Cycle Time Reduction in the Plastic Fuel Tanks Production Line: A Lean Manufacturing Case Study at Kautex Corporation

Faranak Sadeghitabar, Sardar Asif Khan, Hasti Eiliat

Department of Mechanical, Automotive and Material Engineering
University of Windsor
401 Sunset Ave, Windsor, ON
sadeghif@uwindsor.ca, SardarAsif.Khan@uwindsor.ca, Hasti.eiliat@kautex.textron.com

Abstract

In today's competitive market, companies strive to utilize opportunities to survive long-term and remain competitive. Lean Manufacturing is a broadly perceived tool among industries. Organizations and companies are struggling with the new customer driven and competitive market. In order to overcome this challenge, they have turned into Lean Manufacturing utilization. The focus of this study is on reducing cycle time by applying lean manufacturing tools and techniques at Kautex Textron Corporation. The first step of the study was process mapping to have a clear understanding of the whole process of plastic fuel tank production and then, other required data were gathered and measured for the next steps. Pareto Charts, 4W 1H, Fishbone, and 5Why were utilized to identify the problems and to find out where exactly the waste is occurring in the line. After a root cause analysis, MODAPTS and 5S techniques were applied to reduce the waste which were mainly due to the excessive operator movements in conjunction with a disorganized workplace. Operator movements in all stations were observed and recorded and then unnecessary movements were identified as waste and therefore, eliminated. Utilizing root cause analysis tools, we found out that the waste is occurring due to a messy environment. Needless to say that 5S is the most proper tool to increase productivity by providing a safe and efficient workplace. To obtain better results, some further suggestions were recommended such as providing user friendly containers and conveyors for components and changing the layout for more convenience of transportation and waste elimination.

Keywords

Lean Manufacturing, Plastic Fuel Tank, 5S, MODAPTS

1. Introduction

In the past, the ultimate goal of traditional business in the manufacturing industry was to produce a high volume of products at low costs. Nowadays, however, manufacturing organizations are focusing on quality assurance and adding value to the final product by eliminating seven wastes known as "Muda" which are transportation, inventory, motion, waiting, overproduction, over-processing, and defect. They have realized that it is applicable by applying lean to their processes. James P. Womack and Daniel T.Jones explain in their book that how lean thinking is a powerful antidote to muda. They suggest that it is lean because it creates value and get closer to what customer wants while providing a way to do more with less; that is less human effort, equipment, time and space.

While customers demand in the past was a low cost product, today they are demanding services and products delivered on time with high quality. Many are elements that contribute to the success of manufacturing and cycle time is considered as one of the most crucial ones that can bring about efficiency improvement, productivity, and responsiveness and lean is a way with which companies can easily respond to high variety quality and cost with less cycle time (Seth et al. 2017). (Akçali et al. 2001) define cycle time as the set of time including queueing time for the equipment, waiting time due to breakdown maintenance, processing time, inspection time, and transportation time. It can be defined as the time of longest operation in an assembly line.

In this project, lean tools are employed with the aim of reducing cycle time at production line of the new series "x" at Kautex Corporation. Significant delays and downtimes occur in the plastic fuel tank production line jeopardizing policies of lead time and delivery time which affects the relationship between the company and their suppliers and customers for not delivering the products on time. In the current paper, lean manufacturing tools have been employed to identify and eliminate the waste.

2. Company profile

Kautex is one of the 100 largest automotive suppliers in the world and is a pioneer in the field of polymer processing which produces blow-molded fuel tanks (Kautex, 2019). Since 1949, when Kautex produced its first blow mold machine, to their latest plastic hybrid tank, Kautex has been known as "First to Market" trend in its innovation and products.

Plastic fuel tank is one of the main parts of vehicles which holds and transports the fuel to the engine.

Generally, fuel tanks are made of plastic or metal. According to the PlasticFuelTank website, there are numerous advantages in plastic fuel tanks over steel and aluminum tanks.

- They are lighter than most metals which not only make installation and transportation easier, but reduces the overall weight and emission.
- Plastic fuel tanks are more flexible. This allows for the expansion of vapors and bending during an accident.
- Slosh noise (the sound of fuel moving through the tank when the car starts or stops moving) is much less in plastic fuel tanks.

In addition to the advantages above, plastic fuel tanks are more cost effective, durable, and safe and they are primarily made of HDPE with EVOH Barrier layer.

The aim of the current project is to eliminate wastes by first, understanding the processes and then, aggregating data. After accumulating required data, we implemented lean tools to the whole process to first identify, and then eliminate existing wastes. In this project, our main focus is on removing reducing non-value added activities which consequently, leads to cycle time reduction in the process.

3. Literature review

After World War II in 1947, Japan faced huge economic issues. By that time, many companies were in danger of bankruptcy. Taiichi Ohno**,** known as the father of Toyota Production System, introduced a revolutionary system that later became the foundation of Lean Manufacturing. His theory includes a set of principles that helps reaching the goal of improving quality by waste elimination (Houchens & Kim, 2013).

Several studies and projects have been conducted regarding lean manufacturing tools implementation and a great number of them suggest that LM tools are still widely acceptable and adoptable as a way to add value for their customers among countries and industries (Holweg, M. 2006).

Grewal (2008) applied the lean tool *Value Stream Mapping and 5S* in an Indian camshaft manufacturing company. One of the results of the project was a dramatic decrease in lead time, cycle time, and changeover time. In addition, the achievements of lean tools implementation indicate that the tools implementation can make significant improvements even in small businesses.

Reducing process cycle time plays a key role in the overall production lead time because not only does it reduce the manufacturing cost, but it increases productivity and flexibility as well (Ismail, Ghani, Rahman, Deros, and Che Haron, 2013).

Although organizations are using TQM, there are still potential areas of improvement in every production system. Organizations must implement LM tools continuously to eliminate waste and non-value-added activities and more importantly, sustain their improvement (Ghalib, 2012).

Adedeji Adeyemi Charles (2012) emphasizes the importance of employees' participation in suggesting constructive organizational ideas for continuous improvement (Kaizen) in the South African automotive components industry. The findings of this paper show that Kaizen is a vital tool for delivering organizational growth and more effective decision making.

4. Methodology

Lean manufacturing techniques have been used in this project as a way to achieve the objective of the work. The methodology used for this project consists of two main phases, capturing the current state and then demonstrating the future state through analyzing data, observation, and implementation of lean tools.
Initially, the whole manufacturing process was observed and understood and then, the wastes and where exactly they are accruing were identified. In the third step, by using root-cause analysis methods, the causes of these problems and wastes were determined and then suitable lean tools were applied to the production line.

4.1. Current state

First, a detailed observation was carried out for initial understanding of the production processes and current performance of the company. Then, suitable lean tools were employed for capturing the current condition.

4.1.1. Flow Chart

Flow chart is a graphical representation of a sequence of movements and activities which is used to identify defects in a process. Figure1. is the flow chart of the intended line and shows production processes in order.

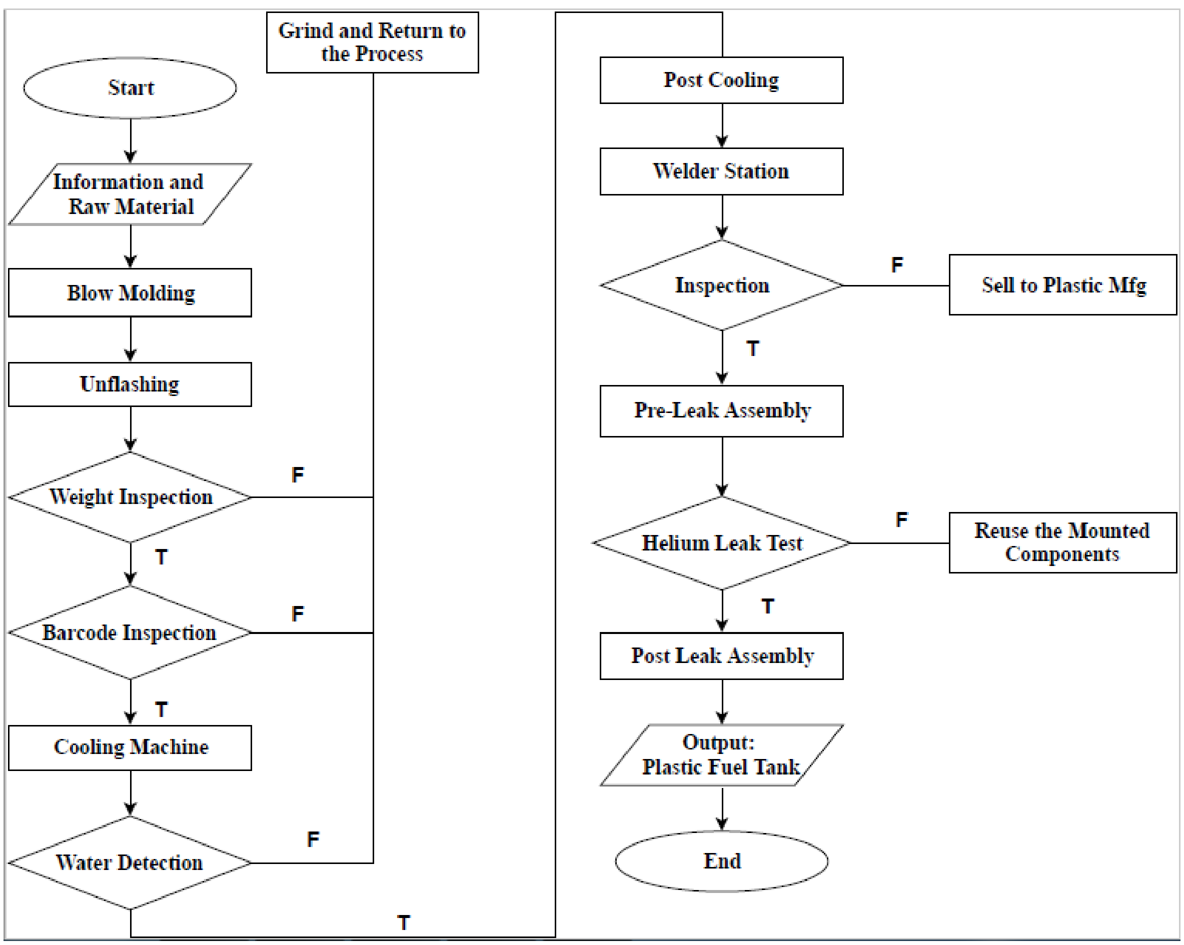

Figure 1. Production Line Flowchart

4.1.2. Kaizen
Kaizen reviews the current state and develops a plan for improvements to achieve regular, incremental improvements to the manufacturing process using 5W1H, 5Why, fishbone diagram, Pareto chart, and cost-benefit analysis. The problems and their causes are identified by the above mentioned tools and then shown in Kaizen.

- **5W 1H**

5W 1H is a method of asking questions regarding a problem in the process, used in lean manufacturing and SixSigma with the aim of improvement.

Table 1. 5W 1H

Problem Statement: There are downtimes and idle times during the process which lead to increase in cycle time.	
What	What machine the problem is on? - *Blow mold machine*
When	When waiting time is occurring? - *Every time the tank is tested for Helium leak*
Where	Where is the waiting time occurring? - *Helium Leak Test Station*
Who	Where is the waiting time occurring? - *Blow Mold Programmer*
Which	Which pattern does the problem have? - *Every Time the machine turns off*
How	How is it being done? - *Waiting for the programmer to fix the machine*

5Why
Similar to the previous method, 5Why is a simple method in the *Analyze* phase of DEMAIC process that asks "Why/How" enough times until the root cause and symptoms for the problem is found. This method was utilized when downtime was observed during the process.

Table 2. 5Why

Why 1	**Why isn't the line running?** - *The Blow mold machine is not working*
Why 2	**Why is the blow mold machine down?** - *A piece of molded plastic is stuck in the axis*
Why 3	**Why the plastic is stuck?** - *Machine was off and plastic cooled down in the machine*
Why 4	**Why the machine was turned off?** - *The operator did not know he should not turn it off*

Fishbone Diagram
There are different tools for root cause analysis. Fishbone is an easy, yet useful tool for root cause analysis which specifically explains if the problem is because of the machine, man, environment, or method. Figure2. Demonstrates how these factors can cause issues.

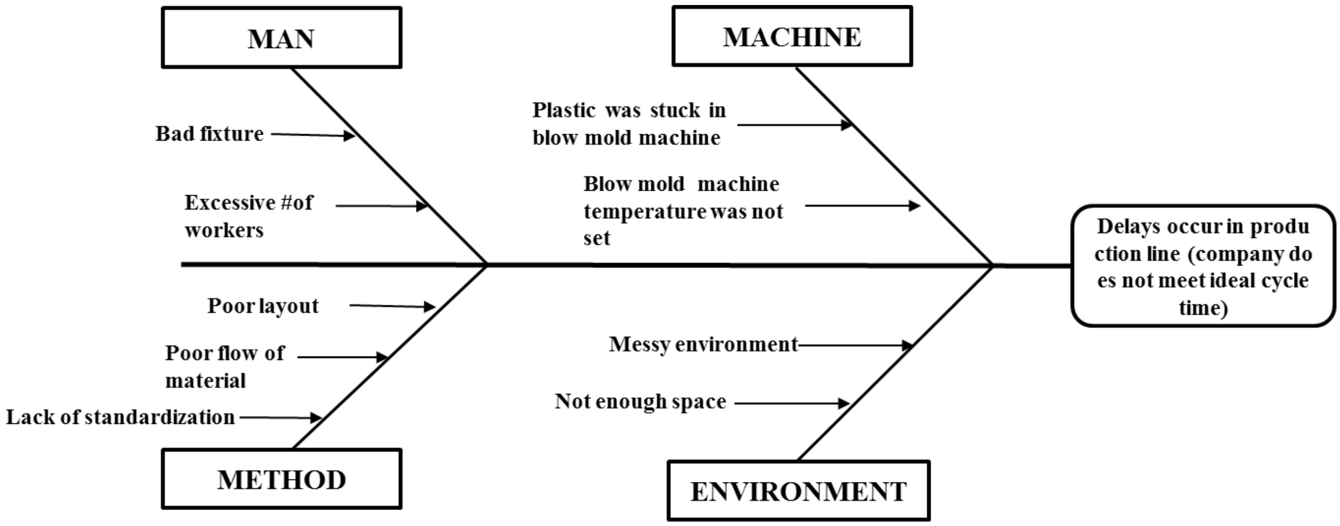

Figure 3. Fishbone Diagram

Pareto Chart

Pareto principle, also known as 80-20 rule, suggests that 80 % of impacts are resulted only from 20% of the causes, usually called "Vital Few". Pareto chart is a tool to identify and then eliminate vital few to improve quality.

In this project, Pareto chart is used for welder, pre-leak test, leak test, and post leak station to identify where the problem is occurring. In order to find the problems, cycle time for each process and the problems were recorded every time they occurred. It can be concluded that operator was the main cause of the problem in torque station. In addition, waiting for Helium and not having rubber damper at the station are the two critical reasons of the process downtime. Other problems can easily be found in the following tables and charts. By fixing these critical issues, the process can improve dramatically.

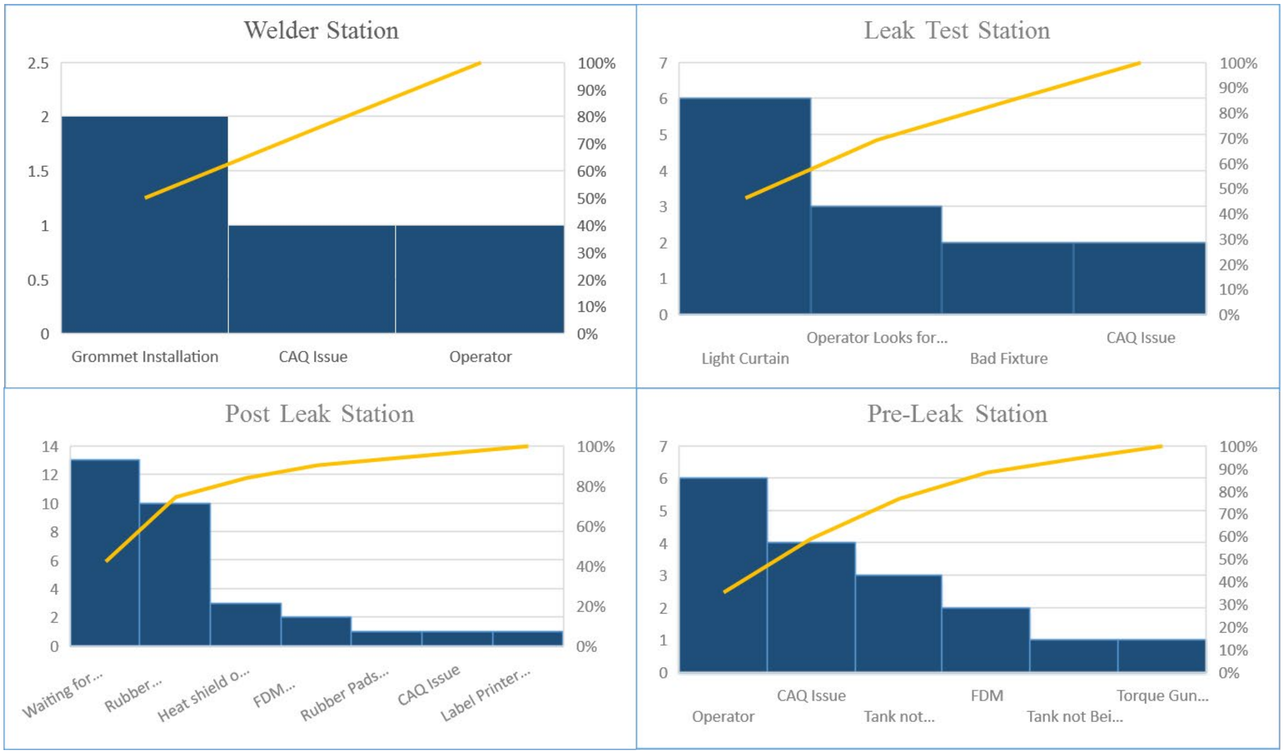

Figure 4. Pareto Chart

4.1.3. MODAPTS

Modular Arrangement of Predetermined Time Standards (MODAPTS) is a third-generation timing system calculated by human movements authored by Chris Heyde in 1966. It is an easier to understand and less complex tool compared to other time-motion studies (MODAPTS Association). Xu et al. 2013 conducted a project on operating conditions of bicycle inner tube of a pipeline using MODAPTS to analyze the process procedures. The results of this project shows how MODAPTS helped decreasing production time, eliminating bottleneck process, and improved operating balance.

In this project we considered some of the stations in which we found gap for movement improvement. Thus we clearly illustrate the current and future state of the MODAPTS by eliminating the non-value-added activities. The tables below illustrate the Pre-Leak, Leak test, Post-Leak and Pack Out operator movement in the current state.

Table 3. Pre-Leak Station Current MODAPTS

	Pre-Leak Station				
	Task Description	**Code**	**Freq**	**MOD**	**Activity**
1	Get and place two washers	M3G3 M4P2	2	24	VA
2	Bend over, carry a component	B17 M4G1	2	44	NA
3	Get a fuel feed line, place it on the tank	M4G3 M4P5	2	32	VA
4	Take a tool, inject air with another tool into the tank	M5G1 M4P5	2	30	VA
5	Fixed the component into the tank	M4G1 M3P2	2	20	VA
6	Place a support lock ring on the other side of the tank	M3G1 M3P2	2	18	VA
7	Get the cushion, open up the stick	M4G3 M2G3	1	12	VA
8	Place the cushion on the tank	M3P2	1	5	VA
	Total MOD			**185**	
	Total time			**23.87**	

Table 4. Leak Test Station Current MODAPTS

	Leak Test Station				
	Task Description	**Code**	**Freq**	**MOD**	**Activity**
1	Get a cushion, place the cushion on the tank	M3G1 M4P5	2	26	VA
2	Carry the vent line with right hand, place it on tank	M3G1 M2P5	1	11	VA
3	Simultaneously get another component with left hand	M3G1	1	4	VA
4	Remove the pump's cover	M4G1 M5P0	1	10	NNA
5	Walk two steps	W5	2	10	NA
6	Attach the Helium injection tool to the tank	M4G1 M3P5	1	13	NNA
7	Press the button	M3G0	1	4	NNA
8	Remove the Helium injection toll from the tank	M3G1 M3P0	1	7	NNA
9	Carry the tank	M4G1	1	5	NA
10	Walk 4 steps	W5	4	20	NA
11	Carry the tank to the next station	M3P2	1	5	NNA
	Total MOD			**115**	
	Total time			**14.84**	

Table 5. Post Leak Station Current MODAPTS

	Post Leak Station				
	Task Description	**Code**	**Freq**	**MODs**	**Activity**
1	Place the tank on the machine	M3G1 M2P2	1	8	VA
2	Press the button	M3G0	1	3	NNA
3	Walk two steps	W5	3	15	NA
4	Turn over	W5	1	5	NA
5	Get the metal shield	M3G1	1	4	NNA
6	Carry the metal shield	L1	1	1	NNA
7	Walk two steps	W5	2	10	NA
8	Place the metal shield	M3P2	1	5	VA
9	Attach four components on the tank	M3P5 M4P5	2	34	VA
10	Walk one step	W5	1	5	NA
11	Press the button	M3G0	1	3	NNA
12	Move the previous tank forward	M3G1 M3P2	1	9	NNA
13	Walk 4 steps to the other side	W5	4	20	NA
14	Pull the tank	M3G1 M3P5	1	12	NA
15	Attach two labels on the tank	M4G3 M3P2	2	24	NNA
	Total MOD			**158**	
	Total time			**20.38**	

Table 6. Pack out Station Current MODAPTS

	Pack out Station				
	Task Description	**Code**	**Freq**	**MOD**	**Activity**
1	Receive the tank, move the tank for checking	M5G1 M3P2	1	6	NNA
2	Walk two steps	W5	2	10	NA
3	Check with marking the tank	H4	16	64	VA
4	Fix the component on the tank	M3X4	1	7	VA
5	Inspect	E2	1	2	NNA
6	Get the tank and put it in the exact load box	M3G1 M4P2	1	10	VA
	Total MOD			**99**	
	Total time			**12.77**	

4.1.4. 5S

Bhamu and Sangwan (2014), suggest that one of the most widely used methods of Toyota Production System is 5S which aims at increasing productivity by providing a safe and efficient workplace. 5S is a simple, yet powerful method for identifying and eliminating waste which consists of five phases: Sort, Set, Shine, Standardize, and Sustain. In the production line, the components are placed outside the line, and are carried to the line by a conveyor. The conveyor, then places the components in front of pre-leak station, behind the operator. The layout of the line is U shape, there is not much space for the conveyor to move easily. Also, when the stored components outside the line should be loaded on the conveyor, it consumes a great amount of time for the operator to find the proper component that should be carried to the line. Root cause analysis tools determined that waste is messy environment. Needless to say that 5S is the most proper tool for solving this issue.

4.2. Future state

Implementing the tools mentioned before, helped improve the process at Kautex Corporation. In this project, two main tools were used for improvement: MODAPTS and 5S. The tables below demonstrate the future state of the line and clarify how practical this tool is. By eliminating non-value-added movements, the final result of total cycle time reduced remarkably.

4.2.1. MODAPTS

Extra movements were observed in stations with operator. Mainly, these movements were due to improper location of boxes of components. Eliminating them, reduced the total cycle time almost 18 seconds. At the last station the operator inspects all parts of the tank and then positions it in a pack out modular. Since, inspection is a necessary-non-value-added process, no remarkable waste was observed to eliminate. Still, it would be an improvement to eliminate even a single extra movement.

Table 7. Pre-Leak Station Future MODAPTS

	Pre-Leak Station				
	Task Description	**Code**	**Freq**	**MOD**	**Activity**
1	Get and place two washers	M3G3 M4P2	2	24	VA
3	Get a fuel feed line, place it on the tank	M4G3 M4P5	2	32	VA
4	Take a tool, inject air with another tool into the tank	M5G1 M4P5	2	30	VA
5	Fixed the component into the tank	M4G1 M3P2	2	20	VA
6	Place a support lock ring on the other side of the tank	M3G1 M3P2	2	18	VA
7	Get the cushion, open up the stick	M4G3 M2G3	1	12	VA
8	Place the cushion on the tank	M3P2	1	5	VA
	Total MOD			**141**	
	Total time			**18.19**	

Table 8. Leak Test Station Future MODAPTS

	Leak Test Station				
	Task Description	**Code**	**Freq**	**MOD**	**Activity**
1	Get a cushion, place the cushion on the tank	M3G1 M4P5	2	26	VA
2	Carry the vent line with right hand, place it on tank	M3G1 M2P5	1	11	VA
3	Simultaneously get another component with left hand	M3G1	1	4	VA
4	Remove the pump's cover	M4G1 M5P0	1	10	NNA
6	Attach the Helium injection tool to the tank	M4G1 M3P5	1	13	NNA
7	Press the button	M3G0	1	4	NNA
8	Remove the Helium injection toll from the tank	M3G1 M3P0	1	7	NNA
9	Carry the tank	M4G1	1	5	NA
11	Carry the tank to the next station	M3P2	1	5	NNA
	Total MOD			**85**	
	Total time			**10.97**	

Table 9. Post Leak Station Future MODAPTS

	Post Leak Station				
	Task Description	**Code**	**Freq**	**MOD**	**Activity**
1	Place the tank on the machine	M3G1 M2P2	1	8	VA
2	Press the button	M3G0	1	3	NNA
5	Get the metal shield	M3G1	1	4	NNA
6	Carry the metal shield	L1	1	1	NNA
8	Place the metal shield	M3P2	1	5	VA
9	Attach four components on the tank	M3P5 M4P5	2	34	VA
11	Press the button	M3G0	1	3	NNA
12	Move the previous tank forward	M3G1 M3P2	1	9	NNA
14	Pull the tank	M3G1 M3P5	1	12	NA
15	Attach two labels on the tank	M4G3 M3P2	2	24	NNA
	Total MOD			**103**	
	Total time			**13.29**	

Table 10. Pack out Station Future MODAPTS

	Pack out Station				
	Task Description	**Code**	**Freq**	**MOD**	**Activity**
1	Receive the tank, move the tank for checking	M5G1 M3P2	1	6	NNA
2	Check with marking the tank	H4	16	64	VA
3	Fix the component on the tank	M3X4	1	7	VA
4	Inspect	E2	1	2	NNA
5	Get the tank and put it in the exact load box	M3G1 M4P2	1	10	VA
	Total MOD			**89**	
	Total time			**11.48**	

4.2.2. 5S

In the future state our group applied some 5S techniques to organize and make the assembly process more convenient for the operators, specially, in the pre-leak station. For improving the work space, we used three different colors of tape to keep, move and remove each equipment to a right place. Additionally, by using Vent hanger we ended up providing more organize place for components which leads to spending less time for operators to do assembly.

Conclusion and suggestions

The primary target of this project in Kautex Corporation was to improve the cycle time using LM tools. MODAPTS and 5S techniques were the main tools used to reduce the waste which were mainly the operator movements in conjunction with disorganized workplace. All these steps have been taken in order to meet the customer demand on time. Another purpose of LM tools are to identify the problems and to find out where exactly the waste is occurring. Pareto chart, and Kaizen, etc. were utilized with the aim of root-cause analysis.

Suggestions:
Observing the whole process of production line at Kautex, we came up with a handful of suggestions.

- Implementing 5S periodically and Kaizen continually,
- Using pull production system along with Kanban,
- Providing user friendly containers and conveyors for components,

- Modifying the layout for more convenience of transportation

Acknowledgment

This project consumed a huge amount of effort and dedication; however, it would not have been possible without the support of many individuals. I would like to express my gratitude towards Mr. Sardar Asif Khan for his encouragement and providing me with the opportunity to embark on this project. I also wish to sincerely thank Dr. Hasti Eiliat, Sean Sharivari, and Keyhan Borooshan for their kind help in every stage of this project.

Reference

Womack, J. P., & Jones, D. T. (2010). *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*. Riverside: Free Press.

Seth, D., Seth, N., & Dhariwal, P. (2017). Application of value stream mapping (VSM) for lean and cycle time reduction in complex production environments: a case study. *Production Planning & Control*, *28*(5), 398–419. doi: 10.1080/09537287.2017.1300352

Akçali E., Nemoto, K. and Uzsoy, R. (2001) Cycle-Time Improvements for Photolithography Process in Semiconductor Manufacturing. IEEE Transactions on Semiconductor Manufacturing, Vol. 14, No. 1, February 2001.

Who we are. (2019, October 1). Retrieved from https://www.kautex.de/en/about-us/who-we-are.

Plastic Fuel Tank Manufacturers, Suppliers and Industry Information. (n.d.). Retrieved from https://www.plastic-tanks.biz/plastic-fuel-tanks/.

Houchens, N., & Kim, C. S. (2013). The Application of Lean in the Healthcare Sector: Theory and Practical Examples. *Lean Thinking for Healthcare*, 43–53. doi: 10.1007/978-1-4614-8036-5_4

Holweg, M. (2006). The genealogy of lean production. *Journal of Operations Management*, *25*(2), 420–437. doi: 10.1016/j.jom.2006.04.001

C. Grewal, An initiative to implement lean manufacturing using value stream mapping in a small company, Int. J. Manuf. Technol. Manage. 15 (2008) 404–417.

Irfan Ghalib, Mujtaba Agha, Shafqat Hameed, Choudhary Muhammad. "A Survey Of Lean Implementation Gap Analysis In Public Sector Organizations.", 2012

Adedeji Adeyemi Charles and Okolie Kevin Chucks, 2012, Adopting the kaizen suggestion system in south african lean automotive component companies, Science Journal of Business Management,Vol:2012,pp:1-10.

Association, I. M. O. D. A. P. T. S. (n.d.). Welcome to International MODAPTS Association. Retrieved from https://modapts.org/.

Xu, R.-Y., Sun, Z.-L., Gao, H.-W., Wang, R., Liu, X.-J., & Wang, L.-H. (2013). The Discussion on the Application of Modapts About Improving the Pipeline of Plastic Enterprise. *Proceedings of 20th International Conference on Industrial Engineering and Engineering Management*, 91–97. doi: 10.1007/978-3-642-40063-6_9

J. Bhamu and K. S. Sangwan, "Lean manufacturing: literature review and research issues," *International Journal of Operations & Production Management*, vol. 34, no. 7, pp. 876–940, 2014.