An Experimental Study on Scrap Reduction by Chip Removal in Cast Iron Groove of a Diesel Engine Piston

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Abstract: Technological advancements are bringing about up gradation in IC engines in terms of fuel efficiency, performance and emissions will surge product demand throughout in the next few years. IC engine is a heat engine where the burning of the air-fuel takes place inside the ignition chamber that produces high temperature and high gas pressure. Piston assists with converting the chemical energy obtained by the combustion of fuel into useful mechanical power. In manufacturing of pistons, the makers who are competing in the market wants their products to be manufactured at less expenses. The arrangement for machining a part should be very effective which takes less time and effort. Scrap is a threat to any manufacturing sector. In a large-scale manufacturing organization, which intends to produce around 800 parts per shift per line each and every single rejection record to the deficiency of Productivity. Scarps are investigated again and rework has to be done to bring down the number of damaged pistons, hence it reduces the quality of the product manufactured, devouring additional man and machine time. The main objective of this study is to minimize the number of defective pistons produced in the Automatic Transfer Line of Piston Machine Shop. Process are appropriately assessed, investigated and the main root cause behind the rejection is identified. The outcome of this study being suggestion to improve the process efficiency by parameter optimization that identifies and determines the root cause and controls the factors leading to desired output

Index Terms - Scrap, DMAIC, Root Cause, Loose Chips, Cutting Speed & Feed, Coolant;

I. INTRODUCTION

With development in productivity, an economy is able to produce and consume-increasingly more goods and services for the same amount of work. Productivity is achieved by improvising the existing methods and procedures and also by controlling rework and rejections through R&D. Rejection is a threat to any manufacturing organization. An automotive manufacturing sector aims at meeting the customer demand by providing the good quality of product. So many companies focus to reach the global market in satisfying the customer demand.

After preliminary study on machining process of piston in LVD production line at FEDERAL MOGUL GOETZE INDIA LTD, it was apparent that production line was having more defect and rework and had rejection percentage rate of about 10%. This study was conducted to in order to observe the process going on in the production line. The main objective of this project is to minimize the number of defective pistons produced in the in Automatic Transfer Line in piston machine shop which includes: Avoid accumulation loose chips in piston groove, Cycle time reduction by eliminating cleaning step, minimization of rework, reducing scrap rate, eliminating extra labor & hence reducing labor cost, Minimizing man hour on rework

Quality of the part is achieved by reducing rework, minimizing the rejection rate and limiting man hour on rework by adopting Six Sigma and certain parameter optimization. Six Sigma have become one of the top agenda for some organizations which are continuously trying to improve efficiency at lesser expenses. It utilizes a detailed investigation of the process to determine the root cause of the problem and proposes an effective improvement. Different methodologies are adopted while following Six Sigma techniques and one of them is DMAIC. Define, measure, analyze, improve, and control (DMAIC) is a quality strategy used to improve processes using data. The successful implementation of DMAIC is discussed in this paper.

Few of tools and techniques used to attain the objectives were check sheet, Pareto chart, cause and effect diagram and control charts. The method that is used to attain the stated objective, includes the study on defect nature & occurrence, collection of data on number of defects that occurred during three months of study by utilizing check sheet, identifying major defect percentage using Pareto chart, discovering the causes using cause and effect diagram and look if the process is in control or not by statistical control charts.

II. LITERATURE REVIEW

This section highlights on different journals papers regarding area of this project study. These researches have provided effective methods and techniques which will enhance the project. The literature review focusses on topics such as root cause analysis, data analysis, Pareto analysis, statistical process control.

DALGOBIND MAHTO [1] in this paper, it gives details of root cause analysis methods and techniques in identification quality of major characteristics in manufacturing sector. It is very risky to identify the problem in multistage operation. In this paper, root cause analysis was adopted to reduce the defect rate during machining in CNC machines. This study gives detail structure to solve human error in manufacturing process. This study gives an idea for collaborators to promote effective and better solution.

A.L. MOE and A.B ABU [2] in this paper, utilization of six-sigma approach in defect reducing in automobile industry. The six sigma processes like define, analysis, measure, improve and control are followed. This study takes into account of tools like quality management tools such as Pareto analysis, data analysis, cause and effect diagram and design of experiments. This study focuses at finding out the root cause to problem and providing solution. This paper has highlighted the cause for product rejection rate. This paper aims at decreasing the rejection rate from 38% to 13%. Therefore, six sigma approach was effective in reducing the defect.

C.J.RAO, D. SREEAMULUA, ARUN TOM MATHEW [3] this paper focus on Analysis the tool life by determining the optimum process parameters. This work suggests an experimental investigation of optimum cutting parameters to attain a better tool life during turning operation. This work has aluminium as a work material and tungsten carbide as tool material. By varying the different parameters like DOC, speed and feed at different conditions the tool life, surface finish, cutting force and other parameters were analysed. The results showed that the tool life is reducing as the cutting force, MRR and cutting speed increases.

VAMSI KRISHNA & ANTHONY [4] this review paper focus on Selection of Cutting Fluids. During machining process heat is generated and affects tool life, higher surface roughness and lower the dimensional accuracy of work material. The selection of coated cutting tools is an expensive another so another solution is to apply cutting fluids in machining operation. Cast iron group materials are brittle in nature & during machining they break into small size chips. The friction between tool and chip leads to small size chip formation. It was suggested that using emulsion type of cutting fluids, it increases surface finish quality and prevents dust during machining. The concentration of emulsion cutting fluid should maintained around 12% – 15% to decrease oxidation. In PCD & carbide cutting tool application, more cooling characteristics from cutting fluids are needed. This is because of high amount of heat is generated in the interface of cutting tool and workpiece material. It’s very important to use water-based fluids.

FIRASAWAJA & DUMITRU PAVEL [5] studied the Effects of lube Oil Contaminants. The lubricating oil properties can be affected by any contaminants that may occur during motor operation. Contaminants may include water, Water even in small amounts causes rusting of iron or steel. The water also results in forming water sludge (emulsions), which may also clog oil passages, pump valves and other oil handling equipment. Water also causes major foaming problems. Solid particles like dirt, dust, grit and metallic fragments, which were circulated by the lubricant these contaminants lead to excessive wear, scoring of bearing surface, and possible failure due to seizing. Contaminants like Sludge and lacquers- the sludge deposits clog small oil passages and clearances in the system. And also, Lacquers causes the sticking of valves and it resists against the continuous operation of oil pump.

2. PROBLEM FORMULATION

2.1. Problem definition-During machining of pistons in automatic transfer line, loose chips resulting from deformation cause severe chip clogging within piston groove, chips which is accumulated between the ring grooves leads to various defects in pistons like Blow-by, Increased Wear & Tear, Lube Oil Contamination, Scuff, Ring Flutter, Poor Quality and The Productivity. As result it leads problems in assembly of rings causing improper sealing in pistons leading to seizure of engine and the cycle time for production has also been increased by following manual method of cleaning the piston grooves.

Fig. 1. Tiny loose chips retained in the Piston groove

Fig. 2. Defects caused in piston due to loose chip accumulation in the piston groove

Defects	Effects
Blow by	Leads to leakage of combustion gases between a piston and the cylinder wall & flows into the crankcase of an engine. It can be loud sound coming out from the engine, followed by clouds of vent fumes.
Lube oil Contamination	Solid contaminants in engine oils leads to a high friction coefficient, wear and frictional power losses & increases the surfaces roughness as a result
Scuff	It prompts to ring wear, which results in damage of ring and leads to loss of ring control. It leads to pressure at bottom, oil consumption and piston scoring, due to the presence of abrasive materials ring scuffing condition is created. This can cause piston seizure if not addressed
Ring Flutter	Piston Ring oscillates inside the groove of the piston many times in the form of a cycle. It means to both the lifting of the piston ring off the bottom contact area and it leads to loss of sealing effect on the ring due to the loss of radial contact on the cylinder wall.
Ring Assembly Errors	Assembly errors of rings contributes to high pressure and can cause oil to flow bypassing the rings. It Leads to huge amount of abrasive carbon in the engine, which in turn leads to ring scuffing, a loss of ring control, and possible piston seizure.
Piston wear	When damage involves piston rings, it can lead oil finding its way into the combustion chamber. It results in failure of compression, increased emissions, leakage of gases from the combustion chamber, and loss of lubrication in the engine. Abrasion wear is due to presence foreign particles in the oil film, Erosion wear is due presence to metal contact between piston and rings.

Table.1 Defects & its effects due to chips

3. DATA COLLECTION

The study exhibited in this chapter includes simple approach in the analysis of rejection rate in LVD production line in piston machine shop. The production line consists of sequence of machining operation in making final product. Defects occur due to deficiency in machining process.

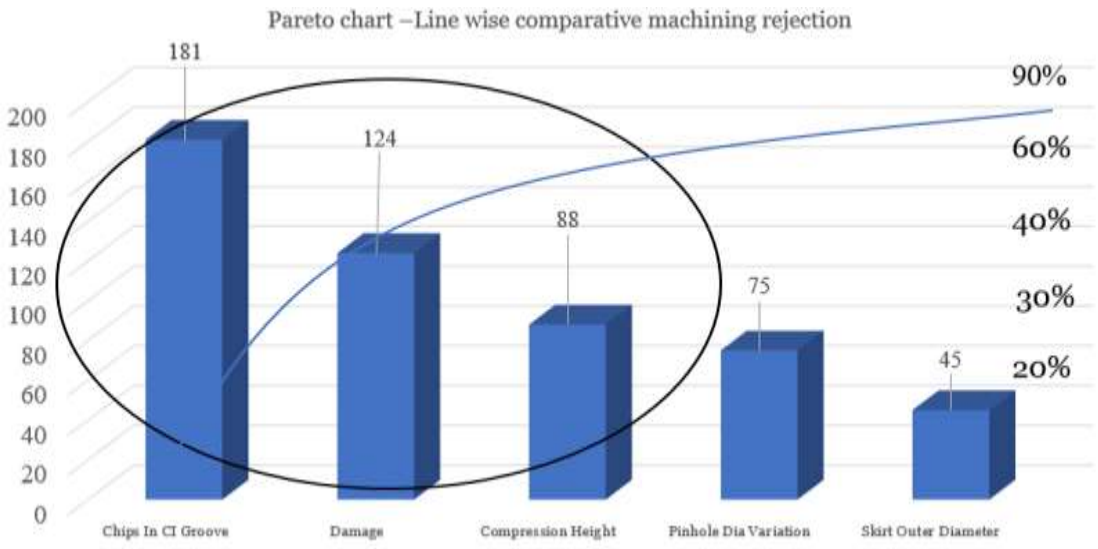

Fig. 3. Pareto Chart

The very purpose of Pareto Chart is to highlight the important factors that is the reason for major cause of problem. Pareto analysis helps to identify and classify the defect according to percentage.

Top 3 problems are selected to next level selection

1. Chips in Cast Iron groove
2. Damages on piston
3. Compression height variation

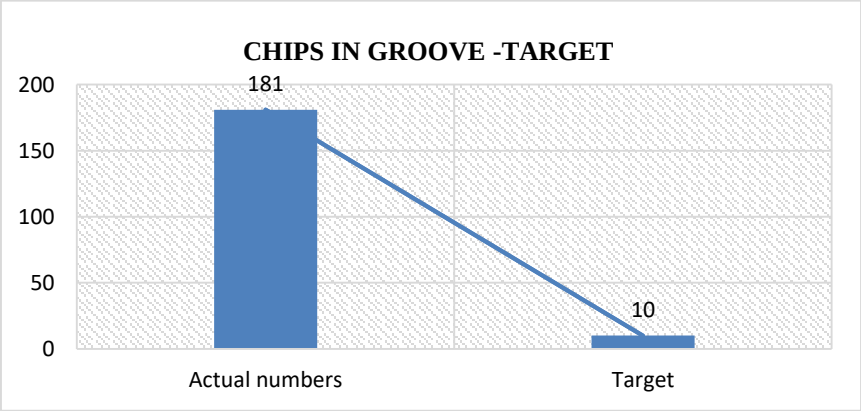

Fig. 4. Target chart

Among the above problems Chips accumulation in Cast Iron groove contributes to 90% of major problem. Our main focus is to reduce chip accumulation between CI groove group up to 10%, by eliminating non-value-added activity like rework, man hour spent on rework and by taking effective measures we can enhance the net profit, saves time and improve overall quality of product.

4. ANALYSE - CAUSE EFFECT DIAGRAM

A fish bone diagram or Ishikawa diagram or cause and effect diagram, it is a tool used to see all the major causes of a problem in order to find out the root cause of a problem. Brainstorming is done by using these tools to provide a right solution. It is usually read from left to right highlighting the possible causes of a problem, the causes are categorized by using “6 M’s” in manufacturing: Manpower, Method, Machine, Material, Mother Nature, Measurement. Using these methods as prompts we generate hypotheses

for the root cause of our problem by visually sorting possible defect causes, and identifying cause and effect relationships, and determining which causes are has the major impact on the problem.

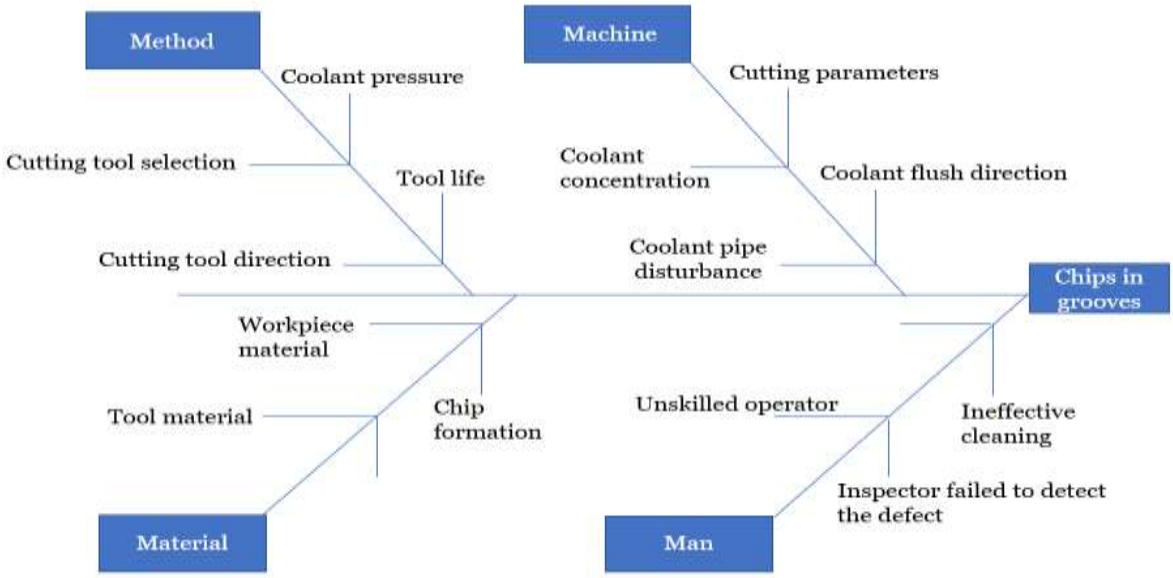

Fig. 5. Fishbone diagram

Identified Cause Type	Cause	Solution
Cutting Parameters Speed & Feed	The cutting speed influences the friction condition of the machining process and the cutting temperature and then affects the brittleness and ductility of chip material of the product and its mechanical properties, leading to the geometrical variation of chips.	Maintaining optimum cutting speed & feed based on tool and work piece material has to be opted.
Cutting Tool Direction	Cutting edge hinders upward movement of material flow and discourages chip formation. This causes low cutting efficiency.	Liquid coolant is directed across the rake side of a tool while machining a material which leads to formation of continuous chip & flushes easily.
Coolant Pressure	The required coolant pressure to break the chip formation wasn't enough, pressure coolant capability of 70/80 bars	Proper application of high-pressure coolant has a positive chip breaking and heat.
Coolant Flush Direction	Coolant pipe direction is disturbed very often due changeover of machining operation and machine set up.	The coolant jets are directed towards the cutting zone on the insert rake & flank side, blow air through the hoses to remove any chips
Coolant concentration	Coolant should be checked to maintain at acceptable concentration level, it can change 5% to 20% every day from evaporation, splashing, misting, and drag out.	Machining coolant systems is need to be monitored, maintained, and adjusted very frequently.

Table 2. Identified Causes and Solution

5. CORRECTIVE ACTION PLAN

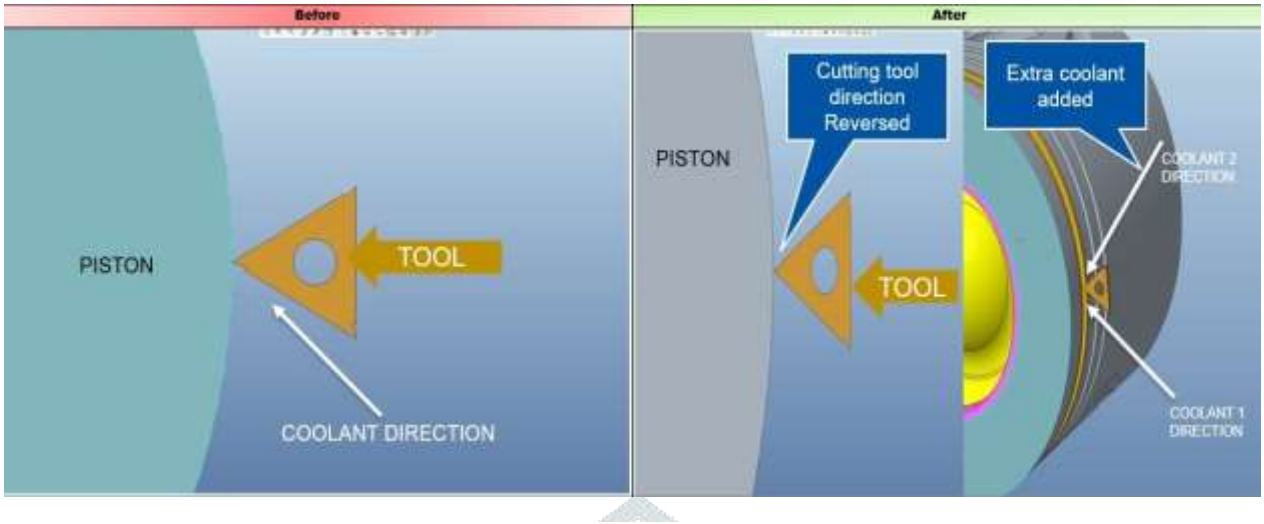

Fig. 6. Corrective Action Plan diagram

5.1. CONTROL MEASURE 1- VARYING CUTTING SPEED, FEED ON TOOL LIFE & CHIP FORMATION

After varying speed and feed, observations have been made and found that by maintaining optimum cutting speed and feed (speed= 600 to 650rpm, feed= 0.3 to 0.4mm/ rev) chips retained in the groove is reduced from 90% to 76.6%
Increasing cutting speed & leads decreases the tool life but also decrease chips retained in the groove up to 40 %. Decreasing cutting speed leads increase in the tool life but also increases the chips retained in the groove up to 89%
Increasing cutting feed leads increase in the tool life but also increases the chips retained in the groove up to 40 %. Decreasing cutting speed leads increase in the tool life but also increases the chips retained in the groove up to 89%.

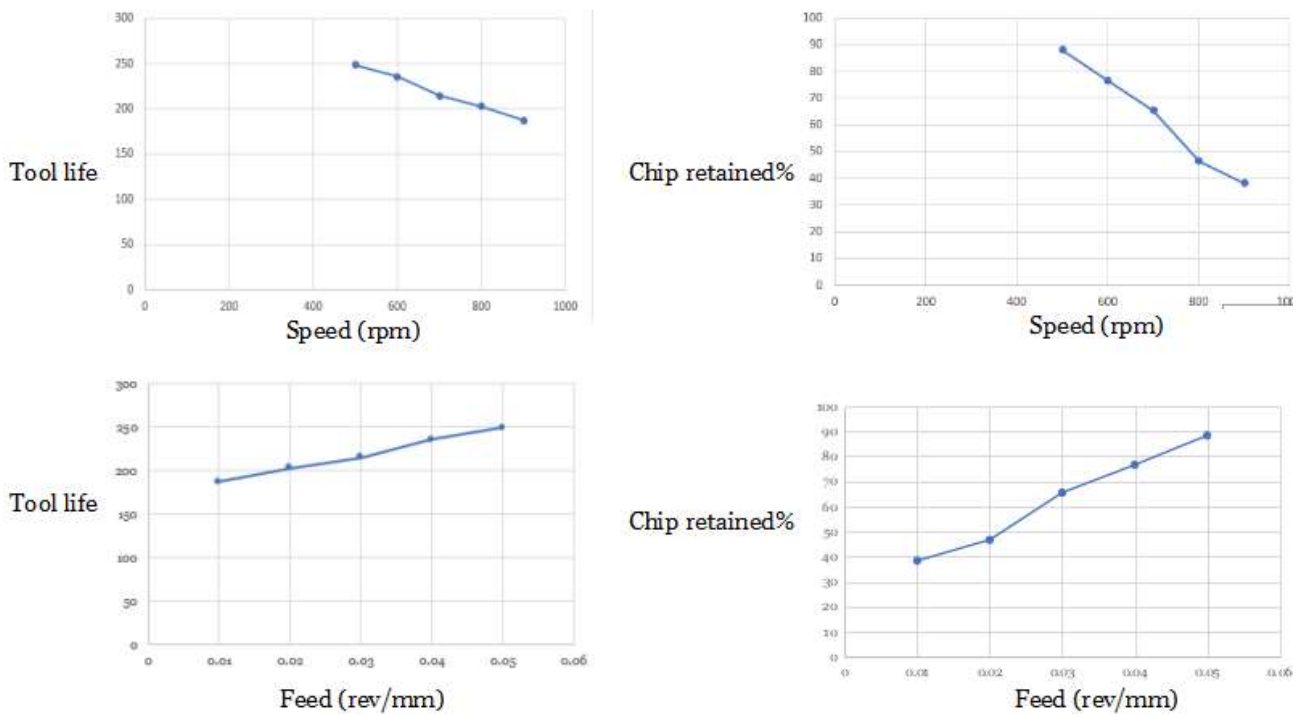

Fig .7. Graph Showing Change in Speed & Feed Along with Chip Retained in the Piston Groove

5.2. CONTROL MEASURE 2-CUTTING TOOL DIRECTION

Tool direction was downwards fig 8. (a) Where the tangential coolant flow was not there & feasibility was to introduce one. As result Cutting Tool Direction was the changed to upwards fig 8. (b) & the coolant flush was introduced to flush the chips formed.

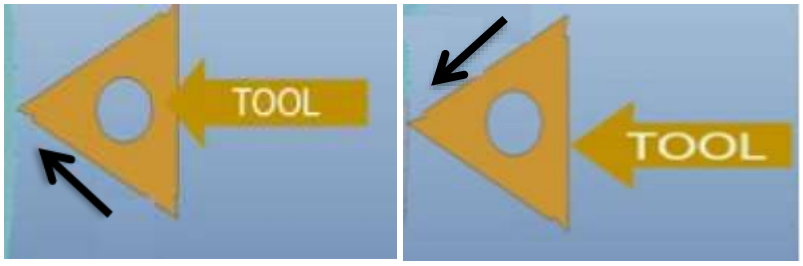

Fig.8 (a) Cutting tool direction is downward, Fig.8 (b) cutting tool direction is up ward

5.3. CONTROL MEASURE 3- COOLANT PRESSURE AND FLUSH DIRECTION

Coolant pipe was introduced both at flank face and rake face. A study stream of cutting fluid is directed towards chip- tool interface (tool rake face) and towards workpiece- tool interface (flank face) helps in carrying away tiny chip fragments retained in the piston groove also helps in increasing the tool life by decreasing the heat generated during machining process

A properly applied high pressure coolant fluid will provide quick response due to increased machine utilization and increased metal cutting efficiency. When combining high pressure along with optimized cutting tools and quick change you will get a great amount of benefits. Properly applied high-pressure coolant removes the chips from the work area so that they never contact the tool or workpiece to cause any damage. Standard pressure coolant capability was 80 bars (1160 psi), which was then increased up to 120 bar which helped in Flushing away chips and small abrasive particles from the work area.

Fig.9 Coolant pipe was introduced both at flank face and rake face

5.4. CONTROL MEASURE 4- COOLANT CONCENTRATION

Concentration control is one of the most important parameters for a coolant user to monitor. It is important for long coolant and tool life. During Machining coolant concentrations can vary 5% to 20% every day from evaporation, splashing, misting, and drag out. Low concentration is the most common cause of all coolant problems. A lower concentration even for a shorter period, could lead to problems like machine and workpiece corrosion, poor tool life and rancidity of the in-service coolant. At the start of each day, the coolant was checked to maintain an acceptable concentration level. Keeping a daily log of concentration levels for each machine provides an understanding of how the system is functioning and how much concentration levels has changed from day-to-day. After continuous monitoring the coolant concentration was increased from 4% to 6% and day to day progress was recorded.

6. RESULTS & DISCUSSION

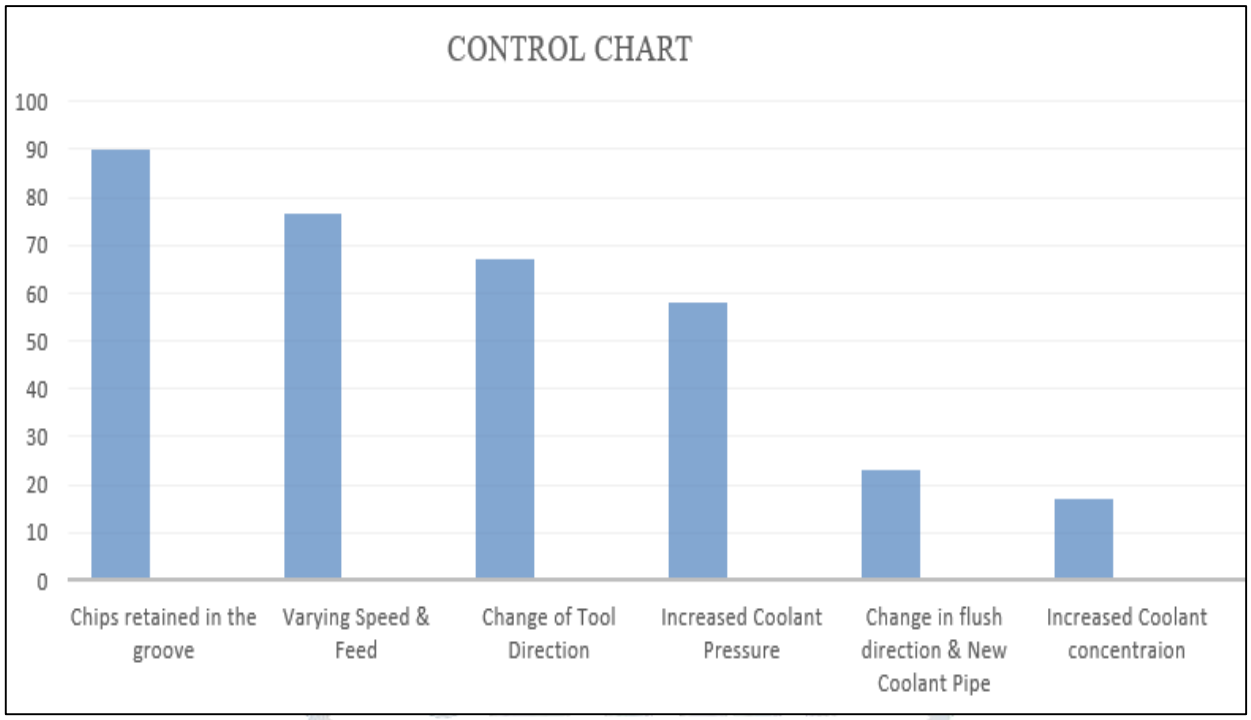

Fig.10 Control Measure Chart

From the above control chart, the x- axis represents the control measures taken and y- axis represents the percentage of chip retained in the groove of piston. After detailed study in piston manufacturing process we found that overall rejection rate can be reduced by mainly concentrating on Cutting conditions, Cutting Tool Direction, Coolant Pressure, Coolant Flush Direction, Coolant Concentration.

In the 1st method as we varied speed and feed, chips retained in grooves was reduced up to 76.6 % from 90% but it led to decreasing tool life and the cutting speed & feed was kept at optimum. The operating speed and feed were speed= 600 rpm, feed= 0.3 mm/ rev and it was improvised to speed= 650rpm, feed= 0.4mm/ rev for grooving operation, the tool selected was carbide and the piston work material was aluminum therefore speed and feed was set according to workpiece and tool material. Through this process 13.4 % of chip retained in the grooves of piston was reduced.

In the 2nd method we changed the tool direction upward from downward and the tangential coolant flush was introduced to remove the chips stuck which reduced chip retained in the groove from 76.6% to 65.8%. Through this process 10.8 % of chip retained in the grooves of piston was reduced.

In the 3rd measure we increased the fluid pressure up to 120bar from 90bar and introduced a new coolant pipe at both rake and flake face of the tool and it provided efficient chip evacuation. When combining high pressure along with optimized cutting conditions we were able to achieve good results. We observed that chip retained in the groove reduced from 65.8% to 24 % which created a major impact in chip reduction.

It's to be noted that coolant flow direction and coolant pressure focused at the right place eliminates heat generated, carries away tiny stringy chip and increases the tool life. In the later part coolant concentrating was increased up 6% and was regularly monitored for low concentration level.

Overall, after observation was made for 4 weeks, the chip retained in the groove was gradually reduced to 20% by optimizing all these parameters and to achieve better results same was to be followed.

7. CONCLUSION

The primary objective of this study was to reduce the rejection rate & increase the productivity rate in LVD segment of piston machine shop. Good quality products result in good establishment of brand name, good providers and builds better reputation in market. We should be aware that 1 % defect leads to 100% defective for customer to buy product.

With the help of DMAIC technique we were able to define the problem, measure the occurrence of defects, after analyzing the machining process we were able to find the root cause of the problem.

Through our study we found that the system before the implementation of corrective action was producing less output units/shift with scrap rate of 10%. After the implementation of the corrective actions the system showed up a daily production Maximum units/shift, with a considerable increase in the output of products with less rejections. With the help of corrective measures, gradually the chip issues were sorted out and the same was suggest to the company side.

Understanding more about manufacturing processes, helps to improve productivity. Collecting data regularly, monitoring the process regularly and reflecting on this information to identify patterns must be made a mandatory thing. Identifying bottle necks and providing suitable solution has to be done as priority.

By following all these measures, productivity can be increased with less expense and better quality. With the help of all these measures & better utilizations of tools and technology and following them regularly, leads to improvisation in productivity with reduced time consumptions, less cost and quality.

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