Implementation of Kaizen Principles in an Injection Molding Machine Manufacturing Company

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Abstract
Kaizen is a Japanese term meaning continuous improvement. It is a philosophy widely adopted by Japanese manufacturing company. However, due to globalization leading to increase in competition among small and medium scale enterprises (SMEs), especially in India. It is pivotal for this organization to provide High quality products at a reasonable price in order for them to survive. Kaizen is lean manufacturing tool used to improvise the overall process of company which ultimately leads to reduction in production cost. Moreover, process efficiency gets improves through implementation of few tools out of many tools lying under the umbrella of kaizen which are Total quality control (TQC), Total productive maintenance (TPM), Quality improvement, Automation, zero defect (ZD), Kanban, Just-in-time (JIT), Quality control system (QCC) and Suggestion system. In this study, Kaizen system was executed though 5S in assembly, machine and mold shop department, Kanban system for Fasteners, Plotting Value stream Mapping (VSM) in machine shop of a critical product, obtaining the process Capability ratio for Gun drill machine and other small improvements

Keywords
Total quality control, Value stream mapping, Kanban.

1. Introduction and Significance of study
The study was conducted at a German MNC involved in production of rubber and silicon injection molding machines. They had engineer-to-order business strategy where they modify the size of FIFO, clamping force, and mold design as per customer requirement. The company is situated at Gujarat India. Here in this study, company's name is given ABC for reference. Since few years, company implemented lean practices like 5S, TQM, OEE, VSM etc. However, none of the practices were used for identifying non-value-added activist use of above lean principles were solely for purpose of achieving ISO 9001 and ISO 14001.Therfore, decision was taken to implement kaizen in some of the pivotal departments. 5S was implemented in Assembly, machine shop and Mold department, Statistical process control (SPC) was implemented in quality control, redesigning of masking plates in paint shop. The above small improvement helped not only to reduce non-value-added activities but also created awareness among employees regarding benefits and importance of lean tools.

2. Literature Review
Kaizen is a philosophy for small continuous efforts resulting into enhancement of productivity and efficiency of company through waste identification and elimination. Moreover, some of the intangible benefits of kaizen implementation are increase in employee's motivation and morale because it requires involvement of all employees (Rewers et al. 2015). To achieve this goals Value stream mapping (VSM)is applied in manufacturing organizations (Rohac and Januska 2015),(Kuhlang et al. 2013), (Tabassum and Khan 2016), quality assurance (Haefner et al. 2014) process companies (Zahoor et al. 2016) and maintenance departments.(kasava et al.2015). moreover, provided an insight on VSM through an analogy by comparing company as a ship and non-value-added activities as icebergs. While a very small portion of ice is visible above water and most of the portion of iceberg is hidden under the water (Dadashnejad and valmohammadi 2017). Similarly, via VSM company can perform top-down and bottom-up survey of process which leads to identification of all hidden non-value-added activities. (Haefner et al. 2014) used VSM for solving quality issues, they advised use of VSM for activities like visualization, analysis and quality assurance design.[Tabassum and Khan 2016), presented Case in automotive manufacturing unit where they used 5S methodology and VSM .VSM helped them to identify the bottleneck operations associated with assembly line and

thereafter they used 5S methodology to organize the poorly designed assembly line leading to 62% improvement in assembly line efficiency (Vamsi and Sharma 2014)mapped detailed process flow chart of machining process carried out in automotive company and used it as a reference to prepare current state VSM. Furthermore, VSM is a static tool which requires few months of time to check sustenance of results .After, waiting for few months the study concluded reduction in process inventory level by 73 % , overall reduction in 7 operational activities , reduction in TAKT time by 24.32%.Moreover 5S and statistical process control(SPC) are also techniques leading to overall improvement in company's performance.(Chickwendu et al. 2020)discussed implementation of kaizen manufacturing techniques(KMT) in tissue manufacturing company to solve the issue of high defective products , low quality products and low output. MATLAB software was used to monitor daily data and results obtained were increase in quality of product up to 30 %, decrement in staff requirement, fewer daily defects and high throughput. Apart from that there are plenty of literatures available providing evidence on improvement in production process through 5S implementation and use of statistical process control (SPC) (Agrahari et al. 2015)stated that 5S provides benefits like reduction in production cost , Effective space utilizations , improved in working conditions , reduction in maintenance costs.(Randhawa and Ahuja 2017) Identified various critical success factors and barriers affecting implementation of 5S(Jain et al. 2014) emphasized on importance of identifying potential barriers and benefits from 5S before implementing it (attri et al. 2020)classified source of barriers and benefits into 3 levels namely top management , middle management and shopfloor workers. Moreover , hypothesis test , identification of critical success factors and interrelationship among various identified barriers through Interpretative structure modelling (ISM) are few of the methods to identify the barriers to 5S Implementation and sustenance(Verma and Jha 2019)Some of the common barriers faced by many manufacturing organizations are lack of commitment from top management, lack of knowledge and training on 5S , low availability of resources etc**.** (Ananthanarayanan 2006)] Performed 5S management system in NDE laboratory which resulted into reduction in waste , organized laboratory in customer friendly manner and better data management(Fernandes 2018) moreover, there is a need to include safety(6th S) and security(7th S) as separate 'S' , resulting into 7S methodology Tabassum and Khan 2016),applied 6s methodology where they reduced total risk by 64% through employee risk assessment tool. Statistical process control (SPC) is one of the techniques used in total quality management (TQM) for controlling, monitoring and managing a process (Oakland 2008)control charts are one of the 7 SPC tools (Shehatal et al. 2018 Implementation of SPC techniques makes it possible to control variation which leads to defective goods leading to failure to meet customer satisfaction and requirement.

3. Research Methodology

The Lean principles were implemented in majorly 5 departments of company. 5S methodology was implemented in Assembly, machine, paint and mold department. Total quality management (TQM) in Quality control (QC) and VSM in machine shop. Initially, literature review was performed by referring to reputed journal and conference papers on various topics like kaizen , 5S, TQM and VSM After which, 5S implementation was started in Assembly department. Assembly department was divided into 5 units, where 5S auditing was conducted based on defined criteria to know the current condition of 5S in various units. Based on auditing major problems were identified and addressed. Furthermore, Value stream mapping of Cavity blocks was started simultaneous in machine shop. However, The major challenge in plotting VSM lies in tracking time of all individual machining process because it was operated 24 hours a day. Therefore, Log books were used to record the machining time, setup time and idle time by operator. Moreover, several technicians were interviewed individually to get their inputs on identifying dedicated place for tools , fixtures and components. Also, Supervisors were involved in 5S implementation process. On the other hand, After completion of VSM , Statistical process control (SPC) was applied to measure process capability ratio and index of process performed using Gun drill machine (GDM). The machining process consisted of making deep holes on cold runner blocks (CRBs) . cold runner blocks keeps the runner or silicon compound at a temperature above the curing temperature and forcibly injects compounds into mold cavity. $\bar{X}$ -Chart , R-chart and Bell shaped curve graph were plotted .

4 Implementation of Kaizen Principles

4.1 5S Implementation

5S is an initial step for implementing any lean practices in an organisation.5S is an approach to organize, standardize and clean. It is an abbreviation of five words starting with letter 's' namely Sort, set-in-order, Shine, standardize and sustain. The first step was 5S implementation in Assembly, machine, paint and mold department. Following are the actions performed under the 5S implementations.

Sorting basically involves identifying and eliminating waste. There were many items eliminated from the shop floor like eliminating non-standard fasteners from the Kanban racks, removing old and obsolete design files in machine shop, removing additional worktable, reusing waste insulating plate for masking and unnecessary paint in the gangway. While sorting between standard and non-standard fasteners it was of utmost important to identify evidence to eliminate any fasteners because if some essential component is disregarded will create problem later unimportant, the part list of all standard machines referred and interview of technicians were taken to prepare list of all non-standard item. Furthermore, red tagged was attached to all unimportant components and they were stored in a separate storage area.

Figure1. Waste insulating plate

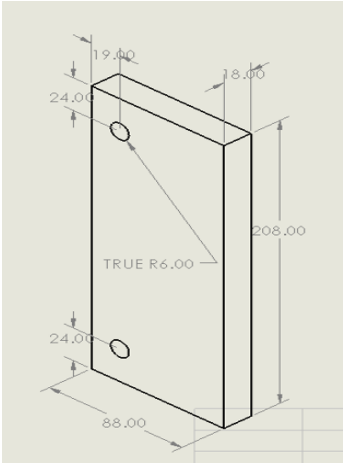

Figure 2. Improved masing sketch

Set-in-order-After elimination of waste, second step involves deciding dedicated place for each and every item and putting that item in its original place after use. Simply, it is a straightening process where stored items are organized according to frequency of use, convenience and future consideration. Moreover, set-in-order involves providing labels where ever necessary which prevents mismanagement of tools and fixtures. Moreover, it also involves ergonomics considerations like proper working table height, easy accessibility to pressurized air, adequate amount of material handling system to prevent manual load lifting etc. Inserts, tool holder, collets as per applications etc. Were given a proper labelling for easy identification in machine shops.

Figure 3. Before (Left) and after (Right)Labelling in in mold department

Figure 4. Before (Left) and after (Right)Labelling Assembly department

Figure 4. Before (Left) and after(Right) Labelling in machine shop department

Shine- once the sorting and set-in-order step are taken, it is now the time for shining phase. Shining involves comprehensive cleaning of area in order to identify any disorder and potential defects in machine which can cause harm to the operator. Furthermore, A clean work environment encourages discipline, motivation towards work. In this study, all Kanban racks were cleaned where some of the lost tools were found. Apart from that, certain amount of cleaning was done while Sticking labels. moreover, no major damages to any CNC machines like oil or coolant leakage were Discovered. Also, no safety threats were identified during cleaning.

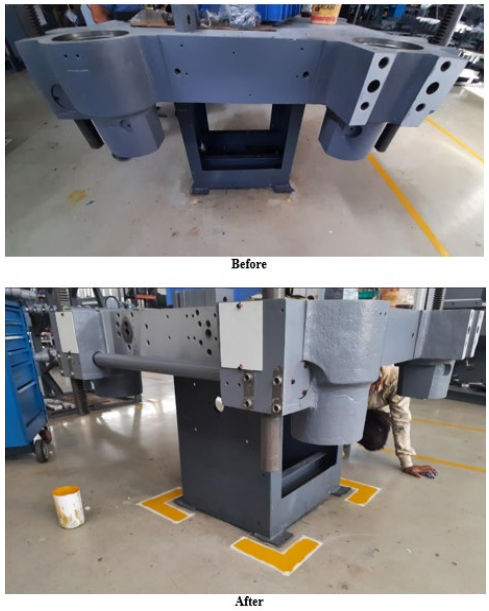

Figure 5. Repainting of Yellow strips

Standardize – The main aim of this step is to sustain the above '3S'. It involves setting rules and standard operating procedures (SOP). The implementation of this step was properly done by company in two phases. First phase involves

making first '3S' as organizational habit, it was done by deciding responsibility for each individual worker for 3S activities in their department. Finally, second phase involves prevention. It was implemented through following strategies.

Incorporation - Frequently used Jigs and Fixture were stored in dedicated rack at each and every workstation, frequently used tools and other equipment were available to technicians in their mobile tool box. Furthermore, there were established SOPs containing instruction on how to perform certain assembly. So that there is no unnecessary waste in repetition or selection of wrong process.

Suspension- pressurized air was readily available to each and every workstation. Air guns were suspended with spring balance, once the use is over it released and gun will return to its original position.

Standardize design -Standard designs of all important makings were prepared. Makings are used to ensure any area which should remain paint free does not get painted. However, Due to repeated usage of makings, excessive paint coats get deposited on them, which affects the function of masking leading to deposition of paint at undesired areas. moreover, the problem lies in reluctance of management in not preparing new masking Even though high amount of time gets wasted in removing paint. It is mainly due to unavailability of standard drawing of masking. Therefore, an attempt was made to standardize the whole process of masking preparation by developing new 2D sketches of masking as per the component name and machine they are used for. So that this design gets saved in the system and whenever demand rises, the company directly sends softcopy of drawing, material and quantity required to supplier.

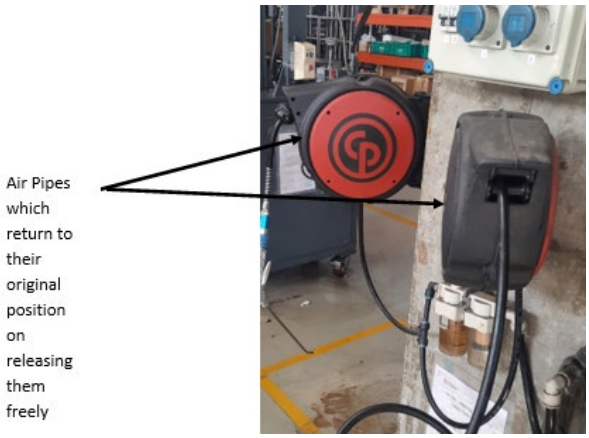

Figure 6. Air pipes

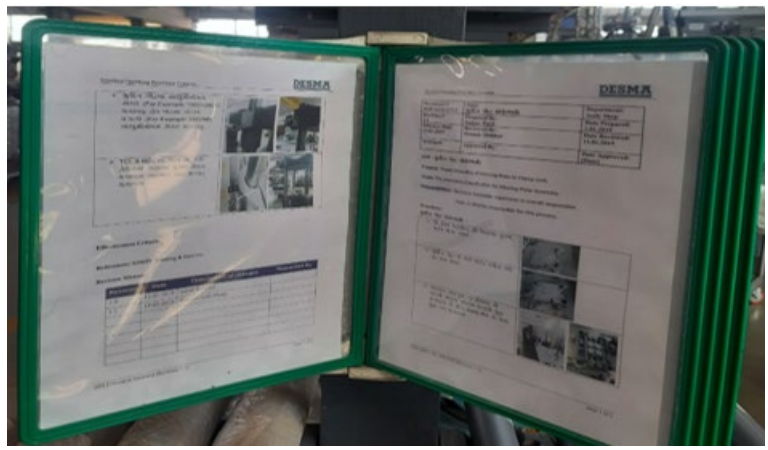

Figure 7. Standard operating procedure of subassemblies

Sustain-The aim of this step was to maintain correct set of procedure. It can be done with the objective of achieving high productivity and better quality through higher employee morale. For implementing this there need to be create awareness on '5S methodology' to workers. It was done by sticking posters in different departments regarding 5S benefits and 5S definitions.

Figure Air pipes

4.2 VSM of Cavity Blocks

Cavity blocks were used to make Insulators used in electricity transmission system. The business strategy adopted by company was Engineer-to-order. Where from designing to manufacturing to shipment was conducted by company itself. There were in total 64 cavity blocks which together on assembly forms a cavity for preparing 8 insulator units at one time in injection molding machine. For plotting VSM, supplier was store department providing P20 mold tool steel (grade-1.2311) of size 280x80x47 mm.Customer was Mould shop which performed the assembly operations to form final cavity out of these 64 pieces was considered as customer. out of 64 pieces 32 were cavity blocks and rest 32 pieces were end blocks. moreover, the process starts and ends with SAP software for getting information like BOM (Bill of materials), create production order, shortage report etc.

Calculation of current state map

Processing time = Uptime = 140.33 hours

Downtime = Setting time + Idle Time = 262.75 Hours

Lead Time = Uptime + Down time = 403.08 Hours

$$\boldsymbol{Process\ efficiency} = \left(\frac{Processing\ time}{Lead\ time}\right) x100\% = \left(\frac{140.33}{403.08}\right) x100\% = 34.81\%$$

Suggestions for Future state map

The mold cavity of Insulators is frequently manufactured by company with some minor changes in design. Apart from that, Surface grinding, Vertical milling center (VMC), CNC turning center are three major machine tools used. There are 2 surface grinding machines, 3 VMCs and 2 CNC Turning centers available but thus machine cannot be run parallel as there are other components to be machined. However, one more VMC is been going too installed in next month. It is possible to use 2 VMCs parallel. One VMC will be new and one will be existing overflowing are the improvements conducted in Future state centers machining on surface grinding machine, 2 VMCs are run parallel. First VMC will machine 32 pieces of Cavity blocks and second VMC will machined 32 Pieces of End block. This step is advisable because End block require an additional machining operation of M4 tapped holes (10 nos.) on Φ66 mm whole side. Also, there will be reduction in Total lead time for VMC by 51.75 hours.

Furthermore, after completion of In-house post processing on 32 cavity blocks and 32 End blocks, they are transported to VMC for machining OFG, runner, Gate, Vacuum and M12 tapping. The machining is carried out on top and bottom side of block. Here the blocks are assembled in quantity of 4 to form cavity of 1 unit insulator. Also, to note that while preparing future state VSM there will be two VMCs running parallely.VMC-1 will machine 32 pieces of cavity block and VMC-2 will machine 32 pieces of End block. Whichever, VMC take more time that VMC only will be shown in Future VSM, as it is the bottleneck operation.

Processing time = Uptime = 128.08 hours

Downtime =Setting time + Idle Time = 200.25 Hours

Lead Time = Uptime + Down time = 328.33 Hours

$$\textbf{Process efficiency} = \left(\frac{\text{Processing time}}{\text{Lead time}}\right)\text{x}100\% = \left(\frac{128.08}{328.33}\right)\text{x}100\% = 39\%$$

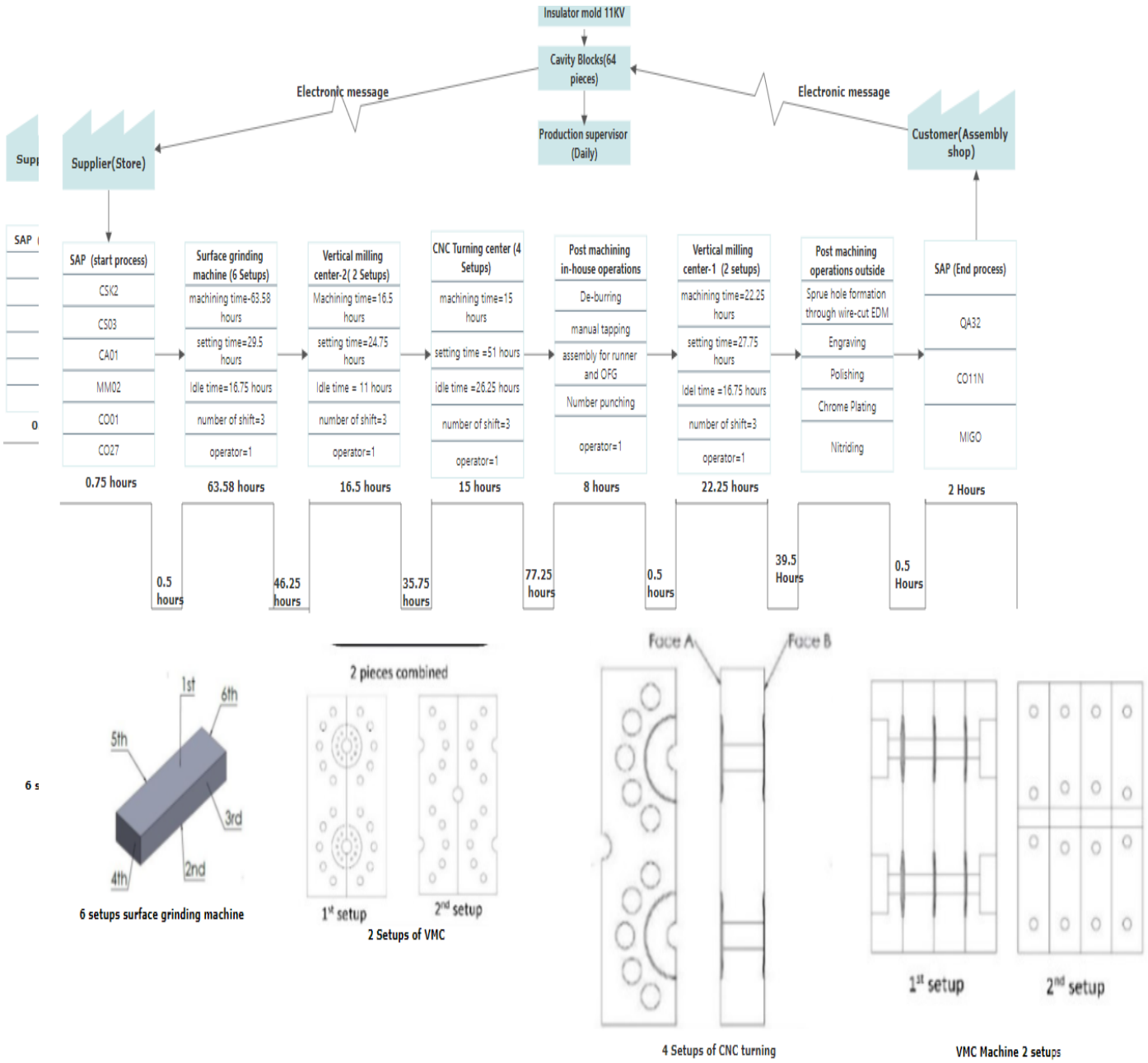

Figure 8. Current state m

Figure 9. Future State Map

4.3 Total quality Control (TQM)

Statistical process control (SPC) comes under TQM. Statistical process control (SPC) is the use of statistical techniques to control the process or production method. SPC tools such as control charts are one of the frequently used SPC tools. Though control charts one can record the data and observe any unusual events causing observation points to exceed upper or lower control limits. There are two causes for such events

Cause-1 Common causes variation which is intrinsic to process and bound to happen.

Cause-2 special cause variations which are due to external source and needs to be solved immediately.

In this study, Control charts were prepared to identify the any unusual event in the process of making deep hole drilling on Cold runner Block (CRB) using Gun Drilling machine. There were 21 holes of Φ16 mm size to be made on cold runner block. The aim of preparing control chart was to check whether or not entire process of machining i.e., Tool selection, dialing process, performing Tool offset, work piece offset, Machining (material removal) etc. are in control and free form any special cause events.

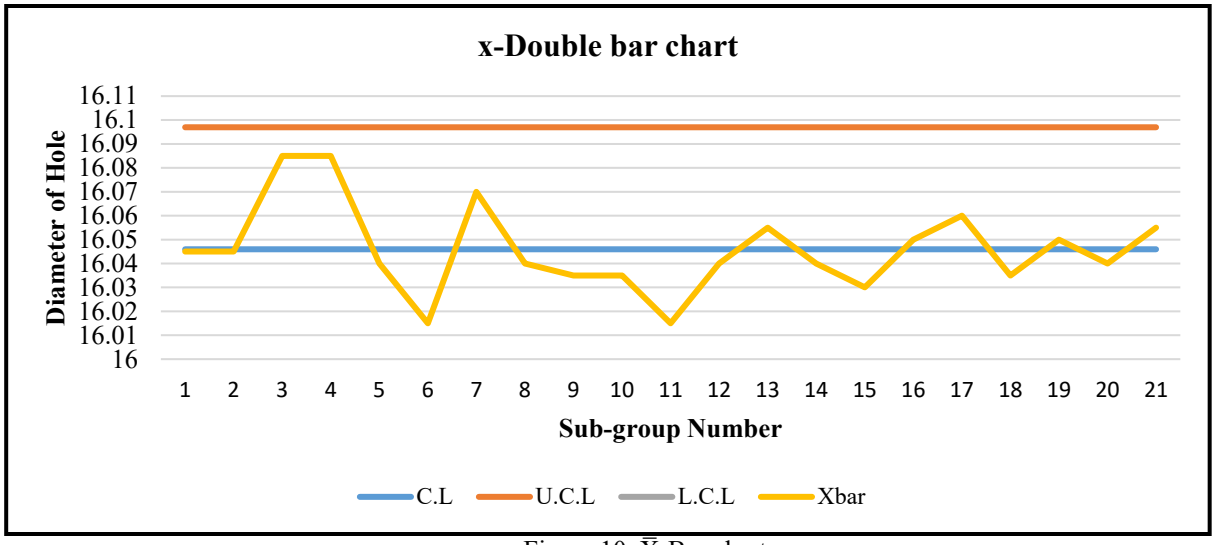

Figure 10. X̄-Bar chart

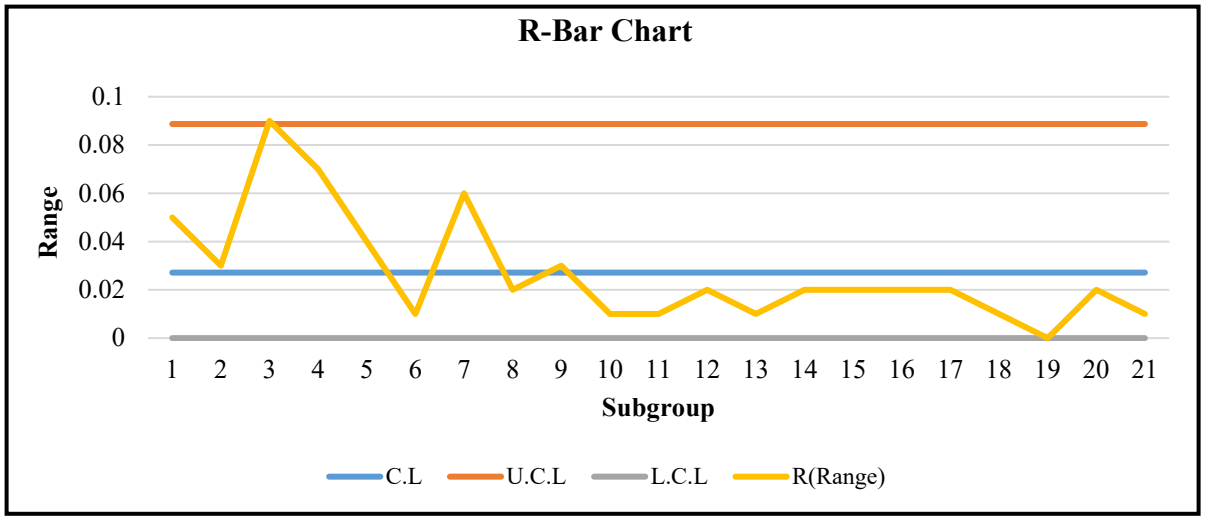

Figure 11. R-chart

As per the above graph observation 6, 11,15,18,20 was found to be out of control limit in X-bar chart. The variations were less than 0.02 mm out of control limit which is of less concern. However, the main reason for variations is high feed rate used while drilling which ultimately affected the accuracy of mechanical systems responsible for moving work piece relative to tool, due to which Gun Drill can no longer machine in range of +/- 0.01 mm repeatability. On the other hand, it can be considered as common cause variation because there is no such demand from the process to work in the range of +/- 0.01 mm. Thus, looking at the customer specification which was between Φ16 mm to Φ16.1 mm, there was no such observation going out of the specifications. Therefore, it can be concluded even though not all observations point lie between U.C.L and L.C.L but process is in control. Also, from the $\bar{R}$ chart process seems to be out of control limit but more points are below the L.C.L line and no points are above U.C.L line. Furthermore, in the case of holes the mating part can be press fitted on the other hand if whole is oversized then it is a defect. Thus, process is not out of control for machining holes.
As the process is in control showing natural cause of variation, we can now find out process capability ratio and process capability index.

A. Process capability ratio (C_p)

It is the ratio of Voice of customer divided by voice of process. Higher C_p value means the engineering tolerance is greater than the process spread which means the process is producing Holes of Φ16 mm well within the given specification by customer. If the value of C_p is less than 1 it means process is not capable. Here in the given example 21 holes of Φ16 mm are to be produced on Cold runner block used in injection molding machine. The machine used is Gun drill and its process capability ratio is calculated.
Sigma (σ) =0.012031 mm
Upper specification limit (U.S.L) = Φ 16.1mm
Lower specification limit (L.S.L) = Φ 16.00 mm
C_p =1.385263
Thus, the value of process capability ratio is greater than 1 meaning entire process of preparing setup, performing machining operation is capable to make holes as per desired specifications.

B. Process capability Index (C_{pk})

C_{pk} Shows the centeredness of the data .Having C_p greater than 1 does not mean that process is in control and near to the mean values. There are special cases where process has C_p greater than 1 but data is not cantered near the mean and process is out of control. It is to be noted that C_p value will be always greater or equal to C_{pk}Value for in control process.
C_{pk}=min (C_{pu}, Cpl)
=min (1.273, 1.49)
=1.273

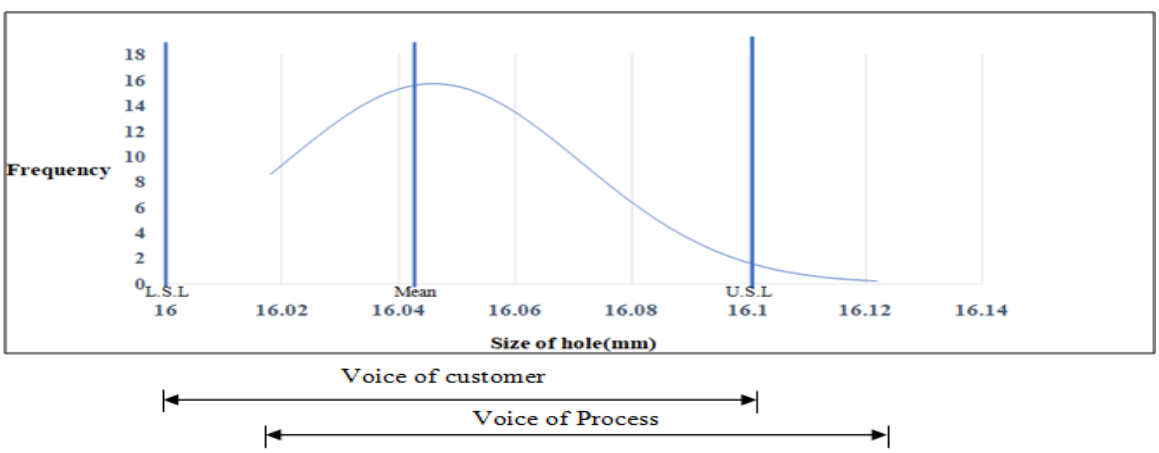

Figure 12. Data Distribution

5. Result and discussions

There were many intangible benefits of 5S implementation like Improvements in working conditions , perfect allocations of essential tools leading to decrease in tool searching time , Dedicated pellets for work-in-process resulting into decrease in percentage space utilization , reduction in human motions and transportation of good , decrement in non-value added activity, improvement in coordination and team work among employee. The above benefits were identified based on personal interview with shop floor workers. Moreover, Due to established SOPs, there was no discrepancy form worker to worker in using cleaning medium, sequence in which to assemble injection moulding machine. Furthermore, VSM of cavity block gave an overall survey on all the machining process and auxiliary process used to prepare cavity blocks. Based on which optimum operation sequencing was proposed, which can reduce machine idle time form 88 hours to 70.65 hours , reduction in machining time by 8.72% and increase in process efficiency by 4.19 %.Thus, cumulatively excluding outside post machining time lead time can be reduced from 16.79 days to 13.68 days. Furthermore, there were few observations going out of U.C.L and L.C.L lines. These variations were less than 0.02 mm out of control limit which is of less concern .Also, R-chart had some points going beyond control lines but more points are below L.C.L lines and no points are above U.C.L line. Thus, process is not out of control for machining holes. As the process was in control showing natural cause of variation, process capability index was calculated and it was found C_p value to be greater than C_{pk}Value indicating process is in control.

6. Conclusion

In this paper, case study is presented with an objective o discussing effect of kaizen implementation in an injection moulding machine. Emphasis was made on identifying and reducing waste, proper arrangement of tools, standardization of certain process. Kaizen is not a new terminology in this highly competitive marketplace. It means quest for consistently identifying problems and solving problems. The kaizen principles involve improving process and employee's performance with low investment. For a company to grow kaizen and Innovation both gets necessary. Innovation involves creating something new with requirement for huge amount of investment. Whereas; the kaizen is continuous improvement in existing system with requirement of very less capital. There, is no earth-shattering inventions required for implementing kaizen, all which is need is common sense and proper understanding of process

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Biography

Mr. Manank Patel is Final year mechanical engineering student at pandit Deendayal Energy university, Gandhinagar Gujarat, India. He has recently published a conference paper on MFAF process at international conference on additive manufacturing and advanced materials .moreover, presented a review paper on 5S at IEOM, Istanbul conference He has completed design project on CVT cooling system. He has completed various courses such as project management for mangers, six sigma yellow belt, Total quality management, Data analytics for lean six sigma from reputed institutes.

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