Process Improvement by Implementation of Lean Techniques

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Lean manufacturing techniques are being increasingly used in many industries due to their success in the Japanese automobile industry. There are many techniques one may use to improve the processes but any techniques have to be continuously implemented (Kaizen) in order to obtain substantial results. Even though the literature on Lean techniques is easily available, not many companies have been successful in implementing them. This paper deals with the application of some techniques in a high mix- low volume environment.

Keywords: Lean, Value Stream Mapping, Single piece flow, 5S methodology, Ishikawa diagram etc.

1. INTRODUCTION

The open gear division (PO) of Power Build Limited (PBL) manufactures custom made loose gears wheels and pinion shafts. Forged blocks were used as the raw material. Suppliers provide the raw material in 6-10 days. The division is thus a high mix- low volume environment. As the customer orders for loose gears, the quality had to be perfect; else, the order was sent back for either for rework or cancelled.

PO Division, like a typical small scale industry does not have the best of machines nor the budget to replace them. In spite of this, the customers expect excellent quality and timely delivery. The PO Division was facing problems on both counts. The rework accounted for nearly 10% of the material and the overdue orders were piling up. This lead to the conclusion that a better process flow could help matters a lot.

Every organization, be it manufacturing or service suffers from the 3 D's :- Delays, Defects and Deviations. Lean manufacturing is a production practice that considers the expenditure of resources for any goal other than the creation of value for the end customer to be wasteful, and thus a target for elimination [1]. From the perspective of the customer who consumes a product or service, "value" is defined as any action or process that a customer would be willing to pay for.

The process for manufacturing the gears and the machines used were as follows:-

1. Turning, Facing and Boring - NCL-02, LC-04.
2. Numbering.
3. Drilling - NCD-01 or VMC-01.
4. Hobbing - H-06.
5. Heat treatment - SQF-01.

6. Bore and face grinding - NCL-16.
7. 2nd side grinding - SG-01.
8. Profile grinding - GG-02 or GG-04.
9. Keyway (wire cut) - WC-01 or WC-03.
10. Outer diameter (OD) grinding - CG-06.
11. Inspection.
12. Sometimes the material is sent for Outside processing mainly for OD grinding.

While the elimination of waste may seem like a simple and clear subject it is noticeable that waste is often very conservatively identified. This then hugely reduces the potential of such an aim.

The original seven wastes are [1]

- Transport (moving products that are not actually required to perform the processing).
- Inventory (all components, work in process and finished product not being processed).
- Motion (people or equipment moving or walking more than is required to perform the processing).
- Waiting (waiting for the next production step).
- Overproduction (production ahead of demand).
- Over processing (resulting from poor tool or product design creating activity).
- Defects (the effort involved in inspecting for and fixing defects).

The first hurdle in implementing Lean was the identification of wastes. According to the observations during the first two weeks, the main problem was delays due to high idle times, i.e., waiting. Hence, the aim was to reduce lead time and my first step was to prepare a Current State Value Stream Map for the PO Division.

2. METHODOLOGY

2.1. Value Stream Mapping

Value stream mapping (VSM) is a lean manufacturing technique used to analyze and design the flow of materials and information required to bring a product or service to a consumer [2]. The first step in implementing VSM is identifying the target product or product family. This was a problem in PO division as it only took custom orders which resulted in there being no standard products [3].

It was decided that exact product families for the first time were not really necessary [4]. This was done by roughly checking the times of four different orders of varying sizes and quantities and comparing the idle time to lead time ratios. In the VSM, inventories were depicted as RMI (Raw Material Waiting) and FI (Finished Waiting). On completing a rough Current State VSM, the time wastage was divided into five parts. They are:-

1. Waiting before Heat treatment (HT).
2. Waiting before all other processes.
3. Waiting during all processes.
4. Waiting after all processes.

5. Misc. wastage (Extra setting time, measuring the piece constantly during machining etc.).

The current state VSM is shown in Figure 1. Four batches of 25 helical gears each were observed and the average times are depicted in the VSM.

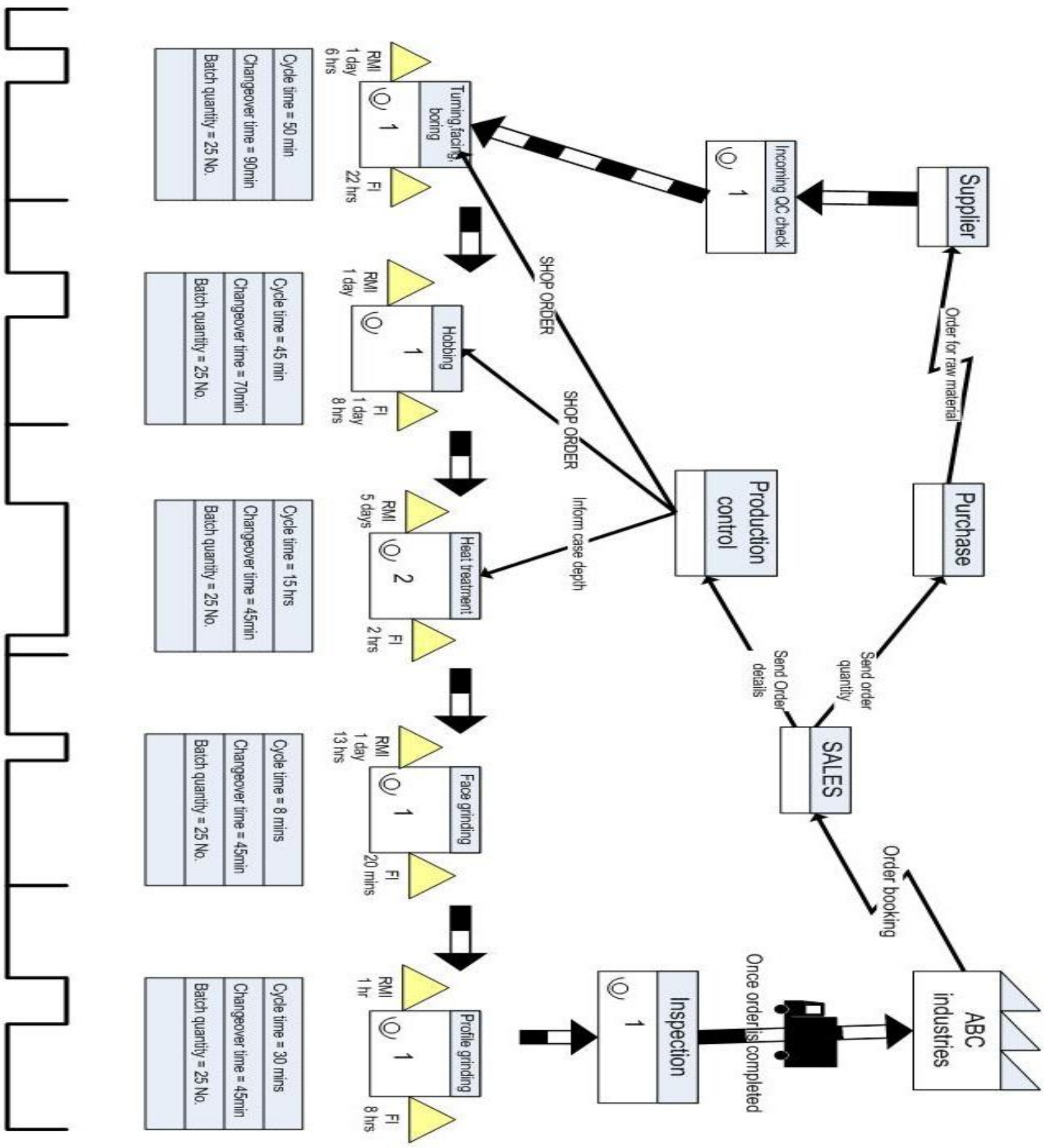

Fig. 1: Current State Value Stream Map.

The Value Stream Map is useful to identify the areas of concern (delays) by using the timeline at the bottom of the Value Stream. The part of the timeline with troughs is the delays and the peaks are the times taken by Value adding activities.

The "Waiting before HT" has been taken separately because its effect on the lead time is bigger. The data for the VSM has been taken by tracking four orders and taking the average of them. As it can be seen from the VSM and the types of delays assumed above, the Table 1 with times is given below:

Table 1: Delay times.

DELAYS	Order 1	Order 2	Order 3	Order 4	Average
Waiting before Heat treatment (HT). (days)	12.00	3.50	2.42	2.08	5.00
Waiting before all other processes. (days)	5.83	4.17	5.42	4.58	5.00
Waiting during all processes. (days)	5.21	5.63	4.79	5.33	5.24
Waiting after all processes. (days)	2.83	3.17	2.50	2.17	2.67
Misc. wastage. (days)	0.42	1.08	0.25	0.33	0.52

2.2. Pareto Analysis

Pareto analysis is a statistical technique in decision making that is used for selection of a limited number of tasks that produce significant overall effect [1,5]. It uses the Pareto principle – the idea that by doing 20% of work, 80% of the advantage of doing the entire job can be generated. In this case the 20% of reasons that lead to 80% of the delay are identified.

Pareto analysis is a formal technique useful where many possible courses of action are competing for attention. In essence, the problem-solver estimates the benefit delivered by each action, then selects a number of the most effective actions that deliver a total benefit reasonably close to the maximal possible one.

Once the top 20% of the causes are identified, then the Ishikawa diagram or Fish-bone Analysis was used to identify the root causes of the problems.

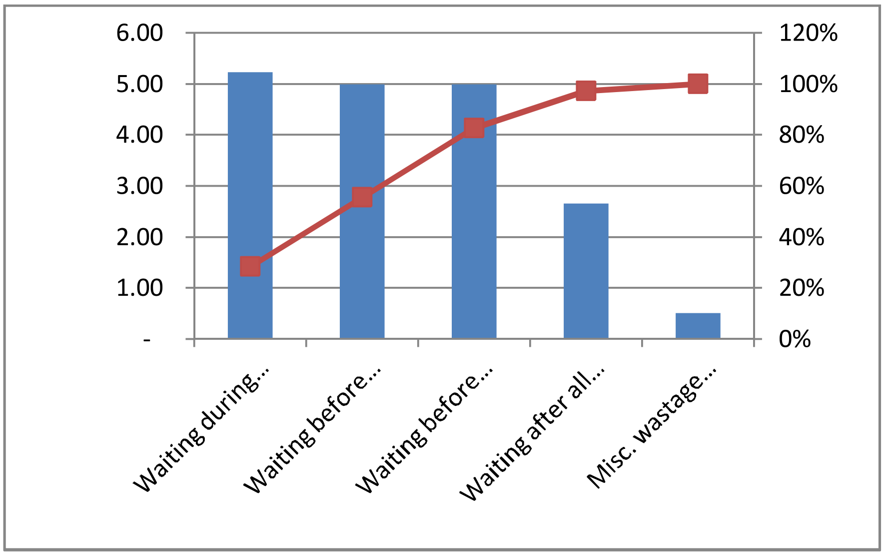

Fig. 2: Pareto graph.

Based on the Pareto graph given in Figure 2, the main three reasons which have to be dealt with first are waiting during the process, waiting before heat treatment and waiting before all other processes. They constitute 80% of the delays.

2.3. Ishikawa or Cause and Effect diagram

Ishikawa diagrams (Figure 3) also called fishbone diagrams, cause-and-effect diagrams, or Fishikawa, are causal diagrams that show the causes of a certain event [1].

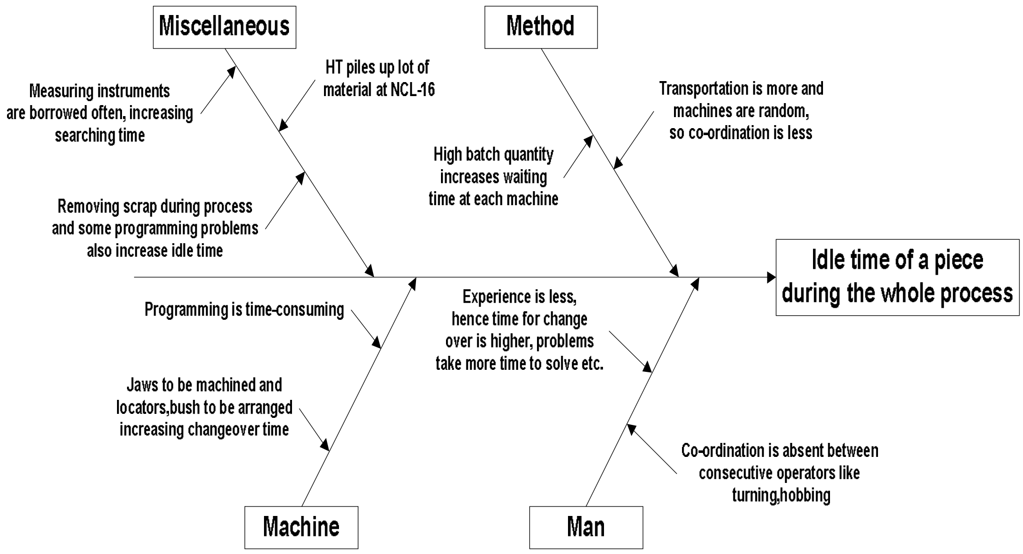

Fig. 3: Ishikawa or fishbone diagram.

Causes are usually grouped into major categories as in Table 2 to identify these sources of variation. The categories typically include:

- Man Power: Anyone involved with the process.
- Methods: How the process is performed and the specific requirements for doing it, such as policies, procedures, rules, regulations and laws.
- Machines: Any equipment, computers, tools etc. required to accomplish the job.
- Materials: Raw materials, parts, pens, paper, etc. used to produce the final product.
- Measurements: Data generated from the process that are used to evaluate its quality.
- Environment: The conditions, such as location, time, temperature, and culture in which the process operates.

Table 2: Suggested Countermeasures.

Suspected cause	Action taken	Responsible	Effect of action
Waiting due to High batch quantity	One piece flow	Production engineer and workers	Reduction of almost one day idle time
Jaws are machined at NCL-02 and 16	New invention called Captex from Hainbach or face drivers	Higher level management	Reduction in setup time for turning and grinding
Co-ordination is less between consecutive operations	Arranging the machines in lean cells or using some kind of system similar to KANBAN	Higher level management, Production engineers and workers	Reduction in transportation times and improved flow of material
Searching for measuring instruments	Continuous 5S implementation	Workers	Reduction in time wastage in searching for required items
Heat treatment idle time	Install smaller HT plant say for 100 kgs or send for OSP	Higher level management	Reduction in waiting times upto 20 days at HT
Large load piles up at NCL-16 after HT	Install smaller HT plant say for 100 kgs or send for OSP	Higher level management	Reduction in idle times at NCL-16 of 1-2 days
Experience of some workers is less leading to more mistakes	Lean cells with 2 experienced and 2 new workers with one engineer	Higher level management	Reduction in mistakes in machining and programming reducing rework

Only four causes were used here: Man, Machine, Method and Miscellaneous. Then, we know the root causes causing the delays in the process. After the causes were identified, some countermeasures were suggested.

3. RESULTS AND DISCUSSIONS

3.1. Countermeasures

From the Pareto Analysis, we infer that the three main reasons for delays are, waiting during the process, waiting before heat treatment and waiting before all other processes.

Waiting during the process – This waiting consists of two parts: Changeover or Setup time and waiting due to High Batch Quantity. For example, consider an order for 25 gear wheels (diameter < 200mm). Consider that the order arrives at the NC Lathe (say NCL-02) at 9'O clock in the morning. The initial setting time ranges from 1.5 hrs to 2 hrs as the jaw has to be machined to fit the piece in exactly. This is a huge wastage of time. It may not appear so for this particular order, but say the order is for 1 piece, then the setting time is greater than the machining time.

Next, consider that machining starts at 11am. Say one piece takes about 30 minutes. That means that it takes about 15 hours, i.e. about 2 shifts (till about 1 am on the next day). The machine also runs for only 2 shifts. This means that one piece has to wait near the machine for the whole 15 hrs even though its machining time is only 30 minutes. This is the data only for one machine.

The countermeasure suggested for this is the implementation of Lean cells and Single piece flow for the Batch waiting and changing the work holding to Face drivers or a new invention called Captex (by a company called Hainbuch). The lean cellular layout will be explained later.

Coming to the change of work holding devices there are two options:

Face drivers – These are already being used at another division in Power Build Limited. Face drivers essentially have some sharp pointy edges which imprint onto the sides of the gear blank as shown in Figure 4. The disadvantage is that lesser speeds and smaller depth of cuts have to be used due to lesser clamping forces.

Fig. 4: Face driver, work holding device.

Captex from Hainbuch – This invention came to light while searching for any new breakthroughs in work holding and setup time reduction [6]. There is not much information available on its working but it has some kind of rubber rings on the inside of the clamp hence adjusting to the changing curvatures as shown in Figure 5.

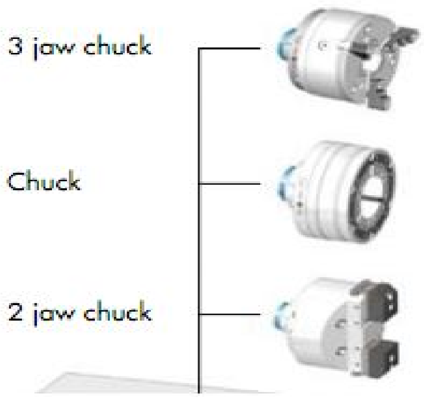

Fig. 5: Captex, a new invention in work holding.

Waiting before heat treatment – Heat treatment takes place after the hobbing and turning. This is done because the main aim of HT here is to increase the gear tooth strength. It is done by case carburizing. Case hardening is the process of hardening the surface of a metal, often a low carbon steel, by infusing elements into the material's surface, forming a thin layer of a harder alloy. Case hardening is usually done after the part in question has been formed into its final shape.

This manufacturing process can be characterized by the following key points: It is applied to low-carbon work pieces; work pieces are in contact with a high-carbon gas, liquid or solid; it produces a hard work piece surface; work piece cores largely retain their toughness and ductility; and it produces case hardness depths of up to 6 mm.

Hence, material needing the same case depth only has to be heat treated at a time. Also, the minimum requirement to start the furnace is 300 kgs which is normally not fulfilled by a single order. Therefore, the material waits at the furnace until sufficient material requiring the same case depth arrives. Hence, it can be sent to Outside Processing.

Waiting before all other processes - This has two components: waiting at NCL-16 after heat treatment due to a number of orders being present and waiting at all other processes. This is the kind of delay which does not have any specific reasons. Some of the reasons are lack of co-ordination between workers of consecutive operations, lack of co-ordination between workers and production engineers, lack of experience of some workers leading to more programming time etc.

This can also be decreased by the lean cellular layout explained later, using single piece flow and implementing single minute changeovers.

Sometimes delays are caused because the worker has to search for the required items. This was avoided by implementing 5S as in Figure 6. 5S describes how to organize a work space for efficiency and effectiveness by identifying and storing the items used, maintaining the area and items, and sustaining the new order. It instills ownership of the process in each employee.

All the bushes required for hobbing and jaws required in lathe were arranged based on the diameter. All the hobs were also arranged based on module and material.

The 5S's stand for:-

- **Sort** - the first step in making things cleaned up and organized.
- **Straighten** - organize, identify and arrange everything in a work area.
- **Shine** - regular cleaning and maintenance.
- **Standardize** - make it easy to maintain - simplify and standardize.
- **Sustain** -maintaining what has been accomplished.

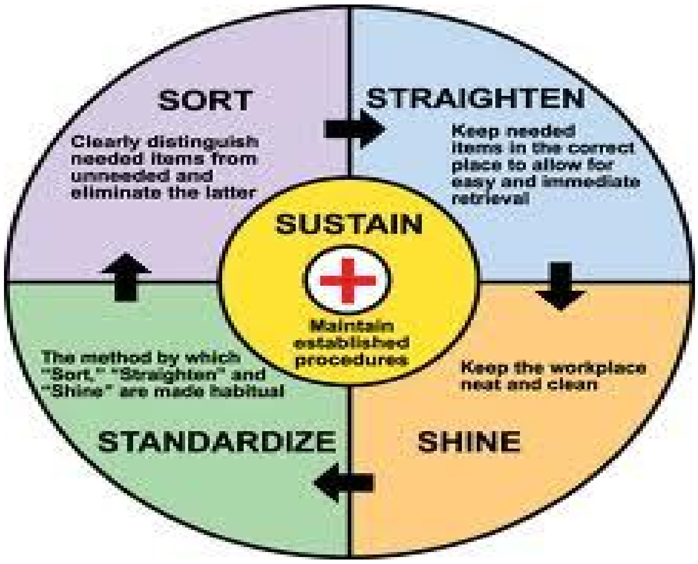

Fig. 6: The 5S Methodology.

One of the major reasons for the increasing lead times was the random placement of machines in the PO division. If the machines are placed in Lean cells, single piece flow can be used and lead times will decrease drastically. As explained before, when cellular manufacturing is applied along with Single Minute Changeovers and One-Piece flows, it leads to the best lead times.

Cell manufacturing is another important part of Lean. A good layout can reduce delays and can also improve productivity. Cellular manufacturing focuses on mixing both product and process layout to obtain an optimized layout for product families [7,8].

The previous layout of the PO division is given below in Figure 7.

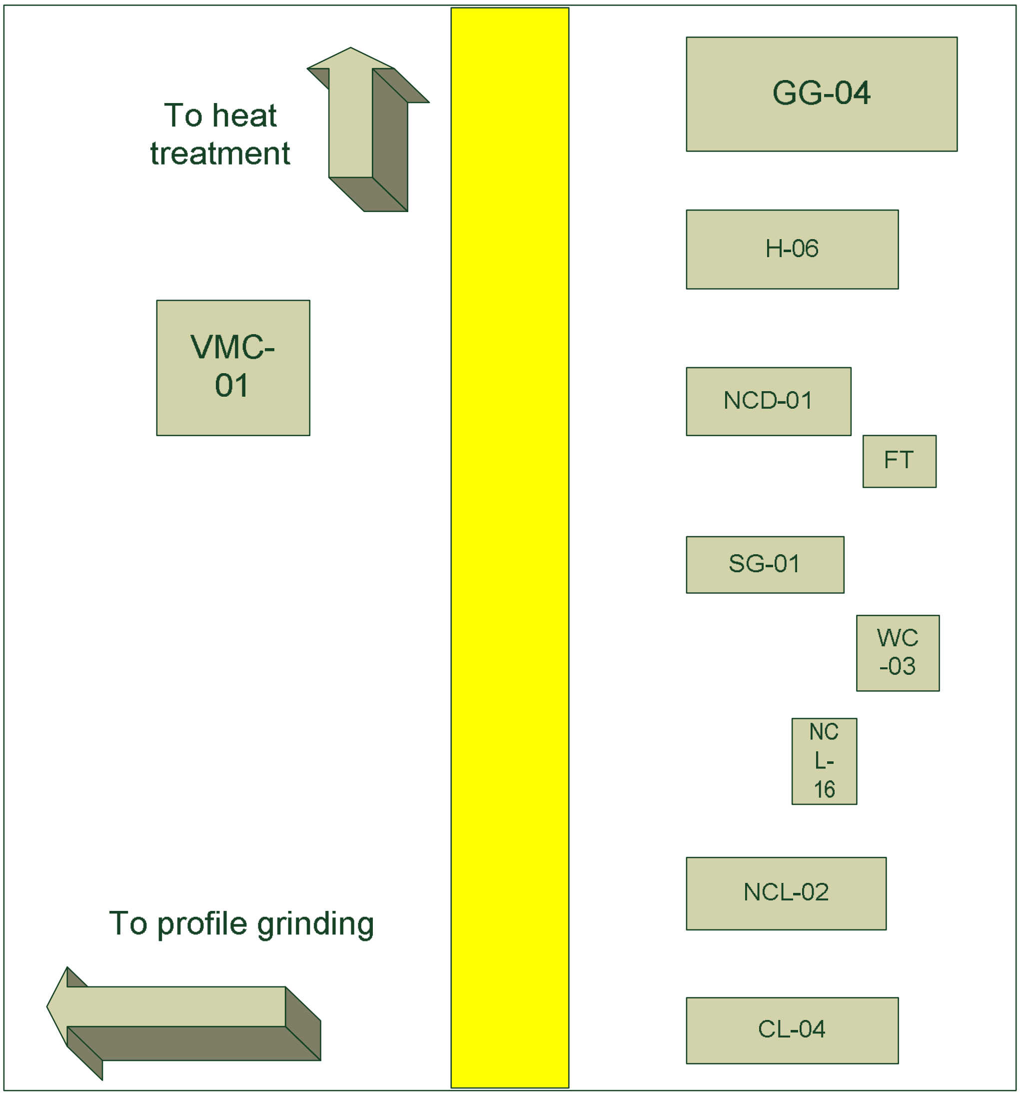

Fig. 7: Original Position of machines in PO Division.

As we can see from the layout in Figure 7, the machines are very randomly placed. This decreases the interaction of workers of consecutive operations. It also increases transportation and acts as a opposition to single piece flow.

I applied the concepts of cellular manufacturing and single piece flow to prepare a layout for a new shed. It is given below in Figure 8.

As we can see, the turning and hobbing machines have be arranged in a cell near the entrance along with the drilling machine.

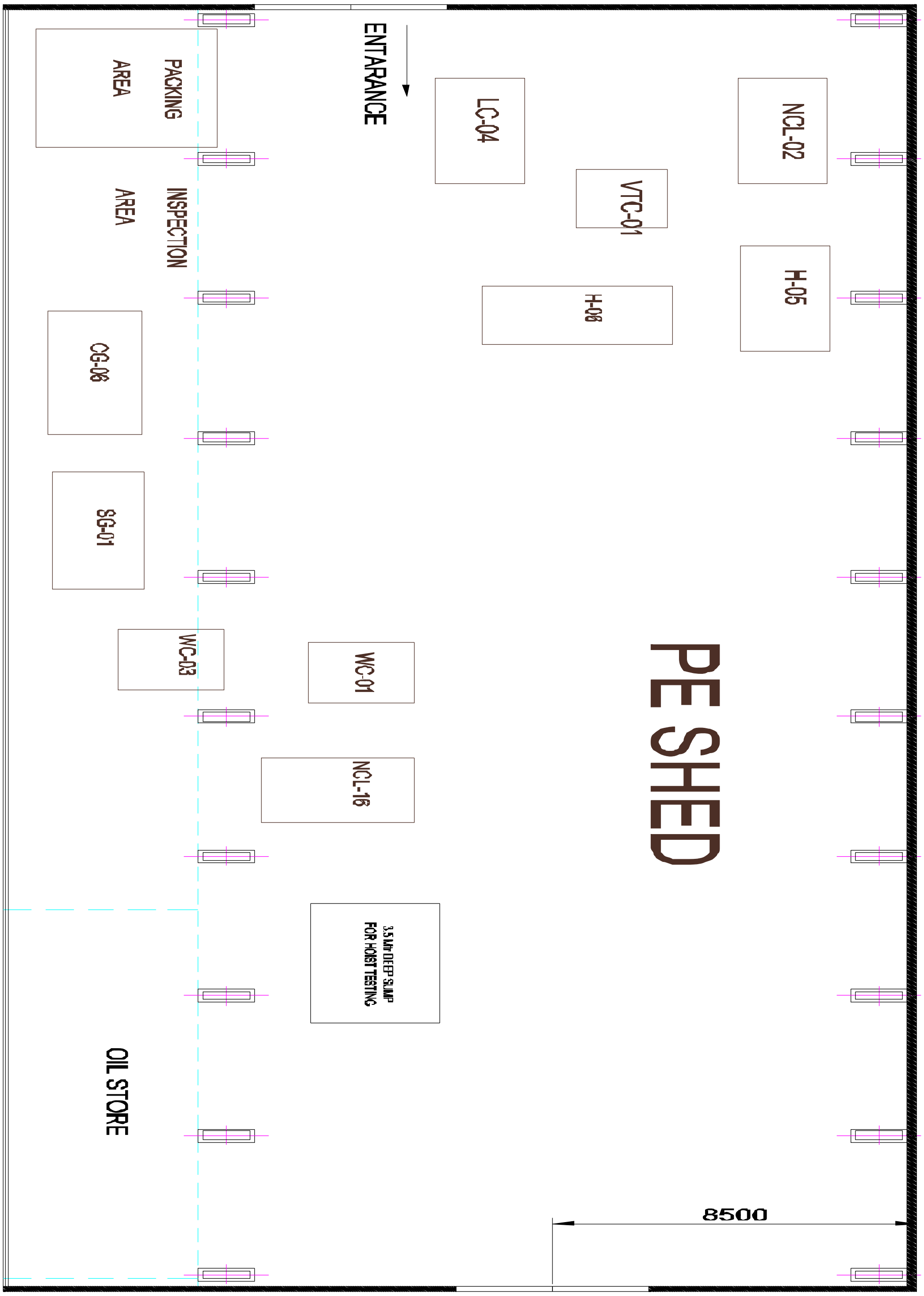

Fig. 8: Suggested positions of machines (cellular layout).

The flow of material is as shown in Figure 9.

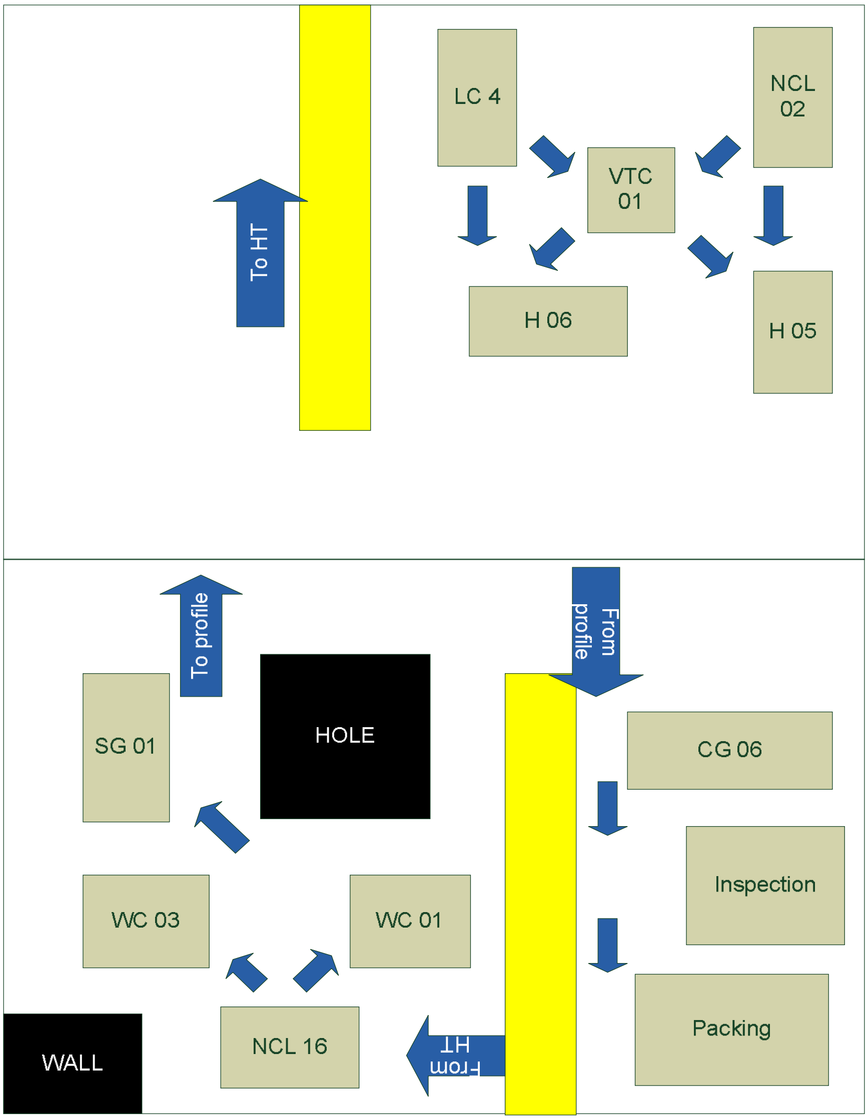

Fig. 9: Suggested flow of material.

3.2. Single piece flow

Single piece flow [9] is the ideal state where parts are manufactured one at a time, and flow throughout the manufacturing and supply chain as single unit, transferred as customer's order. As a company reduces wastes and strives for single piece flow, many other benefits follow. Some of these benefits include (1) improved quality and fewer defects (2) reduced inventory (3) less space required, (4) enhancement of overall manufacturing flexibility etc.

Thus, one-piece flow is a tool that will help a manufacturer achieve true just-in-time manufacturing. That is, the right parts can be made in the right quantity at the right time. In the simplest of terms, one-piece flow means that parts are moved through operations from step-to-step with no WIP in between either one piece at a time or a small batch at a time. This system works best in combination with a cellular layout and small setup times.

Here is an explanation on how it is done. If for example we need 10 different types of gears (quantity 1). The first gear takes 30 minutes at first machine after a setup time of say 2 minutes (after implementation of SMED). Instead of waiting, it immediately goes to the next operation. This decreases the lead time of a product by almost 4-5 days at PO division.

4. CONCLUSION

The machines have been placed in a similar layout as to the one given above. But, it has only been 2-3 days and all the machines have not yet been shifted. Hence it is difficult to obtain the effectiveness of the layout.

But theoretically, the time saved by implementing these techniques can be calculated for a particular order. For example, taking the order of 25 helical gears, it is seen that the lead time can decrease from 19 days to 7 days. This decrease can be obtained just by reducing the idle time in waiting.

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