# Chapter III

## Discussion of the Problems

### 3.1 Background of product

This thesis studied the crankshaft line for compressor that uses in the refrigerator. This study focused on the machining process of crankshaft before grinding, plating and assembly process. The crankshaft line had a change in the process because of the cost reduction program of customer which will be explained in the next section. In practically, the major processes that affect to the quality of crankshaft are turning and drilling because these processes affect to assembly line of customer. There are three major specifications that affect to functions of crankshaft directly as shown in fig. 3.1

1. The distance of eccentric of crankshaft
2. The through of oil hole for circulation in compressor
3. The size of press fit in assembly process

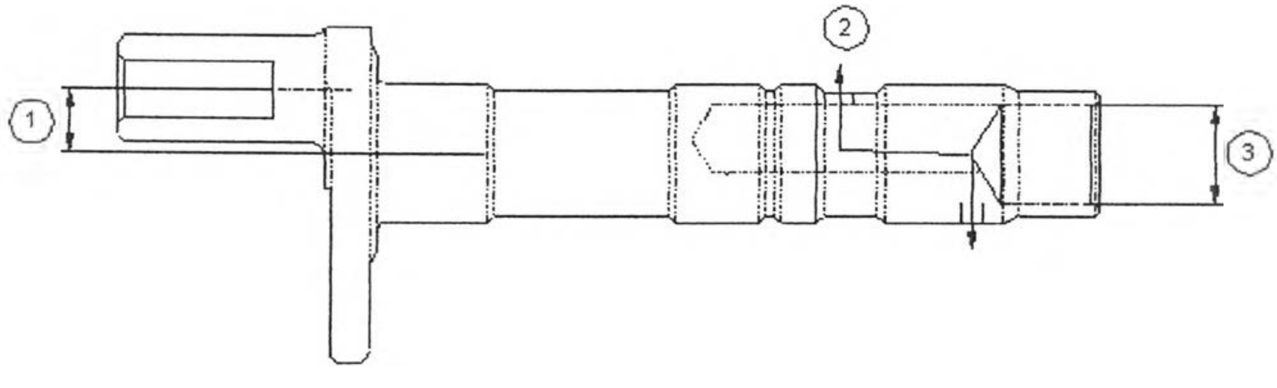


Fig.3.1 The important specification of the crankshaft for compressor

### 3.2 The application of crankshaft for compressor

The compressor is the heart of the refrigeration system. In refrigeration cycle, the compressor is one component between the evaporator outlet and the condenser inlet. The function of the compressor is to maintain a low pressure in the evaporator by removing vapor refrigerant at correct rate to maintain a specific evaporating temperature in the evaporator. Then vapor pressure is raised to a pressure corresponding to the condensing temperature in the condenser while being pumped to the condenser.

There are three commercial types of compressor that has some different in functional of the operation systems

1. Reciprocating compressors
2. Rotary compressors
3. Scroll compressors

The crankshaft is one of the components in the compressor. The crankshaft is the precision device that must be controlled to balance for compressor to work without the vibration. The function of crankshaft, there are the oil passages, drilled from one end to the others for lubricate the rod and bearing. So the lubricating system is very important because in every movement must be lubricated for the compressor to extend its life. The purpose of the lubricating system is to form the thin film or barrier between all moving part in compressor to prevent any contact that is the cause of wear.

### 3.3 The detail of the crankshaft line

There are four groups of processes in crankshaft line, pre-machining process, turning process, drilling and chamfering process. The process flow of crankshaft line has the parallel line in process 3, 4 and 5. At the beginning of production, the process design of this line composed of 2 pre-machining process as shown in fig. 3.2. But after mass production customer has requested to reduce machining cost by cutting off one pre-machining process as shown in fig.3.3 and increasing the line capacity from 25,000 – 30,000 to 35,000 – 45,000 pieces per month.

The scope of this study is to improve quality of product by reducing the defect in process 4 in old process flow that has two pre-machining processes. But after the change of process by cutting off one pre-machining process, process 4 in old process flow (fig. 3.2) is changed to process 3 in new process flow (fig.3.3).

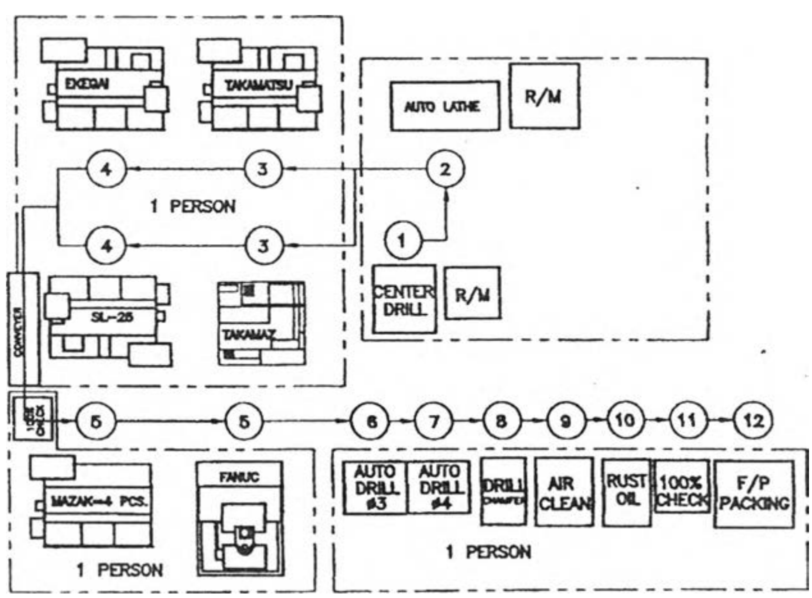


Fig.3.2 The old process flow of crankshaft line

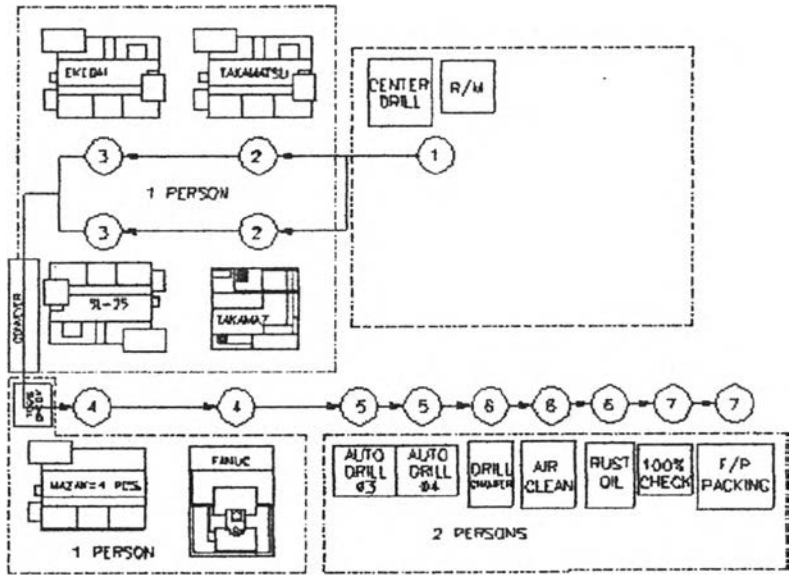


Fig.3.3 The new process flow of crankshaft line

The change in the process affected to the quality of product because this pre-turning process can reduce the variation of raw material. Even though, the change affected to quality of product but it is suggested and approved by customer. In fact, this change is used to cut off the machine to reduce the cost of manufacturing because it does not affect to the capacity of process.

The detail of manufacturing process and operation in each process is shown in appendix. The capacity of this line depends on the process 4 (new process flow) because it has the longest cycle time, bottleneck process. But this thesis emphasizes on process 3 because the rejections in this process are about half of all rejects. Process 3 composes of two major processes, the turning process at diameter 14 mm. and drill diameter 8 mm. at the head of crankshaft. Because of process 3 is parallel process, the first design try to compare between two types of clamping system, the collet and the chuck system. The difference of the clamping system is the function of clamping method.

### 3.4 Classify types of problems

The causes of problems usually come from two categories which are internal environment and external environment. The internal environment includes the activities in organization that is controllable by the effective management. On the other hand, the external environment is hard to control so the predictive and preventive are the best method to control these environment.

3.4.1 <u>The external environment</u>

In the case study, we divide the causes of problem into three sources such as the problem cause of customer, supplier and competitors. In theoretical, other factor such as political, economic, social and culture and technology are in external environment but this product is an unfinished product so these factors are not effect to the manufacturing process directly.

3.4.1.1. The problems related to customer

The quality problems from customer could be classified into three categories such as quality, cost and capacity of production. Because this line is the mass production line so it has to operate continuously at full capacity. As this reason, three categories have closely relationship.

i. Quality problems: The quality is the most important among the three categories. The quality of product is translated to engineering drawing that is designed for lateral process such as machining, grinding and assembly. The specification in engineering drawing is depended on the mechanical function of product. In practically, the product may be out of specification but still acceptable. So the specification of product should be acceptable by both supplier and customer. Another problem of quality is the measuring method and reliable of measuring tools. The difference in measuring result depends on 4 major factors, operator, measuring tools, measuring method and environment. These factors affect the measuring result in the repeatability and reproducibility.

ii. Cost problems: The cost is also an important category in the making decision of customers. The high competition of the finished product market makes the cost reduction program to their suppliers. For example: in production line, customer requests to reduce cost about 20 percent by cutting of one pre-turning process.

iii. Capacity problem/ delivery problem: The capacity of crankshaft line has been designed at about 20,000-25,000 pieces per month but customer has requested to increase to about 30,000-35,000 pieces per month. The increasing of capacity impacts to production planning and quality of product. And the increasing of capacity also increases the rejection in the line because of the lacking of effective planning to control process.

3.4.1.2 The problems related to Suppliers

The raw material of crankshaft has only one supplier so it is easy to control the quality. Supplier tries to improve its quality of product continuously because the policy of supplier is to reduce the lost in its production line. The problems that come from the raw material is the porosity in crankshaft and over-specification of hardness. But these problems usually occurs by production lot so when we find the problem is found. that lot is rejected to supplier.

3.4.1.3 The problems related to competitors

The fabrication by machining process has a lot of competitors but customers usually classify by quality, cost and capacity. In this case, the company uses cost strategy to overcome other competitors. As this reason, the budget for investment is lower than competitors at the same level of quality. In order to reduce the budget, the lower grade of tools and equipment is selected. The results are the higher variation in manufacturing process and difficult to control the quality of product.

3.4.2 Internal environment

The internal environment includes the management, responsibility, knowledge and experience. The management and responsibility can be solved in the same method by setting the effective organization chart, responsibility and quality system. In case of the company, the QS-9000 system has been selected to solve these problems because of two major reasons which are making customer satisfaction and improving the quality system. The QS-9000 system emphasizes on preventive action and continuous improvement. The system consists of special techniques for improvement such as Statistical Process Control (SPC), Failure Modes and Effects Analysis (FMEA) and Measurement System Analysis (MSA).

The effective quality system has the good correlation between departments so each department has to understand all functions and responsibilities in organization then implement them together. The organization chart composes of 6 departments which are production, quality assurance, business planning, maintenance, human resource and accounting as shown in fig. 3.4.

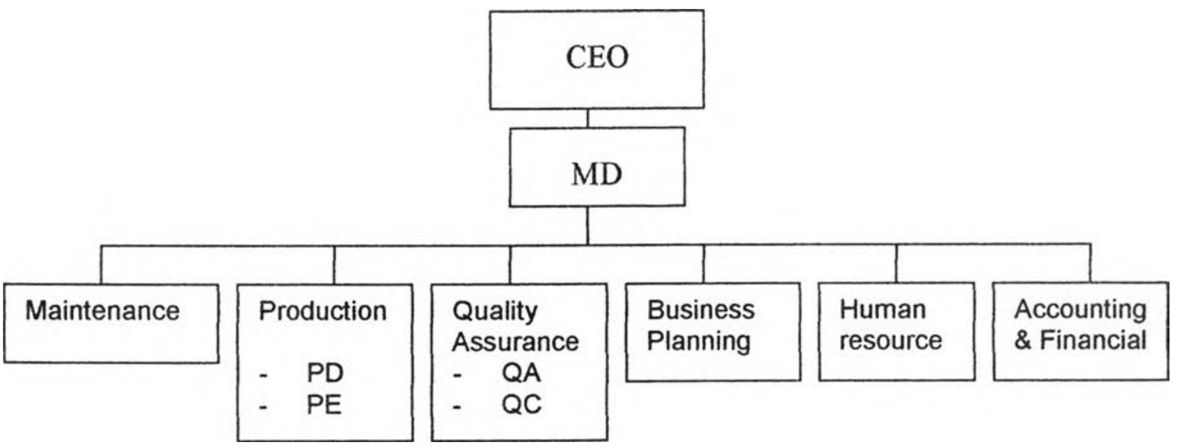


Fig. 3.4 The organization chart of the case company

Although, the organization chart was prepared but it needed the clear responsibility to prevent the overlapping in responsibilities and eliminate conflict in communication and decision.

Quality assurance and production departments are responsible directly on the quality and manufacturing system and product. In production department divides into two sections: production (PD) and production engineering (PE). And quality assurance also divide into two sections: quality assurance (QA) and quality control (QC). As following paragraph would explain about the responsibility of each department.

Quality Assurance departments is responsible for the inspection by sampling, appearance check before packing and delivery to customer, do corrective action when receive the customer complain and assurance quality system.

1. Sampling inspection: the sampling inspection is setting up for inspecting all dimension of product as inspection standard. The frequency of sampling inspection is minimum at 2 pieces per shift, line A and line B, then uses these result as data lots for customer.
2. Appearance check: after cleaning the crankshaft in anti-rust oil, the crankshaft is rechecked the appearance such as porosity, rust and burr before packing. At this check, the critical point of crankshaft would be check to prevent the sending of non-conformity products to customer by using special tools such as plug gage, pin gage and jig.
3. Corrective action: sometimes the non-conformity product is sent with good product so customer requests to rescreen. The quality assurance has to classify problem into 2 groups, finished part and work in process in the factory and finished part at customer. As this method can sort group of defect and reduce time of doing corrective action. The corrective action is depended on the causes, severity, and amount of defect and correction method.
4. Assurance quality system: this assurance includes the reliability of measurement tools, accurate measurement method and audit inspection of in process inspection and sampling inspection to ensure that the quality system could operate effectively.

Production department's activities can be divided into two functions: manufacturing functions and improvement functions. Both of them are the important functions in quality system because the reject can be eliminated by not to produce the defected part and do corrective action immediately after the problems are found.

1. Manufacturing functions: the activities of manufacturing are the manufacturing and in process inspection because the best method to ensure that the process make a good product is self-inspection. But the self-inspection should be easy to determine by operators so the appropriate tools are needed.
2. Improvement functions: the improvement function is the supported activities to reduce and eliminate the reject. This activity should be linked between production and quality assurance department because the causes and effects have to imply and measure continuously.

Other topics, knowledge and experience, are the major problems that need a long period of time to understand and do effectively implementation. In practically, the effective implementation program is very difficult because it needs the participation from all persons in organization from top management to operators to be joining in all activities. (E.g. the support from top management in term of target, policy, and budget, the knowledge from specialist to do improvement or activities, the effective training and look after from leader, the continuous in implementation from operators, and etc.) At this situation, there is no experienced persons who can improve processes and systems to make the effective improvement.

### 3.5 Analysis the current problems

The current problem of the crankshaft line is the quality problem. From the record of the in rejection in manufacturing process showed that the rejection rate of this line about 6-7 percent in Jan.-Mar.'99. The primary rejection of the crankshaft line came from the over specification in dimension during manufacturing and the mark during transportation. The ranking of defects that occurred from January'99 to March'99 is shown by the Pareto diagrams in fig. 3.5, 3.6 and 3.7.

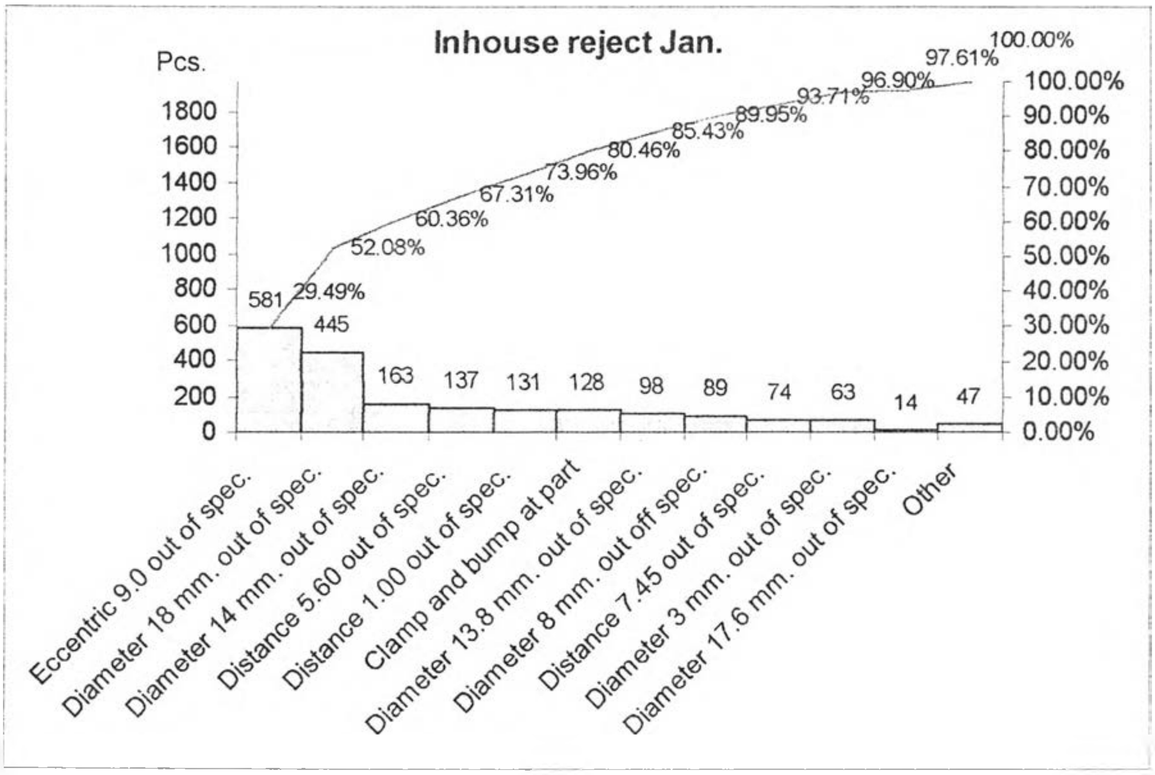


Fig. 3.5 The Pareto diagram of reject from manufacturing process in January'99

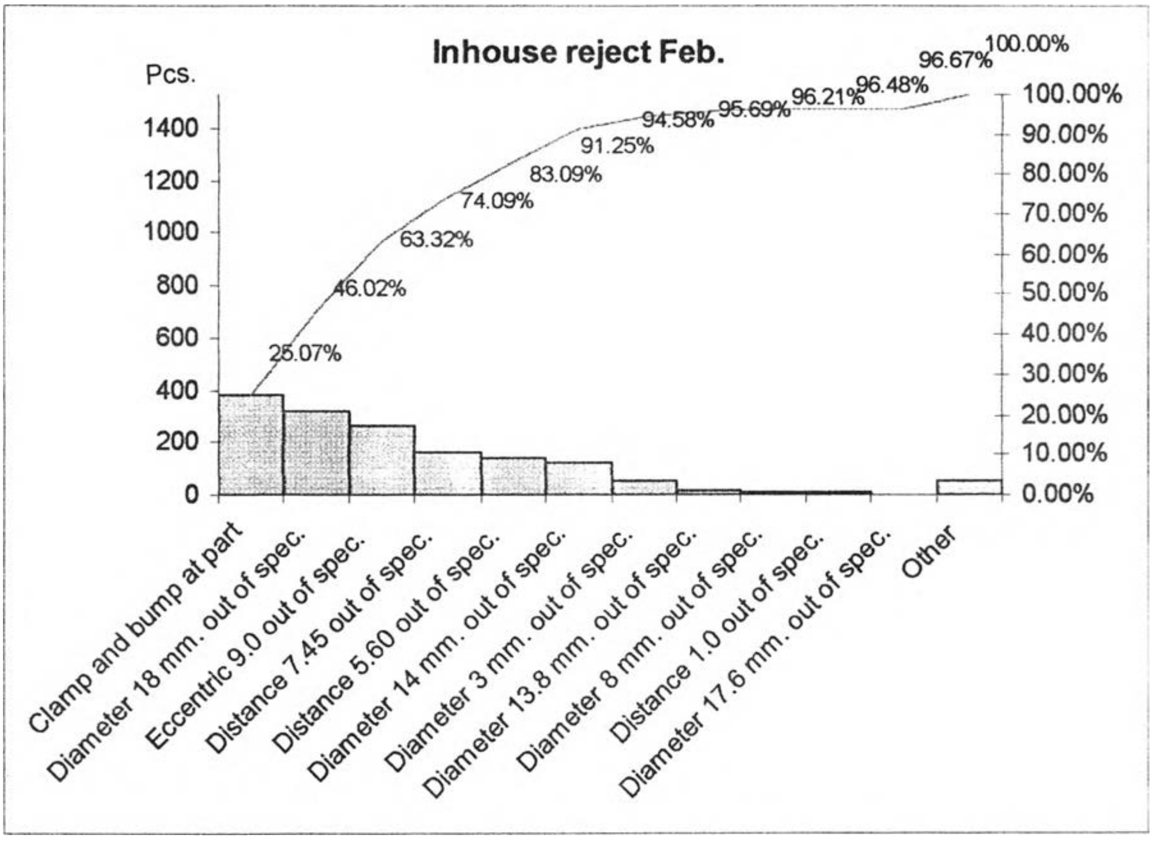


Fig. 3.6 The Pareto diagram of reject from manufacturing process in February'99

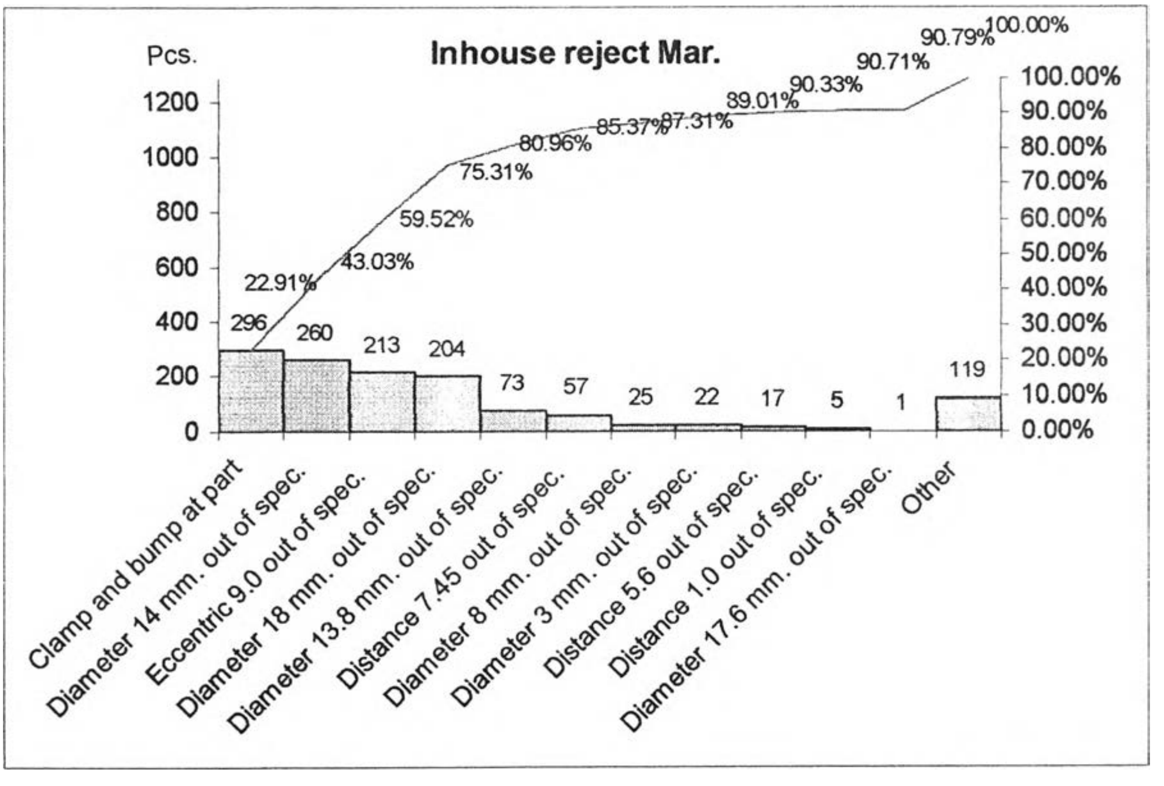


Fig. 3.7 The Pareto diagram of reject from manufacturing process in March'99

In the Pareto diagrams, the major kinds of defect that are found in manufacturing process were:

1. The out of specification of diameter
   1.1 Diameter 18 mm.
   1.2 Diameter 17.6 mm.
   1.3 Diameter 14 mm.
   1.4 Diameter 8 mm.
   1.5 Diameter 13.8 mm.
   1.6 Diameter 3 and 4 mm.
2. The eccentric out of specification
3. The out of specification of the thickness
   3.1 Distance 7.45 mm.
   3.2 Distance 5.6 mm.
   3.3 Distance 1 mm.
4. The mark on the surface
5. Other defect is difficult to identify cause of problem and has a little amount of reject.

These major problems can divide into 2 types of error is mechanical error, defect from manufacturing process, and human error, defect that relates to human. Both of them spread in 4 main manufacturing process. When we rearrange amount and percentage by process, it shows the significant defects in each process. The rejection during January to March'99 in each process is shown in table 3.1

Table. 3.1 The amount and percentage of reject from January to March'99

| | Jan.(Unit) | Jan.(%) | Feb.(Unit) | Feb.(%) | Mar.(Unit) | Mar.(%) |
|---|---|---|---|---|---|---|
| Process 3 | 1172 | 59.49 | 759 | 49.54 | 725 | 56.11 |
| Process 2 | 590 | 29.95 | 462 | 30.16 | 222 | 17.18 |
| Process 4 | 98 | 4.97 | 209 | 13.64 | 221 | 17.11 |
| Process 5 | 63 | 3.20 | 51 | 3.33 | 22 | 1.70 |
| Other | 47 | 2.39 | 51 | 3.33 | 119 | 9.21 |

Where in each process composes of these rejects are:

Process 2 The out of specification of diameter 17.6, 18 mm.

The out of specification of thickness 5.6 mm.

Process 3 The out of specification of diameter 14, 8 mm.

The out of specification of thickness 7.45 mm.

The mark from clamping

Process 4 The out of specification of diameter 13.8 mm.

The mark from clamping

Process 5 The out of specification of diameter 3 and 4 mm

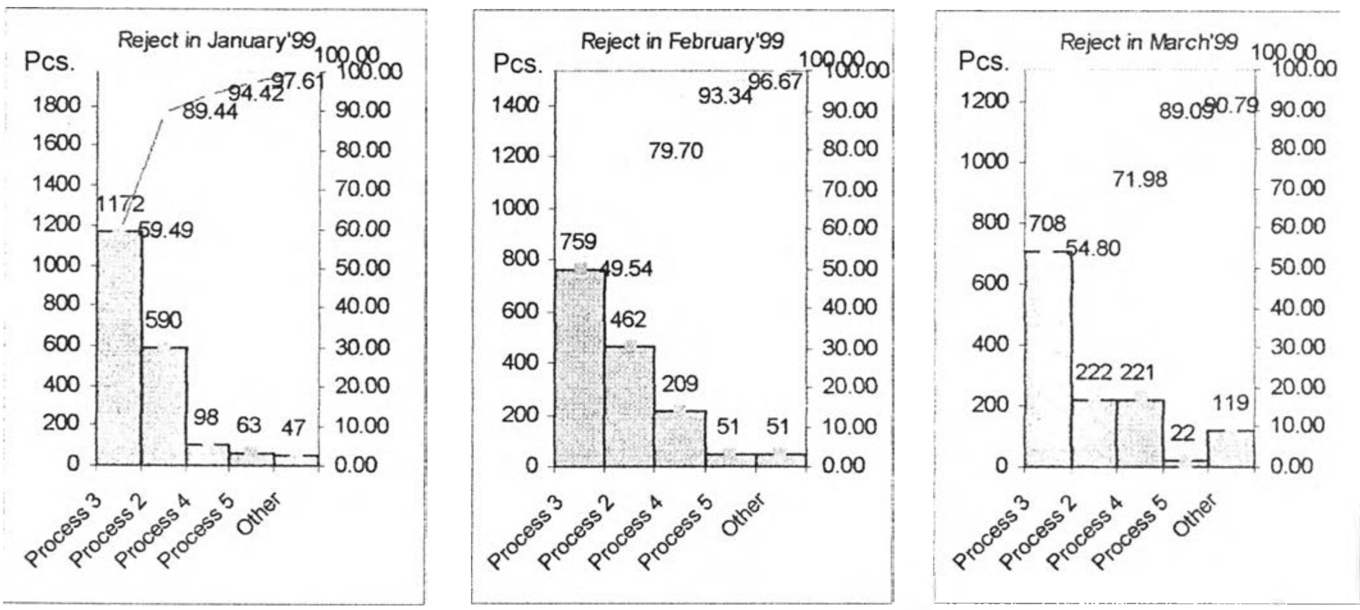


Fig. 3.8 The Pareto diagrams of defects by process from January to March'99

In the Pareto diagrams, the significant of problems that has the highest reject occurs in process 3 about 50-60 percent. So if the reject in process 3 is eliminated the reject of production line can be reduced more than half of all, about 3-4 percent.

The analysis of problems in this project divided into 2 methods: studying the type of problems (normal cause and special cause/ continuous of defect and random of defect) and using cause and effect diagrams.

The result of investigation by the occurrence of defects from the rejection, it is record find that it occurs both random and continuous types. The random type occurs at small amount and unpredictable to happen. On the other hand, the continuous type occurs in larger or run as groups of defect on a long period of time.

From the rejection record from January'99 to March'99, the process capability of this line was 0.69 that mean about 3 percent of defect came from the variation of process. And the capacity of this production line is about 1,000 pieces per day. As this reason, the assumption to classify random and continuous type of defects was the random type of defect found less than 30 pieces per day (one days has 3 shifts) and continuous defect found more than 30 pieces per day as shown in table 3.3 – 3.5. This assumption was setting to classify the occurrence of defect because there was no record about the run of defect.

Table 3.2 The comparison between random defect and continuous defect

| | Random defect | Continuous defect | Ratio (Random/ Continuous) |
|---|---|---|---|
| January'99 | 960 | 1010 | 1 : 1.052 |
| February'99 | 999 | 953 | 1 : 0.589 |
| March'99 | 467 | 825 | 1 : 1.767 |

The continuous defect can be solved easier than random type because it runs continuously as the continuous of small groups. So if there is some systems to point the run then stop them, the defect would be stopped. And if the monitoring system can show the trend of process it can prevent the occurrence of defects. On the other hand, the random type is difficult to predict the occurrence of defect and no specific pattern.

Table. 3.3 The in house defect of crankshaft in January' 99

| Crank Shaft Hitachi Jan. | Total | % | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Eccentric 9.0 | 581 | 29.49% | | | | | 9 | 3 | 5 | | 37 | | | 1 | 35 | | | | | 319 | | 73 | 7 | 5 | 20 | | 7 | 7 | | | 5 | 48 | |
| Diameter 14 mm. out of spec. | 163 | 8.27% | | | | | 2 | 3 | 6 | 1 | 2 | | 9 | 6 | 12 | 7 | 5 | | | 9 | | 75 | 1 | 2 | 7 | | 5 | 3 | 2 | | 1 | 5 | |
| Diameter 13.8 mm. out of spec. | 98 | 4.97% | | | | | | 6 | 7 | | | | 1 | | 4 | 12 | | | | | | | 8 | 7 | 31 | | 16 | | 1 | 2 | | 3 | |
| Diameter 18 mm. out of spec. | 445 | 22.59% | | | | | 8 | 6 | 11 | 14 | 29 | | 19 | 9 | 40 | | 15 | | | 33 | 14 | 41 | 18 | 27 | 8 | | 21 | 13 | 13 | 16 | 69 | 21 | |
| Diameter 17.6 mm. out of spec. | 14 | 0.71% | | | | | 1 | | | | 1 | | 7 | | 1 | | | | | | | 2 | | | | | | 1 | | 1 | | | |
| Diameter 8 mm. out off spec. | 89 | 4.52% | | | | | | | | | | | 1 | | | | 27 | | | 1 | 44 | 3 | 2 | | 10 | | | | | 1 | | | |
| Distance 7.45 under spec. | 74 | 3.76% | | | | | 3 | 1 | 5 | 8 | 13 | | 1 | | 2 | | | | | 14 | | 3 | | 1 | | | 6 | 2 | 9 | 1 | 1 | 4 | |
| Clamp and bump at part | 128 | 6.50% | | | | | 2 | | 2 | | | | 20 | 8 | 4 | | | | | 7 | 2 | 2 | 1 | 3 | 3 | | 46 | | 15 | 6 | | 7 | |
| Distance 5.60 under spec. | 137 | 6.95% | | | | | 5 | | | 2 | 4 | | 2 | 3 | 6 | 3 | 1 | | | 14 | | 1 | | 1 | | | 6 | 3 | 1 | 3 | | 82 | |
| Distance 1.00 under spec. | 131 | 6.65% | | | | | 37 | 15 | 2 | 4 | 3 | | 6 | 2 | 11 | 4 | 21 | | | 6 | 1 | 3 | | | 2 | | | 8 | 2 | 1 | 3 | | |
| Diameter 3 mm. out of spec. | 63 | 3.20% | | | | | | | 1 | | 1 | | 2 | 3 | 1 | 6 | 8 | | | 4 | | | 5 | 1 | 29 | | | | 2 | | | | |
| Other | 47 | 2.39% | | | | | | 7 | 1 | 1 | 3 | | 1 | 2 | 1 | 2 | 1 | | | | 4 | 2 | 6 | 1 | 1 | | 8 | 4 | | | 1 | 1 | |
| Total | 1970 | 1970 | 0 | 0 | 0 | 0 | 67 | 41 | 40 | 30 | 93 | 0 | 69 | 34 | 117 | 34 | 78 | 0 | 0 | 407 | 65 | 205 | 48 | 48 | 111 | 0 | 115 | 41 | 45 | 31 | 80 | 171 | 0 |

Production 34,000

Percentage of rejection 5.794%

☐ Continuous Defects

Table. 3.4 The in house defect of crankshaft in February' 99

| Crank Shaft Hitachi Feb. | Total | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Eccentric 9.0 | 265 | 17.30% | | 2 | | 5 | 3 | | | | | | | | 9 | | 1 | | 47 | 12 | 2 | 2 | | | | 33 | 1 | 148 | | | | | |
| Diameter 14 mm. out of spec. | 125 | 8.16% | | 15 | | 7 | | | | 2 | 7 | | 12 | 1 | 32 | | 6 | 5 | 4 | 1 | 5 | 2 | | | 4 | 2 | 9 | 1 | 10 | | | | |
| Diameter 13.8 mm. out of spec. | 17 | 1.11% | 1 | | | 2 | 1 | | | | | | | 7 | 1 | | | | | | | 3 | | | | | | | 2 | | | | |
| Diameter 18 mm. out of spec. | 321 | 20.95% | 19 | 14 | | 39 | 11 | 20 | | 20 | 26 | 9 | 22 | 23 | 4 | | 21 | 4 | 6 | 3 | 4 | 4 | | 21 | 13 | 10 | 11 | 8 | 9 | | | | |
| Diameter 17.6 mm. out of spec. | 3 | 0.20% | | | | 1 | | | | | | 1 | | 1 | | | | | | | | | | | | | | | | | | | |
| Diameter 8 mm. out off spec. | 8 | 0.52% | | 6 | | | | | | | 1 | | | | | | | | | | | | | | | | | | 1 | | | | |
| Distance 7.45 under spec. | 165 | 10.77% | 2 | 2 | | 58 | 7 | 7 | | 18 | 9 | | 4 | | | | 20 | 12 | 2 | 7 | 3 | 2 | | 1 | | | 7 | 4 | | | | | |
| Clamp and bump at part | 384 | 25.07% | 6 | 6 | | 52 | 7 | 12 | | 28 | 46 | 10 | 8 | 15 | 11 | | 29 | 10 | 14 | 7 | 13 | 8 | | 7 | 16 | 12 | 19 | 17 | 31 | | | | |
| Distance 5.60 under spec. | 138 | 9.01% | 1 | 1 | | 4 | 15 | | | 3 | 4 | 1 | 3 | 2 | 80 | | 2 | 1 | 1 | 5 | 4 | 8 | | | 1 | 1 | | 1 | | | | | |
| Distance 1.00 under spec. | 4 | 0.26% | | | | | | 1 | | 1 | | | | | | | | | | | | | | | 1 | | | | 1 | | | | |
| Diameter 3 mm. out of spec. | 51 | 3.33% | | | | | | 1 | | | | 1 | | 2 | | | 29 | | 1 | 4 | 2 | 1 | | 1 | | 2 | 2 | 4 | 1 | | | | |
| Other | 51 | 3.33% | 1 | 2 | | | 2 | | | | 2 | | 2 | 22 | | | 2 | | 1 | 4 | 1 | | | 3 | 1 | 3 | | | 5 | | | | |
| Total | 1532 | 1532 | 30 | 48 | 0 | 168 | 46 | 41 | 0 | 72 | 95 | 22 | 51 | 73 | 137 | 0 | 110 | 32 | 76 | 43 | 34 | 30 | 0 | 33 | 36 | 63 | 49 | 183 | 60 | 0 | 0 | 0 | 0 |

Production 31,000

Percentage of rejection 4.942%

☐ Continuous Defects

Table. 3.5 The in house defect of crankshaft in March' 99

| Crank Shaft Hitachi Mar. | Total | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Eccentric 9.0 | 213 | 16.49% | | 66 | | 4 | | 120 | | | | 1 | 1 | | | | | | | | | | | | | | | | | | 9 | | 12 |
| Diameter 14 mm. out of spec. | 260 | 20.12% | | 18 | 8 | 10 | 192 | 1 | | | 1 | 2 | 3 | 1 | | | | | | | | | | | | | | | | | 24 | | |
| Diameter 13.8 mm. out of spec. | 73 | 5.65% | | | | | | | | | | 3 | 3 | 37 | | | | | | | | | | | | | | | | | 21 | 9 | |
| Diameter 18 mm. out of spec. | 204 | 15.79% | | 15 | 16 | 18 | 12 | 19 | | | 6 | 4 | 4 | 14 | | | | | | | | | | | | | | | | | 71 | 5 | 20 |
| Diameter 17.6 mm. out of spec. | 1 | 0.08% | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Diameter 8 mm. out off spec. | 25 | 1.93% | | | | | | | | | | 7 | | 1 | | | | | | | | | | | | | | | | | 11 | | 6 |
| Distance 7.45 under spec. | 57 | 4.41% | | 10 | 5 | 4 | 1 | 15 | | | 2 | 7 | 4 | 8 | | | | | | | | | | | | | | | | | | 1 | |
| Clamp and bump at part | 296 | 22.91% | | 35 | 19 | 48 | | | | | | | | | | | | | | | | | | | | | | | | | 157 | 35 | 2 |
| Distance 5.60 under spec. | 17 | 1.32% | | | | | 8 | | | | | 1 | 3 | 1 | | | | | | | | | | | | | | | | | 3 | 1 | |
| Distance 1.00 under spec. | 5 | 0.39% | | 3 | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | |
| Diameter 3 mm. out of spec. | 22 | 1.70% | | 1 | | | 1 | 1 | | | | | 1 | | | | | | | | | | | | | | | | | | 16 | | 2 |
| Other | 119 | 9.21% | | | 1 | | | | | | 1 | | | | | | | | | | | | | | | | | | | | 112 | 4 | 1 |
| Total | 1292 | 1292 | 0 | 148 | 50 | 85 | 214 | 156 | 0 | 0 | 10 | 25 | 19 | 62 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 424 | 56 | 43 |

Production 27,900

Percentage of rejection 4.631%

☐ Continuous Defects

### 3.6 Study of the root causes of defects

The study of the type of problem can help grouping the kinds of defects and reduce time to do corrective action program. On the other hand, the cause and effects diagrams shows the possible cause of problem.

In the Pareto diagram shows that in process 3 has the highest percentage of reject. So the first priority is to reduce the amount of reject in this process. The defects in process 3 can be divided into four groups and sub-groups;

3.6.1 The mark from the bump and clamp

1. The bumping during transportation and packing in process
2. The force of clamping is too high
3. The chip obstruct at clamping area
4. Inappropriate of load/ unload part in machining process

3.6.2 The diameter out of specification

1. Over/ Under-specification of diameter
2. The taper in cylindrical of crankshaft, both small and big in one part

3.6.3 The out of specification of thickness

1. Thickness lower than specification
2. Perpendicularity over specification

3.6.4. The out of specification of eccentric distance

These defects can define the causes of problems by using cause and effect diagrams to generate idea to do corrective action. In these cause and effect diagrams, using the 5M and 4M to analyze problem depends on the kind of problem.

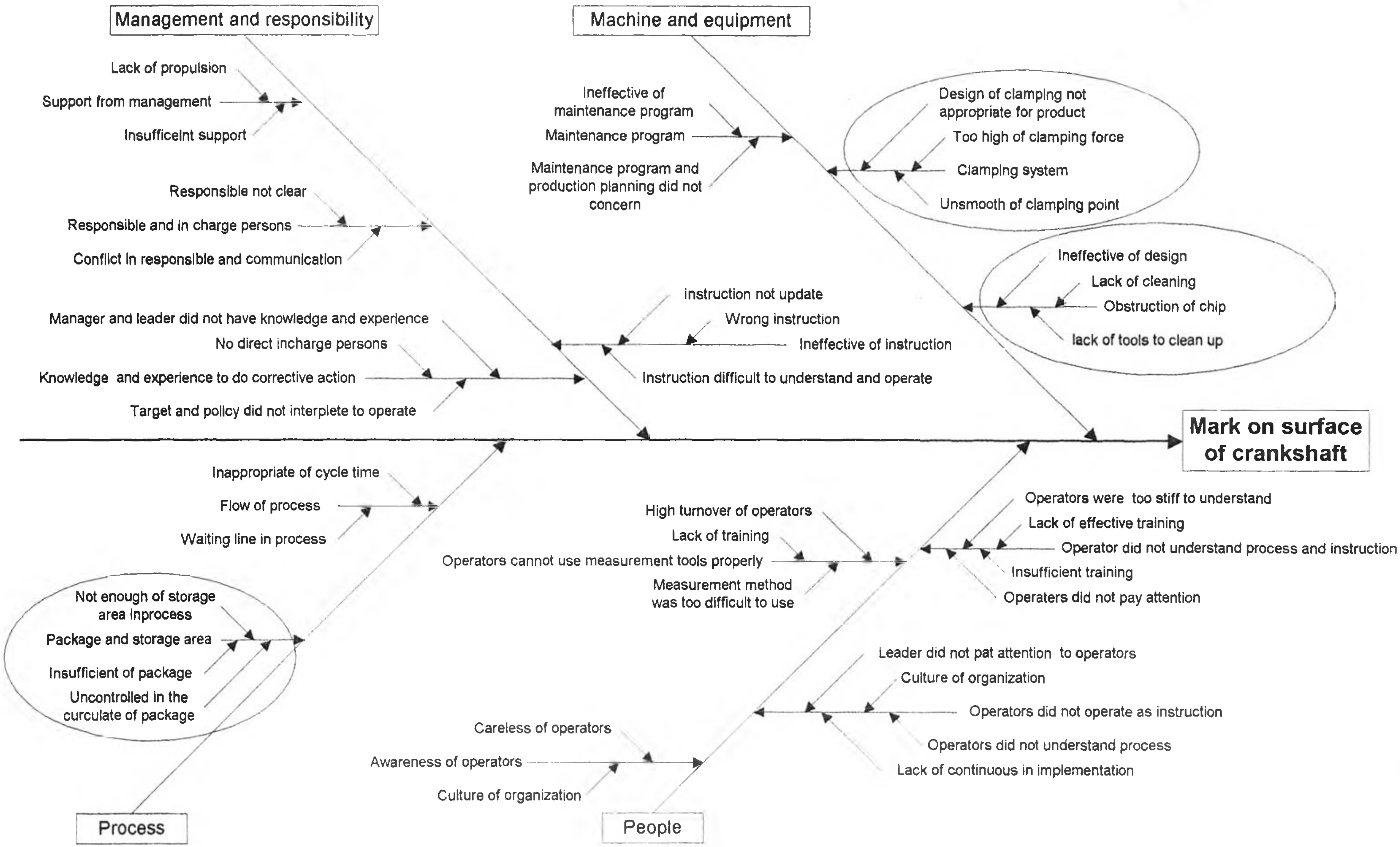


Fig. 3.9 The cause and effect diagram of the mark on the surface of crankshaft defect

3.6.1 The mark on the surface of crankshaft

As the result of the cause and effect diagram in fig. 3.9, the possible cause of mark on the surface of crankshaft comes from four categories; the machine and equipment, the manufacturing process, the people or operators and management and responsibility. The actual causes of problem from the investigation, it usually causes by the chip obstruction between part and clamper, clamping force is too high and bumping during transportation between process.

Machine and equipment: the clamping system in this line consists of two machines with the different clamping system, the collet and the chuck system. Both kinds of clamping system have advantages and disadvantages. The problems usually occurs with collet system because chip could obstruct at clamping area and difficult to remove them.

Manufacturing process: this topic relates to machine and equipment problem. This production line is the mass production so the cycle time and capacity of line is the important factor for designation. When customer has requested to increase capacity of line, it affects to cycle time of process. The bottleneck point makes the change in the flow of process. The mark on crankshaft occurs between process cause of insufficient of storage area and the insufficient of package.

People or operators: the awareness and understanding in process of operators is the most important to solve this problem because operators are the person who make and find problem. The attention of operators about the quality of product is low because they just want to produce the product. So sometimes they do not inspect and operate as instruction.

Management and responsibility: unclear in responsibilities, lack of knowledge and experience to do corrective action is the important causes that make the ineffective system. The monitoring and controlling of the process is necessary to increase effectiveness of process.

Summary the result of cause effect diagram

From the cause and effect diagram that came from the brainstorming in the team, some causes in cause and effect diagram are only possible causes of defect. In this section, the high probability to be actual causes of defect is selected and estimated into percentage of defect.

The mark on surface of crankshaft

1) The clamping force is too high because the mark has been found at clamping point in this process. And there is uncontrolled of standard force and maintenance system for clamping system (~ 10%)
2) The chip obstructs between part and clamper. This cause usually occurs with collet system because chuck system is not found this problem. The collet system did not have the protective equipment to prevent chip go into collet during machining process, the chip still stick at collet and machined parts. And there was no effective equipment to remove chip from the collet. (~ 30%)
3) The mark during transportation within process makes the bump between part to part and part to package. Some rejected parts are found in packing process before delivery to customer that is passed in process inspection by operators in production line. As this reason, these defects are not occurred in machining process but it happen during transportation. The unbalance of cycle time also make the bottleneck and insufficient of storage area between process. (~10%)
4) Inappropriate of clamping method and system make the marks during load/ unload part in machining process. The material of clamping system has much harder than the product to prevent the wear of equipment. This cause makes the mark when part and equipment bumped or crashed during load / unload process. This cause usually occurs from the careless of operators in all process. (~ 50%)

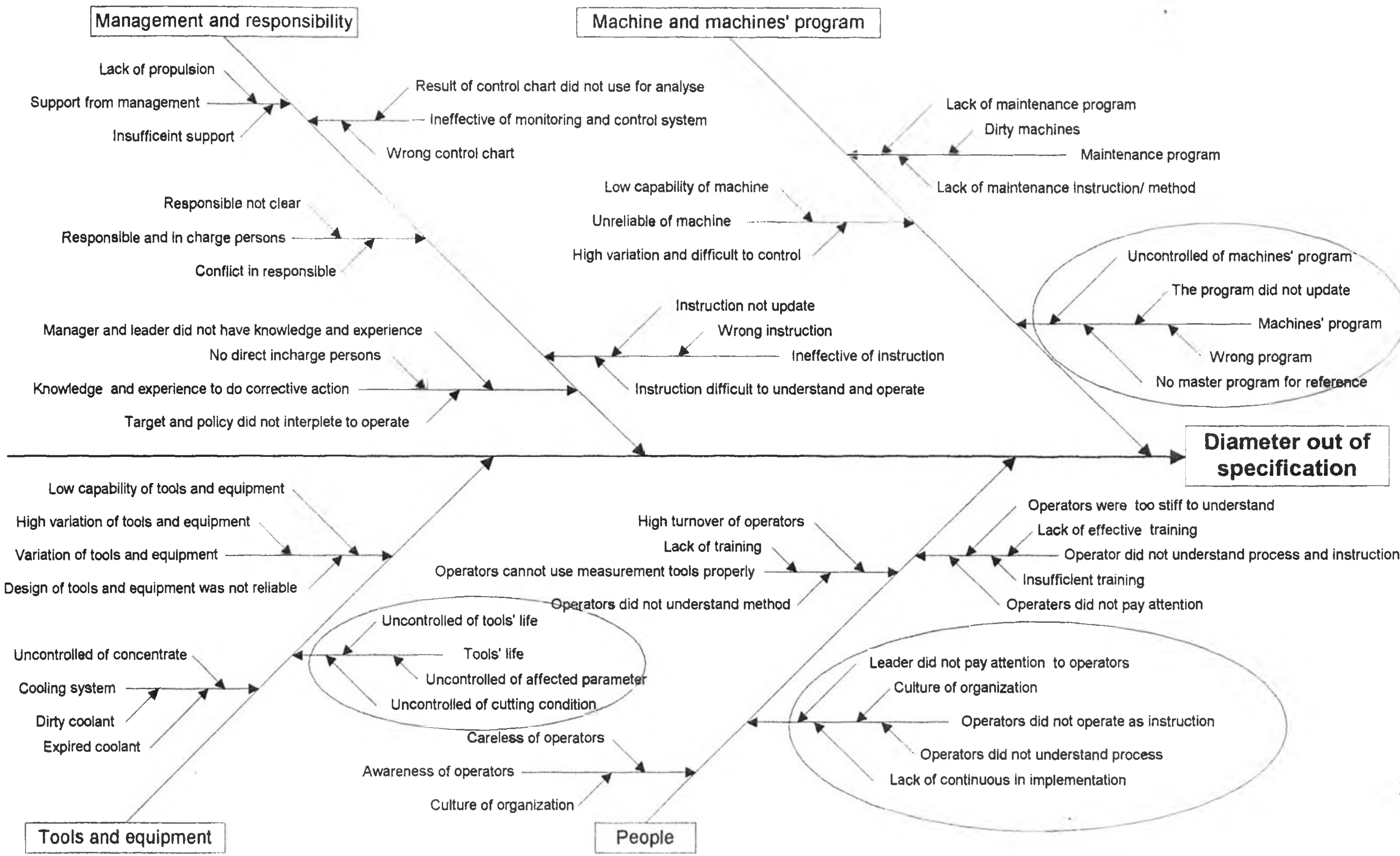


Fig. 3.10 The cause and effect diagram of the diameter out of specification defect

### 3.6.2 The diameter out of specification

The out of specification of diameter is an important problem because it effects to the function of product and the reference point in next machining process. The out of specification of diameter composes of two problems; the over / under specification of diameter and the taper of diameter in cylinder (both large and small at same diameter). The over / under specification of diameter have the same cause of problem, usually comes from the high variable of machine and equipment, which difficult to control. But the taper of diameter causes the missing in alignment of center and the low of centering force that make the oscillation of the part during machining process. The relative causes of this problem is shown in fig. 3.10.

Machines and machines' program: the machine of this line is assumed that they are capable. But the equipment uses to support part for machining such as clamping system, holder, cutting holder and etc. are assumed to have high variation as explain in next topic. The controlling of machines and machines' program are under responsible of operators and group leader. The result of high variation of data, it is found that the machine maintenance program does not implement properly and the machines' program is lack of controlling system.

Tools and equipment: the difference of clamping system affects to control the variation of diameter, collet system has high accuracy but chuck system has high variation. Another two factors that relate to an effective to control diameter are the cutting tools and cooling system. Ineffective controlling of tools' life and concentration of coolant increase the difficulty to control the variation of diameter. Especially, the cutting tools and machines' program is used to control the diameter of crankshaft, the adjustment and change of cutting tools relate to machines' program and usually makes the reject by lot.

People or operators: the frequency of inspection is one method to detect and control the defect in manufacturing line because there is no system to control tools' life. The awareness and understanding in process of operators is necessary for increasing effectiveness of process. The frequency and method to inspect is necessary in the line as same as the training program to make operators to understand process and important point to control and inspection.

Management and responsibility: the improperly of authority and level to do decision making problem in manufacturing process. For example: the authority in changing and adjustment of operators are too much and lack of controlling from leader, the leader cannot solve the problem on time and correctly that make the defect, operators do not check before running production and etc.

<u>Summary the result of the cause effect diagram</u>

The occurrence of this defect, about 50 percent of defect comes from the continuous defect. The causes of defect that has high probability to be rooted causes of defect is:

1) Uncontrolled of tools' life. It is one cause of problem because when the tools' life of cutting insert is expired, it cannot control the diameter and makes the continuous defect. (~60%)
2) No effective methods to control machine and machine program. This cause relate to the tools' life of cutting insert, every time when adjust or change new insert has to change the machine program. In case of machine, it did not have effective maintenance program both routine maintenance and breakdown maintenance that make the lot of reject. (~30%)
3) Operators do not inspect when changed the offset program. This cause happens to all production lines and is usually found in sampling inspection by quality control operators. (~10%)

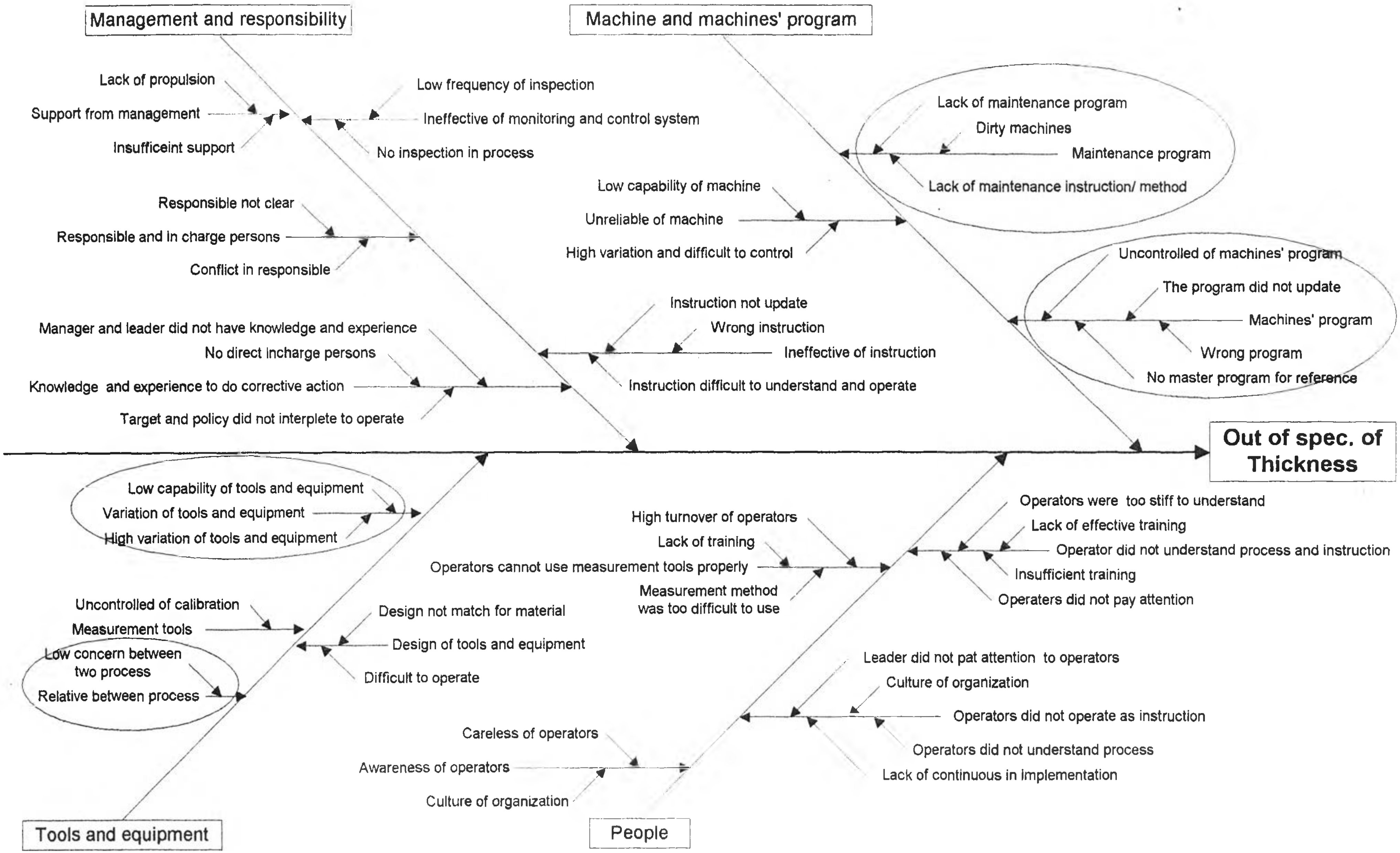


Fig. 3.11 The cause and effect diagram of the out of specification of thickness defect

3.6.3 The out of specification of thickness

The causes of the defect in fig. 3.11 show the major problem is the raw material. The raw material of crankshaft is fabricated by sand mold casting. The possible causes relate to material is the pattern of crankshaft and the sand block. In casting process the pattern is laid in horizontal axis in the sand block, the parting line is long across the crankshaft. The problem is the shift of the parting line that makes the large of total thickness as shown in fig.3.12. But when measuring finished part, the thickness become lower than specification because the shift of parting line makes the part to be machined both sides.

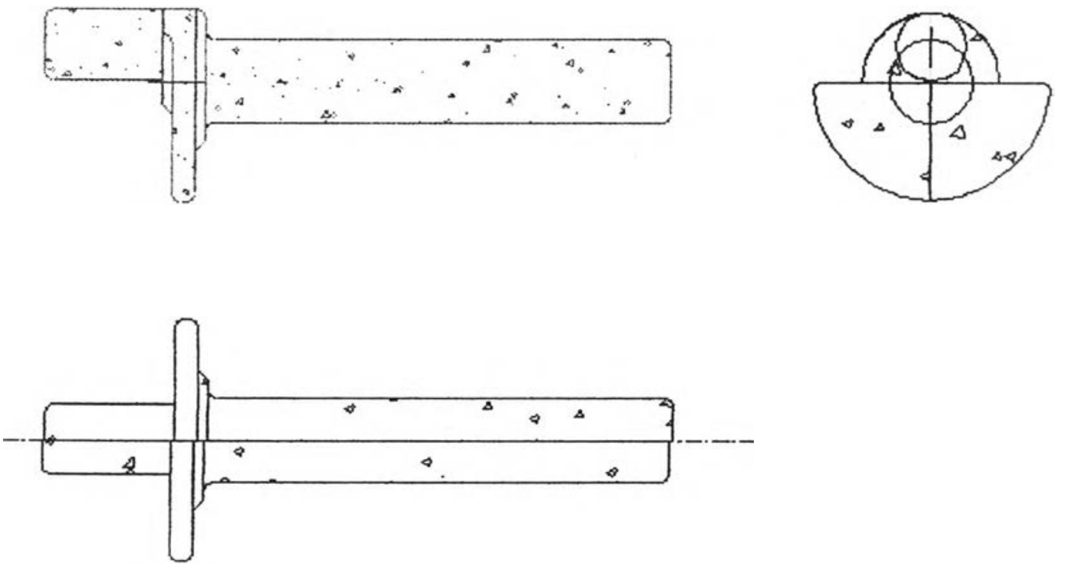

Fig. 3.12 The shift of parting line problem in crankshaft's wing

Supplier solved this problem by controlling the different distance of parting line and increased grinding process for removing the excessive of material before delivery. The solving method can reduce the reject from raw material quite a lot.

Machine and machines' program: uncontrolled of machine program and ineffective of cleaning and maintenance program makes high variation of data. The reference point of this process used surface of raw material and machined surface in previous process that difficult to control.

Tools and equipment: this problem is the result of two processes, process 2 and 3, so it is difficult to identify problem exactly. The excessive machining in process 2 makes the wrong reference point in process 3 which is the most possible cause of problem. The ineffective of design is another problem because the design has large gap and space that is difficult to load part in the right position.

People or operators: the unskilled operators are lack of effective training from leader, ineffective of instruction for operator and operators do not operate as instruction is the major cause. The wrong method to load part in the machine makes the out of specification of thickness.

Management and responsibility: the improving method for reducing tools and equipment problem do not implement to the line. And the training and testing program for operators are not used to increase skill of operators.

<u>Summary the result of cause effect diagram</u>

This defect is the consequence of process 2 and 3 so it is difficult to control. The design of process 3 is used for the machining surface of process 2 to be the reference position. From the occurrence of defect, it occurs in random type that is difficult to investigate actual causes of defect and do corrective action

1) The excessive machining surface from process 2. This continuous defect makes the wrong reference point and made the excess machining surface in process 3. (~90%)
2) High variation of raw material. The wear of pattern in casting process makes wrong position of reference point because of the error in machining process in process 2 that affect to process 3 (~10%)

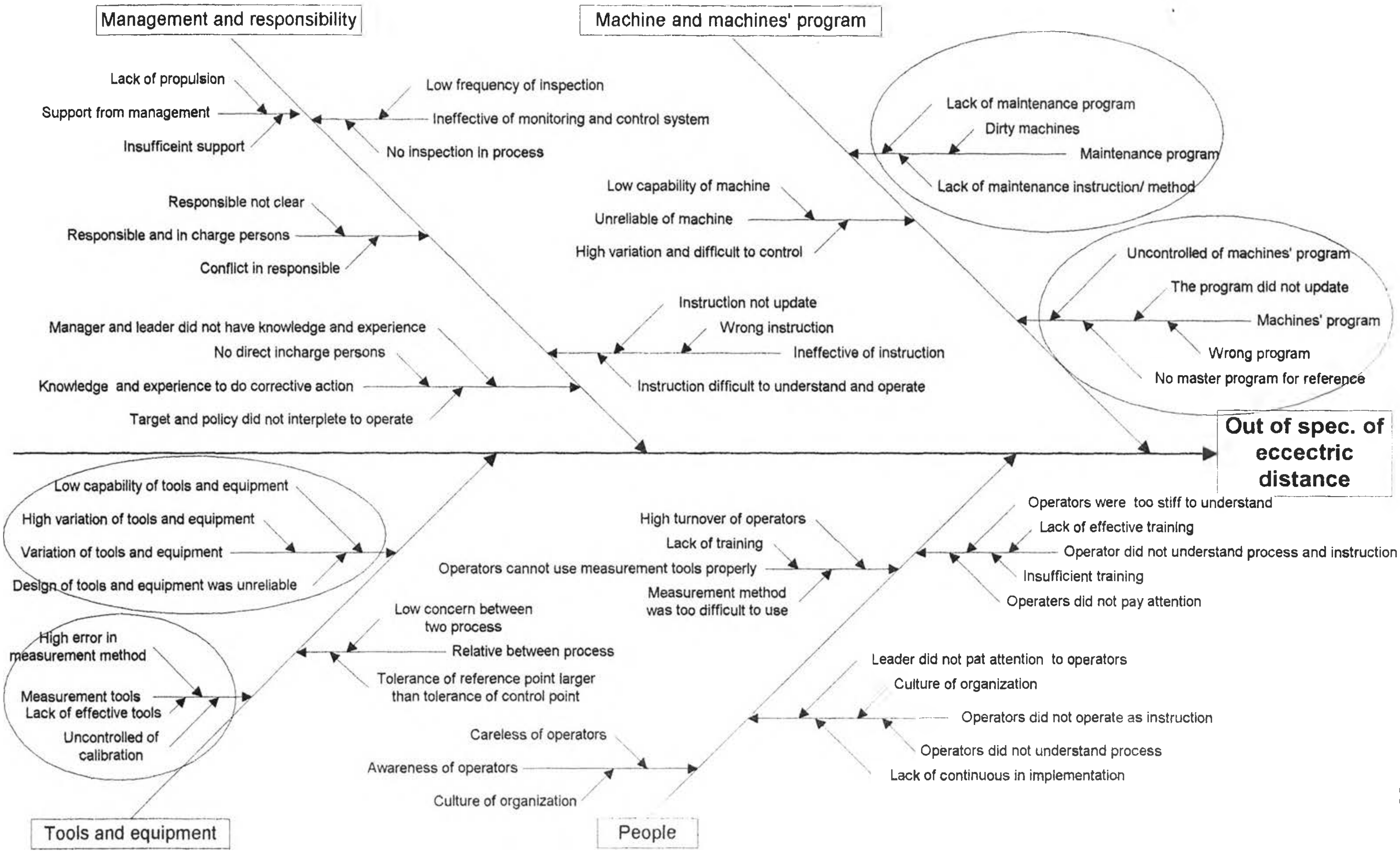


Fig. 3.13 The cause and effect diagram of the out of specification of eccentric distance defect

3.6.4 The out of specification of eccentric distance

As shown in fig. 3.13 is the possible causes of the eccentric distance defect. The distance of eccentric is the most significant problem because it affects to the function of crankshaft directly. The distance of eccentric is shown in fig. 3.14.

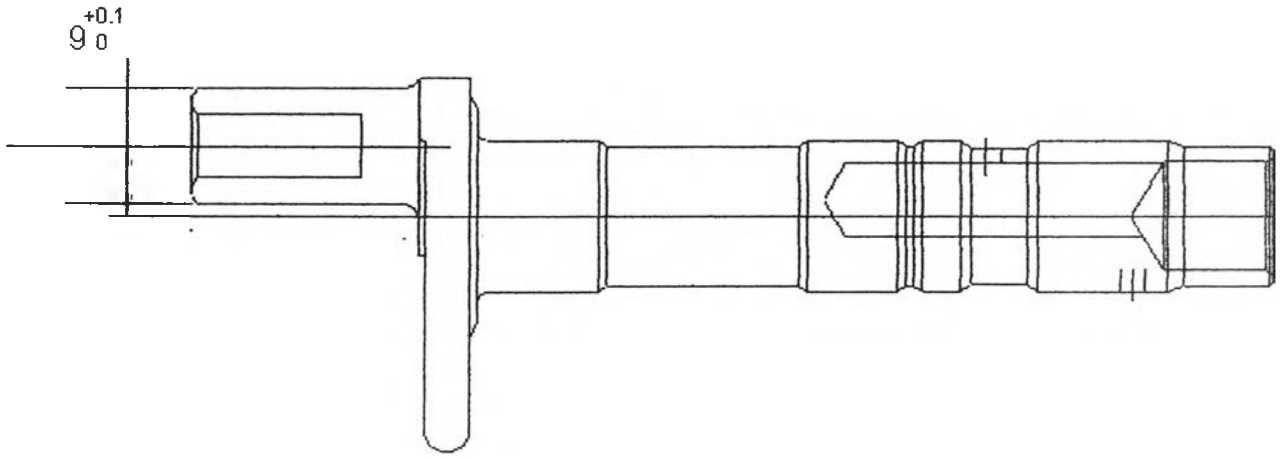


Fig. 3.14 The eccentric distance of crankshaft

The distance of eccentric is the results of process 2 and process 3 same as the thickness problem but the raw material problem does not affect to this problem. The actual problem is the measuring method because there is no specific tools for measuring this value. The process design of eccentric uses the reference point from process 2 then machine in process 3 so causes of problem come from both processes.

Machine and machines' program: the machines' program of this line relates to the design of process and accuracy of tools and equipment. Uncontrolling of machines' program and maintenance program make the collapse of machine that still cause of problem.

Tools and equipment: tools and equipment is the major cause of problem because the lack of specific measurement tools for measure this item that has to use calculation for measuring this item. Another problem is the high variation of reference position on part, tools and equipment make the difficult to control and do corrective action.

People or operators: the unskilled operators who are lack of effective training from leader, an ineffective of instruction for operator and operators do not operate as instruction are still the major causes of problem.

Management and responsibility: this item has no specific measuring tools for measure in process because it was too difficult for the measurement that made the continuous defect cause of the insufficient of inspection.

Summary the result of cause effect diagram

This dimension has the cause like the thickness defect but the occurrence of this defect occurs continuously, about 80 percent. This dimension is lack of effective measuring tools for inspection but it is an important item.

1) Lack of in-process inspection, the measurement method is complex, high probability to error and no effective measurement tools that make the low frequency for inspection. The difference in measuring result between in process inspection and sampling is usually occurred when the defect is found. And they occurred in large continuous lot.
2) Unreliable of tools and equipment because of the ineffective design and low capability of equipment. This dimension has narrow tolerance that need the high precision and reliable tools because the measuring should be more precise than tolerance and can show the result for control.
3) Uncontrolling of machine program and wrong setting standard for reference points are found because the defect is usually occurred by the continuous. The ineffective maintenance programs, routine and breakdown maintenance, makes the difficulty to control in the variation of process.