Lean Implementation in a Turbocharger Service Shop

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Abstract *— In many of the manufacturing and repair shops, the use of industrial machinery is required to perform most production or repair efforts. A Turbo Service repair shop was identified due to its needs of Lean tools and concepts implementation. The source of reworks was identified as contamination on the assembly area and tools reflecting on schedule delays while also increasing human effort, parts defects, and operational costs. In the Shop, there was also lack of organization in the workplace, storage, labeling, and work area and equipment preventive maintenance plans. Based on a 5 Why's analysis, the Lean tools principles to be implemented in the Shop work area were identified as 6S, Total Productive Maintenance (TPM) and Visual Management. Contributions expected from the lean implementation are to reduce reworks, improve safety, improve employee satisfaction, improve Storage space and create a new assembly area.*

Key Terms *— 6S, TPM, Visual Management, 5 Why's Analysis.*

INTRODUCTION

Businesses in all industries and services, including healthcare, manufacturing and governments, are using lean principles in many ways. However, the use of Lean manufacturing is a great tool when addressed to production processes and operability. Most often, implementation of 6S is the most common tool used around the manufacturing environment. Their principles are: Sort, Set in order, Shine, Standardize, Sustain and Safety. Due to the nature of the problem and current condition of the Shop it is one of the best tools to be implemented for process improvement. Total Productive Maintenance (TPM) and Visual Management principles were also identified to be implemented in the Shop work area.

PROBLEM STATEMENT

A Turbocharger Service Shop provide a variety of services for turbochargers which include turbo rebuilding, turbo upgrading, installation services and turbo parts for industrial, commercial and racing applications One of the mayor issues on the company take place during the assembly process caused by the used of these machinery. A problem the company has identified is contamination on the assembly area and products. This is causing additional rework on the assembly process causing delays on delivery dates while also increasing human effort, parts defects, and operational costs. In order to keep the company above customer expectations it is very important to maintain quality and turnaround time for all turbocharger services provided.

RESEARCH DESCRIPTION

By the use of Lean Manufacturing tools we should be able of confirm what the problem is related to, and what are the small and big factors driven the reworks. The research should be focus on eliminate all defects caused by the contamination on the assembly area, increasing quality while reducing rework time and operational costs.

RESEARCH OBJECTIVES

The research objectives are described below:

- Look for Lean manufacturing tools that would guide to reduce rework time in 45%, increase product quality and reduce operational costs.
- Create a separate assembly area to prevent contamination in this process step.
- Lean tools implementation on work areas.

RESEARCH CONTRIBUTIONS

As a result of the research development and lean manufacturing tools implementation, the company will see contributions as: Increasing the quality level -means reducing the number of errors and rework time in a 45%. The result is less demand for company resources and therefore lower total operating costs. Reducing operational cost means reducing the required work time to produce the same parts.

LITERATURE REVIEW

A Turbo Service Shop has been identified as the research area to develop this project. The area was selected due to high contamination in the shop assembly area causing increments in reworks and operation costs. The main objective of a turbo is to significantly boost an engine's horsepower without significantly increasing its weight and durability, which is the huge benefit that makes turbos so popular. They use the exhaust flow from the engine to spin a turbine, which in turn spins an air pump whish compress the air flowing into the engine The turbine shaft in the turbocharger spins at speeds of up to 150,000 rotations per minute (rpm), having contamination inside the turbo can lead to premature failure due its high temperature and speed conditions (Figure 1) [1].

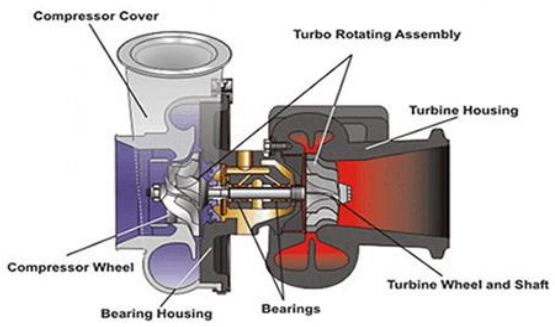

Figure 1
Turbocharger Diagram

Lean Manufacturing is derives from the Toyota Production System or Just In Time (JIT) Production. The core idea of lean manufacturing [2] is persistently work on eliminating waste from the manufacturing process. Waste can take many forms, but the main idea is to eliminate anything and everything that does not add value to the process. In this case, since the source of the problem has been indentified, the right Lean tool can be implemented. The lean tool to be implemented during the research is the 6S methodology using also some concepts from Total Productive Management (TPM) and Visual Management. What is called "6S" derives from the "5S" workplace organization method created by Hiroyuki Hirano. The five "Ss" refer to five Japanese words—seiri, seiton, seiso, seiketsu, and shitsuke which were translate to Sort, Set in order, Shine, Standardize and Sustain. The safety method has been added to maintain a hazard free environment. The (6S) philosophy is described below:

- Sort: In the sorting phase, unnecessary clutter is removed from the workplace.
- Set in Order: On this step the employee need to make sure that there is a place for everything and everything is in their place. Labeling and visual controls are an excellent way to indicate where items belong.
- Shine: In the shining phase, the work environment is thoroughly cleaned and maintenance tasks are identified. Below are some basic steps commonly used during the shine phase.
- Standardize: In the standardizing phase, methods for maintaining 5S throughout the workplace are identified and documented. Standard Work and Checklists are commonly created.
- Sustain: In the sustaining phase, all employees must work together maintain 5S improvements. Sometimes it is the most difficult part of (6S) since it requires a lot of commitment.
- Safety: This is related to the practices and policies that a company puts in place in order to preserve the health and well-being of employees, equipment, and facilities. 5S + 1 improve workplace safety.

METHODOLOGY

Based on the goals defined at the beginning of the research some concepts of Total Productive Maintenance (TPM) and Visual Management tools will be also implemented as part of the productivity improvements to be achieved. A summary the 6S steps are listed below.

Sort

On this step is where the clutter is separated from the tools, equipment, materials and machines that are not needed at the workspace. Unnecessary items will be removed and divided into two categories, see description below.

- Usable: Those items that can be used and placed in another workspace or Storage area. Items would be identified with a "Green Tag".
- Trash: Items that don't have any other used on the shop and will be deposited on the trash or recycle container. Items would be identified with a "Red Tag" (Figure 2).

Figure 2
Tags Classifications

Set in Order

On this step, a place will be created for each item, supplies, tools and equipment needed on the workspace and it will be labeled with the item information. Each employee is responsible of located the items based on frequently of use, flow of work and space occupied. Below are some guidelines to be applied.

- Place items base on the sequences that are commonly used.
- Put the items together if they are used together.
- Try to eliminate items that do the same thing.
- Place items based on their function.
- Create storage places larger than items stored for easy accessibility.

Shine

On this step everything would be cleaned. In order to maintain a Shine workspace the following steps will be implemented as workday responsibilities:

- Clean to inspect because is more difficult to inspect something that is not clean.
- Inspect to detect to make sure that problems have not been missed.
- Detect to correct to resolve any problems that have been found.
- Correct to perfect means that we should avoid problems before they occurs.

Standardize

On this step is where the first three steps are maintained. After the implementation of these steps in the daily work, an employee will be assigned to evaluating the results of the 6S work on a regular basis (i.e. weekly). Visual approaches will be created to assist workers in terms of where, how much and how often duties should be performed on the Shop. Also, results will be posted in a designated and high traffic area so employees get informed on how they are performing.

Sustain

The sustain phase will be based on engage the employees with the work required to maintain 6S as part of the daily work. In other words, create the discipline necessary to keep a % of 6S active in the work area. Implementation will be supported by:

- Recognitions: Rewards and recognitions will be announced and created.
- Maintain 6S: Perform reviews of 6S evaluations with employees, display photos for implementation areas and include it as part of daily conversations.

Safety

An evaluation will be performed on the shop to determine if work areas, utilities and equipments are free of hazards. Verify that all hazards, caution and danger OHSA labels [3] are in good condition,

correctly placed and are the latest standard revisions. See example in Figure 3.

Figure 3
OSHA – Safety and Hazards Labels

Total Productive Maintenance (TPM)

Looking on tools that fit and help to achieve the research goals, TMP [4] have been identified as the one to be implemented. Some of the basics goals of TPM that we are going to be focus are:

- Prevent waste.
- Build an equipment maintenance infrastructure to maximize Turbo Rebuild efficiency.
- Engage employees to keep ownership of their equipment.

TPM implementation should start by selecting the company's bottleneck equipment or area. TPM exercises have been recognized and would be implemented as part of the research to accomplish the goals described above:

- Identify the production area that is related to the reworks.
- Performs a 5 Whys analysis and draws a cause and effect diagram.
- Using the 5 whys and other quality tools, identify solutions and improvements with a preference for low cost and no cost solutions.
- Create a preventive maintenance plan including a chart of daily, weekly, monthly maintenance tasks to be completed.
- Create reference on where the maintenance is to be performed on the equipment using equipment maintenance manuals and drawings.
- Develop a designated area for storage.
- Develop a designated area for assembly.

Using the tools as specified above would help the employees to keep track and be informed of the tasks that should be performed to keep the Service Shop free of reworks, waste and with manufacturing efficiency at high levels.

Visual Management

Visual Management will be focused in meeting production goals, eliminating waste, and be aligned with Turbo rebuilds schedule. The purpose is to engage employees with visual indicators in the lean workplace. Below are some visual tools to be implemented:

- Develop the Shop Layout for a workplace.
- Identify where mistake-proofing (poka-yoke) would be beneficial.
- Obtain employee involvement in the visual systems display.
- Implement 6S as part of the visual workplace.
- Incorporate a board for schedule tracking and production requirements.

RESULTS AND DISCUSSION

As the problem statement was already identified by the owner of the Shop. The research started by visiting the location and confirming that contamination on the assembly area was actually the root cause of the problem. On this step, is where the tools of 6S, TPM and Visual Management are aligned to the Service Shop needs to determine if they actually would help to reduce operational costs and reduce reworks in a 45%.

Sort Implementation

This process step created a visual work place that improved communication between employees and reduced waste. This motivated employees since they were responsible and in control of their work areas. This means that they make decisions of what items, tools, supplies and equipment are actually needed in the current workplace based on their experience. Figures 4 and 5 showed the implementation on this step.

Figure 4
Sort – Workbench Area

Figure 5
Sort – Counter Area

Set in Order Implementation

This actually eliminates the waste identified on the Sort step. It prevents or reduces repetitive mistakes identified. Items were placed base on the sequences that are commonly. Items that do the same thing were replaced with one that does multiple functions. Storages have been added for easy accessibility and use. Labels were used to create a visual workplace so any employee in the workplace can identify, find, use and put the items back in the correct place. Figure 6 showed the implementation of this step.

Figure 6
Set in Order – Welding Equipment & Tool Box Labels

Shine Implementation

Maintaining Shine in the workplace goes well beyond basic cleaning. All employees participated in making basic modifications to work areas during scheduled cleaning times. This actually helps in preventing repetitive cleaning issues cause by debris accumulation. Self-monitoring and cleaning duties have been assigned to each employee and designated based on work areas. Also, goals for maintaining a clean environment have been established as a whole company given recognitions to employees and outstanding areas. Cleaning supplies were located in an accessible storage area making the Shine action easy to perform. Figure 7 showed the implementation of this step.

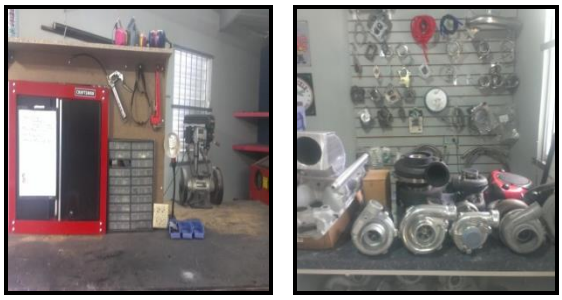

Figure 7
Shine – Workbench Area & Turbo Storage Area

Standardized Implementation

Now that the first three 6S's steps have been implemented, the next step is to standardize the best practices defined based all work areas. With the Standardization, the first three steps are maintained, it actually creates a consistent approach with which tasks and procedures are done. Tables 1 and Table 2 shows 6S Rating before and after 6S implementation respectively.

Ratings are evaluated by different employees and posted on designated areas. Each employee is responsible of improve and maintain areas within a Score of 26-30 to keep the area compliant. Results from 22-26 reflects that areas meets minimal standards and from 22 under reflects that area need urgent attention. There is always is room for improve, but it keeps people engaged and shows them that small deviations are acceptable.

Table 1

Standardized - 6S Rating Checklist (Before 6S)

6S Rating Checklist

Employee: Luis Pagan Auditor: Raul N. Nieves Date: 2/1/2014

Instructions: If the requirement is meet fill blank with "1", if not, assign "0".

	SORT *(Distinguish between what is needed and not needed)*	Result
1	Does the tools and equipment in the correct work area?	0
2	Does the tools on work areas being currently or be used within 24 hours?	0
3	Does all machines have all the tools required to perform work?	1
4	Unused bottles or cans are not left on work areas?	0
5	No unused tools or equipment are left on the Machines?	0

	STRAIGHTEN *(A place for everything and everything in it's place)*	Result
6	Are posters and pictures aligned and well organized?	1
7	Equipment locations and drawers are labeled correctly?	0
8	Are cords, machine cables and water lines well managed?	0
9	Is the 6S Checklist posted montly?	0
10	Are tools and Equipment in their correct locations?	0

	SHINE *(Keep it organized and clean)*	Result
11	Are recycle and waste containers free from overflow?	1
12	Did recycle materials are in the correct containers?	1
13	Are the tools and equipment in good working condition?	1
14	Does tools and equipment are well organized?	0
15	Are the machines free of dust and debris?	1

	STANDARDIZE *(Maintain the first three categories)*	Result
16	Equipment maintaince plan is performed as required?	1
17	Are 6S assessments performed on a montly basis?	0
18	Are equipment maintaince instructions visible?	0
19	Did schedule and production plan on the board is updated?	0
20	Are safety labels on machines visibles?	0

	SUSTAIN *(Create a maintaince and cleaing plan)*	Result
21	Is the employee trained and engaged with 6S.	0
22	Are findings from last month resolved?	1
23	Are improvements from last month implemented?	1
24	Did an acceptable 6S level (26-30) is mantained or improved from the last month.	0

	SAFETY *(Keep working conditions safe)*	Result
25	Are work areas free of electrical or other hazards?	1
26	Does employee know where the first aid station is located?	0
27	Does cabinet and drawers doors are closed?	1
28	Does fire extinguisher is accesible and up to date?	0
29	Are emergency escape routes not blocked?	1
30	Are emergency escape plan and shop layout is up to date?	0

Overall Score ***12***

Table 2

Standardized - 6S Rating Checklist (After 6S)

6S Rating Checklist

Employee: Raul N. Nieves Auditor: Luis Pagan Date: 3/1/2014

Instructions: If the requirement is meet fill blank with "1", if not, assign "0".

	SORT *(Distinguish between what is needed and not needed)*	Result
1	Does the tools and equipment in the correct work area?	1
2	Does the tools on work areas being currently or be used within 24 hours?	1
3	Does all machines have all the tools required to perform work?	1
4	Unused bottles or cans are not left on work areas?	1
5	No unused tools or equipment are left on the Machines?	1

	STRAIGHTEN *(A place for everything and everything in it's place)*	Result
6	Are posters and pictures aligned and well organized?	1
7	Equipment locations and drawers are labeled correctly?	1
8	Are cords, machine cables and water lines well managed?	1
9	Is the 6S Checklist posted montly?	1
10	Are tools and Equipment in their correct locations?	1

	SHINE *(Keep it organized and clean)*	Result
11	Are recycle and waste containers free from overflow?	1
12	Did recycle materials are in the correct containers?	1
13	Are the tools and equipment in good working condition?	1
14	Does tools and equipment are well organized?	1
15	Are the machines free of dust and debris?	1

	STANDARDIZE *(Maintain the first three categories)*	Result
16	Equipment maintaince plan is performed as required?	1
17	Are 6S assessments performed on a montly basis?	1
18	Are equipment maintaince instructions visible?	1
19	Did schedule and production plan on the board is updated?	1
20	Are safety labels on machines visibles?	1

	SUSTAIN *(Create a maintaince and cleaing plan)*	Result
21	Is the employee trained and engaged with 6S.	1
22	Are findings from last month resolved?	1
23	Are improvements from last month implemented?	1
24	Did an acceptable 6S level (26-30) is mantained or improved from the last month.	1

	SAFETY *(Keep working conditions safe)*	Result
25	Are work areas free of electrical or other hazards?	1
26	Does employee know where the first aid station is located?	1
27	Does cabinet and drawers doors are closed?	1
28	Does fire extinguisher is accesible and up to date?	1
29	Are emergency escape routes not blocked?	1
30	Are emergency escape plan and shop layout is up to date?	1

Overall Score ***30***

Sustain Implementation

On this step of 6S, management is helping on creating a habit of properly maintaining the 6S procedures every day within the company. Employees should be focus on maintaining the first four steps, leaving always room for improvements if possible. In this case, a 6S implementation schedule was created and provided to every employee so they can perform their work based on the schedule requirements (see Table 3). Once a week, employees should perform 6S in their workspace based on the 6S Rating checklist. Schedule is updated every month and shows 3 months up front and the previous month for reference purposes. For example, current working month shown on Table 3 is April, so it goes from March up to June. Also, equipment maintenance should be performed by the owners as specified on the equipment maintenance plan (see Table 4.

Table 3

Sustain - 6S Schedule

6S Implementation Schedule	
Month	Days
March	7, 14, 21, 28
April	4, 11, 18, 25
May	2, 9, 16, 23, 30
June	6, 13, 20, 27
July	4, 11, 18, 25

Safety Implementation

The implementation of manufacturing safety standards and technologies not only help to reduce injuries, but they also improve productivity, efficiency and increased confidence on employees. Every employee has been encouraged to review the safety manuals and OSHA requirements. Safety Labels from OSHA has been implemented on each machine and equipment around the Shop, some of them are: Ear Protection Required, Eye Protection Required, Keep hands clear of moving parts, Danger 440V, Hazardous chemicals and Compressed Gas. Also, the use personal protection as Welding Gloves, Welding Helmets, Welding Jackets, Ear Plugs, eyeglasses and ear plugs are required and were provided to employees. An

emergency escape plan has been designed with a familiarization training offered to the team. See Figure 8 for reference.

The existing Fire extinguisher was expired, not in working condition and not placed in a visible location; it was replaced with a new one and properly located in a designated labeled area (see Figure 9) for easy access. A small practice was performed with employees and management about releasing the discharge hose and aiming it at the base of an imagined fire.

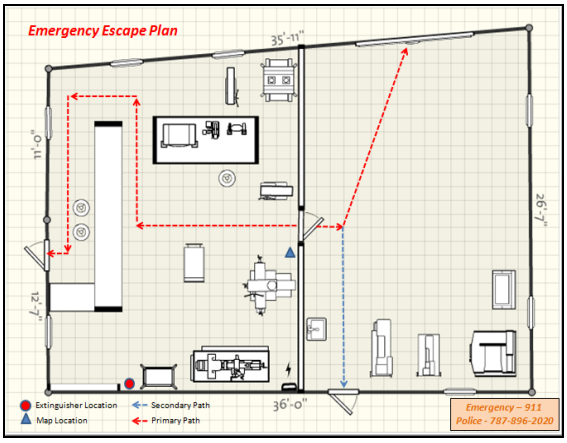

Figure 8
Safety - Emergency Escape Plan

Figure 9
Safety – Fire Extinguisher & Voltage Label

6S Checklist Tracking and Control

Another level of sustaining is by tracking results and trends [5]. All areas are measured and analyzed on a weekly basis. Results are transformed into Bar Charts and the data is posted visually so everyone can see how everyone is performing. Data is also used to catch trends in areas that need more help sustaining. For better response, bar charts are posted in high traffic employee areas. In order to keep motivation on employees, a reward and recognition program has been developed by the management team in order to give credit to employees for the 6S accomplishments within the week. The Bar Charts below showed the 6S Rating results before and after 6S implementation. It is clear, that after the 6S implementation, there is 100% compliant in all work areas. See Figures 10 and 11.

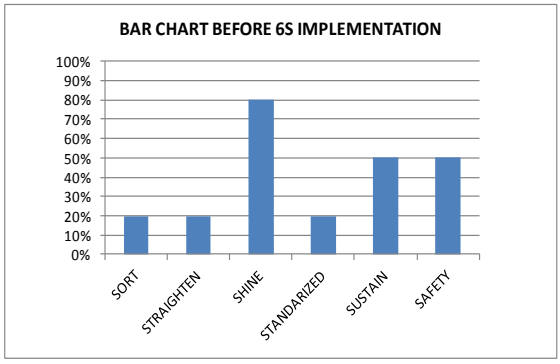

Figure 10
Bar Chart – Before 6S Implementation

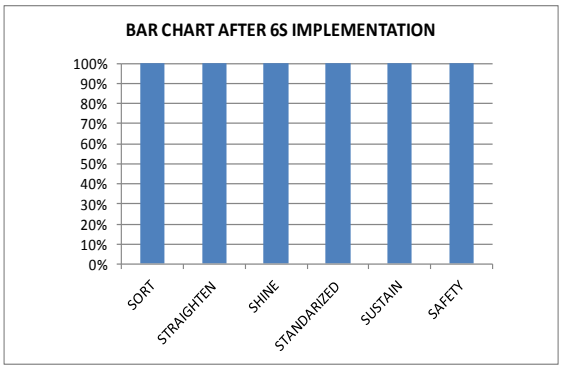

Figure 2
Bar Chart – After 6S Implementation

Visual Management Principles Implementation

As part of the visual workplace development, each employee was assigned to select and implement safety labels for their respective areas based on the type of machine and work requirements. A board was included as part of the work environment, each task is referenced on the board so employees are informed of the work

requirements and schedule. Mistake-proofing (poka-yoke) has been implemented in locations accessible and often used since it is beneficial during tool relocations and pick-up (see Figure 12). A Shop layout has been developed and located at the main entrance (see figure 13). Production areas now have simple visual systems providing the necessary information to the team to accurately work and locate tools and equipment.

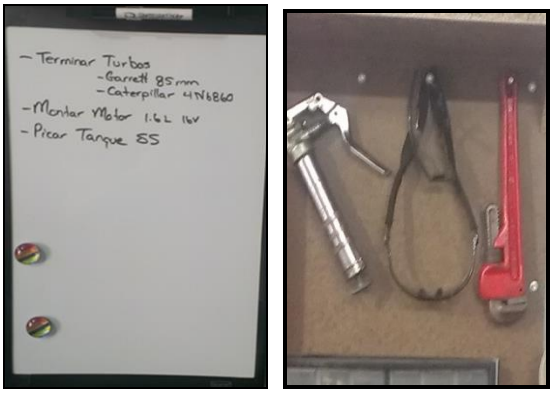

Figure 12
Visual Management – Board & Mistake Profing

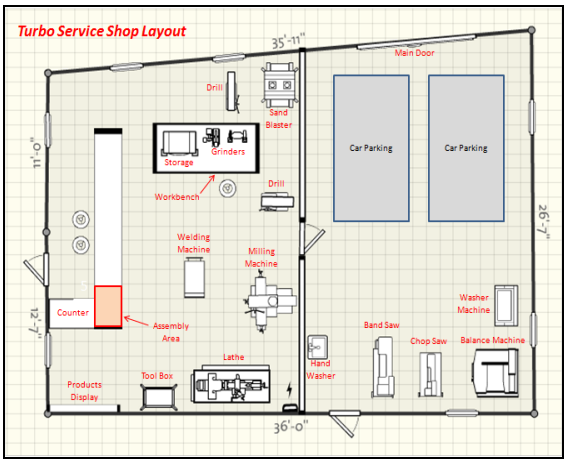

Figure 13
Visual Management – Turbo Service Shop Layout

Total Productive Maintenance (TPM) Principles Implementation

As previously mentioned, the company's bottleneck area has been identified as the Turbocharger assembly area. The team identified contamination as the source of the reworks that were causing production delays and reoperations at the Assembly area. A 5 Why's analysis was the method used to identify and confirm the causes of reworks problems and define the associated corrective actions (solutions and improvements with a preference for low cost and no cost) needed to prevent recurrence of the causes (see Figure 14). Current Turbocharger assembly area was also designated for disassembly, cleaning, painting, and welding purposes. The combination of all this processes creates a lot of moisture, derbies and other types of contamination that actually step in during the assembly process. Figure 15 shows how contaminated was the workbench surface during the assembly process.

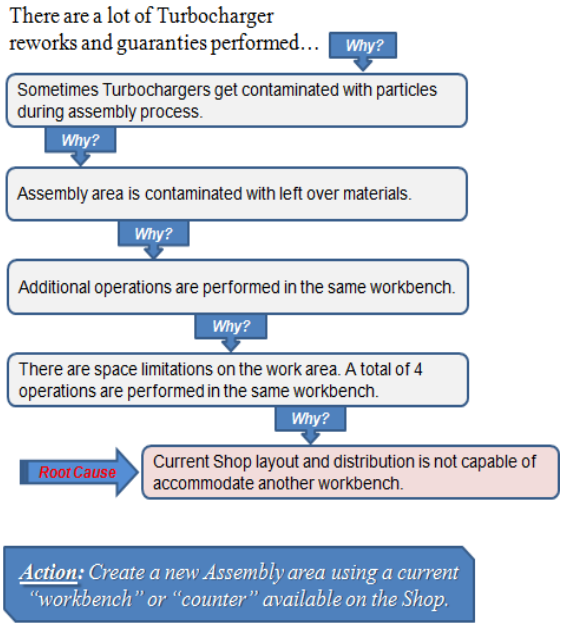

Figure 14
TPM - Why's Analysis

Figure 15
Previous Assembly Area

In order to have quick access to spare parts, storage has been located at the assembly area together with lubricants, cleaners, equipment and frequently used hand tools. It was labeled to have visual reference on parts locations. A new assembly area has been strategically located on the front receiver counter, to minimize costs, and very close to the main tool box for easy tooling access. Having an area just for assembly purposed only actually eliminates most of the reworks related to contamination (see Figure 16).

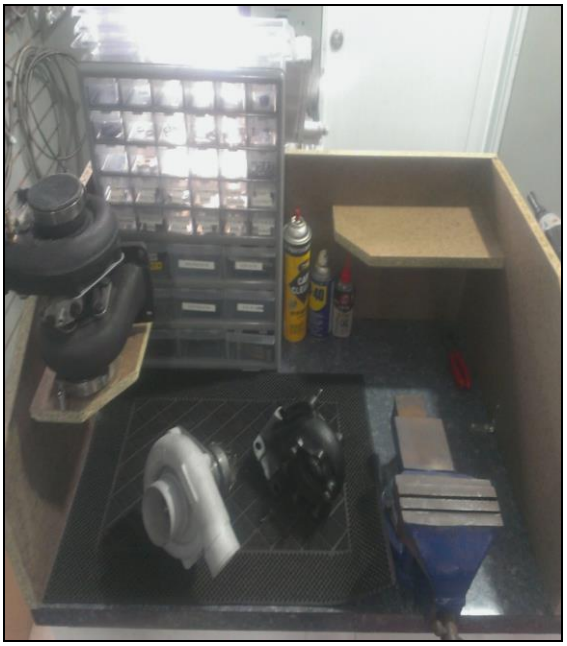

Figure 16
New Assembly Area

Results and Savings after Lean implementation

The total production goal for each time period (2 weeks) was set to 33 turbochargers. During the first two weeks, the team measured and monitored the production without any changes or recommendations implemented. From the first sample, before Lean tools and new assembly area implementation, 10 turbochargers were identified with spinning problems, candidates of rework. The cost of each rework per turbocharger is $76.55, which includes parts and labor costs. Total rework costs before Lean implementation was $765.5. Goal was set to reduce the reworks by 45%, which means $344.5 of rework savings (see Table 5).

Table 4
Rework Costs (Before Lean implementation)

Turbo Production Sample (Before Lean Implementation)	
Time Period	2 Weeks
Rebuided Turbochargers	33
Rework Quantity	10
Rework time (hrs)	28
Parts Cost (dollars)	$24.75
Labor Cost per Hour (dollars)	$18.50
Total Reworks Cost (dollars)	$766
Savings Goal (reducing rework by 45%)	$344.48

Having the results from the first two weeks of production, the team move up to implement the Lean tools and create the new assembly area, as specified on Chapter 3, for next 5 days. Employees were trainined, familiarized and align with Lean requirements and tools implemented in the Shop. At the end of the week, the shop and employees were ready for the next 2 production weeks using and applying Lean principles. During the next two production weeks employees engaged very well with Lean processes and requirements. When the sample was completed, only 3 reworks were identified. Having the parts and labor cost rates the same, the total rework cost was $278, reflecting a 63% of rework savings. Tables 6 showed the actual results and savings. Also, a comparison of rework quantity and costs before and after Lean implementation are shown Figure 17 and Figure 18.

Table 5
Rework Costs and Savings (After Lean implementation)

Turbo Production Sample (After Lean Implementation)	
Time Period	2 Weeks
Rebuided Turbochargers	33
Rework Quantity	3
Rework time (hrs)	11
Parts Cost (dollars)	$24.75
Labor Cost per Hour (dollars)	$18.50
Total Reworks Cost (dollars)	$278
Actual Rework Reduction	63.7%
Actual Savings	$488

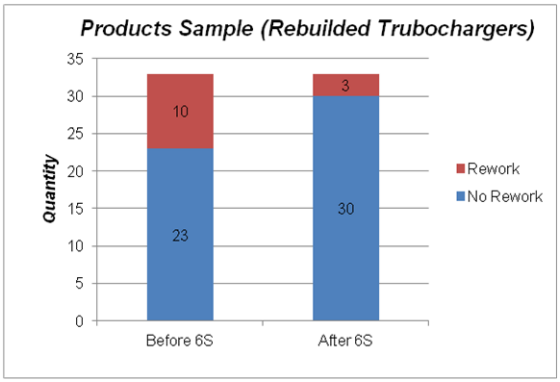

Figure 17
Bar Chart – Reworks Quantity Before and After 6S Implementation

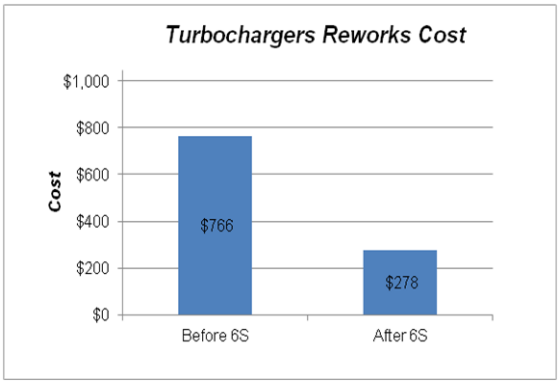

Figure 18
Bar Chart - Reworks Cost Before and After 6S Implementation

CONCLUSION AND RECOMMENDATIONS

The difference between Lean thinking at the strategic level and lean production at the operational level plays a crucial role in understanding what are the right tools and strategies for achieving the business goals. Improvements after Lean tools implementation in the Turbocharger Service shop were positively observed and reflected as employee satisfaction, cost reduction, rework elimination, process improvement and an increase in product quality.

A Goal was establish at the beginning of the research to reduce Turbocharger rework by 45%. Having said that, a study was performed to determine the mayor's offenders causing the reworks and implement corrective actions, solutions and improvements with a preference for low cost and no cost. It was determine and confirmed that combination moisture, derbies and other types of contamination step-in during the turbocharger assembly process as a result of additional process performed in the same area. A recommendation was given to management to create designated area only for Turbocharger assembly purposes resulting in a cleaner environment to prevent contamination to step-in and leading to reworks reduction. Assembly area was strategically located at the front receiver counter, close to the toolbox and most often used tools during the assembly step. It was also equipped with a Storage area with Turbochargers parts for easy access.

After the Lean implementation on the Shop, rework was reduced by 63%, per Table 6. Rework savings were $488 when compared to the performance before Lean implementation in a time frame of two weeks. Management and employees were very pleased with the improvements and transformation implemented into the shop. As part of continues process improvement, a recommendation to take in consideration DMAIC as the next tool to be implemented was given to management. It could be a big improvement to analyze each process step in detail to eliminate additional defects that may cause additional reworks in the future.

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