Continuous Process Improvement for A plastic Company in Western Wisconsin: A Case Study in Improving a Clamping Device's Function

by

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ABSTRACT

Company XYZ wanted to improve product quality and productivity by enhancing the current process for inserting copper nuts. The clamping device has an important role in this manufacturing process. The Plan-Do-Study-Act (PDSA) cycle has been known to promote never-ending improvement and was chosen as the process improvement methodology to improve process variation and help make profit for the company.

The main purpose of this study is to help improve manufacturing efficiency by implementing continuous improvement methods for analyzing the current process and redesign the clamping apparatus for the company.

The objectives of this study were to

1. Create and evaluate a flow chart of current operation steps to determine the

company's current performance.

2. Gather and analyze the data to determine the company's current performance.
3. Learn the relationship between the operator and the clamping device.
4. Develop a new clamping apparatus for effective processing.
5. Make recommendations to improve product quality and processing.

The literature review provides a basic background into clamping technology and continuous process improvement. The methodology used for this study follows the Deming cycle's Plan phase and will help attain the final goals of improving product quality and productivity. The scope of this study is focused on redesigning the clamping apparatus for the purpose of improving the process including reducing production cycle time and defects.

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CHAPTER I: INTRODUCTION

Background

Clamping devices can be small or large but can not be neglected by manufacturing companies (Hesse, 2001). Clamping devices are often seen in drilling, milling, welding and assembly operations and are taking a noticeable role in many industries such as metalworking and woodworking as well as the automobile industry. To achieve optimum costs, manufacturing companies should not only have effective machinery but also should improve clamping devices.

The appropriate clamping device could efficiently reduce production cycle time and ensure quality because it can alleviate fault from complicated production or human error (Enerpac, n. d.). The clamping device could raise productivity for processes in which products are needed to secure, locate and clip under essential manufacturing operation. The purpose of the clamping action should take into account every external active force during operation such as machining force or processing force by a tool in order to ensure product quality and productivity.

Continuous process improvement by using the Plan-Do-Check-Act cycle can help firms to understand their current manufacturing system and figure out ways to effective current production. Thus, even small changes will benefit the manufacturing company (Stevenson, 1993).

XYZ Plastic, Inc. is located in Wisconsin and is one of the pioneers in the rapid prototyping industry. The company provides not only molding but also decorating and assembly of manufactured final products according to the customer's requirements.

XYZ Plastic, Inc. has one process that manufactures male and female plastic control panels. The female plastic panel has four cavities that need to be filled with copper nuts by using a clamping apparatus and air-punching to press it on. The copper nut is a standard size which can not be changed and is purchased from a supplier. The employee inserts one copper nut each time by moving the clamping apparatus into four different positions. After pressing copper nuts in four cavities, copper chips will come out on the product's surface.

The company currently is using compressed air to blow the chips out after pressing the four copper nuts. However, the company received feedback from customers that some delivered products have been missing one or two copper nuts and still have chips on the female surface. The company is working on improving the quality of final products but this causes non-stable production cycle times. The company wants to not only improve product quality, but also to reduce production cycle time. This study will determine the cause of the described problem and make recommendations for how the company can solve it.

Statement of the Problem

XYZ Plastic, Inc. lacks an appropriate clamping apparatus and effective operation in current processes which have caused non-stable production cycle time and quality issues that include unclean surfaces with copper chips in final products.

Purpose of the Study

The purpose of this study is to help improve manufacturing efficiency by implementing continuous improvement methods for analyzing the current process and redesign the clamping apparatus for the company.

Objective of this Study

1. Create and evaluate a flow chart of current operation steps to determine the company's current performance.

2. Gather and analyze the data to determine the company's current performance.
3. Learn the relationship between the operator and the clamping device.
4. Develop a new clamping apparatus for effective processing.
5. Make recommendations to improve product quality and processing.

Significance of the Study

The company is facing non-stable production cycle time as result of trying to improve product quality. Thus, the result of this study will be to determine the relationship between the operator and clamping apparatus and redesign a new clamping apparatus that is more effective by reducing production cycle time and quality issues.

Limitations of the Study

1. The scope of this study is focused on redesigning the clamping apparatus for the purpose of improving the process including reducing cycle time and defects.
2. The data in this study are limited and received from several observations of production cycle time.

CHAPTER II: LITERATURE REVIEW

Introduction

The two major topics of this chapter are clamping technology and continuous process improvement. The first objective is to review literature of clamping fundamentals, clamping design including clamping types, clamping drivers, clamping forces, cam action clamps, toggle action clamps and pin-type locators. The next objective is to describe continuous process improvement, the strategy of process improvement, Deming cycle and quality tools including brainstorming, cause-and-effect diagrams, flow charts, and *p* charts.

Clamping Fundamentals

Clamping devices have two actions, clamping and unclamping, which involve holding and releasing work pieces (Hesse, 2001). Clamping is temporarily holding work pieces in a certain orientation and position against the active force. Unclamping is releasing work pieces from the clamping force after work.

The term clamping is used chiefly in the construction of jigs and fixtures (Hesse, 2001). The function of jigs and fixtures can be described as "production-workholding devices used to manufacture duplicate parts accurately" (Hoffman, 1996, p. 7). Jigs and fixtures both are designed to hold, locate and support work pieces which should provide reliability and be easy to operate in order to achieve a certain product quality and effective process (Binstock, Courter, Csizmadia, & Munro, 1998). The difference between jigs and fixtures is that jigs guide the cutting tool throughout its cutting cycle, while fixtures do not.

Any clamping device should have three basic functions; these are to (1) position the component accurately, (2) support the component adequately, and (3) clamp the component securely for machining (Enerpac, n. d.). Also, Hesse (2001) stated that there are three sub-functions of clamping devices: (1) position, (2) definition, and (3) support. Position involves moving work pieces within the clamping device to the desired orientation for all three coordinate axes. It must not obstruct feeding, processing and gripping. Definition is to determine the orientation and position of the work piece's surface contact with the clamping device. Support is to inhibit against deformation of work pieces from the external force during the process. Figure 1 shows an example of clamp flange. The flange could be located by its center cavity and clamp on the rim; however, when the clamp action would distort the rim, as shown on (a). Therefore, the support tube is necessary to perform locator and designed to against the clamping force, as shown on (b).

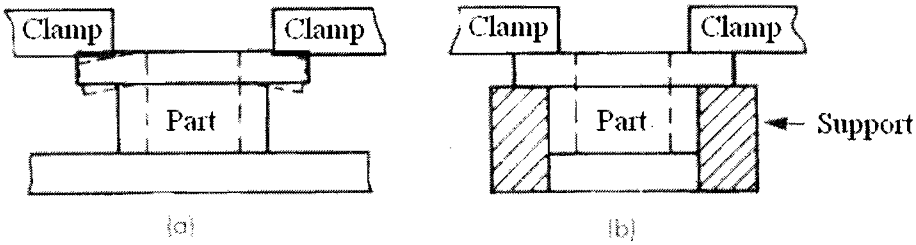


Figure 1. Example of Positioning Clamps

Source: Binstock et al., 1998, p.183

Clamping Design

The purpose of a clamp is "to exert forces and press a work piece against the locating surfaces and hold it there in opposition to the actions of cutting or other processing forces" (Lantrip, Nee, Smith, & Spitler, 2003, p. 111). To meet this purpose, Hoffman (1996) indicated that the clamp used must meet the following conditions:

(1) the clamp must be strong enough to hold the part and to resist movement,

(2) the clamp must not damage or deform the part,

(3) the clamp should be fast acting and allow rapid loading and unloading of parts. (p. 40)

Design of clamping devices has to take into account the shape of the work piece as well as other influential factors (Hesse, 2001). Clamping functions should not obstruct the machining process or deform parts. In addition, clamps should able to grip parts against tool or machine forces in order to perform high-volume production. Figure 2 illustrates the related factors that would influence the clamping operation within the manufacturing environment.

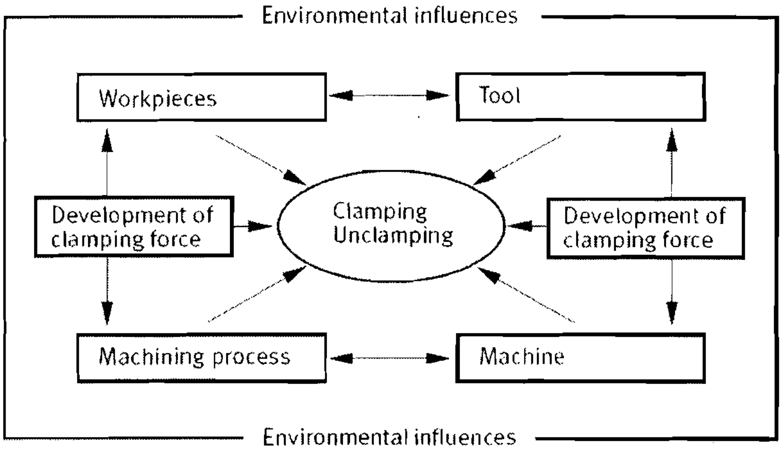


Figure 2. Factors That Influence the Clamping Operation

Source: Hesse, 2001, p.13

According to Binstock et al. (1998), the design and operational factors should be considered as following:

1. Simple clamps are preferred because complicated ones lose effectiveness as they wear.
2. Some clamps are more suitable for large and heavy work, others for small pieces.

3. Rough work pieces call for a longer travel of the clamp in the clamping range, but clamps may be made to dig into rough surfaces to hold them firmly.
4. The type of clamp required is determined by the kind of operation to which it is applied. A clamp suitable for holding a drill jig leaf may not be strong enough for milling fixture.
5. Clamps should not make loading and unloading of the work difficult, nor should they interfere with the use of hoists and lifting devices for heavy work.
6. Clamps that are apt to move on tightening, such as plain straps, should be avoided for production work.
7. The anticipated frequency of setups may influence the clamping means. For example, the use of hydraulic clamps, even if simple and of low cost, might be inadvisable if frequent installation and removal of piping and valves is necessary. (p. 178)

Clamping device design should take into account all manufacturing circumstances relating to clamping functions during the working process. Essentially, clamping devices should to be perfect in every way from input of the parts to output. In Figure 3, Hesse (2001) has shown an example that assumes work pieces are inserted by a handling device with a jaws-type or vacuum gripper in an automatic clamping operation. That clamping device considered all influential factors and optimal performance during the process.

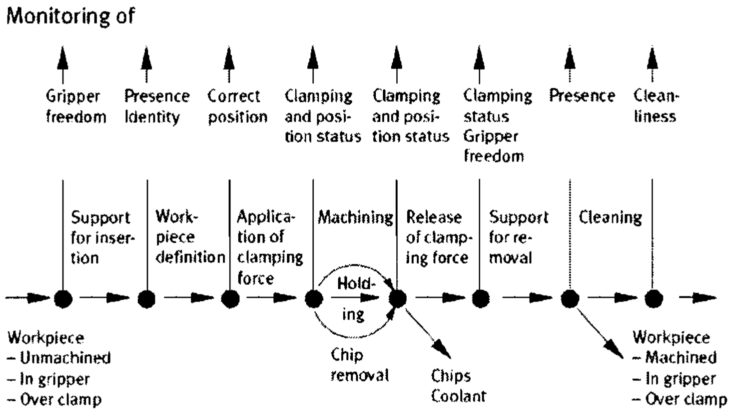


Figure 3. Example of an Automatic Clamping Device

Source: Hesse, 2001, p. 13

Clamping types. Clamp types can vary from rigid to elastic (Binstock et al., 1998). Rigid clamps, such as cam, wedge and screw, are preset to a fixed position of holding. When applying rigid clamp methods, the function of different rigid clamps should be understood. Figure 4 illustrates the six basic rigid clamp methods in a direction of transmitting actuating forces to holding forces (Binstock et al., 1998).

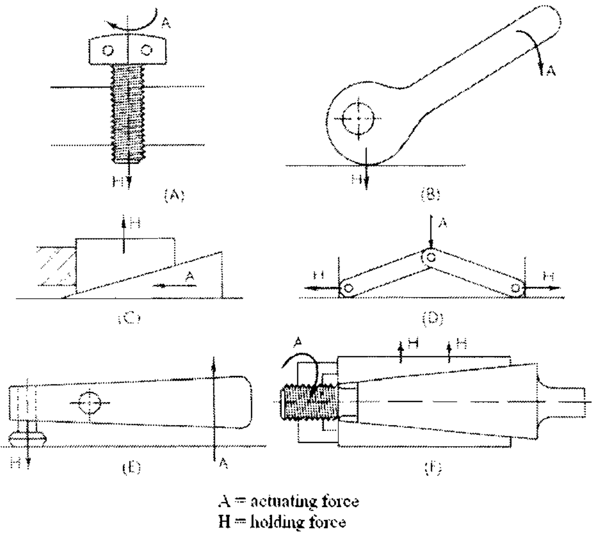


Figure 4. Example of Rigid Clamps

Source: Binstock et al., 1998, p.182

Rigid clamps usually do not provide compensation and contact directly with the work piece to secure against the working force and should not damage or deform on the work piece. In Figure 5, Binstock et al. (1998) have shown an example of rigid workholding of a screw. The work piece surface was not uniform, and the function of the screw was preset and self-locking. Thus, when the work piece moved forward or backward, the screw became out of contact with the work piece, causing loosening.

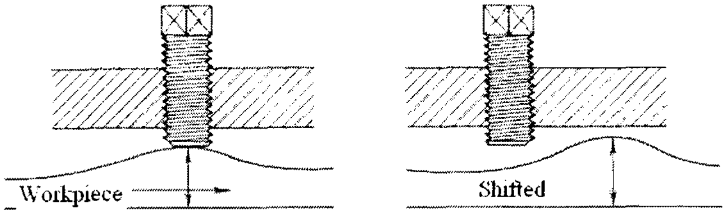


Figure 5. Example of Rigid Workholding

Source: Binstock et al., 1998, p. 185

Elastic clamp methods usually use springs, magnetic force, fluid-power, pneumatics, or hydraulics to provide compensation holding (Hesse, 2001). These provide flexible and adjustable functions in holding work pieces (Binstock et al., 1998). Figure 6 illustrates a pressure-supported piston which, compared to Figure 5, utilizes hydraulic pressure to continue to hold the work piece to the surface (Binstock et al., 1998).

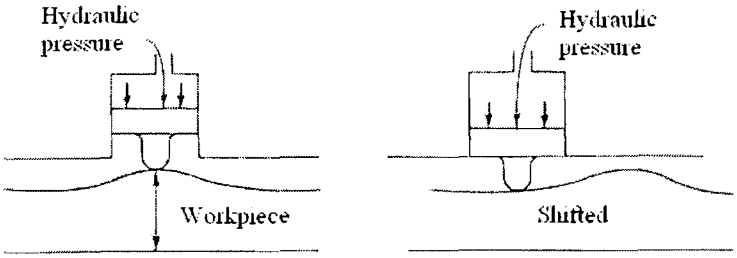


Figure 6. Example of Elastic Workholding

Source: Binstock et al., 1998, p.185

Elastic clamps usually use springs to create easy holding or releasing (Hesse, 2001). For example, the return of pistons to their initial position usually uses built-in springs. Binstock et al. (1998) illustrates in Figure 7 that hydraulic pressure clamping uses a spring to assist the piston to return to its initial position in unclamping (view A) and to hold parts as pressure clamping (view B).

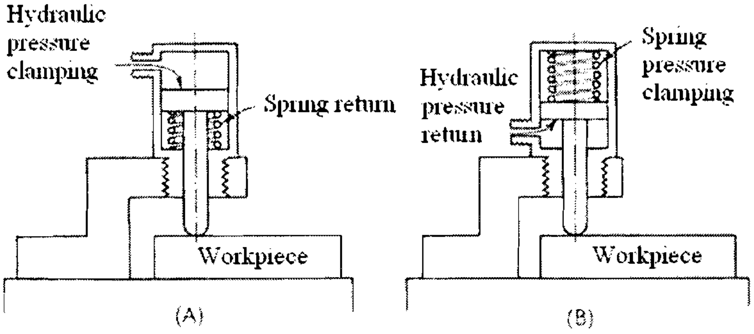


Figure 7. Applications of Hydraulic Pressure with Spring Pressure

Source: Binstock et al., 1998, p.185

Clamping drivers. Clamping drivers generate the clamping force and design according to characteristics of the work piece and work environment (Hesse, 2001). Clamping devices consist of different components that proper clamping driver can economize on labor-cost, and increase productivity. Clamping drivers can be classified into mechanical clamps, magnetic clamps, vacuum clamps and other solutions according to the clamps performance, as shown in Figure 8. Hydraulic or pneumatic clamping drivers would provide advantages of labor-savings, time-savings, authenticity and also can be designed into automation or semi-automation to perform high volume production.

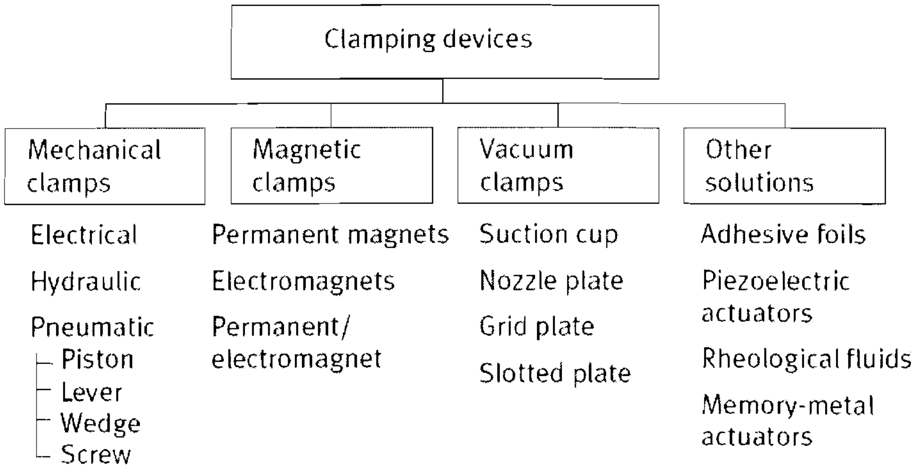


Figure 8. Methods of Classifying Clamping Devices

Source: Hesse, 2001, p. 26

Clamping Force (F_S). Clamping force is the sum of all forces from clamping components when closed and applied on the work piece (Hesse, 2001). Clamping force takes into consideration equilibrium with machining forces or torques and do not deform the workpiece. Some rigid clamps are self-locking when they are designed well. Hesse (2001) illustrates equations of three common rigid clamp devices including clamping cam, clamping wedge and clamping screw to calculate clamping force in Figure 9. F is the drive force that may be produced manually, pneumatically, or hydraulically and F_S is the clamping force which would be applied on the work piece.

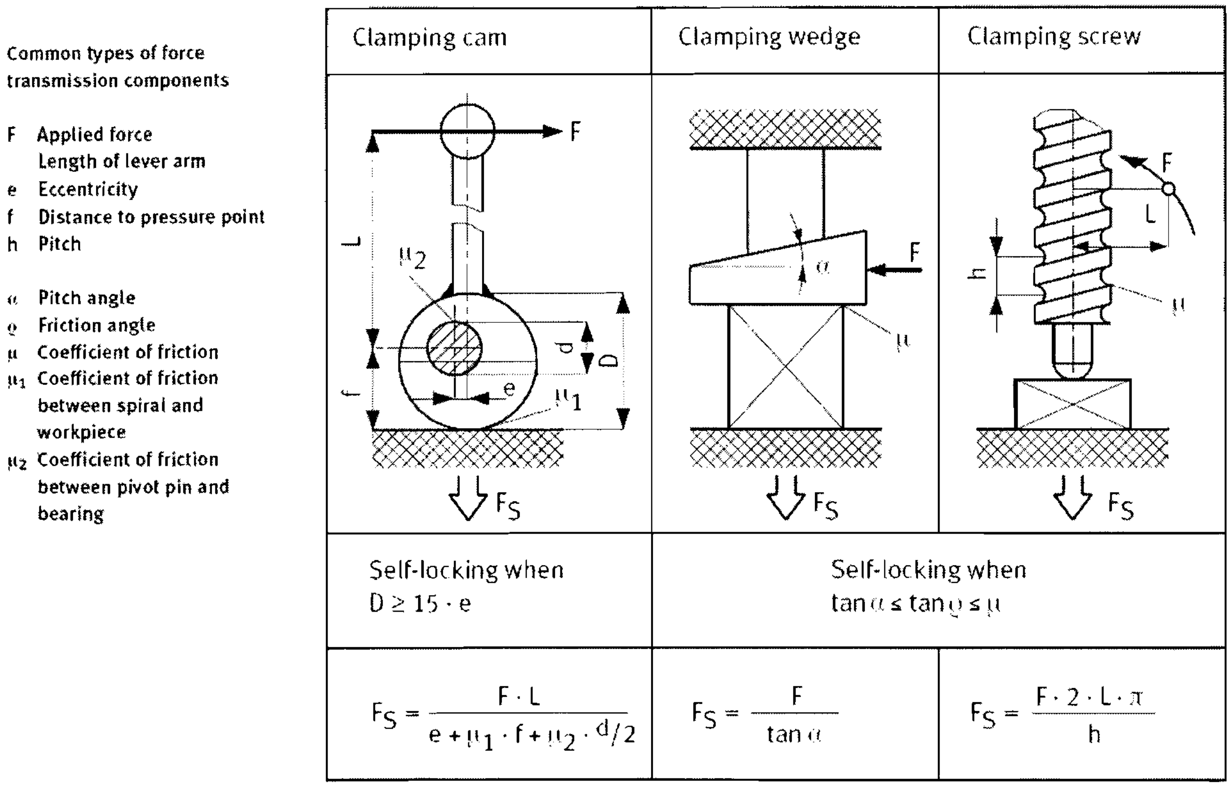
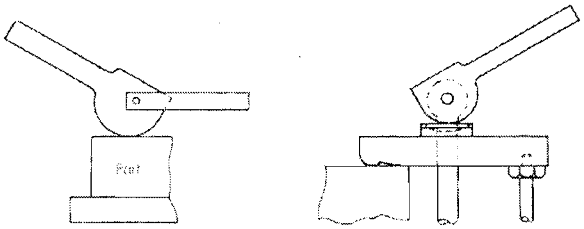


Figure 9. Equations of Clamping Forces

Source: Hesse, 2001, p.30

Cam Action Clamp. Cam action clamps are "used for fast-operating clamping devices" (Lantrip et al., 2003, p. 120) and "provide a fast, efficient, and simple way to hold work" (Hoffman, 1996, p. 47). Cam action clamps can distinguish between direct and indirect pressure applications (Lantrip et al., 2003). Direct pressure cam clamps, as shown in Figure 10 (A), provide direct contact with the work piece. They may lose contact tension due to vibration of the machine (Binstock et al., 1998).

Indirect pressure cam clamps are assembled with a strap that do not make contact with the work piece directly, causing less chance to loosen contact tension (Binstock et al., 1998). The procedure of indirect pressure cam clamps are to release cam clamps and the strap, setup work piece, put the strap back and push cam clamps down to fasten work piece. Figure 10 (B) has shown an example of indirect pressure cam clamp (Binstock et al., 1998).



(A) (B)

Figure 10. Example of Direct and Indirect Pressure Cam Clamps

Source: Binstock et al., 1998, p. 192

Indirect pressure cam clamps also can be assembled with a spring to create more effective operation function (Hoffman, 1996). Figure 11 presents the indirect cam-action strap clamp with spring. When releasing the cam, the spring will push the strap up in order to easily and quickly remove the work piece.

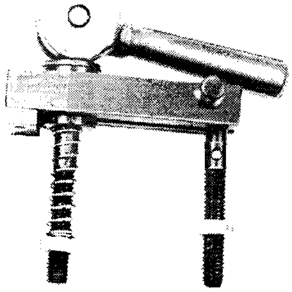


Figure 11. Application of Indirect Cam-Action Strap Clamp with Spring

Source: Hoffman, 1996, p. 140

Toggle Action Clamps. Other popular clamps are toggle action clamps which were commercially available and often seen used for jig and fixture work (Binstock et al., 1998). Toggle clamps provide fast and reliable holding and releasing action. That means toggle clamps can effectively transfer actuation force to holding force and easily move the work piece. Figure 12 presents the standard hold-down action toggle clamp (Hoffman, 1996).

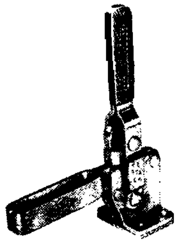


Figure 12. Standard Toggle Clamp

Source: Hoffman, 1996, p. 245

Toggle action clamps are rigid and can mount on jigs and fixtures that are preset and only can tolerate very slight changes in work piece thickness (Binstock et al., 1998). Using hold-down toggle clamps makes it possible to adjust screws and nuts at the front of the strap to adapt hold-down toggle clamps to fit the work piece's thickness. Figure 13 shows how the hold-down standard toggle clamps hold a work piece on the fixture.

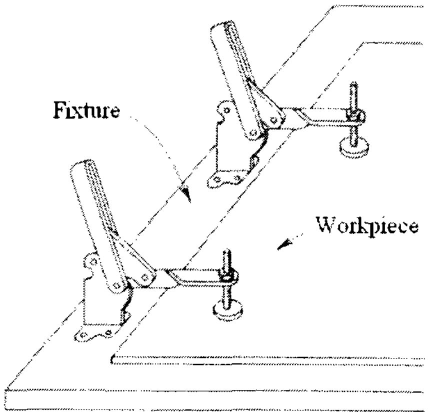


Figure 13. Application of Standard Hold-Down Toggle Clamps

Source: Hoffman, 1996, p. 649

Pin-type locator. The locating pin is "the simplest and most basic form of locating element" (Lantrip et al., 2003, p. 97). The function of a pin-type locator is to easily align the work piece by using a pin and small hole. "When the pins are used for alignment, special bushing should also be used so they can be replaced when they wear" (Hoffman, 1996, p. 28).

Continuous Process Improvement

The definition of continuous improvement is "a philosophy that seeks to improve any and all factors that are related to the process of converting input into output" (Stevenson, 1993, p. 502). Organizations usually strive for high performance in production in order to achieve high profits and customer requirements (Summers, 2005). High performance in production requires continual improvement of production process. The process means taking input and executing value-added activities on those inputs to create an output. In order to improve quality and productivity, the continuous process improvement considers all variability which includes facilities, procedures, material, and people. "Quality improvement is the reduction of variability in processes and products" (Montgomery, 2005, p. 5). To illustrate this point, Figure 14 presents a common production process system with a set of inputs and outputs.

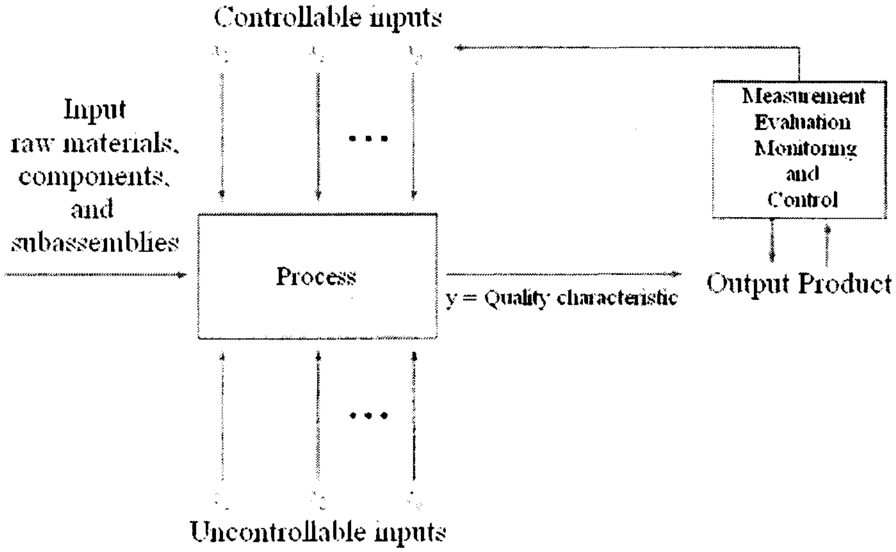


Figure 14. Production Process Inputs and Outputs

Source: Montgomery, 2005, p.11

Continuous improvement makes an organization more competitive by satisfying and meeting customer requisition (Summers, 2005). Improved efforts should concentrate on the customer's value. The customer could be an internal customer such as a worker, the next workstation, or an external customer. The narrow definition of the improvement usually occurs when an organization does not look at values from the customer's viewpoint. The improvement will fail if the customer's needs are not considered.

Continuous process improvement should occur not only to fix problems but also in effective production. Continuous process improvement is not meant to change the whole current process; it can also be used to eliminate any process variation. Stevenson (1993) expounded the following:

> The term "continuous improvement" refers to ongoing improvement efforts. Efforts are directed toward making continual changes—sometimes very small changes—in the conversion process in order to raise the level of customer satisfaction. (p. 485)

Strategy for Process Improvement

The objective of process improvement is to identify problems and set goals to achieve (McNeese & Klein, 1991). Furthermore, current processes need to be determined, and then methods and tools can be utilized to identify ways to improve, leading to implementation of solutions. According to McNeese and Klein, the overall strategy for process improvement, in detail, includes the following:

(1) mission statement, (2) identification, (3) identifying customer needs and concerns, (4) selecting major processes, (5) developing and describing a standard process, (6) developing a measurement system, (7) collecting baseline data, (8) setting goals, (9) identifying improvement opportunities, (10) developing a solution,

(11) implementing the solution, (12) analyzing the results and quantifying gains, (13) developing a system to maintain improved performance, and (14) selecting new process or parameter. (pp. 37-53)

McNeese and Klein (1991) described that step one is to develop the mission statement of the task. A clear mission statement should indicate specific results and not behaviors. For example, what people are doing is a behavior but what people have produced is a result. Thus, the general mission statement should be only one or two sentences in length. Step two is identification of customers, suppliers, products, services, and process. The mission statement could not be developed unless who the customers are is understood. Therefore, these first two steps often should be done at the same time. Step three is to identify customer needs and concerns that the mission result should coordinate with customer requirements.

Step four is to decide what processes relate to customer needs and concerns (McNeese & Klein, 1991). Fully understanding the relationship between processes and customer needs would help the continuous process improvement project to succeed. Step five is to analyze the selected process by using a process flow diagram and writing a standard operation procedure. The process flow chart is easily understood so problems are not hidden.

Next, steps six through eight are developing a measurement system, collecting baseline data and setting goals (McNeese & Klein, 1991). Developing a measurement system involves deciding what type of data should be collected and measured in the current process. Correct data will help to measure performance, set appropriate goals and compare the progress after project is done.

The ninth step is to identify improvement opportunities that usually use quality tools such as cause-and-effect diagrams, scatter plots, experimental design techniques, brainstorming, and selecting-in to determine why a process behaves as it does (McNeese & Klein, 1991). After analysis, the process would eventually generate a solution in step 10 where the solution would help reach the goals.

Step 11 is to implement the solution which was developed in step 10 (McNeese & Klein, 1991). There are two components in this step including one-time action steps and required on-going behaviors. The one-time action steps referring to the action should be done in the implementation period that follows developed solutions. The on-going behavior means to address what the workers can do differently in the future.

In step 12, the purpose is to evaluate how the solution performs after implemented (McNeese & Klein, 1991). If the performance does not meet the goals, the project should go back the previous steps and do them again in order to ensure the process improved. Step 13 is to create a system to ensure and maintain improved performance long-term. The standardized tasks are the foundation for continuous process improvement.

The final step is seeking a new process or parameter of improved process for continuous improvement (McNeese & Klein, 1991). Process improvement should never end. If process improvement is repeated, the result will accomplish the highest achievement level. Figure 15 illustrates the flow chart of these 14 steps that should be taken in process improvement.

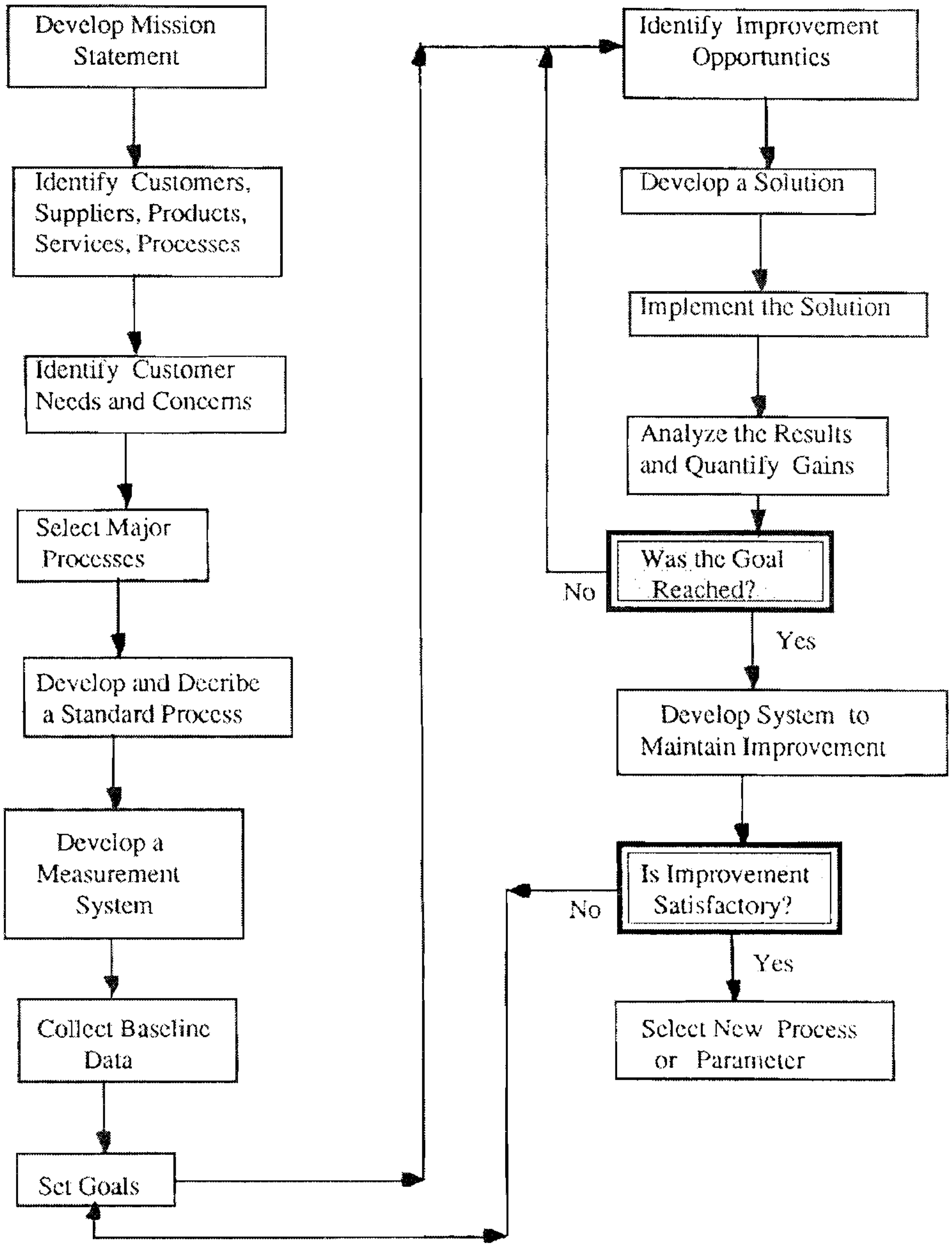


Figure 15. Strategy for Process Improvement

Source: McNeese & Klein, 1991, p. 38

Deming Cycle

There are many themes that relate to continuous process improvement. One of these is the well-known theory from Dr. Edward Deming which promotes never-ending improvement: the Plan-Do-Study-Act (PDSA) cycle. The concept of the PDSA cycle was originally discussed by Walter Shewhart, as a statistical method from the viewpoint of quality control, and later promoted by the famous quality management authority, W. Edward Deming.

The Deming cycle includes four phases for continuous process improvement including the plan phase, do phase, study phase, and act phase as well as the activities within these phases. Summers (2005) described the 10 steps within the PDSA cycle. These included

> (1) recognizing a problem exists, (2) forming a quality improvement team, (3) clearly defining the problem, (4) developing performance measures, (5) analyzing problem/process, and (6) determining possible causes, in the plan phase; (7) selecting and implementing solution, in the do phase; (8) evaluating the solution in the check (study) phase; and (9) ensuring permanence and (10) continuous improvement in the act phase. (pp. 241-293)

The first phase, the Plan phase, is to identify and analyze the existing problem and develop the solution to achieve the goals (Summers, 2005). That refers to defining and analyzing the problems, comprehending what the customer needs, and dissecting the process and collecting the data in order to develop the solutions to reach the objectives. According to Summers (2005) there are several tools to assist in clearly defining the problem and determining possible cause including (1) brainstorming, (2) cause-and-effect diagrams, (3) check sheets, (4) scatter diagrams, (5) control charts, (6) run charts, (7) force field analysis, and (8) why-why diagrams. The organization will find the root cause after clearly identifying problem, and then establishing the action plan that should be implemented.

In the Do phase, the organization will select and implement the action plan which is established from the plan phase and verify the data of results for the next phase. The solution should meet the root cause of the problem and long-term goals. Summers (2005) listed four general criteria which should be considered in selecting solutions:

> 1. The solution should be chosen on the basis of its potential to prevent a recurrence of the problem. A quick or short-term fix to a problem will only mean that time will be wasted in solving this problem again when it recurs in the future.
> 2. The solution should address the root cause of the problem. A quick or short-term fix that focuses on correcting the symptoms of a problem will waste time because the problem will recur in the future.
> 3. The solution should be cost-effective. The most expensive solution is not necessarily the best solution for the company's interests. The solution may necessitate determining the company's future plans for a particular process or product. Major changes to the process, system, or equipment may not be an appropriate solution for a process or product that will be discontinued in the near future. Technological advances will need to be investigated to determine if they are the most cost-effective solutions.
> 4. The solution should be capable of being implemented within a reasonable amount of time. A timely solution to the problem is necessary to relieve the company of the burden of monitoring the current problem and its associated quick fixes. (p. 290)

The Study phase is to evaluate if the result is the same as the goal established in the Plan phase (Summers, 2005). If the result did not meet the goals, the problem should be reanalyzed and a new solution should be developed. There are several tools which can be use to evaluate: (1) control chart, (2) run chart, (3) scatter diagrams, (4) histograms, (5) check sheets, (6) Pareto charts.

In the final phase, the Act phase is a standardization stage if the result confirmed that standardization would provide the standard actions for the organization in future improvement (Fukui et al., 2003). The standardization is concern about the management for continuous process improvement. According to Hosotani (1984, as cited in Fukui et al., 2003), management can be interpreted with two implications: maintenance and kaizen (continuous improvement) purposes. Excellent management could help the company to attain high achievement levels under continuous process improvement. Figure 16 presents that it is important for management to repeat the PDSA cycle to minimize the gap between the status quo and the goal set forth.

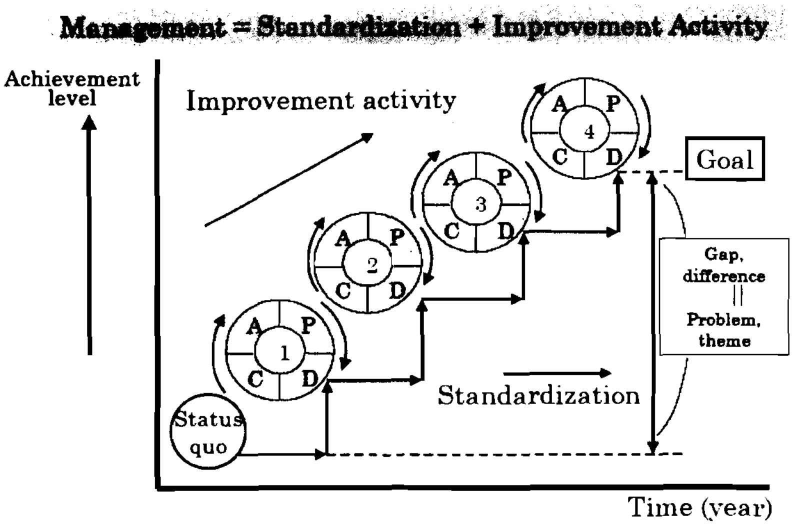


Figure 16. Repeat PDSA Cycle for Continuous Process Improvement

Source: Fukui et al., 2003, p. 23

Quality Tools

Quality tools provide many specific advantages that not only help in understanding problems but also can be utilized in the problem solving model in order to improve quality or productivity (Vanderbilt University, n. d.). There are some common tools used to determine and generate ideas about the root causes of the problems such as brainstorming, cause-and-effect diagrams, control charts, and flow charts.

Brainstorming. The purpose of brainstorming is to bring out a list of problems, opportunities, and possible solutions by a group of people (Summers, 2005). The group should include people from different professional fields who cooperate. During the brainstorming session, the leader should take notes and ensure there is no arguing, criticism, or negativism. After taking notes, the items should be sorted by category, impact, critical keys, or other analyses in order to apply to the solution or other quality tools.

Cause-and-effect diagram. Cause-and-effect diagrams are also called fishbone diagrams. They display all potential causes of the problem or effect (Summers, 2005). This diagram not only displays root causes of the problem but also indicates subcategories related to those causes. Foster (2001) describes the cause-and-effect diagram created during brainstorming sessions with a facilitator by following these steps:

1. State the problem clearly in the head of the fish.
2. Draw the backbone and ribs. Ask the participants in the brainstorming session to identify major causes of the problem labeled in the head of the diagram. If participants have trouble identifying major problem categories, it may be helpful to use materials, machines, people, and methods as possible bones.

3. Continue to fill out the fishbone diagram, asking "why?" about each problem or cause of a problem until the fish is filled out. Usually it takes no more than five levels of questioning to get to root cause—hence, the "five whys."
4. View the diagram and identify core cause.
5. Set goals to address the core cause. (p. 287)

Flow chart. The purpose of a flow chart is to picture the process and determine the parameters for process improvement (McNeese & Klein, 1991). The flow chart presents the logical activities of the process from the beginning to the end that can clearly identify the non-value activity via the flow chart. Flow charts use simple symbols to present decisions, input/output, processing, start/stop, flow lines, and pages that are easy to understand. Foster (2001) described a few simple rules for flowcharts:

1. Use these simple symbols to chart the process from the beginning, with all arcs in the flowchart leaving and entering a symbol. The arcs represent the progression from one step to the next.
2. Develop a general process flowchart and then fill it out by adding more detail about each of the elements.
3. Step through the process by interviewing those who perform it—as they do the work.
4. Determine which steps add value and which don't in an effort to simplify the work.
5. Before simplifying work, determine whether the work really needs to be done in the first place. (p. 294)

p chart. Control charts are used to monitor the variations of the process by statistical method and *p* charts are used when the subgroups are not equal sizes. The purpose of a *p* chart is to determine if the rate of nonconforming product is stable and detect when a deviation from stability has occurred (McNeese & Klein, 1991).

According to McNeese and Klein (1991), the steps of *p* chart will be constructed as following the flow chart in Figure 17.

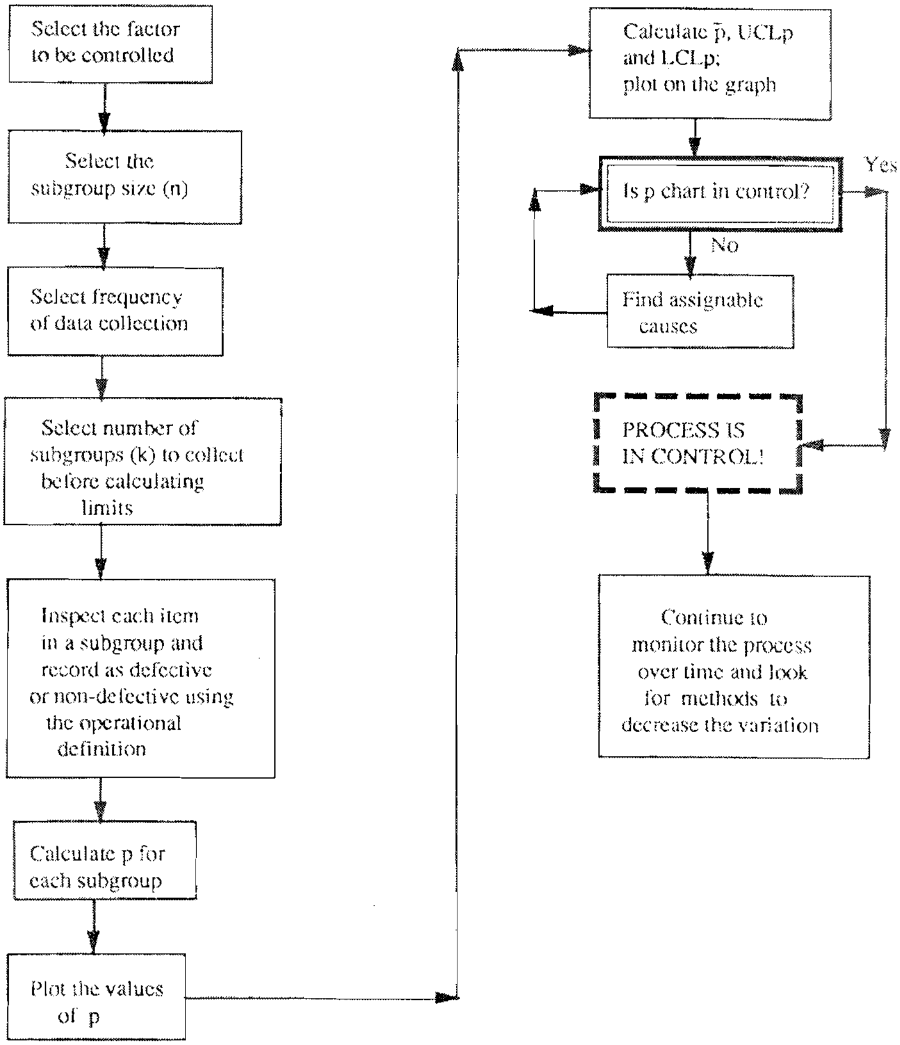


Figure 17. Steps in Construction of a *p* Chart

Source: McNeese & Klein, 1991, p. 150

CHAPTER III: METHODOLOGY

Introduction

The objective of this chapter is to describe methods and tools utilized in this study. The purpose of this study is to improve productivity and maintain product quality for XYZ Plastic, Inc. in the future. The methodology used is a systematic plan for continuous process improvement.

Define the Problem

The objective of this step is to analyze the current process and then identify the problems to work on. The first task is to understand operation procedures that involve using the current clamping device and map the process' flow chart. The purpose of a process flow chart is to determine the actions of the process which relate to the problems. The second task is to design what data should be collected for measuring the current performance. Data will be collected by the quality manager and will contain production cycle time for different operators, number of finished products, and number of nonconforming products. The last task is to develop a goal of improvement for the future performance.

Analyze the Process

The object of this step is to determine current process performance by using quality tools. The tools will use a p chart. The purpose of control charts is to identify if the current process is in control and a p chart is selected to identify the rate of nonconforming product for non-equal subgroups.

Determine Causes

The object of this step is to define the root causes of the problem and effect. The effect in this diagram is quality issues and unstable production cycle time. The causes of variation in this characteristic are categorized into main factors: materials, machine, operator, and methods. Each of these main factors is divided into detailed causes.

Identify Solutions and Select

The object of this step is to develop a solution to reach the goal. Currently, the computer is replacing the drawing board as the method of preparing engineering drawings. Computer Aided Drafting (CAD) provides several advantages for engineering design such as accurate dimensions for alignment before manufactured and the file can be saved longer than a paper drawing. The final result will use CAD to draw a new clamping device in this study.

CHAPTER IV: RESULTS

Introduction

This chapter will describe the results in this study. The first objective is to define problems, analyze the current process, and develop a plan to collect data. The next objective is to analyze data including operator efficiency using a p chart. The third objective is to develop a new clamping device to ensure quality as well as improve production. The final objective is to recommend the continual process improvement method.

Define Problems – Objective 1

XYZ Plastic, Inc. has one production process which involves inserting four copper nuts into a female plastic panel for make-to-order merchandise. The parts for the final products can be separated into dependent and independent parts. An independent part is a female plastic panel, an injection molding product; the number of panels produced depends on customer's orders. A dependent part is a copper nut supplied by outside supplier.

Recently, the quality manager has received feedback from customers that there are some nonconforming products missing one or two copper nuts and having an unclean surface with copper chips on the female plastic panel. The company made a prompt decision that the operator should confirm every final product with 100% inspection; however, this causes the process to take a longer production cycle time than it did before.

To identify the problem, the first task is to understand the current clamping apparatus and process. Figure 18 presents the current clamping apparatus which is comprised of four main parts:

1. Number one is the fixed insertion head which uses compressed air to put a copper nut in a cavity by pushing the switch.
2. Number two is a clamping device that uses a toggle action clamp to secure the panel and support the female panel bottom surface to equilibrate machining forces.
3. Number three is the work table which supports the clamping device and has a rim around four sides. The purpose of the table rim is to support the orientation bar which positions the clamping device into the four corners.
4. Number four is the orientation bar which orients the clamping device by supporting each corner.

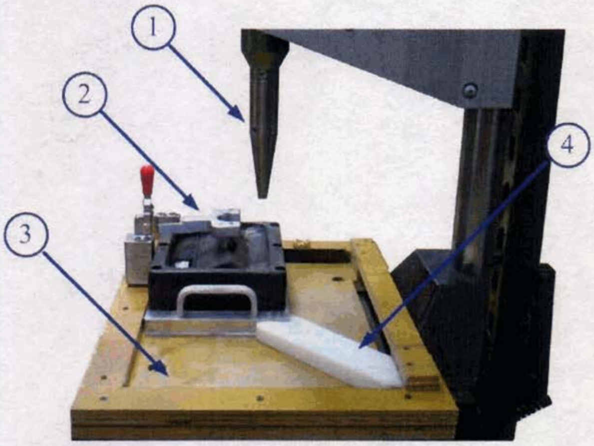


Figure 18. Current Clamping Apparatus

The current operation requires the operator to move the clamping device to four different positions and insert one copper nut each time. Figure 19 presents the operation procedures. The clamping device orients in four different positions, held in place by the orientation bar, and each copper nut is inserted. The black spots in the figures represent the copper nut. After all four nuts are inserted, the operator uses compressed air to blow out the copper chips from the female panel surface and visually inspects it until it is clean.

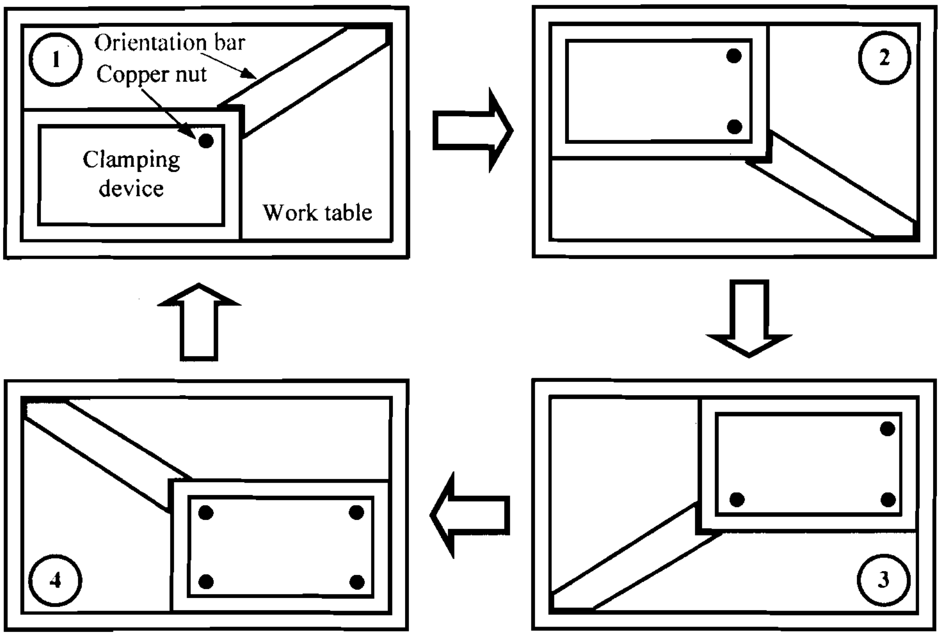


Figure 19. Four Orientations of the Clamping Apparatus

Current process flow chart. Figure 20 pictures the current process flow chart. The purpose of the flow chart is to determine process flow and identify variances in the process.

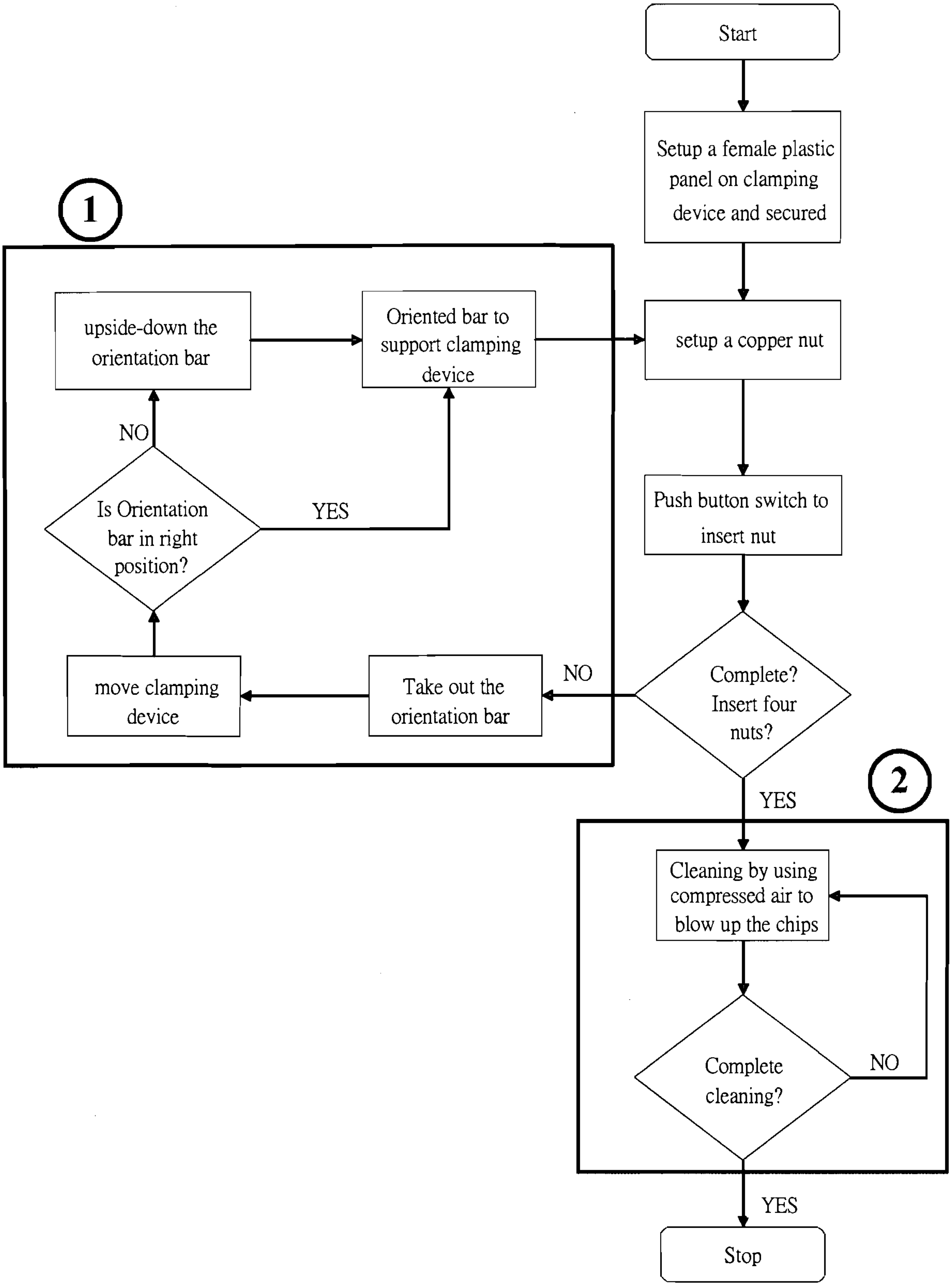


Figure 20. Current Process Flow Chart

There are two results of the flow chart shown in Figure 20, numbers one and two. Number one indicates the repeated actions to check if the orientation bar is in the right position before alignment. The orientation bar has four different positions for each corner which require an upside-down motion. Figure 21 shows the four different positions of the orientation bar. The operators need to concentrate on each movement of the clamping device. A potential issue arises in that the operation might not complete when operators are distracted.

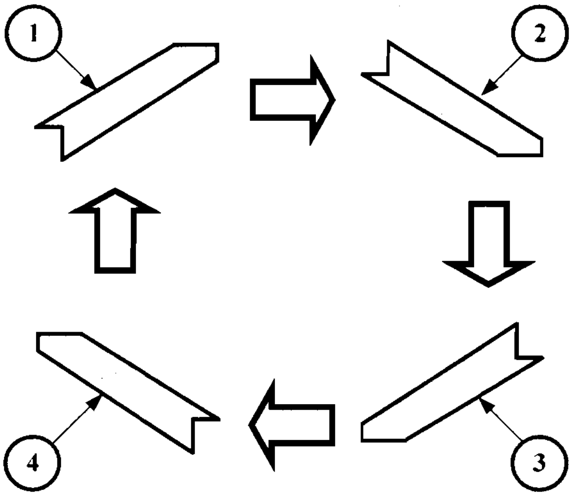


Figure 21. Four Different Positions of the Orientation Bar

The second result from the flow chart in Figure 20 is visual inspection. The dimension is approximate to 30450 mm^2 (145mm x 210mm) and three-dimensional with cavities around the edge. The operator would take time on cleansing copper chips because the copper chips will splash on everywhere including in the cavities. This also creates a more variable production cycle time for different operators. Figure 22 shows the cavities around the edge and four inserted copper nuts.

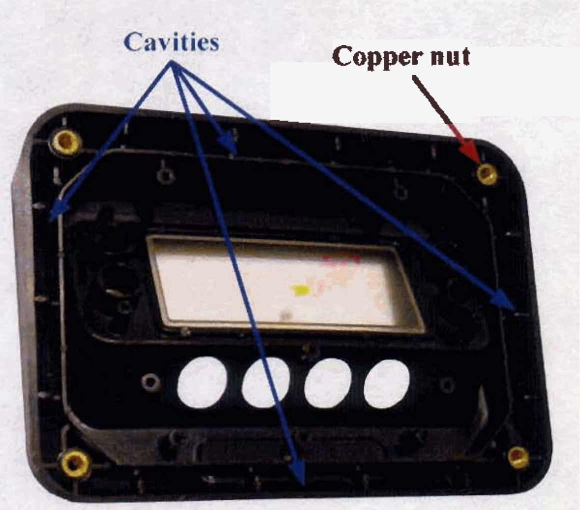


Figure 22. Cavities and copper nuts

Data collection. After analyzing the process flow chart, the data will be collected by the quality manager containing production cycle time of different operators, amount produced, and number of nonconforming products. The limitation of data is that the operation will run according to customer orders, not every day, and it is operated by different operators.

Problem statement. The mission is to improve the process which includes ensuring quality and reducing production cycle time.

Analyze the Data –Objective 2

p chart. The purpose of a control chart is to identify if current processes are in control and a *p* chart is selected to identify the rate of nonconforming product for non-equal amount of subgroups. There is one clamping apparatus, and data was collected by the quality manager with 100% visual re-inspection from 30 diverse observations including 9 different operators, and each operation has a different period. Figure 23 shows the *p* chart from 30 observations.

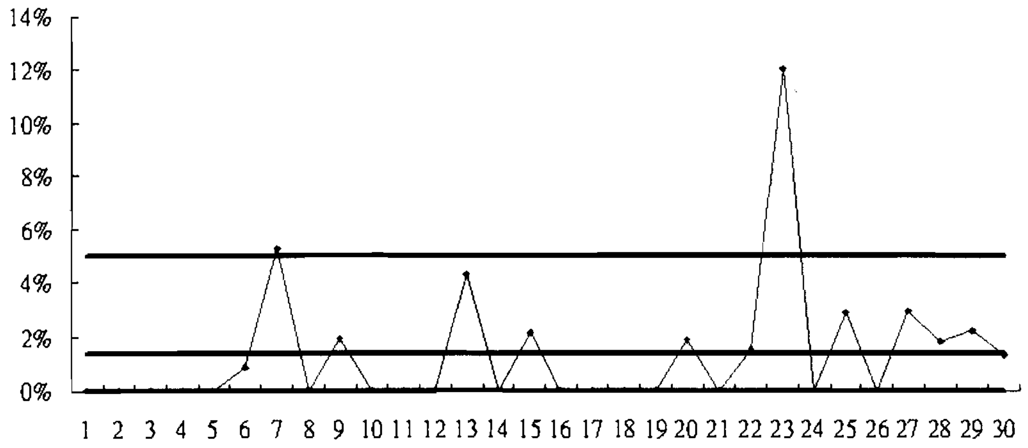


Figure 23. p chart

The *p* chart illustrates the percentage of defective items in a group of items. The average percentage of defects is 1.31% and the percentage of upper control limit is 4.98%. There are two processes in which the percentages are as high as 5.26% and 12%, and other processes are as low as 0. Overall, the current production is not in control, although there are only 2 processes out of control. Indeed, the goal should be to have no defects occur. The result of the *p* chart is not stable. Table 1 presents the average percentage of defective ($\bar{p}$), average of subgroup size ($\bar{n}$), Upper Control Limit (UCL) and Lower Control Limit (LCL).

Table1. Data for the *p* chart

	Value
Average percentage of defective ($\bar{p}$)	1.31%
Average of subgroup size ($\bar{n}$)	86.4000
Upper Control Limit (UCL)	4.98%
Lower Control Limit (LCL)	0.00%

Operator efficiency. Since 30 diverse observations are from 9 different operators, the analysis of operator efficiency will indicate the variation between operators. This analysis is not to evaluate operator performance; it is to understand productivity between operators and then to identify process performance. Figure 24 is not a control chart; it is the average of production per hour from 9 operators. The data was produced by dividing the amount produced by the operation period. It is an average of production in one hour. Figure 24 presents the average number of units produced from 9 operators. One of the operator's produced amounts is as high as an average of 45.7 items per hour and another's produced amount was as low as an average of 24 items per hour. Also, the productivity was variable in different operators as well as within the same operator. That verified the variable productivity in the current process. There is no standard production cycle time which will cause unstable lead time. The definition of lead time is the period from receipt of the customer's order to the time when the customer receives the goods. For make-to-order merchandise, the lead time includes production cycle time, assembly time, and delivery time. Therefore, stable production cycle time is important and will help the company to manage lead time.

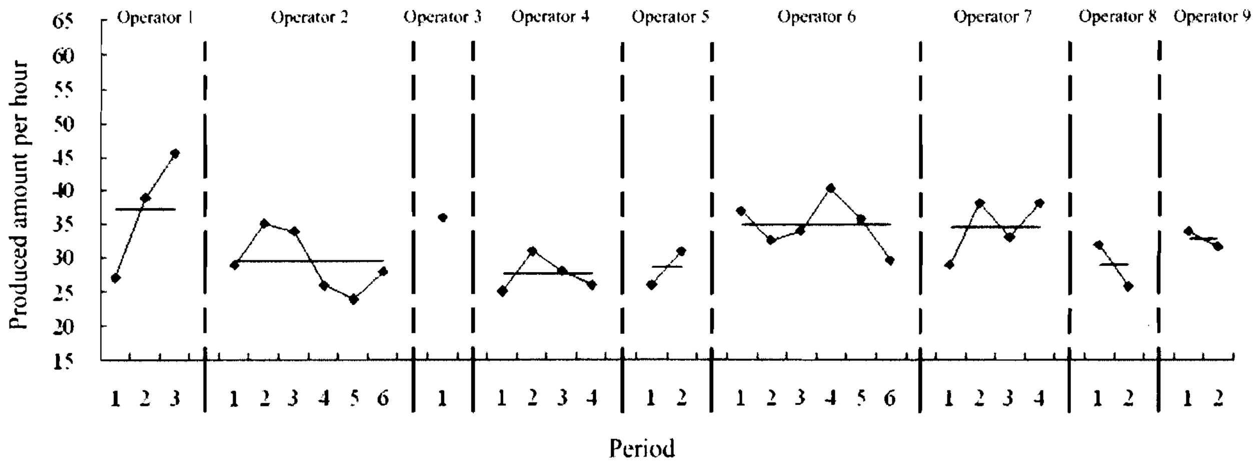


Figure 24. Operator Efficiency

Table 2 shows the average production of the 9 operators. Figure 25 is a chart and clearly indicates the gap between operators.

Table 2. Average Production by Operator per Hour

Operators	Produced amount
Operator 1	37.2
Operator 2	29.3
Operator 3	36.0
Operator 4	27.5
Operator 5	28.5
Operator 6	34.9
Operator 7	34.5
Operator 8	28.8
Operator 9	32.8

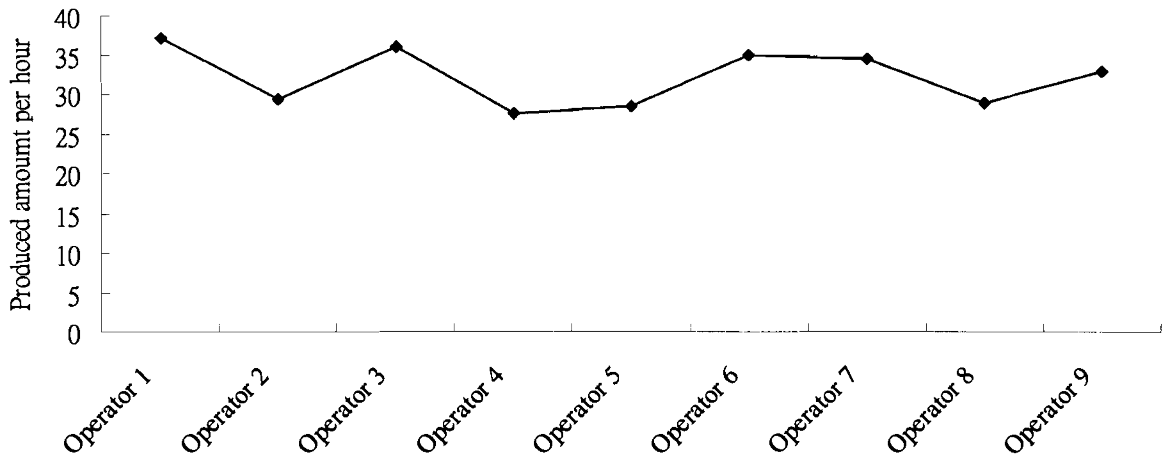


Figure 25. Average Production by Operator per Hour Chart

The conclusions from this data analysis are that the current process is not stable and productivity varies between operators. The variation in productivity might relate to the clamping device functions in the operation since company policy required 100% inspection.

Determine Causes – Objective 3

A cause-and-effect diagram is a quality tool to identify the root cause of the problem and effect. The possible causes of quality issues and productivity were presented in Figure 26 after brainstorming. The major potential areas for causes could be distinguished from materials, machine, operator, and methods. After the diagram was discussed and analyzed, the potential causes and conclusions were illustrated in Figure 26.

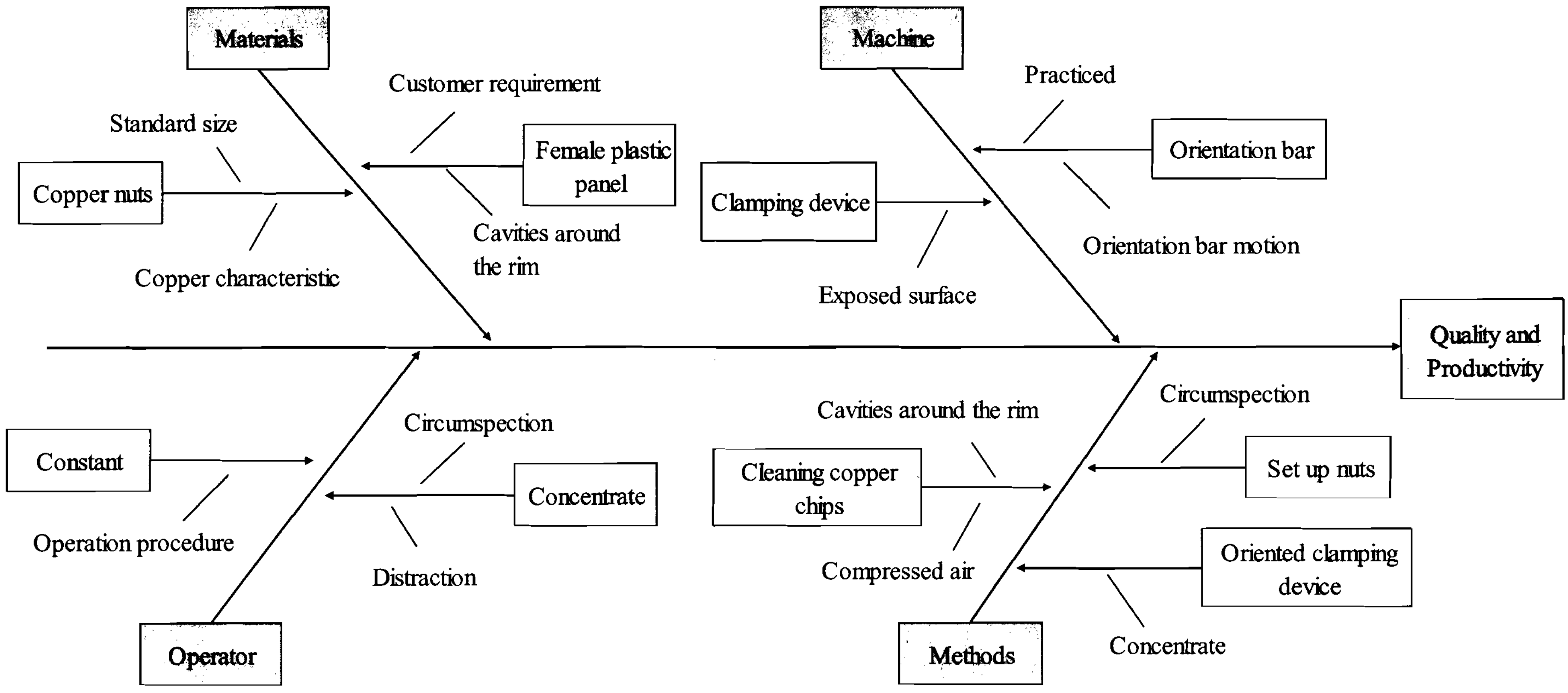


Figure 26. Cause-and-Effect Diagram

The major causes involving materials were included in two parts of the process including copper nuts and a female plastic panel. The female plastic panel and inserted copper nuts are customized and the cavities around the rim can not change. The characteristics of copper are subtle, tiny and adhesive when copper chips occurred.

The causes relating to the machine involved the clamping device and orientation bar. The current clamping device is provided the grip and support functions, but the entire female panel plastic surface is exposed, allowing for copper chips to get stuck. The orientation bar provided position function, however, it needs to be moved in an upside-down motion for orientation of the clamping device.

The causes involving operator were related to constancy and concentration due to lack of a standard procedure. According to Figure 19, there are several possible moves to shift the clamping device. Potential issues might occur when an operator is not concentrating on the process.

The causes relating to methods include cleaning copper chips, setting up copper nuts, and orienting clamping device. Currently, the operator is setting up a copper nut each time until four nuts are inserted, using the orientation bar to orient the clamping device by using an upside-down motion. Compressed air is used to blow out the copper chips that stuck to the female plastic panel's cavities around the rim. Those actions might cause a long production cycle time and quality issues when operators do not concentrate on inserting the nuts four times and do not completely blow out the copper chips.

Recommendation for Improvement – Objective 4

There are two types of solutions that will be recommended in this phase. They will stabilize production cycle time and improve quality issues. The first solution is a surface hood. The second is a redesigned clamping device.

Surface hood. The first solution is to reduce the exposed dimension of the female plastic panel by using a surface hood. The drawing is shown in Figure 27. The manufactured surface hood is shown in Appendix A. The surface hood described as follows:

1. In Figure 27, number one is a small hole fit just right for a copper nut. Number two is a handle.
2. The surface hood would limit the area into which the copper chips could drop and provide an advantage of easy clean-up. Therefore, the copper chips will drop on the four small holes and others will fall upon the surface hood.
3. A surface hood reduces approximately 98.52% of chips dropping into the cavities. The original exposed dimension is approximate to 30450 mm^2 (145mm x 210mm) and will reduce to 452.16 mm^2 ($4 \times 3.14 \times 6^2$) by using the surface hood.
4. The handle will provided advantages of easy setup and bring up functions.
5. The operator can set up four copper nuts in the holes one time.
6. In summary, this surface hood will save the time of cleaning the copper chips and effectively reduce production cycle time as well as assure quality.

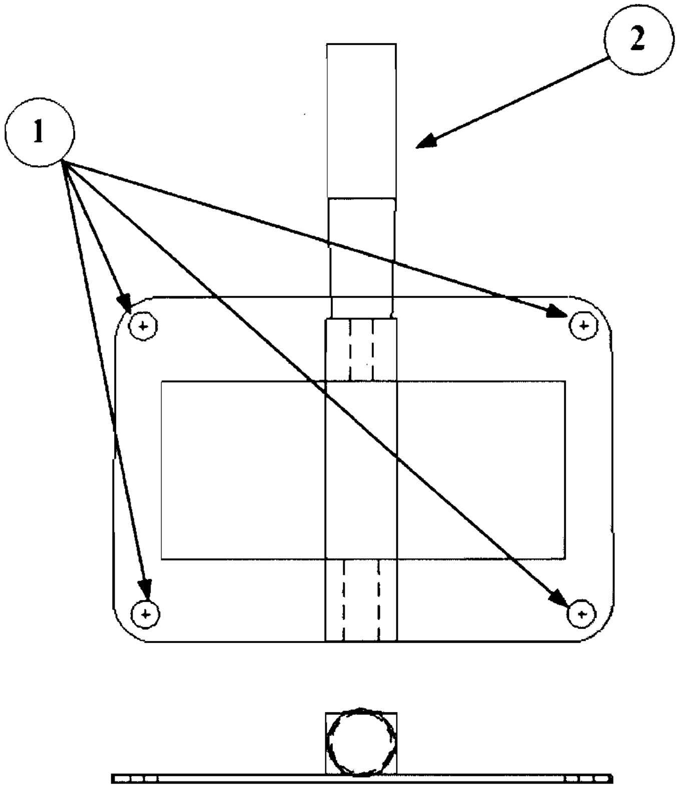


Figure 27. Surface Hood Drawing

Redesigned clamping device. The redesigned clamping device is focused on easy operation and also provides the basic functions of a clamping device including orientation, support, and security.

The orientation function will implement and assemble cam-action function, pin locator, and spring together. The drawing is shown in Figure 28. The objectives of the cam-action pin locator are described as follows:

1. In Figure 28, number one is a cam-action device, number two is a spring, number three is a pin, and number four shows the movement of this device.
2. The purpose of the cam-action implementation was to require less strength and provide a self locking function. When the cam-action device is pushed down, the pin will expel from the bottom, orienting the clamping device.

3. The built-in spring is assembled to help return pins to their initial position when the cam-action release is implemented.
4. A pin type locator is one of the easy orientation methods. It works as easy as just inserting the pin into the hole and orienting.

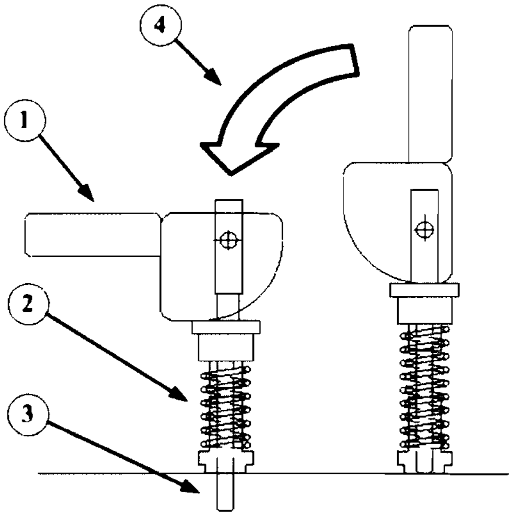


Figure 28. Cam-Action Pin Locator Drawing

5. In summary, there are four cam-action pin implementations in the redesigned clamping device. Figure 29 presents the side drawing of this implementation. The cam-action pin locator design is providing effective operation instead of the previous orientation bar upside-down motion.

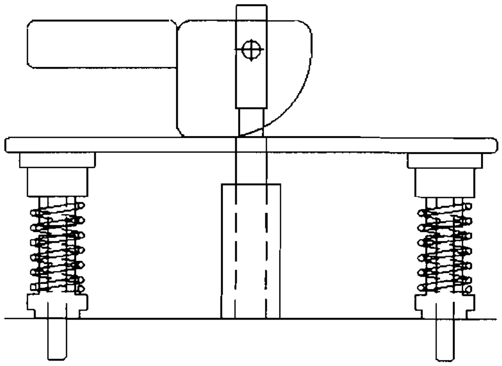


Figure 29. Cam-Action Pin Locator Side Drawing

The cam-action pin locator needs a work table with 9 small pin holes on it. Figure 30 shows the redesigned clamping device oriented at all four positions. The blue spots show the four pin locators and the black spots are a copper nut.

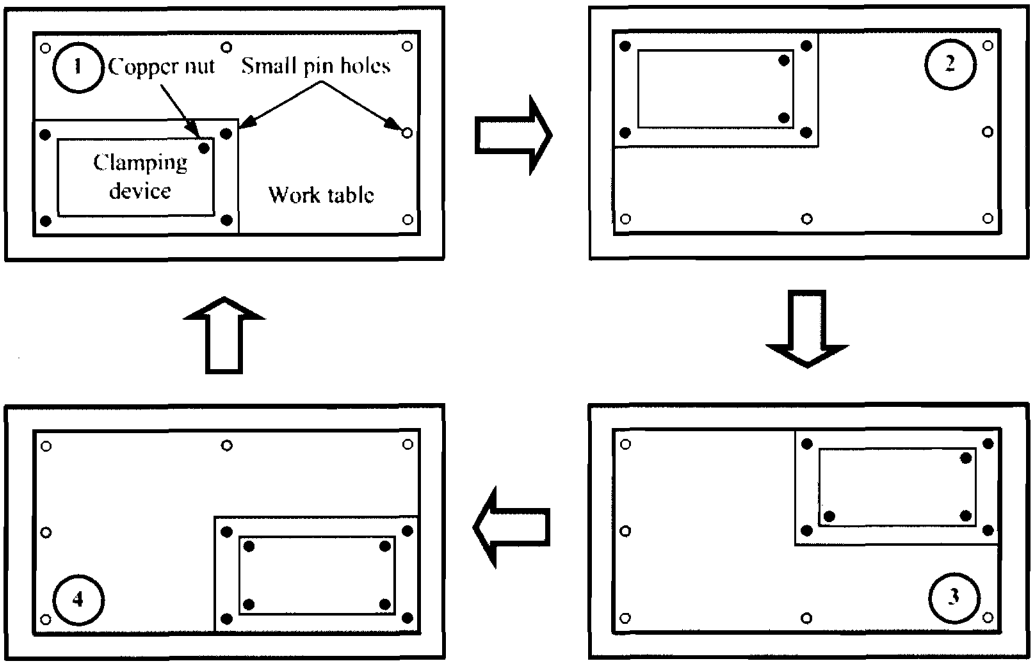


Figure 30. Redesigned Clamping Device Process

Support is needed to define the bottom outline of the female plastic panel that it is not a parallel cube. The work process needs parallel top surface. Thus, a support outline was designed to make the top outline of the female plastic panel parallel. It is made of metal but a rubber cover is put over it to prevent scratching the plastic panel. Figure 31 shows the drawing of the support design. Number one is a female plastic panel, number two is a rubber form, and number three is a support design.

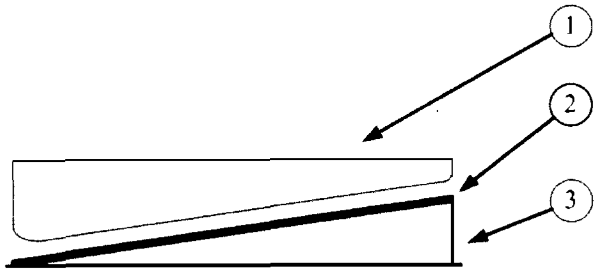


Figure 31. Support Design Drawing

The grip design is using the toggle action clamp to secure the surface hood and a female plastic panel together. The clamping device that was manufactured is shown in Appendix (b)

The new clamping device will improve productivity and ensure quality, eliminating non-value action from the current process. The improved process flow chart is presented in Figure 32, contrasted with the current process flow chart in Figure 20. The improved process is described as follows:

1. The surface hood saves time involved with visually cleaning and inspecting the panel.
2. Using the surface hood, the operator can set up four copper nuts at once reducing opportunities for distraction.
3. The cam-action pin locator provides an easy way to position a clamping device rather than having to move the orientation bar.

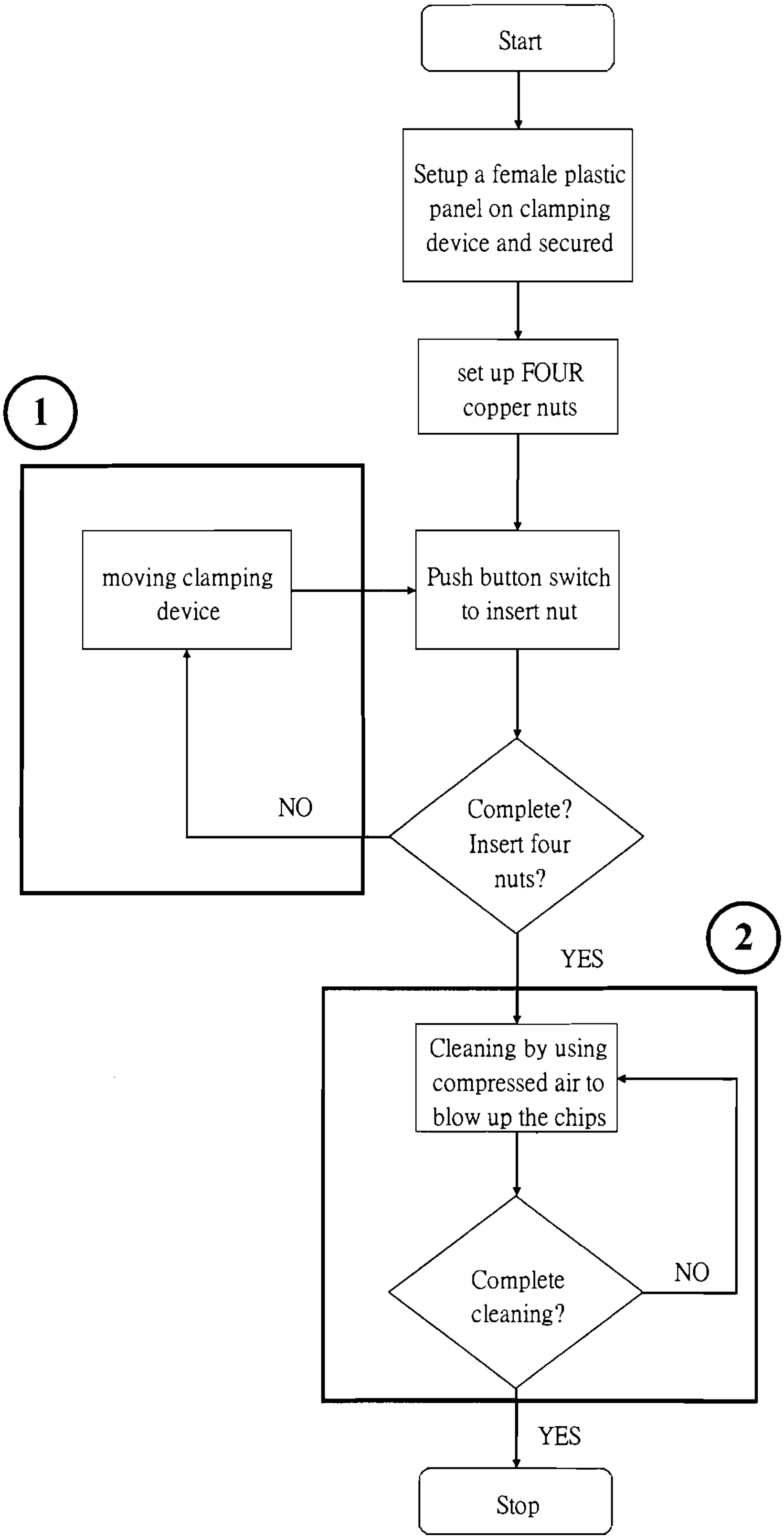


Figure 32. New Flowchart of Improved Process

Recommendation for Continuous Process Improvement – Objective 5

To complete continuous process improvement, the researcher recommends following the Deming cycle, or Plan-Do-Study-Act cycle, to achieve further improvement. The result of this study completed the plan phase which identified the problems, analyzed the process and data, and determined possible causes. To complete the PDSA cycle, the recommendations are described as follows:

1. In the Do phase, the company should implement the solutions from this study, and collect data for measurement result in next phase.
2. In the Study phase, the quality manager should analyze the data from implementing the new clamping device and compare it with the current performance. If performance improved, and then go on to the next phase. If processes were not changed, the study should go back to finding new solutions.
3. The purpose of the Act phase is to ensure improved processes permanently. The standardized document of process procedure will provide a constant method for operators to follow and for continuous improvement.

CHAPTER V: DISCUSSION

Introduction

This chapter discusses the summary, methods, major findings, conclusions and recommendations related to this study. In addition, the researcher suggests areas for further study.

Summary

The purpose of this study was to provide a continuous process improvement plan for XYZ Plastic, Inc. to improve productivity and product quality. The objectives of this study are to

1. Create a flow chart and evaluate the steps of the current operation to determine the company's current performance.
2. Analyze the data to determine the company's current performance.
3. Study the relationship between the operator and the clamping device.
4. Develop a new clamping apparatus for effective productivity and product quality.
5. Make recommendations for the continuous process improvement plan.

Methods

The review of literature included two topics: continuous process improvement and clamping technology. The continuous process improvement topic included strategies of process improvement, Deming cycle, and quality tools. Deming cycle provided a systematic continuous process improvement plan. The quality tools selected for this study were brainstorming, a cause-and-effect diagram, flow charts, and a p chart. The flow charts exhibited the non-value actions of the current process and the solutions that would reduce these non-value actions. A p chart was used to determine if the rate of nonconforming product was stable since the subgroups were not equal sizes. A cause-and-effect diagram was used to define the root cause of the quality issues and production cycle time. Clamping technology was relevant to clamping fundamentals, clamping design including clamping types, clamping drivers, and clamping forces. Cam action clamps, toggle action clamps and pin-type locators were applied to the solutions.

Major Findings

1. The company has received feedback from customers that there are some nonconforming products missing one or two copper nuts and having unclean surfaces with copper chips on female plastic panels.
2. The company made a prompt decision that the operator should confirm every final product with 100% inspection which results in the process taking a longer production cycle time than before.
3. The current clamping device involved non-value actions which results in non-stable productivity.
4. There is no protection against copper chips randomly dropping which affects product quality and production cycle time.

Conclusions

1. The operators repeated actions to check if the orientation bar was in the right position before alignment. The orientation bar has move to four different positions for each corner and needs to use an upside-down motion. In addition, the operation might not complete when operators are distracted.
2. The dimension of the female plastic panel surface is approximately 30450 mm^2 (145mm x 210mm) and is three-dimensional with cavities around the rim. This means there are many spaces for copper chips to randomly drop

into after the four copper nuts are inserted. The operator has to take time to clean up the copper chips and visually inspect it.

3. According to the *p* chart, the current process is not in control. The average percentage of defects was 1.31 % and the percentage of the upper control limit was 4.98 %. For two processes, the percentages were as high as 5.26 % and 12 % while other processes were as low as 0.
4. Operator efficiency was not determined to evaluate operator performance; productivity was different for operators.
5. The major causes of productivity and product quality could be categorized in four categories: materials, machine, methods, and methods.
   - The causes relating to materials included two parts: copper nuts and the female plastic panel. The copper chips are tiny, adhesive, and laborious to clean up. The female plastic panel and inserted copper nuts are customized and the cavities around the rim can not change and will store copper chips.
   - The causes involving the machine included the clamping device and the orientation bar. In the current process, the female panel plastic surface dimension is entirely exposed for copper chips to randomly drop into. The orientation bar provides a support function; however, it needs to be moved with an upside-down motion to orient the clamping device.
   - The causes related to operators were related to constancy and concentration since there is no standard procedure. There are several possible ways of shifting the clamping device to insert the copper nuts

and copper nuts may be missed if the operator was not concentrating on the process.

- The causes involving methods include setting up copper nuts and cleaning up copper chips. The operator set up a copper nut each time until four nuts are inserted and used compressed air to blow out the copper chips. Since the exposed surface area of female plastic panel with cavities around the rim can catch the copper chips, the actions would cause a long production cycle time. In addition, if the operator was not concentrating on inserting the nuts four times, quality issues could occur.

Recommendations Related to this Study

1. *Surface hood.* It will cover the full female plastic surface and only leave four holes for inserting copper nuts. The surface hood reduces approximately 98.52% of the area chips could drop into. The original exposed area is approximately 30450 mm^2 (145mm x 210mm) and will reduce to 452.16 mm^2 ($4 \times 3.14 \times 6^2$). Since the surface hood will limit the area of copper chips randomly dropping and four copper nuts can be set up at once, it provides the advantages of being easy to clean and effective in productivity.
2. *Cam-action pin locator.* It is assembled with a cam-action function, pin locator, and spring together. The cam-action implementation saves strength and self-locks to expel the pins to the small holes on the work table when in need of orientation. The built-in spring is assembled to help return pins to their initial position for moving to the next corner when the cam-action is released. The cam-action pin locator design provides effective operation

instead of the upside-down motion required with the orientation bar. It will raise productivity and eliminate complex actions from the current process.

3. *Support design.* The work process needs the top surface to be parallel with the work table. Support is needed to define the bottom outline of the female plastic panel since it is not a parallel cube. The material proposed to use is metal with a rubber cover to prevent scratching the plastic panel.
4. *Redesigned clamping device.* A new clamping device with a surface hood, cam-action pin locators, and support design will provide the advantages of saving the time to set up copper nuts, move the clamping device, clean, and visually inspect it. Also, it will ensure the product's quality and productivity. The clamping device was manufactured and works with surface hood, as shown in Appendix C.
5. *Continuous process improvement.* The Deming cycle promotes never-ending improvement: the PDSA (Plan-Do-Study-Act) cycle guides the steps for XYZ Plastic, Inc. to improve product quality and productivity. This study provided solutions and completed the Plan phase of the PDSA cycle. The researcher recommended for XYZ Plastic, Inc. to implement the solutions from this study and collect data for measurement results in the Study phase and document process procedures for continuous improvement in the Act phase.

Recommendations for Further Study

This study developed a new clamping device with the goal of eliminating variance from the process that involved inserting the copper nuts. However, the insertion of the copper nuts is only one step of the entire process. The female plastic panel also undergoes the injection molding process, the inserting glass process, and the packing process. The female plastic panel is for make-to-order merchandise and reducing each production cycle time is an important activity for the company to be competitive in the marketplace. For effective productivity, a further study should examine the other processes to reach the goal of continuous process improvement.

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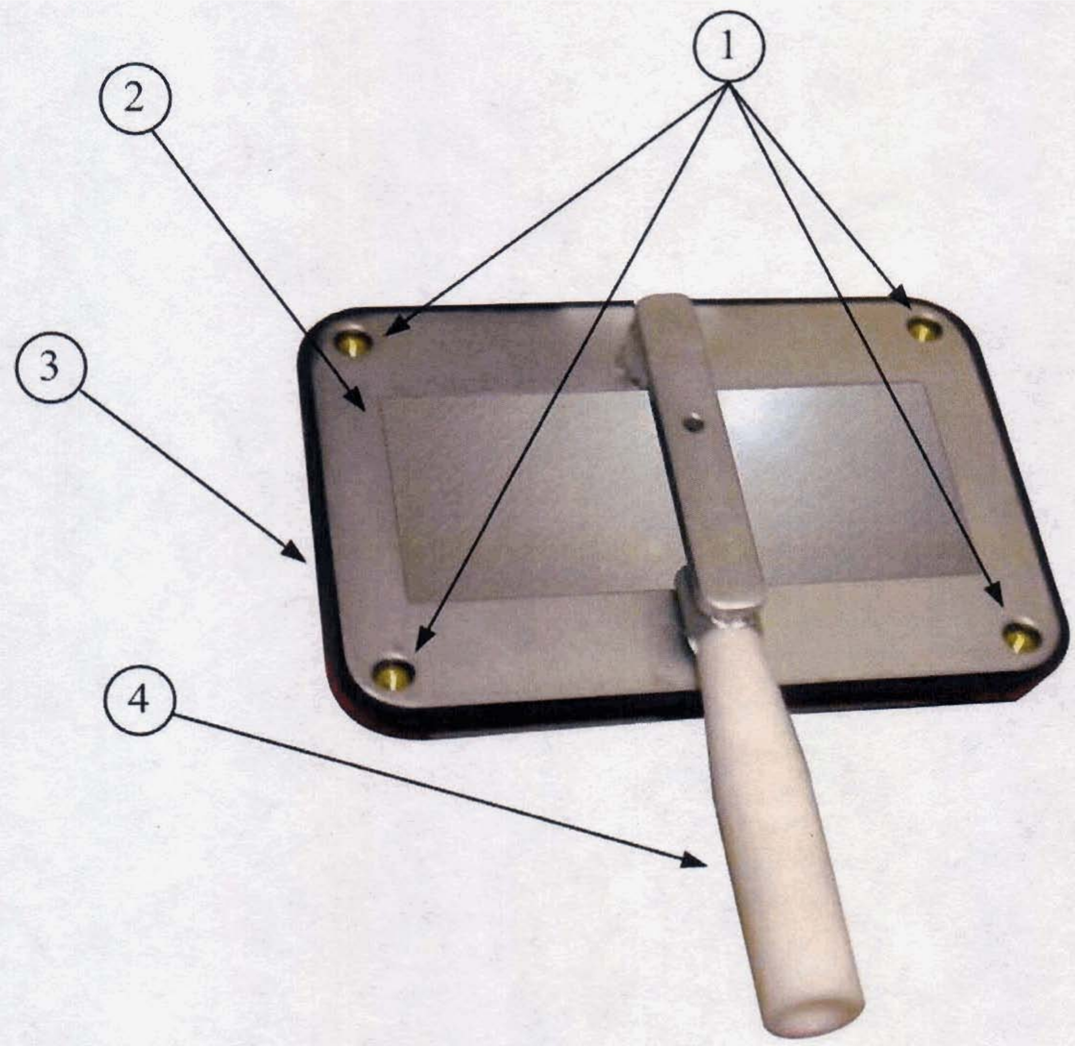
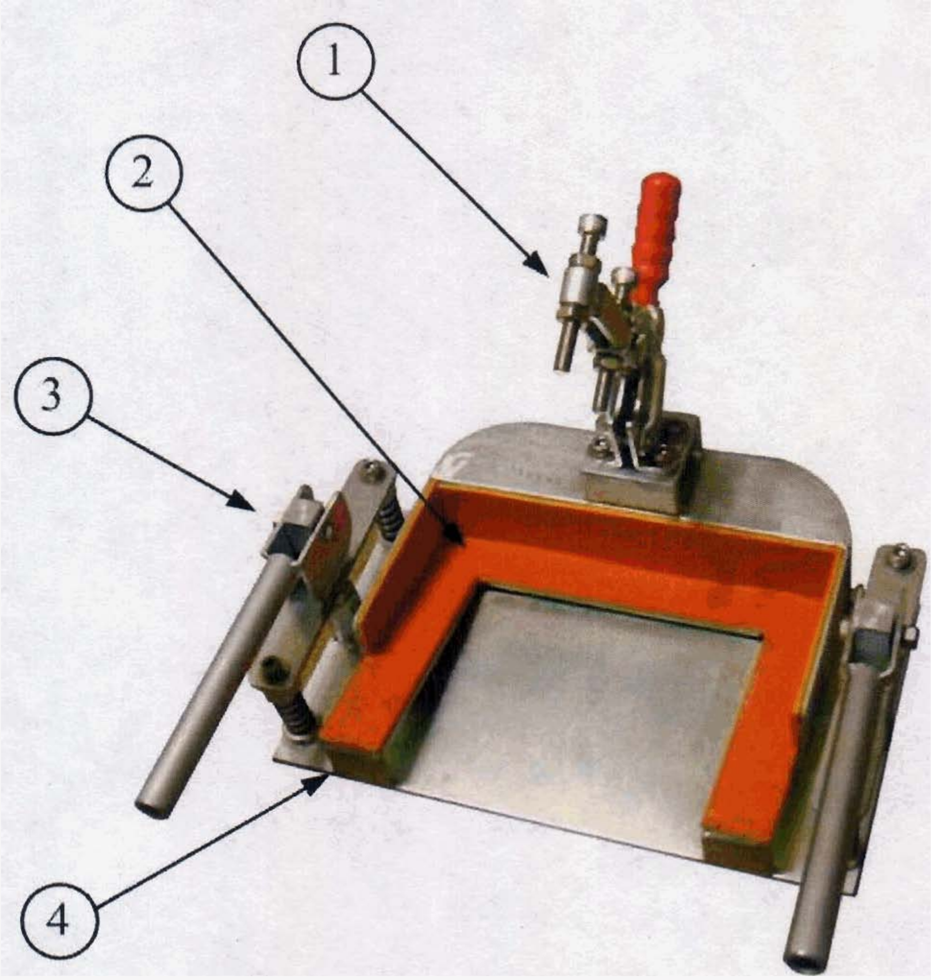
Appendix A: Surface Hood

1. Copper nuts
2. The surface hood
3. A female plastic panel
4. The handle design



pendix B: Redesigned Clamping Device

1. Toggle action clamp
2. The rubber form
3. Cam-action pin locator
4. Support definition



Appendix C: The Redesigned Clamping Device (Cont.)