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Role & Importance of Lean Manufacturing in Manufacturing Industry

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ABSTRACT
As the competition in market is growing at a very fast pace, one can survive in today's industrial world by adopting the philosophy of Lean Manufacturing. In order to stay competitive, producing cheaper products at a faster rate Lean Manufacturing would help the industry. This paper highlights the Lean Manufacturing with its principles, tools & techniques so as to give an advantage by using these tools and techniques. With the help of these tools & techniques a better idea can be generated about the product flow in the organisation, value addition to the product through various processes and the time taken to produce the same. Lean Manufacturing helps to identify the different types of wastes and defects during manufacturing and take the remedial steps to eliminate them.

KEYWORDS*: Kaizen, Kanban, Total Productive Maintenance (TPM), Cellular Manufacturing, Just In Time (JIT).*

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I. INTRODUCTION

Manufacturing operations are continually striving to increase productivity and output of their operations. Their goal is to satisfy the customer with the exact product, quality, quantity, and price in the shortest amount of time. Lean manufacturing is more than a cost reduction program or a problem solving approach (Tapping, 2002). The main idea is that an efficient production can be achieved by a comprehensive approach to minimize wastes. This means eliminating excess production and inventory, redundant movement of material, waiting and delays, over processing, excess worker motion, and the need for rework and corrections.
Part of lean manufacturing is reviewing operations for those components, processes or products that add cost rather than value (Tapping, 2002). Each step of the manufacturing process is monitored to determine if it adds value to the product. If it does not add value, the process could be delegated to a subcontractor or outsourcing company in order to focus the staff on value-added operations of its core business. The goal of any company is to earn profit by selling quality products at a price higher than the cost of the effort and materials used. This can be achieved by converting raw material into something of greater value using various manufacturing processes.

These include the machining of different components of an assembly, and selling them to customers. Machining consists of removing material from the raw stock in order to create an end product that performs the desired function. This is the goal of Company X that is studied. The problem is when the processes produce a defective part; that part is taking up valuable resources such as tools, material and labor without providing any profit to the company. While it is unrealistic to expect a defect rate of zero, Company X is plagued with defective components in the order of 20% of all production. Many of the defective components are often avoidable, and they are overwhelmingly a result of human error. The survival of the company depends on whether or not this problem of making defective components can be overcome.The goal of this paper is to identify and eliminate the root causes of making defective components at Company X. This goal is accomplished by establishing a direct communication and collaboration with every level of Company X‟s infrastructure, from the machine operators to management. The first phase of the project is information gathering and observation using value stream mapping. This organized approach provides us the opportunity to see when and where defective components are made. Solution ideas are generated and iterated to evaluate the best suited ones for Company X. Training programs and clear implementation procedures for the best suited solutions are established. With the focus of the project on the elimination of waste, it coincides with the core principles of lean manufacturing.

Using lean manufacturing, the group is able to eliminate the making of defective parts across the manufacturing lines at Company X.To ensure that the solutions are acceptable to Company X at several levels of their manufacturing infrastructure, a cost-benefit analysis of the impact of making defective components and potential gains for eliminating defects is carried out.

Research Objectives

[1] Work within the production facility to have a firsthand knowledge of the production flow and to be familiar with the activities being performed in the shop floor.
[2] Select which value stream to target for the practical mapping.
[3] Observe and collect information related to product/process flow from raw material to finished goods for the value stream selected.
[4] Determine the current state of the process activities by mapping the material and the information flow.
[5] Calculate lean metrics from the value stream map.
[6] Look at the current state map for opportunities to eliminate wastes and improve the process flow.

Limitations of the Study

The limitations of the project were that
[1] The results of this study are limited to X manufacturing company.
[2] The company defined the lean tools to be targeted for improvements.
[3] The results will be based on data collected from the production activities performed inside the company only.
[4] The development of the future state map will not be included in this study.
[5] The study does not explain how to implement lean manufacturing.

II. DEFINITION OF TERMS

Available Production Time: Determined by taking the shift time and subtracting regular planned downtime events such as breaks.

Available Operating Time: Determined by taking the available production time and subtracting changeover time.

Batch Size: A technique used to run a determined quantity of parts at one operation prior to moving them to the next operations.

Changeover Time: The time that an operator spends at a work center switching the production tools in order to change from one product type to another.

Downtimes: Those are considered break times. Downtimes are regular planned times and usually involve unpaid lunch and paid breaks. During a downtime the production does not run.
Electronic Data Interchangeable: It is a tool that allows companies to process the purchasing order electronically.

Finished Goods: Refers to parts that already have been manufactured and are in the completed stage waiting to be shipped to the customer.

Kaizen: Continual improvement involving everyone within an organization (Ohno, 1998)
Kanban: A tool to achieve just-in-time which consists of a card containing all the information required to be done on a product at each stage along its path to completion and which parts are needed at subsequent processes (Monden, 1993)

Lead Time: The time that parts take to be transformed from raw material to finished goods.

Lean Metrics: A list of measurements that will help for tracking progress toward the targets selected for improvements.

Material Requirement Planning: It is a tool that helps manage the production process. Basically, it is a plan for the production of the components and purchase of materials needed to make an item.

Raw Material: Material that has been purchased but not changed in any way.
Value Stream: The set of processes, including value-added and non-value-added activities required to transform raw materials into finished goods that customers value (Womack & Jones, 1996).

Work-in-Process: Any product in the production process than began as raw material, but is not a finished good yet.

Product Family: Refers to all the parts that are produced within the same value stream. All the parts for the product family group have common production processes and same pattern development.
Operators: Involves those individuals that provide the work hand to perform an operation.
Operative Cost: It is all the money that the company spends in order to turn inventory into finished goods.

III. LEAN MANUFACTURING DEFINITION

Lean manufacturing is defined as "A philosophy, based on the Toyota Production System, and other Japanese management practices that strives to shorten the time line between the customer order and the shipment of the final product, by consistent elimination of waste". All types of companies, manufacturing, process, distribution, software development or financial services can benefit from adopting lean philosophy. As long as a company can identify a value stream, from when the customer orders product to when they receive it, lean principles can be applied and waste removed.(Singh, 1999).Also, lean manufacturing is: "Adding value by eliminating waste, being responsive to change, focusing on quality, and enhancing the effectiveness of work force". (Liker, 2004).Another definition for lean manufacturing: "it is a systematic approach to identify and eliminate waste (non-value added activities) through continuous improvement by following the product at the pull of the customer in pursuit of perfection". (Czarnecki and Loyd, 1998).
Also, lean manufacturing is: "A manufacturing philosophy that shortens the time between customer order and the product build/shipment by eliminating sources of waste". (liker and Lamb, 2000).

IV. TRADITIONAL VS. LEAN MANUFACTURING

For years manufacturers have created products in anticipation of having a market for them. Operations have traditionally been driven by sales forecasts and firms tended to stockpile inventories in case they were needed. A key difference in Lean Manufacturing is that it is based on the concept that production can and should be driven by real customer demand. Instead of producing what is hoped to be sold; Lean Manufacturing can produce what your customer wants with shorter lead times. Instead of pushing product to market, it is pulled there through a system that is set up to quickly respond to customer demand. (Ibrahim, 2011).Lean organizations are capable of producing high-quality products economically in lower volumes and bringing them to market faster than mass producers. A lean organization can make twice as much product with twice the quality and half the time and space, at half the cost, with a fraction of the normal work-in-process inventory.
Lean management is about operating the most efficient and effective organization possible, with least cost and zero waste. (Minggu, 2009).

Table 1 illustrates the differences between the traditional mass production and lean production in terms of organizational characteristics:

Table- 1: Organizational Characteristics of Traditional Mass Production and Lean Manufacturing

Organizational Characteristics	**Traditional Mass Production**	**Lean Production**
Business Strategy	Product-out strategy focused on exploiting economies of scale of stable product designs and non unique technologies	Customer focused strategy focused on identifying and exploiting shifting competitive advantage
Customer Satisfaction	Makes what engineers want in large quantities at statistically acceptable quality levels; dispose of unused inventory at scale prices	Makes what customers want with zero defect, when they want it and only in the quantities they order
Leadership	Leadership by executive command	Leadership by vision and broad participation

Organization	Hierarchical structures that encourage following orders and discourage the flow of vital information that highlights defects, operator, error, equipment, abnormalities, and organizational deficiencies	Flat structures that encourage initiative and encourage the flow of vital information and highlights defects, operator, error, equipment, abnormalities, and organizational deficiencies
External Relations	Based on price	Based on long-term relationships
Information Management	Information-weak management based on abstract report	Information-rich management based on visual control systems maintained by all employees
Cultural	Culture of loyalty and obedience, subculture of alienation, and labour strife	Harmonies culture of involvement based on long-term development of human resources
Production	Large-scale machines, functional layout, minimal skills, long production runs	Human-scale machines, cell-type layout, multi-skilling, one-piece flow, zero inventories

Table 2 illustrates the differences between the traditional mass production and lean production in terms of manufacturing methods:

Table -2 Methods of Manufacturing of Traditional Mass Production and Lean Manufacturing

Manufacturing Methods	**Traditional Mass Production**	**Lean Production**
Production schedules are based on	Forecast-product is pushed through the facility	Customer order-product is pulled through the facility
Products manufactured to	Replenish finished goods inventory	Fill customer orders (immediate shipments)
Production cycle times are	Weeks/month	Hours/days
Manufacturing lot size quantities are	Large, with large batches moving between operations; product is sent a hard of each operation	Small, and based on one-piece flow between operations
Plant and equipment layout is	By department function	By product flow, using cells or lines for product families
Quality is assured	Through lot sampling	100% at the production source
Workers are typically assigned	One person per machine	With one person handling several machines
Workers empowerment is	Low-little input into how operation is performed	High-has responsibility for identifying and implementing improvements
Inventory level are	High-large warehouse of finished goods, and central storeroom for in process staging	Low-small amounts between operations ship often
Inventory turns are	Low-6-9 turns per year or less	High 20+ turns per year
Flexibility in changing manufacturing schedules is	Low-difficult to handle and adjust to	High-easy to adjust to and implement
Manufacturing costs are	Rising and difficult to control	Stable/decreasing and under control

Main Kinds of Wastes: Seven main types of wastes were identified as a part of the Toyota Production System. However, this list has been modified and expanded by various practitioners of lean manufacturing and generally includes the following:

1. Overproduction: overproduction is unnecessarily producing more than demanded, or producing it too early before it is needed. This increases the risk of obsolescence, increases the risk of producing the wrong thing and increases the possibility of having to sell those items at a discount or discard them as scrap. However, there are some cases when extra supplies of semi-finished or finished products are intentionally maintained, even by lean manufacturers.

2. Defects: In addition to physical defects which directly add to the costs of goods sold, this may include errors in paperwork, provision of incorrect information about the product, late delivery, production to incorrect specifications, use of too much raw materials or generation of unnecessary scrap.

3. Inventory: Inventory waste means having unnecessarily high levels of raw materials, works-in-process and finished products. Extra inventory leads to higher inventory financing costs, higher storage costs and higher defect rates. Inventory tends to increase lead time, prevents rapid identification of problems and increase space requirements, thereby discouraging communication.

4. Transportation: Transportation includes any movement of materials that does not add any value to the product, such as moving materials between workstations. The idea is that transportation of materials between productions stages should aim for the ideal that the output of one process is immediately used as the input for the next process. Transportation between processing stages results in prolonging production cycle times, the inefficient use of labour and space and can also be a source of minor production stoppages.

5. Waiting: Waiting is idle time for workers or machines due to bottlenecks or inefficient production flow on the factory floor. Waiting also includes small delays between processing of units. Waiting results in a significant cost insofar as it increases labour costs and depreciation costs per unit of output.

6. Motion: Motion includes any unnecessary physical motions or walking by workers which divert them from actual processing work.

7. Over-processing: Over-processing is unintentionally doing more processing work than the customer requires in terms of product quality or features- such as polishing or applying finishing in some areas of product that will not be seen by the customer.

The seven wastes are shown in **Figure 1**:

Fig.1: Seven Wastes

Lean Manufacturing Tools and Techniques: Once the companies pinpoint the major sources of waste, tools such as provided will guide the companies through corrective action so as to eliminate wastes.

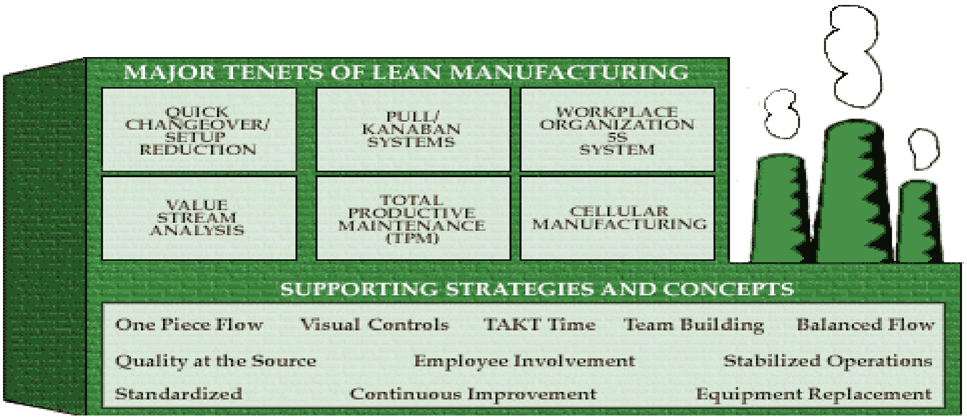

Fig.2: Lean Manufacturing Tools & Techniques

In the following sections, a brief description of the foundations of lean manufacturing tools:

V. CELLULAR MANUFACTURING

Manufacturing cells group machines, employees, materials, tooling, and material handling and storage equipment to produce families. The most important benefit of cellular manufacturing are achieved when manufacturing cells are designed, controlled and operated using just-in-time (JIT), Total Quality Management (TQM), and Total Employee Involvement (TEI) concepts and techniques. Successful implementation of manufacturing cells requires addressing selection, design, operation, and control issue. Selection refers to the identification of machine and part types for a particular cell. (Tompkins, et.al, 1996)**.** Cell design refers to layout, production, and material handling requirements. Operation of a cell involves determining lot sizes scheduling, number of operators, and type of operator's control (push vs. pull). Finally control of a cell refers to the methods used to measure the performance of the cell. (Tompkins, et.al, 1996)**.**

Cellular layouts are characterized by the following characteristics:

[1] Continuous flow: There is a smooth flow of materials and components through the cell with virtually no transporting or waiting time between production stages.

[2] One-piece flow: Cellular manufacturing utilizes a one piece flow so that one product moves through the manufacturing process one piece at a time.

[3] Multi-purpose workers: There are only one or several workers in each cell and unlike batch processing where workers are responsible for a single process, in cell manufacturing the cell workers are responsible for handling each of the different processes that occur in the cell. Therefore, each worker is trained to handle each process which occurs within the cell.

[4] U-shape: Cells are usually U-shaped, with the product moving from one end of the U to the other end of the U as it is processed by worker(s). The purpose of this is to minimize the walking distance and movement of material within a cell.

VI. STANDARDIZATION OF WORK

Standard work means that production processes and guidelines are very clearly defined and communicated, in a high level of detail, so as to eliminate variation and incorrect assumptions in the way that work is performed.

In lean manufacturing, standard work has several main elements :(Alavala, 2008).

[1] Standard work sequence: This is the order in which a worker must perform tasks, including motions and processes. This is clearly specified to ensure that all workers performed the tasks in the most similar ways possible so as to minimize variation and therefore defects.

[2] Standard timing: Takt time (German for rhythm or beat) is the frequency with which a single piece is produced. Takt time is used to clearly specify and monitor the rate at which a process should be occurring at various production stages. For lean manufacturers, the Takt time of each production processes is actively managed and monitored, so that a continuous flow can occur. Takt time is calculated based on the following formula:

$$Takt\ Time = \frac{Customer\ demand\ per\ day}{Available\ work\ time\ per\ day}$$

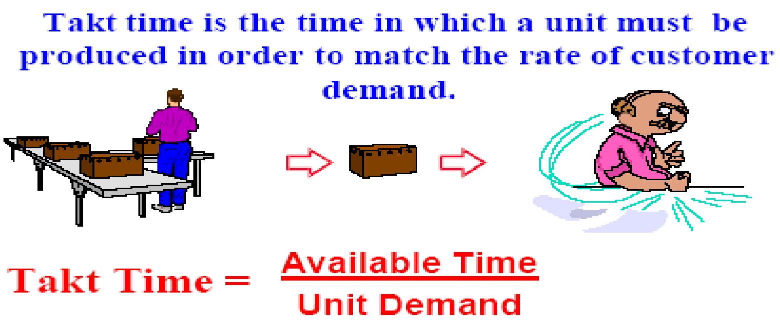

Fig. 3: Takt Time

3. Standard in-process inventory: this is minimum units of materials, consisting primary of units under going processing, which are required to keep a cell or process moving at the desired rate. This should be clearly determined since it is necessary to maintain this minimum amount of inprocess inventory in order not cause unnecessary downtime. This is used to calculate the volume and frequency of orders, or Kanban, to upstream suppliers.

Workplace Organization-The Five S's

One of the most effective tools of continuous improvement is 5S, which is the basis for an effective lean company. 5S is a first, modular step toward serious waste reduction.

5S consists of the Japanese words Seiri (Sort), Seiton (Straighten), Seiso (Shine and Sweep), Shitsuke (Standardize), and Seiketsu (Sustain).

Fig.4: The 5 S's

The 5Ss are some rules for work place organization which aim to organize each workers work area for maximum efficiency. 5 S's are: (Scott, 2011)

Total Productive Maintenance:

Machine breakdown is one of the most important issues that concern the people on the shop floor. The reliability of the equipment on the shop floor is very important since if one machine breaks down the entire production line could go down. An important tool that is necessary to account for sudden machine breakdown is total productive maintenance. There are three main components of a total productive maintenance program: preventive maintenance, corrective maintenance and maintenance prevention.

VII. METHODOLOGY

Problem Formulation and Solutions

The following part discusses the approaches by which the project group was able to identify the problems at Company X and develop correspond solutions. The first section explains the line of reasoning that went into discovering where exactly in manufacturing lines are defective components are created. From the very first observations of the manufacturing facility, the problems at hand began to take form. After extensive data collection and analysis, our initial hypothesis was proved. The hypothesis was that the creation of defective parts was not due to machine-tool failures or break downs, but it was because of Non Standard work, absence of Automation and Workers themselves.

Problem Formulation

One of the main reasons for the group's involvement was to take a fresh look at the problem of creating defective parts at Company X. The first exposure to the company was through a tour of the manufacturing facility with one of the production supervisors.I was able to see the whole manufacturing infrastructure, from the manufacturing floor to the storage and shipment areas. It was management's hope that a fresh perspective on these areas would help bring about positive changes. Even at such an early stage of the project, the problems became apparent. Problems ranging from clutter of raw materials on the floor to poor employee morale were obvious from the offset. With an initial hypothesis as a starting point, I began to collect data that would help to pinpoint the exact causes of making defective parts. As the data began to prove my initial hypotheses, possible solutions to problems began forming. The fact that a majority of the problems are associated with human errors means that my solutions and ideas would be dealing almost exclusively with human problems rather than machine problems. The feasibility of the solutions is investigated. Some solutions are discarded as unrealistic because they do not match the resource capacity of Company X. Those that match are developed further since the problem at hand is rooted in the culture at Company X, drastic measure is needed to be taken to deal with it. There is no magic solution that is both effective and easy to implement. The solutions that the group proposed required major changes in thinking across in the Manufacturing infrastructure of Company X. Only through such changes would it be possible for Company X to eliminate its problems of making defective parts and not meeting customer's needs.

Initial Observations

Raw materials and part bins were scattered across the facility with almost no apparent organization. There were oil and coolant spills all over the floor, surfaces did not seem to have been cleaned and papers at the machine work stations were filthy as well. That was not necessarily a major problem, as even some of the best machine shops in the world are just as dirty if not dirtier. Regardless, it was a problem that needed to be investigated. While there were safety goggles and gloves provided, few workers took advantage of them and others chose to take the risks involved without wearing goggles. All together, the working conditions were not optimal and did not provide a good working environment. It was clear that there were many more components not machined and raw stock on the floor than were needed. The main receiving area was incorporated into the manufacturing area itself. For storage areas, there were shelves against the walls on every side of the facility holding everything from raw material to finished products to old, broken fixtures.

Unfortunately, there was not enough space for everything on the wall and so there was a significant amount of loose objects scattered across the floor. This included a large cage that housed parts that could be classified as firearms, and needed to be secured for legal reasons. This cage was placed right at the entrance of the facility and really obstructed any kind of organized flow in the manufacturing processes.

Data Collection and Analysis

The data collection phase of this project centered on gathering and interpreting data that would either prove or disprove our assumptions. This data came from different departments including Quality Control, Management, and Engineering. The original plan for information gathering was to use Value Stream Mapping to go through the manufacturing processes of three items currently in production. Then through an analysis of the processes could possible sources for error be detected. The group was to work with the production supervisor to gather the necessary information. However, this supervisor was too busy every time the group was at Company X, and proved very unhelpful. As was mentioned in the initial observations, many of the employees were too busy to spare any time. The group then decided to focus on gathering data that the employees could provide expending little effort or time.The most obvious place to start looking for information on defective components was the Quality Control department. Their job was very similar, if not identical, to that of my project: to eliminate the creation of defective parts. The process that was used here involved collecting the parts that had been identified as defective, and trying to interpret what went wrong. These inspections occurred after every process and were performed by the operator themselves.These consisted of a simple “Go, No-Go” system that used dimensioned pegs to determine if the part’s features were in tolerance. There were also final inspections that took place right before the part was shipped out. A defect would cost the company much less if it is caught sooner rather than later. A member of the quality control department would then collect the rejected parts from every station and records where the problem took place, what the problem was, and the suspected cause. These causes ranged from human errors to machine problems, to problems with the raw material. Every defect from that day was then compiled into a report and saved. Any trends could be detected and acted upon quickly to prevent more defects from occurring. The only problem with this was that no one at Company X was taking action against any trends that presented themselves. The main reason that QC was unable to really stop the creation of defective parts was that they are too busy with their day to day responsibilities. These also included inspecting the raw materials shipped in and reworking parts, so there was little time to perform a company-wide analysis for the causes of part defects.

It was clear from talking to members of the Quality Control department that they believed the major source of error was due to human error. The group felt then that the Value Stream Mapping of the processes would not help since the problem had already been identified. Had Value Stream Mapping been used, much time would have been taken up, yet the same conclusion would have been drawn. Using all the Quality Control defective part reports from a one month period, the data was compiled and analyzed to determine why the defects were taking place. The following chart was created to clearly illustrate the main cause of the defective components.The overwhelming cause of part defects was due to error by either machinists or operators. A machinist is a worker who performs mainly the initial setup of the machine and fixture. The operator is then the person who loads the parts in and runs the NC program. Over 86% of the error was due to human error by machinists and operators.The other 14% of error includes a 6% error from tool problems, which were most likely a broken tool. A 6% portion was due to vendor and material problems, which were mistakes in the raw material and were for the most part unavoidable. The remaining 2% was due to machine and fixture error. This data made it clear that the major problem at Company X was human error.While it would certainly be possible to investigate the root causes of the machine errors and possibly eliminate those defects, the group felt it would be far more advantageous to focus on the human aspect. The next step was to see if the current workers had the necessary training and background to perform the machining tasks assigned to them.

Proposed Solutions for the problems:

Evaluation of Employee Background : Management provided all the operator and machinist job applications that they had on file, which included many of the employees currently working there. These applications were analyzed in order to investigate the educational background as well as prior job experience of the workforce. The job application itself was a pretty standard application. It included contact information, educational background, and prior work experience. All the applications were looked over and analyzed to see the specific background that each employee had and whether it seemed adequate for machining job. It was seen that less than 40% of the employees had any experience in Die casting process and fewer than 14% had more than ten years in the field. About 35% had experience in another manufacturing field that did not include casting. The most common fields included machining and welding. The other 28% had no job experience that was relevant to die casting. When coupled with the information from the previous graph, it is clear that many employees lacked the required background for casting. Also, many of those with good backgrounds in Die Casting were also those with higher education. What this means is that there are several well-trained employees who act as supervisors and setup machinists and many untrained employees who work as the operators. Of course this means that when new hires arrive at Company X, they most likely are not adequately trained for the job they are hired for. If the company had an effective training program in place, this may not have been a problem.

It turned out that the opposite was true. Company X had no formal training program in place for either new or current employees. When a new operator was hired, he was assigned to a more experienced operator, and shadowed him for about two weeks before going to work on his own. What this meant for the company was that few of the operators truly understood what the machine was actually doing and could not prevent mistakes from occurring as effectively as they should. There was no guarantee that the impromptu instructor knew exactly what was going on either. Current employees did not receive any formal training either. Much of what they learned was procedural and done through trial and error rather than an organized learning process. This made it very difficult for an operator to advance in skill or in job responsibility.This leads right into the next problem: that of low employee morale. One of the best indicators of morale is employee retention. Obviously happy employees would not want to leave their job for a new one. The retention at Company X was not good, with many employees leaving the minute a better paying job opened up for them. The employee turnover rate last year was over 37%. There are several factors that influence morale including opportunity for advancement, pay raises, and working conditions. Due to the lack of formal training, there really was little opportunity for many of the workers to advance up in the company. Many employees made little more than minimum wage and could not look forward to making much more than that in the future if they stayed with the company. With the high rate of defective parts, there was just not enough money in the budget for these raises or for training, for that matter. Ironically, a major argument against training at Company X was the futility of training employees who will just leave soon anyway. Working conditions were also very poor, due to disorganization and aforementioned safety issues. Poor employee morale had a large impact on the problems already present at Company X. There was a culture built around the principle that creating defective parts was acceptable and even considered unavoidable. Employees that considered their jobs to be temporary rather than careers had no stake in the health of the company. They got paid the same whether or not the parts they made were good or defective.

Organizing the Raw Stock

With this in mind the group evaluated the manufacturing floor with respect to the level of organization. Starting with the beginning of the manufacturing process, we looked at how the raw stock was arranged. Shipments of materials are brought into the manufacturing floor on the left side of the building. Once shipments are received the left side of the facility is dedicated to holding these materials. This creates unnecessary clutter and decreases the area that could be otherwise used to house more machines. The availability of more machines would allow for the production of components to increase drastically.The shipment dock itself was also very problematic. The shipment dock was a large open door in the side of the manufacturing floor wall. During the winter months the door would be open for shipments for hours at a time. This did not allow for the manufacturing floor temperature to be held at a comfortable level for employees during the cold season. In addition, in the warmer months of the year, this door remained open with only a gate being a barrier between the floor and the outside of the facility. The reason the door was continuously open was to create ventilation from the machines. However, this caused a serious security risk. The areas between the links were very large. Machined components could have been easily passed through these holes without being detected.Company X had already started plans to implement a raw stock storage facility. The plans for the facility were in the early stages when our group arrived at the company. The storage facility would be located towards the back of the building and would include a new shipment dock, allowing for any of the previously mentioned drawbacks to be avoided. Additionally, the shipment dock will be removed from the machining area which will make it much more difficult for those intended on removing machined components to do so inconspicuously.

Work Station and Part Organization

The next step of evaluating the floor organization was examining the individual work stations at each machine. Upon initial evaluation of the floor, each work station was cluttered with multiple implements used to inspect recently machined components, rags, and various working drawings. The disorderly manner of the stations will only negatively affect the production of effective components. After each machining process operators were to inspect the components features using particular instruments for each feature. If there were too many instruments on the work station, it is possible that the wrong device was used. Our project group was shown into Company X's assembly area to observe the work stations of employees involved with assembling the completed components. These work stations were neatly organized with specific containers designed and labeled for assembly parts. The structure of these work stations was created by a past WPI student doing their Major Qualifying Project. This level of organization is needed out on the manufacturing floor.After machined, the components that pass inspection would be placed in large plastic boxes and were put on the floor under the workbench, in the aisle, or in between machines. This not only caused a safety hazard by having clutter in passageways, but also created a hazard by not efficiently tracking machined components. With the Massachusetts gun laws becoming stricter, it was imperative for the components that could possibly become functioning firearms to be closely monitored. It was required by the state for the facility to have a caged storage area to house components that could be assembled into a firearm. However, some components that are not required to be locked in the cage needed only a few more features machined to create an operational firearm. Company X had attempted to take precautions to having components carried out of the facility. There was a metal detector located near the exit that employees must pass through at the end of a shift. Although this was sometimes helpful, there was still a possibility of near complete components leaving the facility.

Creation of a Storage Container

Having a centralized component storage container would help with security factors and in decreasing clutter created by current component containers. This area would be dedicated solely to the organization and storage of components. At the start of every shift, workers could pull what they need out of this area. The area would be mostly an open facility however would contain an area for the parts only requiring the last few operations to be secured. Accessing the secure section of this facility would require only the employees permitted to use a key code to be granted entrance. That way only these components that were being machined are out on the floor, diminishing the amount of containers taking up space near machines. This component storage container could be designed to fit within the facility of Company X. There was a wide area being used to store unused fixtures. These fixtures did not rotate into any of the machines because they have been replaced by either new or updated ones. It would be necessary to remove and reorganize the fixtures currently in the allotted area. The fixtures that could still be used or manipulated to create profitable components would remain on the floor and be updated while the others will be discarded. With the construction of the storage facility for the raw stock materials there would be a region available to move these fixtures to. The component storage facility would be able to be built with the relocation of the unused fixtures.

Employee Training

Through inspection of defective component causes at Company X in the problem identification phase of the project, the lack of training became apparent. The background of many employees proved upon inspection to be insufficient as well. Very few employees showed evidence of adequate training for the job at hand. In combination with the hiring screen previous described, training of new employees and retraining of current employees would benefit Company X. The hiring screen would provide workers with some background, but also workers that are more likely to stay at the company, thus making training worth the money.

Incoming Training

With the new hiring system in place, the knowledge of all new employees would be known well enough so that training could be implemented to fill in any gaps in their existing knowledge. Training specific to the processes and machines would be supplied so that the workers begin their careers with the necessary know how. Depending on the new operator's background and initial proficiency, they would be assigned to a certain level of difficulty, starting at drilling and working up to more complicated processes, as mentioned before.

That way, Company X would be able to hire experienced operators from all over, and be able to teach them the communication skills needed to work successfully on the machining floor.

Retraining of Current Employees

It would be very beneficial for Company X to institute a constant learning program as well. The errors on the work floor, from incorrect setup of a work piece to not correctly following and accounting for tool wear, could be monitored more closely by the supervising staff than it is now. That way, a monthly or bi-weekly retraining program could be instituted to address these issues. The retraining program could be a working lunch, so the employees have incentive to come and get free lunch, or mandatory after shift meeting. Not only would these meeting serve as a place for management to talk to and train the employees, but for the operators to talk to their supervisors and managers as well. That way, problems and solutions could be worked out in a group format, similar to Quality Circles, with communication up and down the line of command. With this system in place, workers would have a better chance of moving to more complicated machines and processes, thus earning a higher wage. The supervisors would note, during their monitoring of the work floor, when a particular operator was doing very well, with minimal mistakes for an extended period of time. Then the operator could decide to move up or stay at his current position. This incentive would be a way to keep employee turnover rate down, and morale up. If employees felt that what they are doing is being noticed and matters, they would work harder and more carefully. To move up to a more complicated process and higher wage, an operator would have to undergo retraining on the new machines. This could be done during down time in a shift, or any other time. If an employee really wanted to move up, they would come in for extra hours to learn the new machines, and this dedication would be a good way for management to see which employees are serious about their jobs. That way, supervisors would be able to weed out the workers that just want a higher wage, and those that really care about the Company and their reputation, which is part of the issue currently at Company X. A higher overall morale would occur from the institution of a retraining and advancement program, as well as the reduction of mistakes on the floor that cost the company money.

Cause- Effect diagram (Ishikawa Diagram)

Ishikawa is a graphic tool used to explore and display opinion about sources of variation in a process. (Also called a Cause and Effect or Fishbone Diagram) Its purpose is to arrive at a few key sources that contribute most significantly to the problem being examined. These sources are then targeted for improvement. The diagram also illustrates the relationships among the wide variety of possible contributors to the effect. Most Ishikawa diagrams have a box at the right hand side in which is written the effect that is to be examined. The main body of the diagram is a horizontal line from which stems the general causes, represented as "bones". These are drawn towards the left hand side of the paper and are each labelled with the causes to be investigated, often brainstormed beforehand and based on the major causes listed above. Off each of the large bones there may be smaller bones highlighting more specific aspects of a certain cause, and sometimes there may be a third level of bones or more. These can be found using the '5 Whys' technique. When the most probable causes have been identified, they are written in the box along with the original effect. Further analysis of the diagram can be achieved with a Pareto chart.

Crush

The cause-effect diagram is as shown in fig.5 .Based on experience in foundry, following remedies are suggested:

Remedies:

- Change the hardness of mould.
- Proper clamping of mould boxes.
- Use of appropriate sand with adequate green compressive strength,
- Use proper pins.
- Properly clean the pattern and mould before moulding.

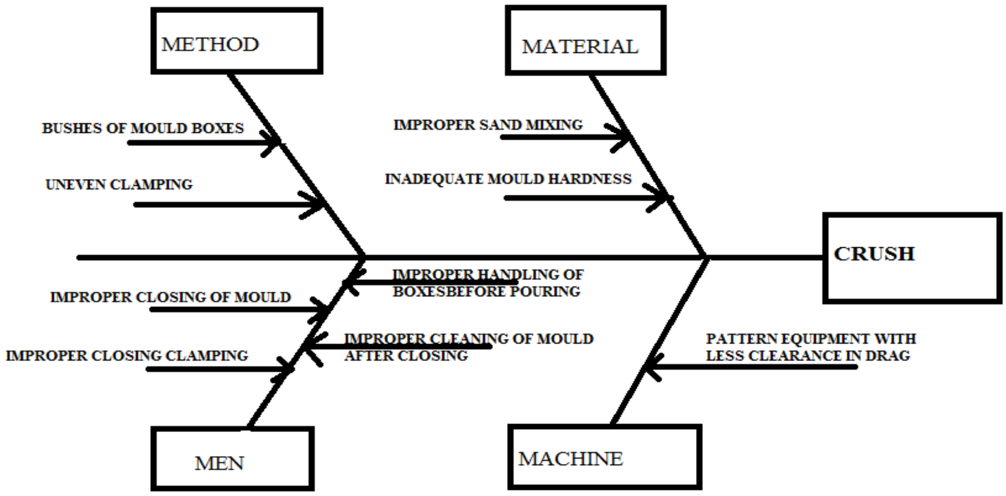

Fig 5:-THE CAUSE EFFECT DIAGRAM FOR CRUSH

Shrinkage

The cause-effect diagram for shrinkage is shown in fig.6. Suggested remedies are as follows:

Remedies:

- Use the suitable composition that is adjusted silicon and (1.80 to 2.10) or carbon equivalent (3.9 to 4.1) .Carry out proper ramming and maintain optimum pouring temperature and time.

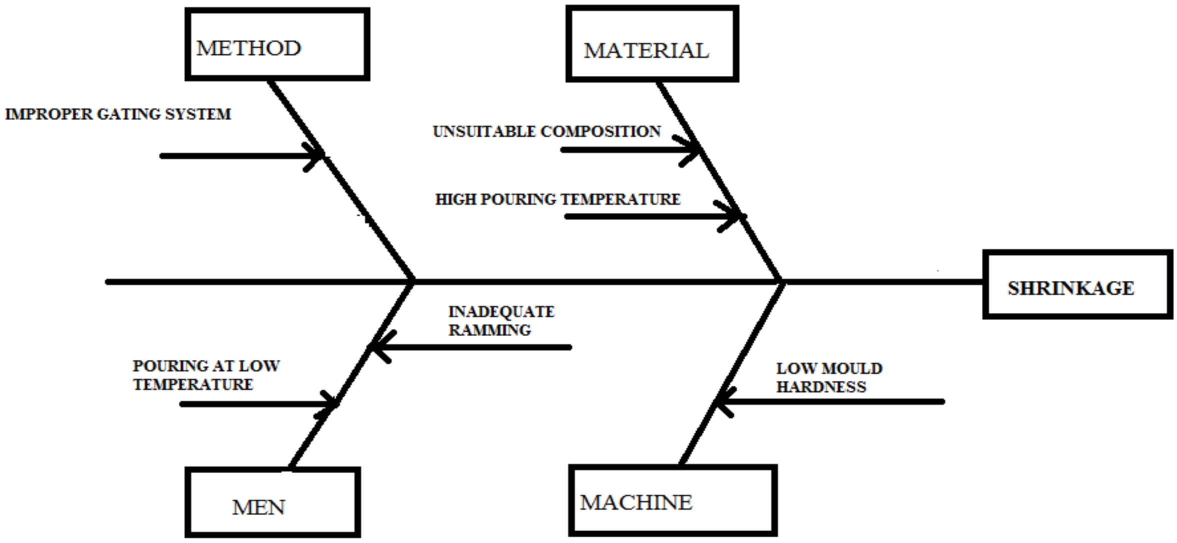

Fig.6: THE CAUSE EFFECT DIAGRAM FOR SHRINKAGE

Cold Shut

The cause-effect diagram for cold shut is shown in fig.7. Based on experience in foundry, following remedies are suggested:

Remedies:

- Smooth pouring with the help of monorail
- Properly transport mould during pouring
- Arrange proper clamping arrangement

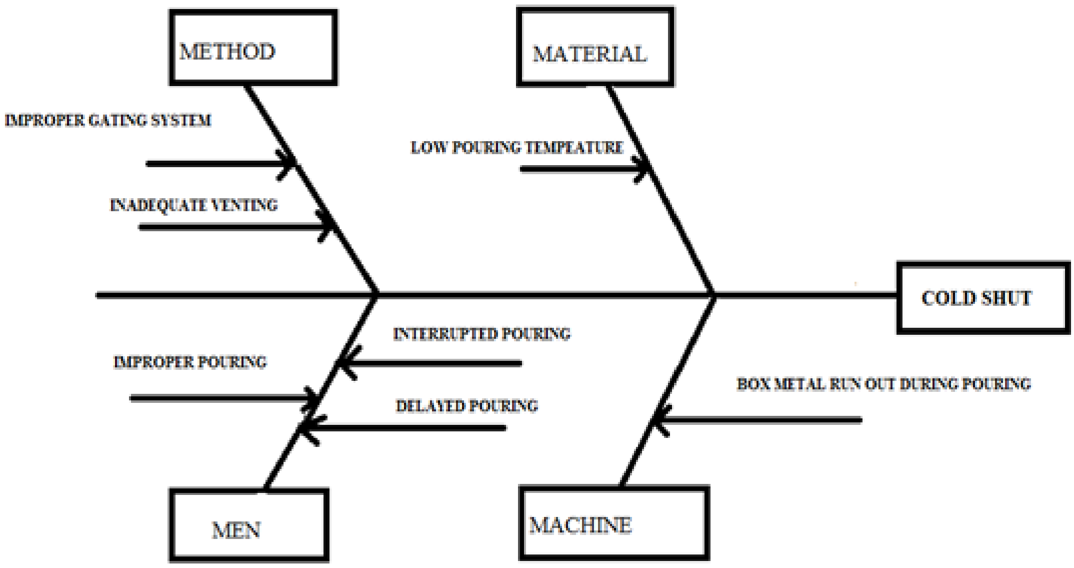

Fig.7: - THE CAUSE EFFECT DIAGRAM FOR COLD SHUT

Mismatch

The cause-effect diagram for mismatch is shown in fig.8. Based on experience in foundry, following remedies are suggested:

Remedies:

- Properly arrange box warpage
- Properly move boxes with pins
- Properly clamp the boxes.

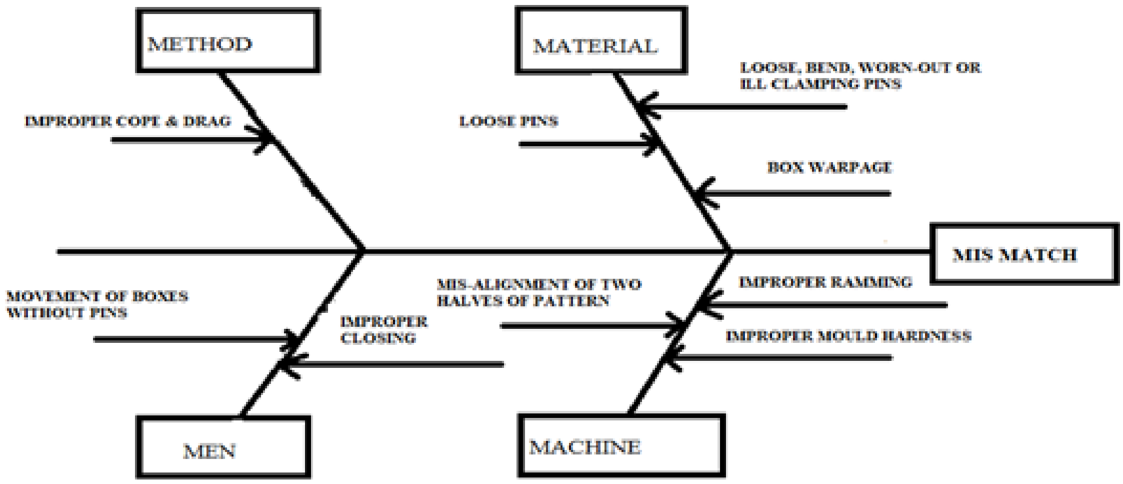

Fig.8: THE CAUSE EFFECT DIAGRAM FOR MIS MATCH

Porosity

The cause-effect diagram for porosity is shown in fig.9. Based on experience in foundry, following remedies are suggested:

- Too high metal temperature
- Poor gating & runner
- Poor ejecting & clamping
- Flow not smooth

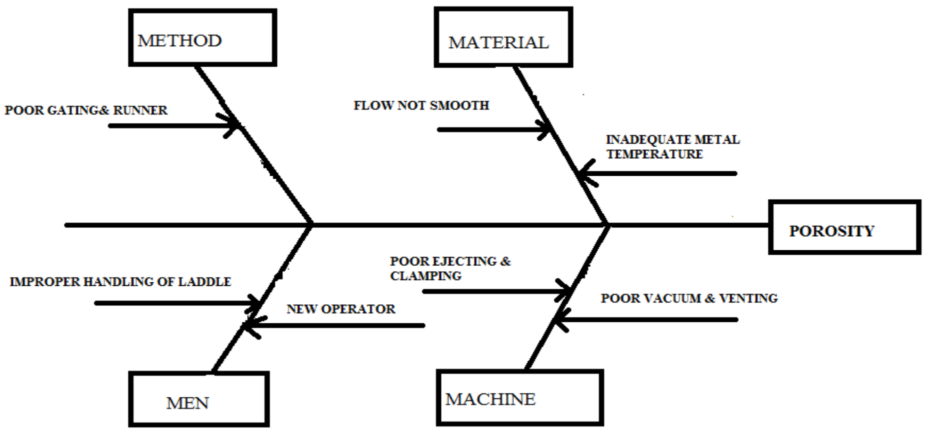

Fig.9:THE CAUSE EFFECT DIAGRAM FOR POROSITY

The cause-effect diagram can easily determine causes of defects and suggest their remedies to eliminate the problems. The main limitation of the cause effect diagram is that it largely depends on the experience and traditionally, it is prepared by experience or intuitively. Also, cause effect diagrams are not easily found out in literature except few casting defects.

VIII. CONCLUSION

Conclusions from Data

All the data gathered above proved my initial hypothesis. The vast majority of defective parts were made through human error. These were for the most part simple mistakes as a result of inadequate experience on the part of the machine operators. Company X did not have the money to pay highly skilled workers and tried to save money by employing low cost, untrained workers. This strategy entailed that many workers were not adequately prepared for the jobs they were responsible for. In retrospect, the high rate of defects was not surprising, given this information. With the money lost due to defective parts, the prices of Company X's products must correspondingly increase to cover that cost. The customers have been willing to pay these higher prices, but with increasing competition, this may not last long. Low cost labor is not strength of Indian-based manufacturing. If that is the route Company X decides to take, the end result will be outsourced operations if not the collapse of the company. The solutions to this problem must fundamentally change the corporate mindset to empower its employees and stop the trend towards cheap labor.While at the outset of the project, the focus was on finding problems with the machining processes, the real problem turned out to be with the human aspect of manufacturing. The direction of the project may have shifted, but the original goal remained the same: to eliminate the root causes of part defects. That root cause was the personnel performing far too complicated machining tasks for their level of training. Other contributing factors included a disorganized manufacturing floor and poor employee morale. With the problem properly identified, possible solutions were developed and their feasibility investigated.The creation of defective parts is so engrained in the mindset of the employees and management at Company X that it is accepted as inevitable and unavoidable. The only way for Company X to come out of the rut it is currently in is through a drastic change in philosophy and company fundamentals. Problems of this magnitude need to be addressed by solutions of the same size. Any solution to the issues that Company X is currently facing will need to take time. There are no instantaneous solutions to a problem that has become so set in the ideals and fundamentals of a company. Company X needs to implement training and retraining program with a chance for advancement in the company. Also, there needs to be repercussions for recurring errors made by operators, and rewards for working for lengths of time without making mistakes. There has to be incentive for employees to care about their jobs. This will lower the turnover rate, and heighten the morale.

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