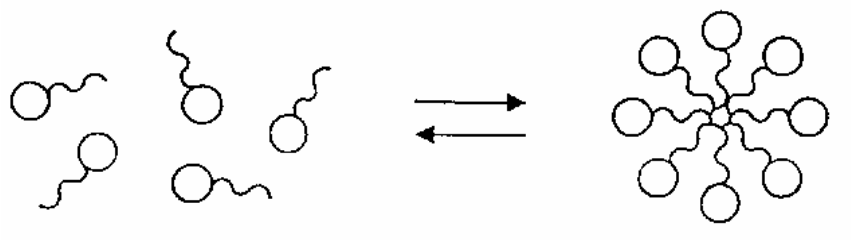
Design of Experiment

Author will take Right First Time problem on viscosity as example of mechanism to create standard procedure for shampoo production since this problem is also affect to other quality parameters.

The factors of Right First Time problem on viscosity are %surfactant and viscosity modifier's concentration.

Supported Theory

Surfactant molecules will nucleate to form aggregates called micelles at sufficiently high concentration in solution. The concentration at which this occurs is called critical micelle concentration (CMC)



Monomer Micelle

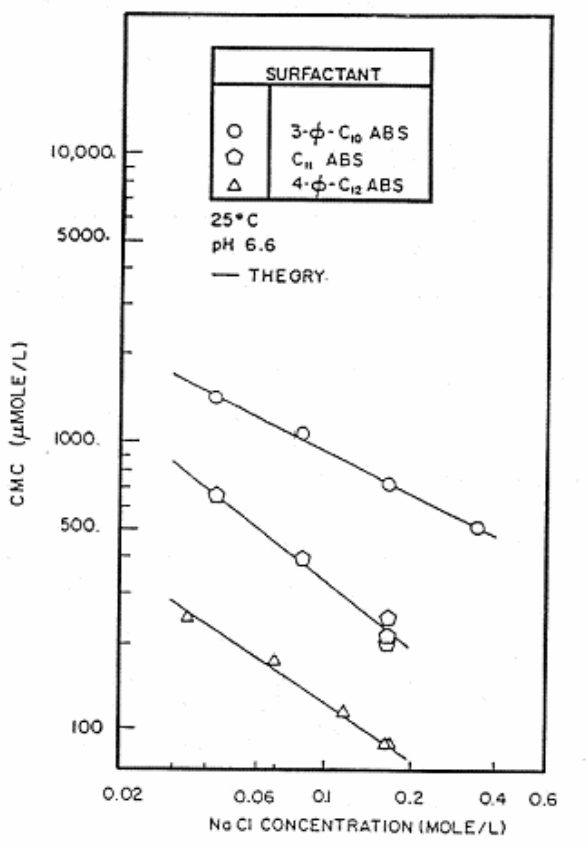
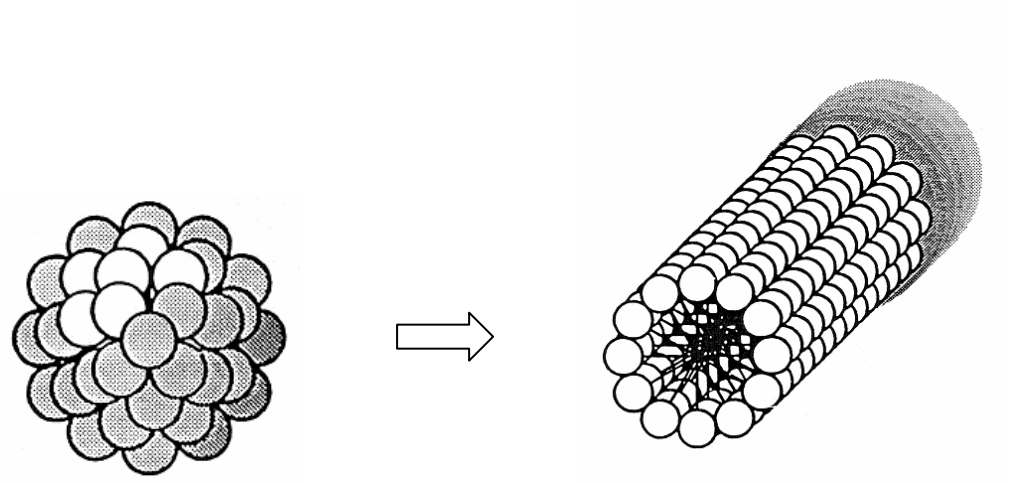


Figure 4.1: Effect of NaCl Concentration on CMC of Surfactants

Source: Surfactant Associates, Inc. (2004)

Critical Micelle Concentration (CMC) will indicate the tendency for a micelle to form. From figure 4.1, the higher [NaCl], the lower CMC. That would let easier the micelle forms since CMC is the lowest total surfactant concentration at which micelles are present.

According to Dow Corning Corporation (2006), “To control the viscosity of many shampoos, salt is added to the surfactant system, the interaction between salt and the long chain surfactant tends to increase the ionic density”. An increase in ionic strength allows head groups to come closer together, as they must in non-spherical micelles. Increasing the salt concentration makes the sphere less stable than the rod or the disk which means shampoo will have higher viscosity since micelles would form more closely.



Spherical Micelles Rod-like Micelles

4.1 Viscosity modifier's concentration factor

4.1.1 Experiment procedure

1. Make the shampoo base in pilot scale
2. Adjust viscosity modifier's concentration by adding viscosity modifier at 25, 23 and 20%concentration respectively.
3. Measure shampoo viscosity at temperature 30C, spindle RVT#5, speed 20 rpm for 1 minute.
4. Analyze the data to find the right concentration of viscosity modifier to achieve viscosity target at 5,000 cps.

Testing result

Table 4.1: Viscosity of shampoo that adjusted by viscosity modifier's concentration

Shampoo	Viscosity (cps)		
Trial # (N)	25%Concentration	23%Concentration	20%Concentration
1	4900	4060	3440
2	5060	4260	3500
3	4960	4100	3460
4	4880	4180	3580
5	4900	3940	3480
6	5080	4040	3440
7	4940	4140	3500
8	5120	4260	3600
9	5060	4140	3480
10	5080	4260	3580
11	4900	4080	3380
12	4860	4000	3400
13	4800	4100	3460
14	5100	4280	3500
15	4960	3980	3340
16	5020	4080	3380
17	4860	3900	3340
18	4900	4040	3480
19	4980	4060	3500
20	5080	4100	3480

4.1.2 Data analysis

One-way ANOVA: Viscosity modifier's concentration

```
Source                DF       SS       MS       F      P
%viscosity modifier  2  22869173  11434587  1308.78  0.000
Error                57    498000     8737
Total                59  23367173

S = 93.47   R-Sq = 97.87%   R-Sq(adj) = 97.79%

                    Individual 95% CIs For Mean Based on
                    Pooled StDev
Level   N    Mean  StDev  ----+---------+---------+---------+-----
20     20  3466.0   73.2  (*)
23     20  4100.0  107.6              (-*)
25     20  4972.0   96.3                           (*)
                   ----+---------+---------+---------+-----
                    3600      4000      4400      4800
```

Pooled StDev = 93.5

According to the data analyzed by MiniTab, it shows that viscosity modifier's concentration has significant effect to shampoo viscosity with 95% confidence as the P-value is less than 0.05.

Because of this viscosity modifier's natural properties, its concentration will be at 25% maximum. From the data analysis, lesser the concentration from 25%, it seems to have more problems about Right First Time achievement at viscosity target 5,000 cps. Therefore, viscosity modifier's concentration at 25% is the most suitable ratio to get the Right First Time for shampoo production. This is the reason why there is no 2 factors trial for this case. Since it is not practical to test at higher viscosity modifier concentration than 25%, while lesser than 25% concentration would make shampoo far from achieving Right First Time more. It is also not practical for the case like adding viscosity modifier concentration at 20% and may be %surfactant at 18% to achieve viscosity target at 5,000 cps because of limitation of shampoo properties.

Conclusion

From the above result, viscosity modifier's concentration would be prepared at 25% since it will improve Right First Time in shampoo production. This will lead to creating standard procedure for preparing viscosity modifier at 25% concentration.

4.2 %Surfactant factor

4.2.1 Experiment procedure

1. Make the shampoo base in pilot scale
2. Adjust %surfactant by adding surfactant 10%, 11%, 12%, 13% and 14% respectively into the shampoo base.
3. Measure shampoo viscosity at temperature 30C, spindle RVT#5, speed 20 rpm for 1 minute.
4. Analyze the data to find %suitable surfactant in the shampoo to achieve Right First Time.

Testing result

Table 4.2: Viscosity of shampoo that adjusted by %Surfactant

Shampoo	Viscosity (cps)				
Trial # (N)	10%Surfactant	11%Surfactant	12%Surfactant	13%Surfactant	14%Surfactant
1	3260	3860	4900	5680	6580
2	3040	3940	5060	5600	6400
3	3160	3720	4960	5740	6540
4	3320	3800	4880	5700	6600
5	3240	3780	4900	5580	6480
6	2980	3740	5080	5680	6540
7	3080	3840	4940	5640	6640
8	3340	3900	5120	5580	6700
9	3260	3720	5060	5780	6580
10	3140	3800	5080	5640	6500
11	3280	3640	4900	5800	6740
12	3160	3700	4860	5740	6600
13	3080	3740	4800	5600	6360
14	3300	3880	5100	5740	6500
15	3120	3860	4960	5680	6480
16	3060	3900	5020	5780	6640
17	3200	3860	4860	5600	6600
18	3140	3680	4900	5700	6440
19	3240	3740	4980	5760	6480
20	3180	3800	5080	5640	6540

4.2.2 Data analysis

One-way ANOVA: %Surfactant

```
Source  DF       SS       MS       F      P
Factor   4  149855056  37463764  4618.31  0.000
Error   95     770640      8112
Total   99  150625696

S = 90.07   R-Sq = 99.49%   R-Sq(adj) = 99.47%


                    Individual 95% CIs For Mean Based on
                    Pooled StDev
Level     N    Mean  StDev  ---------+---------+---------+---------+
10%          20  3179.0  100.4  (*
11%          20  3795.0   83.3       *
12%          20  4972.0   96.3               (*
13%          20  5683.0   71.2                    (*
14%          20  6547.0   95.9                         *)
                    ---------+---------+---------+---------+
                        4000      5000      6000      7000

Pooled StDev = 90.1
```

According to the data analyzed by MiniTab, it shows that %surfactant has significant effect to shampoo viscosity with 95% confidence as the P-value is less than 0.05.

Regression Analysis: Viscosity versus %Surfactant

```
The regression equation is
Viscosity = - 5514 + 862 %Surfactant


Predictor      Coef  SE Coef       T      P
Constant    -5513.6    118.3  -46.60  0.000
%Surfactant 862.400    9.791   88.08  0.000


S = 138.466   R-Sq = 98.8%   R-Sq(adj) = 98.7%


Analysis of Variance

Source          DF        SS        MS       F      P
Regression       1  148746752  148746752  7758.18  0.000
Residual Error  98    1878944      19173
Total           99  150625696


Predicted Values for New Observations
```

New
Obs Fit SE Fit 95% CI 95% PI
1 5000.3 14.0 (4972.6, 5028.1) (4724.2, 5276.5)

Values of Predictors for New Observations

New
Obs %Surfactant
1 12.2

From regression analysis, surfactant should be added into the shampoo at 12.2% in order to get the target viscosity at 5,000 cps. From the analysis, range of shampoo viscosity would be 4724.2-5276.5 with 95% confidence in case that %Surfactant will be 12.2%.

Conclusion

From the above result, %Surfactant in shampoo would be added at 12.2% since it will improve Right First Time in shampoo production. This will lead to creating standard procedure for %Surfactant in shampoo.

CHAPTER 5

Implementation and Evaluation

5.1 Implementation of the FMEA

FMEA team member will have meeting to discuss about the new working procedure before FMEA implementation in order to make sure that all the team members understand the proposed FMEA. It is also important that all involved departments understand and clear about the proposed FMEA.

5.2 Evaluation of the FMEA

5.2.1 With the Failure Mode and Effect Analysis

After the recommended action has been implemented, the FMEA team would reevaluate the Severity, Occurrence and Detection of each issue which has RPN value higher than 18 by using the team judgment. The RPN before and after implementation is shown on the table 5.1

Table 5.1: Comparison of RPN before and after implementation the FMEA

Process FMEA (Failure Mode and Effects Analysis)

Product Name :	Shampoo product										FMEA Number :	PP-001				
Project :	FMEA										FMEA Date (orig.) :	Apr 30, 08				
Prepared by :	Jakkaphan B.										FMEA Date (Rev.) :	Sep 3, 08				
Key date :	Sep 3, 08										Page 1 of 5					
Team :	Team chief, production engineer, process development supervisor, product development supervisor, manufacturing, quality assurance supervisor															
Process Function and Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential Cause(s) of Failure	O	Current Process Control	D	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Results Action taken	S	O	D	RPN	
Chlorinated water	Product pH will out of spec	pH will out of spec.	4	pH water is out of controlled at 5.5-8.0	1	Probe controller /alarm	1	4								
Surfactant	Lump of surfactant	Cleansing performance	4	Surfactant is not completely dissolved	3	Visual check	3	36	Set up work instruction to ensure surfactant dissolution	Process Develoment (June 24, 08)	As recommended	4	2	2	8	
	Low %AI of product	Cleansing performance	4	Lower dosage of Surfactant on%active	4	Control via PLC and weighing system	3	48	Set up work instruction for surfactant concentration	Production, QA (June 27, 08)	As recommended	4	2	1	8	
Surfactant adding	Surfactant is not homogeneous	Cleansing performance	4	Too high rate of Surfactant adding	1	Control recir rate at high during Surfactant adding	1	4								
Machine system	Error on agitator	Non-homogeneous of Product	4	Agitator speed is not proper	2	Process specification	1	8								
		Can not mix at all	4	Agitator motor breakdown	2	Visual inspection	2	16								
	Error on weighing system/ balance	Loss/gain of material	4	Wrong weighing system/ balance calibration	3	Visual inspection	2	24	Set up preventive maintenance	Production, QA (June 24, 08)	As recommended	4	2	2	16	
	Error on PLC	Can not mix properly	4	PLC error	2	Visual inspection	3	24	Set up preventive maintenance	Production, QA (June 24, 08)	As recommended	4	2	2	8	

(continued)

Process FMEA (Failure Mode and Effects Analysis)

Product Name :	Shampoo product										FMEA Number :	PP-001					
Project :	FMEA										FMEA Date (orig.) :	Apr 30, 08					
Prepared by :	Jakkaphan B.										FMEA Date (Rev.) :	Sep 3, 08					
Key date :	Sep 3, 08										Page 2 of 5						
Team :	Team chief, production engineer, process development supervisor, product development supervisor, manufacturing, quality assurance supervisor																

Process Function and Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential Cause(s) of Failure	O	Current Process Control	D	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Results				
											Action taken	S	O	D	RPN
Homogenizer during the process	Product generates a lot of bubble	Filling line cannot fill	3	Introduce the homogenizer after Surfactant dissolution	2	Identify in the batch sheet	2	12							
	Error on homogenizer	Product is not homogeneous	4	Filter deterioration in homoginizer	2	Visual inspection	2	16							
Preparation of Suspending agent's solution	Suspending agent solution get lumping	Product become lumping	4	Speed and time are not properly to disperse the Suspending agent	2	Mixing procedure and visual check	2	16							
			4	Keep Suspending agent solution over than 2 hr. before use	1	Identify in the process batch sheet	2	8							
			4	Use alternative material for Suspending agent	5	Visual check	1	20	Revise work instruction for preparing stock solution of suspending agent	Process Development (June 24, 08)	As recommended	4	3	1	12
	Suspending agent solution is more viscous	Stock solution get lump	2	Use less acid in stock solution	2	Control %acid	1	4							
Suspending agent adding	Broken structure of Suspending agent	Low viscosity	4	Introduce high shear (Homoginizer) after Suspending agent swelling	2	Mixing procedure	1	8							

(continued)

Process FMEA (Failure Mode and Effects Analysis)

Product Name :	Shampoo product	FMEA Number :	PP-001
Project :	FMEA	FMEA Date (orig.) :	Apr 30, 08
Prepared by :	Jakkaphan B.	FMEA Date (Rev.) :	Sep 3, 08
Key date :	Sep 3, 08	Page 3 of 5	
Team :	Team chief, production engineer, process development supervisor, product development supervisor, manufacturing, quality assurance supervisor		

Process Function and Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential Cause(s) of Failure	O	Current Process Control	D	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Results: Action taken	S	O	D	RPN
pH modifier	Uncontrolled pH modifier concentration	Lower or upper on F/G pH	4	Improper pH modifier concentration	4	No control	3	48	Set up work instruction for pH modifier concentration	QA (June 27, 08)	As recommended	4	2	2	16
pH modifier adding	Product pH will out of spec	Long lead time for manufacturing line (pH adjustment)	3	Improper dosage of pH modifier	3	Control via weighing system	2	18							
	Product pH inconsistent	Lower or upper on F/G pH	4	The actual weight of pH modifier is error	3	Use orific in pH modifier valve/ Use the PLC and weighing system	2	24	Check dosing system/ reduce size of pH modifier tube	Production (June 16, 08)	As recommended	4	2	1	4
	pH measurement on neutralization step	pH will out of spec	4	Uncontrol of product pH after pH modifier adding	3	Define amount of pH modifier in neutralization phase	2	24	Extend measurement step of neutralization phase	Process Development (June 16,08)	As recommended	4	2	1	8
Perfume adding	Different odour from the standard	Product write off/ give away fill	4	Add wrong perfume	2	Match with product standard	2	16							
		Odour differentiate	4	Weight wrong amount of the perfume	2	Barcode system	3	24	Set up preventive maintenance	Production (June 24, 08)	As recommended	4	2	2	8
	Viscosity error	High product solution's viscosity at that immediate step	1	Perfume effect	5	Visual check	2	10							

(continued)

Process FMEA (Failure Mode and Effects Analysis)

Product Name :	Shampoo product											FMEA Number :	PP-001				
Project :	FMEA											FMEA Date (orig.) :	Apr 30, 08				
Prepared by :	Jakkaphan B.											FMEA Date (Rev.) :	Sep 3, 08				
Key date :	Sep 3, 08											Page 4 of 5					
Team :	Team chief, production engineer, process development supervisor, product development supervisor, manufacturing, quality assurance supervisor																

Process Function and Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential Cause(s) of Failure	O	Current Process Control	D	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Results				
											Action taken	S	O	D	RPN
Mixture of guar in perfume	Guar get lumping during mixture preparation	Less conditioning effect	4	Long dispersion time and leave product longer than 30 min	2	Mixing procedure	2	16							
		Solution gets lump	3	There is some water left over in the vessel	3	Visual check	1	9							
Mixture of soluble emotive solution preparation	Mica setting/ agglomerate	Effect on film appearance (less shiny)	3	Mica is not well dispersed and leave for 30 min without stirring	1	Mixing procedure	2	6							
		Broken structure of Mica/ less shiny	3	Homogenizer after Mica adding	1	Process specification	1	3							
Adding from side pot	Error on air hose	Can not discharge material/ add via inline instead of discharge	3	Broken air hose	2	Visual inspection	2	12							
Pearlizer	Low %AI of product	Low %AI from pearlizer	2	Surfactant in pearlizer	1	R/M specification	1	2							
Functional material system	Incorrect dosage of Functional material	Less conditioning effect	4	The Functional material is not charged at the right dosage	4	Control via weighing system	2	32	Set up work instruction for functional material adding	Production (June 16, 08)	As recommended	4	2	2	16
Viscosity modifier	Viscosity modifier preparation	Viscosity out of spec	4	Improper Viscosity modifier Concentration	4	Mixing procedure	4	64	Revise mixing procedure/ set up work instruction	Production, QA (June 27, 08)	As recommended	4	2	2	16

(continued)

Process FMEA (Failure Mode and Effects Analysis)

Product Name :	Shampoo product										FMEA Number :	PP-001				
Project :	FMEA										FMEA Date (orig.) :	Apr 30, 08				
Prepared by :	Jakkaphan B.										FMEA Date (Rev.) :	Sep 3, 08				
Key date :	Sep 3, 08										Page 5 of 5					
Team :	Team chief, production engineer, process development supervisor, product development supervisor, manufacturing, quality assurance supervisor															

Process Function and Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential Cause(s) of Failure	O	Current Process Control	D	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Results				
											Action taken	S	O	D	RPN
Viscosity modifier adding	Product viscosity inconsistent	Long lead time for quality adjustment	3	The actual weight of Viscosity modifier is error	4	Control via weighing system	2	24	Develop own equipment/install new equipment with high accuracy		No action				
Amount of water	%AI is out of spec	Cleansing performance	4	Amount of water is not match with batch size	5	Control via weighing system	1	20	Set up work instruction for suitable level of water	Production (June 24, 08)	As recommended	4	2	1	4
QC	Measurement error	Get different product viscosity	3	Inefficient viscosity method	5	Standard global method	1	15							
		Defect of F/G	4	Wrong QC measurement	1	Measurement procedure	1	4							
	Operation skill of operator	Defect of F/G	4	Operators do not well trained on visual check	3	No control	4	48	Specific trainning	Production (June 27, 08)	As recommended	4	2	2	8
	Operator discipline	Defect of F/G	4	Operators do not follow work instruction	3	Process specification	3	36	Mixing instruction training	Production (June 27, 08)	As recommended	4	2	2	16
pH of finished goods	The pH cannot achieve the Right First Time	Long lead time for manufacturing line (pH adjustment)	3	The dosage of pH modifier is error	3	Use the PLC and weighing system/ control the pH after charge the pH modifier	2	18							

5.2.2 Improvement of Right First Time and production batch time in shampoo production

Prior to FMEA implementation, shampoo production in this case study achieves the Right First Time only 60.12% of total batches. After the FMEA implementation, this shampoo production can achieve the Right First Time target at 78.24% of total batches. Moreover, production batch time also reduce from 151 to 116 min after the implementation. Production can save time from QC time because of higher Right First Time achievement. This will lead to batch time reduction for shampoo production. As a result, this company can save production batch time for 23.18% when compare with prior to the implement starting. Therefore, this implementation can help improve Right First Time and production batch time in the shampoo production. This will lead to reduction of production cost and help the company has more competitive power to compete in the market and gain more profit.

Table 5.2: Right First Time data before implement FMEA

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Summary
No. of batch	104	91	76	103	130	122	99	115	840
RFT (Batch)	59	45	46	59	69	82	69	76	505
%RFT	56.7	49.5	60.5	57.3	53.1	67.2	69.7	66.1	60.12

Table 5.3: Right First Time data after implement FMEA

Month	July				Aug				Summary
Week	1	2	3	4	1	2	3	4	
No. of batch	20	25	23	34	38	34	36	29	239
RFT (Batch)	14	19	18	27	30	27	29	23	187
%RFT	70.00	76.00	78.26	79.41	78.95	79.41	80.56	79.31	78.24

Data analysis

Two-Sample T-Test and CI: RFT before, RFT after

Two-sample T for RFT before vs RFT after

	N	Mean	StDev	SE Mean
RFT before	8	60.01	7.17	2.5
RFT after	8	77.74	3.39	1.2

Difference = mu (RFT before) - mu (RFT after)
Estimate for difference: -17.72
95% upper bound for difference: -12.59
T-Test of difference = 0 (vs <): T-Value = -6.32 P-Value = 0.000 DF = 9

According to the data analyzed by MiniTab, it shows that Right First Time after the implementation has improved from before the implementation significantly with 95% confidence as the P-value is less than 0.05.

Table 5.4: Production batch time before implement FMEA

Year 2007	Jan	Feb	Mar	Apr	May	Jun	Jul	Avg.
Mixing time	80	77	67	70	71	79	74	74
QC time	42	48	56	64	56	52	53	53
Discharge time	25	24	23	26	27	23	23	24
Total time	147	149	146	160	154	154	150	151

Table 5.5: Production batch time after implement FMEA

Month	July				Aug				Avg.
Week	1	2	3	4	1	2	3	4	
Mixing time	68	70	72	67	72	71	71	70	70
QC time	25	24	23	23	23	21	20	22	23
Discharge time	23	23	22	24	23	24	23	22	23
Total time	116	117	117	114	118	116	114	114	116

Data analysis

Two-Sample T-Test and CI: Batch time after, Batch time before

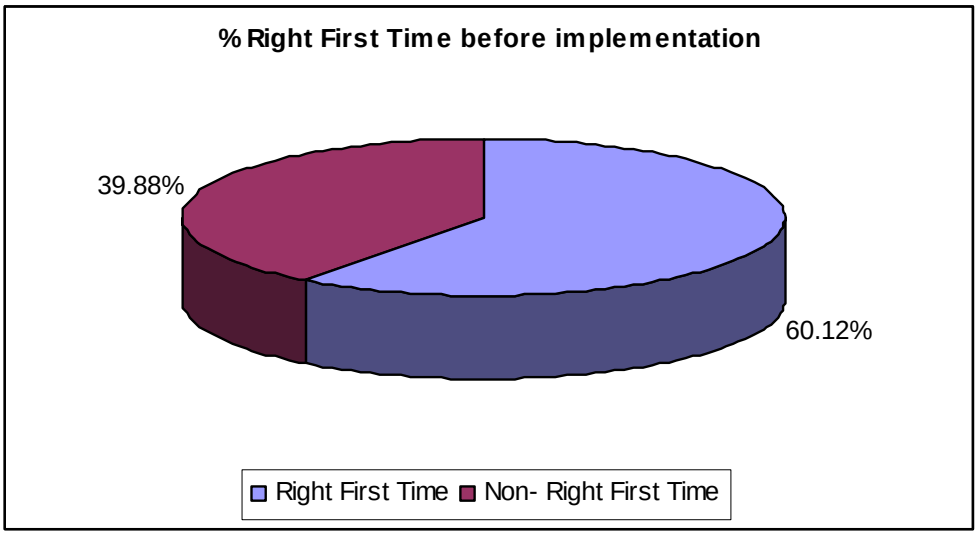
Two-sample T for Batch time after vs Batch time before

	N	Mean	StDev	SE Mean
Batch time after	8	115.75	1.58	0.56
Batch time before	7	151.43	4.89	1.8

Difference = mu (Batch time after) - mu (Batch time before)
Estimate for difference: -35.68
95% upper bound for difference: -32.02
T-Test of difference = 0 (vs <): T-Value = -18.46 P-Value = 0.000 DF = 7

According to the data analyzed by MiniTab, it shows that Production batch time after the implementation has reduced from before the implementation significantly with 95% confidence as the P-value is less than 0.05.

Figure 5.1: Comparison of Right First Time between before and after the implementation



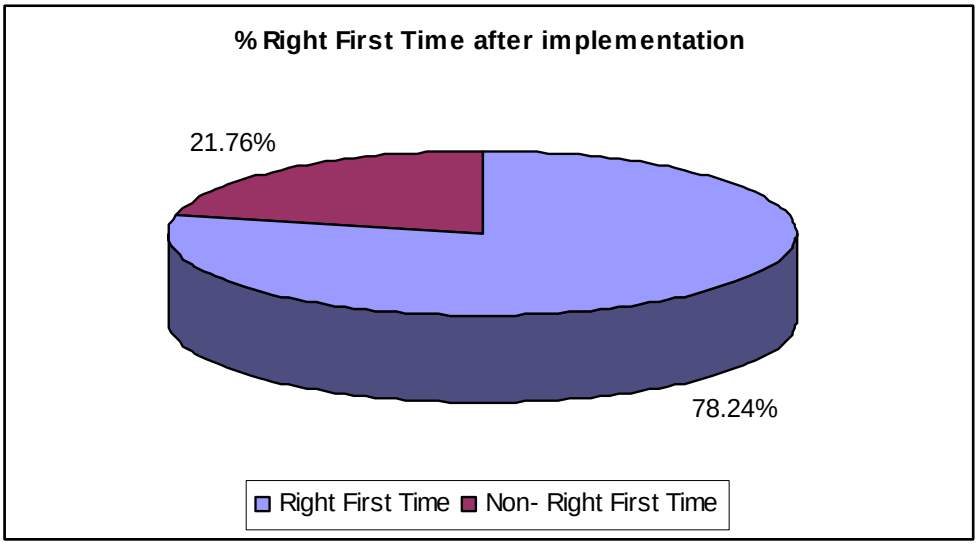
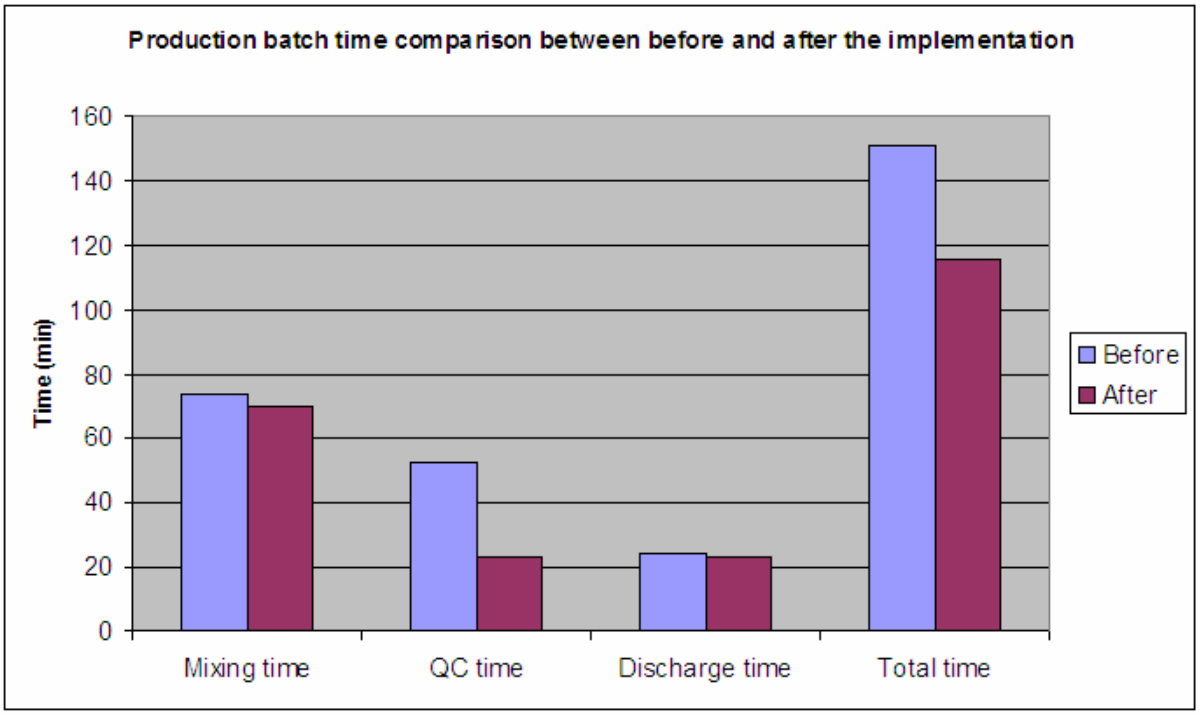


Figure 5.2: Comparison of production batch time between before and after the implementation



CHAPTER 6

Standard Procedure

6.1 Standard Procedure from Process FMEA

From table 3.7 (Summary of process FMEA that the RPN value is higher than 18), 15 items are addressed as high-risk area for shampoo production. Detail of those 15 high risk area will be discussed here whether they can be solved or improved by the following standard procedure or not.

Item 1: Lump of surfactant
This problem would be solved by Standard procedure for surfactant dissolution as Document 2

Item 2: Low %AI of product
This problem would be controlled by Standard procedure for %active measurement for surfactant as Document 3. The procedure would help control the surfactant specification and reduce %Active problem in shampoo production.

Item 3, 4: Error on weighing system/balance and Error on PLC
These problems can be reduced by setting preventive maintenance plan; however, it does not include in this research since machine break down is not covered in this study.

Item 5: Suspending agent solution get lumping
This could be solved or improved by Standard procedure for preparation of suspending agent as Document 1.

Item 6: Uncontrolled pH modifier concentration

This failure can be controlled by Standard procedure for %sodium hydroxide measurement as Document 4. The procedure would help control the pH modifier specification and reduce pH problem in shampoo production

Item 7: Product pH inconsistent
Dosing system checking and tube size reduction of pH modifier would help reduce this problem. Preventive maintenance plan for weighing system would also help.

Item 8: pH measurement on neutralization step
Extend pH measurement step on neutralization phase would help ensure shampoo pH to be in specification.

Item 9: Different odour from the standard
Preventive maintenance plan for balance calibration can help on this problem. However, it is not cover in this study.

Item 10: Incorrect dosage of functional material
This problem could be solved by standard procedure for functional material adding as Document 8.

Item 11: Viscosity modifier preparation
Standard procedure for preparation of viscosity modifier as Document 6 will help control this material at preparation and operation stage. The viscosity modifier specification can be controlled by standard procedure for %chloride measurement as Document 5.

Item 12: Product viscosity inconsistent
Preventive maintenance plan for weighing system can help on this problem. Develop or newly install equipment with high accuracy would also reduce this problem; however, it is not possible in this study period.

Item 13: %AI is out of spec

This problem would be reduced by Standard procedure for weigh water for flush as Document 7.

Item 14, 15: Operation skill of operator and operator discipline
Training for operator about visual check and mixing instruction would increase operators' skill and let them know the right way to operate shampoo batch.

6.2 The standard procedure for shampoo production

The standard procedure for shampoo production would be summarized as following.

- Surfactant

1. This raw material needs to be completely dissolved in order to let shampoo has its fully cleansing property. The procedure to ensure surfactant dissolution shows as following Document 2.
2. In order to improve Right First Time of shampoo production, surfactant must be added at 12.2%. %Active measurement for surfactant as Document 3 would help team to know amount of surfactant that would be added in the production.

- Preparation of suspending agent

The preparation process of suspending agent must cover an alternative material problem. Since the alternative material is quite hard to dissolve in the mixer, new standard procedure for preparing this material has to be generated as Document 1.

- pH modifier

% pH modifier measurement as Document 4 would help control pH modifier specification and improve Right First Time.

- Functional material

This material will help shampoo provide conditioning effect to consumer. The right amount of functional material can be added into main mixer by standard procedure as Document 8.

- Viscosity modifier

1. To improve Right First Time for shampoo production, viscosity modifier needs to be controlled at 25%. The mixing procedure in Document 6 can help team to control this material.
2. The procedure for %viscosity modifier measurement shows as following Document 5.

- Amount of water

Amount of water for flush in the shampoo production can lead to inconsistent of %AI in shampoo batch. Therefore, team will pre-weigh water for flush in shampoo batch as standard procedure in Document 7 instead of flushing in different amount as operators usually do.

The COMPANY, LTD. Standard Procedure	Document No. 1
Preparation of Suspending Agent	**Revision : 0** **Date : 27 Jun 08**
Operator : Mixing Operator	**Page : 1 of 2**

1. PURPOSE

To control process of preparing suspending agent in order to solve lump problem from alternative material.

2. SCOPE

This procedure is applicable for the mixer size of the plant

3. MATERIALS

1. Water
2. Acid
3. Preservative

4. EQUIPMENT

Mixer

5. SAFETY CAUTIONS

Install appropriate safety device such as goggles, mask, rubber glove

6. PROCEDURE

6.1 Charge water into the mixer for 648 kg

6.2 Turn on agitator speed at high

6.3 Add acid for 2 kg in the mixer while stirring together with preservative for 0.3 kg

6.4 Turn on homogenizer at medium speed for 3 minute

6.5 Add suspending agent while stirring into the mixer for 20 kg

6.6 Increase homogenizer speed to high for 15 min.

Control point

- Amount of acid used
- Mixing time

The COMPANY, LTD. Standard Procedure	Document No. 2
Surfactant Dissolution	**Revision : 0** **Date : 27 Jun 08**
Operator : Mixing Controller	**Page : 1 of 2**

1. PURPOSE

To ensure that surfactant will be completely dissolved in the shampoo production process

2. SCOPE

-

3. MATERIALS

1. Water
2. Surfactant

4. EQUIPMENT

Main mixer

5. SAFETY CAUTIONS

-

6. PROCEDURE

6.1 After initial water is added in to the main mixer, surfactant would be the next material added into main mixer.

6.2 Start homogenizer at high speed and maintain agitator speed at low speed (18-20 rpm) during charging the surfactant.

6.3 Charge surfactant into main mixer with dosing rate 240 kg/min.

6.4 When surfactant finish dosing, stop the homogenizer.

6.5 Continue stirring at low speed (18-20 rpm) for 10 min.

6.6 Check clear solution before proceed to the next step.

Control point

Dosing rate of surfactant

The COMPANY, LTD. Standard Procedure	Document No. 3
%Active Measurement for Surfactant	Revision : 0 Date : 27 Jun 08
Operator : Raw Material Controller	Page : 1 of 4

1. PURPOSE

This is method for finding %active in surfactant

2. SCOPE

This method determines the amount of anionic surfactant present in raw materials and finished products by potentiometric titration using a surfactant specific electrode

3. DEFINITION

-

4. REFERENCES

Quality Manual No. 6401 Approved by the case study company

5. MATERIALS

1. Hyamine 1622
2. Sodium Lauryl Sulfate (SLS)
3. Reference electrode inner/outer filling solution
4. Triton X-100
5. Deionized water

6. EQUIPMENT

1. Autotitrator
2. Ion-selective electrode
3. Reference electrode

4. Beaker size 250 ml
5. Balance
6. Cylinders, 10 and 100 ml
7. Magnetic stirrer
8. Flask, 100 ml and 1L
9. Buret 10 ml
10. Pipets, 1 and 10 ml

7. SAFETY CAUTIONS

Ordinary laboratory safety procedures should be observed.

8. PROCEDURE

8.1 Surfactant Electrode Preparation

- Prepare 0.0001 N SLS sock solution by pipeting 1 ml of 0.01N SLS to a 100 ml volumetric flask and diluting to volume with deionized water
- Condition the ion-selective electrode by soaking the tip of the assembled electrode in a freshly prepared 0.0001N SLS solution and rinse the electrode clean with water.

8.2 Double Junction Reference Electrode Preparation

- Fill the inner chamber of the reference electrode with “green solution”
- Fill the outer chamber of reference electrode with 3M KCl solution

8.3 Preparation of 0.05N Hyamine Solution

- Weigh 23.3055 g of hyamine 1622 powder and transfer to a 1 L volumetric flask

- Dilute to volume with deionized water and mix well

8.4 Standardization of Hyamine 1622 solution

- Pipet a 25 ml into a 250 ml titration beaker
- Add 75 ml of water, 1 ml of Triton X-100 electrode cleaning solution into the beaker and mix well
- Immerse the electrodes into the titration solution and allow the electrode to stabilize before performing the titration
- Titrate the SLS solution with hyamine solution until it reaches the endpoint and record the titration volume (V)
- Perform the analysis in triplicate. Calculate the normality of hyamine using the calculation below

$$\text{Normality} = \frac{(V_{SLS})\,(N_{SLS})}{V}$$

Where: V_{SLS} = Volume, in ml of SLS

N_{SLS} = Normality of SLS

V = Volume of Hyamine titrant, ml

8.5 Sample Titration

- Accurately weigh the sample into a titration beaker (0.05g for raw material sample type) and record the weight (W)

- Add 75 ml of deionized water, 1 ml of Triton X-100 electrode cleaning solution into the beaker and mix well
- Adjust the pH of the sample to 3 with 0.1N HCl
- Immerse the electrodes into the titration solution and allow the electrode to stabilize before performing the titration
- Start the titration with standardized hyamine 1622 solution until it reaches the millivolt endpoint (V) and continue the titration 2-3 ml past the endpoint
- Soak the surfactant electrode for 10 minutes after every 14 titrations to maintain electrode performance
- Calculate the %Active using the equations below

$$\% \text{ Active} = \frac{(V)\,(N)\,(EW)\,(100)}{(W)\,(1000)}$$

Where V= Volume of Hyamine, ml

N = normality of Hyamine solution

EW = equivalent weight of anionic surfactant

W = weight of sample, g

1000 = conversion factor of ml to l

The COMPANY, LTD. Standard Procedure	Document No. 4
%Sodium Hydroxide Measurement	Revision : 0 Date : 27 Jun 08
Operator : Raw Material Controller	Page : 1 of 2

1. PURPOSE

This is method for finding %sodium hydroxide in raw material

2. SCOPE

This method is only for liquid sodium hydroxide

3. DEFINITION

-

4. REFERENCES

Quality Manual No. 6019 Approved by the case study company

5. MATERIALS

1. Hydrochloric acid solution
2. Phenolphthalein indicator
3. Methyl orange indicator
4. Freshly boiled distilled water

6. EQUIPMENT

1. Standard Laboratory Glassware
2. 50 ml “A” Quality burette
3. 25 ml “A” Quality pipette

7. SAFETY CAUTIONS

-

8. PROCEDURE

8.1 The weight of liquid sodium hydroxide taken for the assay should contain approximately 40 g of sodium hydroxide.

8.2 Dissolve directly in boiled and cooled distilled water and make up to 1 litre in a graduated flask.

8.3 Pipette 25 ml of the freshly prepared solution into a 250 ml wide mouthed round flat-bottomed flask.

8.4 Add a few drops of phenolphthalein indicator.

8.5 Titrate with 0.2 N Hydrochloric acid until the colour of the indicator just disappears. Record the volume of titrant.

8.6 Add a few drops of methyl orange indicator and continue titrating with 0.2 N Hydrochloric acid until the first permanent red of the indicator is reached. Record the total volume of standard acid used from the first burette reading (normally 0)

8.7 Calculate the percentage of sodium hydroxide present.

$$\%\text{Sodium hydroxide} = \frac{40\,[V_2-2(V_2-V_1)] * 0.2 * 1000 * 100}{W * 25 * 1000}$$

$$= \frac{32 * [V_2-2(V_2-V_1)]}{W}$$

Where W = Weight of the original sodium hydroxide raw material (g)

V_1 = Volume of standard 0.2 N HCl used to titrate to the first end point (ml)

V_2 = Volume of standard 0.2 N HCl used to titrate to the second end point (ml)

The COMPANY, LTD. Standard Procedure	Document No. 5
%Chloride Measurement	Revision : 0 Date : 27 Jun 08
Operator : Raw Material Controller	Page : 1 of 2

1. PURPOSE

This is method for finding %Chloride in raw material

2. SCOPE

-

3. DEFINITION

-

4. REFERENCES

Quality Manual No. 6066 Approved by the case study company

5. MATERIALS

1. Distilled water
2. Silver nitrate
3. Potassium chromate solution
4. Sodium bicarbonate

6. EQUIPMENT

1. Burette
2. Balance capable of weighing to 0.0001 g
3. Volumetric flask, 500 ml

7. SAFETY CAUTIONS

-

8. PROCEDURE

8.1 Weigh 5 g of the material to be tested to an accuracy of 0.0001 g (W)

8.2 Transfer the material quantitatively to a 500 ml volumetric flask and make up to 500 ml with distilled water.

8.3 Pipette 100 ml of this solution into a conical flask and add 1 g of sodium bicarbonate. Swirl to mix.

8.4 Add approximately 1 ml of the 5% potassium chromate indicator solution and swirl to mix. Titrate with the 0.1 M silver nitrate solution until the end point is reached (V) The colour change is from bright yellow to orange.

8.5 Calculate the percentage of chloride

$$\%\text{Chloride} = \frac{V * 2.922}{W}$$

Where W = Weight of material taken

V = Volume of 0.1 N silver nitrate solution used

The COMPANY, LTD. Standard Procedure	Document No. 6
Preparation of Viscosity Modifier	**Revision : 0** **Date : 27 Jun 08**
Operator : Mixing Operator	**Page : 1 of 3**

1. PURPOSE

To control the concentration of viscosity modifier to be at 25%

2. SCOPE

This method is for preparing this specific viscosity modifier

3. MATERIALS

1. Water
2. Salt

4. EQUIPMENT

1. Tank
2. Fine sand
3. Pebble
4. Hard stone

5. SAFETY CAUTIONS

-

6. PROCEDURE

6.1 Mixing tank preparation

6.1.1 Bring tank size 1 T that can add water and salt on top of the tank

6.1.2 Clean fine sand, pebble and hard stone in the water

6.1.3 Store them in the storage until dry

6.1.4 Place the bottom of the tank with filter cloth and spread hard stone out evenly

6.1.5 Add pebble in the tank and spread it out

6.1.6 Add fine sand and spread it out

6.1.3

6.1.4

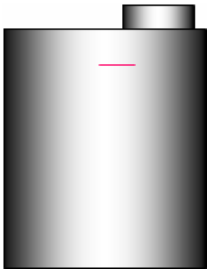
6.1.5

6.1.6

6.2 Operation process

Every 4 hour, mixing operator has to do the following:

- Add salt into the tank until it is higher than the red line of the tank. (Red line is the lower level of salt)



- Add water into the tank until it covers the actual salt level and add water further in order to observe water level as well

Control point

Level of salt added in the tank

The COMPANY, LTD. Standard Procedure	Document No. 7
Weigh water for flush	**Revision : 0** **Date : 27 Jun 08**
Operator : Pre-weigh Operator	**Page : 1 of 2**

1. PURPOSE

To prevent inconstant level of water in the shampoo production batch

2. SCOPE

This method is for water for flush in the shampoo production

3. MATERIALS

Water

4. EQUIPMENT

1. Preweigh station
2. Balance
3. Barcode reader
4. Barcode printer

5. SAFETY CAUTIONS

Install appropriate safety device such as goggles, mask, rubber glove

6. PROCEDURE

6.1 At master menu of preweigh station, move arrow key button to message ‘Preweighing’ then press “Enter”. It will change to batch manager.

6.2 Move the button to targeted batch, press “Space bar”. Then press “Shift + B”, some choices will come up on the screen. Move to message ‘Start preweigh water’ then press “Enter”. Wait for a while, message below will come up.

Started for batch with

Schedule Number

Press “Enter” to acknowledge.

6.3 State of production batch will change from ‘Schedule’ to ‘PW in Progress’. The machine will provide amount of water to balance.

6.4 Item No. of water will show at the screen of balance, so operator would take water to be weighed. First, use barcode reader to project the red light to barcode of water by the length of red light must longer than barcode row a bit. Wait until “Beep” voice happen, it means that the barcode finish reading.

6.5 In case that type of material is correct, the amount of that material will show up on the balance screen. Skip to step 6.7

6.6 In case that type of material is incorrect, message ‘Incorrect Ingredient’ will show up. Then it will show Item No. of water again, so operator would take the barcode of water for barcode reading again until it is correct

6.7 Weigh water by putting clean container on the balance. Press “Tare” and add water into that container until it reaches the desire amount on the screen. Stop adding and press “Enter”

6.8 After pressing “Enter”, barcode printer will print ‘Preweigh Barcode Sticker’ out. Stick that barcode to the container that has already weighed.

The COMPANY, LTD. Standard Procedure	Document No. 8
Functional Material adding	**Revision : 0** **Date : 27 Jun 08**
Operator : Mixing Operator	**Page : 1 of 2**

1. PURPOSE

To control conditioning effect of Finished Goods

2. SCOPE

-

3. MATERIALS

1. Functional Material
2. Alcohol

4. EQUIPMENT

1. Main mixer
2. Barcode reader
3. Alarm
4. Valve

5. SAFETY CAUTIONS

Install appropriate safety device such as goggles, mask, rubber glove

6. PROCEDURE

6.1 When it comes to functional material adding step, alarm will happen at data liner and it will be message to let operator add preweigh functional material.

6.2 Use barcode reader to scan barcode of functional material. Message ‘Add and Acknowledge’ will show up at the data liner display.

6.3 Operator sprays alcohol to the equipment for disinfection, then connect valve to the drum of functional material to be ready to add into main mixer. When it finishes, operator presses “Acknowledge” button.

6.4 System will send the signal to open valve automatically. When the targeted weight is met from load cell of main mixer, system will close valve automatically.

6.5 Alarm will happen again at the data liner. Operator disconnects the valve from functional material’s drum. When it finishes, operator presses “Acknowledge” button.

6.6 Operator cleans the equipment and valve to be ready to use.

CHAPTER 7

Conclusion and Recommendation

7.1 Conclusion

The purpose of this research is to develop standard procedure for Shampoo Products in Cosmetic manufacturing for the performance improvement in term of Right First Time. The shampoo production process in the case study company is in the Chapter 3.1.2.

FMEA team was formed from several departments such as production, product/process development and quality assurance for this project. FMEA team includes production Engineer, process development supervisor, product development supervisor, manufacturing and quality Assurance supervisor. Cause and Effect diagram and Failure Mode and Effect Analysis were used for problem identification and analysis as the Chapter 3.1.6. Base on analysis, there are 15 high risk items for shampoo production (Table 3.7). All of them are identified as processes that Risk Priority Number (RPN) are higher than 18.

Main problems of shampoo production can be categorized into 4 major items as following.

1. Quality of raw material

- Unsuitable active of surfactant
- Improper viscosity modifier concentration
- Uncontrolled pH modifier concentration

2. Standard procedure deficiency

- Suspending agent preparation process
- Surfactant dissolution process
- Viscosity modifier preparation process

3. Inaccuracy of weighing system in main mixer

4. Human error

- Operator discipline
- Operator has low operation skill

Recommended actions for solving these problems have discussed within the FMEA team. They are created and put into recommended actions column in the process FMEA of shampoo product (Table 3.2). Action plan was generated for each responsible department to solve the failure in the shampoo production as in table 3.8.

From implementing DOE, it infers that viscosity modifier's concentration and %active of surfactant have significant effect to Right First Time of shampoo production. Viscosity modifier's concentration is set at 25% and % active of surfactant at 12.2% in order to optimize shampoo production performance in term of Right First Time.

In order to develop standard procedure for shampoo production, author worked as team leader and organized team until achieve the desire result. Detail of shampoo production process flow chart was created by him to let all team members know the process boundary. He led team in discussion of process detail and ensured that everyone understand the process in the same direction. Process FMEA and Cause and Effect Diagram in this study were generated by the author and he would act as leader and also facilitator to bring people ideas and classify them into well-organized information. Evaluation criteria for severity, occurrence and detection need to be cleared for everyone in the team for generating process FMEA. Since this research's evaluation criteria come from the case study company which is different from rank 1 -

10 score like other normal FMEA, author need to explain clearly to team before ranking the failure. High-risk area would be addressed by RPN value and author would lead the team to focus on these failures as they are high priority for the production performance improvement in term of Right First Time. The action plan to improve or solve those failures was assigned to responsible departments by the author. Any pilot plant trials related to the corrective actions for solving the failure before implementing in the production scale were tested by the author. He would also guide, design and help the responsible member in other testing. All testing and trials related to standard procedure in action plan were done and concluded into new standard procedure. Those new standard procedures were prepared and written by the author before the implementation. Standard procedures were created to serve as quality control for shampoo production. During implementation period, he would help production team in collecting the necessary data. In addition, he would control and give suggestion to involved persons such as mixing operator, raw material controller to follow the new standard procedure since he would be responsible person to make sure that everyone related to shampoo production understand the new standard procedure. After implementation, the author and production team would summarize data to see the result in term of production Right First Time and batch time whether they improve or not.

From implementing FMEA project, there is improvement in term of production Right First Time and production batch time. Base on the result, Right First Time of this shampoo production has increased from 60.12% to 78.24%. Moreover, Production batch time also reduce from 151 minutes to 116 minutes which is 23.18% batch time reduction. From these results, Right First Time and production batch time have improved significantly when compare with prior to the implementation. In addition, RPN values of high risk reduce as well.

7.2 Further recommendation

The FMEA is a living document and should be reviewed and managed on an ongoing basis. FMEA should be continually updated as it is important tool for continuous improvement. At the present, Risk Priority Number (RPN) is set up at higher 18 to be addressed for taking into consideration for solving the problems. Therefore, some potential failure modes are not addressed to finding a solution for improvement. Author recommends reducing the RPN value from 18 to 12 (from severity at 2, occurrence at 2 and detection at 3). This would help reducing the potential problems in shampoo production.

Training for operators to understand basic operation of shampoo batch is also important. Human error is one of the potential failure modes in shampoo production. It needs operator with proper skill and also has discipline to operate the batch and improve production performance. Author would recommend training about basic knowledge of shampoo for mixing operator to let them have more skill.

Some recommended action can be further improved for increasing production performance. Preparation of viscosity modifier can be developed into auto dosing system, so operator is no need to add material and water into preparing tank. Functional material can be shifted to be charged into main mixer directly from its storage. Developing own equipment or install new equipment with high accuracy can be achieved to reduce accuracy problem of weighing material. However, financial perspective should be taken into consideration as well since this research has focused on technical analysis.

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APPENDICES

APPENDIX A: Process FMEA Table

Process FMEA (Failure Mode and Effects Analysis)

Product Name	:	FMEA Number	:
Project	:	FMEA Date (orig.)	:
Prepared by	:	FMEA Date (Rev.)	:
Key date	:	Page …… of …….	
Team	:		

Process Function and Requirement	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential Cause(s) of Failure	O	Current Process Control	D	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Results				
											Action taken	S	O	D	RPN

APPENDIX B: Severity Evaluation Criteria

Process FMEA - SEVERITY		
Severity Rating	Severity	Comment
1	very low	no noticeable loss of performance
2	low	**slight** customer/ consumer **annoyance and**
		no noticeable loss of performance
3	moderate	**some** customer/ consumer **dissatisfaction and**
		no noticeable loss of performance
4	high	customer/ consumer **dissatisfaction and some performance failure**
5	very high	**serious** safety and/or legal implications, death
		and/or damage could result

APPENDIX C: Occurrence Evaluation Criteria

Process FMEA - OCCURRENCE			
Occurrence Rating	**Possibility of Occurrence**	**Rate of Occurrence**	**Comment**
1	zero	$\leq$ 0.09%	Will never occur
2	low	0.1-0.9%	Rarely occur
3	moderate	1-4%	Will occur occasionally
4	high	5-49%	Will occur frequently
5	very high	$\geq$ 50%	Will occur very frequently

APPENDIX D: Detection Evaluation Criteria

Process FMEA - DETECTION		
Detection Rating	Likelihood of defect reaching a customer/ consumer	Comment
1	remote	Visually obvious
2	low	only a fair chance of the fault being detected
3	moderate	poor chance of the fault being detected
4	high	a very poor chance of the fault being detected
5	very high	defect will not appear during manufacture

BIOGRAPHY

Jakkaphan Bunkittiporn was born on 15 October 1979 in Bangkok, Thailand. He graduated a Bachelor Degree in Chemical Technology from Chulalongkorn University in 2001. He has worked for Unilever Thai Trading Limited as Process Development Supervisor for 7 years until present. He continues his Master Degree in Engineering Management at Regional Centre for Manufacturing Systems Engineering (RCMSE), Chulalongkorn University (TH) and University of Warwick (UK).