การปรับปรุงกระบวนการผลิตFused Biconic Taper Coupler โดยใช้แนวทางSix Sigma

นาย สารัช ยมลยง

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต
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PROCESS IMPROVEMENT FOR FUSED BICONIC TAPER COUPLER MANUFACTURING BY USING SIX SIGMA

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A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Engineering Program in Engineering Management
The Regional Centre for Manufacturing System Engineering
Faculty of Engineering
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Thesis Title	PROCESS IMPROVEMENT FOR FUSED BICONIC TAPER COUPLER MANUFACTURING BY USING SIX SIGMA
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Field of Study	Engineering Management
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สารัช ยมลยง : การปรับปรุงการผลิตFused Biconic Taper Coupler โดยใช้แนวทาง SIX SIGMA (PROCESS IMPROVEMENT FOR FUSED BICONIC TAPER COUPLER MANUFACTURING BY USING SIX SIGMA) อ.ที่ปรึกษา: รศ. ดำรงค์ ทวีแสงสกุลไทย , 85 หน้า.

วิทยานิพนธ์นี้มีเนื้อหาเกี่ยวกับการศึกษาการปรับปรุงกระบวนการผลิต Fused Biconic Taper Coupler ซึ่งเป็นอุปกรณ์การแบ่งแสงที่ใช้ในธุรกิจการสื่อสารและการส่งข้อมูลทางแสง มีวัตถุประสงค์เพื่อลดปริมาณของเสียและปรับปรุงกระบวนการผลิตให้มีประสิทธิภาพมากขึ้น ผู้เขียนได้ศึกษาการประยุกต์ใช้แนวทางการปรับปรุง และออกแบบเครื่องมือโดยมุ่งเน้นแนวทางของคุณภาพเป็นหลัก ซึ่งมุ่งหวังจะปรับปรุงกระบวนการที่สามารถลดปัญหาการเกิดของเสียได้อย่างมีประสิทธิภาพ และยังคงรักษาคุณภาพในการผลิตได้สอดคล้องต่อความต้องการของลูกค้า

การวิจัยเริ่มต้นตั้งแต่การหาระบบการวิเคราะห์ปัญหาที่เหมาะสม เพื่อการแก้ไขปัญหาได้อย่างตรงจุดและรวดเร็ว โดยใช้แนวทางการแก้ไขปัญหาแบบ DMAIC ซึ่งเป็นหนึ่งในเครื่องมือการปรับปรุงคุณภาพในแนวทางของซิกซิกม่า จากการศึกษาพบว่ามีของเสียส่วนใหญ่เกิดจากกระบวนการผลิตในขั้นตอนการดึงFiber แต่เมื่อทำการปรับปรุงกระบวนการที่ใช้อยู่ในปัจจุบันแล้วไม่ได้ผลลัพท์ที่พอใจ จึงนำหลักการDMADVเข้ามาใช้เพื่อออกแบบกระบวนการผลิตใหม่ซึ่งคือการออกแบบเครื่องมือในการควบคุมการดึงFiber เครื่องมือการดึงfiberแบบใหม่ได้ถูกนำไปทดลองใช้ในสภาพจริงเพื่อเป็นการประเมินผลโดยใช้การวิเคราะห์เชิงสถิติ รวมถึงตรวจสอบผลกระทบทางด้านลบต่อคุณภาพของชิ้นงาน ที่อาจเกิดขึ้นจากการออกแบบของเครื่องดึงFiber ก่อนจะนำไปใช้งานจริง ตลอดขั้นตอนการดำเนินโครงการผู้เขียนได้นำหลักการการทำงานเป็นทีมโดยมีการประชุมแบบระดมสมองเพื่อค้นหาปัญหาและง่ายต่อการตั้งเป้าหมายและทิศทางในการปฏิบัติงาน

จากผลการศึกษาสามารถสรุปได้ว่าเครื่องมือการดึงFiberสามารถเพิ่ม ประสิทธิภาพในกระบวนการผลิตได้ กล่าวคือช่วยลดเวลาในกระบวนการดึงสายfiber 1-2 วินาทีโดยเฉลี่ย, สามารถประสบความสำเร็จในการลดของเสียที่เกิดจากกระบวนการดึงFiberได้ถึง 94% และมูลค่าของเสียต่อหน่วยของการผลิตจะไม่มีผลกระทบจากการเปลี่ยนวัตถุดิบอีกต่อไป โดยมีประโยชน์ทางอ้อมคือ ช่วยเพิ่มประสิทธิภาพในการควบคุมวัตถุดิบ และ ลดต้นทุนในการผลิต

ศูนย์ระดับภูมิภาคทางวิศวกรรมระบบการผลิต
สาขาวิชา การจัดการทางวิศวกรรม
ปีการศึกษา 2550

ลายมือชื่อนิสิต.....
ลายมือชื่ออาจารย์ที่ปรึกษา .....

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This thesis studied the Fused Biconic Taper Coupler manufacture process. The objective of this studied was to improve process of Fused Biconic Taper Coupler with expected results, 1: Reduce scrap and scrap cost per unit 2. Reduce cycle time.

The study used DMAIC which is one of the improvement models in the Six Sigma methodology to find out the root cause. From the study, Draw process is the root cause that makes scrap cost per unit increase. Following DMAIC model, many implement ways were applied to the current process but the result has still shown the high scrap cost and some implementation may cause the new problem. So, DMADV was chosen to be a model for new process design.

To serve with the requirement of both manufacturing team and customer, the Kano model was used to reference for an exciting quality design. After feeding machine was designed, both technical criteria and the efficiency of the machine were verified by using statistical analysis before implement in the production line. Along this study, Brainstorm and meeting environment also are the other important factor that can make the clarify direction and good project management.

In conclusion, result of this study achieves to reduce scrap of fiber in draw process reach to 94%, reduce average cycle time of draw process about 1-2 second, prevent 100% of scrap cost per unit which occur from the price of material changing, and improve inventory information management.

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Field of study Engineering Management
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Advisor's signature .....

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CHAPTER I
INTRODUCTION

1.1 Background of the Research

Cause the very dynamic market and high competitive in optical industry, every OEM try to be the first brand launching a new product or new technology to serve with the demand in the market. From these trends, the manufacturing service provider will receive the impact such as production plan, sourcing new material, inventory management, production cost and waste from new product introduction (NPI). So, the big question for the manufacturing service provider is How to improve their quality and customer satisfaction while decreasing costs and increasing production efficiency?

At the present, one of the premier choices to improving manufacturing operation or serve with the question as above paragraph is Six Sigma. Six Sigma was defined in many definitions. Tomkins(1997) define Six Sigma as “a program aimed at the near-elimination of defects from every product, process and transaction” Harry (1998) define Six Sigma to be “a strategic initiative to boost profitability, increase market share and improve customer satisfaction through statistical tools that can lead to breakthrough quantum gain in quality”

In 1987, Motorola launch the Six Sigma to be the tools for quality improvement. In1992, Motorola success to implement the Six Sigma in the organization. With in ten year, the result from Six Sigma implementation are reduction in process variation, improvement in labor productivity and cost saving totaled US$ 13 billion (Losianowycz, 1999). From the attractive result, most of the leading electronic companies such as IBM, Texas Instrument and DEC try to use Six Sigma to approach the quality problem.

From the result which show the massive advantage, Six Sigma was launched as strategic initiative which rapid growth not only electronic manufacturing but also every industries all over the world. From the consulting experience, (Park et. Al 1999), “Six

Sigma is a new strategic paradigm of management innovation for company survival in this 21st century, which implies three things: statistical measurement, management strategy and quality culture."

The step of change in last decade is the new phenomena and its speed is very faster than ever before. The organization should learn the way how to survive in the change which focus more on customer oriented information society rather than the old as producer –oriented industry society. Six Sigma is the powerful tool for every organization to counter with the rapid change as today business.

This paper is one of the practices which using the Six Sigma philosophy to be a way to clarify & solve the problem. The main problem –solving process for this project are DMAIC (define, measurement, analysis, improvement and control) According to Six Sigma for quality and productivity promotion, (Park et. Al 1999), "DMAIC process works well as a breakthrough strategy. Six Sigma companies everywhere apply this methodology as it enables real improvements and real results. The methodology works equally well on variation, cycle time, yield, design, and others"

1.2 Company Background

This company is a global engineering and manufacturing services provider (EMS) of complex optical and electro-mechanical components, modules and bulk optics serving data communications, telecom, networking, medical and automotive markets worldwide.

The company began operations in January, 2000 by acquiring a 232,000 ft2 (21,550 meter^2) facility from reputation hard disk manufacturer in Bangkok, Thailand. At that time, the company planned to leverage the precision mechanical and processing engineering skill sets from the disk drive industry into the manufacture of optical communications components and modules. With this goal, The Company engaged

some of the most seasoned managers in the industry, creating arguably the industry's most experienced and knowledgeable teams in the region.

The transformation of the company was complete in four short years. By 2003, optics represented the majority of the company's revenue. Three quarters later, optical manufacturing services accounted for 100% of the company's revenue. Today, this company is one of the top 100 contract manufacturers in the world with manufacturing facilities in Thailand, China and the United States.

A vertically integrated solutions provider, This Company also designs and manufactures bulk optical components including glass and crystal through its operating subsidiaries'. With facilities in Thailand, China and the United States, See figure 1.1, The Company is the number one choice for organizations seeking to improve operational efficiency and reduce manufacturing costs for complex high-mix, low – volume manufacturing.

Figure 1.1 - Operating subsidiaries

Reference: Company's website

1.3 Statement of Problem

The business unit which concern in this paper is Fused Biconic Taper Coupler (FBT) unit. The Fiber Biconic Taper Coupler, see figure 1.2, is an optical device that connects three or more fiber ends, dividing one input between two or more outputs, or combining two or more inputs into one output. It uses to split the power of light wave in the various powers and wavelength depends on the using condition. The most of product using coupler as instruments are EDFA, Fiber optic sensor, Fiber network monitoring.

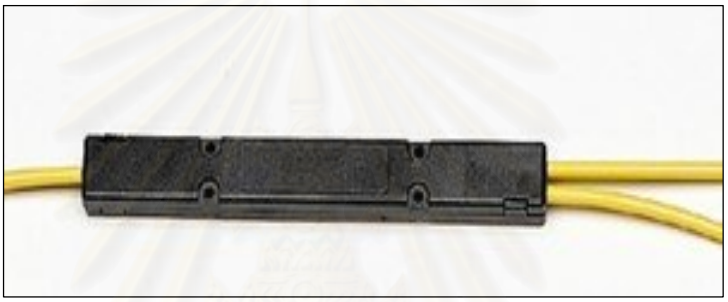


Figure 1.2 – Fused Biconic Taper Coupler

From the data during last eight quarter, the tendency of scrap cost per unit of Fused Biconic Taper Coupler (FBT) was dramatically increase every quarter especially last three quarter of year 2006, see graph 1.3. The average scraps per unit of year 2006 increase about 35% comparing with year 2005, see figure 1.4.

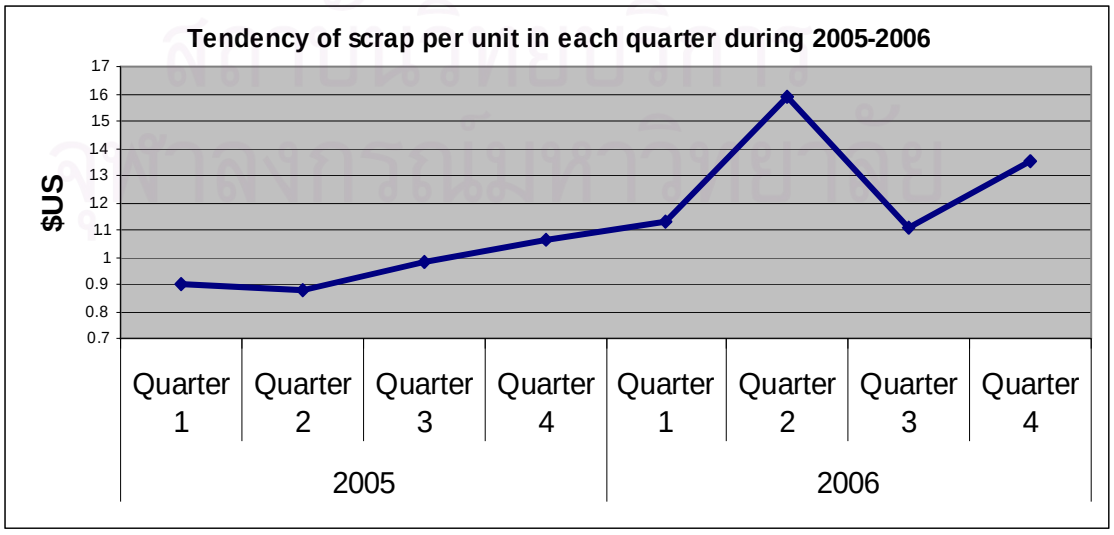


Figure 1.3 – Scrap cost per unit during 2005-2006

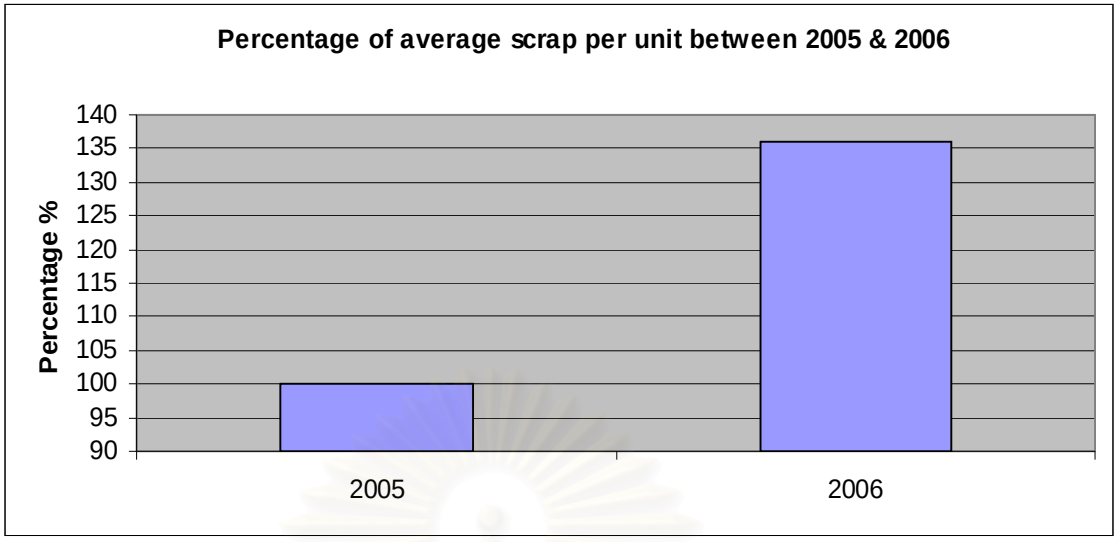


Figure 1.4 – Average Scrap cost per unit during 2005-2006

At the present, year 2007, production line has still faced with the increasing of scrap per unit of Fused Biconic Taper Coupler (FBT). Generally, the rapid growth of scrap per unit as this problem can effect to the revenue directly and it may cause the possibility to stop the business in case of non-profitable.

1.4 Objective of the Research

The objectives of this research is

- To improve process of Fused Biconic Taper Coupler (FBT)manufacturing by using Six Sigma philosophy.

1.5 Scope of the Research

The scopes of this research are

- Waste in this research are defined the scope only, material waste and waste of cycle time
- Waste of this product will concern only coupler machine process excluding packaging shipping and store.
- The research method will follow the 5 phase of Six Sigma (DMAIC)

1.6 Expected Results

The expectation that this research will achieve are

- Reduce scrap and scrap cost per unit
- Reduce cycle time

1.7 Research Procedure

1. Study the operational process of Fused Biconic Taper Coupler(FBT) and the related material as shown in the literature
2. Collect important information.
3. Define the method from data to identify potential improvement opportunity.
4. Measure the performance of interesting data by using the descriptive data analysis to understand the base line.
5. Analysis the process to determine whether the process can be improved or should be redesigned.
6. Improve the process by using brainstorming to create the idea base on data and using statistical tools to validate the new design or new process.
7. Control the improvement process
8. Summarize the result
9. Prepare thesis draft
10. Thesis examination

CHAPTER II
THEORY AND LETERATURE REVIEW

2.1 Fiber Optic Property

(Harry J.R.Dutton, 1998)

An optical fiber is a very thin strand of silica glass in geometry quite like a human hair. In reality it is a very narrow, very long glass cylinder with special characteristics. When light enters one end of the fiber it travels (confined within the fiber) until it leaves the fiber at the other end. Two critical factors stand out::

1. Very little light is lost in its journey along the fiber.
2. Fiber can bend around corners and the light will stay within it and be guided around the corners.

   An optical fiber consists of two parts: the core and the cladding. The core is a narrow cylindrical strand of glass and the cladding is a tubular jacket surrounding it. The core has a (slightly) higher refractive index than the cladding. This means that the boundary (interface) between the core and the cladding act as a perfect mirror. Light traveling along the core is confined by the mirror to stay within it- even when the fiber bends around a corner.

(Jim Hayes, 2001)

The installation specifications of fiber are those that must be met in order to ensure successful installation of the cable. There are six such specifications:

1. Maximum recommended installation load, installation load, or installation force
2. Minimum recommended installation bend radius, installation bend radius, short term bend radius, or loaded bend radius.
3. Diameter of the cable
4. Diameter of sub-cable and buffer tubes
5. Recommend temperature range for installation

6. Recommend temperature range for storage.

(Jim Hayes, 2001)

Optical power- This measurement is the basis for loss measurements as well as the power from a source or at a receiver. Although optical power meters are the primary measurement instrument, OLTSs and OTDRs also measure power differences in testing loss. EIA standard test FOTP-95 covers the measurement of the optical power.

Optical power is based on the heating power of the light, and some instrument actually measures the heat when light is absorbed in a detector. While this may work for high power-laser, these detectors are not sensitive enough for the power level typical for fiber optic communication systems. See table

(Harry J.R.Dutton, 1998)

Fused Taper Coupler – To make these you put two regular single-mode fibers into direct contact, heat the section and then apply pulling pressure to the ends of the fibers. The fibers are drawn out and become thinner (both cladding and the cores). In the process the fiber fused together sometimes the fiber twisted tightly together before heating and stretching.

This give us very much narrow cores and the cores are closer together because of the thinning of the cladding. The narrows core actually increases the extent of the evanescent field in the cladding and assist in the coupling process! The problem is that it is difficult to control the spacing of the cores or the coupling length with great precision. Nevertheless, fused taper couplers are very common commercial devices.

(Rajiv Ramaswami,Kumar N. Sivarajan,1998)

A directional coupler is used to combine a split signals in an optical network. A 2x2 coupler consist of two input port and two output ports, and is shown in figure 3.1. One possible construction for a directional coupler is to fuse two fibers together in the middle;another possibility is to fabricate it using waveguides in ontregrated optics. By careful design, the coupler , shown in Figure 3.1 , takes a fraction alpha of the power from input 1 and place it on output 1 and the remaining fraction 1- alpha on output2 . Likewise, a fraction 1-alpha of the power from input 2 is distributed to output 1 and the remaining power to output 2.

(Rajiv Ramaswami,Kumar N. Sivarajan,1998)

Although we neglected the attenuation loss in the fiber in the derivation of propagation modes, its effect can be modeled easily as follows: the output power Pout at the end of a fiber of Length L is related to the input power Pin by

$P\ out = Pin^{-aL}$

Here the parameter a represents the fiber attenuation. It is customary to express the loss in units of dB/km; thus a loss of a dB/km mean that the ratio Pout/Pin for L = 1 k.m. satisfies;

$10\log_{10} \frac{P\ out}{P\ in} = -a\ dB$

The two main loss mechanisms in an optical fiber are material absorption and Raleigh scattering.

(Gunther Mahlke and Peter Gossing, 1987)

Technical properties of Single-Mode and Multimode Fibers comprise of

1. Tensile Load – The maximum tensile load which can be carried for duration of approximately-printed with ring markings. The colors are applied in such a manner that they have no influence on the optical properties of the fibers

2. Color Coding – In order to identify individual fibers, they are color coded and –if necessary – printed with ring markings. The colors are applied in such a manner that they have no influence on the optical properties of the fibers

3. Temperature Ranges:

Transportation and storage temperatures	-20˚C – 50˚C
Installation temperature	5˚C – 40˚C
Operating temperature	0˚C – 50˚C

2.2 Six-sigma and design for Six Sigma

(Algase, 2003)

Six-sigma and DFSS are linked together. If we are trying to improve the existing product or process, we will use DMAIC (Define, Measure, Analysis, Improve and Control) as the improvement the process. On the other hands, if we need to create the new product or process, we will use the DFFS methodology or IDOV (Identify, Design, Optimize and Validate) as the improve process.

(Kuchar, 2000)

At general Electric, the DFFS Process has been defined into 5 phases, Define, Measure, Analyze, Design and Verify. Briefly, these 5 phases are about, set objective, roles and responsibilities, understand customer needs; specify CTQs, project requirement & quality target, establish high-level design, identify key design parameter and limits, predict sigma; literate to meet quality target , and assess performance, reliability.

(Thomas Grunburg, 2003)

The purpose of this paper was to present a categorization of performance factors and a measurement model. The author briefly describe how most improvement methods generally have the same format, a ‘pre-phase’ preparation and planning step,

measurement and implementation and finally an evaluation and possible restart of the improvement cycle. The most famous example is the Deming ‘Plan-Do-Check-Act’ cycle.

(De Feo and Bar-Ei, 2002)

Design for six-sigma (DFSS) is an established, data-driven methodology based on analytical tools that provide users with the ability to prevent and predict defects in the design of a product, service or process. Making significant reductions in cost and cycle time requires a major departure from traditional design methods. The DFSS process produces the kind of data that show the way to achieve Six-sigma level of quality. Focused on creating new or modified designs that have higher levels of performance, the design for Six-sigma Procedure follows a Define-Measure-Analyses- Design-Verify (DMADV) sequence.

Design- The define phase sets the tone for the entire design project by establishing goals, gather and infrastructure. Activities are shared between management and project design teams. Management defines the design problem, but the project are nominated consistent with the overall business strategy and selected based on the optimal impact on that strategy.

Measure- The measure phase is concerned with identifying key customers, and determining their critical needs and the measurable critical to quantity (CTQ) requirements necessary for a successfully designed product, service or process. A design scorecard is created to track the design evolution and predict what the final product level will be after all design element has been instigated.

Analyze- In the analyze phase, a design is selected from several alternatives, followed by the development of design requirement against which a detailed design is to be optimized. The design team them develops several ‘high level’ options. On of the design or a combination is selected, followed by the selection of the ‘best-fit’ design.

Verify – The purpose of the Verify phase in the DMADV sequence is to 4ensure that the new design can be manufactured and supported in the field within the required quality, reliability and cost parameters. After verification tests and pilot runs, the design is finalize and a ramp-up to full-scale production occurs to highlight any potential production problem.

(Woraphoom, 2004)

This thesis concerns improvement of Head Stack Assembly packaging that is the major component in hard drive. The purpose of thesis is to provide the new packaging design and concept that reduces freight cost and packaging cost. The author had decided to use Six-Sigma methodology in packaging development process and tried to fulfill all customer requirements with Quality Function Deployment flow.

(C.M.Creveling, J.L.Slutsky, &D.Antis, Jr, 2003)

The metrics of DFSS break down into three categories:

1. Cycle-time (controlled by the product development process and project management methods)
2. Design and manufacturing process performance capability of critical-to-function parameters (developed by a balanced portfolio of tools and best practices)
3. Cost of the product and the resources to develop it.

DFSS is focused on CPM. This is done to identify the few variables that dominate the development of base line performance (Yavg), the optimization of robust performance (S/N and sigma), and the certification of capable performance (Cp and Cpk) of the integrated system of designed parameters. DFSS instills a system integration mind-set. It looks at all parameters – within the product and processes that make it- as being important to the integrated performance of the system elements, but only a few are truly critical.

(Peter S Pande,Robert P. Neuman, Roland R. Cavanagh,2000)

You cannot use DMAIC on just anything. There are three basic qualifications for a Six Sigma improvement project :

1. There is a gap between current and desired/needed performance. ”Where’s the pain?” is how we often post this question. If you are going to apply DMAIC,you first need a problem to solve or an opportunity to take advantage of. In the case of process design, there’s a new activity being launched for which there is no existing process.
2. The cause of the problem isn’t clearly understood. You may have theories, but so far no one has been able to factually pinpoint the root cause; that, or else solutions you though would relieve the pain just aren’t working.
3. The solution isn’t predetermined, nor is the optimal solution apparent. If you’ve already planned a short term remedy, there still may be potential for a Six – Sigma project;” quick fixes” can help by time for more rigorous analysis. If a significant effort has already been launched to bridge the gap, however, a separate, concurrent Six Sigma project would be redundant or worse. You can skip “DMAIC” when quick fixes are adequate, or the solution is legitimately obvious. There is nothing in the Six Sigma philosophy that requires you to ban forever the Nike advertising approach to business improvement (“Just do it “) when it’s warranted.

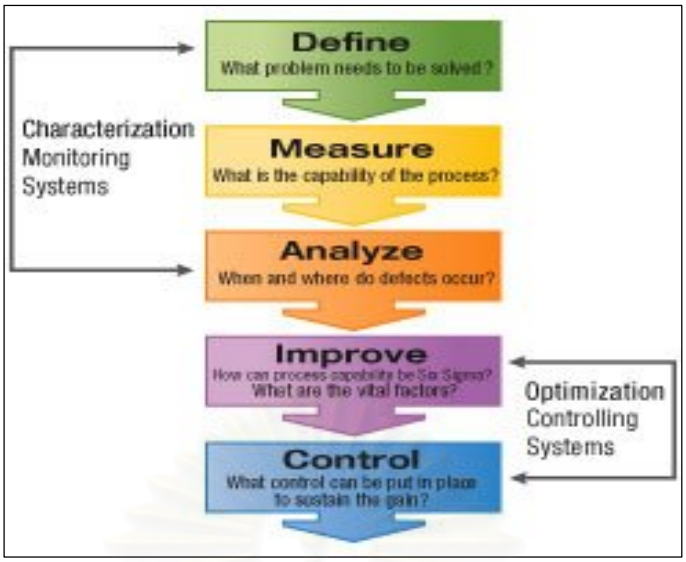


Figure 2.1 – DMAIC model

Source: www.ssqi.com/six-sigma-library/dmaic.html [20/11/2007]

2.3 Quality Function Deployment (QFD)

(Watson, 2003)

QFD provides a systematic way to record agreements on the means to satisfy high priority customer requirements through the design of the core product, its extended product and the production process. It is a powerful design and documentation tool for recording product-level decisions about customer needs, design rules, competitive positioning, and requirement quality for suppliers as well as requirements of the production process. QFD enables product design teams to prioritize these competing needs, develop innovative responses, and orchestrate successful cross-functional effort to meet this need

(John Terninko, 1997)

Once customer needs are understood, they are translated into design requirements; the subjective desires of the customer are mapped into the language of the engineer. QFD focuses on delivering value by understanding the customer's wants and needs and then deploying these expectations throughout the development process.

This includes identifying the best values for components, parts or materials, to manufacture a world class product, the customer information must be deployed to the manufacturing process and control systems. A complete design process would include packaging, delivery and support. The end results are increased market share and greater profits.

(Jack B ReVelle, John W Moran, 1998)

The need for Quality Function Deployment (QFD) was driven by two related objective. These objectives started with the users (or customers) of a product and ended with its producers. The two objective were

1. To convert the users' needs (or customers' demands) for product benefits into substitute quality characteristics at the design stage
2. To deploy the substitute quality characteristics identified at the design stage to the production activities, thereby establishing the nesesscary control points and check points prior to production start-up.

(Tom Droza, Charles Wick, 1998)

Quality function deployment is a structured approach to defining customer requirements and translating them into specific steps to produce products to meet those requirements. "The voice of the customer" is the term to describe these stated and understand requirements. The voice of customer is captured in a variety of ways: direct discussion, surveys, customer specification, and observation, warranty data field reports, etc. This understanding of the customer requirement is then summarizing in a product planning matrix or house of quality. The matrices are used to translate higher level what's into lower level how.

2.4 Kano Model

(Thomas Pyzdek, 2003)

The Kano model shows that there is a basic level of quality that customers assume the product will have. For example, all automobiles have windows and tires. If asked, customer don't even mention the basic quality items, they take them for granted. However , if this quality level isn't met the customer will be dissatisfied; note that the entire" Basic Quality" curve lies in the lower half of the chart , representing dissatisfaction . However providing basic quality isn't enough to create a satisfied customer.

(Jack B ReVelle, John W Moran, 1998)

The Kano Model and related concept are very powerful because they assist any organization to understand hoe t get information from its various sets of customers about those customers' wants, need desires and requirements. This knowledge helps the organization design information gathering processes that are both effective and efficient and typically ongoing. In some organizations these information systems are called marketing research and customer feed back. The Expanded Kano Model details customer perceptions of the different types of quality and gives insight on how to gather information to address them, see figure 2.2.

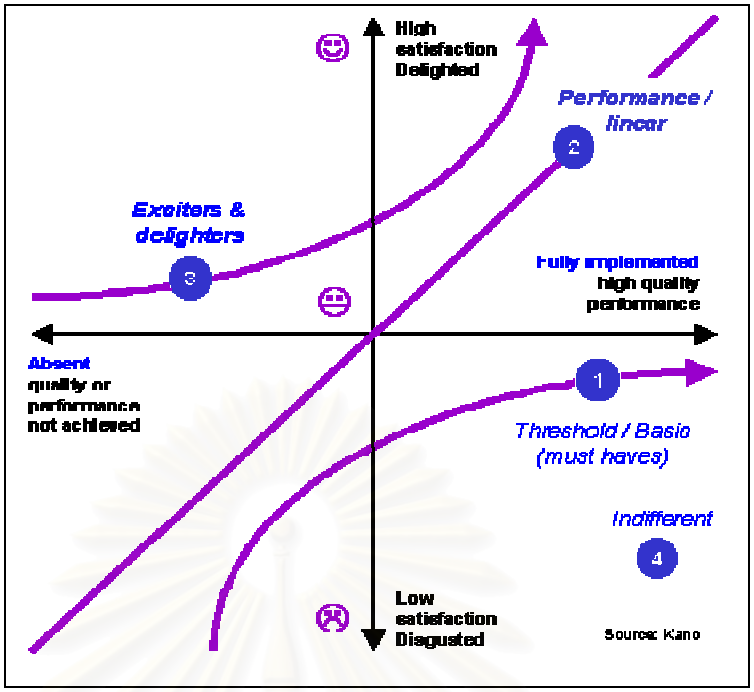


Figure 2.2 – Kano model

Source:http://www.ifm.eng.cam.ac.uk/ctm/idm/tools/definition/images/kano461_456.gif [21/11/2007]

CHAPTER III
APPLICATION OF SIX SIGMA IN PROCESS IMPROVEMENT

In traditional approach, Six Sigma extremely focuses on customer critical requirement, developing process and using as business indicator. Main Six Sigma change Agents comprise of 5 groups, see figure 3.1. Firstly, cause of major key as destroy the across organization behavior, leadership for Six Sigma can not be anyone other than Chief Executive Office, CEO. Leadership has a responsibility for direction and monitoring the project. Secondly, all activity will organize for its success by middle management or Champion & Sponsors. Black belt and Master Black belt that were assign to ensure the Six Sigma project has been close follow as organization system and advises the tools in term of statistical and Six Sigma philosophies. The 3rd, Green belt acting as a project leader manages Six Sigma projects from concept to completion. The two remain factor which involve in the project are Team member and process owner.

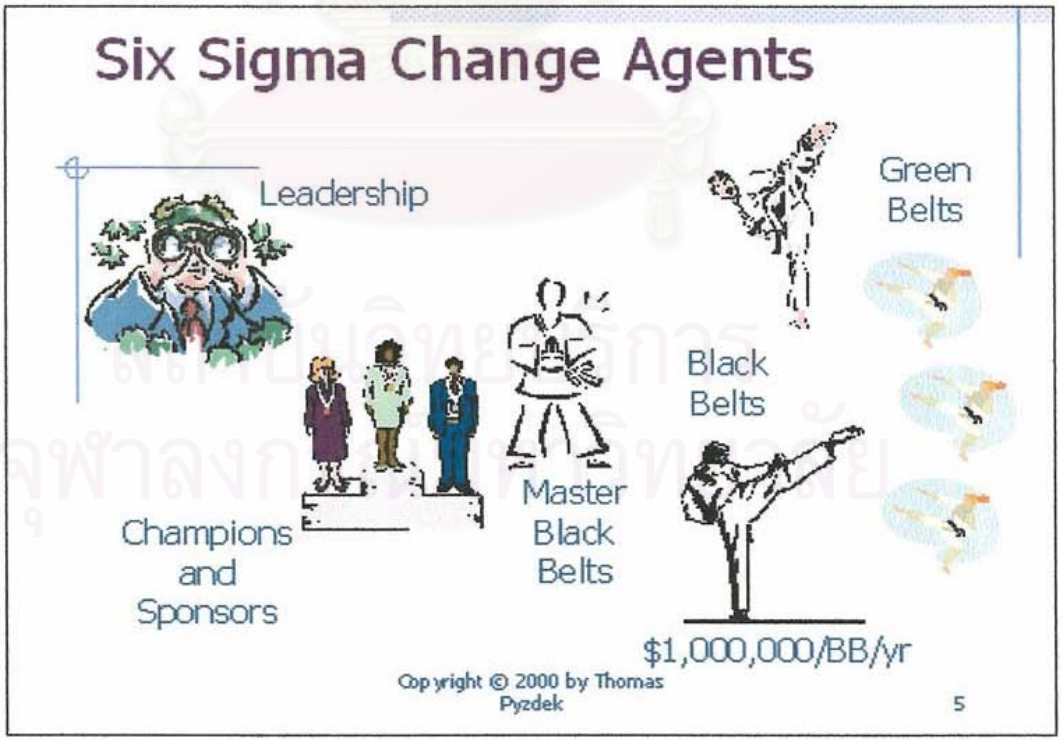


Figure 3.1 – Six Sigma Agents

Source: http://www.pyzdek.com/six-sigma-revolution_files/image003.gif [20/11/2007]

The strategic of Six Sigma implementation comprise of three ways. There are Process Improvement, Process Design/redesign and Process Management. Follow as three strategy, it express the completely improve or change cycle firstly starting from try to improve the existing process(process improvement) and then trying to design new way of doing business or new process(Process design). Lastly, try to approach in the organization by new specific project (Process management).

Process Improvement: try to find out the solution of the problem in the existing process by using the five step process called DMAIC (Da-MAY- ihk), See figure 3.2

Define – the problem and study Voice of Customer
Measure – defects and process maps
Analyze – data and cause & effect analysis
Improve – the existing process refer to receiving data
Control – the process to ensure the defect will not occur again.

Figure 3.2 – DMAIC model
Source:http://blogs.decadesoftware.com/hlarledge/WindowsLiveWriter/dmiac.jpg [21/11/2007]

Process design/Redesign: Even DMAIC is the effective tool to solve the problem, there are still have some cases limited by process it self to improve. For example, when the process need to replace rather than repair , when the improving process will not reach to the Six Sigma level and chance from the organization to change entire product, process or service. In this case improvement team needs to adopt the tool from DMAIC to DMADV, Six Sigma Design (SSD) or Design for Six Sigma (DFSS). DMADV was adapted from DMAIC by adding the step of innovation.

Define: customer requirements, Target from organization
Measure: Matching the process or service with customer requirement
Analyze: new design
Design: new process/design/service
Verify: result and maintain output

Process management: There is the most evolutionary from all three strategies. Process management focuses not only the individual department but also all relevant department or cross functional management. According to Peter S. Pande , Robert P. Newman ,Roland R Cavanagh, “Because it require a fundamental makeover in the way an organization is structured and managed, Process management is often the most challenging of the three Six Sigma strategies to master. Nevertheless, without Process management, Six Sigma is often doomed to become just another flavor-of-the-month-program.”

For effective approach, this project will drive the progress follow as three main Six Sigma strategies; Process Improvement, Process design/redesign and Process Management. Firstly, we will focus on the process improvement. The Fused Biconic Taper Coupler manufacturing is the target that we want to improve so; the DMAIC will use to be a tool to find out the root cause and improve the process.

The problem was defined in the chapter one that in year 2005-2006, Scrap per unit tendency increase gradually. This project will use DMAIC to classify the problem step by step. In any DMAIC phase implementation, there are many tools apply in each phase for example

DEFINE PHASE - Kano Analysis, Voice of Customer, Pareto

MEASURE PHASE – Process Maps, Cost of poor quality, Standard Time Study

ANALYZE PHASE – Brain Storming, FMEA, TRIZ, ANOVA

IMPROVE PHASE – DOE & RSM, DFSS, Force Field Analysis

CONTROL PHASE – Visual Control, SPC, Team Building

Figure below was shown the famous tool in each phase of DMAIC, see figure 3.3. There are not the exactly answer for the question as which tool is the most effective. It depends on the problem, situation and improvement team.

Figure 3.3 –Famous tool in each phase of DMAIC model

Source: Lean & Six Sigma Institute

The following chapter will show the application and implementation process improvement of Fused Biconic Taper Coupler Manufacturing step by step base on DMAIC

CHAPTER IV
APPROACH DMAIC & DMADV
IN THE EXISTING PROCESS

4.1 Define Phase

According to problem statement, the scrap cost per unit tendency start increase gradually from the Quarter 3 rd, 2005. At the present, the tendency of scrap cost per unit has still increase, update information Quarter 4th, 2006. The different of average scrap cost per unit between year 2005 and 2006 is about 30 %, See Figure 4.1.

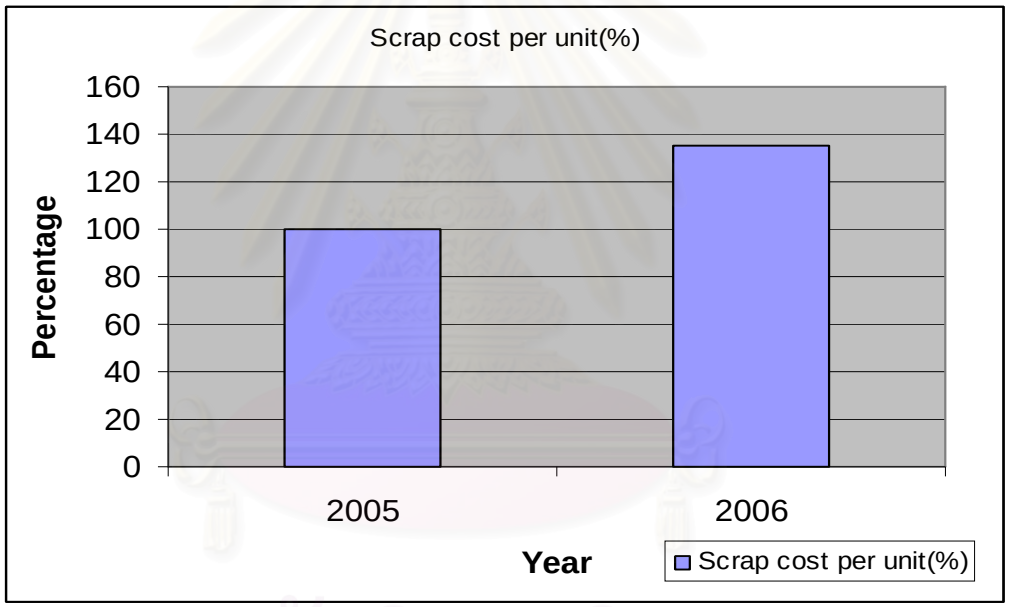


Figure 4.1- Average scrap cost per unit during year 2005-2006

To clarify the reason of scrap cost per unit, we need to understand the definition the term of scrap cost per unit in this project by following paragraph. " *The scrap cost per unit mean the cost of scrap/waste/defect in term of usage material both direct, indirect and consumable which use in the process for 1 final unit output product.*" From the definition, classification type of material posed in scrap data and ranking the type of scrap material by cost and quantity of each type are the next step that help to indicate the type of scrap material which is the main effect in this problem.

4.1.1 Classify the most effect material

Pareto analysis was used to clarify the main scrap material which is the most effect in term of cost and quantity. The scrap information was used to analyze and separate the scrap in each material and then bring the top ten scrap material to plot in the Pareto chart, See result in Figure 4.2 and 4.3. The definition and application of Pareto analysis are described in the following paragraph.

"Pareto analysis is used to stratify data into groups from largest to smallest. A specialize from a bar chart, the Pareto helps you identify the most common occurrences or cause of a problem. To use a Pareto Chart, however, you need to make sure you have discrete or category data – it won't work with measure like weight or temperature (i.e., continuous data). Pareto analysis is based on the '80/20' Rule – The notion that 80 percent of costs or pain in an organization are created by just 20 percent of the problems. The numbers are not always exactly 80 and 20, but the effect is often the same." (Peter S. Pande,Robert P Neuman, Roland R. Cavanagh, 2000)

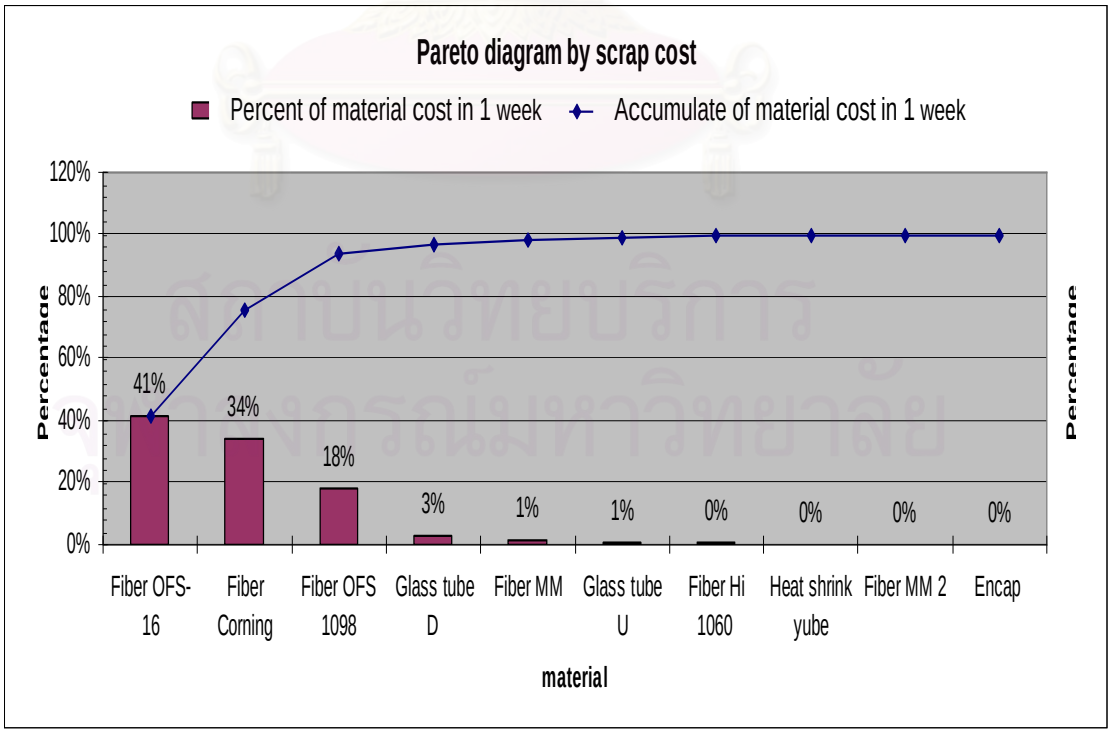


Figure 4.2 – Pareto diagram by scrap cost

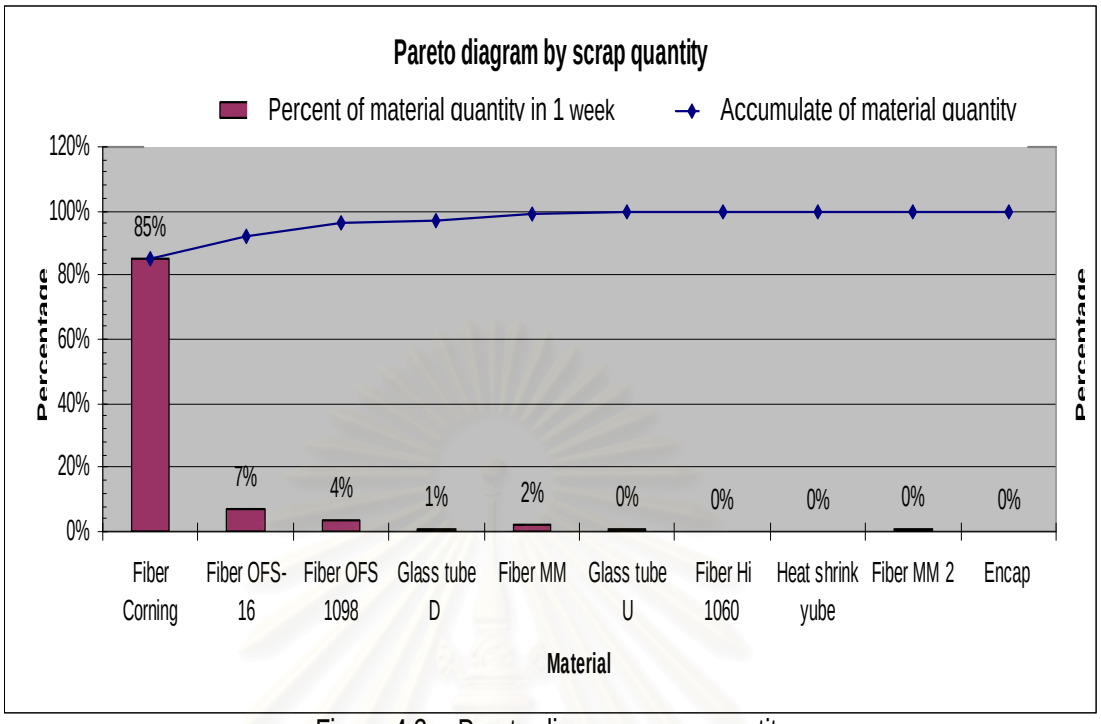


Figure 4.3 – Pareto diagram scrap quantity

From figure 4.2, most of the material in the first 80% effect to the cost of scrap is Fiber; 1st Fiber OFS-16 = 41%, 2nd Fiber Corning = 34%, 3rd Fiber OFS 1098 =18%, total first 3 material = 93% of all top ten scrap material. The result shows that Fiber has a high possibility to be the main point that needs to find out. To study in the other view, Quantity of top ten scrap material was plotted in the Pareto analysis. In Figure 4.3, the highest scrap quantity of material is Fiber Corning= 85 %. The percentage of the first and the second in term of quantity is much different, 78%. When compare with the different between the first and the second in term of cost,7%, the reason of much different in term of quantity may come from yield of product in each material, the cost of each material

To understand more, next topic will break down quantity of both fibers during transition period of new product introduction, April-September 2006.

4.1.2 Study information during NPI transition.

To make a competitive advantage in the market, OFS fiber was chosen to be a major material in the further operation. The table 4.1 and figure 4.4 & 4.5 showed the ratio of both fibers during transition period.

Information during April - September 2006				
Quantity		Scrap cost		Ratio of scrap per unit
Corning	OFS	Corning	OFS	OFS / Corning
99%	1%	91%	9%	9
83%	17%	47%	53%	6
81%	19%	20%	80%	16
87%	13%	45%	55%	8
71%	29%	30%	70%	9
69%	31%	25%	75%	7

Table 4.1 – Scrap information during April-September 2006

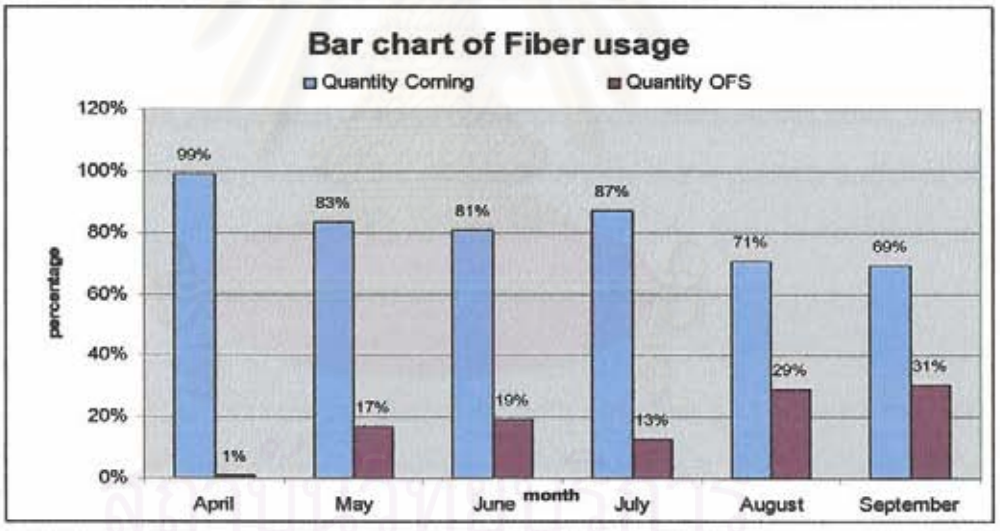


Figure 4.4 – Bar chart of fiber usage

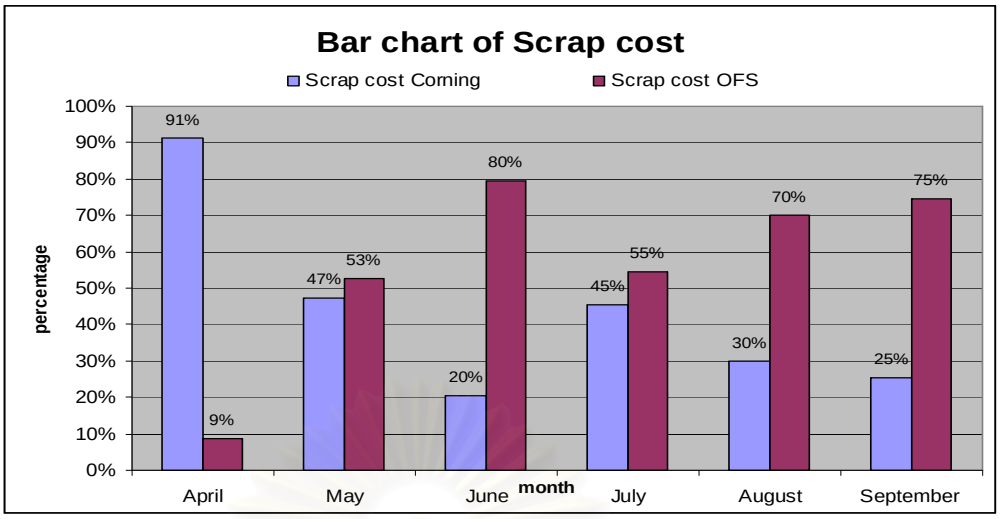


Figure 4.5 – Bar chart of scrap cost

4.1.3 Survey the reason of fiber scrap cost increase

Yield of each model - In the Fused Biconic Taper Coupler manufacturing, there are many model and the yield were vary depend on the specification in each model. For example, using the same material as Corning Fiber in the different model, it will make the much different yield cause of some operation parameters. At this point, the volumes of each model seem to be one of the parameter effects to the quantity and cost of scrap in the snap short information as figure 4.2&4.3. In actually, there is not effect so much cause of contract between customer and contract manufacturer.

Generally, scrap cost will absorb by both customer and contract manufacturer. The costs which absorbed by contract manufacturer will vary depend on yield & contract between customer and contract manufacturing in each model. That mean, if the average yield of each model is not drop so much; the scrap cost will not fluctuate as the statement problem. In year 2005-2006, the average yield of main product is not far from the target but it is much different from the New Product Introduction, NPI. So, the problem of yield of various models can solve directly by negotiation with customer. Moreover low yield from NPI, we found that the scrap cost collected by production is higher than scrap cost calculated from actual yield. That means, there are some processes that make higher variance of fiber usage than specification.

Cost of each material – According to product development & end-customer requisition, our customer need to change type of material from Corning to OFS Fiber because of optical property. From this development, Cost of fiber (per meter) increase about 1,429 %. Moreover, there has one more new product which has still experiment state for bending loss reduction. The cost of model which is in the experiment state model is higher than OFS that we face with the problem right now or you can see the figure 4.2&4.3 on the x axis name Hi 1060. The tendency of Fiber using in the manufacturing will be higher and higher because customer need to develop product to be competitive in the market.

To sum up, the tendency of fiber cost will increase in the future and possible effect to the operation cost. Even know the most of scrap cost come from OFS fiber; we have still required OFS fiber to serve with the market requirement. So, reducing the variance of process relevant to fiber usage is the important key.

4.1.4 Define Phase summary

According to The Six Sigma Way Team Field Book, Peter S.Pande, Robert P. Neuman, Roland R. Cavanagh, 2002, “Customer focus is the top priority in Six Sigma. Performance measurement begins and ends with Voice of Customer (VOC). Six Sigma improvements are defined by their impact on customer satisfaction and the value they add to the customer. One of the first tasks of Six Sigma improvement teams is the definition of customer requirements and the processes that are supposed to meet them.” In Fused Bi-Conic Taper Coupler manufacturing problem, Voice of customer is developing the product by change the new fiber material which has higher price. To serve with customer requirement, Manufacturer as service provider needs to provide manpower and operational skill.

Unfortunately, from the investigated information, there are some sign show the variance of process which according to fiber usage out of specification. The main reason has still can not summarize that problem come form operator or process itself

but the effect of operation cost is obviously appear, See figure 4.6&4.7. To solve this problem, the project focus only scope on process improvement excluding contract between customer and service provider (yield).

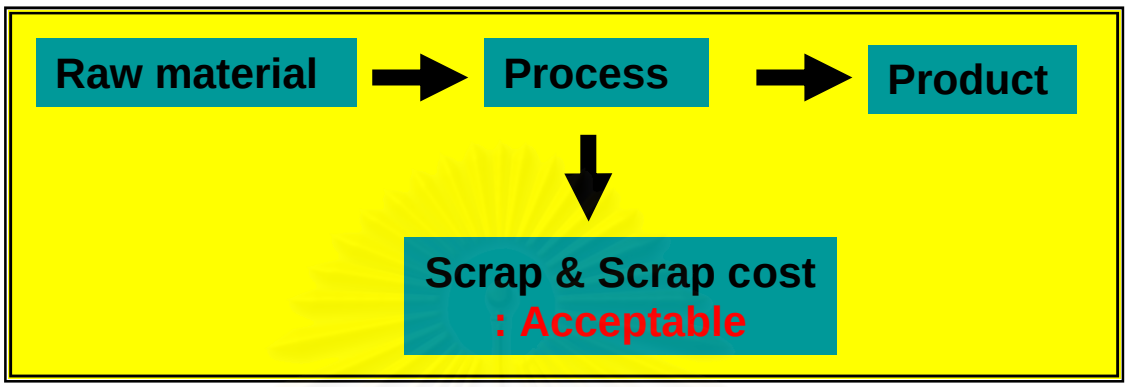


Figure 4.6: Before New Product Introduction:

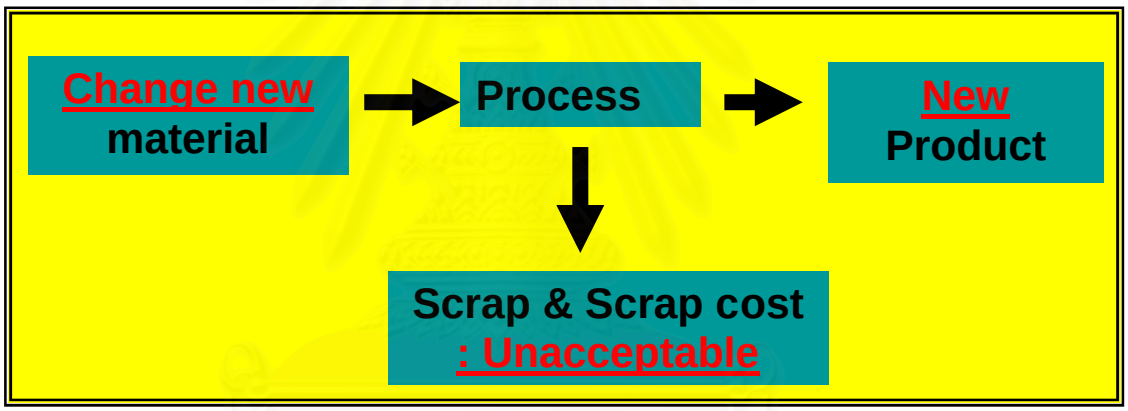


Figure 4.7: New Product Introduction:

4.2 Measure Phase

4.2.1 – Process flow

Cause of having sub-processed in Fused Bi-conic Taper Coupler production, screen and prioritize the most important process are the critical step. At the beginning, yield throughput was brought to investigate. Figure 4.8 shows the three main processes.

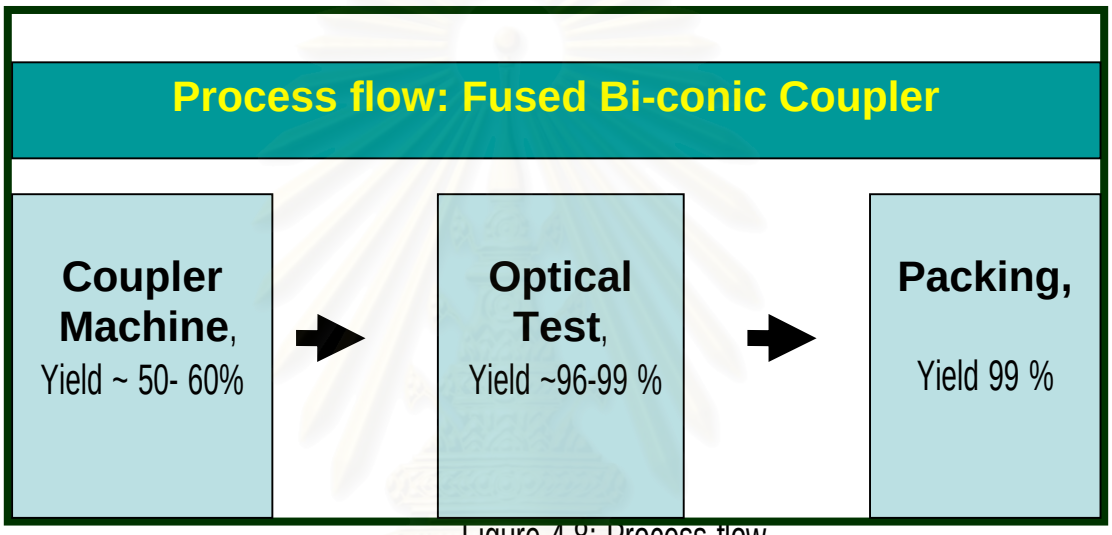


Figure 4.8: Process flow

The Coupler Machine process is the sub-processed which has the lowest yield among sub-processed. To analyze deeply in the next step, we need to narrow the scope of all process by focusing deeply only on Coupler Machine process. Then study the process step with in coupler machine process to find out that which process step is the main point that we need to focus in term of fiber usage problem.

Process flow of Coupler Machine Process

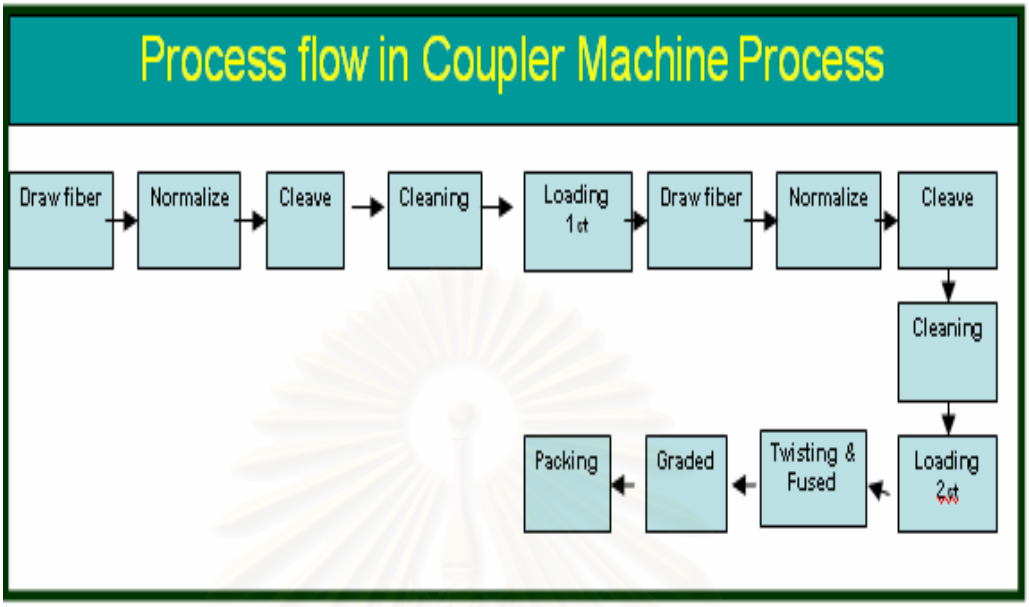


Figure 4.9 Process flow of coupler machine

Figure 4.9 show the process step in the coupler machine process. The relevant processes which effect to the fiber usage are drawing fiber process, Cleaving process, grading process. To identify the cause of fiber usage problem, my mapping is brought to find out the factors.

4.2.2 – Identify the cause by using mind mapping

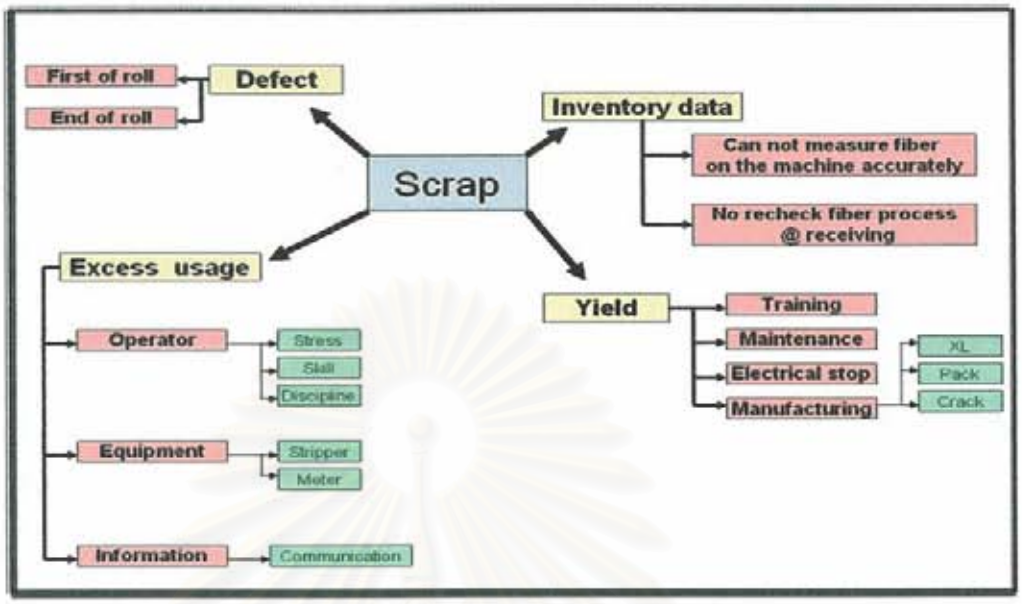


Figure 4.10 – Mind mapping: Cause of scrap

To create an effective mind mapping, the working team which comprise of representative from all duties such as maintenance, process, tooling, and manufacturing was set up. The result was shown in the figure 4.10. There are 4 main reasons that affect the scrap cost by waste of fiber; Excess usage, Yield, Inventory Data and Defect.

Yield – Cause design of the machine and process, the variance of control parameter still hard to control so; the skill of the operator is very important factor to make a low yield. There need to plan the on the job training for new operator and it surely that there are loss of the fiber too much during train new operator. The gap of yield from old and new operator is 25%; 50% and 25%. And the traditional of this product will be low volume during Jan – May. That mean some of operator will be move other product and need to be training new operator when volume become high. Moreover the effects from training, Machine down time and electrical stop are one factor that proposes by the representative of manufacturing. The last one is the top ten defects that make the yield low. These all factor; training, machine shut down, electrical stop and defect are the main factor which effect to the yield in the production line.

Defect of Fiber itself – Cause of some characteristic of fiber and the sensitivity of process, there are some fiber at the beginning & end of roll can not use cause of make high excess loss. Anyway, this loss was already compensated by price from vendor and both of old and new type of fiber also faces with this problem.

Inventory data – One of the idea to find out the root cause is can we believe the data that we got? So; we try to cross check the possibility that can make error in the data of scrap cost which focus in fiber usage. We found that there are no processes to check the fiber length during receiving. One more possibility is error of counting fiber which is used on the machine. It is impossible to measure accurately by present tool or equipment.

Excess usage – Cause of semi auto machine, they still need operator to measure fiber length and there are some limit of the equipment to make operator cannot make the length accurate enough. One more possibility is loss fiber come from miscommunication between planners and manufacturing such as wrong model. So, in this topic there are three factors; equipment, operator and information.

Then, the relationship matrix as QFD was chosen to verify the priority of each reason base on factor that we considering. The list of expected root cause shown in the row and the criteria factor shown in the column. The criteria factor which consider in this table will be propose to find which root cause is the most effective action for reduce scrap from fiber usage.

From trend of high scrap cost, the new type of fiber will be the main reason of this problem and 30% shoot up of scrap cost is not the stable level. The scrap cost will be increase more because this 30% shoot up of scrap cost come from transition period which transfer new fiber only 31% of total fiber usage in the production.
Or within100% of scrap cost after transfer 31%of new material, there are >70% of scrap cost comes from new fiber. So, time consumption and action by internal resource is the

important criteria in this case because we should select the point that can get the result within the short period of time.

Finally, there are three main criteria; time consume, how much it effect to scrap which is come from fiber and Do internal resource can solve by themselves?. The high number show high relation ship between problem and criteria and rate from 1-5. High number mean low time consume, much effect to scrap cost and high possibility to solve by internal resource. The result was shown in table 4.2.

Criteria / Epected cause	Time consume	Effect to scrap: fiber	Solve by internal resource	Total	Catagories	Summary
First of roll	1	1	1	3	Defect	3
End of roll	1	1	1	3		
Stress of operator	2	1	2	5	Excess usage	6.5
Skill of operator	2	3	2	7		
Discipline of operator	2	2	2	6		
Not good measure equipment	2	3	2	7		
Not proper stripper	2	3	2	7		
Miscommunication	2	3	2	7		
Can not record the fiber length on the coupler machine	2	2	2	6	Inventory data	5.5
The actual length is not same as attached label	1	2	2	5		
Excess loss	1	2	1	4	Yield	4.6
Fail pack	1	3	1	5		
Fail crack	1	3	1	5		

Table 4.2 - Relationship matrix, expected and criteria to choose the most effective choice.

In the summary row, Excess usage has the highest point, 6.5 and the second is inventory data, 5.5 point. Yield and Defect get the point, 4.6 and 3 respectively.

In this step, excess usage and inventory data will be the main topic which are focused deeply to find out how to reduce the scrap cost which come from fiber. When we mapping the expected cause topic with process flow of coupler machine, there is only draw process which is concern with. So, for the next step in Measure phase, study and break down every point in draw process is the main concept.

4.2.3 Study Draw Process

In draw process, the important thing is draw the fiber length follows as specification and then operator will use stripper to strip the cladding at the center of the loading fiber. To clarify the method, the following will break down draw process and using equipment step by step, see figure 4.11

Procedure:

After lead the fiber passes through stripper, operator measure fiber length by estimate from the meter which attached at the machine.

After measure the length, operator pull stripper up and try to fix the position which they want to strip.

Move the stripper to the eye level and then strip the cladding length follow as specification.

Figure 4.11 - Draw process

To understand the variance of draw process, the data to indicate or studying will be a piece of fiber which torn after get a finish good. The specification of fiber length of finished good in each model is plus / minus 5 cm. from the center value.

So, that means operator will tear down the fiber which have length more than center value plus 5 cm. A piece of fiber which was torn down will be defined as scrap.

The condition for reference the data are M/C number, operator, stripper, fiber and model number and there will be set up same condition before record the data every time. There are 44 pieces of fiber in the collected sample. The specification is plus / minus 5 so, LSL equal to -5 and USL equal to 5. The target will be zero that mean no scrap occur in this process. To clarify the result, Minitab software was used to calculate and shown the data distribution. See Picture 4.12

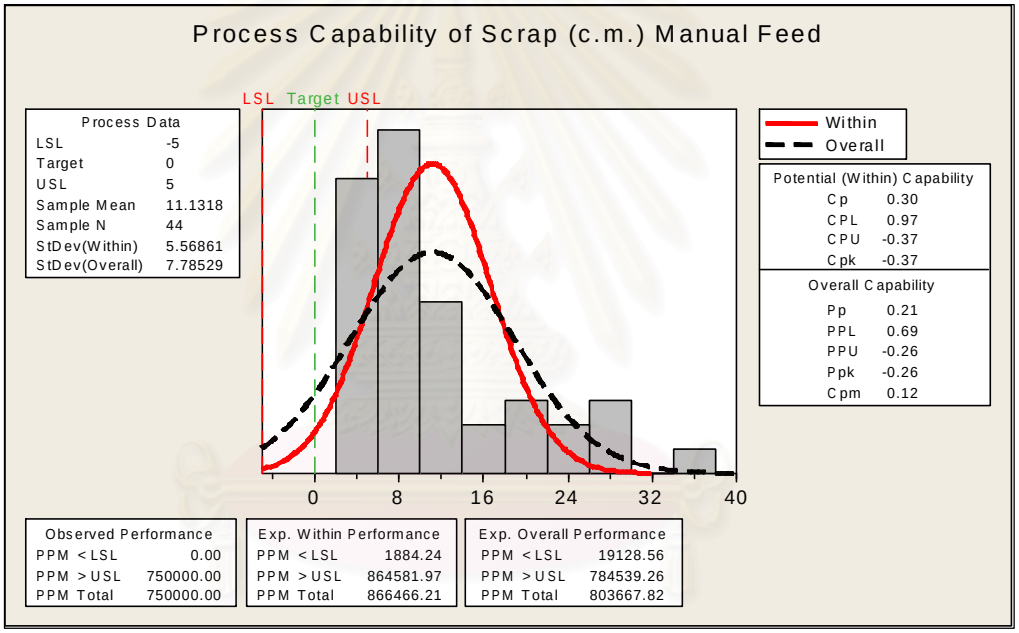


Figure 4.12 – Process Capability of Scrap

From the result, present draw process has very low capability. Cpk of this process is only -0.37, StDev = 7.78 and Mean =11.13 cm.. From Douglas C. Montgomery, the recommend minimum value of the process capability for existing process is 1.33 in Two-sided Specifications and 1.25 One-sided Specification. On which the gap about 1 of Cp from recommended minimum value and existing value, it should be consider how to improve Cp of draw process.

The reason of very low Cp of draw process comes from low price of fiber which use from the past so; there are not effect so much in term of profit even Cp equal to 0.3. However, to compete in the market, the prices of new type fiber which implement for the new product introduction have 200% higher than previous type and there have an opportunity to use the new one which more expensive than implemented fiber right now. So, the target for the analyze phase is improve Cp & Cpk of draw process.

4.3 Analyze Phase

4.3.1 Try with simple action

According to the information from measure phase, the design of this process is not serving to the new requirement which should be make scrap with in upper specification to prevent over loss form fiber scrap. The improvement team was set up again to brainstorm for the opportunity to improve Cp & Cpk of this draw process.

Figure 4.13 - Improvement team during brainstorm

After brainstorm, team want to make sure that this Cp and Cpk can improve by only retrain and alert the situation down to the production line or not?. So, the first thing is try to improve by the existing factor which are expected cause of the high variation of fiber scrap. The factor focused on these come from measure phase. There is Skill of

operator, Discipline of operator, Stress of operator, not proper stripper and not proper meter to measure the fiber length.

4.3.2 Result from first action and analyze draw process

The action of each factor is shown in the below table. After team implement all factors, the Cp and Cpk of fiber become a little bit better than 0.3 but not so much or not good enough for serve with high cost fiber.

Action to improve Cp And Cpk base on existing process	
Factor	**Action**
Skill of operator	Retrain all operator about specification and procedure of draw process
Discipline of operator	Alert operator to know the reason and how much effect of this ascrap
Stress of operator	-
Not proper stripper	Maintenance all stripper in the operation line follow maintenance procedure
Not proper meter	Checking the meter on the machine

Table 4.3 – Action to improve Cp and Cpk

Moreover a little improve Cp & Cpk, new loss occurs after implement the action. The loss of Lower specification limit (LSL) appears and tends to be increase. When LSL occur the scrap is not define only length of fiber which shorten form the specification but it means no output or need to scrap 800 cm. or more depend on model rather than only 10 cm by Upper specification (USL) because we can not extend the fiber length in the finished good.

Form the above phenomenon, we assume one of the reason that operator try to draw fiber length higher than the upper specification limit may come from prevent the short length of finished good. It is very dangerous situation for manufacturing sense to fail the product which have normal yield at 50% by only found at the last step of the process that there length are shorter than specification.

It is hard to say that operator must control fiber length with in the upper specification limit size by move the center specification from 0 to 2.5 because the

position of meter is not proper for operator to measure by operator's eye with the area of 2.5 cm. specification. See figure 4.14.

Figure 4.14 – Measure length in draw process

The design of the stripper is also one of the factors that make error length from specification. After insert the fiber pass through the stripper and draw the fiber until reach the specification, it is hard for operator to measure the exact fiber length because the point of fiber which stripped in location at the end of blue color but operator can not measure fiber at this position, The extend plate; black color which use to measure the strip length is the problem to draw the exact fiber length, see below picture. It is impossible to move the black plate out because the length of strip is very important parameter to affect the yield of production. So, to measure more accurate, the meter should be reducing about 2 cm. from actual length but it also possible to make an error at least >0.2 m.m. from this procedure, See figure 4.15.

Figure 4.15 – The extend plate

In actually, the tolerance of fiber length from the beginning is wider than present. The target of fiber length specification was reducing day by day cause customer requirement. That means there is high possibility for this product to challenge with the narrower specification of the fiber length in the future. There are possibility to cope with this problem not only scrap cost but also the request form customer.

The volume of this product is not quite stable with in a year. Some operators were arranged to other product during low volume which covers about 3 month approximately. The problem is lack of experience operator during volume ramp up. That means if we can reduce process which requires skill of operator as much as we can. The effect of seasoning will reduce because some process does not require skill of operator.

The cycle time will be increase if we focus the result on the accurate fiber length with existing equipment & procedure because there are not proper with the severity of requirement.

Cause of the design of this machine, the skill of operator is very important. The cycle time of one finished coupler is long and low yield. The parameter is defined in the micro meter in some factor and there are not absolutely predict the cause and effect of productivity by a pattern solution. From all of above factors, even normal production, all operators will face with the stress.

Factor	Analysis result
Operator	Prevent fail LSL cause more USL autonomous
	Decision by human eye
	New operator from fluctuate demand
	More accurate length with old equipment more cycle time
	Fail more LSL after action
Stripper	Black plate make error about 2 cm.
	Need to strip fiber at the middle
Meter	Not proper position

Table 4.4 – The summary of analysis result

The summary of analysis result are shown in the table 4.4.Form the existing equipment and procedure that we have right now seem to be not enough to answer for the present situation. So, the alternative choice is new process designing or DMADV.

4.4 Design new process or Design Phase

4.4.1 Study requirement form both internal and external

For effective result, Kano model was chosen to be a template of design. This model shows the relationship between quality and customer satisfaction. There are four areas in the graph which come from the intersection of quality on X axis and Satisfaction on Y axis. See figure 4.16 - 4.17

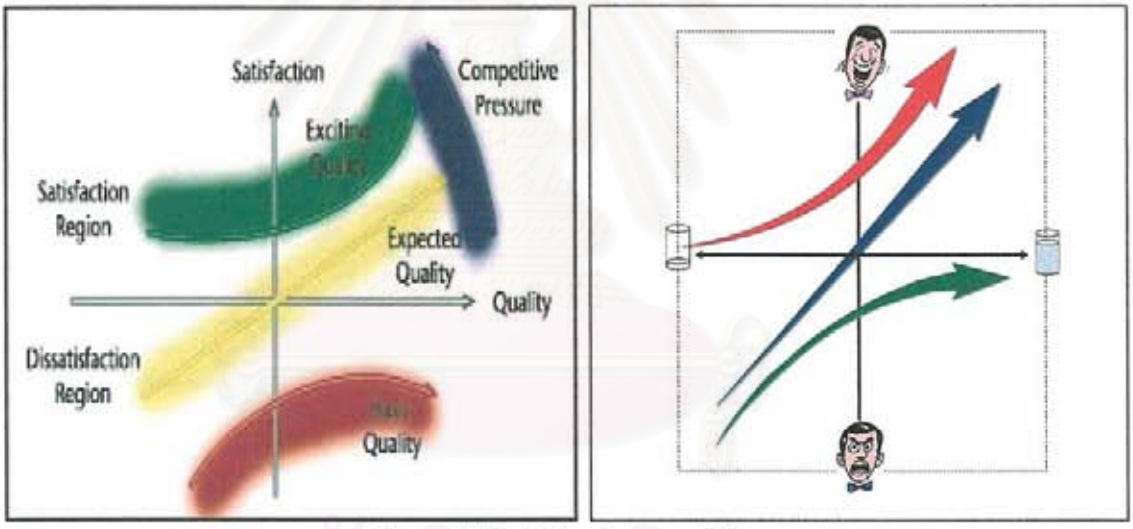


Figure 4.16- 4.17 – Kano model

Source: http://www.qualitydigest.com/nov99/assets/images/Pyzdek_Kano_Model.jpg [21/11/2007]

The customer expectation is not stable. It is very dynamic and competitive pressure in the market is also one of the main factors that raise the customer expectation with no boundary. So, from the Kano model, the key point is how do we keep the exciting quality from customer satisfaction?

With the Kano model perspective, the objective of this design phase will be focus on the "voice of customer" first and then combine with the information from the measure phase. The new process should be serving with the all problem of fiber usage as much as it can.

In this case, this design focuses on only process so there is no competitive information or compares the process or product with competitor or benchmarking, See result in table 4.5.

Criteria / Epected cause	Time consume	Effect to scrap: fiber	Solve by internal resource	Total	Catagories	Summary
First of roll	1	1	1	3	Defect	3
End of roll	1	1	1	3		
Stress of operator	2	1	2	5	Excess usage	6.5
Skill of operator	2	3	2	7		
Discipline of operator	2	2	2	6		
Not good measure equipment	2	3	2	7		
Not proper stripper	2	3	2	7		
Miscommunication	2	3	2	7		
Can not record the fiber length on the coupler machine	2	2	2	6	Inventory data	5.5
The actual length is not same as attached label	1	2	2	5		
Excess loss	1	2	1	4	Yield	4.6
Fail pack	1	3	1	5		
Fail crack	1	3	1	5		

Table 4.5 Expected cause & Criteria table

The previous paragraph showed the priority of factor which effect to scrap cost in the existing line. This information is the internal focusing. It come from the information in the operation or manufacturing feed back. There are also same meanings as voice of customer in term of Kano model. The customer is manufacturing and the service unit is improvement team. So, the voices of customer in term of internal focusing have 2 main areas which are excess usage and inventory data.

More over internal focusing, there is also need to consider the requirement from customer also. The normal requirement or basic quality is the fiber length of finished goods should be within specification and the tolerance of fiber length will be narrower in

the future. We can say that if we want to raise the quality of draw process in the quadrant 2 on the line expected quality in graph . The new process should be have the Cpk about 1.33 reference from Douglas C. Montgomery, the recommend minimum value of the process capability for existing process is 1.33 in Two-sided Specifications and 1.25 One-sided Specification, See figure 4.18

Table 7-4 Recommended Minimum Values of the Process Capability Ratio

	Two-Sided Specifications	One-Sided Specifications
Existing processes	1.33	1.25
New processes	1.50	1.45
Safety, strength, or critical parameter, existing process	1.50	1.45
Safety, strength, or critical parameter, new process	1.67	1.60

Figure 4.18 - the recommend minimum value of the process capability

In the Kano model, it also shows that only expected quality is not enough to be a leader in the market because there still has the influence from competitive pressure to drive the expected quality standard higher. That mean to serve with excellent feed back from customer, the new process should be make the result in the curve of exciting quality. So, the next step of information is find out the point that can make the customer accepted the new process in the feeling of exciting quality.

As mention on the chapter1, this company is the electronic manufacturing service provider. The key performance is manufacture the product follow as customer require. Main of the profit comes from service cost and material cost. To understand the external factor of this company, the external Factor Evaluation,(EFE) has arrange in the past 2 year, see table 4.6 .

The External Factor Evaluation (EFE) Matrix: 2005

Key External Factors	Weight	Rating	Weighted Score
Opportunities			
Projects trends in year 2015 will be increase.	0.050	4	0.200
Thailand has had a good infrastructure	0.075	4	0.300
The key OEM strategic plans are outsourcing.	0.125	4	0.500
Highly supported in Nanotechnology by the government	0.035	2	0.070
Opportunity in China	0.125	3	0.375
Internet usage in the future	0.125	2	0.250
Threats			
Lack of ubiquitous broadband access	0.100	2	0.200
Terrorist problem	0.070	2	0.140
Bird flue epidemics	0.070	2	0.140
High development of China &SEA countries	0.100	3	0.300
Oil crisis	0.125	2	0.250
Total	1.000		2.725

Table 4.6: EFE Matrix

If we compare the dynamic of external factor between 2005 and 2007, it will be found very much change in the many topics. Even trend of telecommunication project has still increase and most of the OEM has still found the developing country for manufacturing base. Focusing in 2007, there have a big impact form many point. Most of the factor that influence for export business is exchange rate between Thai baht and US dollar which reduce from ~ 40 to ~32 baht per one dollar. From this change, some export industry got the effect. There are some company mostly relate in export garment business were closed. Including with the widely expansion of oil crisis with start from

2005 and it is still has not stable till 2007. It makes the impact in all market both actual impact and psychological impact. The impact of unstable politic is also making the impact in term of Thailand economic.

So, the result of EFE should not be good as 2005 data because Thailand absorb many impact such as oil crisis, exchange rate fluctuation and political issue. On the other hand the other countries as China and Vietnam have more advantage both political and low cost manpower. In term of business as service provider in Thailand only produce follow as instruction is not enough to keep the OEM not move to the other low cost country.

Understanding customer direction and the effective reacting for customer requisition are the expected quality in term of business as service provider. For develop the exciting quality in this business, contract manufacturer should be involve or propose the opportunity to improve process which can serve to the main project of customer base on win-win situation view rater than just follow the process or schedule from customer .

Then, transferring above idea with the scrap cost problem. The reason that customer want to change new fiber type is serving to the requirement of end customer. The high volume of loss, parameter of product, occurs by characteristic of the old fiber. Right now, the way to solve this problem is only finding the suitable characteristic of fiber which serves to end customer requirement. The trend of this problem seems to be not stopping only this level. It will be higher and higher.

Normally, if contract manufacturer can make a yield reach to the contract all of scrap will be absorb by customer and contracted manufacturer will absorb scrap on the cost that come from yield lower than contract. Even we can operate new product using new material with a little bit low yield from the target, the scarp cost is not increase rational as it should be but it effect to the scrap cost per unit about 30%. That means this problem effect to profit of this business unit directly.

From information of external effect study, the way to operate product with new type of fiber with the win-win situation between company and customer is the key objective to drive the customer satisfaction move along the exciting quality curve as in the Kano model.

4.4.2 Combine both internal and external requirement for design new process

With the inspiration to make the exciting quality, both of internal and external should be combining together and try to design new process to serve with all requirements as much as it can. From the previous data, it is quite hard to get the Cpk=1.33 by using human and existing equipment. Including with the requirement with narrower tolerance in the future, improvement team decide to design a machine to reduce error from the human in the draw process.

Improvement team list the function of the machine by reference on the list of requirement from manufacturing feed back and also serve to the target that Cpk of fiber length should be 1.33. Following the Cpk at 1.33, the customer and company will not suffer to the cost of scrap even the price of new material will be higher. Or we can say that the price of material as fiber will not be the barrier for customer to developed product to compete in the market. The function of machine listed by improvement team was shown in table 4.7.

Requirement	List of function
Excess usage	Can feed fiber length within specification.
Excess usage	The Cpk of this machine should be at least =1.33
Inventory data	Know the accumulate length that was feed out.
Excess usage	No human error effect to fiber length
Improvement team	New draw process should be synchronize with others
Improvement team	Ease of use
Improvement team	No fiber damage occur after use feeding machine
Improvement team	Good machine lay out ; comfortable
Improvement team	No limit of feed length, incase NPI use higher length

Table 4.7 – List of function

4.4.3 Design feeder machine

The limitation of this design is patent of the coupler machine. That mean, implement team can nt design feeder machine working with coupler machine. The only one way is design prototype to install on the coupler machine and the controller of feeder machine should be separate from the main controller. So, the concept of this machine will be defined as a knock down. It can be able to install and remove easily.

In actually, there are some application already have the feeder machine but it can not use in this case. The different factor which make this process can not apply the simple feeder machine as other application are Fiber roll will not rotate during draw the fiber because it was linked to laser source, The material which we want to feed is very sensitive and ductile. Position of fiber locates at the high level and fix position. To understand the problem all factor will describe in more detail next.

- Fiber roll will not rotate during draw process, see figure 4.19 for reference.

The yellow line at the fiber roll is the laser source which should be connects with fiber all the operating time. So, the blue roll cannot rotate during draw the fiber. Most of the feeder machine apply to measure feed length by round of the roll and then convert to length but it really not apply in this case. Follow the normal operation fiber will be pulled from the left side pass through the circle ring which locate on the left side of the fiber roll, see figure 4.19

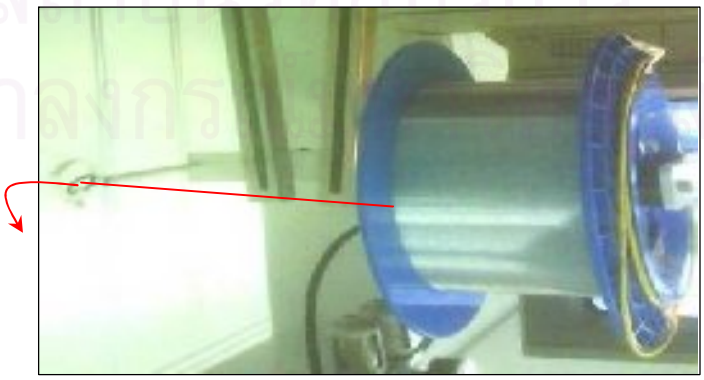


Figure 4.19 – Fiber drawing direction

- The material which we want to feed is very sensitive and ductile, see figure4.20-4.21

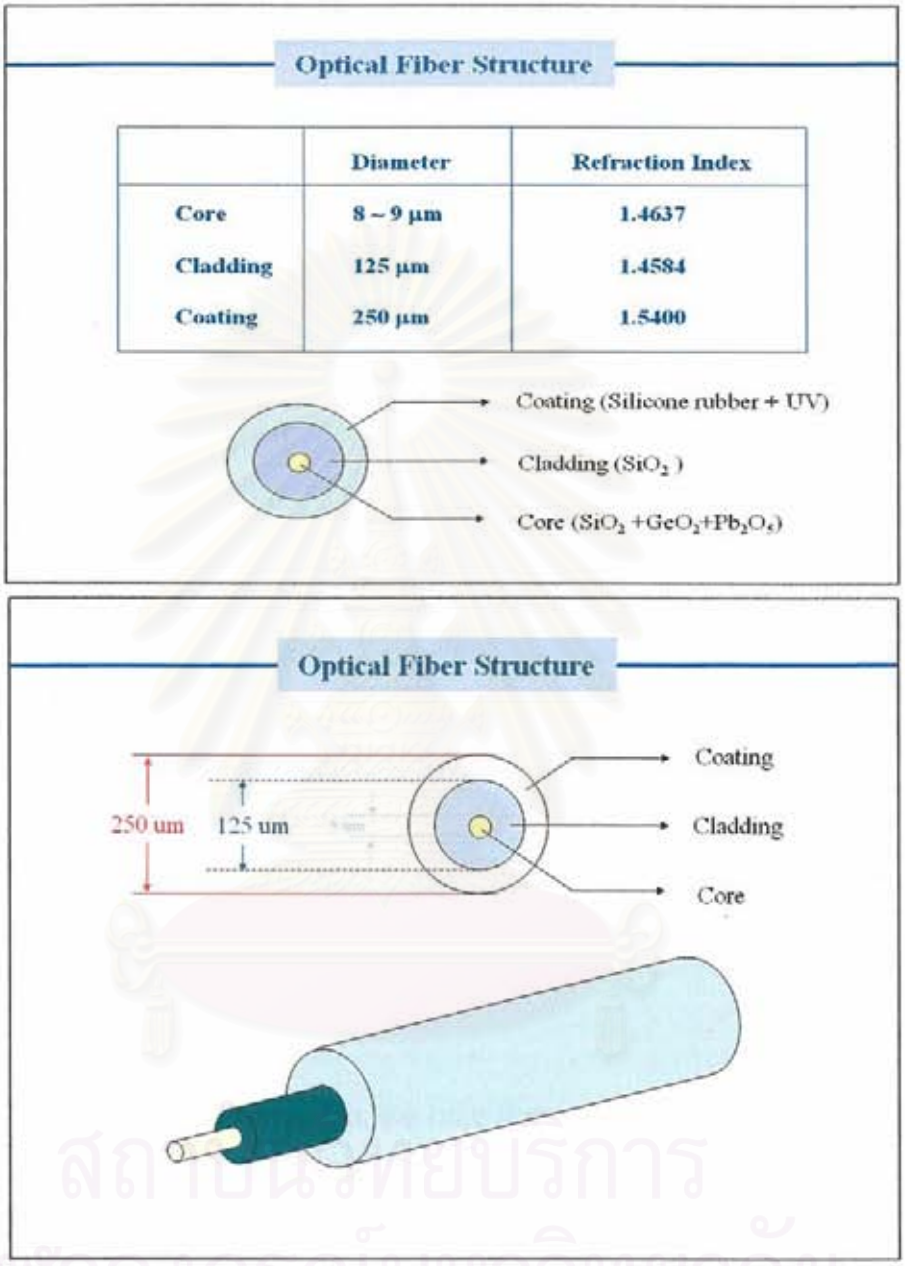


Figure 4.20 - 4.21 Optical Fiber Structure

The dimension of bare fiber which is the typical using fiber in the production line is 250 micron. There compose of three layer Core cladding and coating which made of different material, see picture for more detail. The area using to transfer the light source is only 9 micron called core. At this area made from composition of silica so, the characteristic is nearly same as glass. That mean this area will be break if it absorb over

force. At the outside of bare fiber made of silicone rubber and UV so it helps to protect and absorb force to damage core a little.

More over the size and material property of fiber, there are still have critical value in mechanical property to beware during using or apply this bare fiber. There are short term bend radiuses; Long term bend radius and Proof test level which are absolutely need to be strictly followed up during application. The below table come from fiber specification of OFS fiber which load in the www.ofs.com,see figure 4.22

Dimensions/Geometric Properties		
Core diameter (nominal)	4.4 μm	3.6 μm
Clad diameter	125 ± 2 μm	125 ± 2 μm
Coating/Buffer diameter	245 ± 15 μm	245 ± 15 μm
Clad non-circularity	≤2.0%	≤2.0%
Core/clad offset	≤0.3 μm	≤0.3 μm
Buffer/Coating Descriptions		
Coating material	Dual UV Acrylate	Dual UV Acrylate
Operating temperature	-40°C to +85°C	-40°C to +85°C
Mechanical and Testing Data		
Short-term bend radius	≥5 mm	≥5 mm
Long-term bend radius	≥9 mm	≥9 mm
Proof test level	≥200 kpsi (1.38 GPa)	≥200 kpsi (1.38 GPa)

Figure 4.22 – Fiber Specification

Source: www.ofs.com[20/11/2007]

For the sample specification, the bare fiber should be apply for bending higher or equal 5 mm. radiuses in short term and higher or equal 9 mm. in long term application. The bare fiber can pass proof test in the higher or equal 200kpsi. That mean the feeder machine should be design for operate bend radius higher or equal to 9 mm. In the actual operating, along the cycle time the detector will use to record the power to calculate the loss in many times during produce one coupler. If the feeder machine is not design properly, it will make wrong information to grading the finished good cause bending loss.

Bending loss is occur when fiber bend more than specification. It will make some propagation of light source pass through outer core within some angle. The below picture will show the idea of bending loss and relationship between bending diameter and loss, dB, see figure 4.23-4.24.

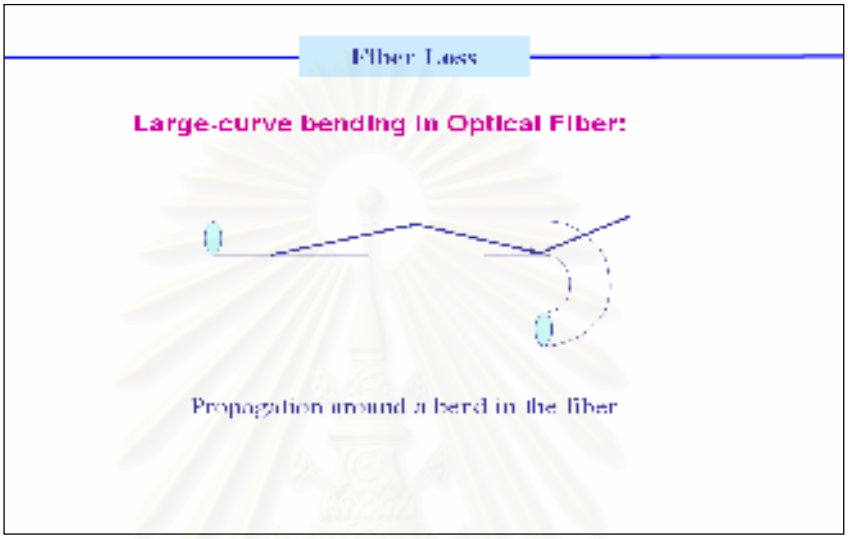


Figure 4.23 - Fiber loss

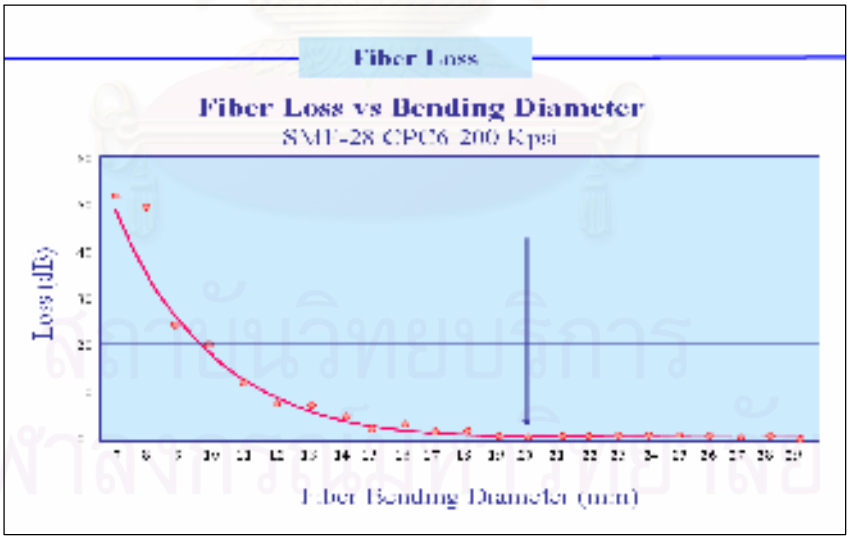


Figure 4.24 - Fiber loss

The next step will show the photo of normal bare fiber compare with the defect which occur during operation. The reason that make scratch or some damage mostly come from only pull bare fiber pass through with the sharp edge with the small force, see sample photo below. The objective of these photos, see figure 4.25-4.29 is to reflect

the image of bare fiber needs to make the special good handling. And it should be one of the criteria that improvement team should be friendly design with this properties.

Figure 4.25 – Clear natural fiber

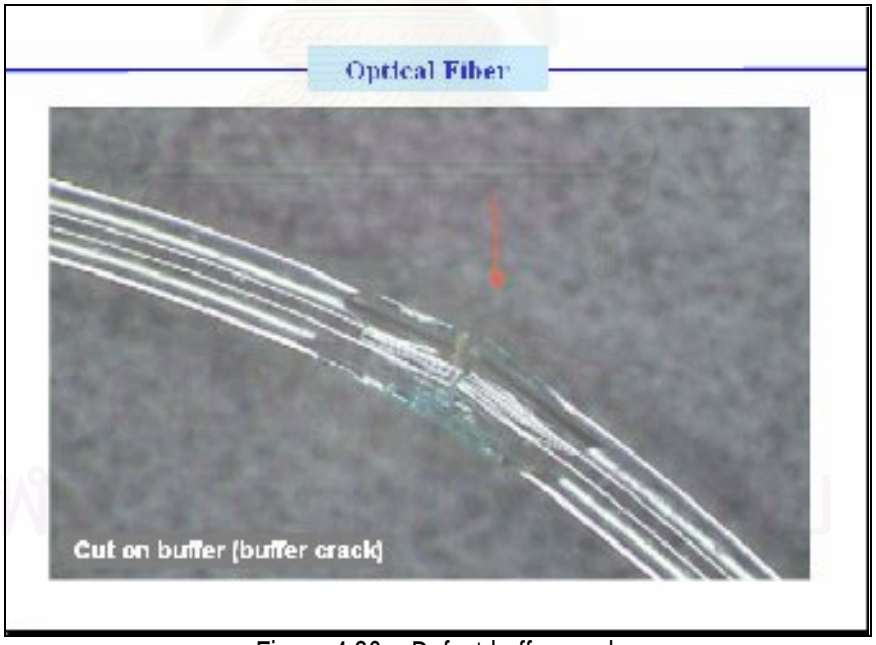


Figure 4.26 – Defect buffer crack

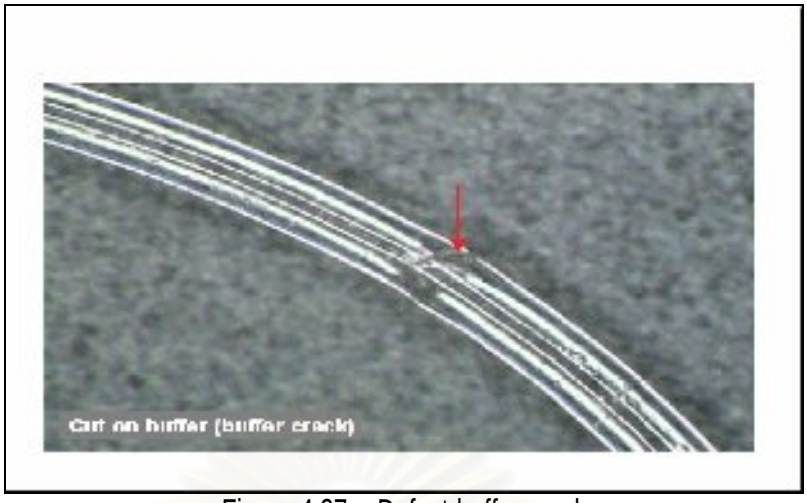


Figure 4.27 – Defect buffer crack

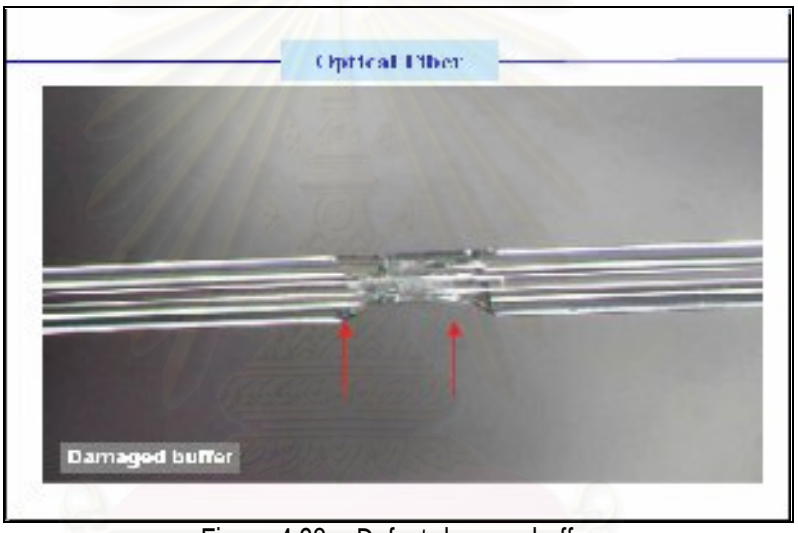


Figure 4.28 – Defect damage buffer

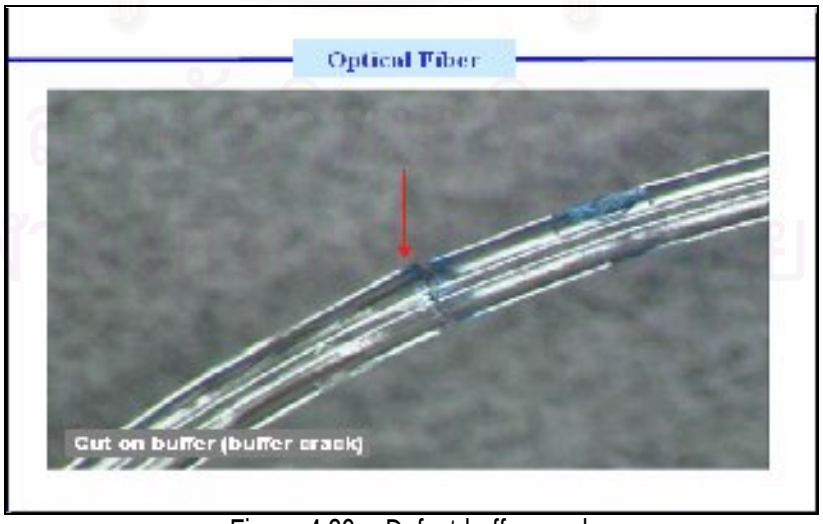


Figure 4.29 – Defect buffer crack

- Location of roll fiber is not available to move

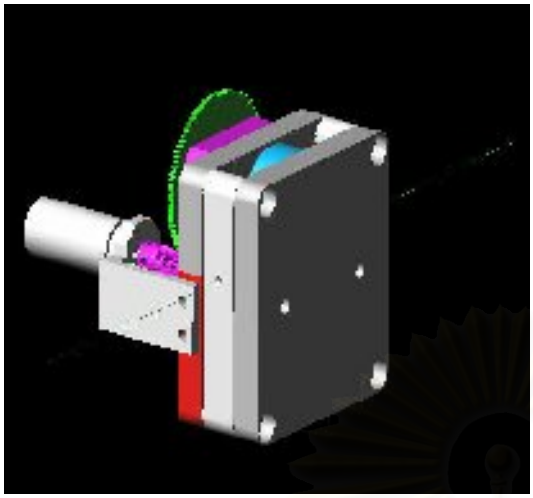
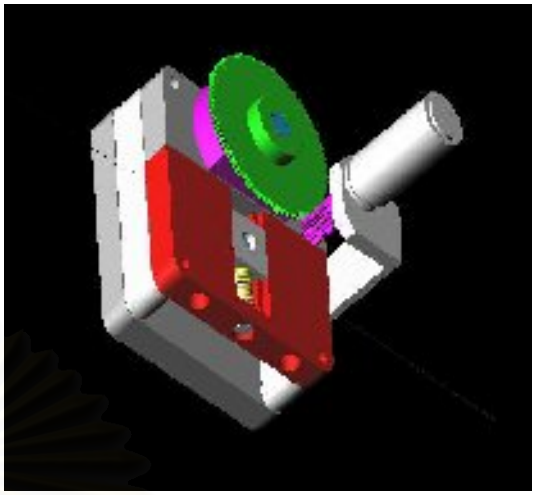
Cause limitation area on the coupler machine and length of laser source

In each machine, there is not easy or the good idea to change the position of roll fiber. Fiber loosen by itself is also one of the problem which feed back from operator. From the pull procedure which operate in existing is pull the fiber pass an iron ring at the left side of the roll. It is not have any problem in this case because stress of fiber which pulled at the side of the roll can release. On the other hand, if we use a roller to feed fiber, the stress should be make the fiber loosen itself (loosen more than 2 turn automatically) and then fiber will be broken spontaneous.

Figure 4.30 Area at coupler machine

Finally, the improvement team has a final prototype of fiber feeding which is based on the requirement both internal and external and sees the prototype of feeder machine in below picture, see figure 4.31-4.35.

- Separate control unit.
- Prevent fiber loosen by itself
- Not bend fiber which radius less than 9m.m.
- Ease of use
- Prevent to make fiber damage
- No sharp edge on the machine
- Can record accumulate length within one roll
- Can work with the other process smoothly.



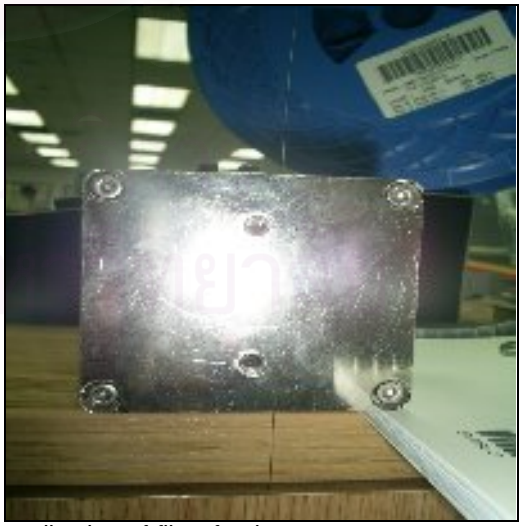


Figure 4.31 -4.35 Model & application of fiber feeder

Figure 4.36- Feeder machine

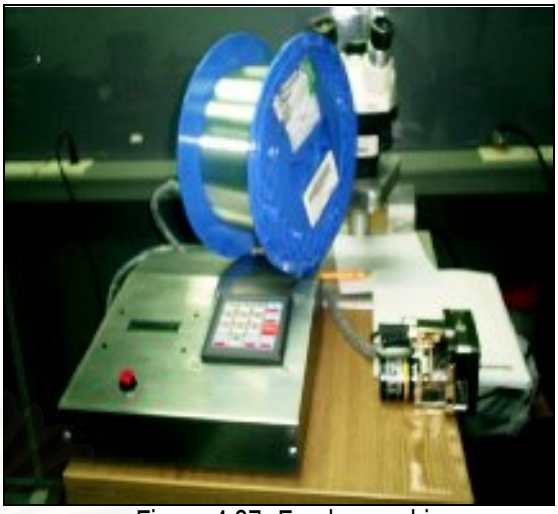


Figure 4.37- Feeder machine

The prototype of feeding machine comprise of control unit (the stainless box), foot switch and feeder (encoder and gear), see figure 4.36-4.37. The fiber will pulled by the two roller which made of soften surface material with the suitable spring force which is not make fiber damage. To feed the fiber operator just guide the fiber in to the Input hole, green arrow and then fiber will pull out from the output hole, red arrow , see figure, see 4.38-4.39. The accumulate length and target length will be recorded and set up target from the control unit.

Figure 4.38- feeding direction

Figure 4.39- Feeder machine

After test the prototype in the production line, we can design lay out which relate to the next process. There are not make the longer cycle time anymore and also can find some technique to prevent the fiber break by stress but it will not describe deeply in this paper. So, this testing can answer in term of setting lay out, effect the conjunction between draw process and strip process and basic procedure to feed the fiber as long as request .

However, only testing in the production line is not enough information to summarize that this design can implement as the common equipment in the production. So, the next step of this project should be considered in the Verify phase.

4.5 Verify Phase

4.5.1 Criteria to verify the feeding machine

According to De Feo and Bar-Ei, 2002 Verify phase – The purpose of the Verify phase in the DMADV sequence is to ensure that the new design can be manufactured and supported in the field within the required quality, reliability and cost parameters. After verification tests and pilot runs, the design is finalize and a ramp-up to full-scale production occurs to highlight any potential production problem. To accept the feeding machine as a common use in the production, feeding machine should be passed three conditions. There are physical property, manufacturing efficiency and optical property.

1. Physical property of fiber - The fiber which is feed by machine will not damage in term of physical property for example Crack, Delaminating and Scratch.
2. Manufacturing efficiency - The finished good, coupler which is feed by machine will not make the longer cycle time and yield should be same as coupler which feed by manual.
3. Optical property - The difference of insertion loss between grading from coupler machine and from test machine should be within specification.

To record the data, feeding machine was set up the schedule to test run in the production line. Team also uses the same coupler machine number and operator as during record fiber length last time. The time for this test run is one shift, 8 hour. Normally, the feeding fiber is not related to yield directly. There is only one critical point in term of yield is the force of roller which pushes the fiber is effect to the power value at the detector or not. And all three technique condition will describe in below paragraph.

During test feeding machine in the production line, the sample of fiber feed by machine was collected. And use microscope to check the physical property by experience operator. Refer to quality standard of fiber -physical property using in the production line, there are no damage on fiber which feed by machine.

The cycle time and yield are also recording during test run. The result show that there feeding machine application is not make cycle time longer and production yield also nearly same present condition. The different of power, dB which read by detector between roller push on the fiber and no pushing force on fiber are no different anymore. This result shown that the application of feeding machine in coupler machine is not effect to manufacturing yield and cycle time but this is not enough for summary in case of optical property

One way to prove that the effect in optical property from feeding machine did not make optical property over specification is compare optical data with some calibrated value or some standard machine. In existing process, there also have testing machine to confirm the optical property after passed coupler machine and this entire testing machine is under maintenance schedule which has a calibration twice a year and also GR&R test. So, we can reference the different of optical property between machine feeding and manual feeding by optical value from testing machine.

So, 5 finished good was chosen from the output during test feeding machine and also 5 pieces from the normal production. The interesting value is insertion loss which shows on the coupler machine and then brings all samples to pass testing

machine, power meter. The specification is different of is insertion loss, IL value between coupler machine and power meter should be ± 0.2 dB. If the different value over ± 0.2 dB, this feeding machine can not using in the production line.

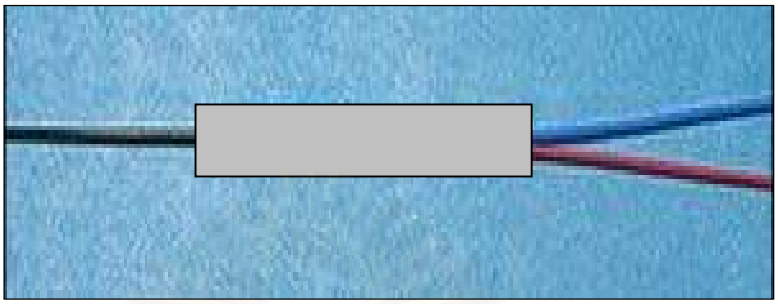


Figure 4.40- Input -output port of coupler

From the specification of fused biconic taper coupler, the insertion loss, IL will be measured both two leg of input which are blue color and red color, see figure . The data of insertion loss of all sample which measure from both coupler machine and power meter shown in the table 4.8.

Serial (Auto feeding)	Power Meter		Coupler Machine		Diff(meter - machine)	
	Blue	Red	Blue	Red	Auto feed B	Auto feed R
264009085	2.46	4.09	2.43	4.13	0.03	-0.04
264009081	2.50	4.17	2.46	4.15	0.04	0.02
264009070	2.46	4.21	2.41	4.18	0.05	0.03
264009074	2.57	3.93	2.50	3.94	0.07	-0.01
264009076	2.56	4.03	2.50	4.02	0.06	0.01

Serial (Normal process)	Power Meter		Coupler Machine		Diff(meter - machine)	
	Blue	Red	Blue	Red	Normal B	Normal R
264009005	2.44	3.93	2.52	3.91	0.02	-0.08
264009059	2.53	3.94	2.43	4.05	-0.11	0.10
264009061	2.44	4.00	2.32	4.13	-0.13	0.12
264009063	2.45	4.14	2.48	4.04	0.10	-0.03
264009064	2.48	4.00	2.42	4.00	0.00	0.06

Table 4.8 – Insertion loss data

In actually, the raw data of different insertion loss between coupler machine and power are within the specification but to make it as scientific data, the summary should be refer to the statistical method.

4.5.2 Application of statistical method

For convenience and exact result, Minitab software was used to calculate and plots a graph. This statistical testing objective is “mean of different insertion loss value between use feeding machine and manual feed are same or not”. To have a clear picture in all data, the simple value in statistical of both groups will be plot such as mean, median, standard deviation and etc..., see figure 4.41-4.43. Because of two input fiber in one coupler, the grouping will separate in four groups which are

1. Input red color, auto feeding
2. Input red color, manual feeding
3. Input blue color, auto feeding
4. Input blue color, manual feeding

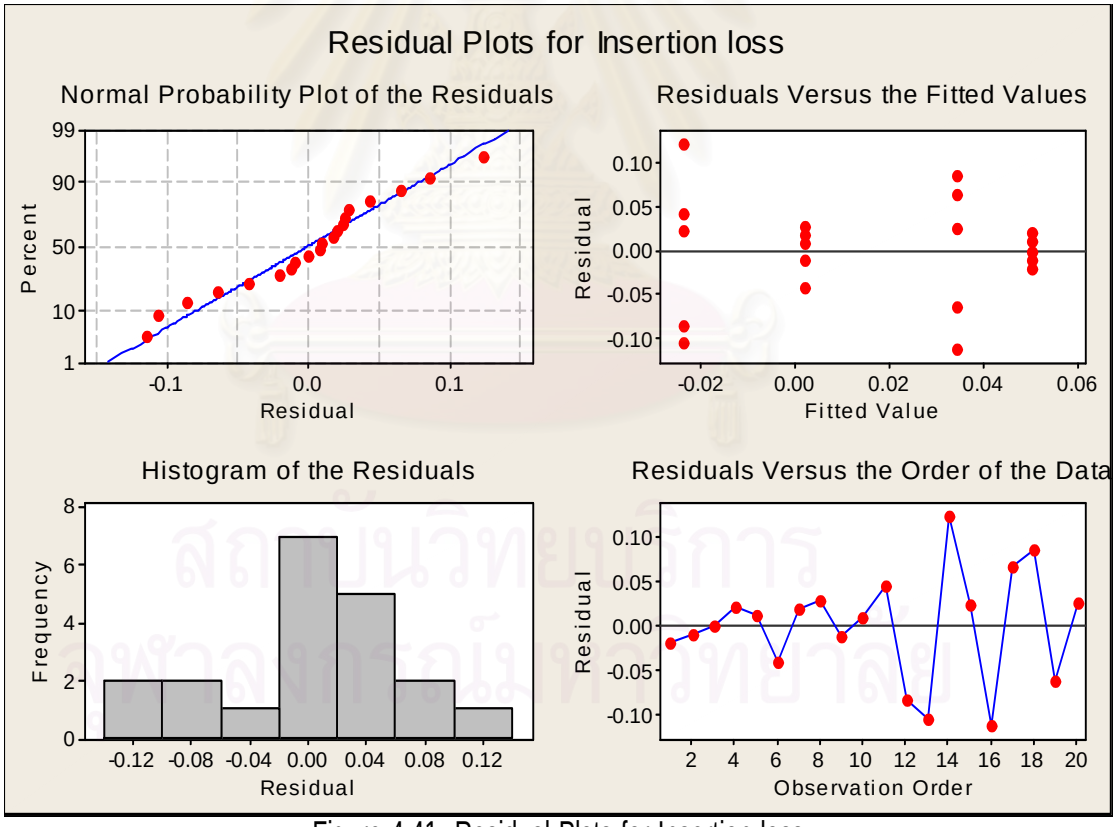


Figure 4.41- Residual Plots for Insertion loss

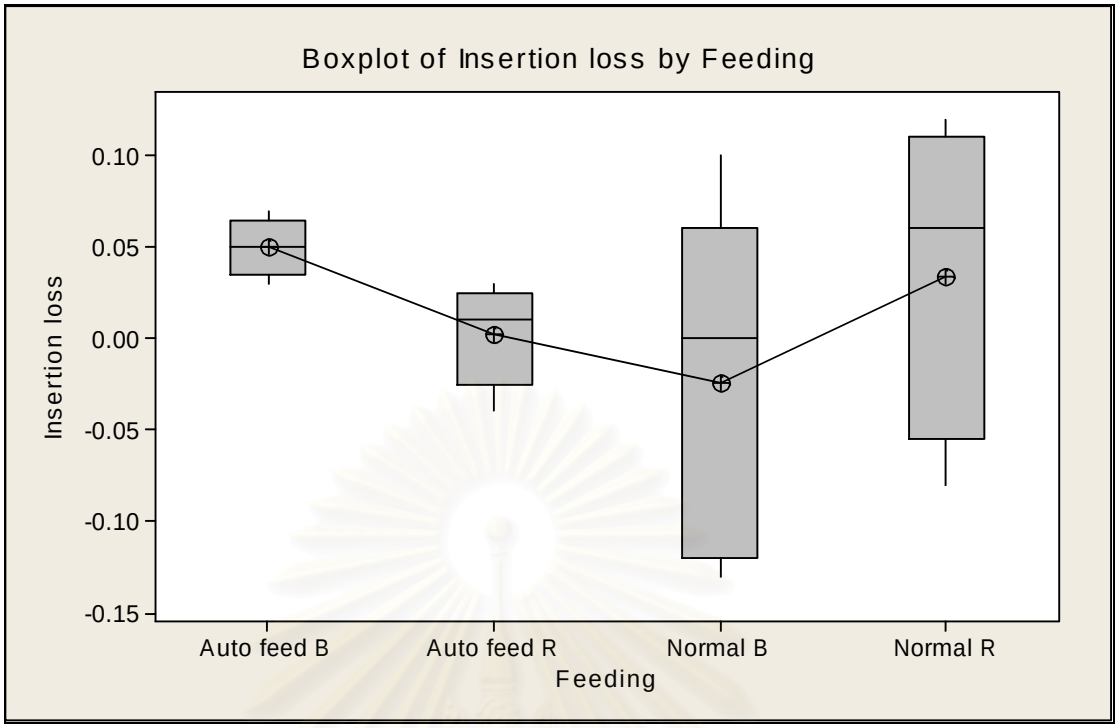


Figure 4.42- Boxplot of insertion loss by feeding

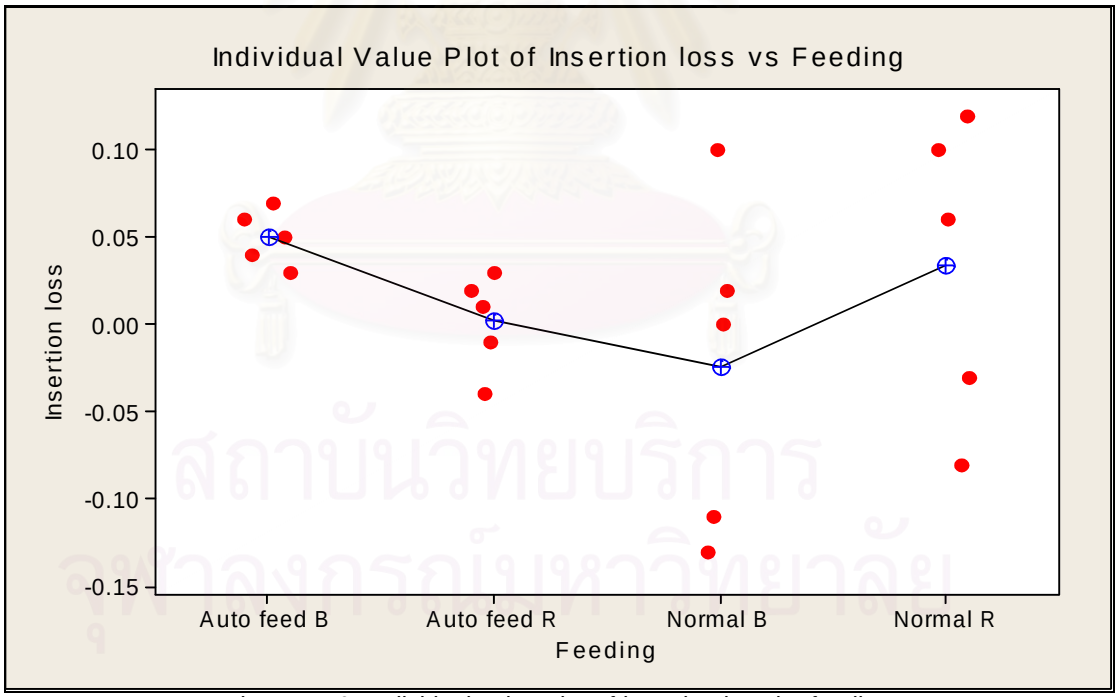


Figure 4.43- Individual value plot of insertion loss by feeding

Descriptive Statistics: Blue Auto, Blue Manual, Red Auto, Red Manual

Variable	N	N*	Mean	SE Mean	StDev	Variance	Minimum	Q1
Blue Auto	5	0	0.05000	0.00707	0.01581	0.00025	0.03000	0.03500
Blue Manual	5	0	-0.0240	0.0427	0.0956	0.0091	-0.1300	-0.1200
Red Auto	5	0	0.0020	0.0124	0.0277	0.0008	-0.0400	-0.0250
Red Manual	5	0	0.0040	0.0304	0.0659	0.0074	-0.0800	-0.0550

Variable	Median	Q3	Maximum
Blue Auto	0.05000	0.06500	0.07000
Blue Manual	0.0000	0.0600	0.1000
Red Auto	0.0100	0.0250	0.0300
Red Manual	0.0600	0.1100	0.1200

Before move to the hypothesis testing, the important value that should be confirmed is power and the sample size. This test is to make sure that the quantity of the sample sufficient to reference the conclusion of hypothesis testing. The following is power and sample size calculation of both red and blue input.

One-way ANOVA: Blue Auto, Blue Manual

Source	DF	SS	MS	F	P
Factor	1	0.01369	0.01369	2.92	0.126
Error	8	0.03752	0.00469		
Total	9	0.05121			

S = 0.06848 R-Sq = 26.73% R-Sq(adj) = 17.57%

Level	N	Mean	StDev	Individual 95% CIs For Mean Based on Pooled StDev
Blue Auto	5	0.05000	0.01581	(----------*----------)
Blue Manual	5	-0.02400	0.09555	(----------*----------)
				-0.060 0.000 0.060 0.120

Pooled StDev = 0.06848

Power and Sample Size

2-Sample t Test

Testing mean 1 = mean 2 (versus not =)
Calculating power for mean 1 = mean 2 + difference
Alpha = 0.05 Assumed standard deviation = 0.06848

Difference	Sample Size	Power
0.2	5	0.980079

The sample size is for each group.

For blue input, the sample has enough power, 98%. That mean 5 sample size is sufficient to reference the hypothesis testing result.

One-way ANOVA: Red Auto, Red Manual

Source	DF	SS	MS	F	P
Factor	1	0.00256	0.00256	0.63	0.451
Error	8	0.03260	0.00408		
Total	9	0.03516			

S = 0.06384 R-Sq = 7.28% R-Sq(adj) = 0.00%

Individual 95% CIs For Mean Based on Pooled StDev

Level	N	Mean	StDev	---+---------+---------+---------+------
Red Auto	5	0.00200	0.02775	(-----------*-----------)
Red Manual	5	0.03400	0.08591	(-----------*-----------)
				---+---------+---------+---------+------
				-0.050 0.000 0.050 0.100

Pooled StDev = 0.06384

Power and Sample Size

2-Sample t Test

Testing mean 1 = mean 2 (versus not =)
Calculating power for mean 1 = mean 2 + difference
Alpha = 0.05 Assumed standard deviation = 0.06384

Difference	Sample Size	Power
0.2	5	0.990378

The sample size is for each group.

For Red input, the sample has enough power, 99%. That mean 5 sample size is sufficient to reference the hypothesis testing result.

According to One-way ANOVA which uses to calculate pooled StDev value for using in power and sample feature, P – value in ANOVA test of both red input and blue input are also higher than 0.05 which is the standard level of significant. The conclusion of this test are mean (μ) of auto feed and manual feed are same of both red input and

blue input group are same or mean of different insertion loss, red input both auto feed and manual feed are same with significant level = 0.451 and mean of different insertion loss, red input both auto feed and manual feed are same with significant level = 0.126.

Anyway, One-way ANOVA will use to calculate in the assumption that both samples should have equal variance, (σ). So, the equal variances testing should be use to confirm the result of One-way ANOVA before conclusion. F-test and Levene's test is the tool for this testing. Below is the result of F-test and Levene's Test from Minitab software, see figure 4.44-4.45.

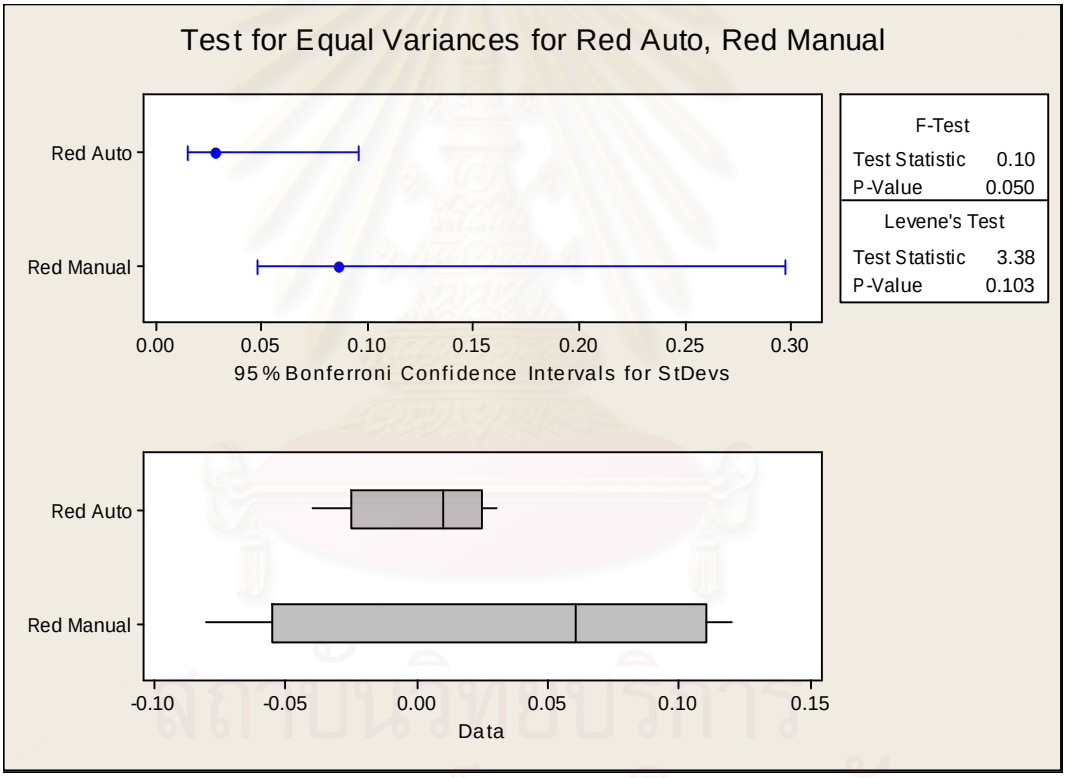


Figure 4.44- Test for equal variances for Red Auto & Red Manual

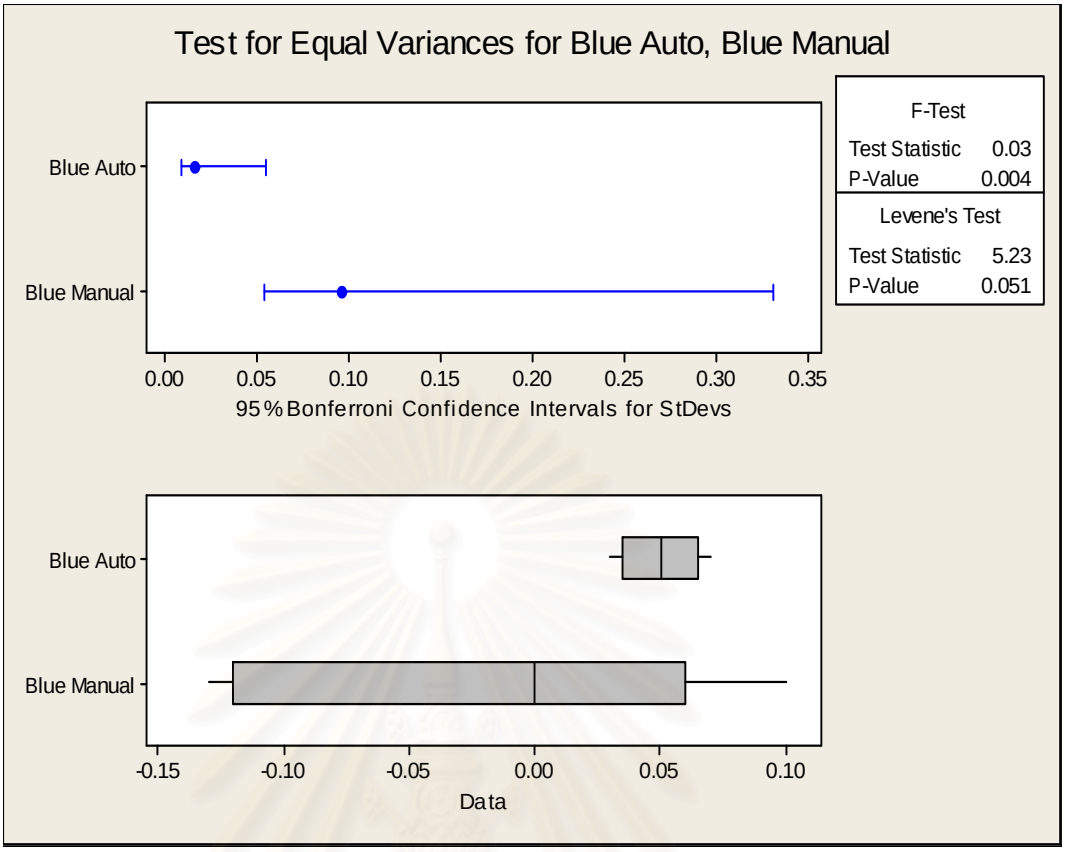


Figure 4.45- Test for equal variances for Blue Auto & Blue Manual

The result shown there are not same variances in blue input in F-Test. P-value equal to 0.004 which is lower than normal significant level, 0.05. More over the other P-value are also not higher than 0.05 so much. For example, F-test of blue input = 0.05.

To test mean (μ) of auto feed and manual feed are same of both red input and blue input group with the assumption that both two group are difference variance, two samples T-test is used. And the following is the plot and calculate of T-test by using Minitab software, see figure 4.46 – 4.47.

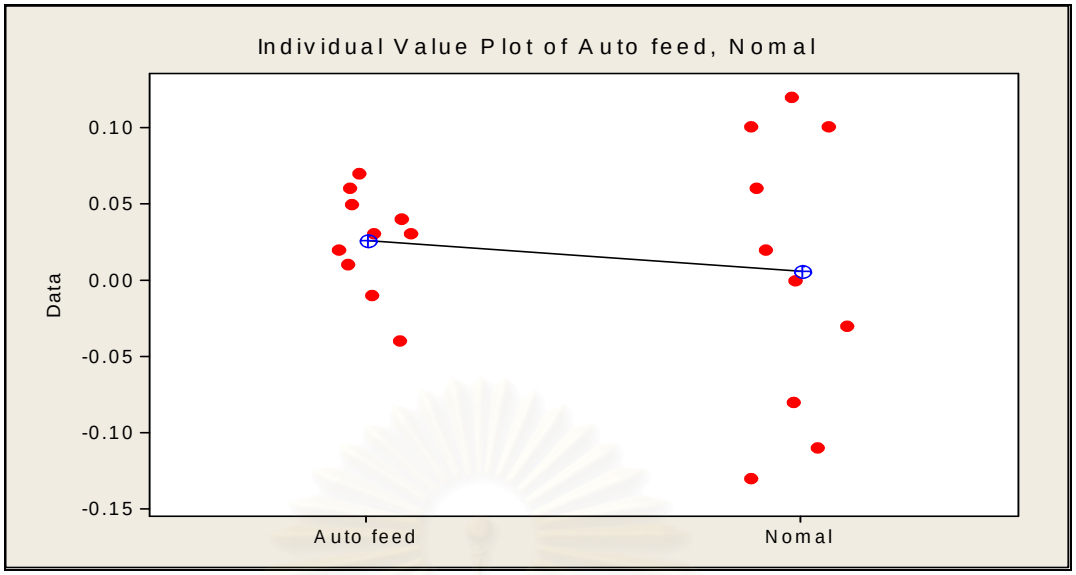


Figure 4.46- Individual Value Plot of Auto feed & Manual

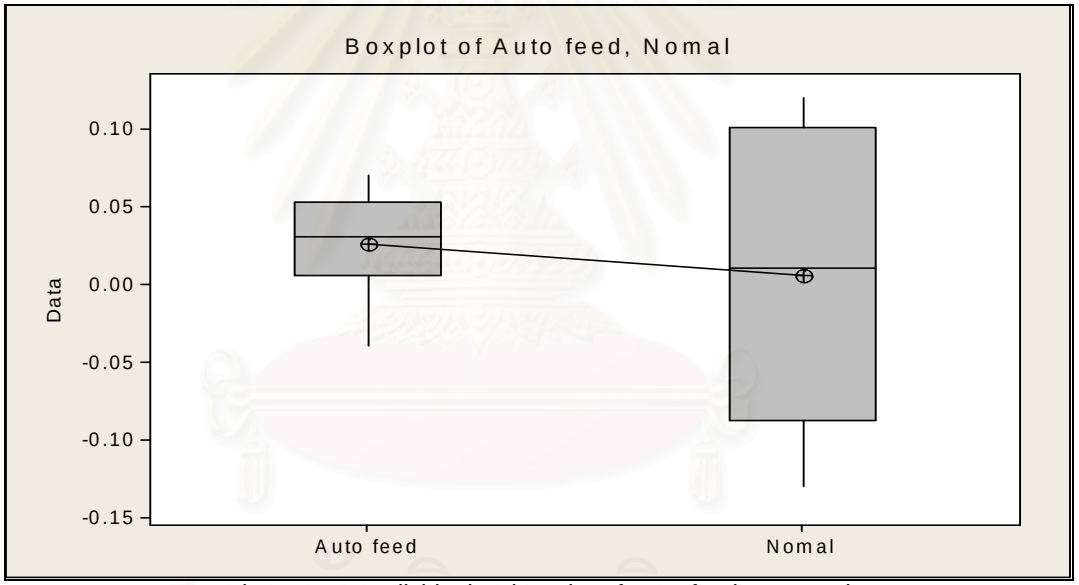


Figure 4.47- Individual Value Plot of Auto feed & Manual

The result show P-value of both red input and blue input are higher than 0.005. so, conclusion is even difference variance, the mean (μ) of auto feed and manual feed of both red input and blue input group are same.

From the statistical testing, the sample of auto feed (different insertion loss between coupler machine and power meter) have lower variance than manual feed (different insertion loss between coupler machine and power meter). That mean there are some change from feeding machine application but trend of the different value seem to be reduce. It is implying that the value of insertion loss when using feeding machine are closer insertion loss from power meter than insertion loss when using manual feed. However, there is no advantage in manufacturing from this closer. But it should be interesting point for further study.

Secondly, we can conclude the assumption mean (μ) of auto feed and manual feed of both red input and blue input group are same or not. The result is equal mean (μ) among two sampling group. That means feeding machine can apply in the production line and it does not make the optical property of coupler change over specification.

The prototype of feeding machine is passing all three technical conditions. At this point, we have enough information to refer the effect of this machine in the manufacturing.

4.5.3 Process capability of feeding machine

The process capability is one of the requirements of this design. Our target process capability is 1.33. In this experiment, the feeding machine will be programmed 5 different lengths, around 10 to 200 cm. 3-10 times per each target length. Then, record the over length that feeding machine feed over target length form programmed. The below graph shown the matrix plot of length with variation, see figure 4.48.

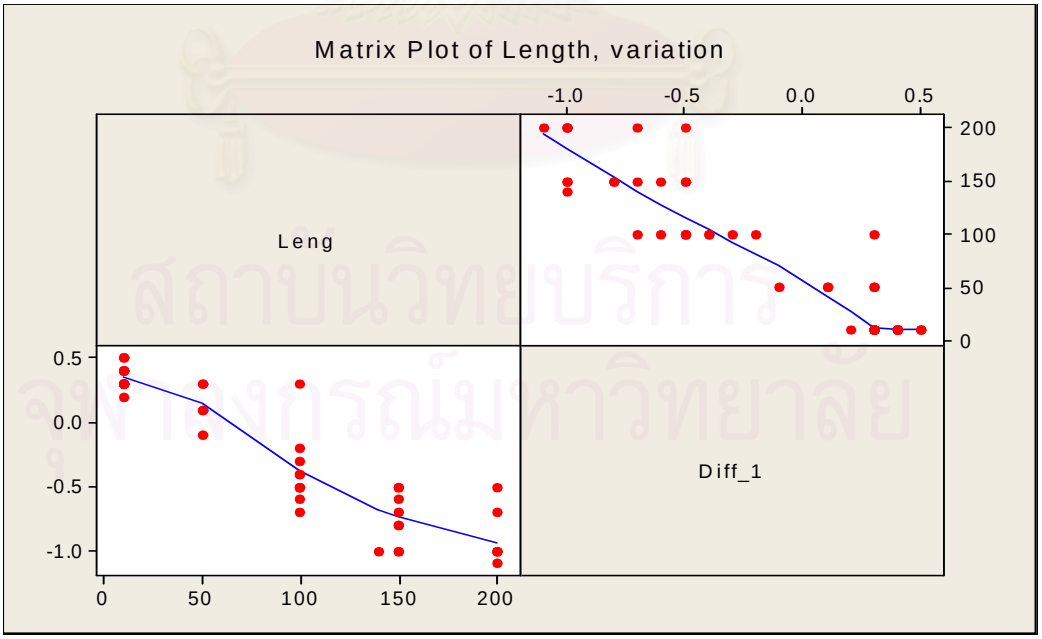


Figure 4.48- Matrix Plot length variation

From the matrix of length and variation, remain length form feeding machine is not over 1 cm with in target length from 0 – 200 cm. but the error of actual length and target length is not stable. It quite accurate in the length which operate about 40-60 cm. and trend to be more in positive for target which operate less than 50 cm. for example operate target at 30cm. the error will be longer than target about 0.3 cm.. On the other hand, if the operate target was set higher than 50 cm; the error will be shorter than target. For example, operate target at 100cm. the error will be shorter than target about 0.5 cm

According to variation of error, the graph of length and average difference in each operating target, see figure 4.49 was plotted to estimate the effect of error in the range of actual working length.

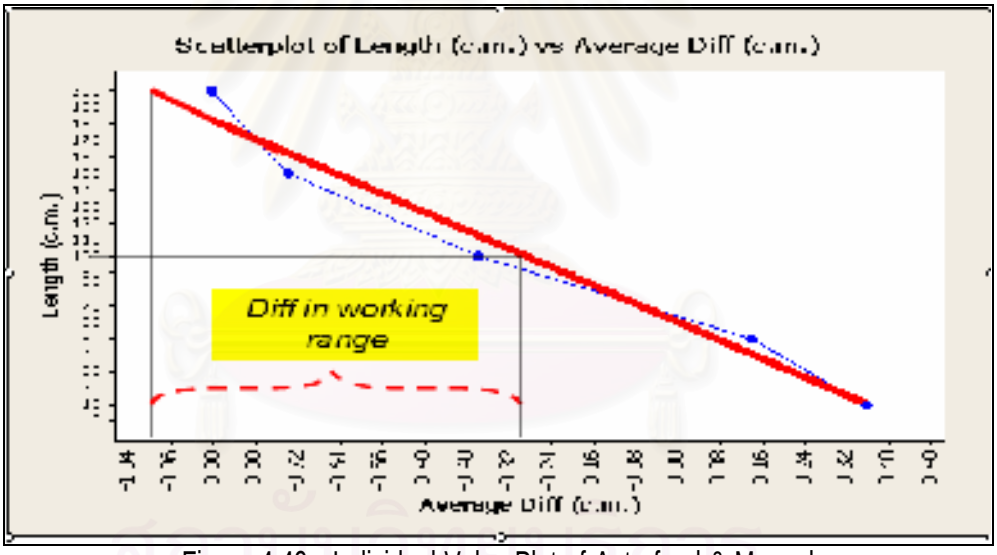


Figure 4.49 - Individual Value Plot of Auto feed & Manual

From the scatter plot of length vs average error, if the range of actual operate target is within range 100 – 200 cm., the error range of length will equal to -0.32 - - 1 c.m. or we can say " The out put of length will be shorter than operating target about 0.32 – 1 cm".

Next step, use the sample of error in the experiment to plot the process capability of fiber feeding, all sample and then compare with the process capability of manual feed to see the improvement, see figure 4.50-4.51

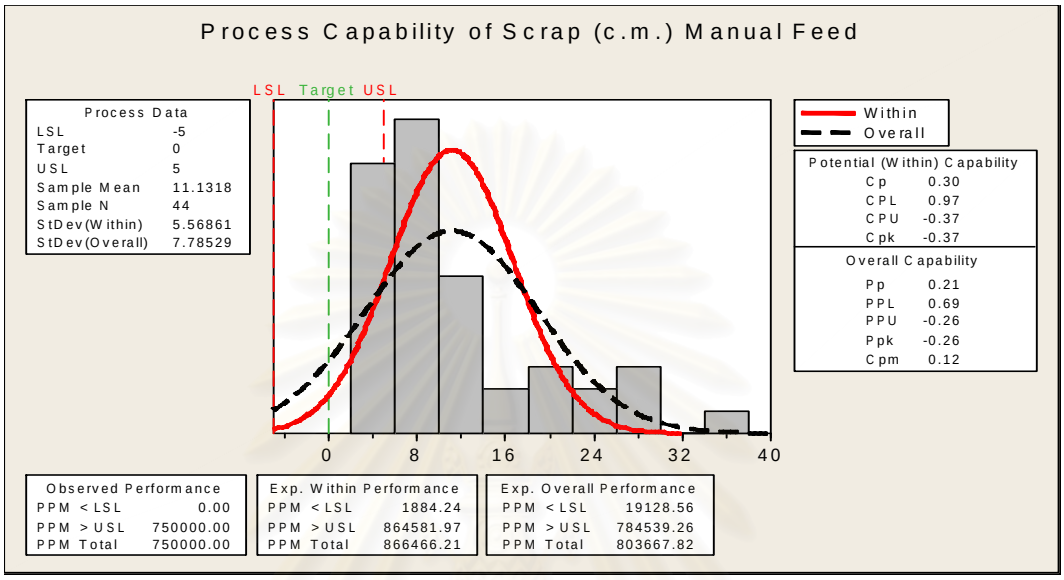


Figure 4.50- Process capability of scrap, Manual feed

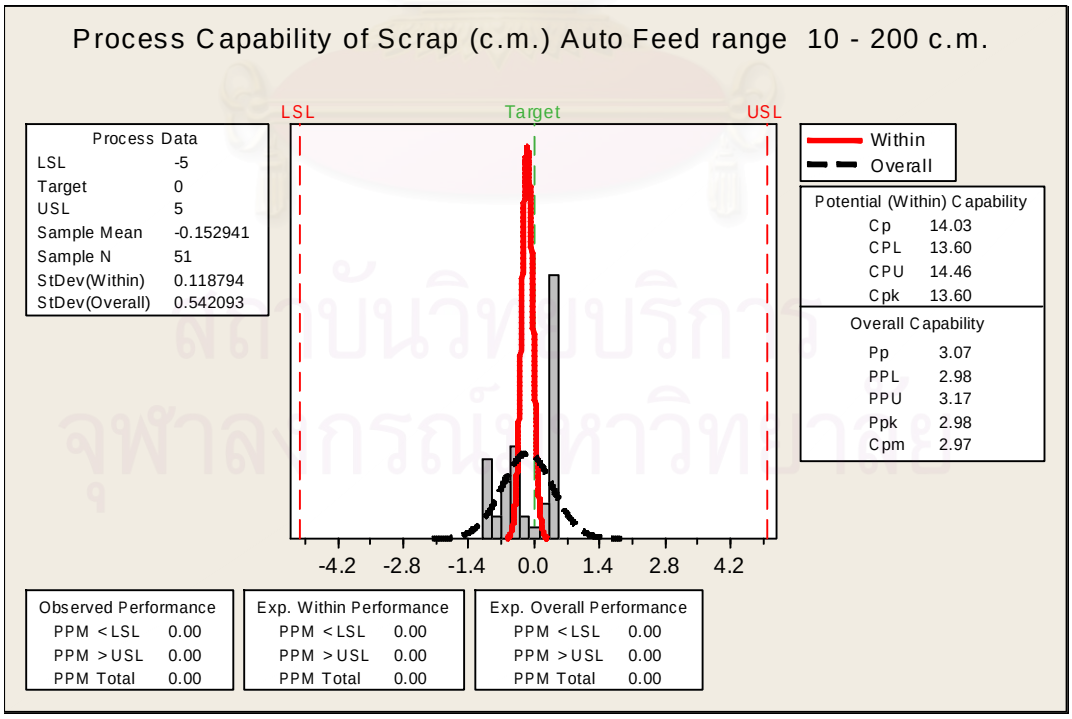


Figure 4.51- Process capability of scrap, Auto feed

There are much improvement on Cp and Cpk of draw process. Draw process which use feeder machine has Cp = 14.03 and Cpk =13.6. Anyway, for reference information, the sample should be in the working range so; the process capability of machine within working range should be plotted, see figure 4.52.

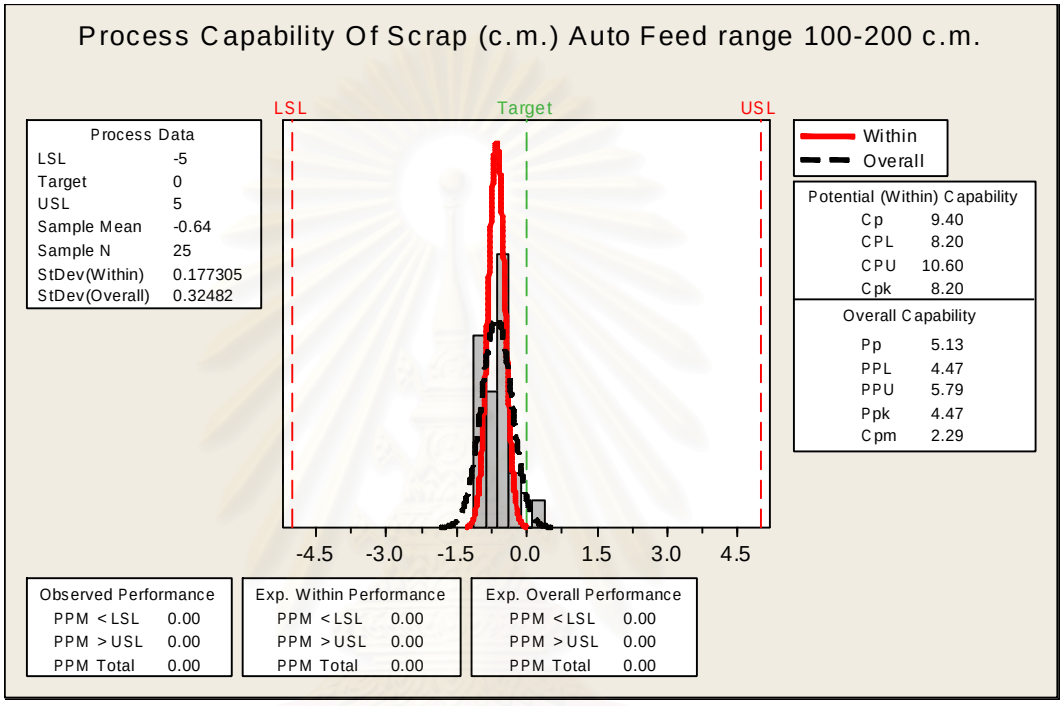


Figure 4.52- Process capability of scrap, Auto feed

Even process capability is reduce after focus only on working range, Cp = 9.4 and Cpk =8.2, It will also higher than manual feed and serve to target of requirement stage, Cpk $\geq$ 1.33.

4.5.4 effective of design compare with requirement

Requirement	List of function	Result
Excess usage	Can feed fiber length within specification.	Yes
Excess usage	The Cpk of this machine should be at least =1.33	Yes
Inventory data	Know the accumulate length that was feed out.	Yes
Excess usage	No human error effect to fiber length	Yes
Improvement team	New draw process should be synchronize with others	Yes
Improvement team	Ease of use	Yes
Improvement team	No fiber damage occur after use feeding machine	Yes
Improvement team	Good machine lay out ; comfortable	Yes
Improvement team	No limit of feed length, incase NPI use higher length	Yes

Table 4.9 – Design result

The conclusion of verify phase is “feeding machine can serve with the requirement of both internal and external”, see table 4.9. For internal requirement,

- Feeding machine can control the fiber length with in specification
- Cpk over than 1.33
- No human error effect
- Information of accumulate length
- Reduce cycle time about 2 %.

From this function, the mind mapping in the measure phase will be change. The factor which cause the high scrap cost will reduce. Below are mind mapping before and after design fiber feeder, see figure 4.53-4.54.

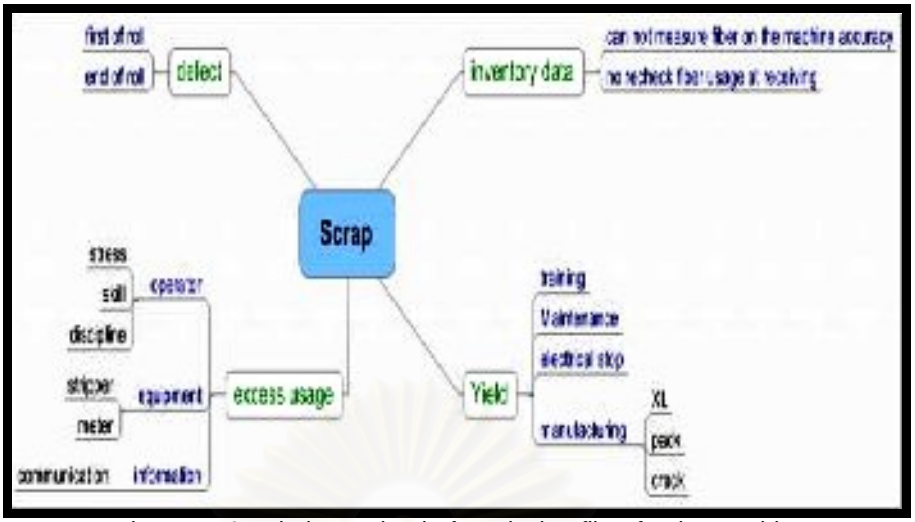


Figure 4.53- mind mapping before design fiber feeder machine

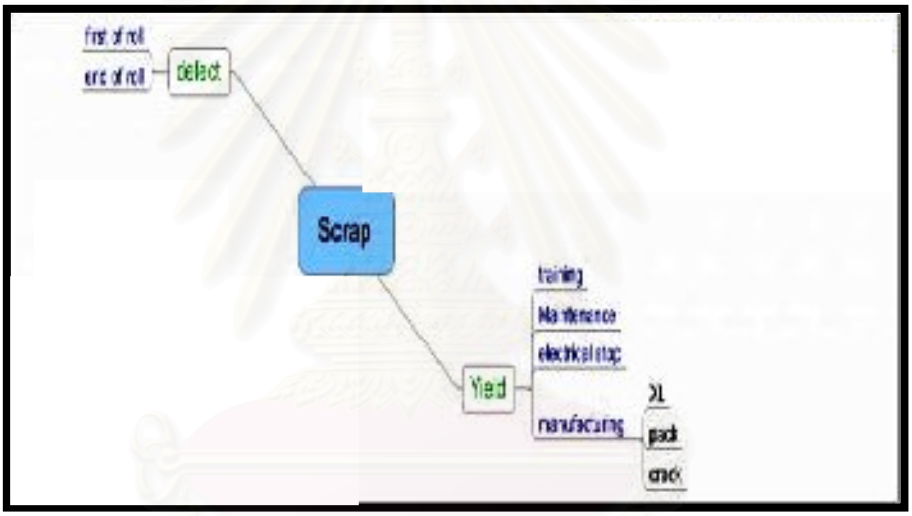


Figure 4.54- mind mapping after design fiber feeder machine

For the external requirement, the result from experiment implies that there is no barrier for customer to change any type of fiber in term of high scrap cost per unit. That is also reduce time of new product to settle in the pilot test with no scrap cost problem. In the side of the company, it no needs to absorb cost when customer request to change new type of fiber. The feeding machine can answer all requirements that set up by improvement team base on exciting quality of Kano model.

4.6 Control Phase

In control phase, on the job training schedule and work instruction was prepared already but as a service provider, the new process and investment on this concept should be approve or inform to customer first.

This project received very good feedback from customer. They decide to invest on the feeding machine project and plan to implement all m/c in the line within end of 2007. To develop the feeding machine more efficiency, they redesign new feeding machine for using same coupler machine controller so; even some part of feeding machine was changed, the main concept and layout are also follow as prototype that designed in this project.

To sum up, this machine can reduce scrap from draw process 94% from the existing process and in the future, the scrap cost per unit will not relate to material changing anymore. For the cycle time, after record cycle time before and after 3 times per each, the average cycle time reduces from 15.5 to 14.6 seconds. There has still not a good improvement in the cycle time. Even the exciting quality is hard to measure; the respond of customer is the good answer for the next step as development together.

Result calculation	
Process	Mean value of scrap(c.m.)
Before process improvement	11.1318
After process improvement	0.64
Percent improve	94%

So, Fiber scrap will reduce 94% after use feeding machine & 100% improve on effect of scrap cost per unit when change material

4.7 Involved member in each phase

The cross functional teams is the characteristic of Six Sigma project and this thesis also have many members from the various job function to involve with. The figure 4.55 has shown the involved member in each phase.

Phase	Team member
Define	Champion, Green belt, Material control, Production
Measure	Greenbet, Production, Materia contro
Analyze	Blackbelt,Greenbelt, Production, Material control,Process,Yield improvement,Line maintenance,Preventive maintenance
Implement	Greenbet, Production, Materia contro,Process,Yield improvement,Line maintenance,Preventive maintenance,Planner
Design	Greenbet,Process,Yield improvement,Line maintenance,Preventive maintenance, SP-Vision
Verify	Greenbet, Production , Process

Figure 4.55 team members in each phase

In Define Phase, the start of this project come from the operation cost meeting which composes of Manager (Champion), Process Engineer (Green belt), Material control, Production. The information in the meeting showed big impact on operation cost. To improve this problem, some project should be set up.

Next phase, all member has still same because at this phase the information from production and material control are enough to identify the main point. After understand the scope of the problem. To make sure that this project can serve to a whole picture, many members from the various functions were invited to join the meeting for example Black belt – to advise some tool and guide for a possibility of the project, The responsible person in each area – to get the idea form the various view from the onsite person.

In the Implement phase, Planner was added in the meeting to reduce delivery problem. In Design Phase, most of members were engineering team. After team has concept and guide line for installation, sub contract, SP-Vision was invited to join in the team. At the final, process engineer and production is the main member in the meeting.

CHAPTER v
The IMPORTANT FACTOR OF SIX SIGMA PROJECT APPLICATION

5.1 Factor for Six Sigma project application.

According to Peter S. Pande, Robert P. Neuman, Roland R Cavanagh, (2000), “In business –speak we are compelled to use short phases to describe complicate ideas. Six Sigma is no more thing than is economic policy or organizational excellence or any dozens of other shorthand terms we use everyday. As we have noted from the start of this book, Six Sigma is a system that encompasses many concepts tools, and principles- it’s not a thing.

We believe - and hope you agree that there are enough essential, power full and valuable elements to make the Six Sigma system, in some way, part of every successful business. At the same time, we strongly encourage you to adapt the discipline and method of Six Sigma to best impact your unique culture, industry, market position, people and strategy. Our biggest fear is that people will accept or reject Six Sigma as if it were a *thing* (falling victim to the Tyranny of the or) and not use it as a flexible system”

The hint that Peter S. Pande, Robert P. Neuman, Roland R Cavanagh express on the above paragraph reflects that there are no instant formula to make the successful Six Sigma project. The way to make Six Sigma system successful is unique and depends on many factors.

Base on the unique and no instant formula, this chapter will share the direct experience of important factor during run project; improve process of Fused Biconic Taper Coupler (FBT) manufacturing.

5.2 Important factor

This project run base on Six Sigma Philosophy so; there is already having a basic factor of Six Sigma road map such as role of the organization, DMAIC road map and etc. Below is the mind mapping of the factors which are the key factor to close this project, see figure 5.1.

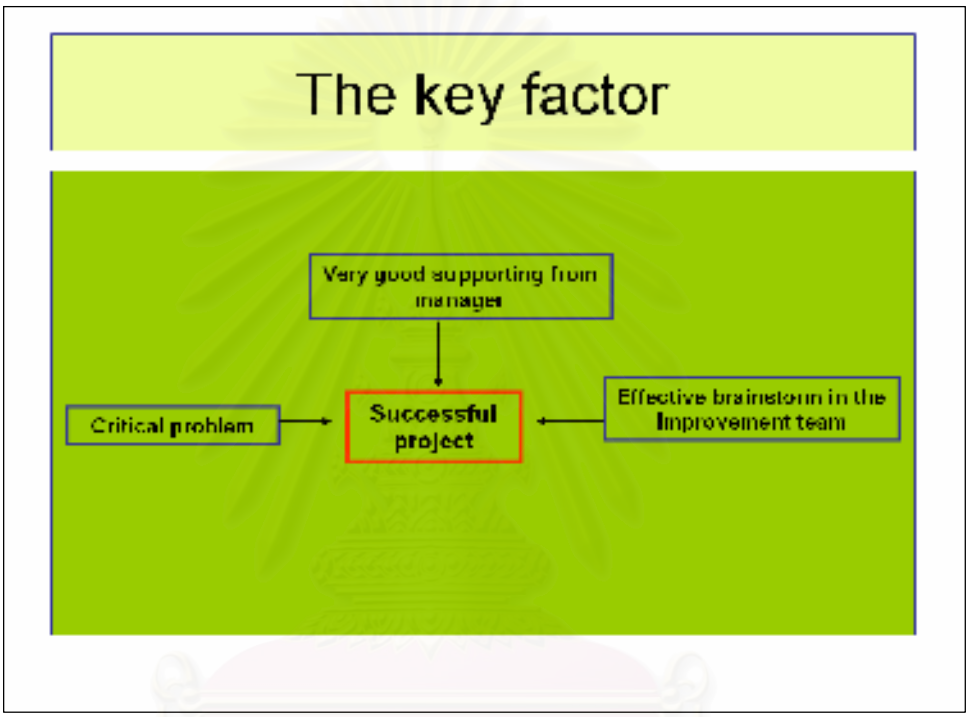


Figure 5.1 – The key factor

Critical problem – one of the key factors that drive the progress to finish as fast as possible is the critical of the problem. Cause the critical problem, everybody want to join and to be a part of the team. The goal of the project is very clear that do anything that can reduce scrap cost as fast as possible.

“Balance results, feasibility, and organizational impact issues, Good project selection can be a key to early success” (Peter S. Pande, Robert P. Neuman, Roland R Cavanagh, 2000)

Very good support from manager – In practical, there are many obstacle during run the project such as available time to meeting, budget for prototype, Machine or meter to test during office time, no operator for test run, need to change production schedule and also advise in all any problem, etc but, with good support from manager or top management is also key factor for receiving the good feedback from other department.

"Champion – a role mentioned in several of our earlier Six Sigma stories- is the manager who "oversees" an improvement project. This is a critical responsibility that can require a delicate balance. Teams need the freedom to make their own decisions, but they also need guidance from business leaders on the direction of their efforts. The most important to the success of an improvement project is to help team refine the scope of their projects. In our experience, many projects slow down or stall simply because the team leader and group are hesitate to narrow of shift their focus, for fear of "disappointing" the top leaders. In practice, though, most projects need some refinement – and the Sponsor's help in adjusting the direction is critical." (Peter S. Pande, Robert P. Neuman, Roland R Cavanagh, 2000)

The effective brainstorm in the improvement team – As a matter of fact, to drive the project successfully, broad function were requires to involve with. That means there are many specialists in any area join in the meeting. The clear objective and environment in the meeting is very important. If leader cannot manage the environment in the meeting as a creative environment and clear agenda, not only the low progress of the project but also increasing of absent member.

The environment problem is also occurring in the first stage of this project. The main reason is come from

- Even clear objective, not all members understand in the same picture. Some good or creative idea will be terminate easily by rapid logic thinking. The step of brainstorm seems to be not effective enough.
- Some behavior (natural) obstruct the creative thinking
- Some creative thinking makes the environment loss of the point.
- Most of the idea come from only 2-3 member

However, the strength of improvement team is everybody wants to be a part of successful project and have all function that required for the project. To improve the environment in the meeting or bring the brainstorms more effective, the desert survival, game which one of the material in the course Organization, People and Performance, program Engineering Management & Engineering Business Management awarded by Chulalongkorn University & University of Warwick, respectively was chosen to be a tool.

Ice breaking; understand the behavior which influence to the meeting environment and clarify what type of the information or idea which advantage for brainstorm is the objective of the game. The three way of information to be accepted are:

1. Come from the direct experienced
2. Creative thinking
3. Base on information

After implement the survival game in the meeting, the meeting environment and also progress of the project become better obviously. During brainstorm and implement the machine in the production line, many time, the situation show that the mix of member who strength in one of three information above are very important. For example, Even creative thinking can destroy the barrier from the traditional thinking, the application on the line such as design layout or modify for fitting will not be perfect and effective, if lack of directed experience person. Or if the members who have a direct experience accept

in only traditional concept rather than new creative idea, it may be use a long time for not effective result.

From experience in this project, one of the most important factor to drive this project to have a good result is effective brainstorm in the improvement team which come from the good mix of member gotten the strength in all three type of information.

Refer to this project, only the Six Sigma philosophy or DMAIC road map is not the instant formula to guarantee that every application will successful. To implement for the good result, there are many scale related with, for example; organization, department, improvement team, and product/service. With the various scale, the different culture, objective and style of each organization are influence the way to successful uniquely.

CHAPTER VI
CONCLUSION AND RECCOMMENDATION

6.1 Conclusion

In this improvement project, we use the Six Sigma philosophy to be a road map for implementation. We use DMAIC and DMADV as a guide line for improvement model.

Firstly, Define phase was used to find out the root cause of high scrap cost per unit problem. With a tool as Pareto and process flow, the main reason was segregate from a ton of possibility. Fiber is the material that shown the high possibility to make high scrap cost per unit increase. After focus on the detail of fiber usage deeply, the overshoot of scrap cost come from new type of fiber which was changed to improve product reliability and competitive in the market. Very different price between new and existing fiber and process which relate to fiber usage is the key answer for this problem.

Secondly, the Fused Biconic Taper Coupler was break down in detail by using concept of measure phase. To reduce the scrap of fiber, draw process is the main point that needs to improve. A pieces of fiber which torn for accurate length, specification, were collected for process capability calculation. The result shows that existing draw process has quite low process capability. That mean, to improve product reliability with higher cost, we need to improve draw process capability. The mind mapping was use to list the factor which relate to draw process low capability.

Next, analyze phase, we try to take a simple action follow the mind mapping but the result shown new problem in the opposite site and explain the reason of some operator behavior. From the information that we got, design new draw process was chosen to be a suitable choice so; the following step will be shift to design phase follow as DMADV model.

In design phase, the new feeding machine was design to prevent human error problem and improve process capability of draw process. The concept to design feeding machine apply from Kano model & QFD. Team decides to use the information both internal and external to make this project shift to the exciting quality in Kano model. More over reducing excess usage in draw process, this machine also have the feature help to improve inventory management more accurate.

Verify phase was use to confirm the capability or efficiency of the machine before implement 100% in the production line. To verify the machine, some parameters in technical term need to be proving by standard quality procedure and statistical testing. The feeding machine can pass all testing parameter.

Finally, control phase, the feeding machine can improve draw process capability. It can reduce fiber scrap from more accurate length about 97% from manual. Expected reduce scrap cost per unit after 100% implement will reduce 20%. The scheduling for finish implement 100% is on end of 2007. For cycle time, this implement can reduce only 1-2 second. Both new procedure and OJT scheduling were prepared.

This project was proposed to customer and we receive a good feed back in both approval and investment. Moreover, acceptation from customer, there are many sequel projects were plan to propose and develop together with customer. From this sign, it can see the benefit of Six Sigma which it can make a real continuous improvement if we can adapt it suitable for the organization.

Refer to this project, only the Six Sigma philosophy or DMAIC road map is not the instant formula to guarantee that every application will successful. To implement for the good result, there are many scale related with, for example; organization, department, improvement team, and product/service. With the various scale, the different culture, objective and style of each organization are influence the way to successful uniquely.

6.2 Recommend for further study

6.2.1 Sequel project: Use DMADV to reduce cycle time

For sequel project, integrate several processes together to reduce cycle time and human error is seem to be interesting. The improvement model as DMADV still can be used to reference, see figure 6.1.

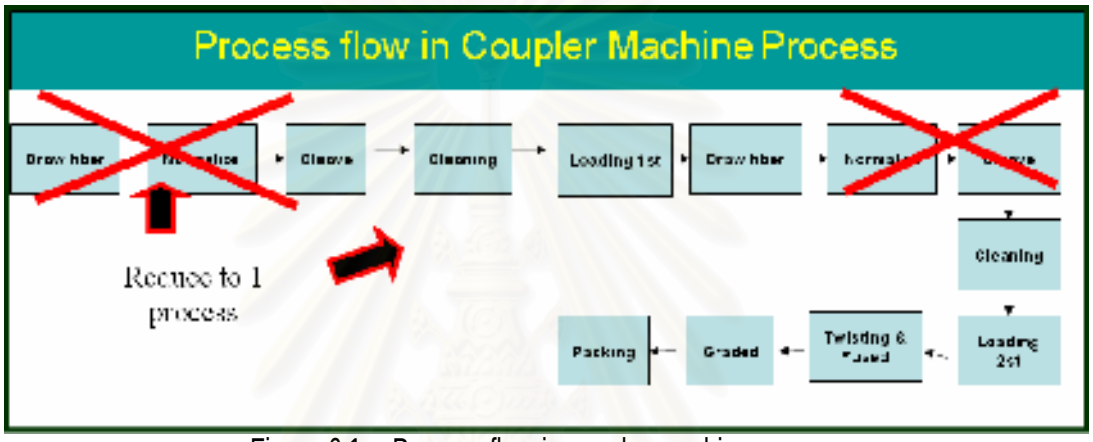


Figure 6.1 – Process flow in coupler machine process

Design feeding machine to reducing cycle time by integrate draw process and normalization together.

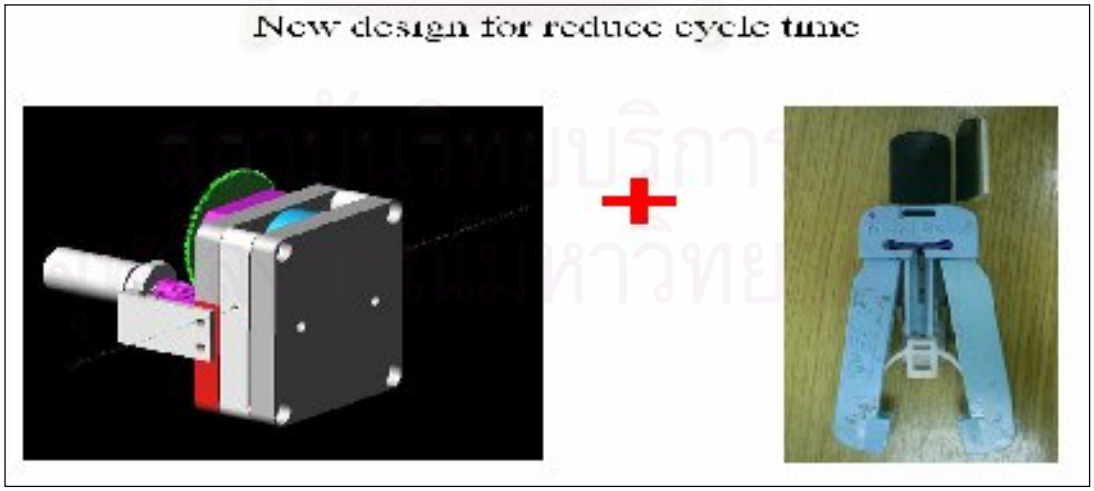


Figure 6.2 – New design for cycle time reduction

6.2.2 The effect of Influence behavior in meeting environment for improvement team

Moreover, road map of Six Sigma itself, the behavior of human to influence in the effective meeting environment is also interesting. The behavior of team member in this project is quite the most important factor to drive the project. We got a big change after focus on influence behavior in meeting environment. And the behavior is also not effect only on progress of improvement team scale but also both bigger and smaller scale relating in the Six Sigma role.

Even we know that there are not instant formula to implement Six Sigma ,It's also interesting to study the behavior of team member in the successful project and then simplify the pattern that which behavior that indicate the successful sign or which behavior of project leader is suitable for each type of improvement team. On the other hand, for the unsuccessful project, is there any project fail by only lack of focus on human behavior or norm?

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Mr. Sarush Yamolyong was born on January 6, 1977 in Bangkok, Thailand. He obtained his Bachelor's degree of mechanical engineering from Sirindhon International Institute of Technology, Thammasat University in 2000. After he got the working experience for 5 year, he decided to study for Master of Engineering and Master of Science in Engineering Business Management jointly offered by Chulalongkorn University and Warwick University at the Region Center for Manufacturing Systems Engineering. He was enrolled as a part-time student and graduate in the academic year 2007