THESIS ADVISOR
RECOMMENDATION LETTER

This thesis entitled "**Optimization of Plastic Thread Production Using Response Surface Methodology in PT. XYZ**" prepared and submitted by **Briggitha Maria Regina Amarisari** in partial fulfillment of the requirements for the degree of Bachelor Degree in the Faculty of Engineering has been reviewed and found to have satisfied the requirements for a thesis fit to be examined. I therefore recommend this thesis for Oral Defense.

Cikarang, Indonesia, February 2017

Johan KrisnantoRuntuk, M.T

DECLARATION OF ORIGINALITY

I declare that this thesis, entitled "**Optimization of Plastic Thread Production Using Response Surface Methodology in PT. XYZ**" is, to be the best of my knowledge and belief, an original piece of work that has not been submitted, either in whole or in part, to another university to obtain a degree.

Cikarang, Indonesia, February 2017

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OPTIMIZATION OF PLASTIC THREAD PRODUCTION USING RESPONSE SURFACE METHODOLOGY IN PT. XYZ

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ABSTRACT

Every company is trying to optimize everything they could to decrease the cost, time, and other factors they want to minimize. In fact, there are always defects in manufacturing company. The different among them are only the quantity and the factors that might cause the defects. Sadly, defects lead to a bad quality management. PT. XYZ is currently producing plastic thread with lots of defect. To find out the factors that related with the production and defects, some methods can be used; one of them is Pairwise Comparison. By conducting pairwise Comparison, factors related and the rank of the factors can be figure out. To conduct the pairwise comparison, interviews with some experts are conducted to give the weight for the calculation. In order to optimizing the productions, the number of defects must be decreased. In this research, the method used is Response Surface (RSM). To optimize the production, defects data and experiments are collected and conducted. Response Surface Method can reduce around 7% of defects from the current composition by giving the optimization solution of the materials compositions which are 80% PP + 10% Calcium + 30% Recycle.

Keywords: *Optimizing, Production, Defects, Pairwise comparison, Response Surface Method*

ACKNOWLEDGEMENT

With all the hard works and a big support, I gratefully could finish this thesis. Therefore, I would like to express my gratitude to:

1. Jesus Christ, the Almighty God. Thank you for Your blessings and Your love.
2. My beloved family, thank you for always there for me every time I struggled.
3. My Thesis Advisor, Mr. Johan K Runtuk. Thank you for not giving up on me and always help me to finish this last assignment. Thank you for your guidance and support until this research is finished.
4. Head of Industrial Engineering Study Program,Ir. Andira, M.T. Thank you for your guidance through my college life.
5. IE'13, my beloved friends. Thank you for always supporting, helping, cheering, and sharing with me.
6. My Industrial Engineering lecturers from the beginning of semester I – X that I could not mention one-by-one. Thank you for the lessons and knowledge.
7. My BBM Girls, Mean Girls, thank you for helping me and coloring my life.

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LIST OF TERMINOLOGIES

Design Experiments	:	A data-driven technique for robust product design
Pairwise Comparison	:	A method that used to weighting some criteria
Production Process	:	The process of making a product
Quality Management	:	A process to ensure that the product meets requirements and expectations of the beneficiary involved
Response Surface Method	:	Are designs and models for working with continuous treatments when finding the optima or describing the response is the goal

CHAPTER I
INTRODUCTION

1.1.Problem Background

Nowadays, companies in Indonesia are strongly competitive with each other. There are structural factors that can affect industry rivalry such as numerous balanced competitors, slow industry growth, high fixed or storage costs, switching costs, capacity increased in large increments, diverse competitors, high strategic stakes, and high exit barriers (Porter, 1998). To survive from this strong and strict competition, companies should have abilities to cover up and to against other companies. To become a leading company, they should optimize their production. One of the ways is increase their output and decrease the defects. Every manufacturing industry is giving high attention on their products and defects. However, lots of outputs with lots of defects are useless.

Many ways can be done to optimize production. But, the most significant things that can give high impact on it, is defect. Decreasing number of defects can directly minimize the production cost and increase outputs. Defect is an imperfection or fault in a person or a thing. In this case, plastic threads are used as the raw materials of woven bag. In other word, if the defects are high, so the number of outputs will be small and there will be lots of lost and high production cost. This situation or condition can give bad effects to the company. Company can reduce the reliability and defects by minimizing or reducing variation of key process that involved in product making (Lowenthal, 2002).

Several changes can be done to give big impacts on the outputs such as process changes, tool changes, set up changes, and configuration changes depends on production requirements (Musharavati, 2010). Impacts that given might be bad and good for the company depend on the action. There are also other aspects that might affect the number of defects such as lack of training for the operators, uncomfortable working place, and unsupported working environment.

PT. XYZ is a manufacturing company that produce plastic woven bag for packaging. They use import plastic seed (Polypropylene/PP) as their raw materials. There are two types of plastic thread that they produce such as white thread and transparent thread. Not only PP seed, there are several seeds too to make the plastic thread such as Calcium and Recycle seed.

Currently, PT. XYZ is having a problem regarding how to decrease the defect of plastic thread in order to optimizing the plastic thread production. Sadly, PP seed's price is increase and decrease suddenly based on the dollar's rate, that's why decreasing defect will absolutely affecting the cost and optimizing production. From the data collected on August – October 2016, defects of the plastic threads reach the amount of around 10.800 kg per month and it is cost about Rp. 175.000.000 per month. The high numbers of defect are caused by the incompatibility of the thread's tensile strength that caused by the composition of the materials. However, there are also several factors that can cause defect which are the machine's setting such as temperature and distance within knifes, materials, pH, others related aspect that can affect the quality of the plastic thread.

In this report, the methods used to identify the factor and to optimize the production are Pairwise Comparison and RSM. Pairwise Comnparison is used to weight the criteria. Some woven bag experts will mention the factors that really affecting the plastic thread production process and pairwise comparison will show the most affecting factor so the production can be optimized. Next, the factors related will be processed byResponse Surface Method (RSM). Response Surface Method is used to optimize something by searching the factors that affected (Kavitha, 2016; Unal, 2016). Hopefully, by combining these 2 methods, the optimize solution can be achieved and the production process will be optimum.

1.2.Problem Statement

The background of the problem leads into the statement below.

- What are the factors that affect plastic thread production and which of them that really affect the production process and causing defects?
- What is the right parameter of the plastic seed composition?

1.3.Objectives

There are several objectives in this research which are:

- To know the factors that affect the thread production and which factors affecting the most
- To find the right parameter or composition of each seeds needed in the mixtures to decrease the number of defects

1.4.Scope

Due to limited time and resources in doing this research, there will be some scopes for this research, such as:

- Defects from machine's setting are not to be counted and discussed. Only from the seed composition that will be discussed.
- Defects are measured by tensile strength. But tensile strength is not going to be calculated in this research. As a substitute, high number of calcium leads to low tensile strength
- The discussion and calculation on this research is only for the production of white plastic thread
- The data is collected on August – October 2016
- The observation is conducted on September – December 2016

1.5.Assumption

Several assumptions have to be made in order to conduct and develop the research, such as:

- All experiments conducted with a good machine condition
- All size and weights of plastic seeds are equals

1.6.Research Outline

Chapter I Introduction

This chapter consists of problem background or the background of the problems, problem statement, and then followed by objective, scope, and also the assumptions made to conduct the research.

Chapter II Literature Study

This chapter elaborates specifically about the Industrial Engineering terminologies, theories, and tools. Theories and methodology for this research will be related to Pairwise Comparison, Response Surface and Design of Experiments. And tools that will be used are Ms. Excel, Expert Choice, and Minitab.

Chapter III Research Methodology

This chapter contains detailed flows of the research step by step from identifying problems, study about the raw materials, mixtures for the plastic thread, list the data, analyze the data, solve the problems, and finally conclusion and recommendation.

Chapter IV Data Collection and Analysis

This chapter provides and elaborates the collected data to support this research and also briefly explained the analysis of the answer.

Chapter V Conclusion and Recommendation

This chapter gives conclusions result based on the calculation and analysis of this research. Recommendations are also given for future used.

CHAPTER II
LITERATURE STUDY

2.1. Quality Management

(Kamcharoen, 2009) reasoned that great pioneers ought to be unequivocal, decided, objective arranged, proficient, and must be reliable to the motivation behind item and administration enhancements for the association's survival in an aggressive situation. (Diminishes, 1999) examined benefit quality and aggregate quality administration as a business procedure intended to increase the value of clients in each division of industry.

The summary from several sources, the meanings of quality as follows.

1. Quality is fitting in with the principles and particulars of an item or benefit.
2. Quality is zero deformities or meeting the particulars 100%.
3. Quality implies that item or benefit has the wellness for reason for utilize in light of its capacities.
4. Quality is the capacity of an item or administration to address the client's issues and desires.
5. Quality is surveyed by client just borne upon the basic components and attributes of an item or benefit considered by client.
6. Quality is dictated by the deviation of the measures of value attributes of an item.
7. Quality is consumer loyalty.

Consumer loyalty gives profitable data to sparing assets by tuning those procedures and its quality viewpoints. Consequently the estimation of consumer loyalties ought to be viewed as a fundamental piece of business administration and ought to be deliberately planned as one of the key measures of the achievement of an association (Salge, 2000).

Quality aspect has turned out to be a standout amongst the most vital figures worldwide rivalry today. Expanding request by clients for better nature of item in commercial center has urged many organizations to give quality item and administrations keeping in mind the end goal to contend in the commercial center effectively. To meet the test of this worldwide rivalry, numerous organizations have put significant assets in adjusting and implementing total quality management (TQM) practices in their operations.

Quality administration originated from two thoughts regarding how to run associations better. Quality administration is the procedure required that guarantees that the item meets necessities and desires of the recipient included (Nedelcu and Dumitrascu, 2010), and comprises of:

- Identification of pertinent quality levels for the item and how to meet them
- Planned exercises executed quality framework proposed to guarantee that the item will be inside the parameters of value arranging
- Monitoring consequences of item

Assessing item's quality measures, Juran divided quality management system into three stages that also known as Juran Trilogy, which are:

1. Quality Planning

   Firstly the firm ought to recognize the focused of the client and its needs to set up the objective to fulfill the clients and accomplish excellent business result based. This arranging stage additionally endeavors to wipe out issues which may happen and turn out to be most noticeably awful as the procedure was composed.
2. Quality Control

   The organizations need to set up a control framework to screen the quality, assess the procedure execution, and contrast the working outcomes and the objectives. It is likewise basic to find the issues, particularly the incessant issues.

3. Quality Improvement

   In this stage the organizations will distinguish the improvement projects and groups and analyze the root causes and eliminate them. After the issues are unraveled, the organizations will institutionalize the new procedure and build up the instruments to control the new procedure keeping in mind the end goal to guarantee the quality.

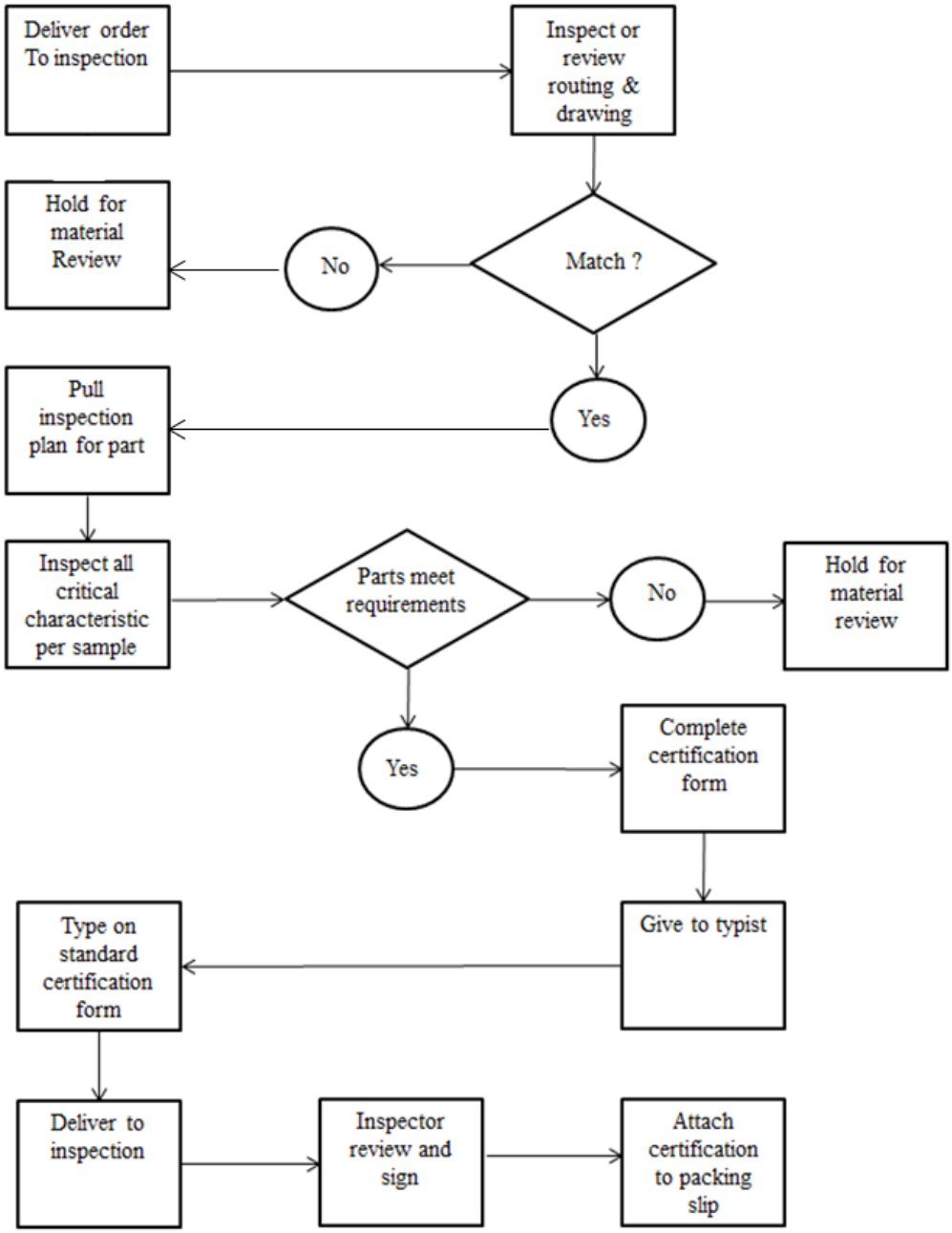
According to (Aized, 2012), the purposes of quality management system are:

- To limit the conceivable mistakes in arranging, coordination and different stages related
- To guarantee a controlled way that subjective prerequisites on procedures, methodologies and items are regarded at all stages
- To discover blunders or missteps at the earliest opportunity, evacuate and decide measures to evade the capability of rehashed similar mistakes
- Check perpetual measures to guarantee quality and effectiveness, the need to start remedial activity
- To decide and start preventive courses so as to improve the production

Quality administration framework will help by overseeing expense and risk, expanding viability and profitability, recognizing improvement opportunities, and expanding consumer loyalty's (Aized, 2012).

There are several positive impacts or advantages from a well-managed quality system, such as:

- Client devotion and rehash business
- Market share and industry notoriety
- Operational efficiency
- Flexibility and capacity to react to market openings
- Effective and productive utilization of assets
- Cost decreases and competitive advantages
- Participation and inspiration of HR
- Control on all procedures



(Source: Aized, T. (2012) *Total quality management and Six Sigma*. Croatia: INTECH.)

Figure 2.1 Product Certification Flow Chart

Based on **Figure 2.1** of product certification and flow chart, the quality of the products is really important. If the review or drawing does not match, product should be hold and remake. But, if all parts meet requirements given, the certification form can be published. There are several inspections should be done to make sure or recheck if the product is qualified enough. Moreover, certification

should be attached on the packaging to let people know if the products are qualified.

As quality is characterized as the totality of attributes of an item that bears on its capacity to fulfill expressed and suggested necessities, consumer loyalty's estimation shows up as the most target method for worldwide appraisal of the quality level of a given item. Consumer loyalty's is a fundamental measure that ought to have a status in corporate culture and impact until process changes. Quality administration and also business systems perceive the essential significance of consumer loyalty's to the achievement of an association (Ahonen, 1999).

To create a good quality, the best accessible level of value is bad practice since it suggests high expenses and moderate generation forms that defer conveyance to clients. A superior approach is to create a sensible essential level of value and after that refine the item in light of client's requests. Nonstop change of a conveyed item is superior to anything investing a long energy enhancing the nature of a potential item. Consumer loyalty's requires contacts between the association and its clients. These incorporate individual, item, emotionally supportive network and general contacts. Every contact makes encounters that alter the client's desires. Consumer loyalty's depends on encounters. Consumer loyalty's is an element of saw execution and desires. In this sense it is a subjective measure. Deming proposed 14 points as the principles of total quality management (TQM) (Deming, 1986), which are listed below:

(1)Make steadiness of reason toward change of item and administration, with the intend to end up distinctly focused and to remain in business, and to give occupations.

(2) Adopt the new theory.

(3) Cease reliance on mass investigation to quality. Wipe out the requirement for investigation on a mass premise by building quality into the item in any case.

(4) End the act of granting business on the premise of price tag. Rather, minimize cost. Move toward a single provider for any one thing, on a long haul relationship of loyalty and trust.

(5) Improve continually and perpetually the arrangement of creation and administration, to enhance quality and profitability, and in this way always diminish costs.

(6) Institute training on the job.

(7) Institute leadership. The point of supervision ought to be to help individuals and machines and gadgets to make a superior showing with regards to. Supervision of administration need update, and in addition supervision of generation specialists.

(8) Drive out dread, with the goal that individuals may work viably for the organization.

(9) Break down hindrances between divisions. Individuals in research, outline, deals, and generation must act as a group, to predict issues of creation and being used that might be experienced with the item or administration.

(10) Eliminate mottos, admonishments, and focuses for the workforce requesting zero deformities and new levels of efficiency. Such urgings just make antagonistic connections, as the greater part of the reasons for low quality and low efficiency have a place with the framework and in this way lie past the force of the workforce.

(11) (a) Eliminate work norms (standards) on the industrial facility floor. Substitute administration. (b) Eliminate administration by goal. Take out administration by numbers, numerical objectives. Substitute initiative.

(12) (a) Remove obstructions that rob the hourly laborer of his entitlement to pride of workmanship. The obligation of managers must be changed from sheer numbers to quality. (b) Remove obstructions that ransack individuals in administration and in designing of their entitlement to pride of workmanship.

(13) Institute a fiery program of training and self-change.

(14) Put everyone in the organization to work to achieve the change. The change is everyone's occupation.

Satisfaction is an articulation of joy or frustration coming about because of looking at the apparent execution of an item in connection to their desires (Zhang, 2000). On the off chance that execution coordinates the desires, the client is fulfilled. In the event that execution surpasses desires, the client is profoundly fulfilled or pleased. On the off chance that execution misses the mark concerning desires, the client is disappointed. The level of desires vigorously impacts the client's conduct in different circumstances of fulfillment. On the off chance that a client with adoration desires gets to be distinctly disappointed the switch is presumably unavoidable.

(Source: www.infointl.com)

Figure 2.2 Commitment to Quality

Figure 2.2 above shows the relationship of methods, people, design and specifications, and material to produce a good quality. Top-level management commitment to quality, empowered, and trained employees. Assessing customer needs and requirement also needed. Management review is a must to continually improve the service.

2.2. Production Process

To maintain a multi-stage cleaner production process, the major task is eliminating all defective items during the production system and an investment is necessary to reduce the probability of in-control state to out of-control state of machinery system. Production process was investigated in order to improve quality of the final product and reduction of production cost or known as optimizing production process (Šatanová, Figuli, and Sedliačiková, 2015). There are several factors as temperature, machine set-up, pH, etc. were observed as well as quality of bonded joints of products.

Several benefits can be achieved by improving production process, includes (Szerszunowicz, 2014):

- Increased throughput
- Reduced inventories
- Reduced production cost
- Reduced lead times
- Increased return on assets
- Greater customer satisfaction

Generation framework are those exercises of an associations where assets streaming inside a characterized framework, are consolidated and changed, in a controlled way, to include esteem, and in understanding to the strategies conveyed by the administration. There are some trademarks from a creation framework which are:

- Every creation framework has a target
- System changes different contributions to valuable yields
- Not work in disconnection from other hierarchical frameworks
- Give an input about the exercises which is basic to control and enhance framework execution

Sorts of production process or framework are arranged on the premise of item or yield assortment and item or operations or yield volume. They are

comprehensively delegated constant creation prepare (stream generation and large scale manufacturing) and irregular generation handle (bunch generation and employment shop creation). The generation forms or referred to likewise as assembling procedures, are extensively partitioned into two classes, for example, made to stock creation process, and made to request creation handle. In made to stock creation handle, the organizations made things that are finished and put it in stock before client request is gotten. In made to request generation handle, the firm made the item subsequent to getting the client arrange on the grounds that producer cannot anticipate what every client needs.

There are several process of production that can be classified by the product, output variety, operations, and any other related factors. Production process consists of continuous production process and intermittent. Continuous production process is divided into two such as flow and mass production. While intermittent production process is consist of batch and job shop.

The production processes or known also as manufacturing processes, are broadly divided into two categories such as made to stock production process, and made to order production process. Made to stock production process is a firm that completely stock the product before the order by the customer is made and received. Different with the previous process, in made to order production process, it produces the products after the order is received from the customer, because each customer might order different thing or a special order.

Repetitive manufacturing system or continuous manufacturing system, the production is directly produced in high numbers of order with the similar products and sometimes it produced more than the customer's order to make it as a stock. In continuous flow or flow shop, products flow continuously through a linear process and mostly the products are not discrete. The examples of the products are chemical plant, and oil and gas.

Below are the detailed explanations of every types of production process (Anupam Kumar, 2013).

a) Process / Flow Production

It is used when material handling is fully automated, dedicated plant and equipment with zero flexibility, process follows a predetermined sequence of operations, component material cannot be readily identified with final product, planning and scheduling is a routine action, product differentiation is limited, and involves high initial investments. However, there are several advantages from this production process which are higher rate of production with reduced cycle time, highest capacity utilization due to line balancing, manpower is not required for material handling, persons with limited skills can be used, and unit cost is low due to high volume of production.

b) Mass Production

It is utilized when material dealing with is completely computerized, committed plant and hardware with zero adaptability, handle takes after a foreordained succession of operations, part material cannot be promptly related to definite item, arranging and booking is a standard activity, item separation is restricted, and includes high beginning ventures. Be that as it may, there are a few focal points from this generation procedure which are higher rate of creation with diminished process duration, most elevated limit usage because of line adjusting, labor is not required for material taking care of, people with restricted aptitudes can be utilized, and unit cost is low because of high volume of generation.

c) Intermitted Production Process

This production process has a low volume of product and generally produces the product by make to order due to a special request by the customer. Every process in this job is very complicated because it might involve some uniqueness and required a special set of production flows. Furthermore, each job in this process needed a particular routing but without standard.

d) Job Shop Production Process

Job shop has the biggest percentage regarding working in process or WIP but there are few types from the raw materials. The limitations of this production process are a complicated production planning and larger space requirement. The advantages of this production process are full potentials of operators can be utilized, operator become more skilled and competent with each job, a large variety of products can be produced with the general purpose machines, and workers with a creative minds and innovative ideas may join this production process.

e) Batch Production Process

Batch manufacturing is a creation procedure in the middle of job shop and repetitive. This procedure is a single creation run, and has a size that implies the amount delivered in a single production run. A batch manufacturing company may witch over the equipment and make a batch of another item. Production equipment should be more flexible than repetitive manufacturing and it is generally less flexible than job shops. Batch production process is utilized when there is a shorter creation run, and adaptable plant and hardware. A few points of interest are offered from this creation procedure, for example, low assembling lead time, minimal effort, high use, low speculation, high adaptability, and high occupation fulfillment. However, there are several limitations or disadvantages that this production process give, which are complexity in material handling, production planning and control, high set up cost because of several changes in set up, and highest WIP inventory.

2.3. Pairwise Comparison

The technique for pairwise comparison gives premise to compare the objects or things in the form of pairs to get rank or positions. Positioning or ranking with pairwise examinations is lately got lots in attention of consideration where several criteria can be utilized successfully to make evaluations or solution quicker for exact rankings.

The pairwise comparison helps decision makers to:

1. Identify the decision goal and decision criteria
2. Structuring the decision criteria
3. Judging the value of the alternative technologies on each decision criterion
4. Judging the importance of the decision criteria
5. Calculating group judgments
6. Analyzing the inconsistency in judgments
7. Calculating the overall value of the technologies, and
8. Conducting sensitivity analyses

It was used by Tahririet. al (2008) to differentiate the selection methods on concerning suppliers and also the advantages and disadvantages of selected methods. Also, Kim, Kim, and Shim, (2017) used pairwise comparison in crowdsourcing platforms.

The pairwise comparison is utilized with two sorts of estimation, relative and outright. In both, matched correlations are performed to determine needs for criteria concerning the objective. In relative estimation, paired comparisons are performed throughout the hierarchy including on the alternatives in the lowest level of the hierarchy with respect to the criteria in the level above. In outright estimation, matched examinations are additionally performed through the chain of importance with the exemptions of the choices themselves. The level simply over the options comprises of powers or evaluations which are refinements of the criteria or sub criteria representing the options.

The alternatives are not pairwise compared, but simply rated as to what category in which they fall under each criterion. A weighting and summing process yields their overall ranks. In order to make an organized and structural decision, some steps should be taken, which are (Saaty and Vargas, 1994):

1. Define the problem and determine the solution desired

2. Construct a set of pairwise comparison matrices starting from the upper level to the lowest. Upper level is used to compare the elements in the level immediately below with respect to it.
3. Use the needs acquired from the correlations with measures the needs in the level quickly underneath and for each component. At that point, every component in the level beneath includes it is measured values and gets it generally. At last, weighing and including until the last needs of the options in the base most level are obtained.

Table 2.1 The Fundamental Scale of Absolute Number

Intensity of Importance	Definition
1	Equal Importance
2	Weak or Slight
3	Moderate Importance
4	Moderate Plus
5	Strong Importance
6	Strong Plus
7	Very Strong or demonstrated Importance
8	Very, very strong
9	Extreme Importance
Reciprocals of above	If activity *i* has one of the above non-zero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*
1.1-1.9	If the activity is very close

Pairwise examinations are keys in the utilization of the comparison. The individuals from parliament should first build up needs for their fundamental criteria by passing judgment on them in sets for their relative significance, accordingly creating a pairwise examination network. Judgments which are

spoken to by numbers from the essential scale underneath are utilized to make the correlations. The number of judgments needed for a particular matrix of order n, the number of elements being compared, is n(n - 1)/2 because it is reciprocal and the diagonal elements are equal to unity (Saaty, 1987).

The best approach to think judgment is to take a couple of components and analyze them on a single property without sympathy toward different properties or different components. This is the reason matched examinations in mix with the various leveled structure are so helpful in determining estimation. Pairwise Comparisons matrix should be made, so the relative importance of one criterion over another can be expressed. **Table 2.1** above shows the number of how importance is the factors. Judgments are used to determine the rank of the criteria. 1 means equal, 3 means moderate, 5 means strong, 7 means very strong, and 9 means extreme.

The best approach to get the rank of priorities from a pairwise matrix is by Eigenvector. Saaty, T.L. (2008) demonstrated mathematically that the eigenvector solution was the best approach. To solve the eigenvector, there are several steps to be done, such as:

1. Raise the pairwise framework to forces that are progressively squared every time.
2. Calculate and standardize the column totals
3. Stop when the contrast between these totals in two sequential figuring is littler than a recommended esteem.

2.4. Design of Experiments

Design of experiments (commonly referred to as DOE) is a data-driven technique for robust product design. It is used to improve the statistical performance of a given circuit or system by predicting the response of the device-under-test (DUT). There are three primary steps in a typical DOE such as:

1. Plan the experiment

   In planning the experiment, there are three important aspects that should be prepared such as asses the experimental resource, identify input and

response variables, and assign level (values) to input variables. Detailing data collection protocol is the first step to do to conduct the experiment. Person or object that will be tested is called as the sampling unit. This is the smallest unit of analysis in the experiment from which data will be collected.

An information gathering arrangement considers four essential elements which are foundation, consistent, wild, and essential. Remembering the ultimate objective to lift confide in the last results, consider all the germane variables (even those components that may, at in any case, have every one of the reserves of being pointless) before the last data aggregation mastermind. Establishment elements can be recognized and measured yet can't be controlled in light of the way that it will affect the aftereffect of an examination. Establishment components will be managed as covariates in the model instead of fundamental variables. Fundamental variables must be managed as covariates in order to keep the traverse of the examination to a sensible level. Unfaltering components can be controlled or measured in the meantime, for no good reason, will be held steady over the traverse of the survey. This action grows the authenticity of the results by decreasing accidental wellsprings of assortment from entering the data. Wild (Hard-to-Change) components are those variables that are known to exist, however conditions shield it from being controlled, or it is particularly troublesome (in view of cost or physical necessities) to gage. The test bumble is a result of the convincing effects of wild components, which will achieve less correct evaluations of the effects.

Detailed measurements of all relevant variables should be made, preferably at the time the actual measurements are collected. For this data collection plan, some of the variables that will be held constant include:

- The utilization of standard working strategies
- The utilization of one administrator for every measuring gadget

• All estimations taken at particular circumstances and areas

2. Perform the experiment and collect response data

   There are several ways to collect the data such as one-way, two-way, three-way, 2n, 3n, D-optimal, central composite, and two-way with some controls. After defining the objectives and the type of data that needs to be collected, the treatment structure can be figured out. Design template can be used to give a draft design that can be used to analyze the data and it leads to a good statistical model. There is a model that used to observe with a large number of factors with small number of observations called fractional factorial.

3. Analyze data using statistical methods

   ANOVA or specific analysis of variance can be used to analyze every experimental design. Other than that, method and software such as JMP, Expert Choice, and Minitab can also create the design and analyze the experiments.

Most formal measurable examinations depend on models. Measurable models are perfect, numerical representations of noticeable attributes. Models are best isolated into two parts. The auxiliary part of the model or basic model indicates the connections between informative factors and the mean or other key element of the result factors. The irregular or mistake segment of the model or blunder display describes the deviations of the individual perceptions from the mean. The two model segments are additionally called flag and commotion individually.

To utilize the measurable approach in outlining and dissecting a trial, it is vital for everybody required in the test to have an unmistakable thought ahead of time of precisely what is to be examined, how the information are to be gathered, and no less than a subjective comprehension of how these information are to be broke down.

There is such an alternate between observational reviews and trials. Examination is the place the principle informative factor of intrigue is connected as a type of the perception under the experimenter. As it were, perceptions are including within the analyses. In directing the trials, treatment can be haphazardly relegated by the experimenter. There will be a factually result and unmistakably sensible clarification. What's more, perception studies open up all plausibility to demonstrate the impact in view of puzzling variables and have a little number of legitimacy. It reasons that analyses are more than only a perception examine in light of the fact that it needs more considerations for every one of the components that will relate in leading the investigations and it include more exact estimation.

Most formal statistical analyses are based on models. Statistical models are ideal, mathematical representations of observable characteristics. Models are best divided into two components. The structural component of the model or structural model specifies the relationships between explanatory variables and the mean or other key feature of the outcome variables. The “random” or “error” component of the model or error model characterizes the deviations of the individual observations from the mean. The two model components are also called “signal” and “noise” respectively.

Statisticians realize that no mathematical models are perfect representations of the real world, but some are close enough to reality to be useful. A full description of a model should include all assumptions being made because statistical inference is impossible without assumptions, and sufficient deviation of reality from the assumptions will invalidate any statistical inferences. Statistical analyses can and should be framed and reported in different ways in different circumstances. But all statistical statements should at least include information about their level of uncertainty.

To use the statistical approach in designing and analyzing an experiment, it is necessary for everyone involved in the experiment to have a clear idea in advance of exactly what is to be studied, how the data are to be collected, and at least a

qualitative understanding of how these data are to be analyzed. Some of the reasons for running the experiment include:

- Factor Screening or Characterization

  This more often than not shows that the experimenters don't know much about the framework so screening is basic on the off chance that we are to productively get the wanted execution from the framework. Screening tests are critical when working with new frameworks or advances so that significant assets will not be squandered utilizing best figure and OFAT approaches.

- Optimization

  The next objective is usually optimization, that is, find the settings or levels of the important factors that result in desirable values of the response. An optimization experiment is usually a follow-up to a screening experiment. It would be very unusual for a screening experiment to produce the optimal settings of the important factors.

- Confirmation

  In an affirmation investigation, the experimenter is typically attempting to confirm that the framework works or carries on in a way that is steady with some hypothesis or past experience.

- Discovery

  The experimenters are usually trying to determine what happens when we explore new materials, or new factors, or new ranges for factors.

- Robustness

  A variety of this is deciding how to set the elements in the framework that can be control to limit the fluctuation transmitted into the reaction from elements that can't be controlled extremely well.

Tests vary from observational reviews in that in an examination at any rate the fundamental logical factors of intrigue are connected to the units of perception (most regularly subjects) under the control of the experimenter. The fundamental preferred standpoint of an examination is that the experimenter can arbitrarily dole out treatment, consequently expelling almost the majority of the puzzling. Without frustrating, a factually noteworthy change in the result gives great proof to a causal impact of the illustrative variable on the result. Observational reviews are constantly open to the likelihood that the impacts seen are because of bewildering elements, and in this manner has low internal validity.

There is such an alternate between observational reviews and trials. Examination is the place the principle informative factor of intrigue is connected as a type of the perception under the experimenter. As it were, perceptions are including within the analyses. In directing the trials, treatment can be haphazardly relegated by the experimenter. There will be a factually result and unmistakably sensible clarification. What is more, perception studies open up all plausibility to demonstrate the impact in view of puzzling variables and have a little number of legitimacy. It reasons that analyses are more than only a perception examine in light of the fact that it needs more considerations for every one of the components that will relate in leading the investigations and it include more exact estimation.

Experiment consists of experimental units that are important to analyze the design of the experiments. It defines every division of the experimental material from the smallest to the biggest to measure the experiment and it has no effect and relation with other experimental units. There is also an experiment called Before-After that shows the comparison of before and after the treatment. It is so powerful because every single experimental unit has its own control and can be clearly shown.

Each great factual technique has a similar target which is to decrease the mistake that may happen and influence the test outline. Each of the measurable strategy

needs to make the conclusion more exact. The following are four general ways that can diminish the blunder in any factual strategy or correlation.

1. Utilize more homogenous exploratory units. This guidance is valuable to research facility experimenters yet is hard to use in many field tests.

2. Utilize data gave by related factors that can be measured in each exploratory unit. The examination of covariance is the least difficult case of this approach (Green, 1979).

3. Utilize more recreates. This is the bulldozer way to deal with factual exactness. It generally works, in the event that you have sufficient energy, cash, and enough space.

4. Utilize a more productive test outline. By this analyst' means the measure of adjusting and obstructing in the format of the trial.

2.5. Response Surface Methodology (RSM)

Reaction Surface Method is extremely regular in industry. Generally it is utilized to test whether the framework is sufficiently ideal for the business. In quite a while, Response Surface Methodology is being utilized as a part of synthetic industry to locate the ideal reaction and furthermore give upgrades for the framework (Myers, Khuri, and Carter 1989).

Response Surface Methodology (RSM) is a collection of mathematical and statistical techniques useful for the modeling and analysis of problems in which a response (factor Y) of interest is influenced by several variables (factor X) and the objective is to optimize this response (Montgomery, 2005).

Response Surface Methods are designs and models for working with continuous treatments when finding the optima or describing the response is the goal (Oehlert 2000). The primary objective for Response Surface Method is to locate the ideal

reaction. At the point when there is more than one reaction then it is critical to discover the tradeoff ideal that does not advance just a single reaction (Oehlert 2000). At the point when there are limitations on the outline information, then the test configuration needs to meet prerequisites of the requirements. The second objective is to see how the reaction alters in a given course by conforming the plan factors. When all is said in done, the reaction surface can be imagined graphically. The chart is useful to see the state of a reaction surface; slopes, valleys, and edge lines.

There are 7 designs properties that can be found in RSM (Cornell, 1990), such as:

i. Produce satisfactory distributions of information throughout the region of interest
ii. Ensure the predicted response of the fitted model closely approximate the true response values
iii. Closely fit the model to the data
iv. Provide the ability to perform an experiment in blocks
v. Build RSM model in increasing order sequentially
vi. Provide internal estimates of error variance
vii. Ensure simple calculation of parameter coefficients

The trials from reaction surface normally include little number (by and large from 2 to 8) of constant component. The model for the trial is typically quadratic. Normally, scientist utilize reaction blunder when the vital variables are characterized. The primary objective of reaction surface investigations is to make a prescient model of the relationship between the components and the reaction. Utilizing this prescient model, it permits the experimenter to discover better working settings for the procedure. In screening tests one measure of the nature of the plan is the extent of the relative fluctuation of the coefficients. Accordingly surface investigations, the forecast difference over the scope of the components is more essential than the fluctuation of the coefficients.

Response Surface Method consists of three models that used to search the optimum spot whether the response is either maximized or minimized. The methods are:

Screening Response Model

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{12} x_1 x_2 + \varepsilon \qquad (1)$$

This model is used for the first order situation involves linear effects and single cross product factor that represents the linear x linear interaction component.

Steepest Ascent Model

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \varepsilon \qquad (2)$$

Steepest Ascent Model is focused only on the first order model and ignores cross products which givean indication of the curvature of the response surface.

Optimization Model

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{12} x_1 x_2 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \varepsilon \qquad (3)$$

In optimization model, there are two order model should be conducted. The first order model used low order polynomial to explain the parts of the response surface by using least square to fits the data and mostly this model gives a flat surface with or without tilted surface. The first order model will give an equation that can examine whether the data is normal or not. Normal plot, contour plot, main effects, ANOVA statistics will clearly given. When the response is not plane, it means that the first order is lack of fit. If the lack of fit from the first order is significant and more structured model, the second order should be conducted to get the optimum solution.

At the point when the principal arrange display demonstrates a noteworthy absence of fit, then an experimenter can utilize a moment arrange model to depict the reaction surface. There are many outlines accessible to direct a moment arrange plan. The focal composite outline is a standout amongst the most prominent ones. An experimenter can begin with 2k factorial point, and afterward

add focus and hub focuses to get focal composite plan. Including the hub focuses will permit quadratic terms to be incorporated into the model. Second-arrange demonstrate depicts quadratic surfaces, and this sort of surface can take many shapes. Consequently, reaction surface can speak to greatest, least, edge or seat point.

Form plot is a useful representation of the surface when the variables are close to three. At the point when there are more than three outline factors, it is practically difficult to envision the surface. Thus, with a specific end goal to find the ideal esteem, one can locate the stationary point. Once the stationary point is found, either an experimenter can make a determination about the outcome or proceed in further examining of the surface.

There are also several advantages from RSM models and disadvantages of other experimental design. Screening designs have the objective of finding the vital few number of factors believed to affect the outcome response variables in interest. Below are the designs:

- Plackett-Burman (P-B) design

  Is a very common design that used for screening. There are two disadvantages of (P-B) designs which are some main effects are confounded with certain two-factor interactions and it does not have enough runs to detect important effects. Other than that, all features in this design are really useful for screening.

- Orthogonal Arrays (OA) design

  This design is parts of Taguchi's robust tolerance design strategy. OA design is help to find out the optimum solutions within the level of the factors setting for the response. However, the optimum solution is not easily found when there is more than a response shown.

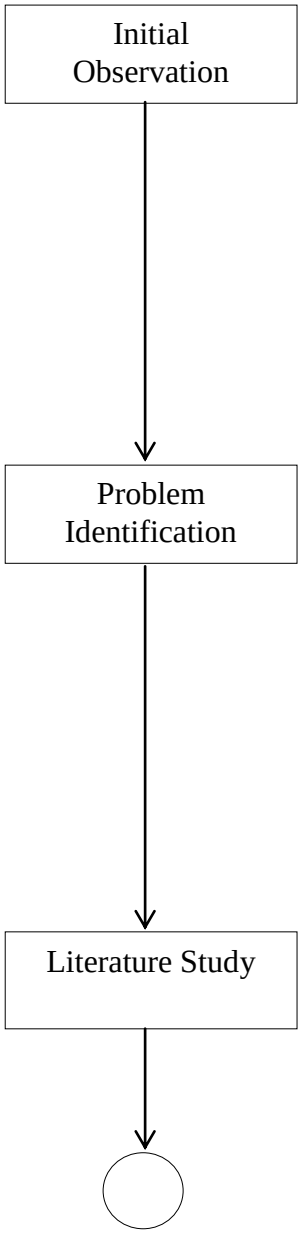
- Schmidt and Launsby (1991) listed major weakness of Taguchi and the One-Factor-At-a-Time (OFAT) are using excessive amounts of resources, results are confines to the factor ranges tested in the experiment, and offer no efficient.

Lucas (1994) pointed that RSM could produce Taguchi analyses. RSM design was more efficient and economical than Taguchi's Inner and Outer Arrays. Lawson and Madrigal (1994) also pointed out the same thing. RSM models were as proficient in improving the relationship between info configuration variables and result execution trademark as other enhancing methods, for example, nonlinear enhancement, dynamic programming, and Monte Carlo reenactment. Moreover, Taguchi's technique is absence of arrangement for looking at decency of-fit.

Other thing that important in RSM is response surface properties and features such as orthogonality, rotatability, and uniformity. Orthogonality is a property that allows individual effects of the k-factors to be estimated independently without or with minimal confounding. Minimum estimation of the variance is provided from the model which means that they are not related with each other. Orthogonality in order two is more complex because of the individuals. Individuals affect also known as orthogonal polynomial terms. Property that allows rotating point about the center of the factors is also called as Rotatability. It is happen when the distribution are constant. Response Y(x) or the variance of the predicted response is equidistant. The variance of contours is a concentric circle for k equals to two dimensions, concentric spheres if k is 3 dimensions, and concentric hyperspheres for k more than 4. Uniformity is also important. It means that (Y) as the response is approximately equal with the estimated response. Uniformity helps to protect against biased regression coefficients.

CHAPTER III
RESEARCH METHODOLOGY

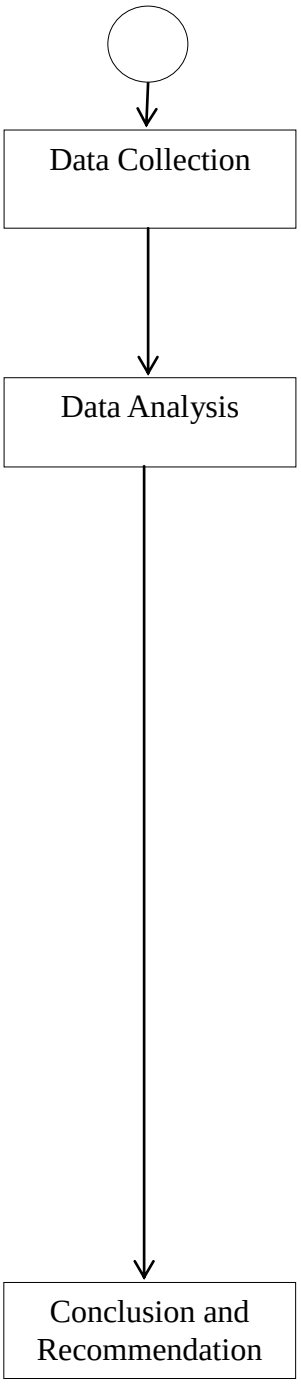
This chapter contains the framework of the research procedures that used to solve the problems. A qualitative and quantitative method was used to obtain the objectives of this research. Research flowchart is mentioned below to guide the researcher find the objectives of the problems. Research framework and explanations will be discussed below as the guidelines of the research.



1. Initial Observation
   - Initial Observation on production system at PT. XYZ
   - Initial Observation on defects and factors related at PT. XYZ
   - Initial Observation on parameter of the seed composition at PT. XYZ
2. Problem Identification
   - Identify background and problem solving. Problem that will be discussed in this research is related to Pairwise Comparison and Design of Experiments (DOE)
   - Determine objectives, scopes, limitations, and recommendations

3 Literature Study
   - Searching for literature references such as books, journal, websites, and researches paper that related to quality management, design of experiment, pairwise comparison, and response surface method

Figure 3.1 Research Methodology of The Research



4. Data Collection
    - Collect the required data needed of factors related with thread production from August - October 2016
    - Collect the required data of defects from production department, especially in thread making

5. Data Analysis
    - Perform the pairwise comparison to find out factors that really giving impact with thread production and analyze the comparison to get the final objective which is to know the rank of the factors that related with thread production and the defects
    - Perform the Response Surface Method (RSM) to find the optimum solution of the plastic seed's composition and analyze the RSM
    - Analyze the impact of implementing RSM to decrease the defects in order to maximizing the thread production

6. Conclusion and Recommendation
    - Conclusion of the research answering the objectives based on calculation
    - Recommendation for further research

Figure 3.1 Research Methodology of The Research (Cont'd)

3.1 Initial Observation

Initial observation must be done to begin the research. There are three main initial observations from PT. XYZ, which are initial observation on production system, defects and factors related, and parameter of seed composition. Reducing defects is one of the ways in order to optimizing the thread production. The observation is conducted from August to October 2016.Observation was used to observe the system and to identify problems occurred. In this case, PT. XYZ still needs to decrease their production defects to make it optimum and it automatically will decrease the production cost.

3.2 Problem Identification

The purpose of problem identification is to identify the problem occurred in this research and to explain the problem briefly. Problem identification is also determined and discussed the objective, scope, and assumptions for the research. There are several problems that need to be solved in this research, which are:

- What are the factors that occurred in plastic thread production, and which of them that really affect the production process and causing defects?
- What is the right parameter of the plastic seed composition?

Besides that, there are also some objectives that need to be achieved in this research, such as:

- To know the factors that affect the thread production and which factors affecting the most
- To find the right amount of each seeds needed in the mixtures to decrease the number of defects

The observation is conducted form September – December 2016, while the defects data is observed from August – October 2016. Limitation or scope, and assumptions also made to conduct the research.

3.3 Literature Study

Literature study is used as the basic theoretical to conduct this research. It explained briefly the method that will be used for solving this research. The literature study is collected from books, journals, and other sources. Everything

related to the problems are clearly described. The literature studies in this research consist of Quality Management, Production Process, Pairwise Comparison, Design of Experiment, and Response Surface Method.

3.4 Data Collection

Data is collected to support the analysis to solve the problem. Several data must be collected to conduct the research and analyses which are:

- Data of Factors related with thread production
- Data of Defects

3.5Data Calculation

After collecting the data needed to conduct the research, researcher should calculate the data. Below is the step to calculate the data.

- Perform the Pairwise Comparison and analysis to know the rank of the factors related with the thread production
- Perform the Response Surface Method (RSM) and analysis to find the best seed composition to reduce defects in order to optimizing the thread production
- Perform the defect comparison from before and after improvement
- Perform the cost comparison from before and after improvement

3.6 Data Analysis

After calculating the data, next step to be done is data analysis. It explained each step or activities in very detailed, starting from the analysis until the problem solved. There are some analysis for this research which are analysis of the Pairwise Comparison for determined the rank of the factor related with the defects of thread production, analysis of Response Surface Method to find the best seed composition, analyze defects before and after, analyze cost before and after, and analyze the impact of implementing Response Surface Method.

3.7 Conclusion and Recommendation

The final step of this research is to give the conclusion and recommendation for further research. It will conclude how Pairwise Comparison can give the most

affected factors for the production and how Response Surface Method (RSM) can decrease the number of defects and minimize the raw material's cost by showing the best parameter of seed composition. In other words, conclusion will be given to answer the objectives stated. Recommendation will also give for further researches to optimize the thread production.

3.8 Detailed Research Frameworks

Figure 3.2 below shows the breakdown of the detailed research framework starting from the beginning to the end of the research. Every step, data collected, calculation, analysis, and conclusion and recommendation will be mentioned and clearly defined below.

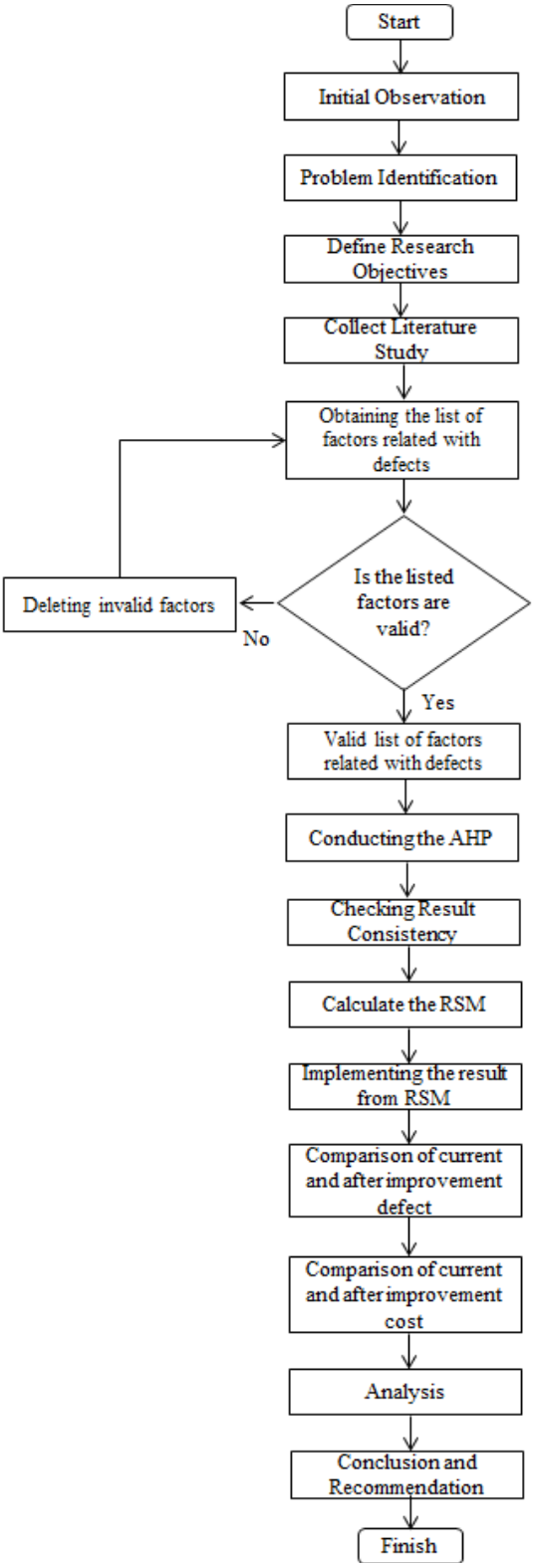


Figure 3.2 Detail Framework of The Research

3.8.1Define Problem

Define problem are consist of initial observation, problem identification, define research objectives, collect literature study, and define the research methodology as a form of theoretical frameworks of the research. Initial observations for this research are conducted on September to December 2016. This initial observation can be done by observing the thread production area and find out what problem might occur in that area. After the initial observation, problem should be identified. The problem that occurs in this research is related with defects. Objectives of the research should be defined in order to finish the research. The objectives of this research is optimizing the thread production by decreasing defects that caused by several factors in the production line. Last step to do in define problem is to collect the literature study regarding the objectives. Literature study can be collected from journals, books, and other scientific source.

3.8.2 Data Collection

Data that need to be collected for conduct the research are data of factors related with the thread production, and data of the defects or rejected thread. Some review and data from experts are also collected to maximize the research in order to optimize the production. Supporting data also needed to conduct the research, such as:

- Data of rejected items that already classified based on the factor affecting
- Factors related with thread production
- The minimum and the maximize set up of the machine (temperature and knife's width)
- Data of the seed's composition that currently used

3.8.3 Data Calculation

After all the data needed is collected, next step to do is calculating the data. First of all, factors that related on thread production should be rank to know which factor is affecting the most by using pairwise comparison method. The weight of each factor is weighted by the statement from the experts. After get the result from the pairwise analysis, check it whether the result is consistent or not by

conduct the consistency test. The result from the pairwise comparison will be used to conduct the Response Surface. Minitab is used to help conducting the calculation and design for the RSM. Before conducting the design, the data of the response from the experiment should be collected completely. Finally, the design surface can be made.

3.8.4 Data Analysis

Done with the calculation, next step to do is analyze. All the result from the calculation must be analyzed and compared with the current system. The comparison for current and after implementing the new system must be analyzed to see the difference between both of them. Last step is to calculate the cost for current and after improvement from the defects.

3.8.5 Conclusion and Recommendations

Conclusions are made to answer the objectives that have been stated before in the beginning of the research. The conclusion given will conclude all the important things form the research. Recommendations for further research will also be given, since there are scope and limitations in this research.

CHAPTER IV
DATA COLLECTION AND ANALYSIS

4.1 Data Collection

Data and information are gathered together to conduct the research for this report. The data that has been collected such as rejected or defects data and cost data will be described below.

4.1.1 Company Overview

PT. XYZ was built in 2002 and located in Karawang. This company produces inner plastic and plastic woven bags. Each month, PT. XYZ can produce around 2,500,000 sheets of woven bag with 34 machines, and around 750,000 sheets of inner plastic. The Vision of PT. XYZ is “Safe and Trusted”. While their missions are:

- Producing plastic woven bag based on the standard
- Delivering products on time in good packaging

PT. XYZ is operating in plastic manufacturing industries especially in plastic woven bag and inner for industries used. It manufactures several sizes of products with several functions, for example:

- Woven Bag for sugar industries
- Woven Bag for fertilizer
- Woven Bag for rice
- Woven Bag for other packaging

This company puts high attention on their quality because they supply local industries that do export and import, and one of the customers itself is the Government.

This research will discuss a problem that occurred in plastic thread production. PT. XYZ wants to optimize their production by decreasing defects of the thread production. By doing so, hopefully the firm can compete well with others firm.

4.1.2 Pairwise Comparison for Determining Factors Related with Defects

The pairwise comparison is conduct to find the most affecting factors of plastic thread production due to optimize the production process by decreasing the defects. Before conducting the calculation, data needs to be collected. To get the weight of the factors related with defects, some questions were asked to the experts. There were 2 experts in plastic thread production which are Mr. D and Mr. N. Both experts are taking charge directly in the plastic thread production to check the quality, defects, and any other problem that occurred during the production. List of the questions and answers from the interview of both experts are listed in the **Table 4.1** below.

Table 4.1 Table of Questions and Answers

Questions	Mr. D's Answer	Mr. N's Answer
What are 3 factors that related to plastic thread production?	- Materials composition - Temperature - Knife's Width	- Materials composition - Temperature - pH
How important is materials composition due to temperature?	Materials composition is very important or extremely important due to temperature	Materials composition is very important or extremely important due to temperature
How important is materials composition due to knife's width?	Materials composition is very important or extremely important due to knife's width	Materials composition is very important or extremely important due to knife's width
How important is materials composition due to pH?	It is important, but not too extremely important.	The important scale is not too high, but still very important or strong
How important is temperature due to knife's width?	Temperature is a bit equals but a little bit more than that.	It is below moderate, both of them are most equals.

Table 4.1 Table of Questions and Answers (Cont'd)

Questions	Mr. D's Answer	Mr. N's Answer
How important is temperature due to pH?	It is moderate. A bit important.	Moderate is the best answer.
How important is knife's width due to pH?	It is same with how important temperature due to knife's width	Little bit more than equal

Table 4.1 shows the result of question and answer conducted in this research. It can be seen that there are two respondents, which are Mr. D and Mr. N. There are five questions in the question and answer and each question is answered by both respondents. In conclusion of the table above, the factors that related in the process making of plastic thread are:

- Knife's width
- Temperature
- Plastic Seed Composition / Materials Compositions
- pH

Based on the discussion, here are the judgments collected, and agreed by both experts:

- Materials Compositions is 9 times as important as temperature
- Materials Compositions is 9 times as important as knife's width
- Materials Compositions is 8 time as important as pH
- Temperature is 2 times as important as knife's width
- Temperature is 3 times as important as pH
- Knife's width is 2 times as important as pH

Noted that,

1 = equal

3 = moderate

5 = strong

7 = very strong

9 = extreme

Table 4.2 Table of Matrix

	Materials Compositions	Temperature	Knife's Width	pH
Materials Compositions	1	9	9	8
Temperature	1/9	1	2	3
Knife's Width	1/9	1/2	1	2
pH	1/8	1/3	1/2	1

Table 4.2 shows the matrix from the judgments collected. Can be seen that there are four factors related in the process of making plastic thread, namely material compositions, temperature, knife's width, and pH. The weight for each factor is agreed based on the discussion with the experts, as explained above. After conduct the matrix, the next step to do is convert it to decimals such as follows.

Table 4.3 Table of Decimals Matrix

	Materials Compositions	Temperature	Knife's Width	pH
Materials Compositions	1	9	9	8
Temperature	0.111	1	2	3
Knife's Width	0.111	0.500	1	2
pH	0.125	0.333	0.500	1

Table 4.3 shows the decimals matrix that has been converted from fraction. Can be seen from the table above that there are four factors in the matrix which are materials compositions, temperature, knife's width, and pH. The decimals are obtained after converting the fractions into decimals. For example, 1/9 is equal to 0.111, ½ is equal to 0.500 and so on. After the number is converted into decimals, next step to do is sum up the matrix and conduct the normalization. The result can be seen in the **Table 4.4** below.

Table 4.4 Table of Calculated Matrix

	Materials Compositions	Tempera -ture	Knife's Width	pH	Sum	Priority Factors
Materials Compositions	1.000	9.000	9.000	8.000	27.000	0.698
Temperature	0.111	1.000	2.000	3.000	6.111	0.158
Knife's Width	0.111	0.500	1.000	2.000	3.611	0.093
pH	0.125	0.333	0.500	1.000	1.958	0.051
Sum	1.347	10.833	12.500	14.000	38.681	1.000

Table 4.4 shows the normalization for all aspects. The values of normalization are obtained from the normality test conducted in Minitab. From the normalization, the factor with the highest rank can be determined. Normalization for material's composition is 0.698, temperature is 0.158, knife's width is 0.093, and pH is 0.051. It is concluded that the highest score was obtained from material's composition and it means that material's compositions give a very high effect with the production of the plastic thread. Therefore, priority factor is calculated from sum of row divided with total sum of row.

Table 4.5 Consistency Test

Matrix Calculation	Matrix Calculation / Priority	λ	CI	RI	CR
3.365	4.821	4.226	0.075	0.99	0.076
0.5741	3.634				
0.3511	3.762				
0.2372	4.686				

Table 4.5 above shows the matrix calculation, matrix calculation per priority, lambda, Confidence Interval (CI), Random Consistency Index (RI), and Consistency Ratio (CR). It shows that the matrix calculation for material compositions is 3.365, for temperature is 0.5741, for knife's width is 0.3511, and the last one for pH is 0.2372. The second column of the table is matrix calculation divided with the priority factor that has been calculated before. As it is mentioned

above, the result for materials composition is 4.821, temperature is 3.634, knife's width is 3.762, and pH is 4.686. Moving to the next column is lambda. The value in lambda column is the average of the matrix calculation over priority. The formula for confidence interval (CI) is lambda minus n-factors over n-factors-1. And the result for this calculation is 0.075. Next column which is random consistency index (RI) have the value of 0.99 from dividing 1.98 times n-factor minus 2 with n-factors which is 4. Last column is CR or consistency ratio. It determines whether the calculation is consistent or not. The formula for CR is CI divided by RI. If the value is below 0.1, it means that the calculation is consistent and valid. In this calculation, the result is 0.076, which means the data are consistent and valid for further research. Because the 1st rank from the pairwise comparison above is materials composition, the next research will be focusing only for the defects that caused by materials composition. Other three factors will not be used anymore in further calculation.

4.1.3 Rejected Plastic Thread

To conduct the experimental design, a complete data are needed. **Table 4.6** below will show the number of defects on every shift in 3 months starting from August 2016. There are 2 shifts per day with defects of 10% from every shift. The current seed composition used is 75% PP + 15% Calcium + 10% Recycle. In a month, the average of the production is 108.000 kg, with around 10.800 kg in a day (2 shifts).

Table 4.6 Defects Table from seed composition in August 2016

Day	Defects from Shift 1 (kg)	Defects from Shift 2 (kg)
1	180	170
2	183	165
3	185	166
4	182	168
5	180	171
6	175	173

Table 4.6 Defects Table from seed composition in August 2016 (Cont'd)

Day	Defects from Shift 1 (kg)	Defects from Shift 2 (kg)
7	177	175
8	173	177
9	174	175
10	170	180
11	171	185
12	169	188
13	172	185
14	175	183
15	178	179
16	183	189
17	180	193
18	180	195
19	185	187
20	190	192
21	191	194
22	192	190
23	195	185
24	193	179
25	190	175
26	186	170
27	183	166
28	179	173
29	184	174
30	180	169
Sum	**5435**	**5371**

From **Table 4.6** above, shown that the total defect from the first shift is 5435 kg and 5371 kg from the second shift. In total, there are 10.806 kg defects of plastic thread in a month with 30 working days. In shift 1, the lowest defect is on day 12 which are 169 kg and the highest defect is on day 23 which are 195 kg. While from shift 2, the lowest defect is on day 2 which are 165 kg, and the highest defect is on day 28 which are 195 kg of defects. The next table will show the defects data on September 2017.

Table 4.7 Defects Table from seed composition in September 2016

Day	Defects from Shift 1 (kg)	Defects from Shift 2 (kg)
1	171	177
2	173	165
3	177	170
4	180	173
5	183	175
6	185	180
7	180	179
8	183	172
9	179	174
10	176	175
11	174	180
12	170	184
13	166	185
14	160	187
15	162	183
16	167	186
17	171	188
18	175	190
19	173	193
20	177	197
21	184	192
22	190	189
23	193	181

Table 4.7 Defects Table from seed composition in September 2016 (Cont'd)

Day	Defects from Shift 1 (kg)	Defects from Shift 2 (kg)
24	191	174
25	190	177
26	184	172
27	180	180
28	183	181
29	187	179
30	194	171
Sum	**5358**	**5409**

The data on **Table 4.7** shows the defects of plastic thread in September 2016, with the total defects of 10.767 kg. There are 5358 kg of defects from the first shift and 5409 kg from the second shift. The lowest and the highest defect on the first shift is 160 kg on day 14 and 194 kg on day 30. For the second shift, the lowest and the highest defect is on day 3 and 20 which are 170 kg and 197 kg. The range of the kilos might be different with the previous month or the following month.

Table 4.8 Defects Table from seed composition in October 2016

Day	Defects from Shift 1 (kg)	Defects from Shift 2 (kg)
1	160	173
2	158	180
3	168	185
4	174	183
5	172	188
6	180	190
7	184	192
8	185	187
9	181	185
10	176	180

Table 4.8 Defects Table from seed composition in October 2016 (Cont'd)

Day	Defects from Shift 1 (kg)	Defects from Shift 2 (kg)
11	169	183
12	168	176
13	173	173
14	171	177
15	174	171
16	179	170
17	184	163
18	190	168
19	184	166
20	179	172
21	175	177
22	175	173
23	179	179
24	177	183
25	184	189
26	185	193
27	181	188
28	189	183
29	182	177
30	188	173
Sum	**5324**	**5377**

Based on **Table 4.8** above, the total defects from shift 1 and 2 are 5324 kg and 5377 kg. Compare to August and September, October has the lowest number of total defect which is 10701 kg. Day 2 and day 18 is the lowest and the highest defects from shift 1 which are 158 kg and 190 kg. While day 17 and 26 is the lowest and highest defects from the second shift which are 163 kg and 193 kg. From August to September, the number of defects was decreased from 10806 kg to 10767 kg. There are 39 kg of differences and from September to October, there

are 66 kg of differences. These decreasing number might affected by the performance of the worker and problems occurred on the machine or any other related problem that might affect the plastic thread production.

4.1.4 Response Surface Method

Before conducting the response surface, experiments are needed. Below is the figure of a table of each seed composition (in percentage) and the defect response from its composition (in percentage). From the **Figure 4.1**, shows that the smallest number in PP column is 54.8866 and the highest number is 80.1134. In Calcium and Recycle column, both the lowest value is 4.8866 and the highest value is 30.1134. The result or the response of the experiment shows that the lowest percentage of defect which is 4% is came from 80.1% + 17.5% + 17.5% composition. While the highest percentage of defect which is 40% that came from 60% + 25% + 25%. The combination for the experiments below are given by the software by fillling the factor of 3, 4 for the levels, with the high and low of factor 1 is 75 and 60, for factor 2 is 25 and 10, and last factor is 25 and 10. . The factors are PP, Calcium , and Recycle. While the level for PP is 60,65,70, and 75. And for both Calcium and Recycle is 10, 15, 20, and 25.

↓	C23	C24	C25	C26	C27	C28	C29	C30
	StdOrder	RunOrder	PtType	Blocks	PP	Calsium	Recycle	Response
1	10	1	-1	1	80.1134	17.5000	17.5000	4
2	6	2	1	1	75.0000	10.0000	25.0000	13
3	12	3	-1	1	67.5000	30.1134	17.5000	33
4	14	4	-1	1	67.5000	17.5000	30.1134	28
5	17	5	0	1	67.5000	17.5000	17.5000	24
6	2	6	1	1	75.0000	10.0000	10.0000	13
7	4	7	1	1	75.0000	25.0000	10.0000	13
8	16	8	0	1	67.5000	17.5000	17.5000	24
9	13	9	-1	1	67.5000	17.5000	4.8866	15
10	7	10	1	1	60.0000	25.0000	25.0000	40
11	19	11	0	1	67.5000	17.5000	17.5000	24
12	20	12	0	1	67.5000	17.5000	17.5000	24
13	9	13	-1	1	54.8866	17.5000	17.5000	30
14	11	14	-1	1	67.5000	4.8866	17.5000	22
15	15	15	0	1	67.5000	17.5000	17.5000	24
16	1	16	1	1	60.0000	10.0000	10.0000	18
17	3	17	1	1	60.0000	25.0000	10.0000	27
18	5	18	1	1	60.0000	10.0000	25.0000	30
19	8	19	1	1	75.0000	25.0000	25.0000	20
20	18	20	0	1	67.5000	17.5000	17.5000	24

Figure 4.1 Response Defect Table

Based on **Fig. 4.1**, there are 6 same combinations or repetitions from composition 67.5% PP + 17.5% Calcium + 17.5% Recycle. However, the response from all 6 repetitions is same. Other than that, there are no similar compositions.

After completing the data of response, the next step is to analyze the ANOVA. **Fig. 4.2** shows that the analysis of variance has determined significance of each factor. There are 3 models which are linear, square, and 2-way interaction. All factors which are PP, Calcium, and Recycle have the significant P-Value.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	9	1282.62	142.513	223.38	0.000
Linear	3	1085.67	361.891	567.24	0.000
PP	1	728.23	728.235	1141.46	0.000
Calsium	1	145.00	144.999	227.28	0.000
Recycle	1	212.44	212.440	332.99	0.000
Square	3	130.45	43.482	68.16	0.000
PP*PP	1	90.22	90.217	141.41	0.000
Calsium*Calsium	1	21.11	21.109	33.09	0.000
Recycle*Recycle	1	11.96	11.961	18.75	0.001
2-Way Interaction	3	66.50	22.167	34.74	0.000
PP*Calsium	1	18.00	18.000	28.21	0.000
PP*Recycle	1	40.50	40.500	63.48	0.000
Calsium*Recycle	1	8.00	8.000	12.54	0.005
Error	10	6.38	0.638		
Lack-of-Fit	5	6.38	1.276	*	*
Pure Error	5	0.00	0.000		
Total	19	1289.00			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.798739	99.51%	99.06%	95.69%

Figure 4.2 Analysis of Variance

Can be seen on the figure above, that there are five columns shown which are Degree of Freedom (DF), Adjusted Sum of Squares (Adj SS), Adjusted Mean Square (Adj MS), F-Value, and p-Value. Adjusted sum of squares are measures of variation for different components of the model, while adjusted mean squares measure how much variation a term or a model explains. Most of the factor's p-Value is 0.000 except Recycle*Recycle and Calcium*Recycle which are 0.001 and 0.005. However, the p-Value is acceptable. The analysis reveals that they are statistically significant for the optimization. R^2 is close to 1 and 99.51% of total

variations can be identified by the model. R^2 (pred) is also compatible with R^2 and R^2 (adj).

Figure 4.3 shows the response surface regressions of the model. There are Effect, Coefficient, Standard of Error (SE) coefficient, T-Value, P-Value, and Variance Inflation Factor (VIF) for all factors related. The formula to calculate the response is also mention.

Coded Coefficients

Term	Effect	Coef	SE Coef	T-Value	P-Value	VIF
Constant		24.004	0.326	73.69	0.000	
PP	-24.562	-12.281	0.363	-33.79	0.000	1.00
Calsium	10.960	5.480	0.363	15.08	0.000	1.00
Recycle	13.266	6.633	0.363	18.25	0.000	1.00
PP*PP	-14.154	-7.077	0.595	-11.89	0.000	1.02
Calsium*Calsium	6.846	3.423	0.595	5.75	0.000	1.02
Recycle*Recycle	-5.154	-2.577	0.595	-4.33	0.001	1.02
PP*Calsium	-8.485	-4.243	0.799	-5.31	0.000	1.00
PP*Recycle	-12.728	-6.364	0.799	-7.97	0.000	1.00
Calsium*Recycle	5.657	2.828	0.799	3.54	0.005	1.00

Regression Equation in Uncoded Units

Response = -201.4 + 6.198 PP + 1.170 Calsium + 3.482 Recycle - 0.04448 PP*PP
+ 0.02152 Calsium*Calsium - 0.01620 Recycle*Recycle - 0.02667 PP*Calsium
- 0.04000 PP*Recycle + 0.01778 Calsium*Recycle

Fits and Diagnostics for Unusual Observations

Obs	Response	Fit	Resid	Std Resid	
6	13.000	12.047	0.953	2.08	R
10	40.000	41.056	-1.056	-2.30	R
16	18.000	19.151	-1.151	-2.51	R
19	20.000	18.952	1.048	2.28	R

Figure 4.3 Response Surface Regressions

In this calculation,

Response = -201.4 + 6.198 PP + 1.170 Calcium + 3.482 Recycle – 0.04448 PP*PP + 0.02152 Cal*Cal – 0.01620 Recy*Recy – 0.2667 PP*Cal – 0.04000 PP*Recy + 0.01778 Cal*Recy

Below is the figure of residual plots for response. Data normality has been tested by means of normal probability plot. Normal probability plot of residuals are used to verify the assumption that the residuals are normally distributed and the plot of residuals should follow the straight line given.

Based on **Fig 4.4** below, there are four different types of residuals plot of response which are normal probability plot, residual fitted values, histogram of the residuals and residuals versus order of data. According to the residual plots and estimated regression coefficients, the whole parameters and their interactions are significant for the model because the p-Value are quite similar and smaller against 0.05.

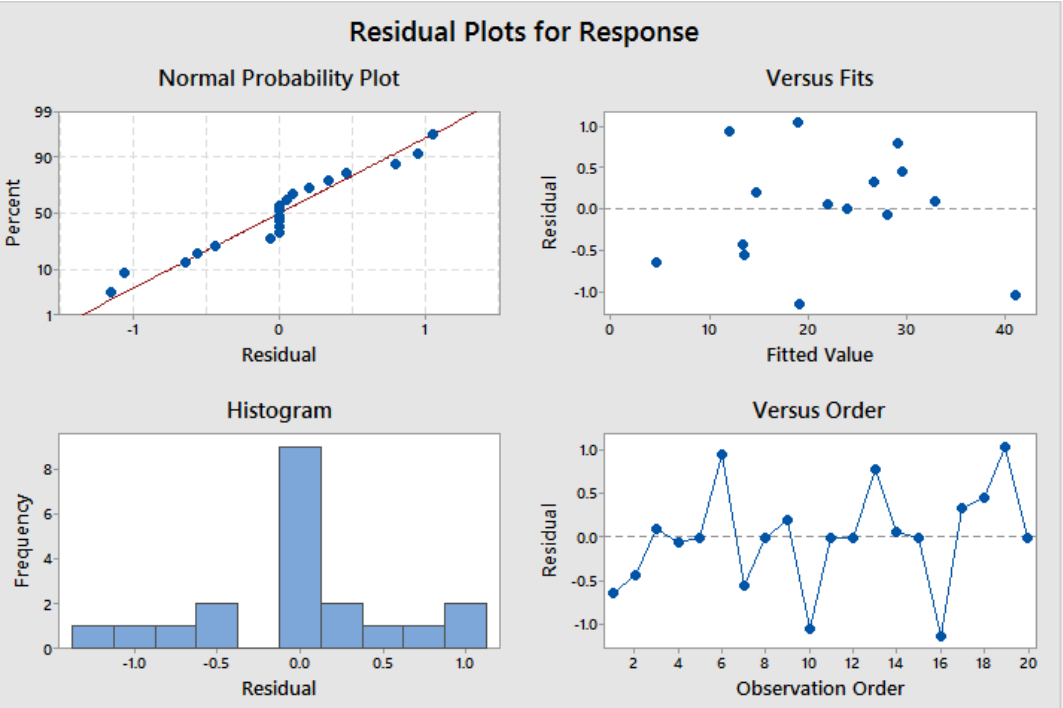


Figure 4.4 Residual Plots for Response

Figure above shows that the residuals plot nearly to the straight line and some of them are on the straight line in the normal probability plot. Residual versus fits graph plots the residuals on the y-axis and the fitted values on the x-axis. This graph is used to verify the assumptions that the residuals are randomly distributed and have constant variance. Normally, the ideal plots should fall randomly on both sides of 0 with no patterns on it.The histogram of the residuals indicates the distributions of the residuals for all observation. Histogram is effectively used for 20 or more data points. On residuals versus order graph, shown that thee residuals are independent from one another. The used of versus order graph is to verify it. If no patterns are shown on the graph, that means the residual are independent. Normally, the residual plots should fall on the center line.

Fig. 4.5below shows the contour plot of response (in percentage) with Calcium and PP and hold values of 17.5% Recycle. Mentioned in the small box on the figure, the lightest the color of the response, the lowest the defect produced. The range for the Calcium is 5 to 30 while PP is 55 to 80. Contour plot of Response can be seen below.

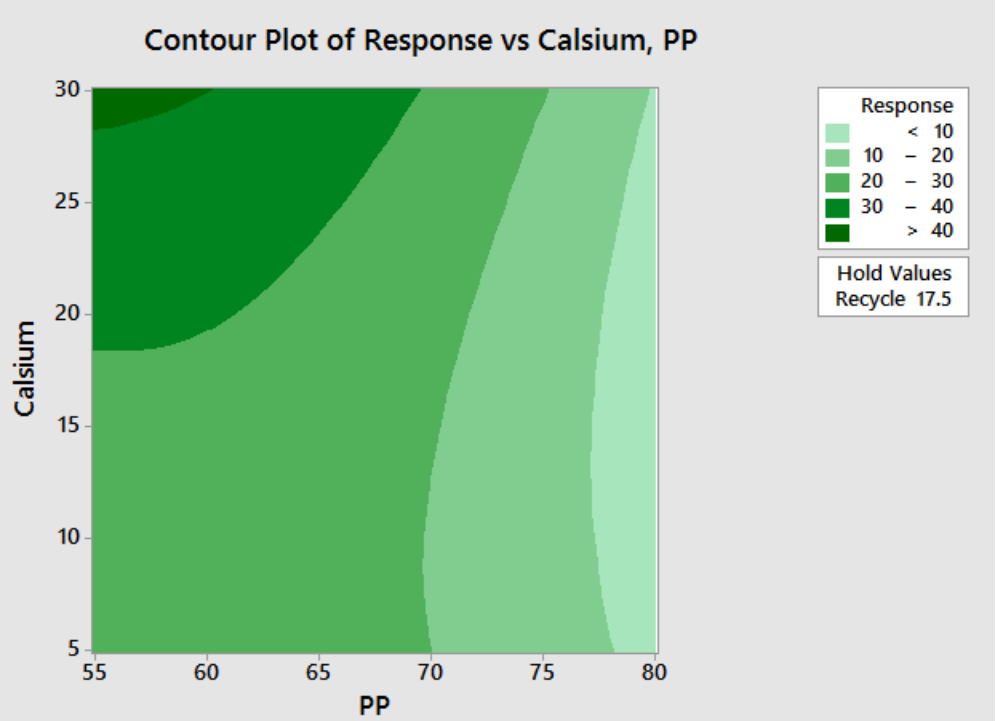


Figure 4.5 Contour Plot of Response vs Calcium, PP

There are five classifications based on the response on **Fig. 4.5** which are below 10% with the lightest green as the color, 10% to 20% response with a not-so-light green, 20% to 30% response with medium green, 30% to 40% response with dark green, and last is for more than 40 with the darkest green.

The lowest response which is under or 10% is located near 80% PP and 30% Calcium. It means that the area is nearly optimal. The 10% to 20% defects located in 70% to 78% PP and 30% Calcium. The response 0f 20% to 30% defect takes the biggest area of the contour plot starting from 55% to 70% PP and 18% to 30% Calcium. The rest of the contour plot shows the response of 30% to more than 40%.

Fig. 4.6 below shows the contour plot of response (in percentage) with Recycle and PP and hold values of 17.5% Calcium. Mentioned in the small box on the figure, the lightest the color of the response, the lowest the defect produced, same like the previous contour plot. The range for the Recycle seed is 5% to 30% while PP seed is 55% to 80%. Contour plot of Response versus recycle and PP can be seen below.

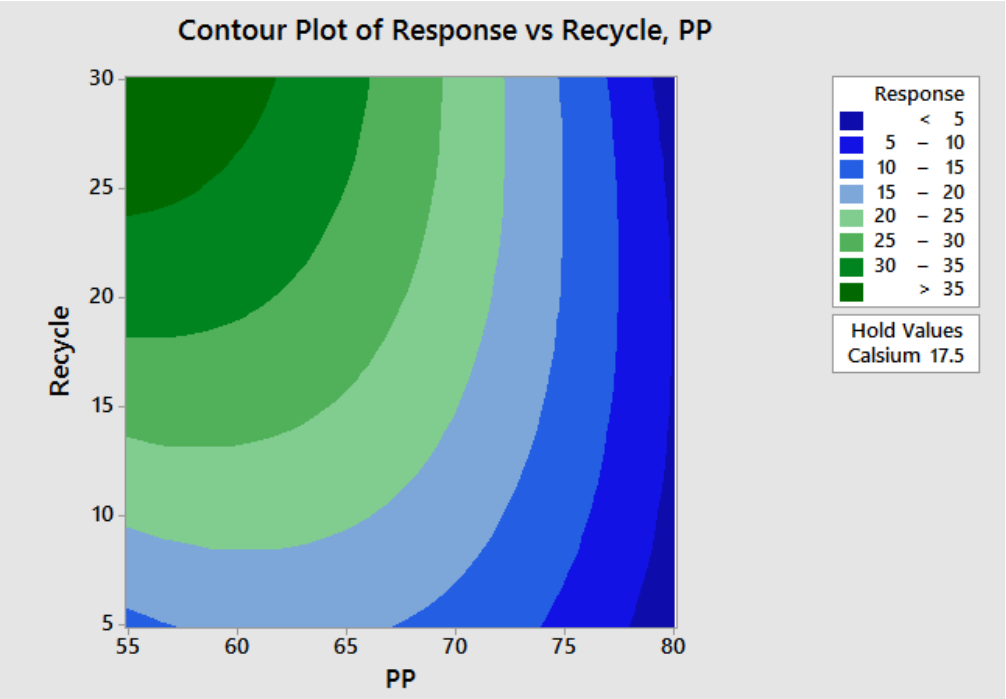


Figure 4.6 Contour Plot of Response vs Recycle, PP

Figure 4.6 above shows the contour plot of response with recycle and PP and hold values 17.5% of Calcium. Shown in the response box in the figure, there are eight classifications of the response. Response under 5% is located on 75% to 80% PP and 5% to 30% Recycle. This area is the nearest area to the optimum result. Next response is 5% to 10% that located in around 67% to 74% PP and 55% PP in the corner with the same 5% to 30% Recycle. The 15% to 20% defects are located on 6% to 9% Recycle with 55% to 70% PP and 10% to 30% Recycle with 68% to 73% PP. The rest of the area shows highest response until more than 35%.

Fig. 4.6 below shows the contour plot of response (in percentage) with Recycle and Calcium and hold values of 67.5% PP. Mentioned in the small box on the figure, the lightest the color of the response, the lowest the defect produced, same like the previous contour plot. The range for both Calcium and Recycle seed is 5% to 30%. Contour plot of Response versus recycle and calcium can be seen below.

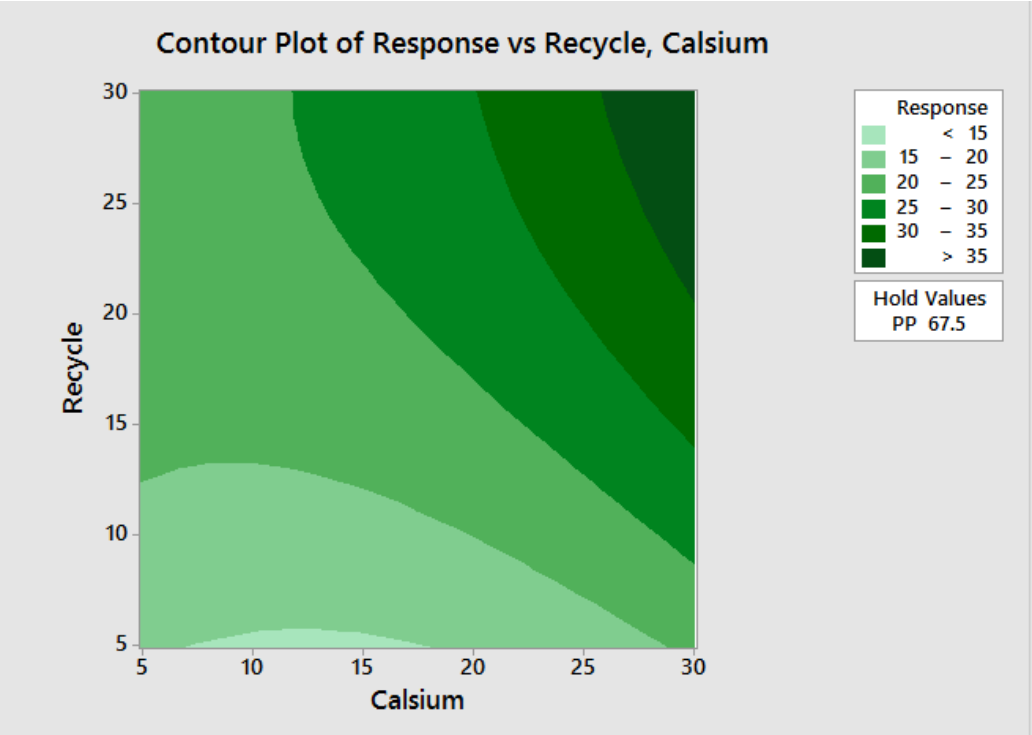


Figure 4.7 Contour Plot of Response vs Recycle, Calcium

The contour plot of response with Recycle and Calcium, with hold values of PP 67.5% is shown in **Fig 4.7** above. There are 6 classifications of response which are under 15%, 15% to 20%, 20% to 25%, 25% to 30%, 30% to 35%, and more than 35%. The area located on 7% to 18% Calcium and 5% Recycle shows nearly to the optimal result. While the area located in 30% Calcium and 20% to 30% Recycle shows the highest number of response.

After conducting the contour plot of PP-Calcium, PP-Recycle, and Calcium-Recycle, below is the surface plots of response from all of them.

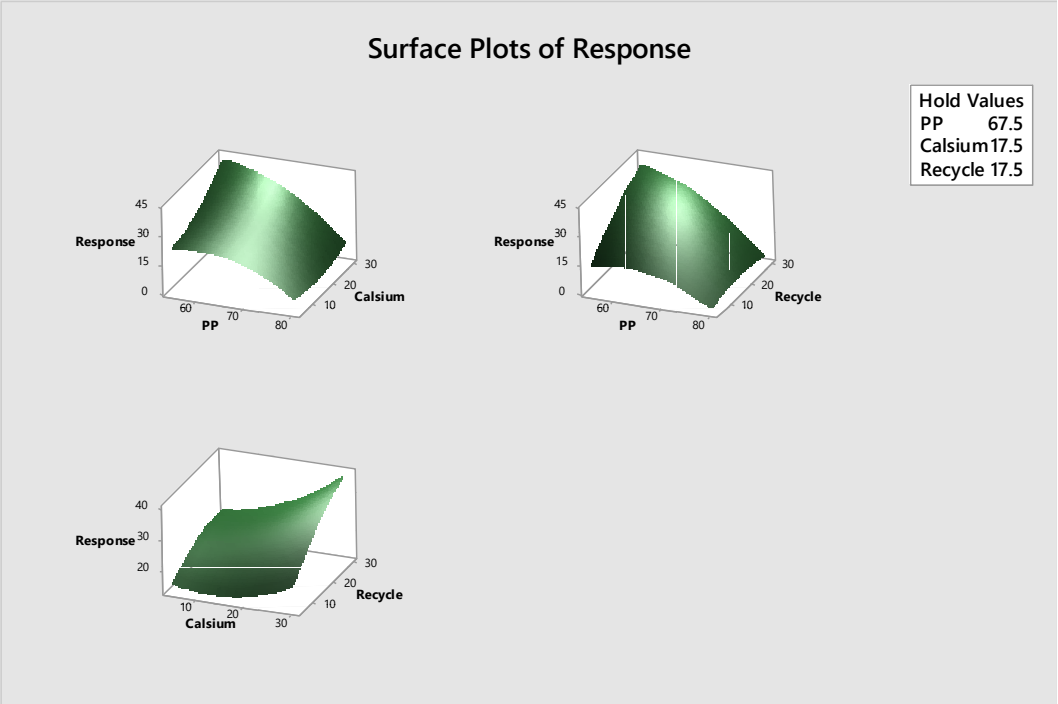


Figure 4.8 Surface Plots of Response

Shown in **Fig. 4.8** that all of them has a different surface plots with hold values of PP 67.5%, Calcium 17.5%, and Recycle 17.5%. Starting from PP with Calcium response, the higher the PP and the higher the Calcium, the response will be high too. As it is shown on the picture, that the surface is raising to nearly 45% responses. While the lower the PP and the lower the Calcium, the reponse will be low also. On 80% PP and under 10% Calcium, the surface plots is going closer to the bottom. Next surface plots is the response with PP and Recycle. The lowest PP and the highest Recycle leaeds to a high response. High number of Recycle and high number of PP leads to a low response. It shows on the surface plots that the surface is going down. The last surface plot shows the relations between the response with Calcium and Recycle. Based on the surface plot, the more the calcium and the more Recycle leads to a high surface which means high response. But low number of calcium and low number of recycle leads to a small number of response.

4.1.5 Optimization Solution

After conducting the response surface with the data collected, the next step to do is to find the optimum solution which is to minimum the defects. The response optimization is generated using Minitab in the folowing figure. The parameters and the soultions given is clearly stated below.

Parameters

Response	Goal	Lower	Target	Upper	Weight	Importance
Response	Minimum		3	40	1	1

Solution

Solution	PP	Calsium	Recycle	Response Fit	Composite Desirability
1	80.1134	9.98290	30.1134	1.13146	1

Multiple Response Prediction

Variable	Setting
PP	80.1134
Calsium	9.98290
Recycle	30.1134

Response	Fit	SE Fit	95% CI	95% PI
Response	1.13	1.38	(-1.94, 4.20)	(-2.42, 4.68)

Figure 4.9 Response Optimization

From the previous calculation, it is known that the smallest number of response is 4%. In order to optimize the production, can be seen in **Fig 4.9**, the goal is set to minimize the response and the target is set to 3**.** There are three variables such as PP, Calcium, and Recycle seed. The solution from this model is shown that the number of PP should be 80.11%, Calcium 9.98%, and Recycle 30.11%. With this optimum solution, the defects should be under than 4.20%. There are four response given too which are Fit, Standard of error (SE) Fit, 95% Confidence Interval (CI), and 95% Prediction Interval (PI). The smaller the standard error, the more precise the predicted mean response.

This materials composition is proven by the contour plot and surface plot of previous calculation. It is shown that with this new composition, the plot is located on the light area with low response.

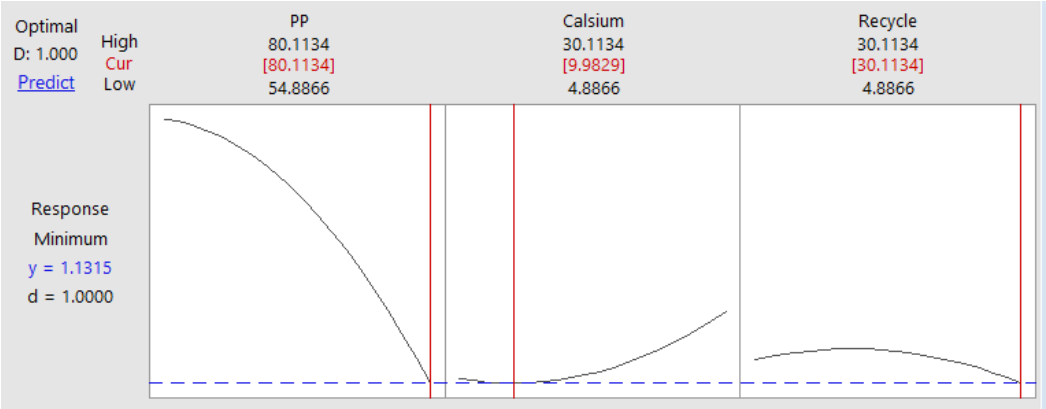


Figure 4.10 Graph of Response Optimization

The graph above on **Fig. 4.10** shows the prediction from the optimum solutions given in the previous section. It shows three level of composition such as high, current, and low. Response optimization helps to identify the perfect combination of variable settings that jointly optimize a single or a set response.

The highest level of the composition is 80% PP, 30% Calcium, and 30% Recycle. While the lowest composition is 54% of PP, 5% of Calcium, and 5% of Recycle. The red line in the graph indicates the positions of the composition.

From the optimum composition that has been predicted before which is PP 80%, Calcium 10%, and Recycle 30%, shows that minimum response from this new composition is 1.1315%. This response is decreasing by 3% from the lowest defect response in the previous calculation.

4.1.6 Cost Calculation

In calculating the cost, the cost that will be defined is only from the seed. Electricity, manpower, and other related aspects are not included. To ease the calculation, the price of each material will clearly defined below.

- PP : Rp. 18.150,- / kg
- Calcium : Rp. 7.800,- / kg
- Recycle : Rp. 14.500,- / kg

The calculation of the cost is following the current composition which is 75% PP + 15% Calcium + 10% Recycle, below is the calculation.

Cost for PP :Rp. 18.150 x 75% = Rp. 13.612,5

Cost for Calcium : Rp. 7.800 x 15% = Rp. 1.170

Cost for Recycle : Rp. 14.500 x 10% = Rp. 1.450

Total : Rp 16.232,5

Then, to get the total cost for a day, times the total with 3600 kg, because each day (consist of 2 shifts) can produce up to 3600 kg. Then the cost each day is Rp. 58.437.000. So, in a month, the total cost from the production is around Rp 1.753.110.000. Because the current defect is 10% from the total production, so the cost for the defects is Rp. 175. 311.000 each month.

From the response optimization in Minitab, it shows that the optimal composition with the target defects of 3% is 80% PP + 10% Calcium + 30% Recycle. So, the calculation for the defect cost is:

Cost for PP : Rp. 18.150 x 80% = Rp. 14.520

Cost for Calcium : Rp. 7.800 x 10% = Rp. 780

Cost for Recycle : Rp. 14.500 x 30% = Rp. 4.350

Total : Rp 19.650

Like the previous calculation, the total should be times with 3600 kg, and the cost is Rp. 740.000.000 each day. So, in 30 days, the total cost for the production is Rp. 2.122.200.000. In this optimization, the defects are decreased from 10% to 3% from the production. So, the 3% from Rp. 2.122.200.000 is Rp. 63.666.000.

As the conclusion of the cost calculation, the cost is decreasing almost 3 times from the current composition.

CHAPTER V
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

It is concluded that the factors related with the production process of plastic thread are material composition, knife's width, temperature, and pH. However, based on the pairwise comparison, materials composition is the most affecting factors. Current seed composition in PT. XYZ proved that it still needs optimization because there high number of defects produced. Based on the research objectives, there are 2 conclusions that can be concluded, such as:

- There are 4 factors related with the plastic thread production which are materials composition, knife's width, temperature, and pH. And the most affecting factors to the defect is materials composition. All of the factors are generate from the pairwise comparison with the help of interviews that conducted with some experts.
- After optimizing the materials composition, the optimum composition with below 4% of defects is 80% PP + 10% Calcium + 30% Recycle is defined by generating Response Surface Method in Minitab. RSM shows the contour and surface plot for current composition and give the optimum solution for decreasing defects.

5.2 Recommendation

There are scope and limitation in this research; therefore recommendations are needed for further research. The recommendation for further research in optimizing plastic thread production, are:

- To have better understandings regarding Response Surface Method
- Better problem solving tool especially to conduct the Response Surface Method, algorithms, and methodology
- Besides Response Surface Method, the next research can use other method to conduct the experiments

While recommendations for the company are:

- Conduct more experiments with different factors
- Update data regularly
- For more accurate cost analysis, would be better for the company to consider the losses caused by delay, manpower, machinery, and other types of cost involved in the production process

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