

APPLICATION OF LEAN SIX SIGMA METHODOLOGY IN MANUFACTURING ORGANISATION

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Abstract: In the age of globalization and disposable consumerism, the demands of global markets and consumers are pressing companies, particularly in the industrial sector, to look for production systems that can quickly and efficiently adapt to this new reality. It was in response to this need that Lean Manufacturing emerged, with methodologies and tools that aim to eliminate waste and increase productive efficiency and therefore add value to organizations. This thesis, carried out in a company of the injection molding industry, has precisely as objective, the application of Lean and Six sigma Manufacturing tools aiming at the continuous improvement.

Lean Six Sigma combines the strategies of Lean and Six Sigma. Lean principles help to reduce or eliminate process wastes. Six Sigma focuses on variation - reduction in process. Thereby, the principles of Lean Six Sigma help to improve the efficiency and quality of the process. With the help of control charts, Ishikawa diagrams and DMAIC methodology we were able to solve their problems and help increase their yield percentage.

Keywords: *Lean six sigma, Control Charts, Consumer markets*

1. INTRODUCTION

The current industrial competitive context has been defined by an increased raising in accessibility and services offered, where the consumers became more demanding, in order to obtain high quality customized products with high performances at a low price. Therefore, companies had to develop quick responsive productive systems, ready to accept new challenges. Nowadays industries are constantly seeking to innovate in order to remain competitive, to reduce their waste and consequent costs associated with their production processes, increasingly seeking the implementation of the Lean philosophy in their organizations. However, in some companies, this has been implemented superficially, since they focus on the massive application of the tools, without understanding that the Lean is a system that must be transversal to the entire culture of the organization. The injection molding company where this work was carried out, was precisely intended to start this way of responding to this need to produce what the customer wants, with the least associated waste, aiming at competitiveness and increasing production efficiency.

This paper mainly focuses on Six Sigma quality philosophy that would be implemented in order to identify the problem during the Injection Molding process. The “Six Sigma” Philosophy is used as it provides a step-by-step quality improvement methodology that uses statistical methods to quantify variation. Being highly disciplined process Six Sigma helps to focus on developing and delivering very close to perfect solutions, products or services. The Present study focuses on the quality improvement of one of the major defect in Plastic Injection Molding of components. One of the main defect which is the causes of the rejection is “Black specks” (small dark particles on the surface of the opaque parts), on the appearance of the product. In order to study the problem a research has been carried out by studying the literature review on TQM, Six Sigma and visiting a company.

The objectives of this paper is to identify the problem and root cause of Black specks, that occurs in the plastic products during the Injection Molding process and which reduces quality, due to defects in manufactured parts, and to suggest measures for the improvement in the Injection Molding operation using Six-Sigma DMAIC methodology. This paper encompasses introduction and implementation of Six Sigma tools for removing the Black specks in the Injection Molding process. DMAIC stands for Define, Measure, Analyze, Improve and Control.

2. LITERATURE SURVEY

Though the term lean was introduced by Krafcik (1998), it became globally renowned after the book ‘The machine that changes the world’ by Womack, Jones and Roos was published in 1990. After that, lean became related to supervisor productivity and quality supposedly due to the use of various lean tools and practices (Oliver, Delbridge, Jones and Ipwe, 1994). In their quest to operationalize lean by means of individual lean tools, practices and principles.

Saja Ahemad Albliwi, (2017) Heriot Watt University, UK had published this paper in 2017, “Implementation of Lean Six Sigma in Saudi Arabian organizations: Findings from this survey”. In the paper the extent to which LSS has gained importance in various organizations has been discussed. A survey for 400 organizations using Qualtrics online software was undertaken and found that less than half of the industries have completely implemented and analyzed. It has been found that LSS implementation in Saudi Arabia is still in early stages. At last it is suggested that LSS implementation in all the industries can make the country economically strong by effective utilization of the resources and thereby reduce wastages and improve quality.

Seyed Moji Bzahradeh (2016) He is from Malaysia has published a paper in 2016, “Lean manufacturing implementation in production industry” in Iran. Lean manufacturing (LM) practices and tools are among the key concepts that assist manager and engineer’s competitiveness in expanding global market. They have emphasized some implications and suggestions that reducing cost is more effective and decreased inventory is less effective in lean manufacturing implementation.

Osama Alaskari, RubenPinedo(2016):- Cuenca, Mohammad Munir Ahma from Middlesbrough, UK presented a paper in 2016, “Development of a methodology to assist manufacturing SME’s in the selection of appropriate lean tools”. This paper focuses on the selection of an appropriate lean tool for manufacturing SME’s the methodology contains of an quantitative approach that can assist the SME’s in identifying the appropriate lean tool the findings revealed that the proposed methodology was effective in identifying the appropriate lean tools for companies. The strength of using this methodology is that appropriate lean tool can be ascertained relatively easily and inexpensively. There is the prospect of this methodology being applicable to most types of SME’s this methodology is proven to be use full for recommending the application of lean tools in a company.

Kurthozak(2015):- Professor from coastal Carolina University, USA has published the paper in 2015, “lean psychology and the theories of thinking, fast and slow”. In the paper the author has provided in sites about the psychological factors that contributes to lean success as a holistic and adaptive system. In the paper the author has used the concept of lean psychology to describe the relationship between psychology theories and lean. Finally, he has concluded that by applying lean psychology, organizations can go beyond superficially adapting a check list of tools and techniques to more fully take advantage of lean and improve their operational performance.

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Sreedhar Karunakaran(2016):- He is from Kolkata, India has published a paper in 2016 “Innovative application of LSS in aircraft maintenance environment”. The purpose of this paper is to eliminate the waste and inefficient procedures in the maintenance organizations of aircraft so as to reduce its down time and increase mission availability. Customized lean Six Sigma (LSS) was applied at the task level and servicing cycle level to reduce the task content, cycle length and resources in servicing. The loading of the servicing facility was simulated through a simulation program developed from a statistical analysis of historical data for validating/simulating/determining optimum loading of servicing facility. Optimization at the task level and its re-organization at the servicing cycle level reduced the cycle length by 55-68 per cent and manpower resources by 26 per cent. This further reduced facility-level manpower by 25 to 40 per cent, capacity requirements by more than 33 per cent and annual aircraft downtime by 78 per cent. The paper provides cursory approach to lean practitioners in the elimination of wastes in the maintenance of capital assets like aircraft.

3. OBJECTIVES

- Ability to use a structured approach to process improvement
- Ability to use DMAIC (Define, measure, analyse, implement and control) methodology.
- Skill to predict, prevent and control defects in a process. Understanding the elements of wastes.
- Skills to achieve sustainable quality improvement through process improvement.
- Understanding of variation in processes.
- Skills to reduce variation in processes and achieve predicted outcomes.
- Ability to identify, measure and analyse process potential.
- Usage of inferential statistics usage of hypothesis testing.
- Reduce production cycle time.
- Improve labour productivity by reducing the idle time workers.
- Flexibility in production with minimum changeover costs and changeover time.
- Increase output by achieving the above-mentioned objectives.

4. METHODOLOGY

Six Sigma is contemporary and adaptive set of methodologies move towards improving and developing the efficiency and effectiveness of manufacturing processes, it has evolved to become present within the successful business improvement strategies and is attributed with reducing the number of defects in manufactured goods to less than 3.4 per 1 million units.

DMAIC

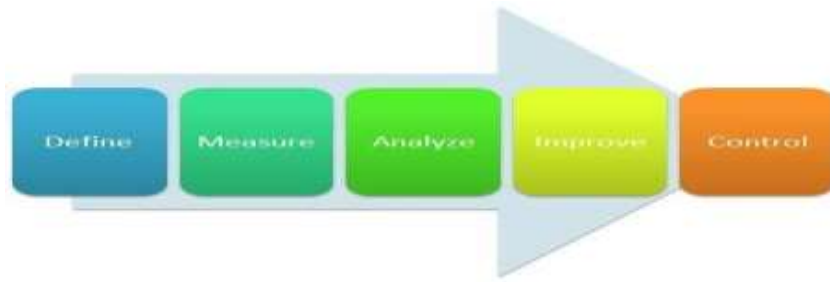


Fig 1. Methodology

The Six Sigma methodologies that is most applicable to the manufacturing or production side of a product, DMAIC includes these project stages:

Define – Address the identification of specific information to be examined

Measure – Record data and use metrics to track effectiveness and evaluate efficiencies

Analyze – Utilize critical thinking skills to review data and clarify goals

Improve – Create changes in business processes geared toward improvement and better alignment with corporate goals

Control – Build a system of check and adjustments for ongoing improvement in production processes

Table 1: Widely implemented Lean Tools across manufacturing verticals (Automotive, Machine tool and electronics and Consumer Products).

Automotive industry	Machine tool industry	Electronics & Consumer Product industry
5S	TPM	VSM
VSM	Standardized work	Kanban
Kanban	VSM	Visual Management
Kaizen	Batch production	5S
TPM	JIT	Machine cell
		Layout
Line Balancing	Kaizen	Line Balancing
OEE	One piece Flow	Multi Skill Workers
SMED	Kanban	Standardized Work
Batch Production	Root Cause Analysis	Poka - yoka
Standardized work	FMEA	TPM
Machine cell layout	Six sigma	Kaizen
Line balancing	Kanban	JIT (just in time)
Poka – Yoka		Six sigma

Table 2: Widely implemented Lean Tools across manufacturing verticals (Construction, Process and Textile)

Construction industry	Process industry	Textile industry
5S	TPM	VSM
5 Whys	SMED	5S
Kaizen	VSM	Andon
Poka – Yoka	5S	Kaizen
Heijunka	Visual control	Six sigma
VSM	Poka -Yoka	Kanban
Kanban	Andon	Poka -Yoka
Root cause analysis	Pull system	JIT
Business information modelling	Kanban	TPM
SMED	Heijunka	

Effective steps for lean manufacturing implementation

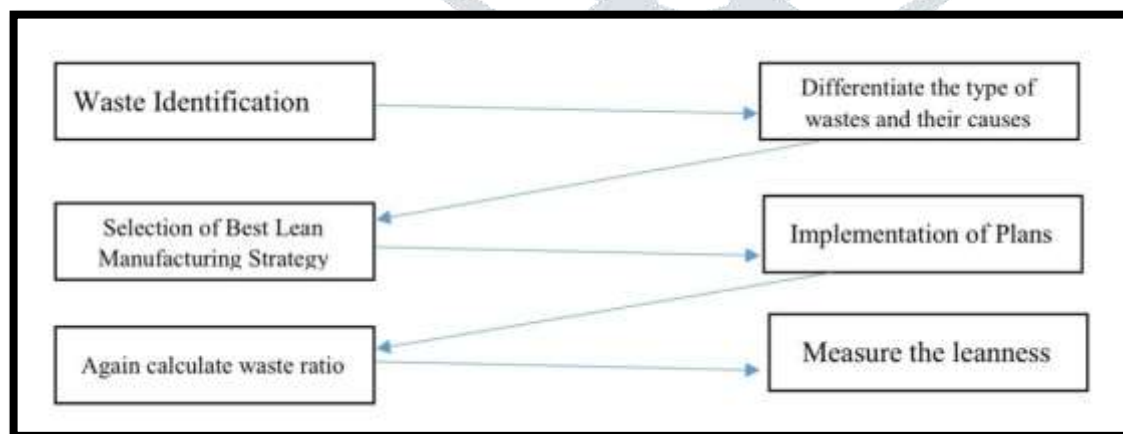


Fig.2 Effective steps for lean manufacturing implementation

- **Waste Identification:** Every industry knows that there is some waste but not able to find out all types of hidden and unhidden wastes in industry.
- **Differentiate type of wastes and also their cause:** This is very important to differentiate all types of waste and their causes. If the cause is eliminated then automatically waste will be reduced. There are so many techniques to eliminate different wastages.

- **Choose best lean manufacturing strategy to eliminate these wastes:** In this step, we select a suitable lean manufacturing strategy for the identified wastes. There are many techniques which will give optimum solution for this plan. So, we make appropriate plan for elimination.
- **Implementation of plans:** After making plan, next step is implementation the plan.
- **Again calculate waste ratio:** Compare the current waste table with past record.
- **Leanness measurement:** it can be measured with different lean measure techniques.

METAL INJECTION MOLDING PROCESS

1. Incoming material inspection of powder and binders

Indo-MIM maintains a specialised and well-equipped metrology department. analyse and operate the raw powders, feedstock and finished materials

Materials laboratory has the capability to

2. Compounding

Precise and error proofed batch preparation of powders and binders are done in well controlled compounding equipment is used to process the mixture into a consistent, high quality feedstock. The mixing process and material characteristics are continuously monitored.

3. Molding

In molding the latest and most precise closed loop injection molding equipment on the market, monitor the injection molding machine and its output continuously using SPC tools

4. De binding

Debinding is nothing but converting normal martial to hardness material that should be done in (50c) for every material the hardness part is also called as Brown part

The debinding process is done by the general motor (GM). It takes around 3 to 5 hrs to make one batch and one batch consist of 50 products

Sheet of operation

Ceramic inspection and inventory control

Process for debinding

- Ceramic material from inhouse or supplies
- Check the physical quality as per mentioned
- After verification of material store the material in ceramic area
- Inspect the received material
- Specific required dimension in ceramic drawing and same will be inspected
- In ceramic drawing not all specific dimension is not mentioned so contact the engineer and get the survey done
- Sample used for specification or object is 10% of the batch received if the part is more than 100 number
- If the received quantity is less than 100 number inspect all the batch
- Record the data on process capability for the dimension
- If the martial s not meet the required point then reject the material
- Move the approval batch for heat treatment approximately (200 F)
- After heat treatment move the material to the bake out cycle
- Re inspect
- If it is within the specification (other parts) mix the batch with production batch
- After every process upgrade the inventory list

5. Sintering

Sintering takes place in either batch vacuum or high temperature continuous pusher furnaces. Vacuum furnaces maintain precise temperature control using various process gasses that allows for flexibility to process a wide variety of alloys.

Sheet of operations

❖ Part staging process

- Check parts staged as per staging work instrument from molding
- Verify the staging and load it into graphite plate
- If not properly staged make sure part doesn't enter machinery
- Use ceramic tray from ceramic department approval only
- Ensure the ceramic tray (bend/cracks) and it must be free from stuck
- Ensure part name, martial, tracker number and mini weight loss before staging the part
- During staging min 5min gap should be maintained between parts

❖ Graphite loading procedure

- Before every graphite tray used it must clean
- Clean the graphite tray with specific procedure
- Remove all the deposit and stuck material and burning material from both the sides of the graphite tray
- Put traceability tag and identification tag

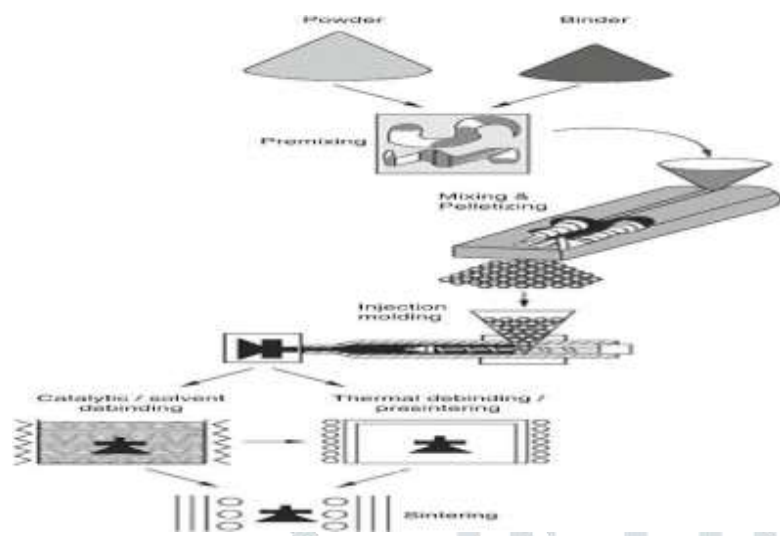


Fig: MIM process

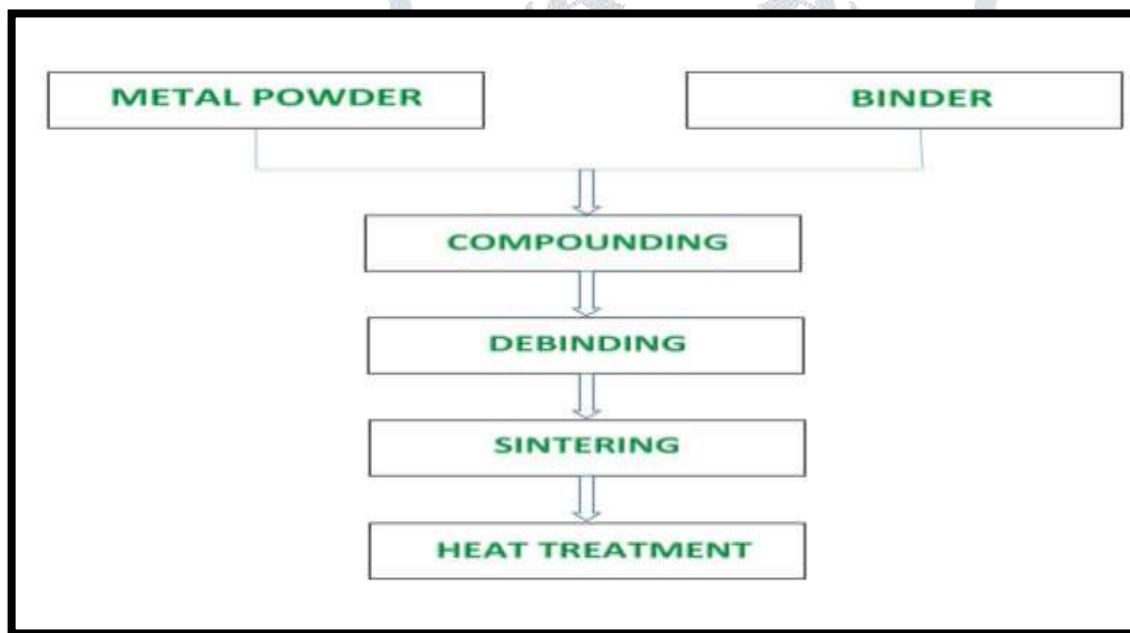
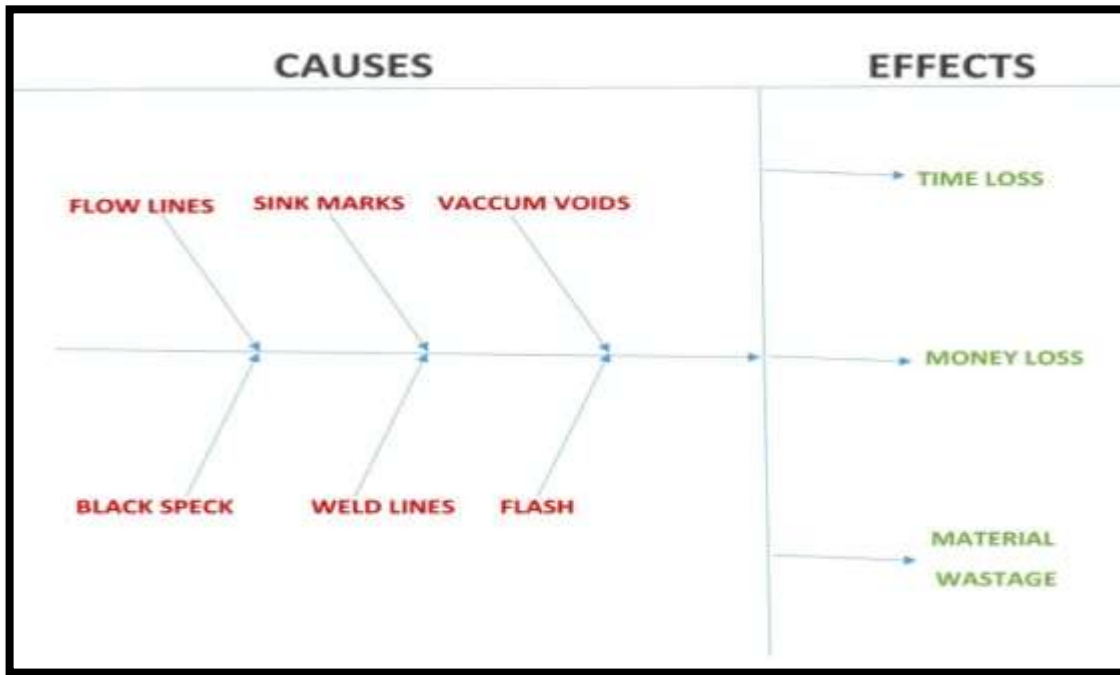


Fig: 3. Procedure flow chart

Ishikawa Diagram for Major Rejections:*Fig. 4 . Ishikawa Diagram Rejections*

DATA COLLECTION

Table 3: Finding out the product is scrap or non-scrap by using infinity software

MACHINE	B-26	B-39	B-12	B-34
Number of cavities	8	2	8	2
Full time	0.41 sec	0.54 sec	0.88 sec	0.49 sec
Cooling time	12	15	5	12
Cycle time	30	36	30	30
Switch over time	16.50	17.50	7.20	14
Nozzle temp	140	140	140	185
Injection speed	40	35	40	25
Peak pressure	430	718	745	563
Pressure 1	650	700	850	400
Pressure 2	350	350	500	200
Time 1	0.40	0.20	0.50	0.80
Time 2	3.00	2.00	3.50	1.40
Time 3	-	-	-	-
Injection pressure1	1200	1200	1200	1200
Injection pressure 2	1200	1200	1200	1200
Mold chiller temp(core)	45	50	40	41
Mold chiller temp(cavity)	45	50	40	41
Clamping force	550kw	450kw	550kw	500kw

Table: 4. Weight Inspection Values

Sl no:	Software Used	Part no:	Tool no:	Bat no:	Tracker no:	Estimated UCL & LCL	Result (g)	Conclusion
1	Infinity	SMW062	2001	18	T21031420	15.296 15.205	15.220 15.218 15.214 15.218 15.217	Not a scrap
2	Infinity	SMW064	2001	10	T21041475	2.176 2.158	2.170 2.168 2.168 2.170 2.170	Not a scrap
3	Infinity	SMW186	2001	21	T20031445	6.990 6.982	6.991 6.992 6.992 6.991 6.993	Scrap
4	Infinity	SIG621	2001	12	T21031435	5.690 5.667	5.681 5.681 5.681 5.682	Not a Scrap

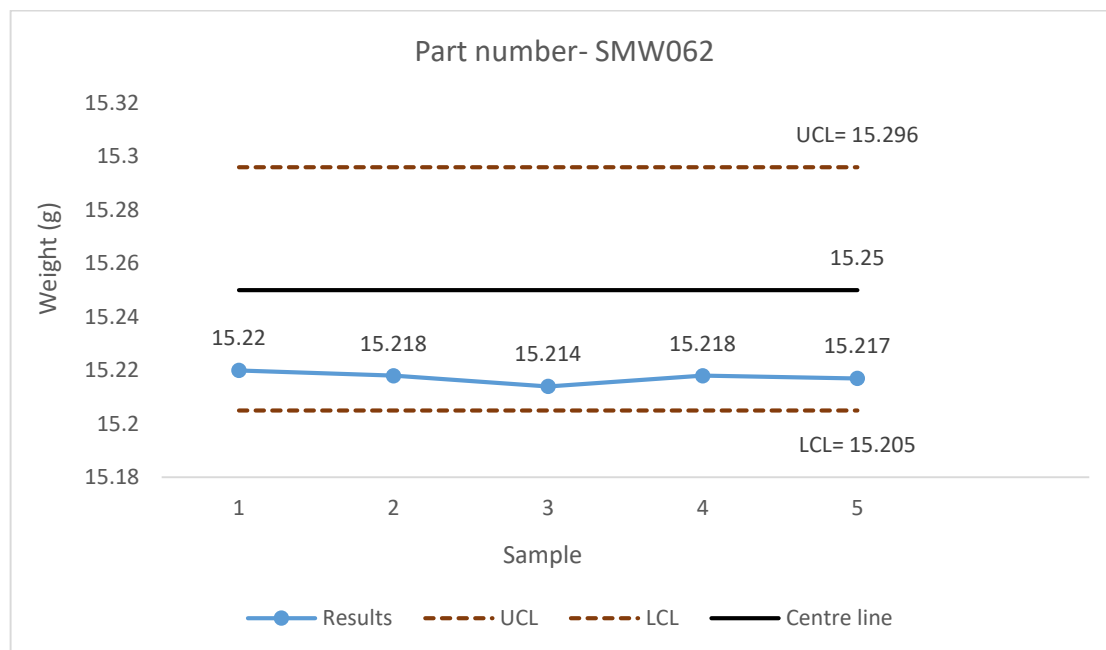


Fig 5: Graph representing the Part number SMW062 is not a scrap

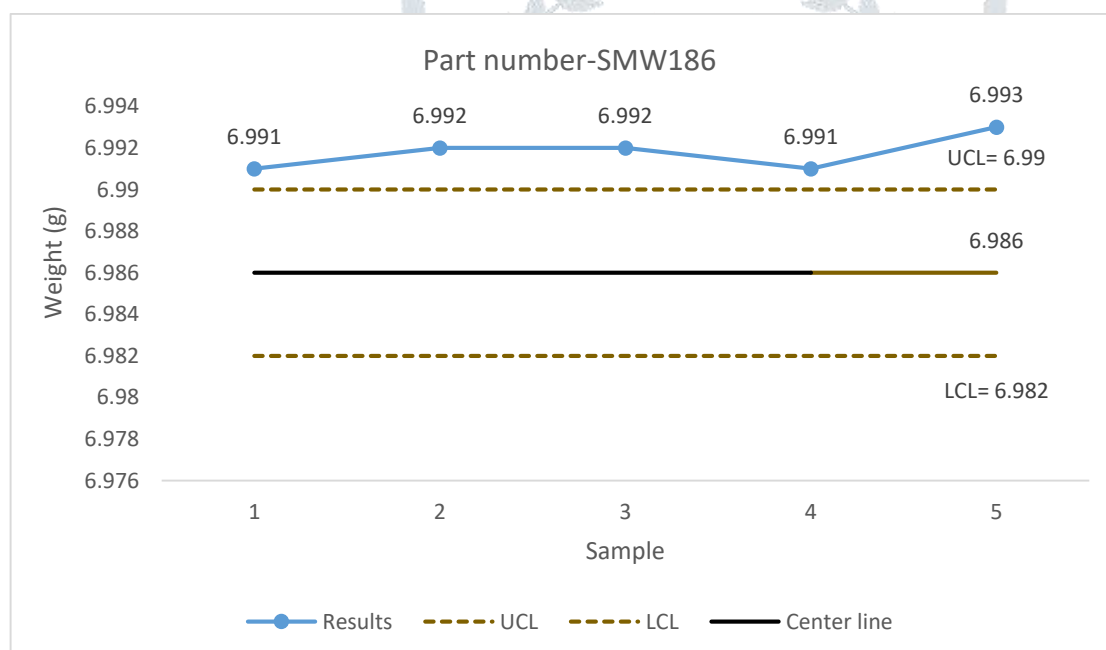


Fig 6: Graph representing the Part number SMW186 is a scrap

Six sigma is being applied to the MIM process and tool used is DMAIC method which has the following stages:

Define the process

Before the process can be investigated, all circumstances have to be defined. Such circumstances are often described as SIPOC (Suppliers, Inputs, Process, Outputs and Customers)

Measure phase

In measure stage the defects per million opportunities is (DPMO) is calculated measure to help monitor progress towards the project goals. Customer expectations are defined to determine "out of specification" conditions.

Analyze stage

In analyze stage the root cause of the Black Specks defect is found out in the parts produced which is due to five major factors which are machine, environment, operator, method and the material.

Machines are one of the factors that must be given Black Specks consideration. The machine contributes a lot of possibilities to Black Specks rejection defect. Examples, without proper parameter setting, it will result to a carbonized screw. Aging machines also can lead to defects. Maintenance also plays an important part because, without maintenance the performance of machine will be affected and the desired output could not been gained.

When an operator does not have enough experience and practice, it is quite obvious that the operator produces more defects than the others. Defects might occur when jobs carried out without guidance of leader or without any instruction. Besides that, number of defect will increase when untrained operator or new operators are assigned to do the job. The work method is another major cause of the problem. It was found that the operator did not know the correct method set the machine and the parameters but only followed the instructions without knowing the correct method. As a result the operator can lead to black specks defect or other rejection.

Besides that, a material is an important medium in injection moulding process that contributes to some major defects. Examples, when material are contaminated with other foreign particles it will affect the properties of the part and at the same time it lead to major defects.

Some other factors are-

DAMAGED BARREL OR SCREW; A cracked injection cylinder or pitted screw is a cause of material hang-up and degradation. Eventually this degraded material breaks loose and enters the melt stream, appearing as specks

CONTAMINATION FROM LUBRICANTS: Excessive use of mould release will clog vents. The trapped air cannot be evacuated and burns. Also, grease that is used for lubricating cams, slides, ejector pins, etc., can seep into the mould cavity and contaminate the moulded part.

Improve stage

After collecting and analysing the data suggestion is recommended to reduce the defect. And the suggestions are to clean Barrel and use of cleaning agent for cleaning Screw and Barrel Screw.

MINIMIZE DOWNTIME AND REDUCE SCRAP; Special Material is cleaned on the first pass, minimizing machine downtime to maximize the productivity. This also reduces scrap so do not waste resin.

ECONOMICAL; Only a small amount of material is needed to purge quickly and effectively. It has unlimited life.

SAFE TO USE; Special material is non-chemical / no-hazardous and no abrasive. It does not cause wear on machines. It is safe for machines and operators and safe for disposal.

Based on the suggestion given, the rejection rate can be reduced and at the same time the sigma level can be improved.

Control stage

Control stage is another important stage before completing DMAIC methodologies. This stage will describe the step taken to control. One of the common types of quality tool used is the control chart.

Sigma level is computed as $Z = 0.8406 + \{29.37 - 2.2211n(DPMO)\}$ Where, $DPMO = \frac{DPU}{CTQ} \times 10^6$,

DPU= defect per unit =Rejection/Total pieces, CTQ=critical to quality....through SIPCO (supplier, input, process, customer, output)

II. Result and Discussion

DMAIC method of Six Sigma was implemented considering four machines as shown in Table 1.

It shows that the highest rejection rate was identified in the month February (2012). Thus lowest sigma level i.e. 4.2356 was recorded for the month of February whereas the highest being 4.331 for May. The study is focussed for February. Further, Machine E02 has higher rejections due to black specks. Thus this machine will e required for analysing the root cause.

Table: 5. Total output and sigma level

Work	Output			Machi nes		total	DPMO	sigma	Defects (%)	yield
		1	2	3	4					
Week 1	4000	146	180	110	214	650	162500	2.48	16.25	83.75
Week 2	4000	120	145	95	165	525	131250	2.62	83.75	86.87

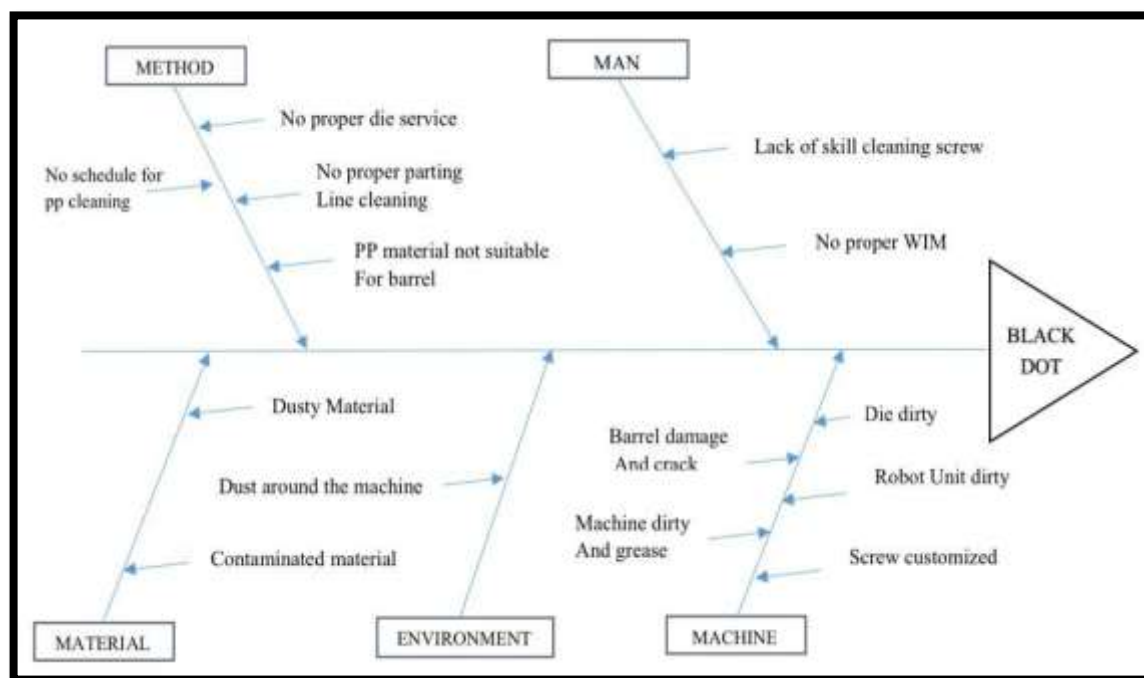


Fig:7. Ishikawa diagram showing the root cause analysis for black specs

CONCLUSION

In this journey to the business, an organization is successful if specific goals for serious processes of the organization are identified. The modern management programs implemented can be modify and simplify activities towards the ultimate goal of the business. When the selected program in six sigma, the organizational goal is to reach a sigma level of 6, or the objective of 3.4 DPMO. Organizations with such operational quality re called six sigma level companies being a member of “world class” ones. In identifying the defects, the six sigma focuses on developing a very clear understanding with the customer requirements and hence it is fully customer focused.

To apply the six sigma in any organization, or any management it needs to make sufficient planning in providing overview training for all employees. Besides, that is necessary one of the associates who is very knowledgeable about the management structures and cultures as a six sigma black belt leader. They are trained to take the control for the project and coaches are made to take lead and get into all analytical tools and software suitable for data analysis and lead the organization into the improvement in the long run.

The most important points to keep in mind as management gets ready to implement six sigma are:

- Showcasing the case well studied for change;
- Concentrate on problem and starting with cautions and performing it slowly
- Working with right team to work with
- Creating the right foundation to work;
- All team member should involve in all the stages of the work;
- Communication with team members;
- Train in accordance with the strategies undertaken.

These projects based on six sigma have to be very carefully reviewed, planned and selected to maximize the benefits of implementation. The projects have to be feasible, organizationally and financially beneficial and must customer satisfaction. However, the projects under study need get reviewed periodically in order to evaluate them and gets hands on the performance of six sigma tools and techniques being employed. The fundamental concept of six sigma because it is important for small and large organization to employ six sigma concepts into their working methodology for quality improvement and bottom-line enchantments. In six sigma there should be regarding leadership commitment, what six sigma would bring o the organization, how does the six sigma work, six sigma business strategies, six sigma methodologies, new six sigma, benefits of six sigma, The five principles of lean, Introduction to some important lean tool, What is six sigma, what is lean six sigma, Seven waste production in industry, Objectives, Quality tools, Impact of implementing the lean six sigma on companies, critical success factors and the future scope of six sigma work, in addition to that DMAIC steps to be very important to understand the cause of the problem and to eliminate the wastes and make profit to that company the competition is high all around the globe and management is under pressure to produce the quality products at the right time and with the lowest price. The implementation of six sigma with all efforts that it requires and investments that it need is the answer because it would make the path for the growth of the future.

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