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Schooley, Steven P. *JLTV Weld Rework Reduction***Abstract**

Oshkosh Defense, LLC, a segment of Oshkosh Corporation, is a manufacturer of military trucks with both domestic and international customers. In 2015 Oshkosh Defense was awarded a contract by the United States Government to manufacture the next generation of Joint Light Tactical Vehicles, commonly known as the JLTV. During the ramp up of JLTV truck production, the Oshkosh Defense Harrison facility was experiencing an elevated level of rework stemming from weld defects. The Harrison facility quality team was tasked with reducing costs associated with rework to help increase profitability of the contract and enhance competitiveness to be better prepared for future JLTV contract bids. The Harrison facility quality team utilized tools including Pareto analysis, Six Sigma DMAIC problem solving methodology and statistical process control to drive down costs associated with JLTV weld rework. This study describes the Oshkosh Defense Harrison facility quality team's use of these tools and the sequential results.

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Chapter I: Introduction

Oshkosh Defense, LLC is a manufacturer of military trucks in Oshkosh, WI. The company manufactures products for both domestic and international customers. On August 25th, 2015 Oshkosh Defense was awarded a contract by the U.S. government to manufacture the next generation of Joint Light Tactical Vehicles, commonly referred to as the JLTV. Oshkosh Defense's JLTV is a newly designed truck that will be replacing many of the military's current fleet of Hummers. Since being awarded the JLTV contract, the company has been developing and improving upon fabrication and assembly processes as delivery demands increase.

One clear competitive advantage of the JLTV design by Oshkosh Defense is the armored capsule that is designed to provide soldiers with protection against ballistic projectiles and improvised explosive devices which have proven to be a major threat in hostile locations. Unlike the Hummer's flat bottom design, the JLTV has more of a "V" shaped bottom which helps deflect the force of an underlying explosions resulting in less impact felt by persons inside the truck capsule. Another noticeable advantage of the Oshkosh JLTV is the suspension system which uses cutting edge technology that can autonomously or manually adjust to the terrain, providing much greater ride comfort, stability and control.

The Oshkosh Defense Harrison facility's processes consist of manufacturing many different weldment parts for various truck models. Manufacturing processes conducted at the Harrison facility include blasting, cutting, forming and welding various structural and armored truck parts. The manufactured parts are then sent to other Oshkosh Defense facilities for further processing and assembly.

The 4-door JLTV known as the GP variant incorporates 17 weldments that are fabricated at the company's Harrison facility in Oshkosh, WI. Weldments manufactured at the Harrison

facility specific to the GP variant include the GP capsule floor, both GP sidewalls, GP rear wall, GP roof, both GP rear doors, GP rear door window frame, and the GP cargo deck. The 2-door JLTV known as the UV variant incorporates some common weldments with the GP variant and others specific to the UV variant including the UV floor, both UV sidewalls, UV roof, UV rear wall, UV cargo deck and the UV stowage panel. Weldments manufactured at the Harrison facility that are universal to both UV and GP JLTV variants include the firewall, both front upper subframes, both front lower subframes, both rear subframes, both front doors, both windshield frames, and both front door window frames.

The initial manufacturing of the JLTV weldments consisted of bay builds in which each type of weldment had one dedicated work station where the components were tacked and welded together. Shortly after being awarded the contract, the company began ramping up JLTV production which required the various welding processes to be divided into more linear manufacturing lines by breaking the welding processes up into multiple work stations for each type of weldment. By reducing the work content in each work station, the Harrison facility was able to increase their JLTV weldment manufacturing capacity.

During the initial JLTV weldment production ramp up, the Oshkosh Defense Harrison facility was experiencing elevated costs stemming from labor time spent repairing weld defects on JLTV weldments. To help maximize the profitability of the JLTV program and enhance the competitiveness of Oshkosh Defense in future JLTV contract bids, it was imperative that the weld quality outputs were improved upon to reduce wasteful costs associated with rework time. As a result, the Oshkosh Defense Harrison facility quality team was tasked with reducing labor time associated with the repair of defects on JLTV weldments.

Statement of the Problem

Oshkosh Defense, LLC needed to reduce labor costs associated with nonconforming weld repair time on JLTV weldments manufactured at their Harrison facility to increase the programs profitability and enhance their competitiveness in preparation for future JLTV contract bids.

Purpose of the Study

The purpose of this study was to evaluate the effectiveness of identified quality tools used by the Oshkosh Defense Harrison facility quality team to reduce the costs associated with nonconforming welds on JLTV weldments. The Oshkosh Defense quality team worked with the operations leadership team along with other support teams and weld employees to obtain sustainable weld quality improvements. In addition, this study was critical to establishing structured quality assurance and quality improvement methods in the JLTV weld program. The results of this study could justify the expanded use of certain quality methods in other manufacturing processes within Oshkosh Defense, LLC.

Assumptions of the Study

This study assumed that Oshkosh Defense, LLC needed to improve the cost efficiencies of their JLTV production to stay competitive in future JLTV contract bids and to maximize profitability of the current contract. It was also assumed that with the scheduled manufacturing demand increases of JLTV trucks, the quality of weldments needed to improve to help assure defective welds were not escaping the Harrison facility manufacturing process. It was also assumed the data being recorded by the JLTV weldment quality gate inspectors was accurate and complete. A final assumption was that utilization of certain quality and continuous improvement tools would be effective in achieving enhanced weldment quality and repair labor cost reductions.

Definition of Terms

The following terms and definitions provide necessary understanding to certain portions of the study:

Define, measure, analyze, improve, and control (DMAIC). The five basic steps to Six Sigma problem solving. An improvement system for existing processes falling below specification and looking for incremental improvement (Desai, 2010).

Pareto analysis. Utilization of a type of bar chart that displays the categories plotted in descending order (Chiarini, 2012). Especially useful in showing problems in a prioritized order, or to distinguish a vital few from the trivial many (Kang & Kvam 2012).

Statistical process control. A tool that can be very effective in reducing instances of assignable cause and common cause variation in manufacturing process outputs. Can be defined as a method which monitors, controls, and ideally improves a process through statistical analysis (Chiarini, 2012).

Limitations of the Study

While this research study focused on the weld quality of JLTV weldments manufactured by Oshkosh Defense, LLC, it did not cover all aspects of the overall weldment manufacturing quality. The research study did cover the actual weld quality and efforts to reduce weld defects and associated rework. The research did not cover instances of nonconforming dimensional requirements of the weldment components that also led to rework and sequential repair costs. The research study also did not cover any rework reduction efforts in pre-weld and post-weld processes or weld processes conducted outside of the Harrison facility. The research study covered utilization of Pareto analysis and DMAIC problem solving progression over the course of one week of weldment manufacturing. The study also covered the use of statistical process

control in one of the JLTV weld stations over the course of one month of weldment manufacturing.

Methodology

The Oshkosh Defense, LLC Harrison facility quality team focused on identifying top contributing factors of weld rework time on JLTV weldments to subsequently implement preventative and corrective methods that eliminated or reduced such occurrences and associated rework time.

To be sure the team was devoting quality resources to the areas having the greatest impact on the cost of weld rework, the team needed to develop a method for recording defect data in a way that would allow for easy prioritization of rework reduction efforts. While there were already quality gates established to identify and repair weld defects on JLTV weldments, there had been limited data collection taking place which resulted in insufficient understanding of top rework time contributing issues. Therefore, the first step in achieving JTLV weldment quality improvement was to establish structured data collection methods in each of the JLTV weld quality gates.

Once the defect data recording structure was established, the team utilized Pareto Analysis to prioritize quality resources allocated to address the top contributing factors of weld defect rework time. This process of identifying and addressing top quality issues in the JLTV weld processes was a continuous cycle as the team continued to target the top issues causing weld rework.

When it came time to implementing preventative and corrective actions in reducing top occurring defects, the team utilized the DMAIC (define, measure, analyze, improve and control)

problem solving methodology. By utilizing a structured problem solving approach, the team was able to work together to achieve measurable and sustainable quality improvements.

The quality team also piloted the implementation of statistical process control in the JLTV firewall weld station to monitor weld quality inspection data and quickly allocate quality resources to address instances of elevated weld defects and rework time. By having a structured reaction plan in place, the quality team was able to sustain rework time reductions while continuing to drive for additional reductions through constant quality data monitoring and reaction.

Summary

To help maximize profitability and remain competitive in the manufacturing of JLTV trucks, it was imperative that Oshkosh Defense reduced wastes associated with rework. For the Oshkosh Defense Harrison manufacturing facility, one area identified as having a lot of opportunity for rework waste reduction was in the JLTV weld processes. The Harrison facility quality team was tasked with reducing time spent on reworking weld defects on JLTV truck weldments.

By establishing effective methods for recording data pertaining to weld quality, the Oshkosh Defense Harrison facility quality team was able to use Pareto analysis to identify the top weld locations and defect types contributing to most of the rework time on JLTV weldments. To assure effective and sustainable improvements were achieved, DMAIC problem solving methods were utilized in addressing top weld defects. Once some quality improvements were achieved and the overall JLTV weld processes became less volatile, statistical process control was implemented to sustain prior improvements and continue striving for additional rework time reductions. The following chapter provides a review of literature pertaining to types of weld

defects and the quality methods that were implemented by the Oshkosh Defense Harrison facility quality team.

Chapter II: Literature Review

During the ramp up of JLTV truck production, Oshkosh Defense, LLC was experiencing elevated amounts of rework time on weldments manufactured at the Harrison facility. One reason for elevated weld defects was the limited amount of experience many of the new weld employees had. Another main contributing factor for weld defects was the weldment designs that incorporated armored materials which, even for the most experienced weld employees, proved to be challenging in avoiding weld defects. A high quantity of new custom designed weld fixtures also contributed to elevated quality issues as some presented problematic weld locations due to limited access which hindered proper torch angle and travel speed.

The Harrison weld quality team was tasked with addressing each of these contributing factors to sequentially reduce the average rework time for each of the thirty-four JLTV weldments manufactured in their facility. To achieve these objectives, three main quality tools were utilized to drive down weld defects and sequentially drive down rework time. Quality tools utilized by the Oshkosh Defense Harrison quality team included Pareto analysis, DMAIC problem solving and statistical process control. The purpose of this chapter is to review various pieces of literature that address weld quality defects and the quality tools that were utilized to reduce weld defects.

Weld Defects

Welds are used to keep parts and assemblies together. When welds fail, the consequences of the failure may be disastrous, depending on the application. For critical applications, welding may be regulated by recognized standards. These weld standards have requirements that affect the design of the connections, the nature of the welding processes, the

procedures that are permitted to be used, the qualifications of the weld employees, weld inspection requirements, along with many other factors. (Miller, 2015).

The JLTV weld program uses gas metal arc welding on all weldments manufactured at the Harrison facility. Gas metal arc welding is an arc welding process, using an arc between a continuous filler metal electrode and the weld pool. The process is used with shielding from an externally supplied gas and without the application of pressure. (Miller, 2015) Code specifications for welding address the finished shape, dimensions and extent of any anomalies in the finished weld. A single crack is considered a defect, automatically failing an inspection. However, other problems, known as discontinuities, may be minute enough to be considered acceptable. What is acceptable to the inspector is spelled out in the designated weld code that is followed within a defined process (Regello, 2012).

Within the Oshkosh Defense JLTV weld operations quality gate inspection stations, manufactured JLTV weldments are inspected for weld defects. For every defect that is identified, an acceptable repair method is completed. The Ground Combat Vehicle Welding Code specifies the acceptable repair method for each type of weld defect. For weld overlap, excess weld metal shall be removed by machining or grinding. For excessive concavity, undercut, and undersized welds, surfaces shall be prepared, and additional weld metal deposited in accordance with the specified welding procedure. Excessive weld porosity or incomplete fusion shall have unacceptable portions removed and the area rewelded in accordance with the specified weld procedure. Cracked welds shall be removed and the area rewelded in accordance with the specified welding procedure.

Pareto Analysis

Pareto, Vilfredo F. D. was a nineteenth century Italian engineer, sociologist, economist, political scientist and philosopher. Vilfredo Pareto's Economics textbook titled *Cours d'Économie Politique Professeé a l'Université de Lausanne* was published in 1896. It was in this textbook that Vilfredo estimated 80% of Italy's land was owned by 20% of the population. (Kang, Kvam 2012). Vilfredo went on to conclude that this 80-20 distribution was evident in many other social and economic data sets. Since then many additional data set observations have been conducted in which the 80-20 distribution was found to be prevalent and this common distribution came to be known as the Pareto Principle. Since Vilfredo's initial observation there have been a multitude of quality experts who have applied Pareto analysis to identify the vital few issues that were causing most of the costs associated with poor quality.

A Pareto chart is a type of bar chart that displays the categories plotted in descending order (Chiarini, 2012). The Pareto chart is especially useful in showing problems in a prioritized order, or to distinguish a vital few from the trivial many (Kang, Kvam 2012). The Pareto chart also incorporates a line that displays the cumulative total of the bars from left to right.

Whether the subject is quality complaints, quality defects, costs associated with quality defects, or any other measurable key performance indicators, Pareto analysis can be a very powerful tool in driving organizational improvement focus.

For Pareto analysis to be most effective in driving the focus, the data being analyzed must be reliable. It is common for the data being analyzed to be originated by the employees' input. This is what makes effective training and clear standardization so important to assure the data is not subjective or inaccurate. Only accurate data will allow for clear baselines to improve upon.

Data that is not accurate will lead to false conclusions and resources will sequentially be allocated to issues that are not truly causing the greatest amount of impact. Aside from data accuracy, the relevance of the data being analyzed is of great importance as it will be used to drive an organization's decision making. It is important to verify the data that is being analyzed is relevant to the organizations goals.

One limitation to Pareto analysis is it does not calculate which issues will be the least costly to correct (Chiarini, 2012). While the analysis will help distinguish the vital few from the trivial many, further investigation is required to understand the cost of correcting the top issues and whether the top issue will be the most desirable to address first or if perhaps some of the lower impact issues will be less costly to correct and should be prioritized first.

DMAIC Problem Solving

DMAIC problem solving is a Six Sigma method that can be used to identify and implement highly-effective and sustainable solutions to manufacturing issues. Six Sigma is a tool used for improving customer satisfaction, increasing profitability, and shareholder value through process variation reduction and elimination of product defects. (Geng, 2015). DMAIC stands for Define, Measure, Analyze, Improve, and Control which are the five basic steps to Six Sigma problem solving. Six Sigma is a quality improvement system originally developed by Motorola in the mid-1980s (Levin, 2011). Six Sigma is the management of sources of variation in relation to performance requirements. At the heart of Six Sigma is the concept of data driven decision making, that is, exploiting the data from measurements or simulations at various points in the life cycle of your product or service. (Cox, Gaudard, & Stephens, 2016).

DMAIC problem solving is something unique and it helps in the deployment of projects without failures. Every stage, from define to control, is validated through a tollgate check, which can stop the project if the result stage is not what is expected (Chiarini, 2012).

The define phase involves defining the problem or opportunity that the organization seeks to address, along with the costs, benefits, and the customer impact. It also includes defining who is on the team, specific goals, a timeline, and the process. (Cox et al., 2016).

The measurement phase verifies the appropriate measurements are in place that are relevant to the defined scope. The team develops or verifies the operational definitions of the targeted process outputs that are to be improved upon, which are often critical to quality metrics or measures. A baseline is established showing the level and current variation of the targeted process outputs. The team may elect to quantify how much variation there is in the measurement process itself to adjust the observed variation in the targeted outputs and to improve the measurement process. The team also works to identify all potential root causes of variation in the targeted process outputs so those too can be measured to establish a baseline to be improved upon. (Cox et al., 2016).

The analysis phase of DMAIC problem solving consists of evaluating the data that has been collected in the proceeding measuring phase. Assessing the measurement data through statistical methods, evaluating the process centering and variation, stability, performance and product trends, and defect rates. The main activities consist of analyzing the causes of defects and sources of variation and prioritizing the opportunities for future improvement (Barone & Franco, 2003).

The improve phase incorporates the actual implementation of the selected solution. The project team identifies which process changes will deliver the best possible values for the

targeted process outputs, develops a plan to implement the process changes, pilots the process changes to verify improvement of the process outputs, and works to sustain changes having a positive impact (Cox et al., 2016). The main activities of the improvement phase are improving the process to eliminate variation and developing creative alternatives and implementing enhanced solutions (Barone & Franco, 2003).

The control stage often incorporates a measurement of effectiveness the implemented solutions had on the process and helps the team decide whether further work is needed or if the effectiveness was sufficient in meeting targets. The main activities of the control phase are to control process variations to meet requirements, develop a strategy to monitor and control the improved processes, and implement the improvements of systems and structures (Barone & Franco, 2003).

By utilizing the DMAIC problem solving method, teams are required to go through each of the needed stages to assure effective solutions are developed, implemented and sustained. Having a structured approach to problem solving makes it less likely for a team to miss critical stages or have issues resurface because the root cause was not adequately addressed with a sustainable solution.

While the DMAIC problem solving approach assures all the necessary steps are taken for effective problem solving, it does not help control which problems or processes are targeted for improvement and therefore it is not effective in assuring an organizations resources are focused on areas with the greatest value opportunities. The problem identification process needs to be completed prior to beginning the DMAIC process so the organization is working on areas that have the most opportunity for improvement.

Statistical Process Control

Statistical process control is a tool that can be very effective in reducing instances of assignable cause variation in manufacturing process outputs. Statistical process control can be defined as a method which monitors, controls, and ideally improves a process through statistical analysis (Chiarini, 2012). By analyzing historical data of various process outputs, an organization can understand the capability of each process and distinguish normal or common cause variation from abnormal or assignable cause variation. Chiarini (2012) explains that the assignable cause might be some unnatural or unwanted pattern observed in the process where as a common cause is treated as random, unavoidable noise or natural variability in the process.

No matter the process or how the data is collected, all data will display variation and there are many reasons for this. Each process will likely have dozens, even hundreds of cause-and-effect relationships (Wheeler, 2010). Whenever a set of uncontrolled factors contains a dominant cause and effect relationship, they will haunt the process, creating exceptional variation and excess costs. You cannot optimize any process or system when some of the dominant cause and effect relationships remain unidentified (Wheeler, 2010).

Common cause variation will consist of many different cause and effect relationships where no single factor is dominant. The resulting process variation will be routine and inherent in every production process. Seeking to identify and control common causes will generally prove to be a low payback strategy (Wheeler, 2010).

When a set of uncontrolled factors contains one or more assignable causes it will be cost effective to identify them and make them part of the controlled factors. Without controlling the dominant causes of variation, a process will likely have increased costs associated with scrap and rework. Increased variation always results in increased costs (Wheeler, 2010).

The only critical difference between an assignable cause and a common cause is the magnitude of their effects upon the process outcomes. If routine variation can be filtered out, anything left over is likely to be assignable variation. The question then becomes where to draw the line between routine, common cause variation and exceptional, assignable cause variation. To make this distinction, it is necessary to use an agreed upon method that limits occurrences of false signals as well as missed signals when analyzing process data. Three-sigma limits balance the economic outcomes of getting false alarms with those of missing some signals. This can be shown in what is known as a control chart (Shewhart, 1931). A control chart defines an ideal, provides a methodology for moving toward that ideal, and allows judgement to be made about how close to the ideal a process is (Shewhart, 1939). Whenever a data point goes outside the three-sigma limits it identifies a departure from the routine, a change in the process, and the presence of an assignable cause of exceptional variation (Wheeler, 2010).

Summary

It is vital that the Harrison quality team understands the various weld standards that Oshkosh Defense is contractual required to follow in the fabrication of JLTV weldments. By having a thorough knowledge of acceptance criteria for JLTV weldments, the quality team was able to assure all identified nonconforming welds were corrected prior to being sent to the next processes. Knowledge of the various weld defects also allowed the quality team to work with weld employees in identifying the possible causes for the nonconforming welds so that they could then work together to eliminate future occurrences.

Pareto analysis can be a highly effective tool when it comes to prioritizing issue resolution. Pareto analysis helps separate the vital few quality issues from the trivial many. It is common to see just 20% of a manufacturing process' quality issues lead to 80% of all costs

associated with quality issues with the other 80% of the quality issues only accounting for 20% of the associated costs. This is known as the 80-20 Rule. By understanding which specific quality issues are creating the most costs, an organization can prioritize resolution of those issues to maximize the return on their issue resolution investments.

As with any data analysis, Pareto analysis is of the greatest value when the data being analyzed is accurate and relevant to the goal at hand. For this reason, it is of the utmost importance that organizations take the necessary steps in establishing and sustaining structured and standardized quality data gathering processes.

For the quality team at the Oshkosh Defense, LLC Harrison facility, Pareto analysis was an effective tool in identifying which weldments required the greatest amount of weld rework time. The Harrison quality team also found that Pareto analysis was useful on a more micro level such as identifying specific welds that were causing the most weld rework on each weldment as well as identifying which types of weld defects were most prevalent on each type of weldment.

The DMAIC problem solving methodology can be highly effective in addressing quality issues. The Harrison quality team used DMAIC problem solving to address top weld quality issues that were identified through Pareto analysis. Defining the problem allowed the quality team to be sure they were going after a specific issue and not being distracted by other issues at hand that were outside the defined scope. By measuring the data outputs of the process being targeted, the quality team was able to establish a baseline to be improved upon which became useful in later measurements in gauging the effectiveness of implemented improvement actions. The analysis of specific issues allowed for gathering of feedback from employees most familiar with the problem. By understanding the true cause of the problem being targeted, the quality

team was able to develop solutions that directly addressed the identified causes and decide which solution was going to create the greatest return on the investment required for implementation. Once improvement efforts had been made, the control stage allowed the team to reassess the issue to see how effective they were in correcting it and decide if they were fully satisfied with the results.

Understanding of the weld standards and quality improvement methods discussed in the literature review allowed the Oshkosh Defense quality team to apply this knowledge to drive down costs associated with JLTV weld rework. Chapter III explains the specific methodology the Oshkosh Defense Harrison facility quality team utilized to reduce JLTV weld rework.

Chapter III: Methodology

To eliminate waste, increase profitability and enhance competitiveness, the Oshkosh Defense Harrison facility quality team was tasked with reducing rework time stemming from weld defects on JLTV weldments. To effectively allocate quality resources towards JLTV weldment rework reduction efforts, the quality team needed to develop a way to gather relevant weld defect data. Once data gathering and extraction methods were developed and implemented, the quality team needed to identify a method for analyzing the data to maximize efficiencies in quality resource allocation. After development and implementation of data analysis methods, the quality team needed to implement a structured approach to problem solving that was both effective and sustainable. The quality team was also challenged with implementing a method for sustaining any improvements that had been made while continuing to strive for further JLTV weld rework reduction.

Methodology Overview

Once assembled, JLTV weldments manufactured at the Oshkosh Defense Harrison Facility make up the entire JLTV truck capsule and frame. Weldments manufactured at the Oshkosh Defense Harrison facility were inspected in a designated quality gate near the weld stations they were welded in. Within each quality gate, a trained quality gate inspector reviewed each individual weld for defects. Each quality gate inspector was a certified weld employee that had been selected by the operations leadership team as being someone who could effectively identify, correct, and communicate weld defects back to the appropriate weld employees. Any weld defects found during inspection were documented and reworked using authorized repair methods prior to being delivered to the next manufacturing process.

While developing the JLTV weldment quality defect data recording processes, three data sets were identified as being of greatest importance in deciding how and where to allocate quality resources to achieve rework time reduction.

The first identified data set was the average amount of rework time recorded on each type of JLTV weldment. Since costs associated with rework were directly affected by the labor hours spent completing the rework, it was of great importance to have the rework time recorded for analysis. The second type of data that was needed was the location of defects identified on each weldment. By recording specific weld locations that were found to have defects, the team was able to identify individual weld locations contributing the greatest amount of defect repair time on each type of JLTV weldment. The third type of data needed for rework time reduction was the type of weld defects being identified in the quality gate inspection. Recording the type of defect found in each weld location allowed for data analysis that would identify the types of weld defects having the greatest amount of impact on repair time totals in each weld location.

Once a solid method of identifying and recording defect data was established, the quality team was able to use the Pareto Methodology to identify which weldments were contributing the most to the total amount of weld rework throughout the JLTV weld processes. Pareto Methodology was also used to understand which specific weld locations and which types of weld defects were causing the greatest amount of rework time. In having the ability to identify specific details such as top weld defect locations and types, the quality team was able to develop and implement specific preventative and/or corrective methods, techniques, and tools to be implemented and sequentially monitored for effectiveness in reducing rework. Actions that were proven effective could then have appropriate sustainment methods implemented to assure the addressed issue would be less likely to return in the future.

To assure effective and sustainable JLTV weldment rework reduction, the Six Sigma DMAIC problem solving methodology was utilized. By defining the scope of a problem, measuring the impact the problem was having, analyzing the root cause, implementing improvement actions and controlling any achieved improvements, the Oshkosh Defense JLTV weld quality team was able to have a structured approach to achieving sustainable weld rework cost reductions.

After addressing many of the major contributors to rework time on JLTV weldments, there was a need to implement controls to sustain the improvements made while seeking even greater rework time reductions. Statistical process control was identified as a tool that could be utilized to meet the sustainment and improvement needs.

Structured Quality Data Recording

Since most of the data that was used for Pareto Analysis in the JLTV weld rework reduction effort was originated by quality gate inspection employees completing the weldment inspections and rework, it was crucial that they were given adequate training. Training was provided to the quality gate inspectors to enhance accuracy of data recorded as well as understanding weld standards that the JLTV weld program was required to adhere by. Training provided to all JLTV weld employees included a review of each type of weld defect and the applicable acceptance standards as outlined in the U.S. Army Ground Combat Vehicle Welding Code and the American Weld Society section D1.1 weld standards. The Oshkosh Defense manufacturing engineering team created the training materials and provided the training sessions.

The selected weld quality gate inspectors were given additional training that included coaching on the use of the newly developed weld maps which assigned a weld identification number to each weld on each JLTV weldment manufactured at the Oshkosh Defense Harrison

facility. These weld maps were referenced by the weld quality gate inspectors when entering weld defect locations into the Oshkosh Defense data collection system. Additional training in identification of weld defects was also provided as needed to assure adherence to applicable standards and continuity between all JLTV weld quality gate inspectors. The extensive training provided to the JLTV weld quality gate inspectors helped assure accurate defect data identification and associated data recording accuracy. Accurate data capturing in the JLTV weld quality gates made Pareto analysis a very useful tool in identifying the weld defects creating the most rework time for each JLTV weldment.

With a wide array of contributing factors affecting JLTV weld rework time, it was important for the JLTV weld quality team to identify which factors were contributing the most costs associated with weld rework. By applying Pareto analysis to the defect data that was being recorded within the quality gates, the quality team was able to identify which weldments were requiring the most rework time, which specific welds were creating the most rework time and which types of weld defects were creating the most rework time for each JLTV weldment. In understanding the vital few defects creating the greatest amount of rework, the quality team was able to deploy quality resource to work on prevention of those specific quality defects to maximize the effectiveness of the rework reduction efforts.

Recording of rework time was made possible through utilization of the company's already established ERP system. All direct work completed by hourly employees is recorded with the use of work order bar code scan cards and assigned operator badge bar scans to record the start and stop time for each operation sequence. By creating a weld rework work order operation sequence for each JLTV weldment, weld employees were able to record any time spent reworking defective welds. This time data was then extracted from the ERP system each week

which allowed the team to use Pareto analysis in identifying which weldments were contributing the most to overall weld rework time.

After the rework recording method was implemented in each JLTV weld station, a weekly report was established that consisted of line graphs which displayed the weekly average rework time for each type of JLTV weldment. This rework time report was utilized each week to support the allocation of quality resources to the JLTV weldments that had the greatest weld rework time averages.

The raw rework time data used to create the line graphs for each JLTV weldment was also included in weekly rework time report which allowed the quality team to identify individual weldment rework time totals. This individual weldment rework time data became very useful when investigating exceptionally high rework time recordings as the team was able to identify which employees had worked on those weldments.

To identify top rework contributing locations on each weldment, the quality team developed weld maps of each JLTV weldment to be used by quality gate inspectors in recording defect locations. Each JLTV weldment had a weld map created which consisted of views from each side of the weldment with each individual weld highlighted and assigned a weld identification number. Upon visual inspection, weld quality gate inspectors recorded each defect location by the designated weld identification number in the company's data collection system.

Along with each weld defect location, the type of weld defect was also recorded by the quality gate inspectors. By recording both the type and location of each weld defect identified in the quality gates, the quality team was able to identify the weld locations and defect types occurring most frequently on each JLTV weldment.

With a great focus on rework time reduction in JLTV weldments, it was important for the quality team to understand not only defect occurrence, but also the amount of rework time required to rework each identified defect. If only occurrence was monitored, the defects that were occurring the most frequently may or may not be contributing to the greatest amount of rework time since each individual weld defect requires a unique amount of time to repair. For instance, one defect may only take a few seconds to rework while another defect may take several minutes. Without giving weight to the rework time of each recorded defect, it would seem all defects were of equal severity when it came to costs associated with rework time. Since the actual rework time data recorded in the company's labor tracking system was provided on a weekly basis, the quality team also implemented the recording of estimated rework time for each defect recorded in each of the quality gates. This allowed the quality team to monitor the estimated rework time data at a greater frequency and also provided rework time estimates for each individual defect.

Pareto Analysis

Structured quality data gathering methods allowed the team to conduct weld defect rework data analysis. Since there were far too many weldments and weld quality defects for the team to address all at once, it was important that quality resources were utilized to address the issues causing the greatest amount of rework time. Pareto Analysis was identified as a method of separating the vital few from the trivial many.

The Harrison facility quality team utilized the data captured over the course of one week of manufacturing to identify the weldments contributing the greatest amount of recorded rework time. With there being a total of thirty-four JLTV weldments manufactured at the Harrison facility, the team needed to understand which weldments were contributing the most to the total

rework time. The Harrison facility quality team utilized Pareto analysis to identify which weldments contributed to most of the total recorded weld rework time over the previous week of production. JLTV weldment types that contributed most to the total weld rework time recorded the prior week were then targeted for quality improvement efforts. Figure 1 displays an example of a Pareto chart used to identify weldments contributing to most of the recorded rework time.

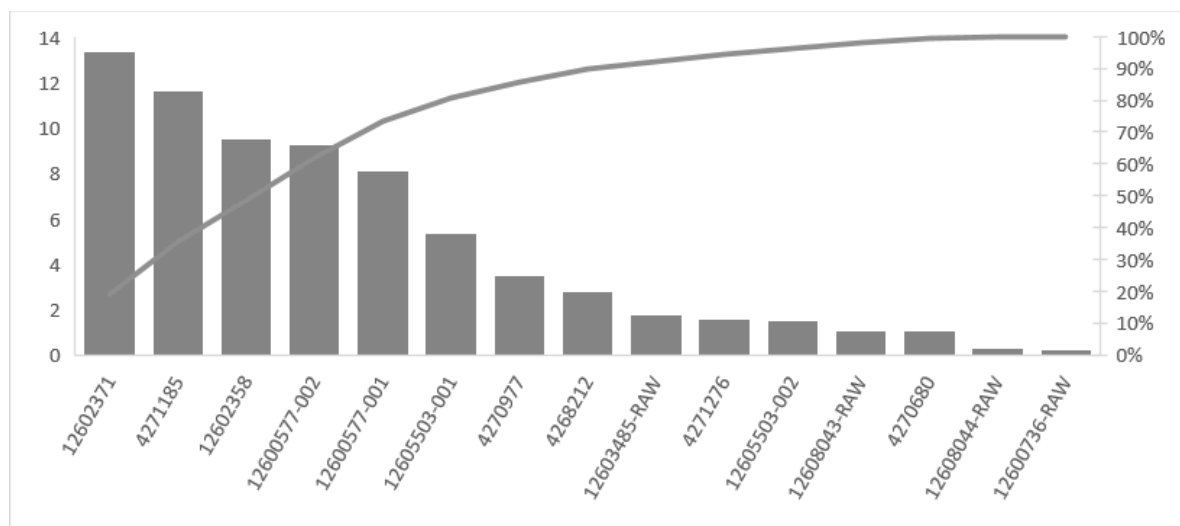


Figure 1. Example of Pareto chart used to identify weldments.

Specific quality gate data for each of the targeted JLTV weldments was analyzed to understand which three weld locations contributed to the most weld rework time on each weldment that had been identified as a top rework time contributor during the prior week. This was done by creating pivot charts utilizing the data that had been captured by quality gate inspectors. The pivot charts were set up to display only the top three locations on each weldment that had the most estimated rework time recorded. At times there were more than three weld locations identified due to instances of two or more of the top three weld locations having the same amount of rework time. Figure 2 displays an example of a pivot chart displaying the top three locations with the most estimate rework time recorded.

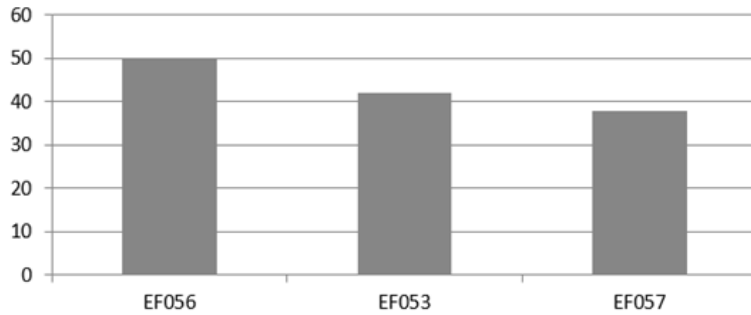


Figure 2. Example of pivot chart showing top three weld locations for rework time.

Upon identification of the top three estimated rework time contributing weld defect locations, the quality team used another pivot chart like the one displayed in Figure 3 to identify the top three rework time contributing defect types in each of the identified weld locations. On some occasions, only one or two types of defects were recorded in a single location. The quality engineer and responders were then tasked with working with weld employees in station to address the identified top defect types in the targeted locations through DMAIC problem solving methodology.

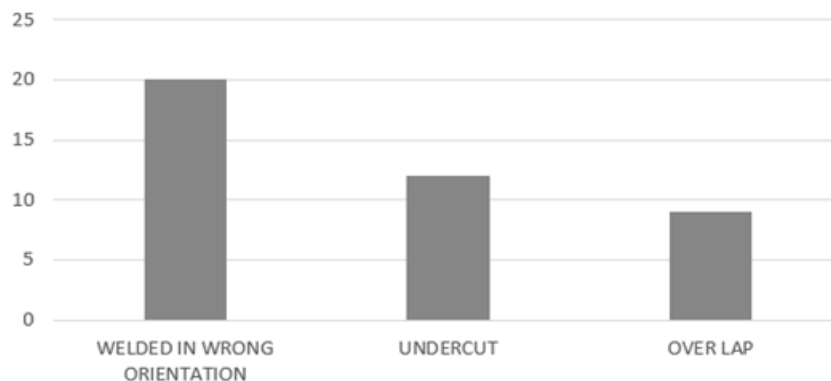


Figure 3. Example of pivot chart showing top weld defect types.

DMAIC Problem Solving

Since the defect locations and defect types identified through Pareto analysis were specific, it became much more manageable to identify the root cause and develop preventative

and corrective actions. The Harrison facility quality team utilized the DMAIC problem solving methodology to address the top rework time contributing weld defects from the prior week that had been identified through Pareto analysis and subsequent pivot charts.

Part of the defining phase was completed through the Pareto data analysis efforts which was used to identify which JLTW weldments were having the most rework time recorded. The Harrison facility quality team then identified which specific weld locations were having the greatest amount of rework on each of the top rework contributing JLTW weldments. Once the specific weld locations were identified on each weldment, the weld defect types were identified for each location. The result of this data analysis was the Harrison facility quality team having specific weld defect types in specific weld locations on specific JLTW weldments that were then targeted for rework time reduction. The Harrison facility JLTW weld problem solving team was established and included quality engineers, manufacturing engineers, industrial engineers, and operation leaders, along with weld employees most familiar with the targeted areas.

The measurement phase was also mostly completed through the prior data analysis as the team was able to identify the current measurement baseline which was the amount of rework being recorded in the targeted weld locations. Since the quality gate inspectors recorded the location, defect type and estimated rework time for each weld defect they identified during their inspections, the team was able to total the amount of estimated rework recorded in each location. The team was able to use the location specific rework time totals to use as a baseline to improve upon as preventive and corrective actions were implemented. Progress was then monitored by calculating the estimated rework time totals in the targeted locations after implementation of preventive and corrective actions.

The analysis phase was completed through interaction with weld employees who had been completing the targeted welds. The weld employees' feedback was utilized to understand the primary root causes of the identified weld defects. The weld employees' feedback of potential solutions to the identified issues were also noted as the quality team worked to identify what actions to take in preventing the defects going forward. The Harrison facility quality team utilized a template like the one displayed in Figure 4 to document any information pertaining to each of the targeted weldment defects. The weld employees' feedback was documented in this template under the investigation notes section which was then discussed with the rest of the Harrison problem solving team in the weekly quality meeting. Following the feedback discussion in the quality meeting, action items were assigned to team members along with targeted completion dates. All investigation notes and action plans were documented in the JTLV weld quality report, with each targeted issue documented in a one page document which is displayed in Figure 4.

	Open Date:	Due Date:
	Closed Date:	Status:
Problem Description:		
Containment:		
Investigation Notes:	Related images of targeted problem	
Potential Root Causes:		
Corrective Action:		
Verification:		

Figure 4. Example of document used to record information on each issue.

In the improvement phase, action plans that were developed during the weekly JLTV weld quality meeting were implemented. Corrective actions taken were documented and communicated to the rest of the Harrison operations team the following week during the JLTV weld quality meeting. The same template displayed in Figure 4 was also used to document the results of the implemented actions in the verification section. Recorded quality data relative to the targeted defects were monitored to measure the effectiveness of the actions taken.

The control phase consisted of any further training and documentation to assure rework time reductions were sustained. Training was facilitated by the quality engineer and quality responders with the appropriate weld employees. Process changes, when applicable, were documented through updates to the appropriate work instructions as well as updates to the process failure mode analysis and process control plan documents.

Statistical Process Control

After making some progress in reducing the JLTV weld rework time, the Oshkosh Defense Harrison quality team began utilizing another tool to sustain achieved improvements while simultaneously working to further reduce JLTV weld rework time. Statistical process control was identified by the quality team as a tool that could allow the desired sustainment of the quality improvements achieved while also working towards additional improvements.

The JLTV weld quality team selected the JLTV firewall weld quality gate as the pilot station for utilizing statistical process control. The selection of the JLTV firewall weld station was due to the recorded rework time being higher than all other JLTV weld stations. The quality team decided to use statistical process control methods to monitor and react to estimated rework time and defect total recorded for each firewall weldment. The quality team utilized data recorded by the weld quality gate inspectors during the prior two weeks to set upper control

limits for each of the data sets to be monitored. The JLTV quality gate inspectors used a designated quality control document to record the total amount of estimated rework time and total amount of weld defects for each firewall weldment they inspected. Figure 5 displays the quality control document used to record this data.

Badge Number: _____ Date: ____/____/____ Shift: _____

Directions: Fill out form with complete information, for use per one quality gate.

Gate Type:				
<input type="checkbox"/> JLTV <input type="checkbox"/> FHTV <input type="checkbox"/> FMTV <input type="checkbox"/> Cargo Body <input type="checkbox"/> Running Gear <input type="checkbox"/> S-Series <input type="checkbox"/> PLST <input type="checkbox"/> CTE				
#	PWO	Part #	Est. Rework Time	# Total Defects
1				
2				
3				
4				

#	PWO	Part #	Est. Rework Time	# Total Defect
21				
22				
23				
24				
25				

Figure 5. Example of document used to record quality gate data.

At the end of each day the weld quality gate inspector submitted the completed quality documents to the quality responders. The quality responders entered the recorded data into an Excel spreadsheet. Having all the needed quality data in digital format allowed the quality team to input the firewall quality data into a control chart template which calculated the mean and control limits for defect totals and estimated rework time per weldment.

The control chart template allowed the quality team to simply paste the prior two weeks' worth of firewall data into the Excel control chart template which used formulas to calculate the mean average and control limits for the recorded data set. The formula used to calculate the mean took the sum of the values that had been copied into the template and divided it by the quantity of values entered. The formula that calculated the upper control limit took the mean and added the moving range average multiplied by two standard deviations. The formula for calculating the lower control limit took the mean and subtracted the moving range average multiplied by two standard deviations. Figure 6 displays the formulas in the Excel control chart template for calculating the mean, the upper control limit and the lower control limit.

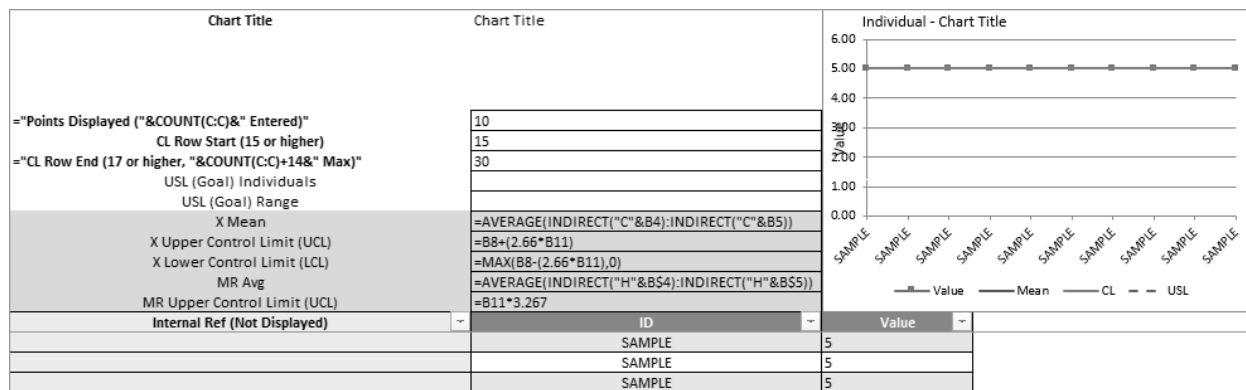


Figure 6. Example of Excel control chart template.

Since the quality gate inspectors were already tasked with recording defect data and working with weld employees within their designated areas to reduce defects, the quality team decided to have them be the first to react to any weldments with estimated rework time totals or defect quantity totals exceeding the upper control limits that had been set. The quality team developed a reaction log quality control document to allow documentation of out of control weldments by the quality gate inspectors. Figure 7 displays an example of the reaction log used to record weldments that breached the upper control limits for estimated rework time or total defects.

Work Station Subframes Date Started 11/7/17 Est. Rework Time UCL NA Defect UCL 12

Instructions: Begin a new sheet each week and turn in completed sheets at the end of each week to the zone quality responder. The Est. Rework Time Upper Control Limit (UCL) and the Defect UCL will be issued by the zone quality responder. Record any work orders with a total estimated rework time greater than the Est. Rework Time UCL and any work order with the number of total defects greater than the Defect UCL. Contact the zone quality responder for any assistance needed in identifying the primary cause(s) and implementing corrective action(s).

Work Order #	Est. Rework Time Total	Defect Total	Special Cause(s)	Action(s) Taken
6867402	45min	14	one weld had OL and UC (take out redo)	talked to ops operator and was over part with him
6867403	45min	16	UF NOT with fill IN CONDUIT	SAVED FOR operator OPERATOR

Figure 7. Example of quality gate inspection reaction log.

Quality gate inspectors were given the autonomy to determine the root cause of the out of control weldments and implement the preventive measures required to eliminate future occurrences. The quality gate inspectors were encouraged to seek support from the Harrison

quality responders and quality engineers if they needed additional support in completing the root cause investigation and implementation of preventative and corrective actions. The documentation of each instance of out of control weldments included the weldment work order number, the estimated rework time, the defect total, the root causes of the control limit breach and any actions taken to address the causes.

While there are many possible variations of reaction criteria in using statistical process control charts, the JLTV weld quality team decided to only focus on the instances where the upper control limit was breached. Any firewall weldments that had a total amount of estimated rework time or a total quantity of weld defects that exceeded the set upper control limits were considered to have abnormally bad quality and required immediate action. As improvements were made in the firewall weld station quality output, the upper control limits were sequentially recalculated using the prior week's data to assure that the improvements were sustained. Recalculating the control limits also supported continuous improvement as greater weld quality output was expected going forward.

The quality gate inspectors were encouraged to record detailed information including which weld station most of the defects came from and which weld employees they worked with to develop preventative and corrective methods to address the targeted weld issues. The reaction log quality control document was submitted at the end of each week to the quality responder who entered the information into an Excel reaction log. By having the information recorded in a spreadsheet like the example displayed in Figure 8, the quality engineer was able to create a bar chart which displayed the number of occurrences out of control weldments were addressed with each weld employee.

Part Number	Part Name	Work Ord.	Date Inspected	Est. Rwrk Time (Min.)	Defect Total	Special Cause	Actions Taken	Operator Badge
4268212	FIREWALL	6830543	10/31/2017	405	76	New operator in station 3	Sent 135930 back to training area	135930
4268212	FIREWALL	6830543	10/31/2017	405	76	New operator in station 2	Spoke with operator on 2nd	214529
4268212	FIREWALL	6830533	10/31/2017	210	42	2nd shift operator	Coached operator	151701

Figure 8. Example of control chart reaction log spreadsheet.

The reaction log information proved to be valuable in identifying individual weld employees who were struggling the most and required additional coaching and accountability. A pivot chart like the one displayed in Figure 9 was used to visually display weld employees having the most occurrences of poor quality outputs leading to breaches in the set control limits.

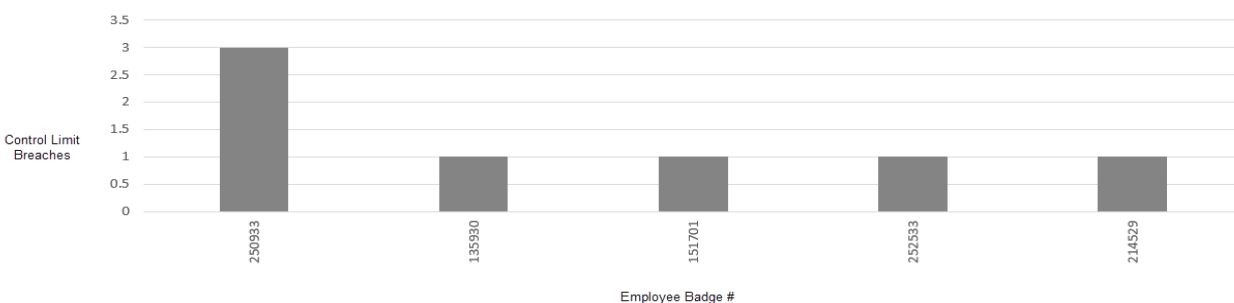


Figure 9. Example of pivot chart showing welders who exceeded set control limits.

Weld employees who had been identified as having the highest number of out of control weldments coming from their station became a topic of discussion between the problem solving team during the weekly JLTV weld quality meeting. The first method of addressing struggling weld employees was to provide the additional feedback and coaching on their weld quality. If improvement was not made after additional coaching had been provided, some struggling weld employees were placed back into the weld training program while others were moved to less challenging weld stations.

Summary

To reduce rework time associated with JLTV weld defects, the Harrison facility quality team developed and implemented methods of quality data gathering and analysis. In utilizing

Pareto Methodology to analyze recorded JLTV weld quality data, the Harrison facility quality team was able to allocate quality resources appropriately to address the issues that were identified as being top weld rework time contributors. Utilization of DMAIC problem solving methodology allowed the entire Harrison manufacturing leadership team to work together in efficiently implementing training and process changes intended to improve JLTV weld quality outputs. Improvements that were gained were able to be sustained through constant monitoring of the quality outputs through statistical process control. The following chapter will cover the results of using these methods.

Chapter IV: Results

The research covered in this study focused on the Oshkosh Defense Harrison facility quality team's effort to reduce labor hours spent reworking manufactured JLTV truck weldments. The Oshkosh Defense Harrison team was faced with JLTV weldment quality output challenges stemming from a high quantity of new weld employees, new weld fixtures, and materials and processes new to the Harrison facility's manufacturing team. There was an elevated amount of weld defects and associated rework time that needed to be reduced to allow the organization to be more profitable and more competitive in future JLTV contract bids. To lower weld defect rework labor hours, the Harrison facility quality team established structured methods for recording defect and rework time data. The recorded data was analyzed utilizing Pareto analysis to understand which JLTV weldments were contributing most to the recorded weld rework time. The team identified specific weld locations and types of weld defects occurring on the weldments identified as being top rework time contributors. DMAIC problem solving methodology was utilized to identify the causes of the targeted defects and sequentially implement sustainable solutions. Statistical process control was then piloted in one of the JLTV weld stations to sustain prior improvements that were achieved by identifying and quickly addressing weldments that had significantly high amounts of defects and rework time.

This chapter will review the results of implementing structured quality data collection, utilizing Pareto analysis of recorded quality data, utilizing DMAIC problem solving methodology to address the identified issues, and implementing statistical process control to sustain improvements on JLTV truck weldments manufactured at the Oshkosh Defense Harrison facility.

Structured Quality Data Recording

The first step in assuring accuracy of weld defect identification and data recording was to provide detailed training to each of the JLTV weld quality gate inspectors. This training was completed with all the quality gate inspectors through a group training session followed by additional one on one training sessions with each of the quality gate inspectors as needed. The training covered identification techniques and measurable acceptance criteria for each type of weld defect. The training also covered acceptable repair methods and common prevention techniques specific to each type of weld defect. The knowledge that was gained by the weld quality gate inspectors proved to be effective in their ability to identify defects and communicate corrective and preventive methods to the weld employees who created the identified defects.

To allow quality data recording, including specific weld defect locations identified on each weldment, the Harrison quality team developed weld maps for each of the JLTV weldments manufactured at the Harrison facility. The weld maps were provided to the appropriate quality gate inspectors for their reference in recording the weld location identification numbers for each identified defect during their quality gate inspections. Training was conducted with the quality gate inspectors on how to enter the defects they identified into the company's ERP system.

Aside from establishing quality gate data recording by the quality gate inspectors, the Harrison operations team also implemented a method for recording the rework labor time on individual weldments through the development of a dedicated operation sequence for any weld rework that was performed. Having an work order operation sequence dedicated to weld rework allowed weld employees to record the rework labor time in the company's ERP system. This rework time data was then made available in a weekly report which included both line graphs displaying the weekly average for each weldment as well as the raw data that was captured from

each instance of weld rework performed on individual JLTV weldments. The raw data in this weekly report was used by the Harrison quality team to conduct Pareto Analysis of the recorded rework time data to understand which JLTV weldments were contributing the most to the total weld rework time.

Pareto Analysis

The Harrison quality team applied Pareto methodology to analyze weld rework time recorded for each of the thirty-four types of JLTV weldments manufactured within their facility over the course of one week. Figure 10 displays the results of rework data that was subject to Pareto analysis. The Harrison quality team targeted the vital few weldments which made up most of the recorded rework time. Weldment part numbers 4268212, 4270977, 4271185, and 12602371 were identified as being the top contributors to weld rework time and therefore were targeted for quality improvement.

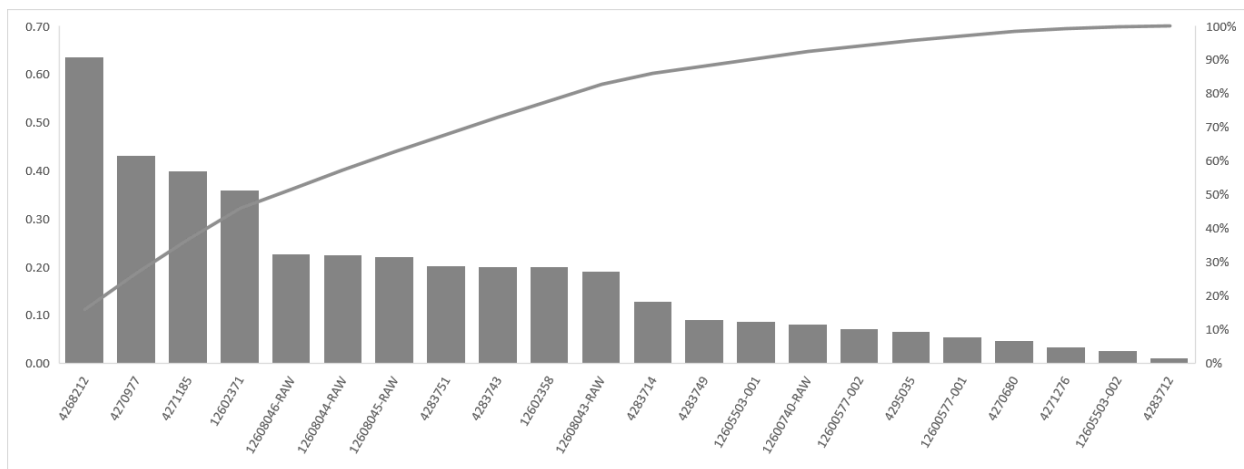


Figure 10. Pareto chart displaying average rework time recorded on JLTV weldments.

To allow effective quality improvement of the four targeted JLTV weldments, the quality team needed to identify the weld locations contributing the most rework time. For each targeted weldment, the data that had been entered by the quality gate inspectors was pulled into a pivot

bar chart that displayed the top three defect rework time contributing weld locations. For each weld location, the types of weld defects recorded by the quality gate inspectors were also identified along with the estimated rework totals for each defect type. Figures 11 displays the top estimated rework time weld locations on JLTV firewalls, weldment part number 4268212. Appendix A shows the top rework contributing weld locations for each of the other targeted weldments.

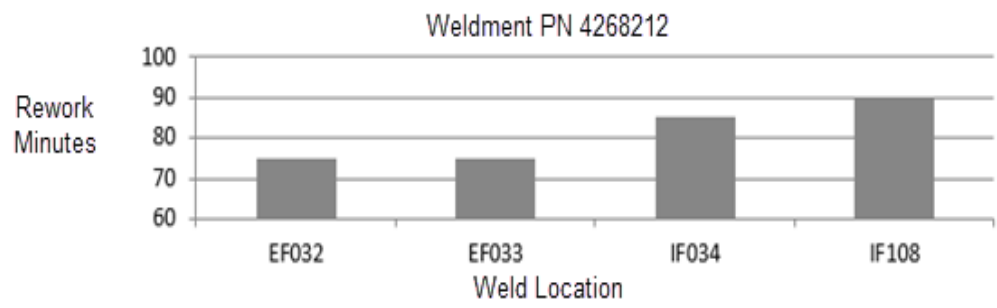


Figure 11. Pivot bar chart displaying weld locations with most rework.

Each identified weld location was broken down by the amount of estimated rework time for each type of weld defect recorded in those locations. Figure 12 displays the type of defects making up the rework time recorded in the weld locations identified as being the top areas of rework time. Appendix B displays the pivot bar charts showing the top defect types in each targeted weld location on the other three targeted JLTV weldments.

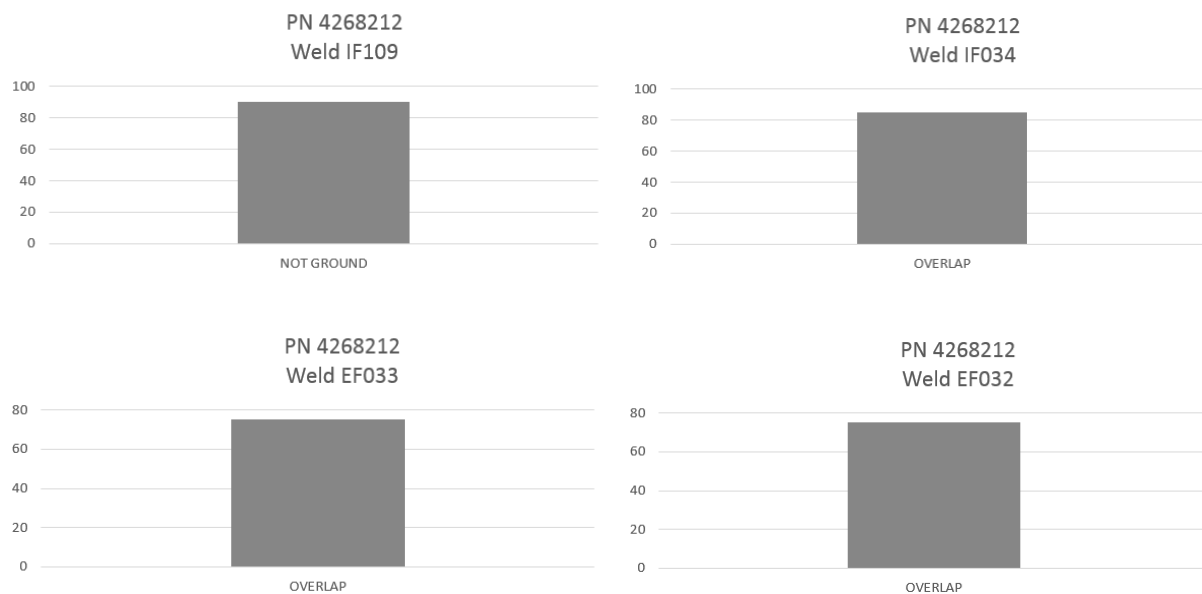


Figure 12. Bar charts displaying rework minutes by defect type in each weld location.

Once establishing an understanding of the top weld defect types and locations on the four targeted JLTV weldments, the Harrison quality team utilized the DMAIC problem solving methodology to address each identified weld location and the associated defects.

DMAIC Problem Solving

The weldments and corresponding weld locations that were identified through Pareto analysis were targeted for improvement using DMAIC problem solving methodology. With the JLTV weld problem solving team already established, the specific weld locations identified, and the baseline estimated rework time totaled for each location, the define and measure phases of DMAIC problem solving methodology were complete.

Analysis of the identified weld locations and the associated weld defects within those locations included getting feedback from the quality gate inspectors and weld employees who were completing the identified welds. The feedback that was gathered was documented in the JLTV weld quality report which was covered with the JLTV weld problem solving team during

the weekly quality meeting. The feedback that was gathered helped determine the root cause of each targeted defect and allowed the JLTV weld team to develop measures for preventing the issues going forward.

In weld locations EF032, EF033, and IF034 on weldment part number 4268212, it was determined that the cause of the weld overlap defects was due to reduced penetration at the weld start and stop point. This was identified as a common defect on circular welds on many JLTV weldments where the weld stop point meets the weld start point as it was difficult for weld employees to get good weld penetration when overlapping welds using stainless steel weld wire. Only the most skilled weld employees were able to prevent weld overlap from occurring on circular welds.

To help reduce instances of overlap on circular welds where the end of the weld goes over the start of the weld, the Harrison engineering team developed a weld feature that could be programmed into each weld machine and allowed for a hotter weld start. The hotter weld start allowed for less buildup of weld in the beginning which in turn allowed for less overlap when tying in the end of the circular welds to the start point. The updated weld feature took some time for the weld operator to adjust to. Since the weld employee who was completing welds EF032, EF033 and IF034 was still not able to consistently avoid creating weld overlap defects at the start and stop points of these weld locations, the JLTV weld operations team decided to train the weld employee on the proper methods of identifying and mechanically removing weld overlap in these locations. While this took some additional time for the weld employee to complete the overlap removal, it stopped the defects from moving on to the next weld operation. By the following week, as the weld employee became more accustomed to the new weld feature, he became more

and more successful at preventing the overlap from occurring, reducing the need to correct the defect.

In weld location IF108 on weldment PN 4268212, one of the weld employees who completed this weld was new to the weld station and was not aware of the need to grind the weld flush. Training was conducted with the weld employee which consisted of reviewing the weldment drawing which indicated the need to grind the weld flush. After the training occurred, the weld employee was able to eliminate reoccurrence of the defect.

Once the preventive and corrective actions were implemented, the Harrison quality team monitored the estimated rework time recorded in the targeted weld locations to recognize any improvement. If improvement was achieved, the JLTV weld team worked on sustaining the improvement through various control methods.

For weld locations EF032, EF033 and IF034 on weldment part number 4268212, the added weld feature along with the trained method of identifying and mechanically removing the weld overlap defects at the start and stop points on each weld had proven to be effective in reducing the weld defects recorded in these locations as they were no longer contributing to any estimated rework time recorded in the quality gate the following week. The JLTV operations team decided to conduct training on weld overlap identification and removal with all other weld employees that completed similar, circular welds on other JLTV weldments.

The training that was conducted with the weld employee who completed weld IF108 also proved to be effective as there was no rework time recorded the following week in this weld location. Figure 13 shows the quality report used to communicate the DMAIC methodology in addressing these weld defects. Appendix C includes the same quality report for each of the other

three targeted weldments that were identified as being top contributors to weld rework time totals during the same week of manufacturing quality data capture.

Problem Description:

- Escalated rework time in weld locations EF032, EF033, IF034, and IF108.

Containment:

- Weld defects identified and corrected in quality gate.

Investigation Notes:

- EF032, EF033, and IF034 are all around boss welds which are prone to overlap defects at the start/stop intersection
- IF108 is a weld that is required to be ground flush

Potential Root Causes:

- Torch angle
- Weld settings
- Travel speed
- Wire feed speed
- Weld techniques

Corrective Action:

- Installing "arc start" feature to get better penetration at weld starts
 - Received operator feedback that this feature is helping in some welds but not on others
 - Working with ME to get this feature added to each welder in JLTV
- Working with welders completing these welds to establish best torch angle to prevent overlap
- Working with welders to help them identify overlap at start/stop points so they are able to correct

Verification:

- Monitoring weld rework in these areas in following weeks to see if implemented actions have helped reduce rework time
 - Areas where "arc start" feature was implemented have seen a decrease in the amount of overlap coming from those stations

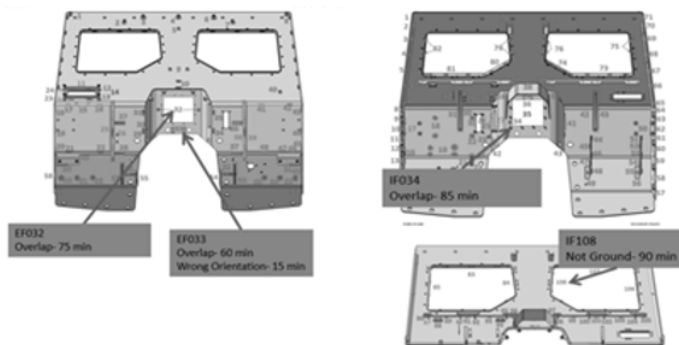


Figure 13. Weld rework problem solving report for PN 4268212.

To help sustain the improvements made through DMAIC problem solving, the Harrison quality team implemented the use of statistical process control which would serve as a constant monitoring tool and allowed immediate action to address any significant quality output regressions.

Statistical Process Control

The Harrison quality team acknowledged that the most common cause for weld rework time was stemming from certain weld employees who were struggling to prevent or correct weld defects. To create greater accountability and assure struggling weld employees were receiving additional coaching to help them succeed, the Harrison quality team implemented the use of statistical process control to monitor and react to occasions of exceptionally poor quality coming from specific weld stations. To establish best practices in implementing the use of statistical

process control, the Harrison quality team decided to pilot it in the JLTV firewall weld station. Using recorded quality gate data and an Excel control chart template, the JLTV weld quality team set upper control limits for JLTV firewall weldments that went through quality gate inspection. The quality team targeted two sets of data for statistical process control monitoring. Upper control limits were established for the total quantity of defects and the total estimate rework time recorded for each weldment in the designated quality gate for JLTV firewalls. Figure 14 displays the completed Excel control chart template that was used to set the control limits for JLTV firewall defects totals. The data set included the work order number and total amount of defects recorded for each JLTV firewall weldment inspected over the prior two weeks of manufacturing. The upper control limit for firewall defect totals was set to thirty-four defects.

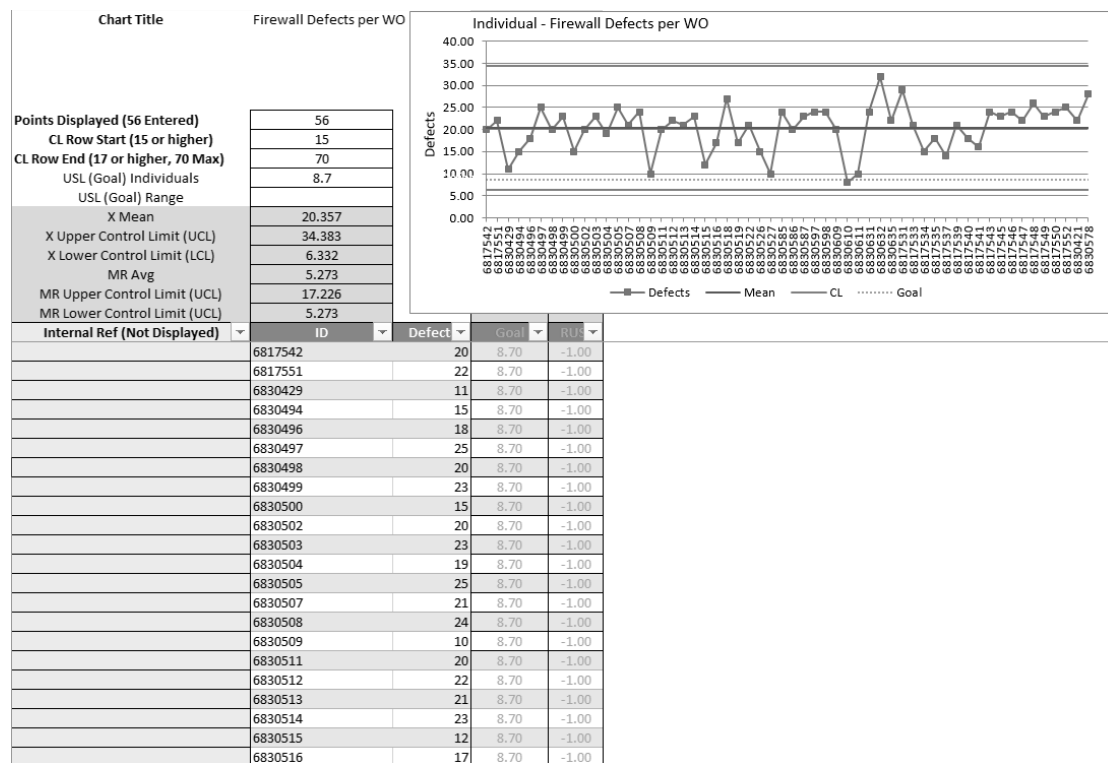


Figure 14. Control chart for JLTV firewall defect totals per weldment.

The same method was used to set the upper control limit for estimated rework time recorded for each JLTV firewall. Recorded estimated rework data from the prior two weeks was copied into the control chart template and the upper control limit was calculated. Figure 15 displays the completed control chart and the resulting upper control limit for estimated rework time on JLTV firewalls. The upper control limit for estimated rework time on JLTV firewalls was 131 minutes.

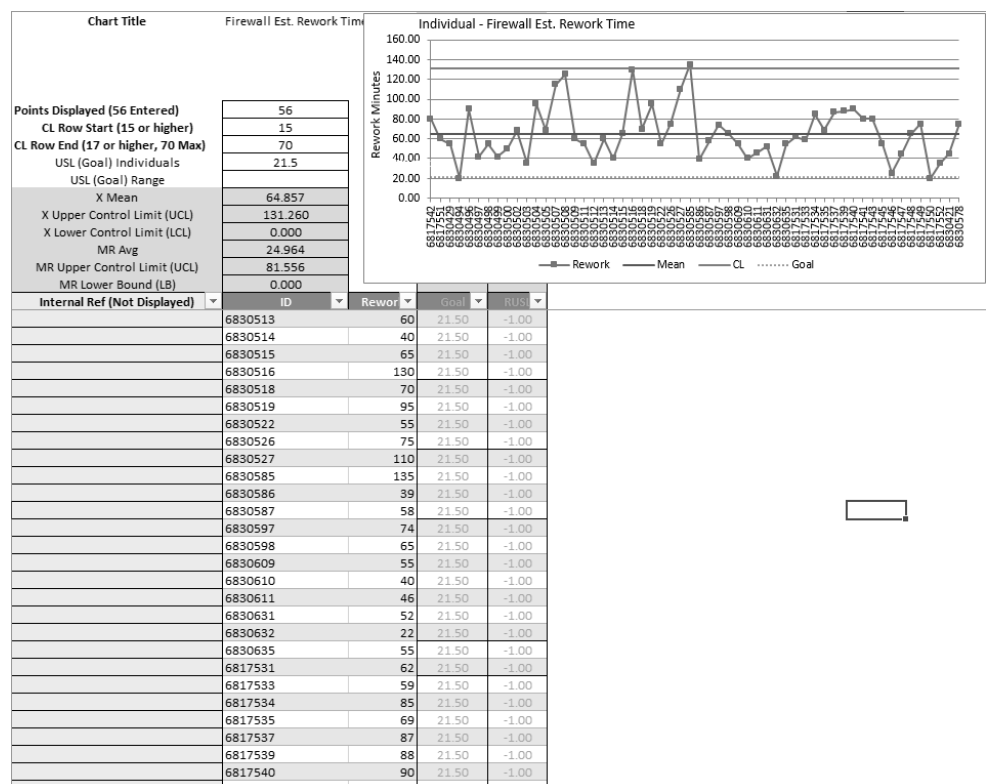


Figure 15. Control chart for JLTV firewalls estimated rework time per weldment.

The quality gate inspectors were provided training on reacting to any inspected weldments that exceeded the upper control limit for either the total amount of defects or the total estimated rework time. The quality gate inspector recorded the weldment part number, the weldment name, the weldment work order number, the date of inspection, the estimated rework time, the total amount of defects, the assignable cause, and the corrective actions taken for each

weldment that had exceeded the set upper control limits. This information was then recorded in an Excel spreadsheet by the JLTV weld quality responders. Figure 16 shows the reaction log for the first month of recorded information from the JLTV firewall weld station.

Part Number	Part Name	Work Order	Date Inspected	Est. Rework Time (Min.)	Defect Total	Special Cause	Actions Taken	Operator Badge
4268212	FIREWALL	6861419	11/16/2017	140	28	Fill-in operator in station 2	Passed on to 1st shift to have gate key	64801
4268212	FIREWALL	6861424	11/17/2017	180	36	Fill-in operator in station 2	Passed on to 1st shift to have gate key	64801
4268212	FIREWALL	6861434	11/20/2017	235	47	2nd shift welder in station 3	Spoke with TC and responders who a	153678
4268212	FIREWALL	6861434	11/20/2017	235	47	2nd shift welder in station 4	Spoke with TC and responders who a	151701
4268212	FIREWALL	6880658	11/29/2017	205	37	Bad gun angle causing defects	Showed welder the proper gun angle	
4268212	FIREWALL	6861434	11/29/2017	235	47	2nd shift welder in station 4	Spoke with TC and responders who a	151701
4268212	FIREWALL	6861434	11/29/2017	235	47	2nd shift welder in station 3	Spoke with TC and responders who a	153678
4268212	FIREWALL	6880672	11/29/2017	210	42	3rd shift welder in station 3	Spoke with TC and responders who a	153678
4268212	FIREWALL	6880672	11/29/2017	210	42	2nd shift welder in station 4	Spoke with TC and responders who a	10902

Figure 16. Reaction log data recorded for JLTV firewall weld station.

In addition to quality gate inspectors driving back each instance of out of control weldments to the appropriate weld employees, the JLTV weld quality team was able to use the information that was captured in the reaction logs to identify which weld employees were contributing to the most occurrences of weldments exceeding the set control limits. This information was shared with the operations team to supplement decision making pertaining to additional weld employee training and weld employee relocation into other weld stations.

Summary

This chapter provided results of the methods and tools used by the JLTV weld quality team in reducing the weld rework labor hours. Of the four JLTV weldments that were targeted in this study, three of the four had reduced rework time the following week for an average rework time reduction of 0.31 hours per weldment. All four targeted weldments had reduced rework time over the following month of production with an average rework time reduction of 1.17 hours per weldment. In the first month of SPC implementation in the firewall station, there were eleven instances of out of control weldments stemming from five different weld employees who were each provided additional coaching. The quality tools covered in this chapter continued to be used by the quality team in the JLTV weld processes and were also implemented into other

weld processes within the Harrison facility. The following chapter will review the previous chapters, how the identified limitations affected the study, the impact the study had on the company, and how the findings of the study can be applied to other areas of the company.

Chapter V: Discussion, Conclusion and Recommendation

This study focused on tools utilized by the Oshkosh Defense Harrison facility quality team to reduce costs associated with weld rework time in the manufacturing of JLTV truck weldments. Due to many new weld employees, processes and weld fixtures, the weld quality defects and associated rework time were at exceptionally high levels. Decreasing the amount of waste associated with weld rework was important to increasing profitability of the JLTV program and enhancing Oshkosh Defense's competitiveness in future JLTV contract bids.

Chapter I introduced Oshkosh Defense's attainment of the JLTV contract by the United States Government and the types of JLTV weldments manufactured at the company's Harrison facility. The chapter also included the statement of the problem which encompassed the need to reduce costs stemming from JLTV weld rework labor. Chapter I also covered the purpose of the study which was to analyze quality tools used by the Harrison quality team to reduce JLTV weld rework time. The rework reduction efforts were intended to increase profitability of the JLTV program and enhance competitiveness in preparation of future JLTV contract bids. Assumptions of the study were also covered in the first chapter as well as definitions of used terms and limitations of the study.

Chapter II reviewed the literature related to the different types of weld defects and the quality tools utilized by the Harrison quality team in reducing weld rework costs. The first quality tool covered in the literature review included Pareto analysis, a method of identifying and separating the top few contributors of a problem from the many other possible causes. Six Sigma DMAIC problem solving methodology was also covered in the literature review to better understand how to effectively define, measure, analyze, improve, and control manufacturing quality problems and solutions. Statistical process control was the final tool covered in the

literature review to understand applicable utilization and effectiveness in controlling process variation.

Chapter III addressed the methodology utilized by the Oshkosh Defense Harrison quality team in reducing costs associated with JLTV weld rework time. The chapter noted the observed causes of the elevated rework costs. The chapter also defined the methods used for capturing the necessary weld quality data and the methods of utilizing that data through the application of Pareto analysis. Chapter III also reviewed the methods utilized by the Harrison quality team to have a structured approach to problem solving using DMAIC methodology. The last portion of Chapter III covered the implementation of statistical process control within the JLTV firewall weld station.

Chapter IV covered the results of developing quality data capturing methods and implementing Pareto analysis, DMAIC problem solving and statistical process control to drive down JLTV weld rework. The chapter included the results of applying Pareto analysis to one week of weld defect rework data. The chapter then covered the Harrison team's efforts to resolve the top identified issues using DMAIC problem solving methodology. The chapter also covered the results of implementing statistical process control in the JLTV firewall station over the course of one month. The chapter concluded with the noted success the Harrison quality team achieved in using these quality tools.

This chapter summarizes the content of the previous chapters, reiterates the limitations of the study and draws conclusions from the results of the study. This chapter also makes recommendations on how the lessons learned from the study could be applied to other areas of Oshkosh Defense's manufacturing processes.

Limitations

While this study focused on rework time stemming from JLTV weld defects identified in the quality gate inspections, it did not cover all aspects of rework associated with JLTV weldment quality. The research did not cover instances of nonconforming dimensional requirements of the weldment components that also led to rework time. The research study also did not cover any rework reduction efforts in JLTV assembly and finishing manufacturing processes or weld processes completed outside the Harrison facility. The study also was limited to the Pareto analysis and DMAIC problem solving methodology utilized over the course of one week and did not cover the utilization of these tools in weeks prior to and after that week. The study also covered the implementation of statistical process control in one weld station over the course of one month and did not cover the use of this tool in other weld stations during the following months.

Conclusions

The quality tools utilized by the Oshkosh Defense Harrison quality team to reduce JLTV weld rework proved to be effective. The issues that had been identified through Pareto analysis and addressed through DMAIC problem solving were effectively eliminated or reduced in all instances. Statistical process control also proved to be effective in understanding which weld employees needed additional coaching to improve their weld quality output.

Training conducted with the JLTV weld quality gate inspectors allowed for accurate identification of defects on JLTV weldments. Development and implementation of quality documents and systems used to record weld defect data allowed the quality team to effectively analyze the data that was gathered.

Pareto analysis of the recorded JLTV weld defect rework data allowed the quality team to identify which weldments were contributing the most rework time. Further data analysis allowed the quality team to understand specific weld locations and defect types that were contributing to most of the required rework. By having the ability to identify specific defects causing most of the weld rework, the quality team was able to identify and implement specific preventative and corrective methods to reduce future defect occurrences in the targeted weld locations.

Using the DMAIC problem solving methodology helped the quality team make significant gains in rework reduction efforts and helped the team sustain the improvements that were achieved. Many improvements were achieved through team collaboration in identifying the top issues, developing baseline measurements to improve upon, identifying the root causes, developing and implementing solutions, and sustaining any changes that had a positive impact.

Implementing statistical process control methods in the JLTV firewall weld station also proved to be effective in acting upon any instances of exceptionally poor quality. While the weld quality gate inspectors were already tasked with driving back reoccurring quality defects to the appropriate weld employees, the implementation of set control limits, reaction criteria, and documentation methods allowed for a more structured approach to defect reduction. Statistical process control also allowed the Harrison JLTV leadership team to identify weld employees who were struggling so additional training resources could be provided. Documented reactions addressing out of control weldments allowed team coordinators the ability to hold employees accountable. It also helped the operations team monitor individuals who were receiving additional training to understand if they were improving their quality outputs.

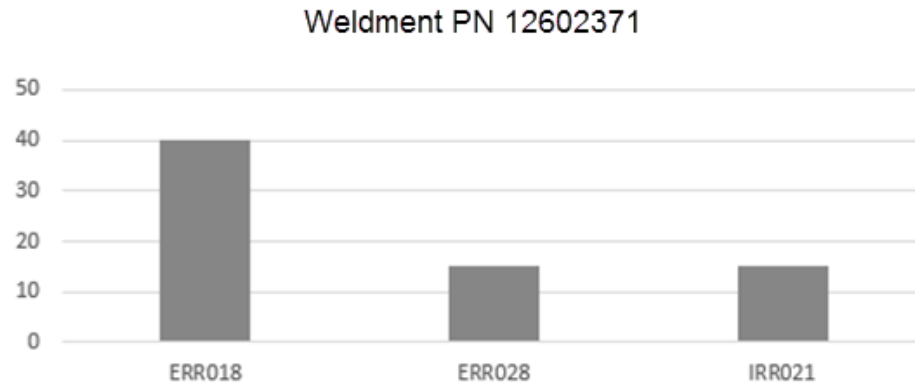
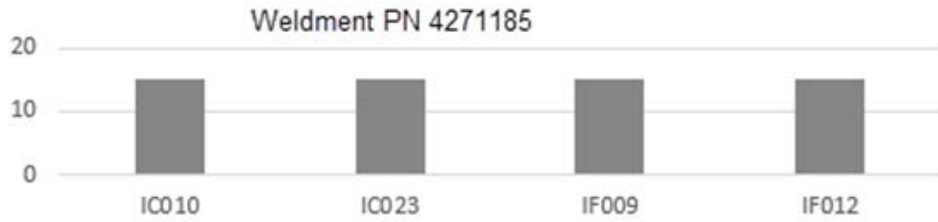
Recommendations

The methods and quality tools implemented by the JLTV weld quality team led to many improvements pertaining to weld defect rework time reduction in the areas targeted. Since the Harrison facility has many other weld manufacturing lines in which similar processes are in place, it was recommended that the same methods and tools be utilized in the other weld areas. Since all other product lines within the Harrison facility have been in place longer than JLTV, there may not be as many opportunities for improvement as those processes are more mature and have more experienced weld employees. However, the tools and methods discussed in this study would still be favorable to consider since they would assist in continuous improvement efforts. It was also recommended that these methods and tools are used throughout the Harrison facility to create a standardized approach to quality improvement methods.

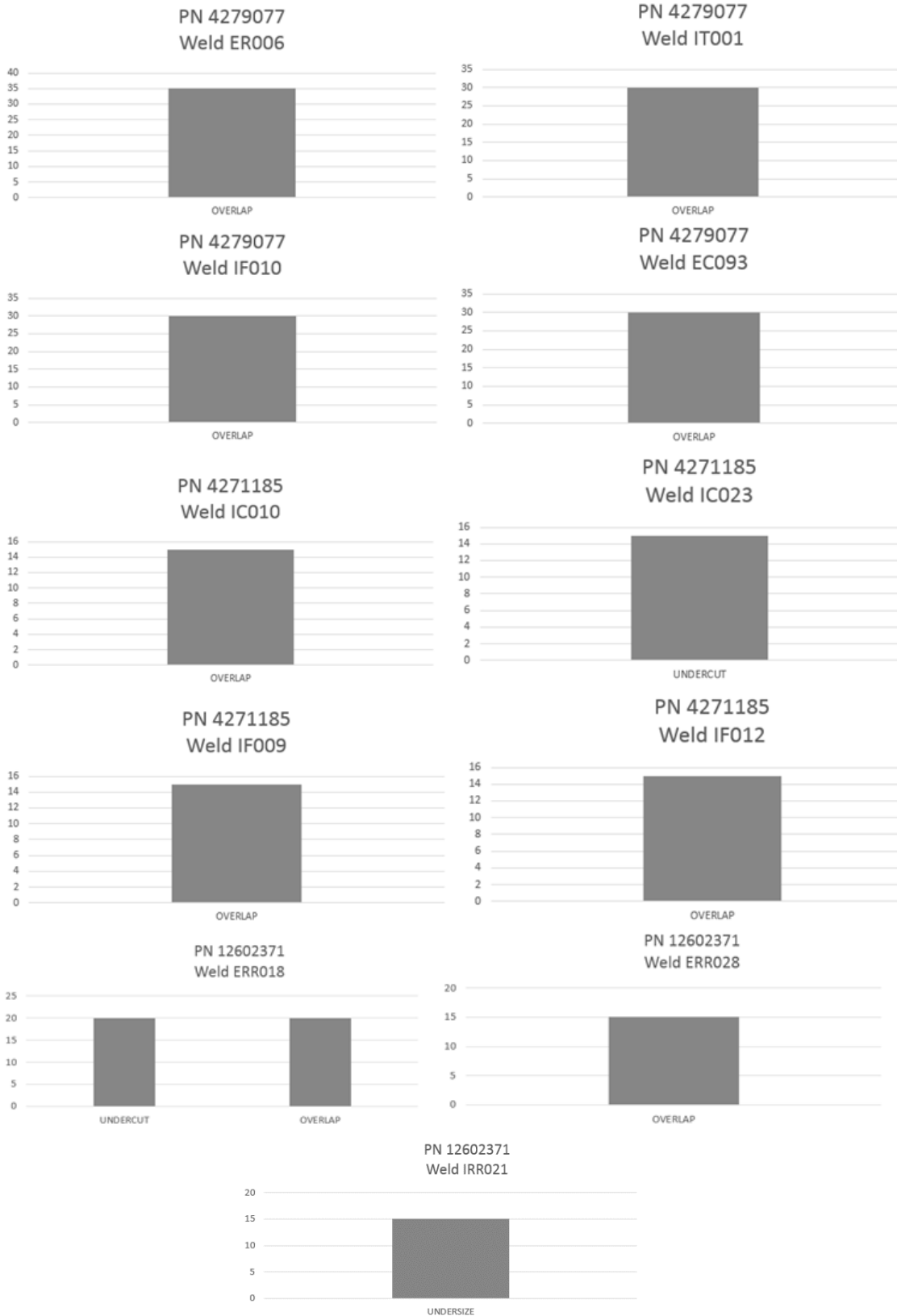
Aside from the Harrison facility, other facilities within Oshkosh Defense may also benefit from greater utilization of Pareto analysis, DMAIC problem solving, and statistical process control. While these tools have and continue to be used by other Oshkosh Defense quality teams, greater standardization of how these tools are utilized could be beneficial in allowing teams to work together, creating greater synergy in efforts to reduce costs associated with quality defects. Standardized methods would also allow quality team members to have clear expectations and readily available tools to use in their day to day efforts. Greater standardization of quality tools would likely be an improvement from the current state where it is often up to individual quality team members to decide how to capture, analyze and act upon data to improve processes.

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Appendix A: Weld Location Pivot Bar Charts

Appendix B: Weld Defect Type Pivot Bar Charts



Appendix C: Weld Rework Problem Solving Reports

Problem Description:

- GP Floor (PN 4270977) has had escalated amounts of rework time in weld locations ER006, IT001, IF010, and EC093

Containment:

- Reworking defective welds in the quality gate

Investigation Notes:

- Rework in all four locations due to weld overlap

Potential Root Causes:

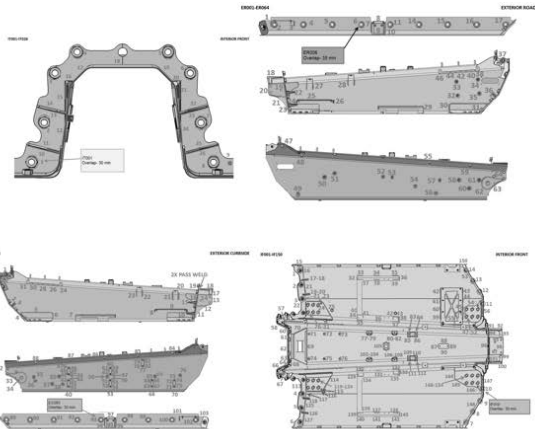
- Torch angle
- Weld settings
- Travel speed
- Wire feed speed
- Weld techniques

Corrective Action:

- Installing "arc start" feature to get better penetration at weld starts
 - Received operator feedback that this feature is helping in some welds but not on others
 - Working with ME to get this feature added to each welder in J.LTV
- Working with welders completing these welds to establish best torch angle to prevent overlap
- Working with welders to help them identify overlap at start/stop points so they are able to correct

Verification:

- Monitoring weld rework in these areas in following weeks to see if implemented actions have helped reduce rework time
 - Areas where "arc start" feature was implemented have seen a decrease in the amount of overlap coming from those stations



Problem Description:

- UV Floor Weldment (PN 4271185) has had an escalated amount of weld rework recorded in location IC010, IC023, IF009 and IF012.

Containment:

- Repairing defects identified in quality gate

Investigation Notes:

- Identified High Rework Locations
- IC010, IF009 and IF012 were all weld overlap defects
- IC023 had all weld undercut recorded

Potential Root Causes:

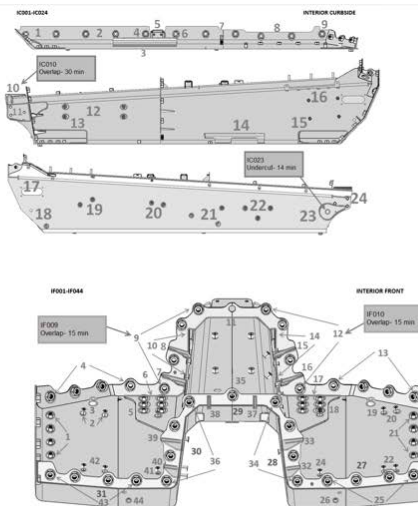
- IF009 and IF012 overlap at the starts and stop points
- IC010 presents difficulty in getting the proper torch angle due to weld fixture being in the way
- IC023 inner diameter undercut due to poor torch angle

Corrective Action:

- Installing "arc start" feature to get better penetration at weld starts
 - Received operator feedback that this feature is helping in some welds but not on others
 - Working with ME to get this feature added to each welder in J.LTV
- Working with welders completing these welds to establish best torch angle to prevent overlap and undercut in identified locations

Verification:

- Monitoring weld rework in these areas in following weeks to see if implemented actions have helped reduce rework time
 - Areas where "arc start" feature was implemented have seen a decrease in the amount of overlap coming from those stations



Problem Description:

- Escalated rework time on rear LH subframe (PN 12602371) in weld locations ERR018, ERR028 and IRR021

Containment:

- Defects being repaired in quality gate

Investigation Notes:

- Identified High Rework Locations
 - ERR018 had 20 minutes rework for undercut and 20 minutes for overlap
 - ERR028 had 15 minutes rework for overlap
 - IRR021 had 15 minutes of rework for undersize

Potential Root Causes:

- ERR018- found that 2nd shift welder wasn't aware his torch angle was causing too much heat on one surface and not enough on the other
- ERR028- Overlap occurring where end of weld ties in with ERR027
- IRR021- Operator was unaware of the weld size requirement and had undersized welds as a result

Corrective Action:

- ERR018- coached on getting better torch angle to avoid overlap/undercut
- ERR028- coached welder on ending ER027 in the corner rather than starting there to allow prevention of overlap when tying in ER028
- IRR021- show welder drawing weld size call out

Verification:

- Monitoring rework time to see if areas targeted improve

