

## **Six Sigma Methodology In A Plastic Injection Molding Industry: A Case Study**

**Ashish Mishra, Pankaj Mishra and Sachendra**

*Krishna Engineering College  
95, Loni Rd, Mohan Nagar  
Ghaziabad, U.P., India*

### **Abstract**

This study mainly focused on six sigma quality philosophy and other related philosophy that is implemented in these studies in order to identify the Current problem or rejection criteria facing by a manufacturing company. The root cause in this study for the black dot defect had been successfully determined. Corrective action to overcome this quality problem has been suggested. The “Six Sigma” Philosophy provides a step-by-step quality improvement Methodology that uses statistical methods to quantify variation.

**Introduction** Most recent quality philosophy to be adopted by businesses around the world is known as “Six Sigma.” The founder of the “Six Sigma” philosophy is Mikel Harry (Harry and Schroeder, 2000). Mikel Harry developed and implemented his “Six Sigma” philosophy with the Motorola Corporation and the philosophy has had great success at the GE Corporation (Harry and Schroeder, 2000). Six sigma focuses on the reduction and removal of variation by the application of an extensive set of statistical tools and supporting software. This powerful business management strategy has been exploited by many world class organizations such as General Electric (GE), Motorola, Honeywell, Toyota, ABB, Sony, to name a few from the long list. Six sigma applications in the service sector are still limited although it has been embraced by many big service oriented companies such as J P Morgan, American Express, Lloyds TSB, Egg, City Bank, Zurich Financial Services, BT, etc.

Six sigma today has evolved from merely a measurement of quality to an overall business improvement strategy for a large number of companies around the world.

The concept of six sigma was introduced by Bill Smith in 1986, a senior engineer and scientist within Motorola’s communication Division, in response to problems associated with high warranty claims. The success of the efforts

at Motorola was not just achieving six sigma quality level rather the focus was on reducing defect rate in processes through the effective utilization of powerful and practical statistical tools and techniques. This would lead to improved productivity, improved customer satisfaction, enhanced quality of service, reduced cost of operations or costs of poor quality, and so on.

### **Literature Review**

Nowadays, Six Sigma has been widely adopted in a variety of industries in the world and it has become one of the most important subjects of debate in quality management. Six Sigma is a well-structured methodology that can help a company achieve expected goal through continuous project improvement. Some challenges, however, have emerged with the execution of the Six Sigma. The development a novel approach to create critical Six Sigma projects and identify the priority of any projects. Firstly, the projects are created from two aspects, namely, organization's business strategic policies and voice of customer. Secondly, an analytic hierarchy process (AHP) model is implemented to evaluate the benefits of each project and; a hierarchical failure mode effects analysis (FMEA) is also developed to evaluate the risk of each project; and from which the priority of Six Sigma projects can be determined. Finally, based on the project benefits and risk, projects can be defined as Green Belt, Black Belt, or others types of projects. An empirical case study of semiconductor foundry was utilized to explore the effectiveness of this approach [1]. The cost benefit analysis is crucial, especially for companies whose products have a small profit margin. Researchers are undergoing and two optimization models are proposed that will assist management to choose process improvement opportunities. These models consider a multi-stage, asynchronous manufacturing process with the opportunity to improve quality (scrap and rework rates) at each of the stages. The first model is to maximizing the sigma quality level of a process under cost constraint while the selection of Six Sigma alternatives to maximize process returns is considered by the second model [2]. The strategic criteria are evaluated by the management team using a Delphi fuzzy multiple criteria decision-making method. Then, the tactical sub-criteria which contain additional operational issues are evaluated by the Six-Sigma Champion [3]. Implementation of the DMAIC (Define, Measurement, Analyze, Improve, and Control) based Six Sigma approach in order to optimize the radial forging operation variables. In this research, the authors have kept their prime focus on minimizing the residual stress developed in components manufactured by the radial forging process [4]. Despite the pervasiveness of Six Sigma program implementations, there is increasing concern about implementation failures. One reason many Six Sigma programs fail is because an implementation model on how to effectively guide the implementation of these programs is lacking. Using a successful Six Sigma program in a Network Technology company, the purpose of this research is to develop an effective implementation model which consists of six steps. The first step is to perform strategic analysis driven by the market and the customer. The second step is to establish a high- level, cross-functional team to drive the improvement initiative. The third step is to identify

overall improvement tools. The fourth step is to perform high-level process mapping and to prioritize improvement opportunities. The fifth step is to develop a detailed plan for low-level improvement teams, and the sixth step is to implement, document, and revise as needed. Important for both practitioners and academicians, implications of our implementation experience along with directions for future research are provided [5].

Based on literature review, this research aims at

1. To utilize six sigma methodology in performing the study.
2. To study the “Black dot” rejects utilizing QC tools at the
3. Identified production lines.
4. To identify the root causes of the “Black dot” rejects.
5. To recommend actions to improve the Black dot rejects and
6. Sigma level.

### **A Case Study**

The application of Six-Sigma methodology is a statistical analysis approach to quality management. In this approach the rejection ratio of 60-tone injection Moulding production department in a company VIMAL PLASTICS, Noida was analyzed statistically using DMAIC methodology and suggestions for quality improvement will be made to the department.

### **DMAIC – Define stage**

#### **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). The circumstances around the Moulding of Jar are listed in chronological order below.

- Suppliers -Material supplier, Reliance
- Inputs -Material, PMMA(Acrylic)
- Process -Receive PMMA and load into hopper
  
- Dry PMMA
- Feed PMMA into Moulding machine
- Mould Jar
- Deliver Jar
  
- Outputs -Jar
- Customers - external customers

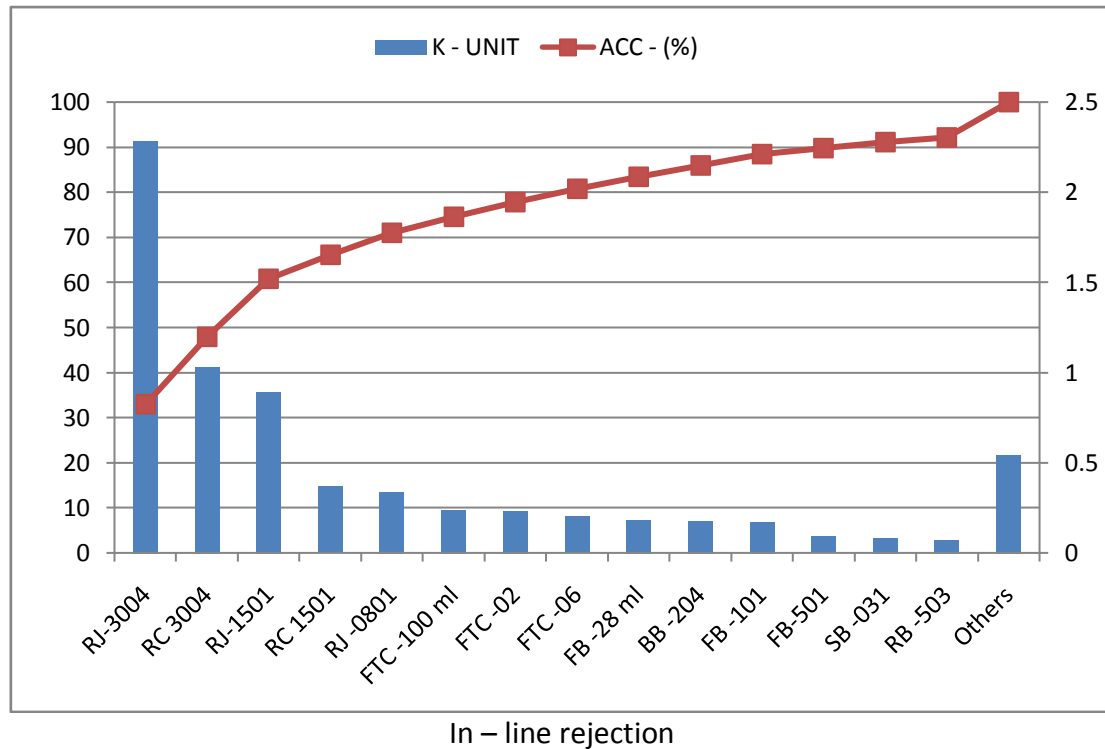
**Identify the current reject problem**

The in-line rejection based on the part produced.

**Table 1. In- line rejection based on part produced**  
TOTAL 6.92

Model	In-line reject unit	In-line (k-unit)	Percentage	Acc.
RJ- 3004	2284	2.284	33.01	33.01
RC-3004	1033	1.033	14.92	47.93
RJ- 1501	895	0.895	12.93	60.86
RC-1501	371	0.371	5.36	66.22
RJ-0801	338	0.338	4.88	71.10
FTC-100 ml	239	0.239	3.45	74.55
FTC-02	231	0.231	3.34	77.89
FTC-06	202	0.202	2.92	80.81
FTC-28 ml	186	0.186	2.69	83.50
BT-204	177	0.177	2.56	86.06
FB-101	175	0.175	2.53	88.59
FB-501	92	0.092	1.33	89.92
SB-031	84	0.084	1.21	91.13
RB-503	72	0.072	1.04	92.17
Others	543	0.543	7.85	100

Table 1 shows the rejection data for 60 tone injection Moulding for the month of May 2009. This data shows the highest rejection ratio compared to the previous months rejection data ). Figure 1 shows the Pareto diagram for the particular part rejects based on the code name. The result shows that, part named ROUND JAR-3004 have the highest rejection rate for the month which is 2284 units and contributes 33.01 % of the total rejection rate. Since the part has the highest rejection rate it has been taken as the studying element for the research.



**Figure1: In- line rejection based on part produced**

#### **DMAIC- Measure stage**

Data was collected for 4 months continuously from June to September **2009** (Appendix B) for output line reject that occurred in the 60 tone injection Moulding part production that focused on the production of part named Round Jar-3004 to track down the problem encountered by this particular part. Since there are four machines producing the same part, the reject data were collected for each machine. These data were used to calculate defect per million opportunities (DPMO) for each month. Table 2 shows the total output, reject quantity, DPMO and sigma level for each month from June to September **2009**.

**Table 2: Total output and Sigma level**

Month	Output	Machine(reject quantity)				TotalRej/mth	DPMO	SIGMA
		E01	E03	E04	E06			
June	149760	60	935	910	405	2310	3084.9	4.2356
July	149760	53	937	908	367	2265	3024.8	4.2420
Aug	149760	59	946	878	398	2281	3046.2	4.2397
Sept	149760	23	914	495	291	1723	2301.1	4.3301
<b>TOTAL</b>	<b>599040</b>	<b>195</b>	<b>3732</b>	<b>3191</b>	<b>1461</b>	<b>8579</b>		

**Sigma level from the above database for four months June 09 to Sept 09.****Basic steps to Compute Sigma level**

- Identify the CTQ
- Define defect opportunities
- Collect data on defects
- Compute DPMO
- Use Standard formula to arrive at the Sigma level

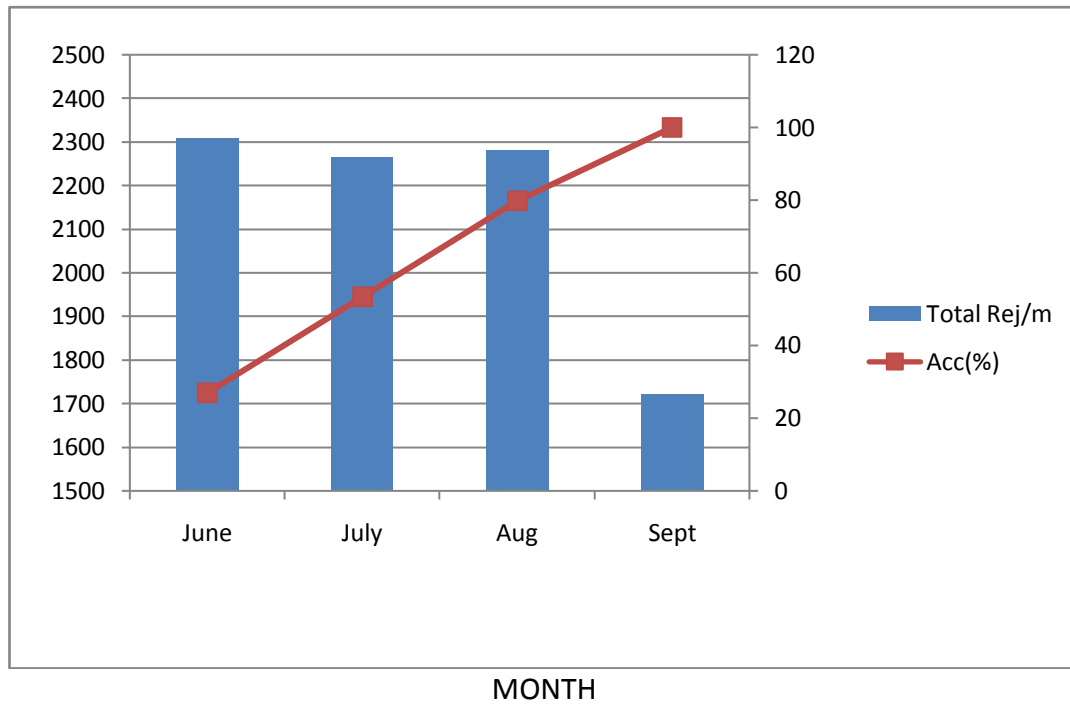
**Formula used to compute Sigma level**

- Total pieces manufactured = P
- Total rejection = R
- Total CTQ = O
- Defect per unit (DPU) = R/P
- DPO = DPU/CTQ
- DPMO =  $DPO \times 10^6$
- Sigma level ( Z ) =  $0.8406 + \sqrt{\{29.37 - 2.221 \ln(DPMO)\}}$

**Computed Sigma level for June 2009**

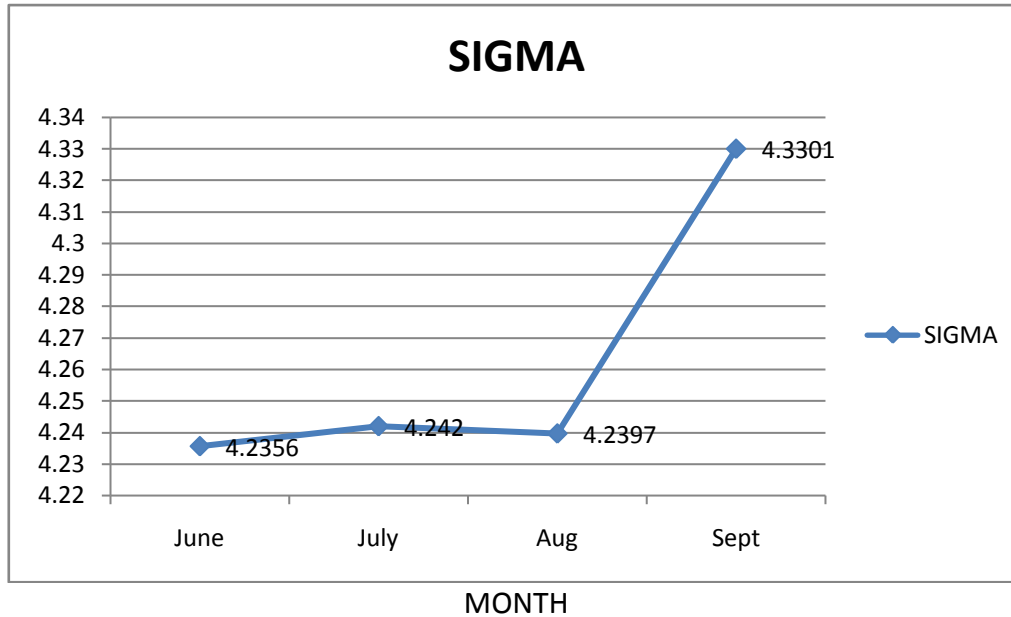
- Total pieces manufactured, P = 149760
- Total rejection, R = 2310
- Total CTQ, O = 5
- DPU, R/P = 0.0154247
- DPO, DPU/CTQ = 0.0030849
- DPMO,  $DPO \times 10^6 = 3084.9$
- Sigma level  $\bar{\sigma} = 0.8406 + \sqrt{\{29.37 - 2.221 \ln(3084.9)\}}$   
= 4.2356

A bar graph was constructed as in Figure 2, for each month based on Reject Quantity. Figure 2 shows that the highest rejection rate was identified in the month **June 2009** meanwhile for other months the data collected shows small variations.



**Figure 2: In-line rejection from month June to September 2009**

Based on the data in table 2, the sigma level for the process were calculated and illustrated as in figure 3. Calculation for the sigma level July to **Sept 09** is attached in Appendix C. The figure 3 explains that the sigma level from the month June to September ranging from 4.2356 to 4.3301. This shows the average sigma level for the whole process is 4.262. The lowest sigma level was recorded for the month June and the highest sigma level was recorded on the month September. Since the sigma level for month June has the lowest sigma level, the studies or research will be focused on the month June. This data will used to track down the problem that contributes to highest reject on the part.



**Figure 3:** Sigma level from month June to **September 2009**

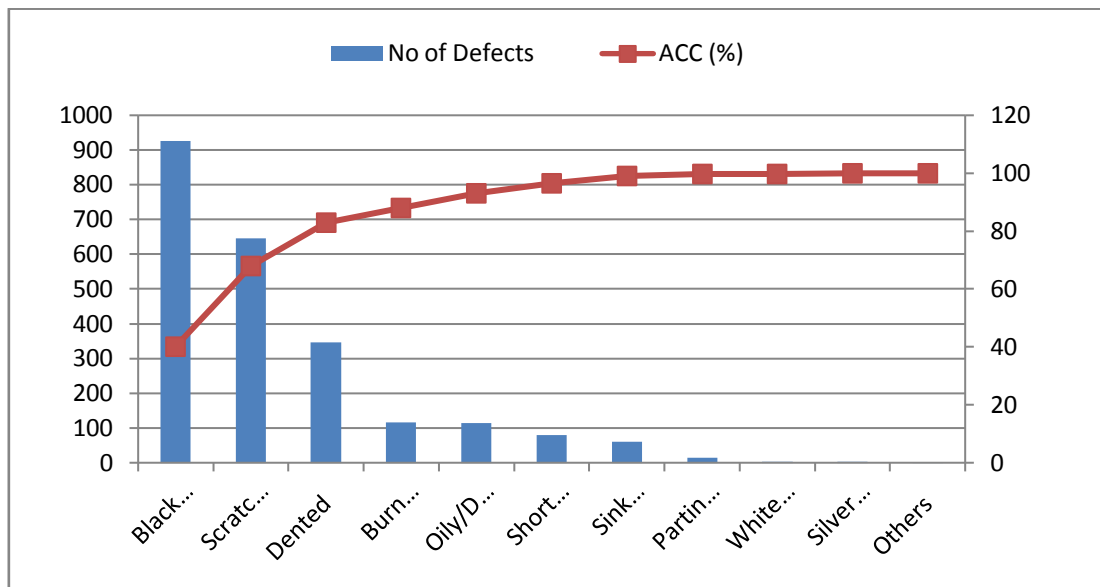
#### **DMAIC- Analyze stage**

Table 3 shows the defect type's data for the month **June 2009** and Figure 4 illustrate the Pareto diagram for this particular data. As mentioned before, there are four machines which produce the same part which known as Round Jar-3004 and the data for defects were collected based on machines. This is to identify the machine E03 which contributes to the highest rejection rate. The defects which are recorded in Table 3 are the comment types of defects which normally occur on plastic parts which produced by using injection Moulding process. Figure 4 explains that black dot defects are the major contributor for the rejection rate for the month June which contributes almost 40% of the total rejects compared to other defects. If defect data compared by machine, still black dot contributes the highest defects compared to others and for the machines, machine E03 contributes to highest black dot defect compared to other machines. As a measure to track down the problem machine E03 will be used to analyze the root cause for the black dot defects since it shows the highest rejection rate and the analyze data will be used as references for other machine.



**Table 3:-** Reject data based on the defect type for month **June 2009**

Defect	Machine No				SubTotal	Percentage	Acc.
	E01	E03	E04	E06			
Black Dot	38	347	273	268	926	40.09	40.09
Scratches	2	304	245	144	645	27.92	68.01
Dented	0	160	165	22	347	15.02	83.03
Burnmark	0	0	117	0	117	5.06	88.09
Oily/Dirty	14	43	50	8	115	4.98	93.07
ShortMold	2	64	10	3	79	3.42	96.49
Sink Mark	2	8	42	8	60	2.60	99.09
PartingBurr	1	8	6	0	15	0.65	99.74
Whitemark	0	0	0	3	3	0.13	99.87
SilverMark	0	0	2	0	2	0.09	99.96
Others	1	0	0	0	1	0.04	100
Total = 2310							

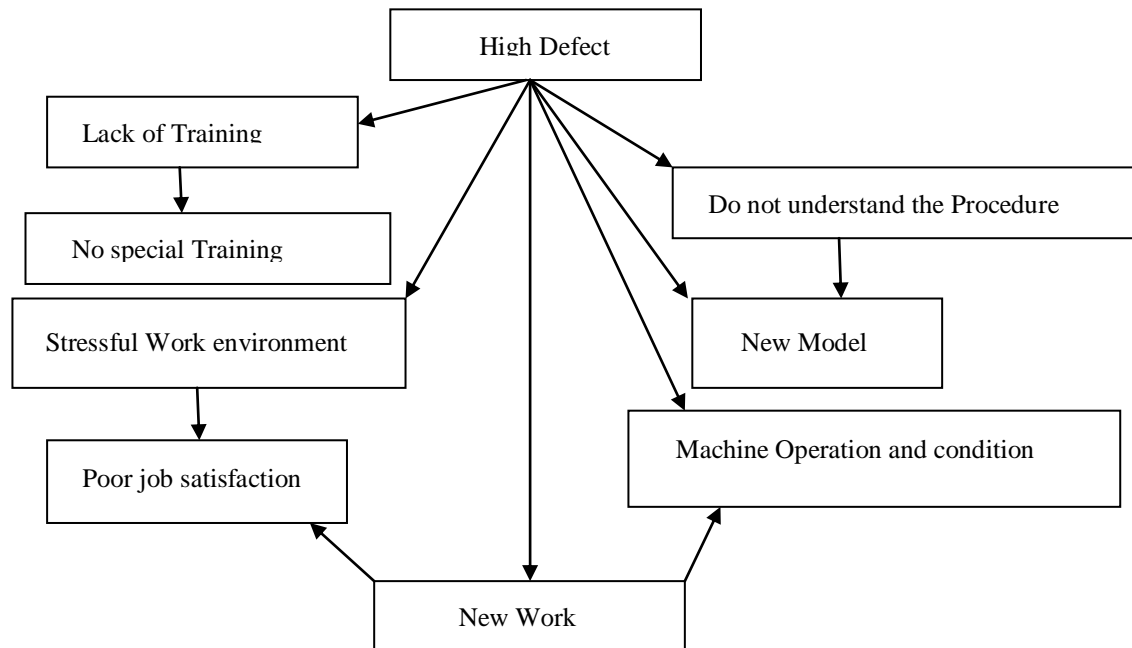
**Figure 4:** Reject data based on the defect type for month **June 2009**



**Figure5:** Jars with black dot defect

**Potential causes for high defects occurred in part Round Jar-3004**

Analyzing the rejects based on models indicates that the highest percentage of defects occurred in model Round Jar-3004. Figure 6 shows the potential causes for high defects. The number of defects is high when there are new models being introduced. It may be due to the operators not given enough training or no special training for the operator to understand the correct method to produce the part. Besides that, the high defects might contributed by the machines. The machines Might operate by new technicians that lack of training or experience. This will lead to misjudging in solving the problem during the machining process. Stressful environment also can lead to high rejects. It's a human nature, where when workers find that the working environment stressful, this will lead to dissatisfaction in working condition and at the same time it also leads to high defects. Besides that the method or standard operation principles also can lead to high defects. Methods or SOP for the particular process might be varying from the actual SOP for the process and this will contributes to wrong machine setting or operation parameters.



**Figure 6:** Potential causes for high defects

### Root causes analysis

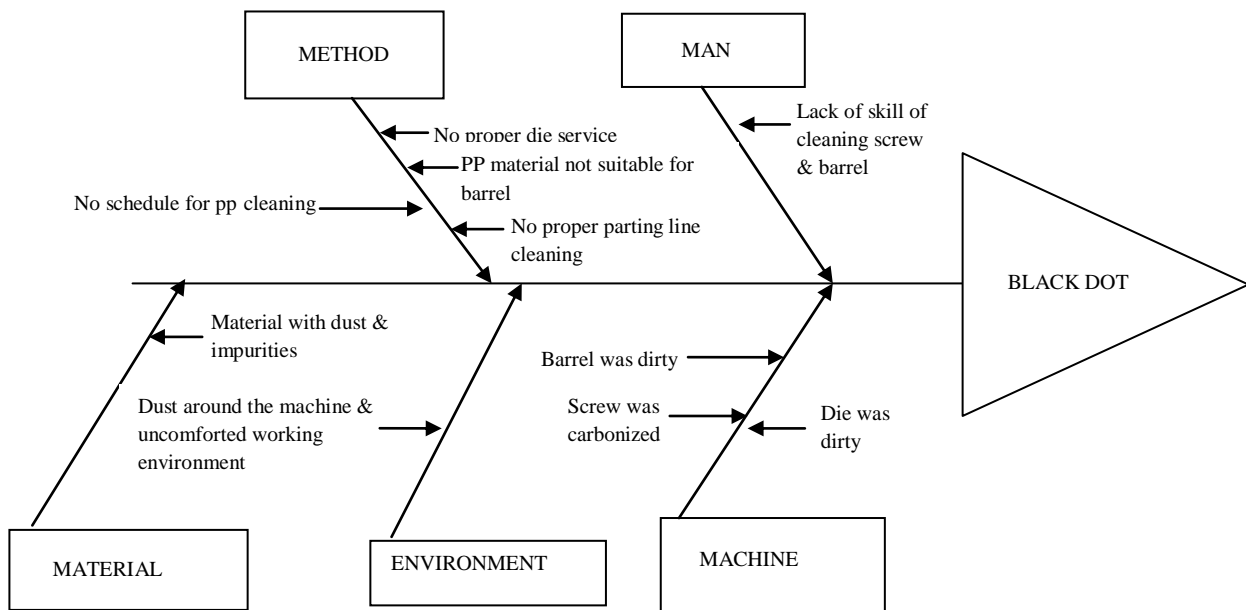
In order to determine the exact and most likely causes of major defects, a Brainstorming section was carried out with the Quality Engineer. Through the brainstorming section, all possible causes including major and minor causes were listed in the cause and effect diagram. The following section will discuss on the root causes for black dot defects.

### Root causes analysis for Black dot defect

The wrong part defect is caused by five major factors, which are machine, environment, man (operator), method and the material. Figure 7 shows the cause and effect diagram for the black dot defect. Machines are one of the factors that must be given black dot consideration. The machine contributes a lot of possibilities to black dot 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 be 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 are carried out without guidance of a leader or without any instruction. Besides that, the number of defects will increase when untrained operators 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 to 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 dot defect or other rejection. Working environment was another cause for the defect. It is based on company policy where, there are two shift with 12-hours working period each in the production department. This can cause the operator to loose concentration, become tired and bored doing the job. As a result the organizations will hire new operator who do not have any knowledge or experience in the production line. Besides that, a material as an important medium in injection molding process also contributes to some major defects. Examples, when material are contaminated with other foreign particles it will effects the properties of the part and at the same time it lead to major defects.



**Figure 7:** Root causes analysis for black dot

### Summary on the analysis

As the conclusion for the analysis stage, the major defect found were black dot and several problems were identified as the main problems causes high defects in 60 tone injection Moulding line. The main problem identified from the analyze section is the machine. This due to the data which colleted indicates that the major problem for each machine is the black dot. This shows that the major defect might cause by the machine. Although there are other factors affecting the reject problems, the main consideration has given to the machine factor. The next section will discuss about suggestion for improvement.

### DMAIC- Improve stage

After collecting and analyze the data, the identified defect was the black dot defect which caused major quality problem in the 60 tone injection Moulding line. Cause and effect diagram was also drawn to identify the causes of major defects. From here suggestions recommended to reduce the defects was Screw and barrel cleaning.

## Screw and barrel cleaning

### Screw cleaning

The injection screw was carbonized before cleaning, which was used to mould the Round jar-3004. After a request as a suggestion to the engineering group to clean the screw. Sand paper and some chemical solvents were used to clean the screw. Most of the dirt was identified from the material which was carbonized because of overheated in the barrel. The overheated material will stick on the screw and will released slowly each time injection and caused for the black dot on the surface of the Round jar-3004.

### Barrel cleaning

It was seen at the time of study the condition of machine which was not cleaned properly where a lot of scrap material surround the tie bar and hydraulic unit area. This condition will lead to a situation where the foreign materials or scrap material will mixed original material and at the same time leads to black dot and other defects.

After carry out the cleaning activity on the machine, the machine was covered with a plastic to make sure no dirt or dust affects the machine condition.

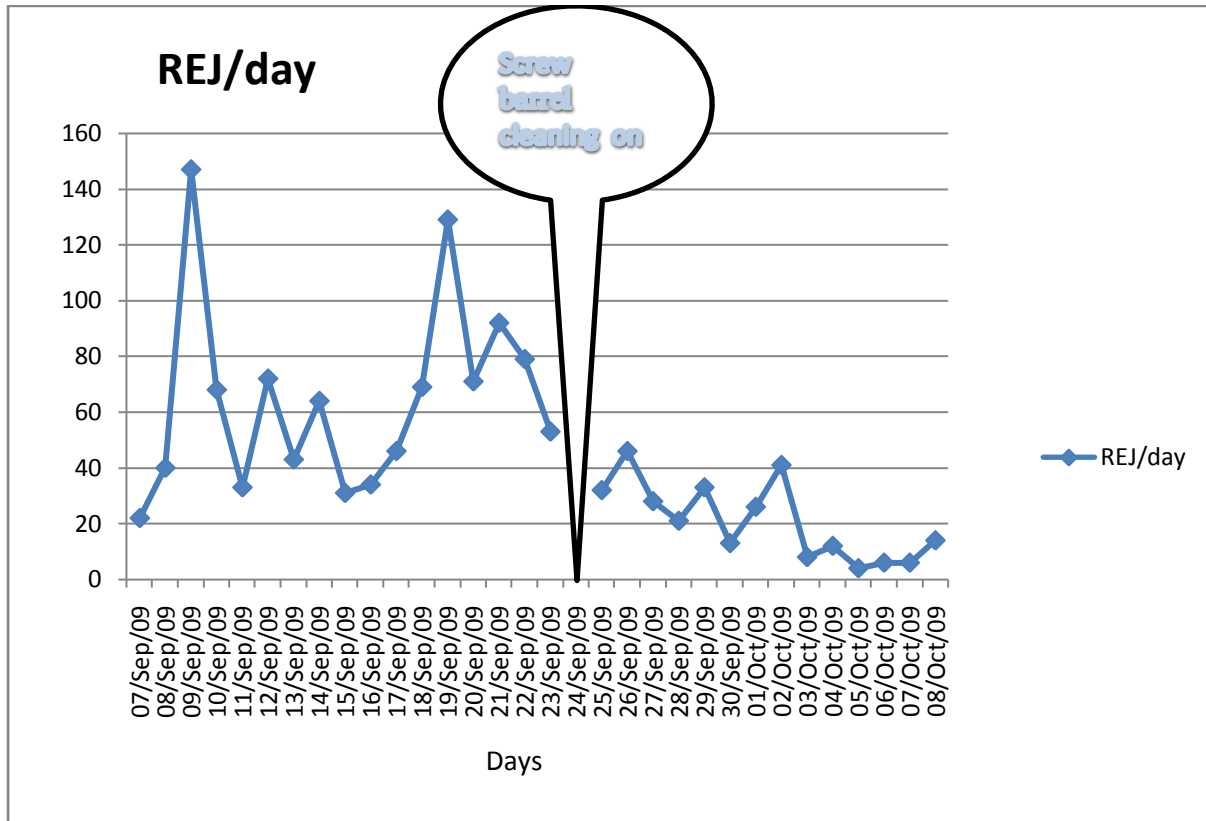
Figure 8 shows a run chart that represent the Black Dot trend before and after screw cleaning process for machine E03. Based on the figure 8, the trend before cleaning shows that the defects per day from 7th September to 23rd September is higher than the trend after cleaning where the cleaning process perform on 24th of September. This clearly shows that the machine factor plays an important role and it needs to maintain for time of period in order to eliminate or reduce the black dot problem.

The chart itself concludes that one of the main causes for the black dot is the machine condition. These results will be used by the production in charge member to perform continues action and at the same time improve the sigma level for the process.

**Table 4:-** Total no. of rejection per day from 07 Sept 09 with Screw Barrel cleaning on 24 Sept 09

<u>Round Jar-3004</u>	Machine No E03
DATE	REJ/day
07-Sep-09	22
08-Sep-09	40
09-Sep-09	147
10-Sep-09	68
11-Sep-09	33
12-Sep-09	72
13-Sep-09	43
14-Sep-09	64
15-Sep-09	31

16-Sep-09	34
17-Sep-09	46
18-Sep-09	69
19-Sep-09	129
20-Sep-09	71
21-Sep-09	92
22-Sep-09	79
23-Sep-09	53
24-Sep-09	Screw barrel cleaning
25-Sep-09	32
26-Sep-09	46
27-Sep-09	28
28-Sep-09	21
29-Sep-09	33
30-Sep-09	13
01-Oct-09	26
02-Oct-09	41
03-Oct-09	8
04-Oct-09	12
05-Oct-09	4
06-Oct-09	6
07-Oct-09	6
08-Oct-09	14



**Figure 8:** black dot trend before and after screw cleaning for machine E03

From the analysis done for this project, a conclusion can be made that machine condition is the major contributor for the black dot problem. Since the engineering group member cannot clean the injection screw or the barrel every day, a new cleaning material agent was proposed or suggested to solve this problem.

#### **Summary on improve stage**

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

#### **DMAIC- Control stage**

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

Control charts is another popular statistical process control tools which is used in this stage because it can detect abnormal variation in the process. In this operation we can use c-chart because c-chart can monitors the number of defects per inspection unit. Besides that c-chart also will monitor multiple types of quality in a product.

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