Chapter IV

Solutions and their implementation

In previous chapter has talked about the causes of the problems that occurs in process 3. These causes can occur in related to other processes so the countermeasure and preventive method may relate to other processes and by itself. There are four major problems in chapter 3 that occur in process 3. They are

1. The mark on the surface
2. The out of specification of the outside diameter
3. The over specification of the eccentric distance
4. Under specification of the thickness at the wing

These causes were shown in the cause and effect diagrams in previous chapter by using 5M method for analysis. But the solutions and implementation method needs the participation of the correlative functions to make the result more effective. The implementation plan of this project can be defined into 5 steps;

4.1 Establishment of the project team

4.2 Study causes of problem and corrective method

4.3 Preparation of the project planning

4.4 Setup the quality system to monitor and control process

4.5 Summary and conclusion

The result of this study is measured by comparing the rejection rate before and after an implementation. The result of implementation and conclusion of this study will explain in chapter 5.

4.1 Establishment of the project team

The project team consists of the person who are responsible for the functions and activities that correlate with the production process. The project team member and their responsibilities are shown in table 4.1

Table. 4.1 Project team member and their responsibilities

Team member	Responsibilities
Managing director	Project leader, making decision and controlling the budget of project
Production manager	Consultant of project in technique for improvement process
Production engineering chief	Generating the idea for improvement process and design
Production chief	Training and controlling the implementation of operators
Quality assurance chief	Collecting data and making conclusion to measure the result of improvement program and recording the method and result of corrective and preventive action
Project engineer	Following up the implementation program and solving the simple problems
Production planning officer	Controlling the production planning and schedule for improvement

After the project team is established, team members study the causes of problems from the cause and effect diagrams then prepared the planning of implementation plan for countermeasuring and preventive action. The project planning consists of the time schedule of implementation plan, milestones, measuring method and conclusion.

4.2 Study causes of defects and corrective method

The solving method for general problems can be classified into two types by studying from the occurrence of problem. One is the continuous defect, occur continuously or high percentage in production lots. The other is the random defect which cannot predict the occurrence of problem and there is no pattern of occurrence. The former takes less time and is easier to correct and reduce than the later.

From the causes of problems in chapter 3, the corrective action can be divided into two methods, countermeasure step and preventive action step, but both of them can be implemented in parallel to reduce the time of corrective action. The countermeasuring step is emphasized on the method to control and eliminate the previous and current problems especially the continuous defect. On the other hand, the preventive action is the method to prevent the possible problems or the random of defect that may be occurred by using the experience of related products and processes.

In the cause and effect diagrams in process 3 have similar topics and different topics. The similar topic in the cause and effect diagrams is the management and responsibility and people. These topics can explain separately from the different topics. Another cause of problem is the mechanical problem that related to machine, tools and equipment.

In four major defects of process 3, the causes of defect can be grouped into two groups, the causes relate to human and the causes relate to process. But there is only mark on the surface defect that composed of both groups. Other defects have only the problems relate to the process such as machine, machine's program, tools and equipment.

Management and responsibility problem

Although, the responsibility and organization chart was established but it still had the conflict in responsibility and communication in the organization. The organization has two departments to have responsibility in the improvement program. They are production department and quality assurance department as explain in chapter 4. Practically, the improvement program cannot work effectively because of the lack of experience and knowledge to do this program. The communication in the organization is also the major trouble causing an ineffectiveness of communication and uncontrolled of datum in the organization.

There is no measuring the process capability in prototype and mass production period is the cause of the continuous problem. The process capability and process capability index can tell the ability of the controlling and variation of the process. The actual capability of this process is low that caused a high probability to find the defect.

The QC circle and 5S activities are implied in the production line to increase an awareness and good attitude to the operators in their work but the result of implementation is ineffective. The operators need only manufacture to achieve production planning but they do not pay attention to the rejection that occur in their responsibilities.

These causes from management and responsibility are difficult to correct in short period of time. But the corrective method in this case are setting project team to be responsible activities as shown in table 4.1 and using the group activities (5S and QC circle) in the production line to make awareness to operators.

4.2.1 The mark on the surface of crankshaft

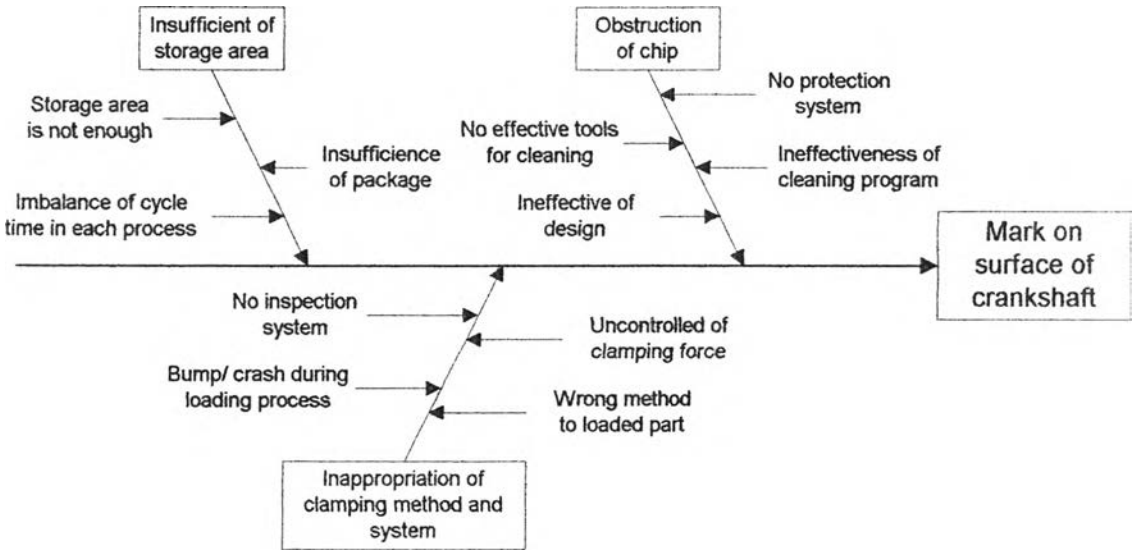

Fig. 4.1 The cause and effect diagram of the mark on the surface of crankshaft defect

In fig. 4.1 it can be seen that the causes of the mark defect come from three major categories, the obstruction of chips at the clamping area, the inappropriate of clamping method and the system and the insufficient of storage area. The result of studying in details, this defect occurs in two processes, process 3 and 4, so it is difficult to identify the accurate percentage of defect in each process.

4.2.1.1 The obstruction of chips at the clamping area

The causes of the obstruction of chip at clamping area come from chips go into clamping system, collet system, during machining process. The design of collet system had the space when the part is clamped. During production period, the chips stick at space of clamping system then they flow into the collet when unloaded parts. This cause had been occurred about 35 percent of defect because it is difficult to prevent the chips from flowing into collet system.

The corrective method is wiping the clamping area inside the collet to remove the chips because the blowing method makes the diffusion in the machine and nearby

area. But the wiping method can not use every time before the operation because it spends a lot of time. The wiping method is implied at a period of time, about one time per hour. Another reason that makes it is difficult to clean and remove the chips is the stickiness and wetting of the coolant.

There are three methods to prevent chips flow into the collet or clamping area. They are the redesigning the reference point and clearance of clamping system and preventing chips from sticking to the space by covering them.

4.2.1.2 Inappropriate of clamping method and system

This problem related to the obstruction of chips in term of the design. The clamping force also affect to this defect because excessive of clamping force makes the mark on surface of crankshaft. The suitable clamping force from an experiment was 15 lbs. per inch^2 but there is no system to monitor the clamping force during processing. From the experiment, these causes occur during loading and unloading process from the collet or clamping system about 60 percent of the mark defect because the material of collet is much harder than the surface hardness of crankshaft.

The corrective actions of this problem are monitoring the clamping force during processing and setting the standard of the control. From investigation of clamping force, this problem comes from the broken collet made the slip when clamping. So the operators have to increase the clamping force to solve this problem and the gauge for measuring clamping force is error. The solving method needs the participation of operators to prevent the bump between part and clamping system.

Preventive action is having system to control the clamping force and maintain the clamping system. (E.g. randomly or periodically checking by leader, having maintenance program for tools and equipment)

4.2.1.3 Insufficient of storage area

The storage area in process consists of two zones, the storage area in the process (raw material and work in process) and the packing area (containers for finished product). In the first area, the imbalance of cycle time in each process makes the leap of work in process at the longest process or bottleneck process. Another case, the insufficient of containers for packing and ineffective circulation of containers between supplier and customer, the containers do not increase enough for new capacity. These causes of the defect is occurred about 15 percent

There are 2 methods for corrective and preventive action, increasing amount of containers for finished products and balancing the cycle time of in this line. The first method is easier and uses short period of time for implementation but it needs the management system to control the circulation of containers and finished product in stock of suppliers and customers. The later is the controlling of cycle time and implementation during processing to reduce the bottleneck process. But this method spend lots of money and time for implementation because cycle time of each process relates to the process design that include the machining process and application of each machine. After the process is balanced the just in time (JIT) system will be implied to control the flow of process and sequence of manufacturing process.

4.2.2 The diameter out of specification

The out of specification of diameter can be divided into two types of defect was the over/ under specification of diameter and unstable or taper of diameter. The occurrence of these two types of defect in ratio was 90:10 percent. And when we study the time of occurrence it occurred randomly and continuously. Fig. 4.2 showed the cause and effect diagram of the out of specification of diameter defect. The major causes come from three categories; the uncontrolling of machine and machine program, uncontrolling of tools' life and operating without following the instruction.

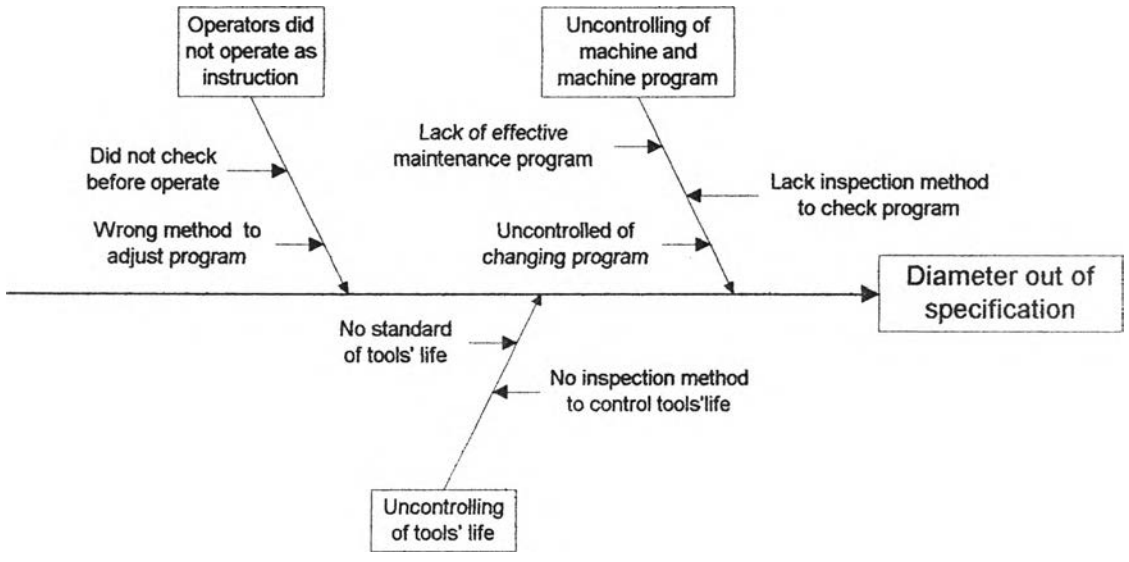

Fig. 4.2 The cause and effect diagram of the diameter out of specification defect

4.2.2.1 Uncontrolled of machine and machine program

This topic consists of the machine maintenance program, cleaning program and maintenance program to ensure that machine can operate effectively. Because this production line is a continuous line and has full capacity, it is no breakdown maintenance. The breakdown maintenance will operate when the accident happens and the run of continuous defect that operators cannot solve problem. (E.g. the collapse of machine, holder and clamper) The routine maintenance only inspects the level of lubricant oil and coolant and cleans the external boundary of machine at the operated area. This cause will occur randomly at the first period and occur continuously in later period about 10 percent of defect of diameter.

The corrective action is setting the breakdown maintenance program for checking and maintenance machine to reduce variation of machine such as roller, bearing, co-ordinate axis of machine and machine program. The cleaning program at the end of shift is another method to detect the error of machine. (E.g. the leakage of lubricant oil, the miss of cooling position, wear and damage of tools and equipment and etc.).

Preventive methods are setup the effective maintenance programs, breakdown and routine maintenance and instruction. The training program for operators about implementation in the production line is the next step. The maintenance programs have to relate to the production planning because it need an sufficiency of time for preparing tools and equipment for maintenance.

4.2.2.2 Uncontrolled of tools' life

Tools' life of cutting insert depends on three major factors such as the program for machining, the cooling system and the hardness of material. The machine program includes the depth and speed of cutting. These two topics affect to the wear of cutting insert and cycle time of machining process same as the hardness of raw material. The investigation of the hardness of raw material shows that there is the difference along the surface of raw material because the difference in cooling temperature in casting process. The last factor is the cooling system, the coolant uses to reduce temperature and remove the scrap from cutting point so the sufficiency of coolant can expand to tools' life of cutting insert. Tools' life of cutting insert affects continuously to the controlling of diameter and adjustment of the offset program, when cutting insert is wore. The crack or broken of cutting insert that occurs by accident is difficult to detect can make the randomly defect.

Corrective and preventive methods are setting the method to inspect and change of cutting insert and controlling the variation of raw material. Because it is difficult to predict tools' life of cutting insert so the period of time for checking must be set. In practically, the operator changes of cutting insert when the surface roughness and diameter are near the specification. As this reason, the master sample of surface roughness and measurement tool is prepared in production line. The statistical process control is implemented in the production line for warning when the diameter is near specification in control charts. So an effective result of implementation needs the usage and interpretation of control charts training for leaders and operators.

4.2.2.3 Operating without following the instruction

When the diameter of crankshaft is near upper limit of specification, operators have to change the offset program or new cutting insert. Sometimes, operators change the offset program but they forget to measure the diameter after the changes that make the continuous defect.

Corrective and preventive methods for solving these problems are the training. The training programs have to include the instruction for operation and measurement method. Because this production line has high turnover rate and run continuously, the leaders have to be trained and randomly audit the result of training and implement the result of operators continuously. The training programs for operators should be emphasized on the inspection when we change the offset program and new cutting insert. The inspection and monitoring method by using control chart can show the trend and status of cutting tool.

4.2.3 The out of specification of thickness

The out of specification of thickness comes from two causes, the uncontrolling of machine and machine program and the inappropriation of correlation during procession as shown in fig. 4.3. The out of specification of thickness defect consists of two types of minor defects, the over specification of perpendicularity between wing and shaft and under specification of thickness from raw material.

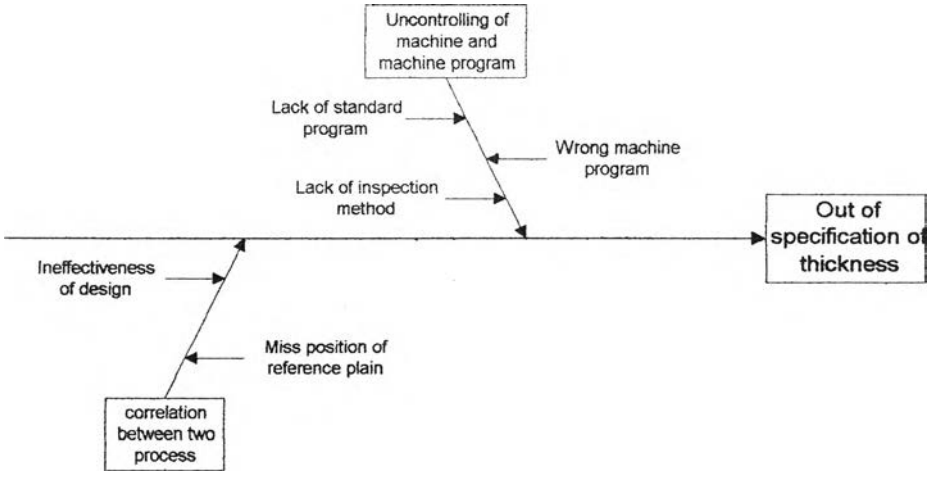

Fig. 4.3 The cause and effect diagram of the out of specification of thickness defect

The move of part during machining or the missing a reference plain makes the over specification of perpendicularity between wing and shaft. This defect is randomly found so it depends on the method to load part in the right position. In case of the under specification of thickness, the excessive machining in process 2 makes the wrong position of reference plain in process 3. The causes of excessive machining in process 2, it comes from the miss position of loading because the surface of the reference plain in process 2 is raw material surface.

4.2.3.1 Uncontrolling of machine and machine program

Ineffectiveness of maintenance is also the cause of this defect such as lacking of maintenance method, the wear of the clamping system and reference point and plain. Unstable of holder and the collapse of machine makes the change of axis or error caused by this defect too. In term of machining program, an ineffectiveness of controlling method makes unpredictable defects.

Corrective and preventive action for this cause is to have machine and machine program maintenance continuously by having schedule for checking all components that affect to the quality of product. (E.g. the wear and stability of a reference point, stopper and reference plain, the stability of holder and clamping system, performance of machine, and etc.)

4.2.3.2 Inappropriate of correlation among each process

The reference of process 3 is the machine surface in process 2, so both processes have to relate in term of specification and tolerance. The studying in the kinds of defect at rejected part, it finds that about 60 percent of this defect come from the excessive machining in process 2. So the controlling of excessive machining part in process 2 could reduce defect in process 3. But the excessive machining parts have to be separated from other production lot.

Corrective and preventive action is to check the design and correlation during processing such as references plains, reference points, tolerance and specification. Another alternative method to prevent this defect in the future is preparing the new design to correct the problem of correlation.

4.2.4 The out of specification of eccentric distance

The out of specification of eccentric distance come from 3 causes, an ineffectiveness of inspection method, an uncontrolling of machine and machine program and the unreliability of tools and equipment as shown in fig. 4.4

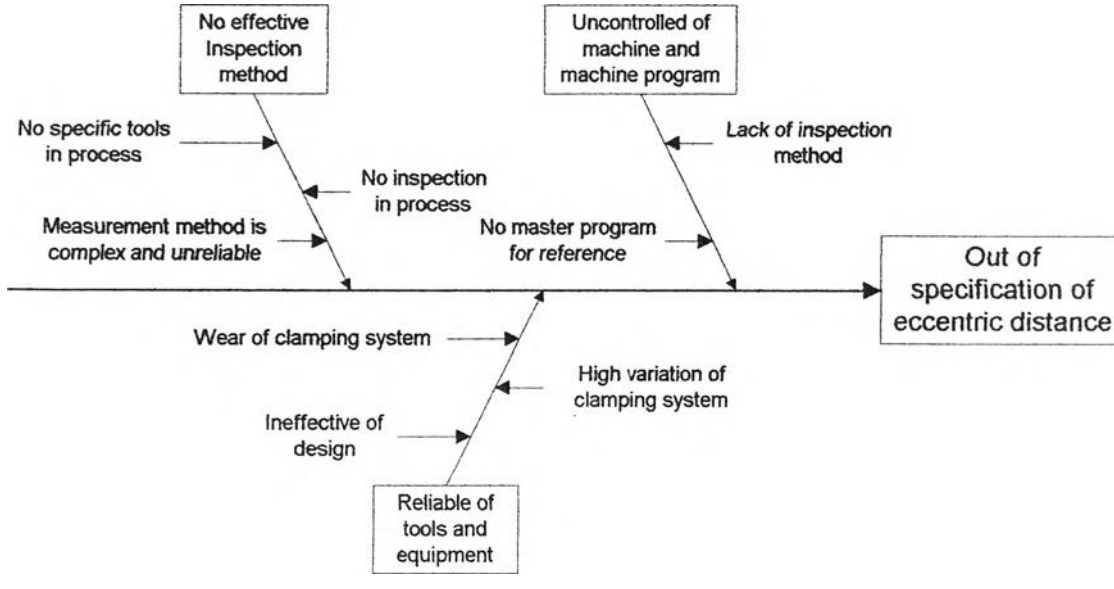

Fig. 4.4 The cause and effect diagram of the out of specification of eccentric distance defect

Distance of eccentric is the most important dimension of crankshaft so we use this dimension for calculating the process capability of process 3. The measuring method for the eccentric distance is difficult to measure because it needs a specific measurement tool. There is the distance between alignment of center of body and head of shaft. The measurement method is explained in following steps as shown in fig. 4.5.

1. Measure outside diameter of shaft's body, diameter 18 mm. then record
2. Divide result of 1 by 2 then record
3. Measure outside diameter of shaft 's head, diameter 14 mm. then record

4. Divide result of 3 by 2 then record
5. Set the center of alignment of shaft 's body and shaft 's head in the same axis then measure the highest point of two diameter and record
6. Calculate the distance of eccentric = 5 + 2 – 4

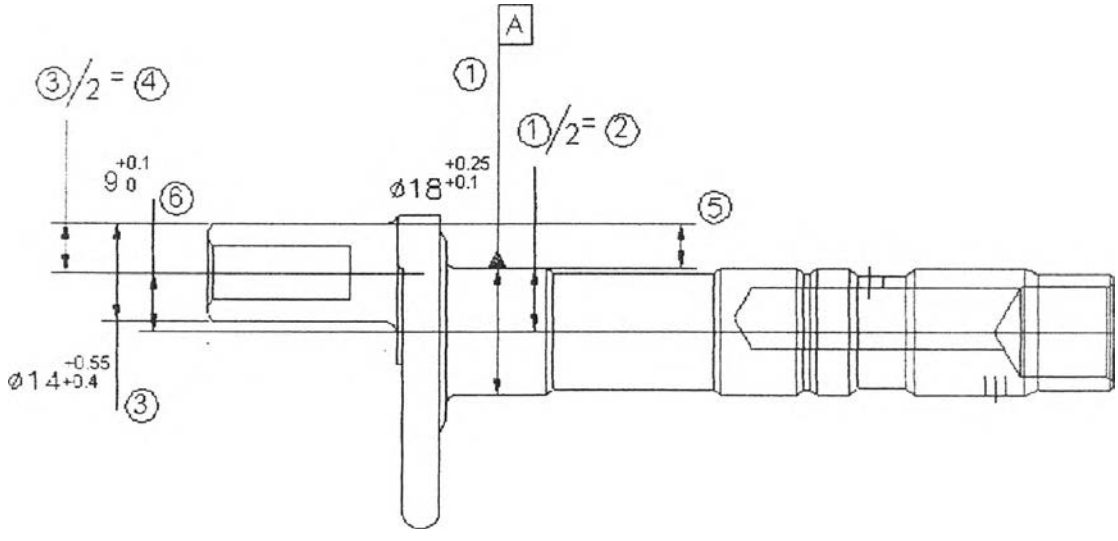

Fig. 4.5 Measuring method of the distance of eccentric

The correlation between process also affects to this problem in the tolerance of dimension. But the reference point that is machined in process 2 does not affect to this defect because the design of this process compensates for the turning of raw material adequately. And the design of this process uses the alignment of center in crankshaft' s body for reference that does not related to the diameter.

Unreliable of tools and equipment is another major causes of this defect. The stopper is used to make the reference position for loading part in clamper system. As this reason, the stable of stopper and the right of position is important for quality of product. The stopper is designed for helping operators to load part at right position. Although, the design of stopper likes the mistake proving method but it can change position by operators and uncontrolled method as shown in fig. 4.6. The stopper can change its position from the loose of bolt and the crash when load part that make the shift of alignment of eccentric distance as shown in fig. 4.7.

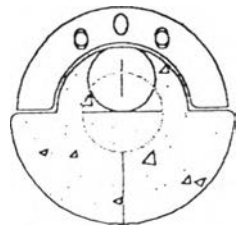

Fig. 4.6 The picture of stopper for making reference point in clamping system

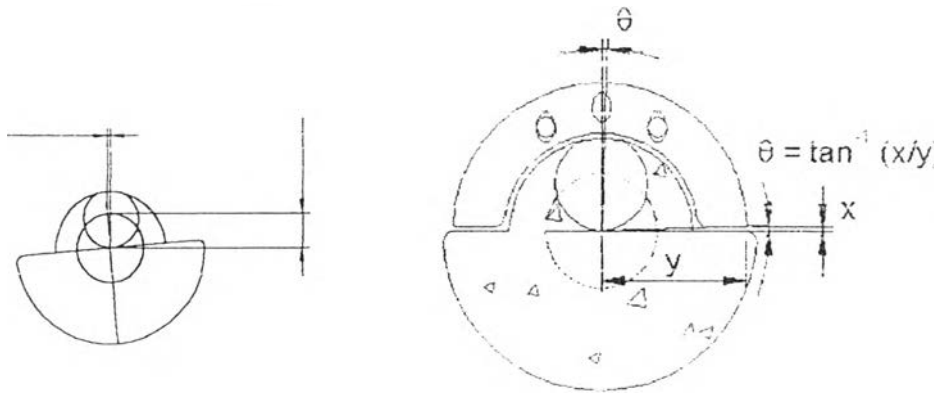

Fig. 4.7 The misalignment of eccentric distance that come from the inappropriate angle of loading

When we study the crankshaft in clamping system, we find that the clamped angle of crankshaft relate to the distance of eccentric as shown in appendix.

Another relative causes that affect to stopper is the wear of the collet. The collet is designed for snapping the part by mechanical system. The wear of collet at clamping area between part and collet and the wear of the transfer area between collet and clamping system are shown in fig. 4.8. The wear of the collet system reduce the clamping force of the collet and make the unstable of part when machining, moving, rotating and miss alignment.

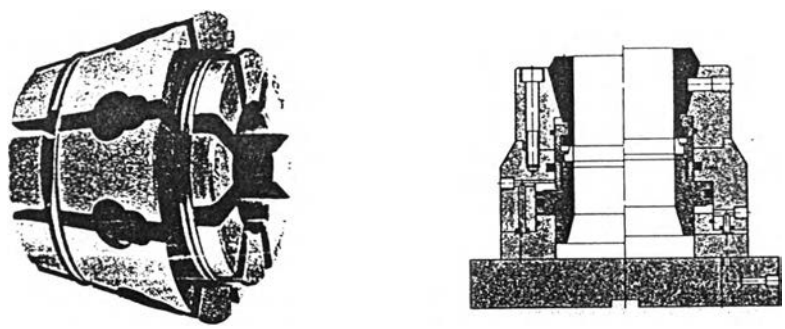

Fig. 4.8 The figure of collet and its mechanical function

The unstable of stopper and the moving of collet cause the broad variation of process as shown in fig.4.9. From the graph, the result run like the cycle, operators adjust the stopper when it places near the lower specification because it can not adjust the position of collet.

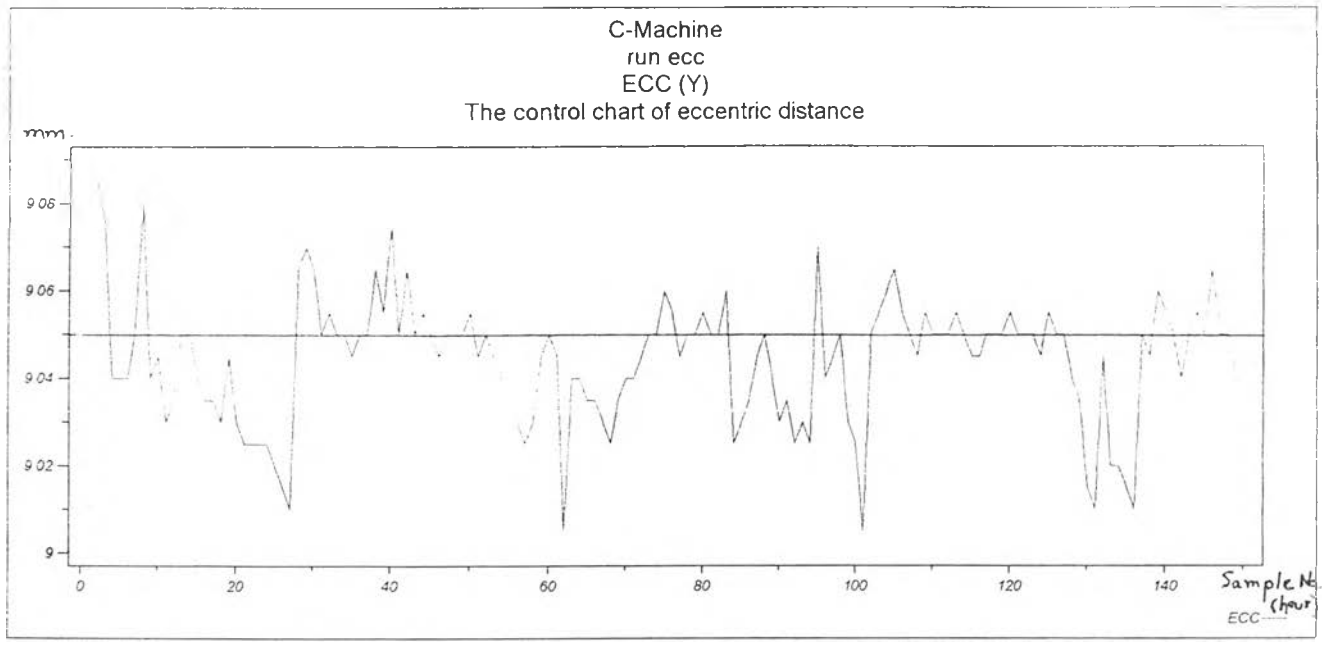

Fig. 4.9 The run of process because of unstable of stopper and the move of collet

5.2.4.1 Ineffectiveness of inspection method

As explain in the previous section, these causes can be divided into two causes; there is no the appropriate measuring tool and no in-process inspection. The lack of specific measuring tool made the error from reading and calculation. The difficulty to inspection and lack of in-process inspection make the continuous defect.

Corrective actin of this cause is to set the period of time for inspection in process and sampling. But the operators who are responsible for measuring this dimension have to pass special training about the measuring method, the usage and reading of measuring tools and understanding the calculation method. Another thing is to prepare the reliable measuring tools and measuring area for operators.

In term of preventive method, the specific measuring tools should be prepared to reduce the error of reading and calculation and reduce the time for measurement.

But the accuracy of the specific measuring tools is also determined because the tolerance of this specification is tightened and the measurement point is only the alignment that cannot be measured directly.

4.2.4.2 Uncontrolled of machine and machine program

This cause consists of the maintenance program, routine maintenance and breakdown maintenance, cleaning program and controlling of machine program. The crankshaft line is the mass production line that has to run continuously because of its capacity. As this reason the maintenance programs and cleaning program have to relate to production planning. But in practically, the production plan does not concerned with the maintenance and cleaning programs because of the delay of purchase order from customer so the production plan uses the forecasting from previous month. The breakdown maintenance always starts when the accident happen to machine or the large continuous defect occurs or the problems cannot be solved.

Corrective and preventive method is to prepare the schedule for maintenance and cleaning program and have the instruction for cleaning and routine maintenance. The breakdown maintenance uses a lot of time for checking and repairing, so the schedule for break down maintenance is necessary because it needs time for preparing equipment and spared part for maintenance. In term of machine program, having the method to control the change of program and responsible persons is necessary for effective controlling system. The machine program can be locked by the key and check by leader every 3 months compared with the master program that is prepared by production engineering.

4.2.4.3 Unreliable of tools and equipment

The ineffective maintenance programs of tools and equipment are the major cause of this defect. The wear of tools and equipment lead to the uncontrolling of variation of process. After investigation of the tools and equipment, the design of

machining process and its clamping system, the result showed that the process capability was lower than 1.00 that could not assure the reliability of process as shown in fig. 4.10.

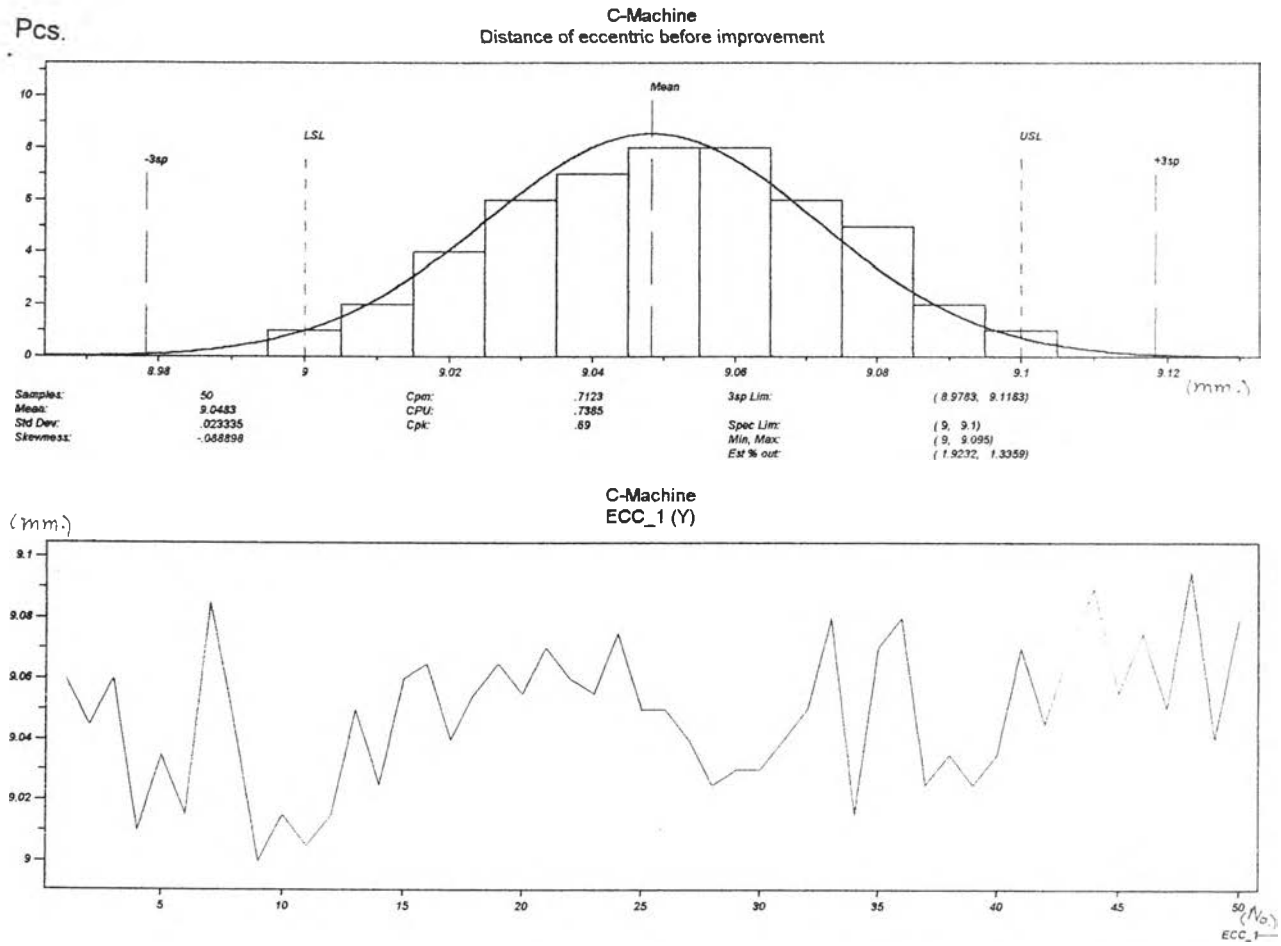

Fig. 4.10 The histogram and run chart of the distance of eccentric by random sampling

From the histogram in fig. 4.10, the variation of data is too broad and the value of 3σ is larger than tolerance of specification. It has high probability to be defected about 1 percent of production from this defect. When we study the detail of clamping system, we find that the relative root cause is the wear of equipment and the clearance of each component of clamping system. The manufacturing of the clamping system is manufactured by local supplier who buy local raw material for manufacturing and use low precision and low accuracy of machine for manufacturing, so it uses in lower budget than standard supplier about 3 time. But the quality and life cycle of them is lower than standard.

The corrective action of this problem is to increase the frequency of inspection to control the continuous defect as explained in previous section. And training operators in the correct method for load/ unload parts in this process is also important because the variation from the human error is difficult to control.

Preventive action can be devided into two steps, temporary and permanent method, because it needs time and budget for preparation. The temporary method is to fix the position of collet at the right position to prevent the rotate of collet in the clamping system. In this method, the screw is drill from holder through the collet to fix the position of collet. The permanent method is to change the new standard clamping system because it has more reliable and guaranteed from supplier. These causes occur about 60 percent of this kind of defect and it usually occurs continuously. So if the clamping system is changed the eccentric distance defect will be reduced about half of all defect. But this action needs the time and budget to invest so in this project does not change new clamping system.

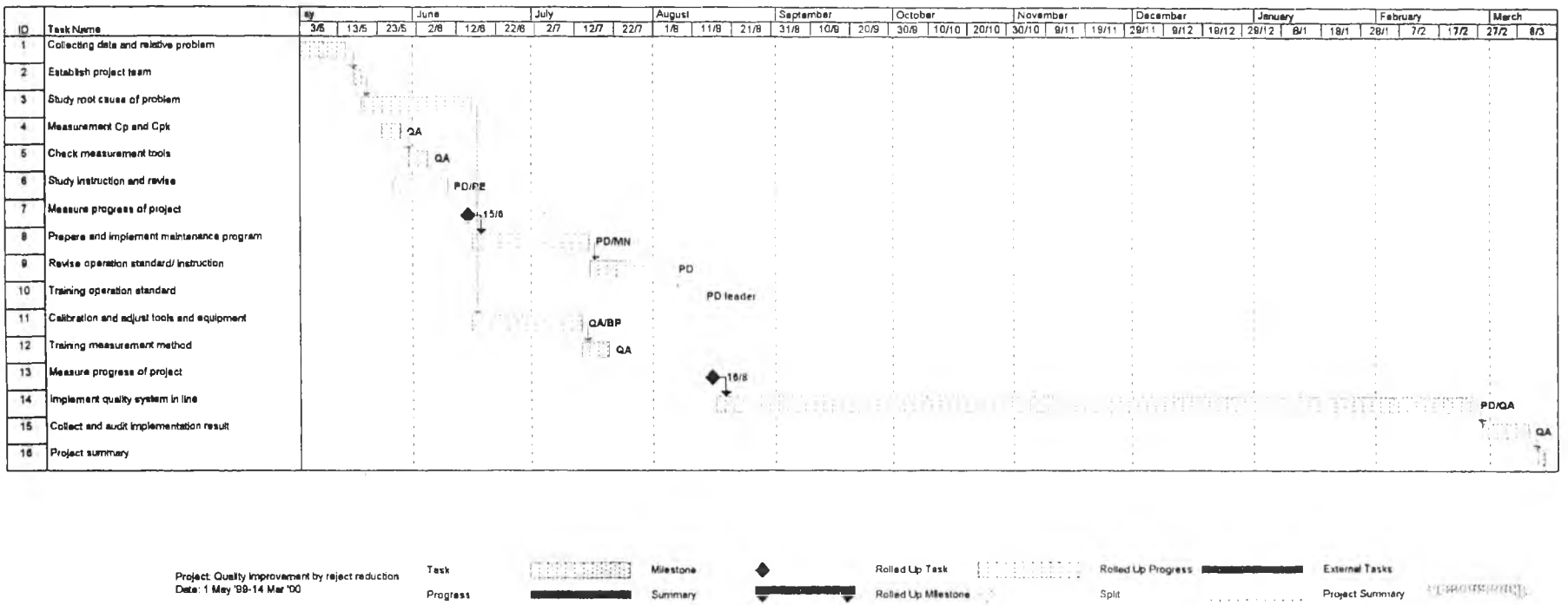

Fig. 4.11 The project planning of the thesis

4.4 Setup quality and monitoring system

The quality system of this project can be divided into 2 levels, the inspection and self-inspection. As explain in chapter 2, the inspection is the method to detect and control reject not to delivery to customer but it can not reduce and eliminate the reject in production line. The last one, the self-inspection can reduce the reject in production line but it needs the effective quality system to monitor and control processes.

4.4.1 The inspection

In this line, it uses two operators to do 100% inspection part before delivery to customer that is the waste inspection because it can only classify conformity product and nonconformity product. This method can only make the reliable for customer and increase satisfaction. In practical, the 100% inspection still have probability to accept reject and customer usually requests to do 100% inspection again when the problems are found.

The ordinary of 100% inspection method is used to appearance checking and the checked point is still the ex-problems and the current problems so in several times the new defect occurred but the inspection is not found. As this result, the inspection is the waste in production process. But having the inspection is better than no inspection because it still makes customer satisfaction.

In practical, we can make the inspection to be more effective by using accessory tools and equipment to reduce the variation from human error (e.g. GO/ NO GO gage, inspection jig, master sample for conformity product and nonconformity product, and etc.). But these tools and equipment have to make reliable activities such as calibration or approved by customers.

4.4.2 Self-inspection

In production line, the operators should be the first person who finds the problem, so it uses the lowest time to do corrective action. The self-inspection method consists of three levels of inspection (e.g. the appearance used the visual and experience to identify status, the dimension used gage for identify pass or fail of part and dimension used measurement tools for identify status).

The self-inspection method is the method to reduce and eliminate defects because it uses the least time to communicate and take action that can reduce the loss of production. When the problems is found, the production line should be stopped for elimination the defect.

In case of the crankshaft line, operators and leader implement the self-inspection but the wrong method of corrective action is still problem. When operators find the problem such as the out of specification of diameter and distance of eccentric, they will adjust and change the program but they do not investigate the actual causes of problem. So the correction method and instruction for corrective action is necessary for operators to prevent the error.

Other factors that relate to self-inspection are the reliable tools for inspection and the method for using tools. The reliable of tools is depended on several factors such as the operators, method, frequency of usage, the environment and controlling method (calibrating program and maintenance program). In several times, operators cannot understand the usage of measuring tools that causes the failure in inspection and adjustment. So the effective self-inspection needs several factors especially for the participation of instructed operators.

4.4.3 Monitoring system

In this production line, there is no effective system for controlling tools' life of cutting insert and in-process inspection for some dimension. As this reason, the control chart is selected to implement for controlling and monitoring the status of process. At first step, the design of control chart or record form is prepared from its measurement method and significant of dimension. In control chart can be divided into two type, measuring method and recording method. The first method is the attribute inspection methods by using the special tools for identify conformity or non-conformity of product. (E.g. Go/ No Go gage, snap gage and plug gage) This method is easy to operate and implement by operators but it cannot show the trend of process and it is only corrective action like the inspection method that cannot eliminate defect just only stop to make new defect. This method is used for normal dimension and high frequency of inspection or 100 percent inspection. The result of measurement, operators just only mark in it to show status at that time. So the measurement tools for this method has to calibration regularly because operators do not know the status of tools.

Another method is the control chart for variable or run chart, it can show the trend of process that the preventive action method same as the self-inspection method. But this method is more complex than the first method in reading and recording. At initial period, the control chart divides range of tolerance into 5-6 range for 2 warning range and 3-4 controlling range and training program for leaders and operators also started at this period too. In this chart, each width of range is the same because we do not know of standard deviation value. When we have implemented for 2-3 month, these width of range and ranges should be change to the standard deviation range. The next step is implemented the control chart in production line and then record the result of implementation and adjust the appropriate range for the production line.