Author: **Riedel, Paul, E**

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STUDENT'S NAME: Paul E Riedel

STUDENT'S SIGNATURE: [redacted] **DATE: 12/9/2011**

ADVISER'S NAME: James Keyes PhD.

ADVISER'S SIGNATURE: [redacted] **DATE:** 12/9/2011

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Riedel, Paul E. ***Material Burr and Sharp Edge Identification***

Abstract

This study examined practices of identifying burrs and sharp edges at a high volume metal fabrication company. The focus was the occurrence, cost impact and detection methods. The information from the study will determine if the stamping equipment is adequate versus the justification of more advanced equipment. The review of tool maintenance dialogs, process control plans and inspection methodology emerged as the point of interest to establish consistent reliable data. The study targeted the Underwriters Laboratories (UL) Standard 1439 Test for Sharpness on Equipment. The conclusions determined that current equipment was adequate for the company's application and requirements. Written standards of process methods and techniques needed to be refined and implemented.

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Chapter I: Introduction

Company XYZ is a worldwide manufacturer of lawn care products ranging from the average consumer to the top golf courses in the in the world. The corporate office is located in Minnesota with manufacturing plants throughout the United States, Europe, and Mexico. Product outlets consist of dealers, distributors, big box stores and internet sites with gross sales in the billions of dollars. Snow removal and lawn care equipment are the majority of the company's product line with additional ventures in irrigation and utility vehicles.

Company XYZ has the reputation for producing a high quality product at a competitive price while maintaining a safe working environment for its employees. In order to maintain customer confidence level, Company XYZ annually contracts a third party testing source to test equipment to ensure it complies with guidelines set by the American National Standards Institute (ANSI) for product safety.

A majority of the products are made from mild steel using a variety of methods. Stamping, forming, shearing and casting are some of the methods used to make the components while welding, staking, riveting and fastening are methods used to assemble the product. In an attempt to become more linear integrated, some metal components are manufactured internally at the assembly plants. Producing their own metal components internally has allowed them flexibility to increase or decrease part quantities based on demand, make changes to parts and leverage costs by utilization of existing equipment. The company currently employs a vast array of equipment varying in age, brands, tonnage and capabilities. Due to the lack of documented historical data, addressing equipment maintenance, set-up procedures and inspection methods was a common problem. The identification of burrs and sharp edges was unfamiliar territory for Company XYZ due to a lack of standardized criteria of edge quality.

The problem was that burrs and sharp edges affected the efficiencies of the production process in several ways. A major area of cost to production was the required secondary operation for burr removal. When considering that this unplanned secondary operation was not determined in the beginning before product cost roll-up, burr removal was associated to the loss of production time and efficiency. One other area affecting efficiency was the cost of repeated idle time of the presses while maintenance was performed through sharpening dies or replacing punches. The continual operation of the press without planned maintenance resulted in premature wear on tooling and equipment while increasing the risk of injury. Risk of injury was increased due to the increased formation of burrs and sharp edges on parts made from degraded tooling.

Problem Statement

Company XYZ had a need for a written process and standard for manufacturing plants and suppliers to follow in order to identify burrs and sharp edges on parts used in the assembly of finished products. Poor edge quality had caused several problems in terms of cost; which included loss of productivity and efficiency, production delays, and the risk of injury to workers and customers.

Purpose of the Study

The purpose of this study was to examine the reason burrs formed on parts, the time spent on burr removal, the injuries caused from poor edge quality and the benefits of implementing a standard for edge quality to serve as a guide for plants and suppliers to follow. The project improvement plan will focus on the edge quality of parts produced, develop a standardized process control plan and thereby improve the workflow process and reduce injury occurrences. This study will incorporate problem solving methodology involving Statistical Process Control

(SPC) and Root Cause Analysis while utilizing tools such as the Fishbone Diagram, 8D Status Reports and comparison charts. The goal of this project was to develop a strategy to address process deficiencies through incorporating measureable criteria that define and identify material burrs and sharp edges. This study reviewed the criteria dictated by Underwriters Laboratories (UL) Standard 1439, Standard for Determination of Sharpness of Edges. This study also examined different types of inspection tools and methodology used for the detection of burrs and sharp edges on material including the frequency of inspection. The study also considered the pros and cons of traditional manufacturing technology versus non-traditional methods of manufacturing. In conclusion, a choice of optional recommendations was presented to Company XYZ management to decide whether to make the parts, buy the parts, upgrade equipment or leave as is.

Assumptions of the Study

This study held two assumptions; that the current equipment over an expected run time was incapable of producing parts without burrs or sharp edges and the inspections tools used for detection were inadequate to provide repeatable results for detection. While the current working environment was producing parts that were functional, many non-compliant parts with burrs or sharp edges had put the employees and customers at risk of injury. For the purpose of this study, the information gathered was based on testing methods employed by UL in recognition of International Standard 1439, Determination of Sharpness of Edges. The process efficiency was determined by calculating the average amount of parts produced over a three day period.

Limitations of the Study

This study was limited to one specific part produced at a given period of time. The opportunity to observe other equipment and dies was hindered by limited production requirements and seasonal production runs. The amount of historical data regarding inspection procedures on past production was also limited as was the available data on injuries. This study was given the latitude by Company XYZ to observe the production process and review tool maintenance records.

Definition of Terms

American National Standards Institute (ANSI). A premier source for timely, relevant, actionable information on national, regional, international standards and on to the monitoring and control of a process to ensure that it operates at its full potential to produce conforming product (American National Standard Institute, 2011).

Burr. "A thin ridge or area of roughness produced in cutting or shaping metal" (Gillespie, 1999, p. 1).

Root Cause Analysis. A systematic approach to get the true root causes of process problems (Rooney & Vanden Heuvel, 2004).

Statistical Process Control (SPC). The application of statistical methods conformity assessment issues (Nelson, 1985).

Underwriters Laboratory (UL). Is a not-for-profit product safety testing and certification organization (Underwriters Laboratories Inc., 2004).

Methods

The primary goal of this project was to gather and analyze supporting data concerning edge quality, and then present options for consideration to Company XYZ for decision making. The desired outcome was to avoid any issues of burrs or sharp edges from reaching the customers. By incorporating the problem solving technique of Root Cause Analysis, the focus highlighted the problems and not the symptoms. Root Cause Analysis is a systematic approach to determine the real cause of the process problem so proper corrective measures could be implemented. These corrective measures needed to comply with UL Standards 1439 Standard for Edge Sharpness.

- 4.1 An edge of an enclosure opening, frame, guard, handle or the like of an appliance or equipment shall be smooth and rounded so as not to cause a cut-type injury when contacted during normal use or user maintenance (Underwriters Laboratories Inc., 2004).

The key to Root Cause Analysis lies in asking *why* the problem occurred, continuing to ask *why* until the root of failure is exposed. This process is also known as the 5 why's due to repeating the question five times after each answer is given. This is similar to a young child asking his parents a question until a satisfactory answer is reached.

A Fishbone Diagram was used during the brainstorming session to address all potential causes of process failure. The fishbone diagram resembles a fish and the bones on this diagram represent the five inputs of a process: Man, Machine, Material, Methods, Measurement, and Environment. The head of the diagram represents the problem being investigated. Once the root cause is determined, the proper metrics are implemented to reduce or eliminate the issue.

Summary

The purpose of this study is to identify the causes of burrs and implement process changes to eliminate them. In the next chapter, literature will be reviewed and cases of burrs including how they may be reduced.

Chapter II: Literature Review

Company XYZ desired to eliminate problematic burrs and sharp edges unintentionally created during the metal fabrication process. In order for assembled components to function in their intended designed, it was imperative that sharp edges and burrs be removed (Gillespie, 2000). Burrs and sharp edges have taken a toll on the metal fabrication industry and have served as a catalyst for further research advancement in manufacturing technology. Personal injury litigation, misaligned component assembly, plating and paint buildup, increased wear of moving parts, fluid leaks and failed electrical circuits are results of poor edge quality that have become the driving factors for industry change.

Economic Impact

Burrs and sharp edges impact business by increasing WIP (work-in-process) where the parts require a secondary operation to remove the burr. Burr removal can be done mechanically or with the aid of hand tools specifically designed for this removal. The cycle time for most stamping operations produces parts at a rate faster than an operator could keep up therefore requiring additional labor to maintain process flow. When the condition occurs that the machine output is greater than the product flow a bond area is needed to avoid the risk of unacceptable parts getting mixed in with reworked parts.

The costs associated with this condition are added labor to remove burrs, tools and materials, storage area for WIP that needs burr removal, additional work area, and tying up resource dollars on parts that cannot be used. The risk are parts getting shipped to a supplier with burrs and sharp edges only to be rejected and returned which adds freight costs. This could also lead to penalties assigned for lost production or a possibility of losing a client altogether.

Personal safety is also a concern when dealing with burrs and sharp edges. Burrs and sharp edge criteria are outline by government agencies like the Consumer Protection Safety Committee (CPSC), Underwriters Laboratory (UL) and Occupational Safety and Health Administration (OSHA). Contact with these surfaces without proper safety attire may result in cut or laceration to internal or external people. The severity of the injury it could result in an emergency visit at the hospital or self-treatment with a bandage. Longer term injuries if not properly treated could become infected could result into additional lost time for an employee or litigation for a personal injury settlement to an unsuspecting customer.

The Occupational Safety and Health Administration (OSHA) incidence rates are one of the most common methods of measuring safety performance. Some of the more common rates are the OSHA recordable incidence rate, lost time rate, and severity rates. The calculations are based on a rate of 200,000 labor hours. This number (200,000) equates to 100 employees who work 40 hours per week and who work 52 weeks per year.

- OSHA Recordable Injury Incidence Rate = (number of recordable injuries) x 200,000 / number of hours worked
- Lost Time Case Rate = (number of lost time cases) x 200,000 / Number of hours worked.
- Severity Rate = (number of lost days) / Number of hours worked

Manufacturing experienced an increase in the incidence rate of lost time injuries and illnesses in 2010. The increase was due to a larger decline in hours worked and not the case of an increase in the number of reported cases in the industry sector. In 2009, the incidence rate was 4.3 cases per 100 workers and that number increased to 4.4 cases in 2010 in the industry sector (United States Department of Labor, 2011).

Table 1

Death/Injury Table: Average Economic Cost by Class and Severity, 2009

	Death	Disabling Injury
Home injuries	$1,050,000	$6,800
Public injuries	$1,050,000	$8,600
Work injuries without employer costs	$1,320,000	$48,000
Work injuries with employer costs	$1,330,000	$53,000

(National Safety Council, 2009)

Based on data released by the National Safety Council for the year 2009, total accident cost industry $1.3 million dollars in quantifiable losses for work injuries. This figure does not take into account the cost for re-training individuals to take the place of absent workers due to the accident. These cost figures are includes the following categories expenses:

1. Wage and productivity loss including wages and fringe benefits (National Safety Council, 2009).
2. Medical costs include doctor fees, hospital charges, the cost of medicines, future medical costs, and ambulance, helicopter, and other emergency medical services (National Safety Council, 2009).
3. Administrative include the administrative cost of public and private insurance, and police and legal costs. Private insurance administrative costs are the difference between premiums paid to insurance companies and claims paid out by them. It is their cost of doing business and is part of the cost total (National Safety Council, 2009).

The National Safety Council reports that human error underlies a full 80% of all industrial accidents and injuries (Babcock, 2011)

Types of Injuries

Injuries caused by burrs and sharp edges ranged from minor scratches to severe lacerations, metal slivers on hands and fingers, burns on skin using a heat source, and eye injuries from flying debris from burr removal. The injuries occurred during the handling process either by contacting the material edge while assembling product, grasping parts from a part bin or unintentional contact with the material edge while equipment was moving on an assembly line.

Burr Description

Burrs and sharp edges come in all shapes and sizes. Burrs and sharp edges are defined as excess material rolled over the cut edge not resulting in a fine finished edge or better known as a Poisson Burr. Burrs are accepted in metal fabrication but limited by size. The rule of thumb is 10% of material thickness is acceptable on lighter gauge material or not to exceed 0.005 inches in height (Gillespie, 1998). Burrs and sharp edges are not confine to just metal but can be found in plastic components as well. This condition is commonly referred to as flash which is excess material found on the finished edge of the material.

Detection Methods

Measuring burrs and sharp edges was challenging for Company XYZ and in many cases had been overlooked resulting in a measureable dilemma. Before development and implementation of a process control plan, a burr verification system needs to be implemented. Some types of verification methods used consisted of utilizing equipment such as a microscope, a magnifying lens, a fingernail test, a toothpick test, a No. 2 wooden pencil test or a sharp edge gage. These methods are customary among the most effective techniques used in identifying burrs (Gillespie, 1998). The simple probe test using a pencil, toothpick or dental pick works well to detect the presence of a burr, but does not provide any method of measurement. This testing method could be prone to scratching high finished areas creating other material surface finish defects (Gillespie, 1998). Visual checks only inspect for the presence of a burr but fails to measure them. The most common visual inspection used is the unaided eye with the ability to detect a burr height at 0.005 inch or greater. A secondary visual inspection method with greater refined ability consists of using a 4X magnifing glass to detect a burr height at 0.002 inch. In an application where more percise visual detection is required, inspectors then use an illuminated 50X microscope. A significant drawback to using a microscope is the limitation to viewing only small parts (Gillespie, 1998). The fingernail test is another method to ascertain the presence of burrs by scratching the fingernail over the material edge. This method is capable of detecting burrs, but unreliable due to inconsistencies resulting from the various sensitivities of differing individuals. In addition, this method is accompanied by the risk of injury through exposing fingers and hands to poor edge quality (Gillespie, 1998). The Sharp Edge Testor SET-50 was the tool of choice for Company XYZ for reasons that it is portable, repeatable, accurate and provides immediate results as well as its recognition by Underwriters Laboratories (UL) for its ability to identify burrs and sharp edges (Technical Engineering Service Corporation, 2010).

Metal fabrication companies incorporate a variety of machines that perform various functions to process metal into assorted shapes and sizes. Whether it is blanking, forming, punching or shearing metal, a burr may result due to incorrect or misaligned die clearances of the mating tools. Poisson burrs or roll over burrs are the most commonly created burr in metal fabrication. The actual side of the burr is proportional to the cutting edge radius and the applied pressure (Gilllespie, 1976, p. 26). When a change to material structure occurs, there is also a change taking place within the existing properties. By addressing these issues at the beginning of the process, the risk of failure is reduced. Quality edge standards were poorly defined, thus corporations were faced with the dilemma of educating customers, suppliers and quality personnel of a true depiction of consistency in sustaining burr-free operations (Gillespie, 2000).

A burr is defined as "a thin ridge or area of roughness produced in cutting or shaping metal". Sharp edges are the result of inadvertently leaving an edge that typically has many sharp facets (Gillespie, 1999). Some of the common causes of burrs are the result of the material tearing during the cutting or forming process. The location of the burrs is on the edge of the material caused by material breakage during the cutting or stamping process. This process consists of two mating tool surfaces that meet on a cutting plane allowing one tool to over travel the other during the cutting or forming process. This over travel is built into the mating tool, being smaller in size than the other tool, to allow it to travel which is referred to as die clearance. The burrs and sharp edges form in the area of where the X and Y surfaces intersect.

Another cause of burrs is the ductility of the material (Gillespie, 1999). Ductility refers to the flexibility of the material. Material with less elasticity will have a smaller burr while the more elastic material produces a larger burr. Thickness of material also plays a causal role in the formation of burrs on the edge of material. The thicker the material the higher is, the probability that the shear will cause breakage resulting in a deformed edge versus a cut edge. Another potential cause is dull or worn tooling. This condition will stretch the material, opposed to precision shearing, causing a tearing effect leaving a rough edge with sharp features.

The formation of burrs and sharp edges typically are not the result of poor planning or poor engineering. They are a natural result of the machining and blanking process (Gillespie, 1999). Controlling feed speeds, material hardness and sharp tooling can minimize burr formation. The best solution is to engineer the issue out during the design process. This can be done by using different cutting technology such as laser, plasma or even a water process to cut the material. In the forming or stamping operation, implementation of a secondary operation is utilized to remove the burr from the edge of the material. There are a variety of methods to remove burrs consisting of hand operation tools, thermal heat, mechanical rolling tools, robotics, abrasive grinding wheels and the use of chemicals to dissolve the burr edge (Gillespie, 1999). Secondary operations in most cases are not desireable but are used to reduce the cost of producing components.

An acceptable burr condition referred to as Industry Standard is quoted as "10% of the material thickness not to exceed 0 .005 inch height", which covers most industry standards unless special surface finishes are required (Gillespie, 1998, p. 1). Cost is always a factor when considering edge quality. The higher the requirement the greater the part will cost to produce. Knowledge of the application will help determine the quality of the surface finish requirements and the final cost to produce the part.

Company XYZ used a number of methods in managing sharp edges and burrs. They included adding a written requirement indicating "no burrs, sharp edges or protrusions" on the piece part print. With no internal standard, this requirement was difficult to control and even harder to measure. In most cases this written requirement was overlooked leading to a reported injury or application predicament.

Another method called de-burring, a secondary operation, was used to manage burrs and sharp edges. A hand tool or an abrasive grinder applied directly to the edge was used to remove the suspect matter. The disadvantage of this method was in the risk of damaging the part resulting in inconsistent material removal and by-passing the root cause of the problem. The grinding also created a serrated edge condition that was prone to leaving metal slivers and protrusions that were potentially harmful to anyone in contact with the surface edge.

Traditional Methodology

Traditional manufacturing methods of stamping, shearing, punching and forming could not completely eliminate the development of burrs and sharp edges, but tool maintenance would aid in minimizing burrs by keeping the cutting edge sharp. The traditional method has proven its worth over the years and is still used on many fabricating shops today. The manufacturing operations can be done in sequence on independent machines or by using a larger machine with greater tonnage to cycle a cluster die or progressive tooling to so all steps in a single stroke of the machine. The advantage to using single step operations is cost of equipment is less because of less tonnage needed to perform to operation. The tooling also cost less because of the lack of complexity by only performing a single step in the machine cycle. Smaller tonnage equipment can provide versatility for interchanging die in multiple machines in case of equipment breakdowns. The less complexity of tools involved usually requires less training and time to repair. The downside is increase machine operators and floor space for equipment. This equipment runs by either hydraulic rams or by a flywheel that provides the down pressure onto the die to create the part. This down pressure is measured by tonnage. The mechanical down pressure would form, punch holes and trim the metal inside the die resulting in a finished part in a progressive die. The investment on this type of equipment is more cost effective than non-traditional equipment; however the maintenance required is more frequent.

Non-Traditional Methodology

Non-traditional methods of fabricating consist of Water jet cutters, Wire EDM cutters, Laser cutters and Plasma cutters. This type of equipment increases process flow, eliminates burr removal, and provides a clean finish for welding, plating and brazing (Gilllespie, 1976). The disadvantage to these non-traditional methods entails high equipment costs, limited geometries, work piece tolerances, and material limitations (Gilllespie, 1976).

A Water jet Cutter is a nontraditional method that is fast speed with an ability to cut thick material with accuracy and produce a clean, finished surface. There is no heat generated during this process allowing the machine to cut various types of material. This finished process is still capable of leaving a slight burr which is difficult to detect (International Waterjet Machines, 2001). Wire EDM is slow in speed, but able to cut very thick material. EDM has very high accuracy producing an excellent surface finish allowing for zero burrs while generating no heat. A limitation to EDM is that only electrically conductive materials can be cut (International Waterjet Machines, 2002). A laser cutter has good speed, provides flexibility, is repeatable, is efficient with material use and cuts with precision when cutting thin material leaving no burrs. Lasers become less effective on thicker material of 0.4 inches or more (International Waterjet Machines, 2002). A last method, Plasma, cuts at high speed generating heat and leaving rough edges. Accuracy is a disadvantage although it has the advantage of cutting electrically conductive material like aluminum. Another downside is the need for special gas to assist the process adding to the cost of the process (International Waterjet Machines, 2002). The following table is an Equipment Comparison Chart (Appendix A) is for the purpose of visually comparing all forementioned non-traditional equipment. Other concerns are the return on investment (ROI) and obtaining the qualified personnel to maintain the higher technical equipment. Operator training is also a concern in order to maximize the capability od the machines.

Summary

In conclusion, burrs and sharp edges have been problematic for Company XYZ due to lacking definition and standards. Personal injuries, misaligned component assemblies, scratches and premature wear and failure of moving parts resulted in increased costs to manufacturing. Even with research advancement in manufacturing technology and processes, material burrs and sharp edges continue to create issues for the company's manufacturing plants and suppliers. Without a common industry standard to guide by, Company XYZ was forced to develop their own internal standard and interpretation of the fine line between acceptable and unacceptable burrs and sharp edges.

Upon reviewing both traditional and non-traditional methods of manufacturing the frequency may be reduced but issue of burrs and sharp edges still exists. Early intervention and detection is the key to avoid unplanned costs of rework and personal injuries. Injury Incident Report for Company XYZ data over a three year period revealed there were 87 injuries within a three year timeframe. The majority, 67% were classified as minor injuries resulting in lost time of less than one day. This majority consisted of cuts and lacerations that did not require outside medical attention. The remainder, 33% required one or more days of lost time for a work related injury.

Chapter III: Methodology

This project focused on the problem with burrs and sharp edges forming on the edges of the parts. Parallel to this study was the impact of cost and safety to the employees and customers. While the existing tools and equipment were at the work station, data was gathered and observations recorded. The review of data collection and methods were also scrutinized for the accuracy and reliability. Additionally, focus was on the results from the fishbone diagram after a brainstorming session. The diagram (Figure 1) referred to as a cause and effect diagram invented by Dr. Kaoru Ishikawa, a quality control statistician who invented the diagram method to analyze problems through a structured process of Root Cause Analysis (Office of Organizational Excellence, 2002). The following discussion of the bones from the fishbone diagram; Man, Material Machine, Method, Measurement, and Environment, was handled respectively to ensure all facets were addressed by the team. To determine the root cause of the problem, tools like a fish bone diagram are used to determine all contributing factors to the problem. In order to maintain the accuracy of the data collected a list of procedures were established to make this study a repeatable process.

Brainstorming

The Fishbone Diagram was used to keep the team on focus to determine the Root Cause of burrs and sharp edges on parts. Additional bones were added to amass further process details. The problem was previously defined, “Burrs and Sharp Edges”.

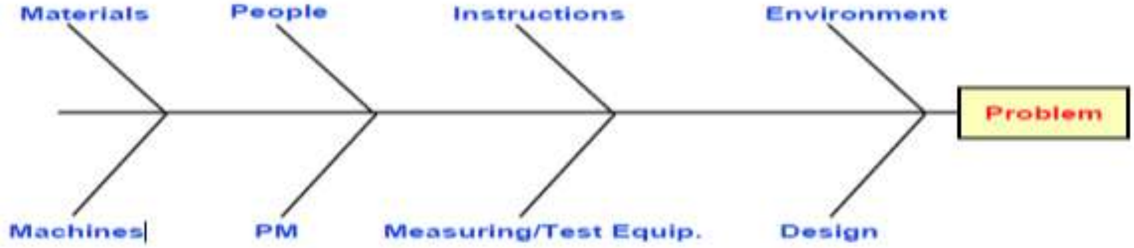

Figure 1. Fishbone diagram.

- *Materials* were discussed and it was determined that the correct material was used. It was suggested to have the material thickness verified and recorded on the work order that travels with the material. That would be done at the shear before cutting the blanks to size.
- *Machine* ability to produce desired edge quality was questionable, yet was determined to have the capability to perform other operations effectively. Time studies needed to be done to determine if the equipment could produce specific parts cost effectively. Options were presented and decisions made whether to make or buy parts based upon ROI.
- *People* (or Man) were knowledgeable of their job duties but lacked proper training in other areas of manufacturing. A suggestion was offered to cross-train workers to monitor the production process including data collection to maintain tighter controls on the process.
- *PM* (preventive maintenance) on the tooling and equipment appeared to be sufficient but lacking in historical data. The need to incorporate a PM plan was important to make the process sustainable.
- *Instructions* were either difficult to follow or ignored. Therefore, a suggestion was made to document all required standards for process consistency in relatable terms. Consistency of the process will produce repeatable and reliable data.
- *Measuring and Testing Equipment* was not accessible at the work stations. Distinct devices were needed to aid in the detection of burrs and sharp edges. The cost for the purchase and training of new inspection tools was deemed minimal.
- *Environment* was considered a non-factor. Demographics of where the parts were

produced and the location of the suppliers manufacturing plant were considered in the decision.

- *Design* engineers were challenged to design parts using the Design for Manufacturing and Assembly (DFMA) principles.
- *Problem* was stated previously: 'burrs and sharp edges on parts'. It was determined that deficiencies in the process contributed to this issue. The goal is to implement some or all suggestions into the process to improve edge quality, reduce costs from burr removal and reduce injuries.

Data Collection

The area that was targeted first at the beginning of the process was to determine if the equipment was in proper working order and capable of performing the required functions. Tools and presses needed to be maintained when using traditional methods of manufacturing like punch presses to avoid premature breakdown and maintenance. That was the most significant check considering that if the equipment was not capable, then any steps after that would only be a waste of time. Once the equipment was verified and deemed acceptable, the next step was assuring the required measuring tools were accessible. The proper tools needed to be capable of supplying data that was repeatable and reliable for accurate decisions. The inspectors or operators responsible for collecting the data had to have the ability and training for proper use of the inspection devices. The Process Inspection Log (Table 1) was used to document the findings during the production run. The data was used to identify trends to predict process behavior. The samples were selected randomly during the production run of March 20, 2011 thru March 23, 2011 to monitor the variability of the process.

The last item addressed was the frequency of the inspection checks. The higher frequency provided more data as well as detected the out of control condition quicker while the quantity of parts to disposition was less. Due to the vague definitions of material burr and sharp edge characteristics in the manufacturing industry, measureable criteria was needed to provide consistent standards for measurement and identification (Gillespie L. , Inspecting for Burrs, 1998). The following chapter will address the instruments used to collect data.

Equipment and Tooling

Prior to the start of production, tooling maintenance records were validated that preventative maintenance (PM) was completed. The files were located in the tooling room and the dies were filed under the tool number (TL). This number was stamped on the die for inventory reasons. The file for this tool contained entries of all past maintenance.

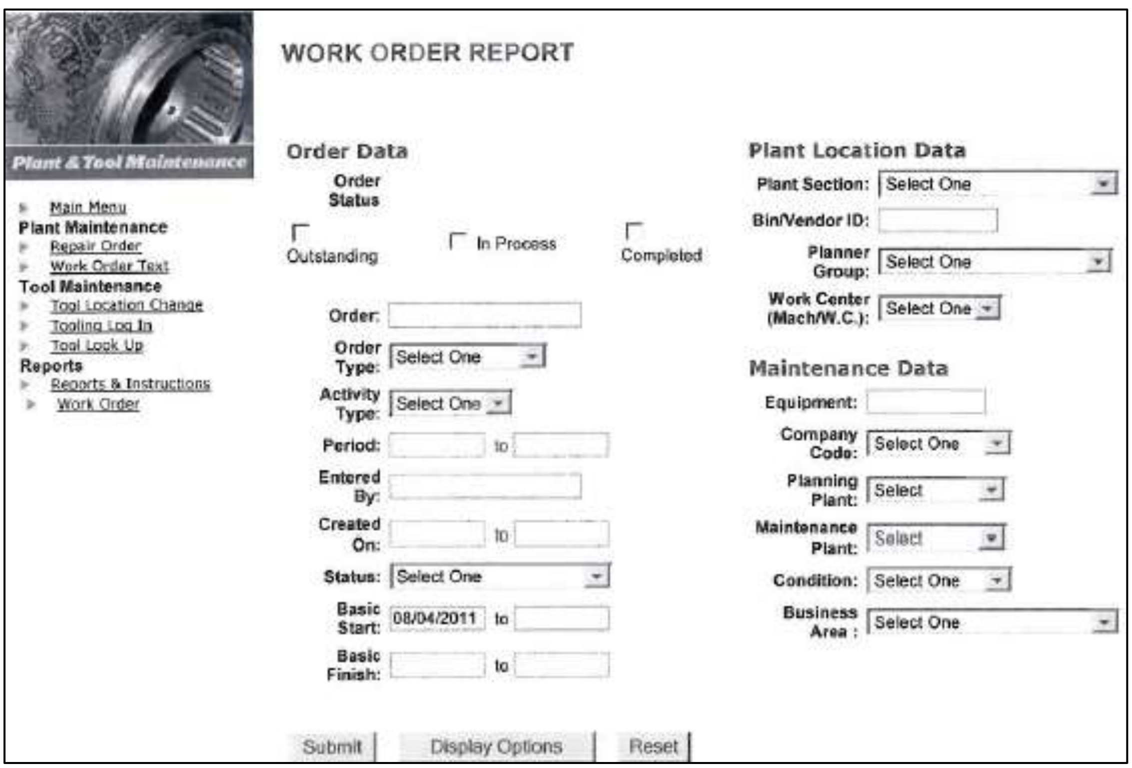

Figure 2. Tooling work order report

Documentation consisted of broken punch replacement, tool sharpening, part replacement and lubrication of dies and presses. Depending on the size of the tools, the set-up process may take anywhere from an hour to days to complete. Sample parts needed to be run and verified by the quality control department to validate the machine set-up.

Instrumentation

Figure 3. Sharp edge tester illustration

Company XYZ used three tools in gathering information for the purpose of researching material burr and sharp edge identification with the ability to provide repeatable and reliable measurement data. The first of three tools implemented was a Sharp Edge Tester SET-50. A Sharp Edge Tester SET-50 was the only tool on the market approved by Underwriters Laboratories (UL) to test according to the UL 1439 "Standard for Determination of Sharpness of Edges", a current worldwide industry standard for sharp edges (Technical Engineering Service Corporation, 2010).

This testing device is portable and can provide immediate results using a pass or fail methodology. The above photo is a Sharp Edge Tester SET-50 taken from the Technical Engineering Service Corporation. A detailed description of the Testers function can be found in the following section, Inspection Procedure.

Figure 4. Micrometer illustration

A second data collection instrument used was a micrometer. A micrometer is portable and lightweight with the ability to measure to a high degree of accuracy. This device is able to measure the height of the burr along the edge of the material. This method is adequate when measuring burrs that are rigid, however superfine burrs require more precision methods due to the risk of crushing the burr height. The above photo is of a micrometer taken from the website, The L.S. Starrett Company (L.S Starrett Company, 2007).

Figure 5. Cycle counter illustration

The last device used was a cycle counter located on a punch press that counts the number of parts produced. This aided in the ability of the material handler to pinpoint when the machine began producing non-compliant parts due to burrs (High Pressure Technologies, 2008). The above photo was taken from the website High Pressure Tech.

Inspection Procedure

The next items checked were the measuring devices that were used to verify the process. These tools must be calibrated annually to insure accuracy and reliability. Calibration dates are located on the instrument while all other data is located in the inspection department files. All process control charts, prints, visual aids, check fixtures and other data collection sheets were assigned to appropriated station where the in-process checks take place. The process control plan included all key features that needed to be monitored, including the inspection intervals. Production began following all verifications and the cycle counter was reset to zero.

Frequency and Data Collection

The inspection frequency of finished parts varied in time based upon the confidence level of the production process. This information was listed in the process control plan unless historical data was absent. It was best to base the frequency on the conservative side and verify more often than not, reducing the quantity of parts that needed to be contained. All parts between the ranges of the last compliant check to the point of non-compliance were suspect requiring some type of rework or disposition.

Listed in Table 2 is an example of a control chart used to record results from an in - process inspection check.

Table 2

Process Inspection Report Log

Date	Time checked	Number of Cycles	Burr Height (inches)	Sharp Edge Test (Pass/Fail)

The inspection data that was gathered during the process was recorded in the required fields for the purpose of creating a smooth running process. The following is a description of the attributes listed in the Process Inspection Report Log. The Date was documented for historical purposes as well as to verify production start and the length of the run. Time was utilized to monitor the frequency and facilitate the minimizing of scrap or potential rework. The Number of Cycles was used to verify the quantity of parts produced and to determine the suspect range of non-compliant parts. The Burr Height is a check that uses the micrometer to verify the height of the burr on the edge of the material. The data could also be used for historical purposes to complete trend analysis or statistical analysis to measure process variation.

The Sharp Edge Tester Set-50 gage has only the ability to check a pass or fail condition. This instrument provides immediate results when a burr or sharp edge was present. The test arm has the ability to maintain constant and equal pressure as the operator moves along the part edge. The cap located on the end of the arm that is in contact with the material is comprised of two layers simulating the skin on a finger. The first and second layer consists of Sensing Tape while a third and innermost layer is black foam (Underwriters Laboratories Inc., 2004, p. 17). The cap material is examined after moving it along the edge of the part to determine pass or fail. If the materials are cut deep enough where the black foam is exposed, it results in a failure and the process is halted (Technical Engineering Service Corporation, 2010). A disadvantage of the Sharp Edge Tester Set-50 is the limited travel of the device. The recommended measurement travel is two inches back and forth over a suspect area. If a spot check in a critical area is all that is requried, then that would be adequate for the application. Cost is a drawback to the tester as the cap may need replacement often, but is replaced only after damage occurs.

Data Analysis

The initial research question was does the solution solve the problem? The data from the process control charts revealed several key insights that determined the next course of action. Were traditional methods capable of producing parts that met requirements? The volume of parts produced over the given length of time was directly proportional to the capability of the equipment. If the time duration had been short and maintenance had been required to restore the equipment back to producing acceptable parts, then the presses, the dies or both would have needed to be replaced. As for the effectiveness of the inspection methods; did the equipment identify an unacceptable condition in a timely manner to avoid secondary operations? The frequency of the inspection checks and the implementation of the Sharp Edge Tester minimized the quantity of parts that needed to be quarantined. When the frequency was increased, the quantity of defective parts decreased.

Overview

Once the deficiencies have been addressed from the fishbone diagram results and the proper tools, data collection sheets and equipment adjustments are completed for the machines, samples can be checked and recorded. Let the machine run for a while so the equipment has the chance to stabilize. Using the Sharp Edge Tester run the cap along the edge of the material with the arm approximately in-line with the body. The arm is spring loaded and calibrated to a constant load which will provide immediate result that is repeatable regardless of the gage operator. This method is quick and portable. The other methods will provide the same results but are subjective due to the loads applied on the part. This method is a pass or fail criteria and if numerical data is needed, then the aid of a measurement system using laser, a micrometer or magnification with a calibrated scale. Cycle counters will provide the quantity of parts produced during the duration in time. Once the cycle counter is reset at the beginning of a production run this devise will count the cycles or parts produced by the machine. This data collection will help refine the production control process to ensure parts produced are within the required specification requirements.

Limitations

The data collection was hindered by time constraints. Company XYZ is a seasonal based company that produces products during the opposite season. Products made for the summer are produced during the winter months and winter products are produced in the summer. Parts are produced in batches which compromised the effectiveness of the implemented changes such as the maintenance program. The limited amount of historical data forced the creation of new control plans in several areas of the plant. The skill level of workers and their willingness to adapt was unknown which limited the accuracy of the data. An unknown amount of training was needed to implement new inspection tools and methods while the tools needed to be incorporated to monitor the process to avoid rework and injuries in the future. The press equipment had limited capacity and capability which was a constraint on part size and geometry. Without the volume of parts it would only create more difficulty to justify upgrading or replacing equipment.

Summary

This study focused on the issues of poor edge quality and the effects of cost and safety to production, employees and customers. Chapter Three discussed the team brainstorming process that utilized the method a Fishbone chart, a cause and effect diagram used for root cause Analysis. The outstanding points of outcome in this chapter covered an in-depth description of the data collection details, equipment and tooling, Instruction, Inspection Procedures, Frequency of Data Collection, and analysis of the limitations of seasonal production despite a determinate number of machines. In Chapter Four the results will be reviewed including an Injury Report Log (Table 4) covering Company XYZ injuries during a time span from January 2007 thru December 2010.

Chapter IV: Results

Burr and sharp edge identification standards had been missing from Company XYZ policies resulting in misinterpretations of what constitutes a good quality edge on their metal fabricated parts. Without guidelines, the terms burr and sharp edge had become subjective based on interpretation which led to a gray area in the quality control process. Anytime a gray area is present in the quality control process, the end product will show no consistency and lead to unplanned costs that cannot be controlled until the specifications are set. This situation led to a study that was determined to research, identify and resolve the issue providing a number of real options for correction.

A study was conducted in Company XYZ consisted of a review of the company's internal injury reports over a three year period beginning January 2007 thru December 2010. This review concluded that a high percentage of injuries were the direct result of burrs and sharp edges on the fabricated parts. By addressing this issue at the source, proper metrics were implemented into the control plan to reduce burrs and sharp edges from occurring. The review of production processes, tool maintenance and inspection methodology showed a lack of consistency in the understanding of a good quality edge. In turn, inspection procedures and tools were inconsistent as well. The data collected was unreliable resulting in the inability to identify burrs and sharp edges. With no quality plan or standard to guide by, a new documented process was needed to provide standards for reliable and repeatable methods to identify burrs and sharp edges. The new standard would eliminate improper diagnosis and provide consistency to edge quality identification thereby provide consistency to the end product which would reduce injuries and cost.

Item Analysis

Listed below on Table 3 is data collected on the deck stamping process over a period of three consecutive days.

Table 3

Process Inspection Report Log

Date	Time checked	Number of Cycles	Burr Height (inches)	Sharp Edge Test (Pass/Fail)
3/20/2011	7:30 am	0	0.0005	Pass
3/20/2011	6:30 pm	3000	0.0006	Pass
3/21/2011	7:30 am	6,000	0.0007	Pass
3/21/2011	6:30 pm	9,000	0.0008	Pass
3/22/2011	7:30 am	12,000	0.0011	Pass
3/22/2011	6:30 pm	15,000	0.0014	Pass
3/23/2011	7:30 am	18,000	0.0020	Fail

Table 3 is an example of a Process Inspection Log Report. Listed is the frequency between process checks which took place during the timeframe of April 20, 2011 thru April 23, 2011 approximately 11 hours apart. The number of cycles or part count was taken from the cycle counter mounted on the press that counts every stroke of the camshaft which is equivalent to one part produced. The sampling plan baseline batches of 3000 parts produced. The burr height was measured by using a micrometer. The micrometer features a ratcheting barrel to avoid crushing the burr and provides a high degree of accuracy of measurement. The last column is the Sharp Edge Test which is pass or fail criteria. This test is conducted by using The

Sharp Edge Tester and running the foam cap along the suspect area, then check for a cut on the multilayer cap to determine the pass or fail criteria provided with the gage. This pass or fail criteria is based on the depth of the cut into the layer on the cap.

Based on the data provided in Table 3, there were 3000 parts produced on April 22, 2011 at 6:30 pm thru 7:30 am on April 23, 2011 that failed the sharp edge test. This means that those 3000 parts are all suspect for non-compliance. Since it was uncertain which part out of those 3000 was the first to fail, all 3000 parts need to be quarantined and sorted. Sorting the parts by hand has led to the probability of risk of injury and added additional cost to the process by accruing rework time and interrupting production. Based on past rework for burr removal and sorting, the additional cost (based on one person) is as followed:

- Labor cost is $15 per hour (sort/de-burr) one person
- Sort/de-burr rate: total parts (3000) / parts per hour(30) = 10 hours
- Cost equals: $15*10 = $150 additional cost per laborer (this quote does not include material costs such as secondary operation equipment)
- Fallout percentage is calculated by: fallout (3000) /quantity produced (18000) = 16.7%

This additional cost had to be absorbed into the piece part costs. The information was based on past costs and rework averages on the rates per hour. The risk of using secondary de-burring operations, i.e. grinding, is that de-burring can potentially create small metal slivers because the grinder does not always remove the entire burr. So in addition to increased labor costs of secondary operations, another risk of injury is added from the grinders for incomplete burr removal.

Prior to January 2007, injury log records were incomplete and inconsistent in defining the cause of injury. The data in Table 4 listed below was taken over a period of three year from January 2007 to December 2010.

Table 4

Injury Report Log

Severity	Frequency (N=87)	Percent
Minor	58	67%
Major	21	24%
Critical	8	9%

Table 4 contains only information concerning the most common type of injuries, cuts and abrasions that result from burrs and sharp edges. Table 4 does not reflect all injuries occurring in the manufacturing plant, but only those pertaining to cuts and abrasions. After the new process control plan and preventative maintenance program was implemented there was a noticeable reduction in injury occurrences including a reduction in the severity of injuries. The classification for severity of injuries is based on the criteria of loss time ranging from 0 - days, 0-1 days and more than 1 day of missing work. The reduction of the frequency of injuries was directly related to the reduction of burrs and sharp edges.

Preventive Maintenance

Preventive Maintenance is a proactive approach to keeping the dies in top working condition. Tooling that is in proper working order will reduce the risk of interruption of the production flow while reducing the risks of producing nonconforming parts.

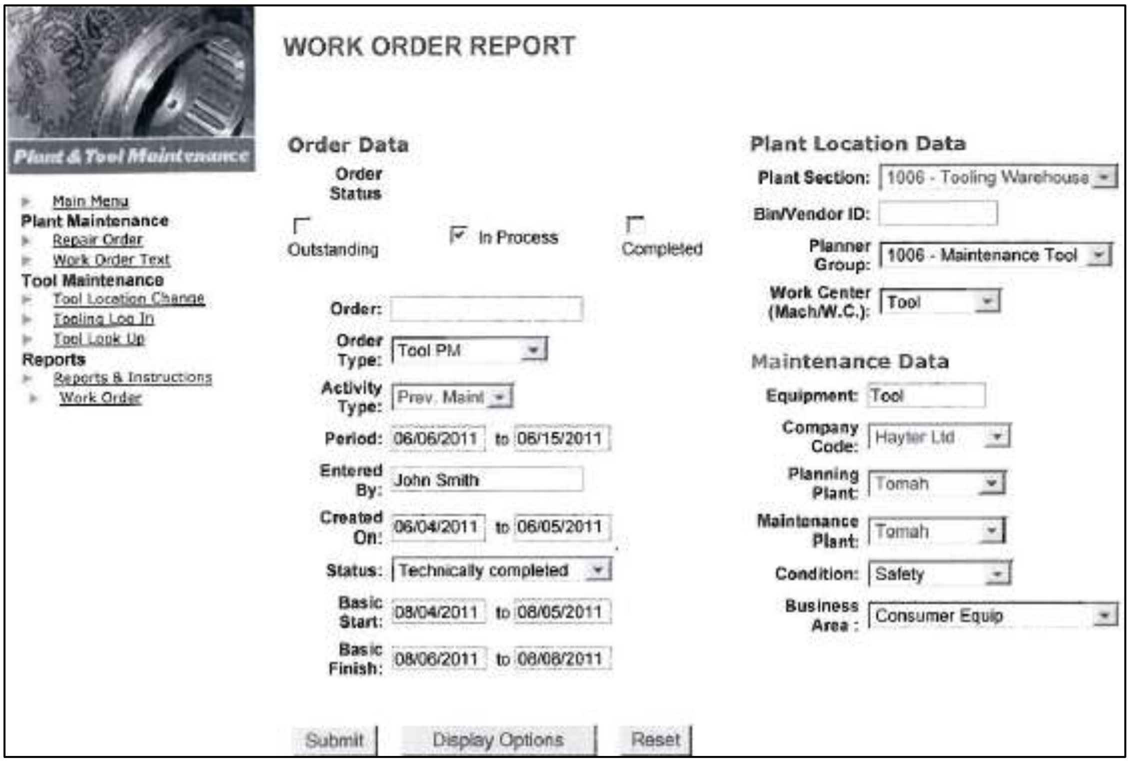

Figure 6. Completed tooling work order report

Figure 6 represents a completed work order report outlining the tool maintenance status, tool location, reason for maintenance and timeline of start to finish. The cells are pull downs to provide standardization of terminology and ease for submission of the work order. The information provided in this work order will provide historical information during the life cycle of the die. The frequency of tool maintenance may indicate needs for advanced planning to replace the tool. The average time for replacing a tool is about 9 to 12 weeks based on the complexity of the tool.

Proper maintained tools will reduced the amount of burrs on parts which in turn reduces the potential of injuries like cuts/lacerations and secondary operations cost for sorting and rework.

Summary

In conclusion, the test results show that process control plays a vital role in identifying burrs and sharp edges. Information from Table 3 indicates that equipment and tools in optimum running condition at the beginning of a process accompanied with the tools like the cycle counter and frequency of inspection will provide a quantity of acceptable parts between process audit checks as well as provide a starting point as to when the process deficiency occurred. The other tools used to monitor the process are a micrometer and sharp edge tester will show the gradual degradation of the process to the point of unacceptable parts are being produced. The micrometer provides numerical data representing the increase of burr height over time and the sharp edge tester identifies when the process went out of control and produced unacceptable parts. This early intervention of in-process audits will contribute in reducing the quantity of unacceptable parts being produced. By reducing this quantity less time and resources will be needed for secondary operations and will reduce the financial impact. Figure 6 is an example of a tool work order report used for preventive maintenance. This report provides historical information on all maintenance that occurred to the equipment and tooling.

Based on the results from Table 4 pertaining to the injury log over a 3 year period, 67% were documented as minor injuries or cuts and abrasions. The majority of these cases were the direct result of handling parts that had burrs or sharp edges however the occurrence of this type of injury was showing a downward trend. It is believed that this was due to the preventative tool maintenance and improved process control metrics.

Chapter V: Discussion

Company XYZ had a need for a written process and standard for manufacturing plants and suppliers to follow in order to detect burrs and sharp edges on parts used in the assembly of finished products. Poor edge quality had caused several problems in terms of cost, which included loss of productivity and efficiency, production delays, late shipments and injuries.

While researching the cause for the increase in injuries reported, the root cause was determined that the equipment was leaving burrs and sharp edges on the fabricated parts. The lack of clear and defined standards concerning burrs and sharp edges allowed production to continue making questionable parts. The research reinforced the need for standardizing the way production was conducted and controlled. The first area addressed was the equipment capability. Why was it leaving burrs on the parts and was there anything that could be done to correct the issue? Further investigation determined that the tooling needed to be sharpened and correctly set-up in the presses. The incorporation of a preventative maintenance (PM) plan can address the symptoms of an issue, the emergency response action required, concise description of the problem and the root cause. The process control plan in Appendix B addresses the directive in UL 1439 Standard for Edge Sharpness. This standard that Company XYZ has complied with for identification of burrs and sharp edges. The next item addressed was how the production process was being monitored. Before a process control plan could be implemented there needed to be a review of the sequence in which the events took place. The items of concern were the frequency of checks, the inspection tools required to perform the checks, the production control chart used to capture the data and the ability to determine when the machine was producing non-conformant parts. Once the process was proven, it was documented and implemented as the Process Control Plan (Appendix B). This Control Plan provides a roadmap from the beginning of the production process until completion of the production run, monitoring the integrity of the parts produced. This plan serves as a catalyst for future production to minimize the amount of non-conforming parts from production that would require a decision whether a secondary operation would be necessary for de-burring or scrapping parts.

Conclusion

By determining the root cause of the problem and correcting the manufacturing deficiencies, the end result was establishing a repeatable process that could be used for future production runs. The implemented and documented control plan referenced in Appendix B resulted in the reduction of burrs and sharp edges by reducing labor expenses from secondary operations and in turn reduced the number of injuries associated with burrs. In addition, the repeatable process created an ability to predict production output, improve part interface, reduce scrap, reduce sorting of non-conforming parts, improve scheduling around planned maintenance, increase tool life and eliminate any discrepancies defining a good part from a bad part. The data collected was value added for determining future print requirements and justification of equipment needed to meet those requirements. The study correlated with previous research regarding process improvements, inspection methodology and cost avoidances. By having a documented production control plan in place it provided the opportunity to create a process that was repeatable and reliable.

Option One

Option One is to maintain the status quo and continue business as usual. The traditional manufacturing methods are adequate in producing parts that meet the requirements as long as the revised control and preventive maintenance plans are followed. The risks are still present in that the same aging equipment is used to produce parts while the new production control and preventive maintenance plans have increased the ability to detect non-compliant parts. The aging equipment and dies are unpredictable and preventive maintenance will only delay Company XYZ's decision to refurbishing or replacement equipment. If a catastrophic mechanical breakdown to equipment occurs the company can still shift tooling to one of the other machine. Another option would be to contract work to another stamping house short term. The fact is that this process will create burrs and sharp edges and rework will always be a part of the equation. The risks are loss time injuries, warranty costs for premature failures, injury settlements and product recalls. These risks can be reduced by following the Preventive Maintenance Program and validate the process by adhering to a formable quality control plan. An advantage to this option is that it requires no capital investment.

Option Two

Option Two is to invest into non-traditional methods of state of the art equipment that have the ability to minimize or even eliminate burrs and sharp edges all together. The value in purchasing new equipment is that in the long run, it will be less than what the company spends on secondary operations. Option Two is a plan for the future but costs may outweigh the benefits. Costs will drop due to the near elimination of burrs and sharp edges, the risk of injury would be reduced due to improved edge quality and production delays decline due improved production flow. The initial capital cost would be substantial and flexibility limited based on the type of equipment purchased. New equipment means additional costs in installation, training, software, computers, special fixtures, and stocked replacement parts in case of breakdown. An increased level of skills may be required of the operators and maintenance personnel due to the complexity of the equipment and hiring may be required to speed up the implementation. As mentioned earlier, the investment is high and the return in investment (ROI) is unknown.

Option Three

Option Three suggests to resource parts to an outside source. There is an opportunity to outsourcing the more difficult parts that have higher edge quality requirements and run the lower level parts in house. The advantage to resourcing some of the more difficult components is that machine capacity time increases and creates opportunity to produce more profitable components on available equipment. Option Three requires no capital investment. The downfall of this option is the increased cost per part produced will take away from the profits and the loss of flexibility scheduling product demand increases or decreases. The dependency on another supplier source may not reduce the same risks that Company XYZ is facing today.

Summary

In conclusion of this study, further research is required to keep pace with continued quality improvement and industry technology. As product design changes so will the technology to manufacture the product. Three options were developed and presented for consideration that included current production process, equipment availability, existing data, and internal standards and guidelines. The study revealed Option One the best choice for the reasons that the current process is capable if control plans and preventive maintenance are incorporated into the production process. Option One does not require Company XYZ to make any capital investment into equipment based on the time and outcome of this study. The ability to reduced burrs and sharp edges thereby reduces injuries and unplanned secondary operation costs that impede the production flow. This may open up the opportunity to apply those resources into new product development which may replace the current product with something new and improved. With proper preventive maintenance of existing equipment and tooling, there is no need for replacement and extended life can be expected.

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Appendix A: Equipment Comparison Chart

Equipment Comparison Chart

Comparison matrix of different cutting process such as water jet, wire EDM, laser, plasma, and punch.

	Water jet	Wire EDM	Plasma	Laser	Punch
Accuracy	Waster jet cutting accuracy average of ±0.003"(±0.1 mm) Better result can be achieved with more advanced software.	Wire EDM is extremely precise parts at ±0.0001" (± 0.025 mm)	Plasma cutting accuracy is in the range of ±0.030 to ±0.060"	Accuracy to ±0.001" (±0.025 mm) or better in thin material.	Fair
Thickness	Water jet Machines mostly cut less than 3" (75 mm) Thicker parts can be cut with reduced accuracy and slower speed.	Very thick parts can be cut with wire EDM. Over 12" (30 cm) has been reported.	Plasma cutting usually cuts less than 1.25"	Usual cuts thin mild steel less than 0.25" (6.35 mm)	Usually works well on thin sheets.
Cutting Speed	Water jet machine cuts five to ten times faster than EDM when thickness is less than 1"	Wire EDM cuts at very slow speed when compared to Water jet.	Fast with thin sheets	Very fast cutting in thin, non-reflective materials.	Fast batch production when initial programing is done.
Quality of Edge	Good	Excellent	Fair	Excellent	Fair
Heat affected zone (HAZ)	No HAZ	Some HAZ	Some HAZ	Cuts by melting the material, resulting HAZ, often need additional process to avoid micro cracking.	No HAZ

(IWM: International Waterjet Machines, 2002)

Appendix B: Implemented and Documented Control Plan

[redacted] Manufacturing, Inc. CONTROL PLAN

Prototype / Pre-Launch / X Production		Page 1
	Key Contact / Phone: /	Date (Orig.):
Part # / Latest Change Level: /	Core Team:	Customer Approval / Date:
Part Name / Description:	Supplier / Plant Approval / Date:	Cust. Quality Approval / Date (If Req'd):
Supplier Plant: Company XYZ Supplier Code:	Other Approval / Date (If Req'd):	Other Approval / Date (If Req'd):

Part Process Number	Process Name / Operation Description	Machine, Device, Jig, Tools For Mfg.	Characteristics				Methods					Reaction Plan
			No.	Product	Process	Special Char. Class (★ Denotes Critical)	Product / Process Specification / Tolerance	Evaluation Measurement Technique	Sample Size	Sample Freq.	Control Method	
Oper #10	RECEIVING Raw material			Type of Material	Sub-Supplier Quality System Review Purchase Order References Consistency in Documentation		HRS P/O DQAK per ASTM A10011/A-A-0005 Type A or CRS DQAK per ASTM A620C1	Cert / Tag / Visual	Each Set Up	Every Lot	Comparison of supplier documentation. Conversion to inventory Tag. Supplier transportation method.	Recheck Set up and verify. Segregate material to hold area pending disposition. Contact purchasing and generate non-conforming Report.
				Material Thk.			0.0700	Cert / Tag / Mic	Each Set Up	Every Lot		
				Blank			Width: 34.0 Length: 43.250	Cert / Tag	Each Set Up	Every Lot		
				Appearance			No rust or shipping damage	Visual	Each Set Up	Every Lot		

Part Process Number	Process Name / Operation Description	Machine, Device, Jig, Tools For Mfg.	No.	Product	Process	Special Char. Class	Product / Process Specification / Tolerance	Evaluation Measurement Technique	Sample Size	Sample Freq.	Control Method	Reaction Plan
Oper #20	SET UP			Type of Material			HRS P/O DQAK per ASTM A10011/A-A-0005 Type A or CRS DQAK per ASTM A620C1	Cert / Tag / Visual	Each Set Up	Every Lot	Comparison of supplier documentation. Conversion to inventory Tag. Supplier transportation method.	Adjust setup and re-submit new samples. Scrap any pieces prior to adjustment. Quarantine suspects parts. Identify parts with non-conforming material tag. Determine Corrective action. Inspect parts from adjusted process. If samples accepted, approve process.
				Material Thk.			0.0700	Cert / Tag / Mic	Each Set Up	Every Lot		
				Lubricant			5V45	Tag / Visual	Each Set Up	Every Lot		
				Progressive			Tool #s T-39386 A,B,C,D	Traveler / Visual	Each Set Up	Every Lot	Tool Tryout	
				Stamping Parameters			Die Set Up Sheet - speed, lubricant, handling	Traveler	Each Set Up	Every Lot	Press Monitor Visual Observation	

Appendix B continued: Implemented and Documented Control Plan

Prototype / Pre-Launch / X Production		Page 3 of 3
	Key Contact / Phone: /	Date (Orig.):
Part # / Latest Change Level: /	Core Team:	Customer Approval / Date:
Part Name / Description:	Supplier / Plant Approval / Date:	Cust. Quality Approval / Date (If Req'd):
Supplier Plant: Company XYZ Supplier Code:	Other Approval / Date (If Req'd):	Other Approval / Date (If Req'd):

Part Process Number	Process Name / Operation Description	Machine, Device, Jig, Tools For Mfg.	Characteristics: No.	Characteristics: Product	Characteristics: Process	Special Char. Class (★ Denotes Critical)	Methods: Product / Process Specification / Tolerance	Methods: Evaluation Measurement Technique	Methods: Sample Size	Methods: Sample Freq.	Methods: Control Method	Reaction Plan
Oper # 30 A thru D	STAMPING		F8	Hole Diameter	Production	★	.328 +/- .015	Caliper	1pc.	Setup - 2 Hrs.	IHR QAD-FRM-107-10 1100 PIR QAD-FRM-108-10 1100 Log Data on 1st piece sheet and in-process inspection sheet.	Quarantine suspects parts. Identify parts with non-conforming material tag. Determine Corrective action. Inspect parts from adjusted process. If samples accepted, approve process.
			E8	Distance Dimension		★	1.20 +/- .03	CMM	1pc.	Setup		
			D8	Hole Diameter		★	.328 +/- .015	Caliper	1pc.	Setup - 2 Hrs.		
			G7	Perpendicularity		★	.060" max	CMM / Check Fixture	1pc.	Setup - 2 Hrs.		
			G7	Distance Dimension		★	16.50 +/- .03	CMM	1pc.	Setup - 2 Hrs.		
			C6	Perpendicularity		★	.050" max	CMM / Check Fixture	1pc.	Setup - 2 Hrs.		
			C6	Distance Dimension		★	16.50 +/- .03	CMM/Caliper	1pc.	Setup - 2 Hrs.		
			G4	Basic Hole Location			2.800 +/- .015	CMM / Check Fixture	1pc.	Setup		
			F4	Hole Diameter (2X)			1.500 +/- .015	Caliper	1pc.	Setup		
			F4	Hole Diameter		★	.328 +/- .005	Caliper	1pc.	Setup - 2 Hrs.		
			D4	Hole Diameter		★	.328 +/- .005	Caliper	1pc.	Setup - 2 Hrs.		
			D4	Basic Hole Location			.400 +/- .015	CMM / Check Fixture	1pc.	Setup		
			D4	Hole Diameter (2X)			1.400 +/- .015	Caliper	1pc.	Setup		
			E1	Hole Diameter (2X)		★	.265 +/- .005	Caliper	1pc.	Setup - 2 Hrs.		
			Note 3	Appearance			Free of pits, scratches, tool marks, rust & scale or any other surface irregularities.	Visual	1pc.	Setup - 2 Hrs.		
			Note 4	Appearance			Free of pits, scratches, tool marks, rust & scale or any other surface irregularities.	Visual	1pc.	Setup - 2 Hrs.		
			Note 7	Sharp edges		★	No sharp edges	Sharp Edges Tester	1pc.	Setup - 2 Hrs.		
Oper # 40	PACKAGING			Container:	Traveler / Work Order						Compare to Customer Specifications or Traveler.	
				Container Type			Plastic Pallet	Visual	1 Pallet	Each Lot		
				Container Size			N/A	Visual	1 Pallet	Each Lot		
				Skid Size			48 x 45	Visual	1 Pallet	Each Lot		
				Quantity :								
				Per Carton			N/A	Visual / Production Tag	1 Pallet	Each Lot		
				Per Skid			40					
				Weight :								
				Max Weight per Carton			TBD	Scale	1 Pallet	Each Lot		
				Part Orientation :								
				Alternating, see visual aids			Alternating, see visual aids	Visual	1 Pallet	Each Lot		
				Type Identification								
				Standard FIFO Label			See visual aids	Visual	1 Pallet	Each Lot		
	PREVENTIVE MAINTEINANCE	As appropriate use of tooling		Company XYZ Tools for 114-7917	Preventive Maintenance		Every 25k shots and/or as required if necessary	Run and compare First Piece Before and after Maintenance		Every 25k shots and/or as required if necessary	Form PSTMP-FRM-050-0500409 and Die Repair Ticket	Quarantine suspects parts. Identify parts with non-conforming material tag. Determine Corrective action. Inspect parts from adjusted process. If samples accepted, approve process.

Appendix C: Internal Review Board (IRB) Approval

Material Burrs and Sharp Edge Identification

Date: April 19, 2011

To: Paul Riedel

Cc: Jim Keyes

From: Sue Foxwell, Research Administrator and Human Protections Administrator, UW-Stout Institutional Review Board for the Protection of Human Subjects in Research (IRB)

Subject: **Protection of Human Subjects**

After review of your project, "*Burr and Sharp Edge Identification*" I concur that your research **does not** involve human subjects or official records about human subjects. Therefore, your project does not need further review and approval of the Institutional Review Board (IRB) for the Protection of Human Subjects.

This project has been reviewed by the UW-Stout IRB as required by the Code of Federal Regulations Title 45 Part 46

Thank you for your cooperation with the IRB and best wishes with your project.

***NOTE: This is the only notice you will receive – no paper copy will be sent.**

SF: am