Jurnal Teknologi, 35(A) Dis. 2001: 21–34

IMPROVING QUALITY WITH BASIC STATISTICAL PROCESS CONTROL (SPC) TOOLS: A CASE STUDY

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Abstract. In order to survive in a competitive market, improving quality and productivity of product or process is a must for any company. Some simple techniques like the "seven basic quality control(QC) tools" provide a very valuable and cost effective way to meet these objectives. This paper presents a case study in which a local plastic injection moulding company deployed some part of the "seven basic quality control(QC) tools" to significantly improved the monthly defect quality from 13.49% to 7.4%. However, to make them successful as cost effective and problem solving tools, strong commitment from top management is required.

Keywords: Statistical Process Control (SPC), Plastic Injection Moulding, Control Charts

Abstrak. Syarikat mesti berusaha untuk meningkatkan kualiti dan produktivi produk atau proses untuk maju bersaing. Sebahagian daripada tujuh alatan asas kawalan kualiti merupakan suatu teknik yang sangat berkesan untuk mencapai objektif tersebut. Kajian kes yang telah dijalankan di syarikat "plastic injection moulding" tempatan telah mengaplikasikan sebahagian daripada tujuh alatan kawalan kualiti dan keputusan menunjukkan purata bulanan kualiti kecacatan produk menurun dari 13.49% ke 7.4%. Untuk mencapai kejayaan seterusnya dalam mempertingkatkan kualiti produk, sokongan daripada pihak atasan syarikat amatlah diperlukan.

Kata kekunci: Kawalan Kualiti Berstatistik, "Plastic Injection Moulding", carta kawalan

1.0 INTRODUCTION

The competitive business in the telecommunication market has encouraged "the company" in this study to provide lower cost, better quality product. Quality improvement program had been designed and implemented to increase the potential of making more profit. By improving the quality, it also means improvement in productivity and lower reject rate. Quality goals can be included in the business plan and as a degree of a product or service excellence provided to customer. Quality improvement should not only focused on external customer but also its internal customer. The purpose of this study is to improve the quality of plastic injection moulded lenses used in telecommunication devices. The objective of this study is to reduce the defect rate from 13.49% to 10%.

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2.0 QUALITY TOOLS

The company had used some of the "seven basic quality control tools" in their problem solving technique. The seven quality tools are [1]:

a. Check Sheet
b. Pareto Chart
c. Histogram
d. Scatter Diagram
e. Process Flow Chart
f. Cause and Effect Diagram or Fish Bone Diagram
g. Control Chart

The control chart is perhaps the most widely used of the "seven basic quality control tools". It is the key tool in statistical process control (SPC) because it displays process behavior graphically and it is used to monitor and control processes within the specified control limits [2]. There are two basic types of control chart, depending on the type of data collected; namely variable control chart and attribute control chart.

Variable control chart are designed to control product characteristics and process parameters which are measured in continuous scale. Examples of product characteristics are length, weight, and diameter and examples of process parameters are temperature, pressure, and PH value [3]. The primary variable control chart used are the *X*-bar and *R* chart and moving range chart, while the other two, rarely used charts include *X*-bar and *s* chart and median chart [4].

Attribute control charts are designed to control the process. Measurements used are in terms of good or bad, accept or reject, go/no-go, or pass or fail criteria (eg. conforming or non-conforming) [3]. The distinction between nonconforming or defective unit and nonconformities or defects is very important in attribute control chart because it will determine the selection in the type of attribute control chart used. Examples of nonconformities or defects in injection moulded lenses are flow lines/marks, dirty dots and scratches. A nonconforming or defective unit, however, may fail to meet the assesment criteria because of one or more nonconformities or defects exists. For attribute data, there are: *p* chart, *np* chart, *c* chart and *u* chart. The *p* and *np* charts are the most widely used. They are primarily used to monitor the fraction of nonconforming unit, while, the *c* and *u* charts are used to monitor the number of nonconformities or defects. Wodall [5] discussed in detail the theory and future research of attribute control chart.

3.0 DATA COLLECTION AND ANALYSIS

The company collected the data over a period of three months based on daily check sheet which include the quantity output of good parts and defective parts as shown in Figure 1.

	PERCENTAGE (%)															
					Types of Defects											
Month	**Total Production**	**Total Good Parts**	**In-Process Fall-Out**	**Rework Fall-Out**	**Flow Line / Marks**	**Dirty Dots**	**Scratches**	**Other Defective**	**Gate Crack**	**ROI / Line Check**	**Silver**	**Foil Peel**	**Foil Defective**	**Dust**	**Alignment Out**	**Sink Mark**
February	100.00	84.07	17.06	1.13	4.90	4.13	2.76	1.36	0.39	0.53	0.55	0.03	0.03	0.06	0.03	0.02
March	100.00	85.29	16.59	1.23	5.18	4.07	2.36	0.78	0.52	0.34	0.14	0.05	0.03	0.01	0.00	0.00
April	100.-00	87.27	15.26	0.55	5.02	3.67	1.69	0.58	0.74	0.39	0.02	0.03	0.02	0.00	0.00	0.00
Average	100.00	85.55	16.31	0.97	5.04	3.96	2.27	0.91	0.55	0.42	0.24	0.04	0.03	0.02	0.01	0.01
Target	100.00	89.03	16.31	0.97	5.00	2.50	1.20	0.90	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00

Total % Defect: **February:** 14.80% **March:** 13.48% **April:** 12.18% **Average:** 13.49%

Figure 1 Data Collection

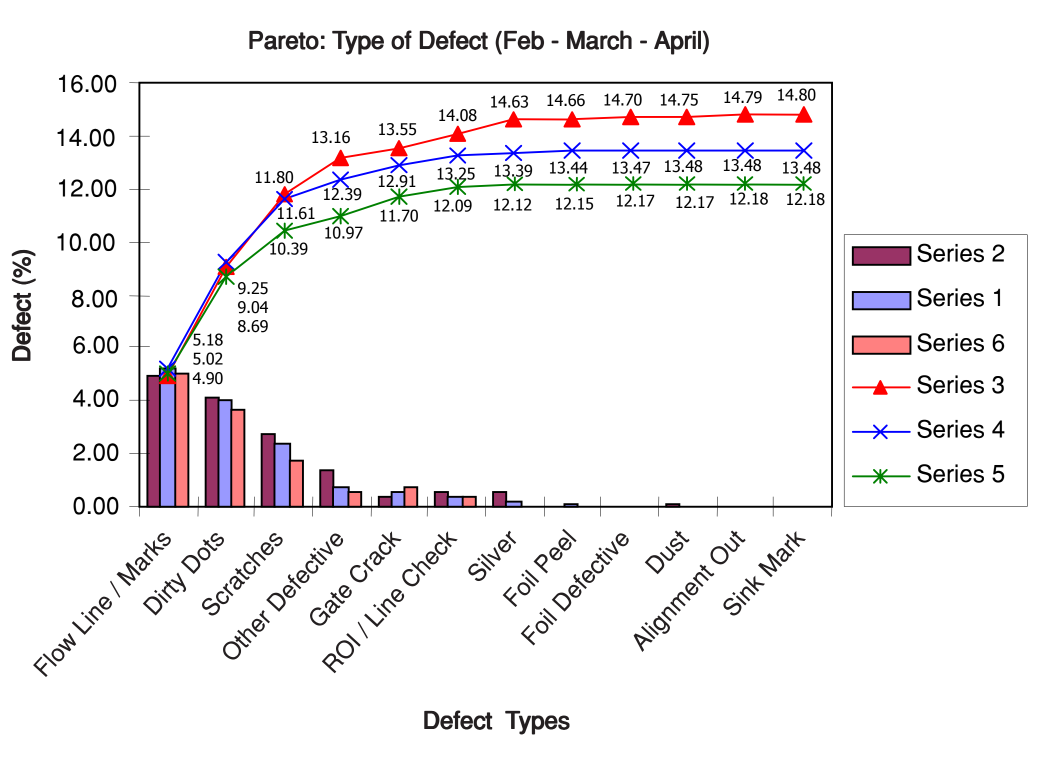

Figure 2 Pareto Chart

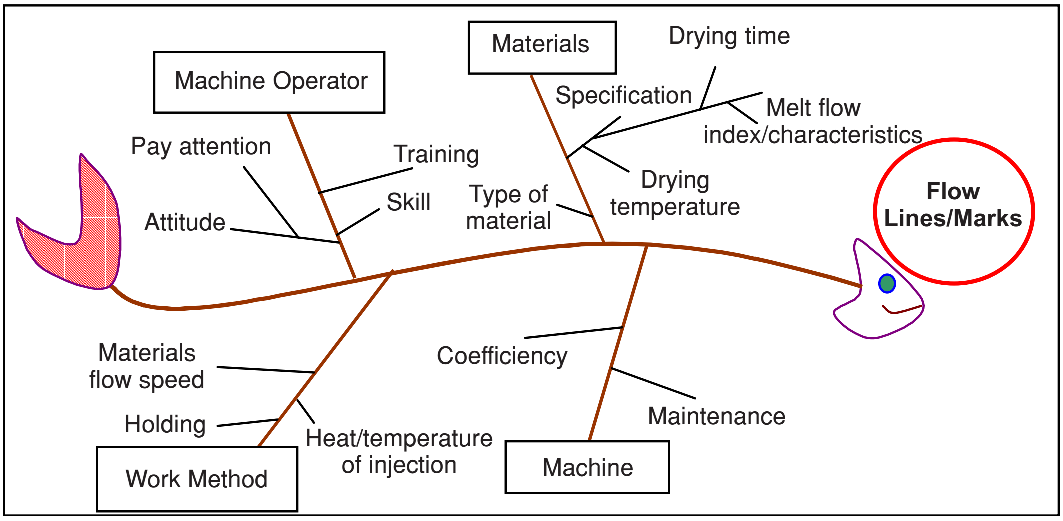

Figure 3 Fishbone Diagram for Flow Lines / Marks

Based on information in Figure 1 a Pareto chart was constructed to identify the most common defect as shown in Figure 2. The chart revealed that flow lines/marks is the highest defect with average of 5.04%, dirty dots with average of 3.96%, and followed by scratches with average of 2.27%. All other minor defects are also shown in the Pareto chart. Only the top three major defects are chosen for this case study.

Figures 3 to 5 show the fishbone diagram for the top three defects. The root causes of these three defects can be grouped into machine operator, work method, environment, material, and equipment.

3.1 Flow Line/Marks

Flow lines/marks is usually caused by injection moulding process parameters such as holding time, injection temperature and flow pressure. Raw material itself and tooling design can also cause the problem. Figure 6 shows some possibility that may cause flow lines/marks.

3.2 Dirty Dots

Dirty dots are not only caused by incoming raw material but also due to the mould and operator's handling. Figure 4 shows the possible causes of dirty dots.

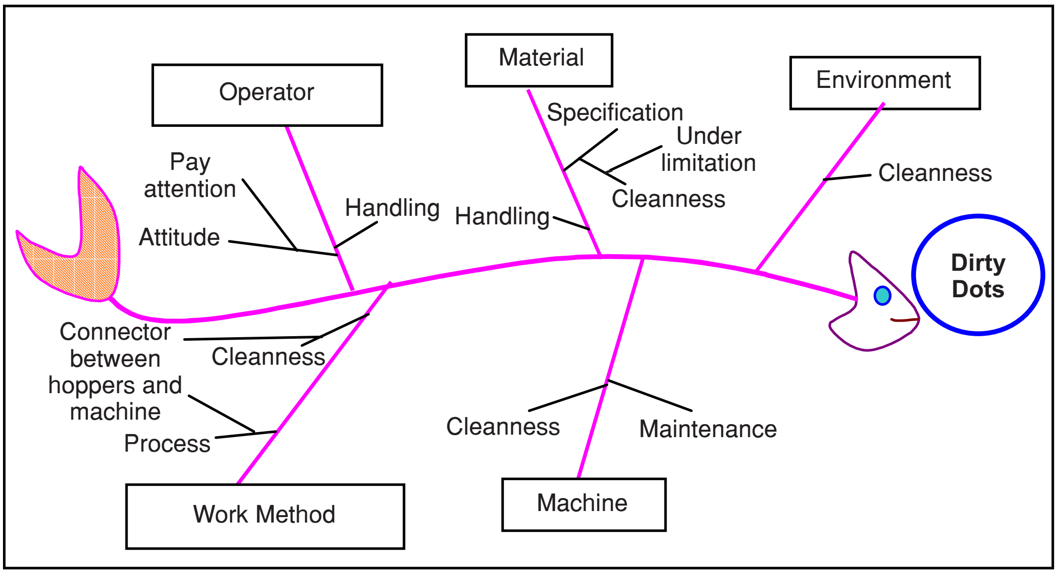

Figure 4 Fishbone Diagram for Dirty Dots

3.3 Scratches

Packaging and handling process may cause scratches as well as mould condition. Figure 5 shows the possible causes of scratches.

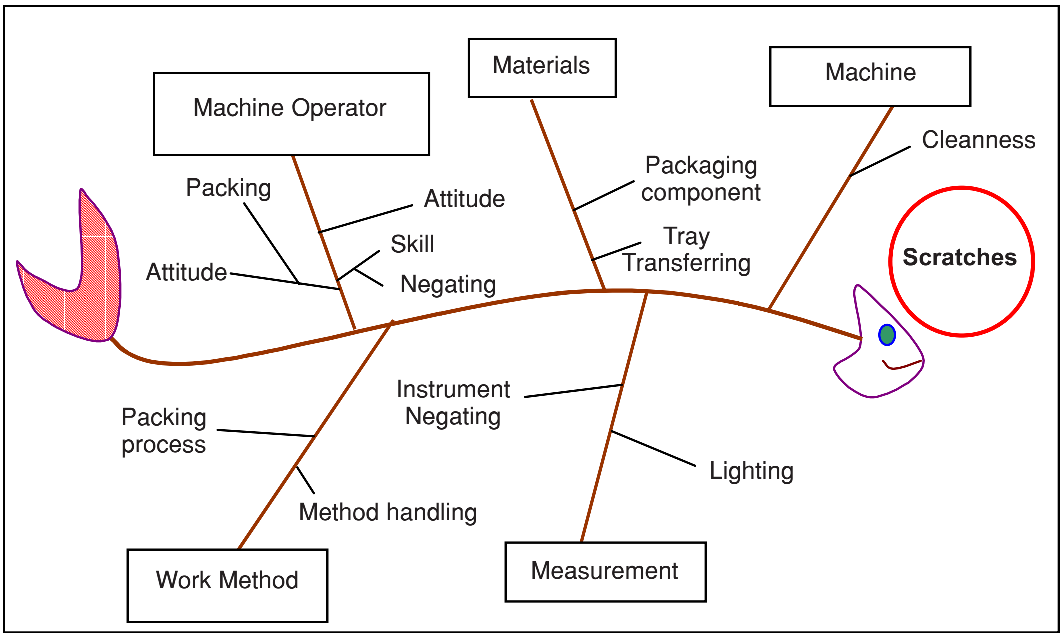

Figure 5 Fishbone Diagram for Scratches

4.0 IMPROVEMENT ACTION PLAN

The related areas for improvement can be classified into operator, material, machine, work method and environment. Tables 1 to 3 summarize the action plan for flow lines/marks, dirty dots and scratches respectively.

Table 1 Action Plan for Flow lines/marks

Type	Action Plan Suggestion for Flow line/Marks
Machine Operator	– Must have skill/provide training knowledge – Must have good attitude/pay full attention – Follow work procedure
Material	– Every incoming material/resin must go through MFI (Melt Flow Index) – Must have correct drying time/temperature (in hopper) as specified
Machine	– A preventive maintenance to ensure machine always in good condition
Work Method	– Machine must always ensure correct temperature, holding time and flow condition during injection period

Table 2 Action Plan for Dirty dots

Type	**Action Plan Suggestion for Dirty Dots**
Operator	– Material must be handled properly from any dirt – Must have good attitude/pay full attention.
Material	– Maintain cleanness
Machine	– Machine, mould and hopper must be clean all the time
Work Method	– Connector between machine and hopper must be clean – Follow work procedure
Environment	– Work environment must be clean

Table 3 Action Plan for Scratches

Type	**Action Plan Suggestion for Scratches**
Operator	– Condition packaging. Follow work instruction – Must have good attitude/pay full attention – Skill/knowledge on negating
Material	– Packing component. Correct design/requirement – Transferring/handling on tray
Machine	– Clean
Work Method	– Packing process must be correct. Follow work instruction. – Method of handling of part
Environment	– Work environment must clean

5.0 RESULT ANALYSIS AND SPC IMPLEMENTATION

After implementing the action plans for the top three defects, significant improvement was observed. This observation is done for three months after implementation. The Pareto chart in Figure 6 shows that monthly defect had reduced from 10.28% in May to 8.27% in June and 7.41% in July.

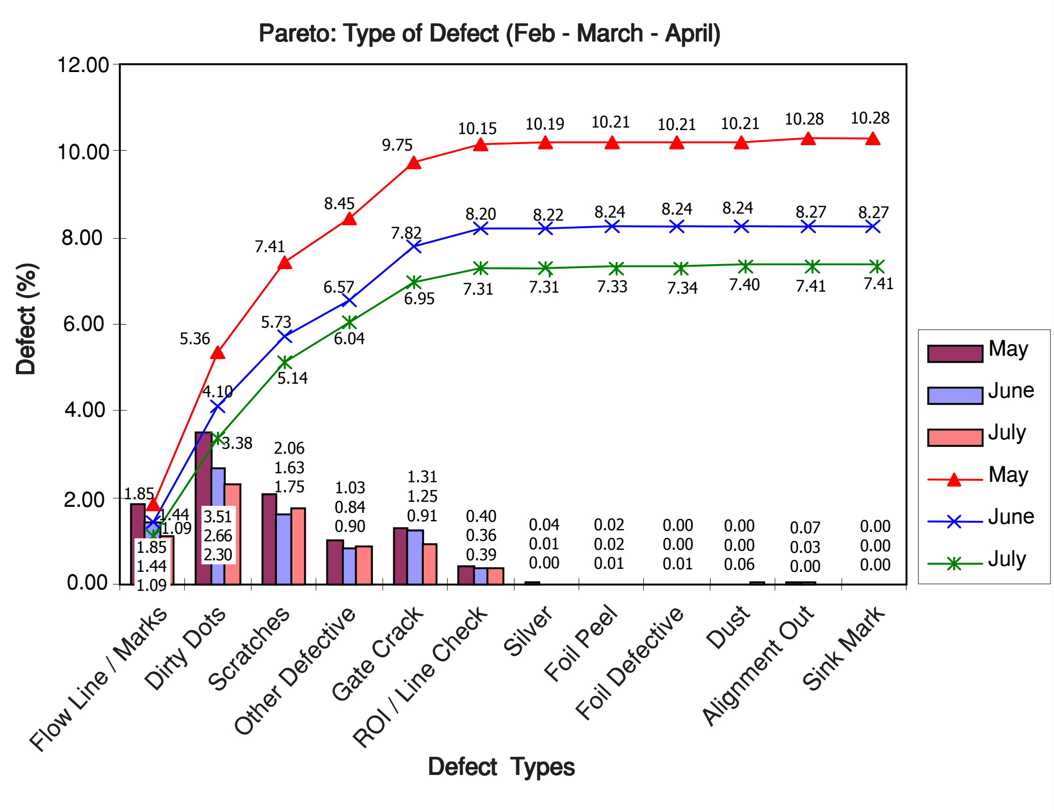

Figure 6 Pareto Chart for May, June and July

The *p* chart was also constructed to analyze the process and help determine how to yield further improvement. The *p* chart was constructed according to MIL STD 105E LEVEL II AQL 0.4% SINGLE NORMAL INSPECTION as requested by the customer.

Table 4 shows that inspection level II had been recommended and applied to the sampling plan with code letter K and L for different sample size depending on output lot size of above 1200 and below 10000 parts. The customer has requested that our part be inspected according to MIL

Table 5 shows that for level II code letter K, sample size is 125 and if 2 or more defective is found, all parts in that lot will be rejected. For letter code L, sample size is 200 and defective unit allowed is only 2 or less, otherwise the lot will be rejected.

6.0 CONCLUSION

A few of the "Seven basic QC tools" had been used for quality improvement activities. For example, fish-bone diagram had been used to describe an unsatisfactory condition or phenomenon and help to examine why that problem arised by

Table 4 Sampling Size Code Letters [6]

Sampling size code letters									
Lot or batch size			Special inspection levels			General inspection levels			
			S–1	S–2	S–3	I	II	III
2	to	8	A	A	A	A	A	B
9	to	15	A	A	A	A	B	C
16	to	25	A	A	B	B	C	D
26	to	50	A	B	B	C	D	E
51	to	90	B	B	C	C	E	F
91	to	150	B	B	C	D	F	G
151	to	580	B	C	D	E	G	H
281	to	500	B	C	D	F	H	J
501	to	1200	C	C	E	G	J	K
1201	to	3200	C	D	E	H	K	L
3201	to	10000	C	D	F	J	L	M
10001	to	35000	C	D	F	K	M	N
65001	to	150000	D	E	G	L	N	P
150001	to	500000	D	E	G	M	P	Q
500001	to	over	D	E	H	N	Q	R

TABLE II-A - Single Sampling Plans for normal inspection (Master Table)

Sample size code Letters	Sample size	Acceptable Quality Levels (normal insinspection)																									
		0.010	0.015	0.025	0.040	0.065	0.10	0.15	0.25	0.40	0.65	1.0	1.5	2.5	4.0	6.5	10	15	25	40	65	100	150	250	400	650	1000
		Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re
A	2														↓	0 1		↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	30 32
B	3													↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	30 32	44 45
C	5												↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	30 32	44 45	↑
D	8											↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	30 32	44 45	↑	
E	13										↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	30 32	44 45	↑		
F	20									↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑			
G	32								↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑						
H	50							↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑							
J	80						↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑								
K	125					↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑									
L	200				↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑										
M	315			↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑											
N	500		↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑												
P	800	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑													
Q	1250	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑														
R	2000	↑		1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑															

↓	Use first sampling plan below arrow. If sample size equals, lot or batch size, do 100 percent inspection.
↑	Use first sampling plan above arrow.
Ac	acceptance number
Re	Rejection number

Table 5 Single Sampling Plans for Normal Inspection [6]

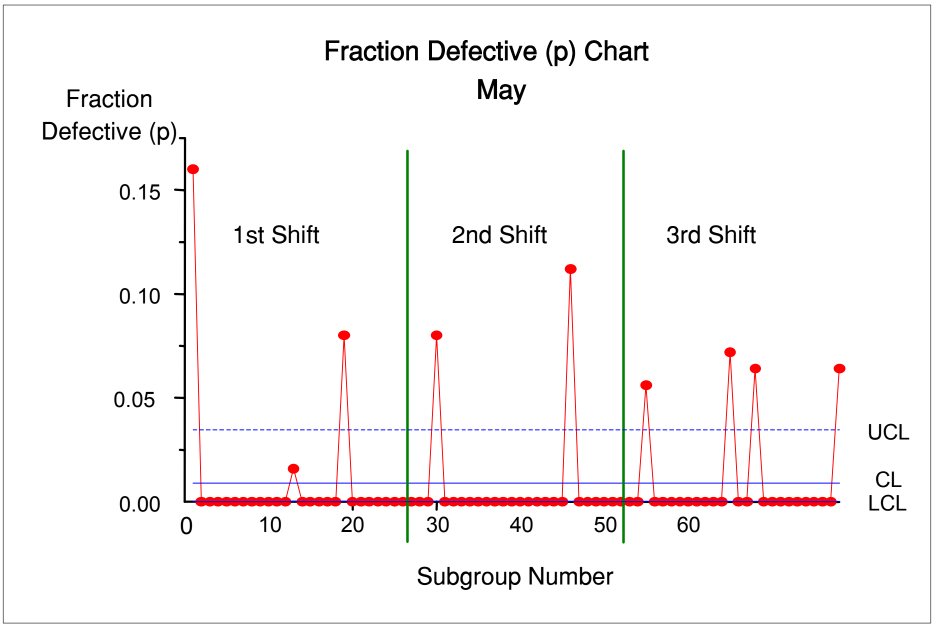

Figure 7 *p* Chart for May

Interpretation:

Figure 7 shows that the process appears not in statistical control because there are eight points outside the upper control limits(UCL). Further investigation from the check sheet shows that the contribution factors to the fraction of defective are scratches from packaging material, scratches due to handling by operator and sink marks from machine. Other defectives are due to stain mark that caused by operator, dirty dots due to resin/material and some small quantity of flow lines/sink marks.

Corrective Actions:

1) All reject lot goes to through 100% sorting. Parts with scratches and sink marks will have to be scrapped and separated from good parts.

2) Operator will have to rework the parts with stain mark by using hexane to clean it and those with dirty dots will have to be sorted out.

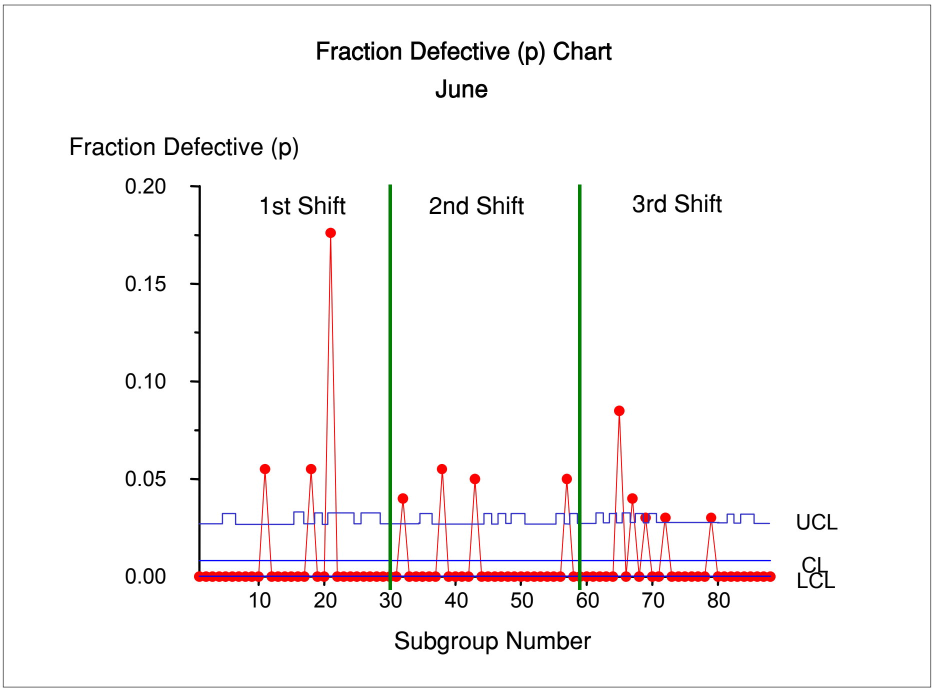

Figure 8 *p* Chart for June

Interpretation:

Figure 8 shows that the process appears not in statistical control because there are twelve points outside the upper control limits(UCL). Further investigation from the check sheet shows that the contribution factors to the fraction of defective are scratches due to operator and stains (others) due to mould. The uneven UCL of the chart is due to different sample size taken. For example, from calculation, the UCL for sample size of 125 is 0.03213 and 0.02709 for sample size of 200.

Corrective Actions:

1) Parts with scratches is sorted out and separated from the good parts. All scratched parts are scrapped.

2) Mould surface is cleaned from dirt that caused the stain mark.

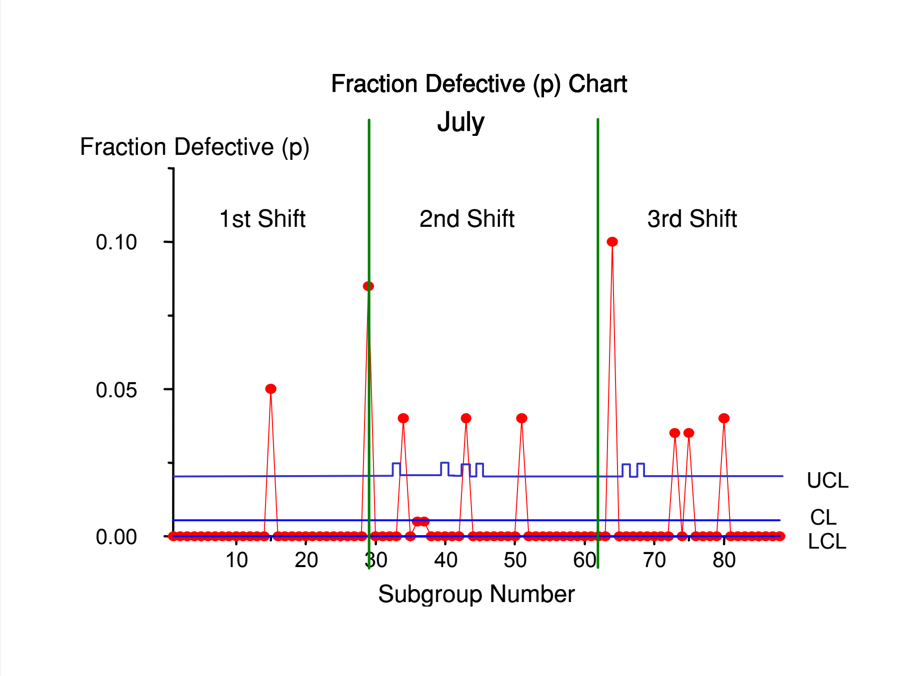

Figure 8 *p* Chart for July

Interpretation:

Figure 9 shows that the process appears not in statistical control because there are nine points outside the upper control limits(UCL). Further investigation from the check sheet shows that the contribution factors to the fraction of defective are scratches caused by operator's handling, broken ribs of the part due to carelessness of operator during negating process and some other defects which include dirty dots and gate crack

Corrective Actions:

1) All rejected lots are sorted and separated from good parts. Good parts will proceed to the next process.

2) Operator is advised to be more careful on their part handling to prevent defects caused by human error.

systematically arranging the contributable factors. *P* charts were used to monitor the distribution pattern of average defect rate. Improvement action plans were set-up and data was collected for the next three months and analysed. Data collected showed that the average defect has improved to 7.4 % from 13.49 % initially. Thus, the study has achieved its set goals. It is noted that simple QC tools can make significant improvement to the company. Some future improvement plan that had been suggested and recommended are:

1. Company should be more disciplined and all operators must go through some simple training especially on how to handle parts to avoid defect caused by human handling for example finger print, stain mark and scratches. New operator must be trained to handle the parts properly. Work instruction sheets can be used as a guide for the proper work method.
2. Machine must have a daily check sheet and machine operator must check the machine condition for every shift to confirm that the machines are in good condition. The machine's pressure, temperature and holding time must be accurate to avoid flow lines/marks defects. Mould must always be in good condition and free from any dirt or dust that may cause stain marks and scratches.
3 Every incoming lots material must go through Melt Flow Index checking to avoid flow line defects.

REFERENCES

[1] Ishikawa, K. 1985. *What is Total Quality Control*. Prentice Hall. Englewood Cliff, N.J.
[2] Bisgaard, S. 1993. Statistical Tools for Manufacturing. *Manufacturing Review*. 6(3): 192–200.
[3] Freeman, J, G. Mintzas. 1999. Simulating c and u Control Schemes. *The TQM Magazine*. 11(4): 242–247.
[4] Anjard, R.P. 1995. SPC chart selection process. *Microelectronic Reliability*. 35(11): 1445–1447.
[5] Wodall, W. H. 1997. Control Charts Based on Attribute Data: Bibiography and Review. *Journal of Quality Technology*. 29(2): 172–196.
[6] Duncan, A. J., 1974. *Quality Control and Industrial Statistics*. Richard D. Irwin, Inc. Illinois.