CHAPTER 4

DATA COLLECTION AND ANALYSIS

This chapter describes a data collection and analysis of the company. It starts from data collection and then analyse the possible cause of problem by the cause and effect diagrams. Next, the FMEA will show the severity, occurrence, current control, risk priority number of each failure and Pareto diagram will show the ranging of priority failure. The Why-Why analysis will show the root causes of failures and the relation diagram will show the relation between of each failure. Finally, the decision tree diagrams are used to make a decision to implementing the chosen failure.

4.1 Data collection

The only biggest company's problem in the present is defective products that affect the company's expenses. Especially, injection department is the highest section with the defective products. According to chapter 1, the research focuses on silver streaks of front cabinet of 14-inches television in injection process. Therefore, the researcher collects the number of research defects from March to August 2003 for which total productivity is 100,000 pieces. The data collection is shown in the following table.

Month	Monthly productivity	Silver streaks (Piece)	% Defect	% Accumulate	% Of total productivity
March	16792	950	5.66	5.66	0.95
April	14079	954	6.78	12.44	0.95
May	20181	1650	8.18	20.62	1.65
June	22142	1430	6.46	27.08	1.43
July	18297	925	5.06	32.14	0.93
August	18509	1236	6.68	38.82	1.24

Table 4.1: Data collection of silver streaks defect on selected product from March to August 2003

From the data collection above, the total percentage of defect accumulation is not 100% because we only focus on the silver streaks issue. If we focus on all forms of defect, the total percentage will be 100%.

4.2 Cause and effect diagram

In injection process, there are many forms of defective product such as uneven colour distribution, sink marks, flow marks, bubbles, cracking and crazing, brown streaks, black spots, short shot, flash, un-melted granules, and silver streaks. However, the most important defect is silver streaks (see figure 4.1).

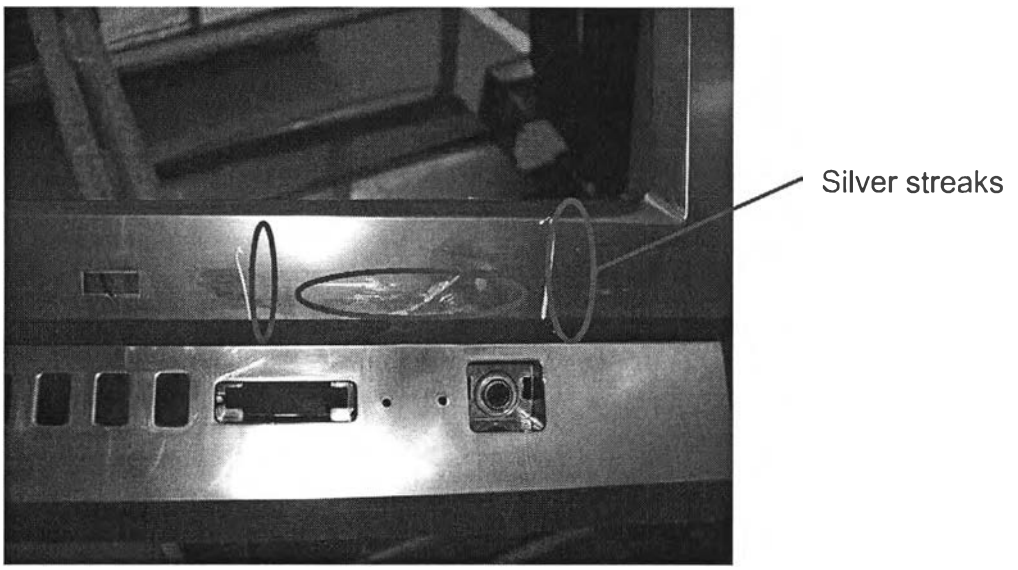

Figure 4.1: Silver streaks defect

There are many causes and factors that affect on the front cabinet of 14-inches television in injection process. Also, a team of improvement is established to brainstorm and arrange these factors. The team consists of personnel from related department: chief of production process, production personnel, chief of quality control, process quality control personnel, raw material quality control personnel, engineers, manager and researcher, who collect data for analysis, conduct the meeting, including the summary and suggestion of this quality improvement. According to the data collecting process, there are many types of related data to process such as:

- The operating condition for individual sub-process related to men, method, machine and material.
- The actual record of the setting/conditions during the defect occurrence.
- The actual record of the defect quantity.
- The quality of raw material.

In addition, data from the first and the last piece inspection report and rejection report analysis is also means to collect data on quality defects. According to improvement team, the meetings and discussions are set many times to find the possible causes. After the brainstorming, they divide the possibilities causes into four categories that are raw material, method, machine and man. Each major category has subcategories. It is followed by applying cause and effect diagram (see figure 4.2).

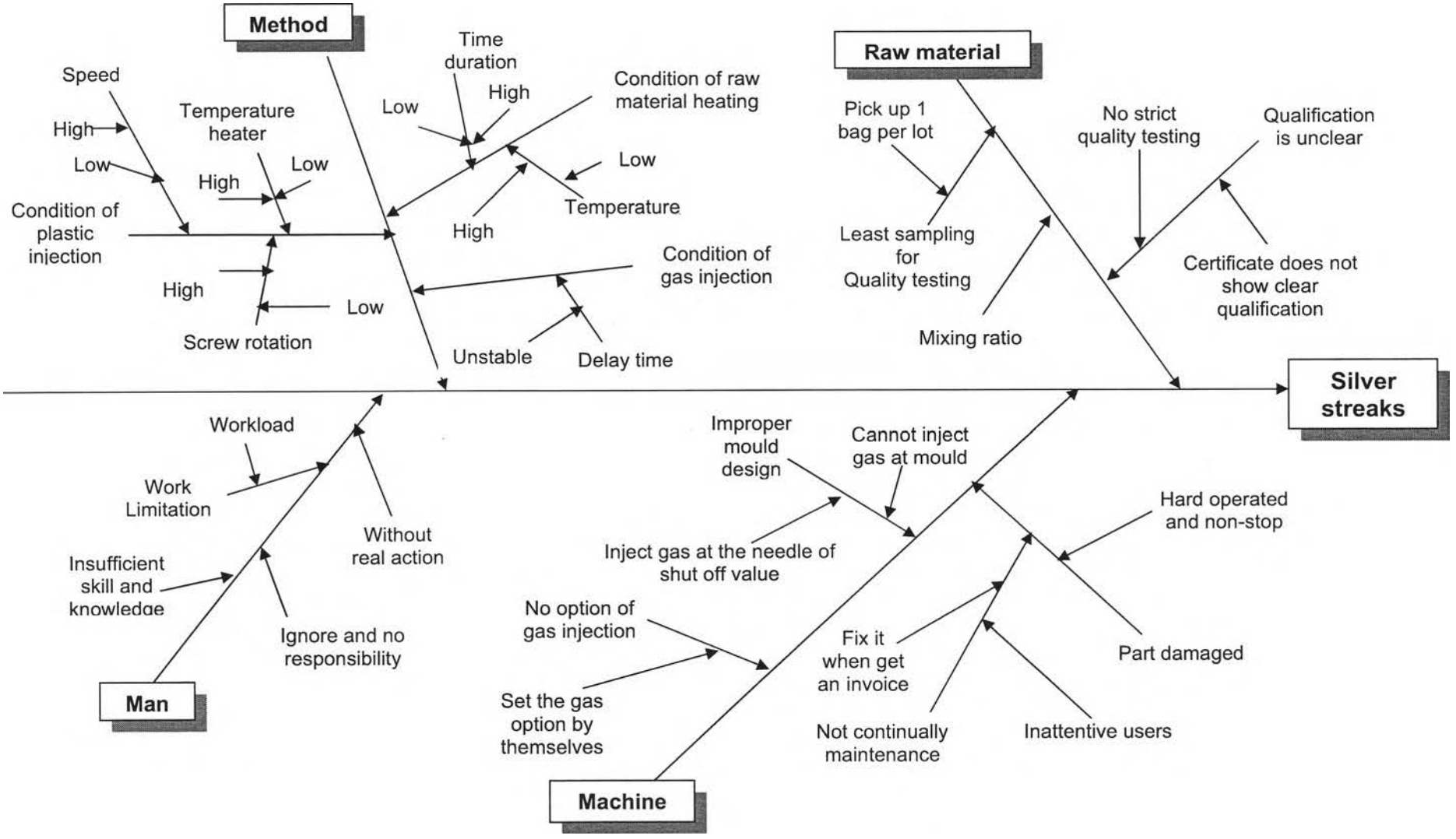

Figure 4.2: Cause and effect diagram of silver streaks defect

The figure above shows four categories of possible causes of effect as followed.

1. Raw material

There are three subcategories in this category. The first subcategory is the qualification of raw material is not clear. It comes from the company, which does not have a strict quality test before. That means the company only test the quality on one topic, which is inflammable by the lighter. The checker only checks if it is inflammable and tick its "pass" on the check sheet. They do not know the exactly temperature of flashing and melting point. This may be affected the machine setting. In addition, the company checks all appearances visually such as the quantity of lot (one bag is twenty-five kilograms), lot number at raw material bag with certificate, the colour with master colour plate, neatness of raw material bag, and dimension.

The certificate is one important of this subcategory because the certificate does not show the clear qualification of that lot. It shows the method of quality testing and show the result in some features. For instance, it shows ASTM D638 for yield tensile strength and the result is 3565 psi. But it skips in some simply features such as melting temperature, humidity, or flash point. If it shows all of qualifications, the staff will be able set a function of the machine easier without trial and error condition.

The second subcategory is a least sampling of quality testing. It is according to the first subcategory. The checker picks up one bag per lot for quality checking when they receive a lot of raw material. They do not pay attention to the quantity of raw material ordering. For example, they pick up one bag if they receive 250 kilograms or they receive 500 kilograms. This is not following the switching sampling plan. In contrast, the appearance testing is followed by the plan. In the team opinion, the checker thought the raw material's quality must be the same in every bag.

The last subcategory is a mixing ratio. Most of the production personnel always pour one bag of raw material grade A into the hopper machine before they measure raw material grade B and master batch. They will not take it out, if it over limit. As they think it is not effective and they are lazy to do that.

2. Man

There are four subcategories in the man factor. First, the man or worker has a work limitation. Some of them have a lot of work in hand. Therefore, they cannot do their work as good as they can. For example, the process quality control personnel who go inline of production process for PQC checking and working on a product's quality document. Sometimes they work hard on document because the company must speed up the operation to catch up with the customer's order. Thus, the process quality control cannot go to the inline many times and cannot do the PQC checking. Also, they will do their assignments without real action that is the second subcategory.

Third, some of them ignore and have no responsibility to their jobs. For instance, the production personnel operate the machine and ignore the plastic leak or oil leak at the shut off valve. Because of they always think it is not their responsibility and they only have one duty, which operates the machine to produce the product, not to maintain the machine properly.

Eventually, an insufficient skill and knowledge of workers is one of the factors of failed product. Some of them are new employees. Also, they are lack of work experience while some of the old workers have lower level in English skill. They cannot understand English document clearly.

3. Method

There are three subcategories in this issue: the condition of raw material heating, the condition of gas injection, and condition of plastic injection. The condition of raw material heating has two important factors that is temperature and time duration for heating. If both of these two factors cannot be set in the proper condition, it will be an unsuitable raw material for feeding to the next step. For example, the heated raw material will still have humidity if the temperature is too low and the time duration is too short.

The condition of gas injection is affected injected plastic as well. The major factor of gas injection condition is a delay time. The unstable delay time done the setting time of front injected resin is not equal to the rear injected resin.

There are many factors in condition of plastic injection category: speed of injection, rotation of recovery screw, and temperature of heater. Low speed of injection is affected on silver streaks because the setting time of the front injected resin is not equal the rear injected resin. If the speed of the injection is too high, the melted resin will not join together when it is cool. However, low speed of screw rotation has an effect on silver streaks because the compound cannot mix together. On the other hand, high speed of screw rotation has an influence on brown streaks because the high friction between melted resin and screw is happened and it will burn some melted resin. The over temperature of heater has an effect on brown streaks as well because the melted resin is burnt in the cylinder part of machine and we will drain it off. If the temperature of the heater cannot reach the set point, it will affect silver streaks because the melted resin becomes sticky and difficult to inject. All of these factors will affect to the injected product.

4. Machine

There are three major subcategories in machine issue. First, machine did not have an option of gas injection. Therefore, the company set the gas option by themselves. This is according to a delayed time in condition of gas injection. If the delay time is too high, the melted resin will set to the plastic before the nitrogen gas can get into the product.

Second, mould is an improper design because we cannot inject nitrogen gas at the mould. Also, we change to inject nitrogen gas at the needle of shut off valve. From this reason, the nitrogen gas can leak to meet the melted resin in the shut off valve. However, the nitrogen gas cannot leak to meet the melted resin if the shut off valve close quickly enough.

Thirdly, part or equipment of machine damaged, which is not ready in use, will come the possible cause of failure product. There are many reasons of part damaged such as the hard operation and non-stop using machine. It always happens when the company needs to keep up with the ordering from customers. Inattentive users are one reason of part damaged as same as the maintenance personnel fix it when they get an invoice from the production personnel. That means they did not continually maintained.

4.3 Failure Mode and Effect Analysis (FMEA)

After brainstorming and discuss in the cause and effect diagram, the improvement team need to focus the high priority of failures. We need to see severity, potential effect, occurrence, and current control and think about the solution for improvement in the next step. Therefore, the improvement team uses Failure Mode and Effect Analysis (FMEA) to analyse and show the Risk Priority Number (RPN) of failures. The following table shows the FMEA analysis of silver streaks defect.

Process	Potential failure mode	Potential effect of failure	S	Potential cause	O	Current control	D	RPN	Recommended action	Action result				
										Action taken	S	O	D	RPN
1. Raw material receiving	Raw material qualification is not clear such as melting temperature or melting point and humidity.	The company cannot set a suitable heating condition between it and that raw material lot.	4	The company did not have a strict inspection of raw material's qualification one reason is they believe in a certificate too much.	4	Check colour and dimension visually, test inflammable by the lighter that they do not know an exact melting point. They were sampling 1 bag per lot for quality checking (dimension and inflammable). They do not pay attention to receive quantity in addition, they never think about a mistake in supplier's certificate	7	112						
2. Raw material heating	Hopper machine cannot get rid of humidity.	Raw material still has humidity and pass to the next process.	5	Time duration and temperature does not match the raw material	3	Hopper machine has an alarm alert for an error	3	45						
	Improper mixing ratio	Wrong colour	4	A lot of raw material grade A in the mixing ratio	4	The production personnel measure the mixing raw material follow by UL standard	4	64						

Table 4.2: FMEA of silver streaks defect

3.Injection	Incomplete mixing	Compound not together	4	Low speed of screw rotation	4	The production personnel read and check rotation speed program in injection machine	3	48						
	Sticky melted resin	Stop machine for changing heater	6	Temperature cannot reach the set point	6	The production personnel read and check temperature program in injection machine	5	180						
	Setting time of the front injected resin is not equal to the rear injected resin	The front injected resin will meet the nitrogen gas before the rear injected plastic. Therefore, the front is cool down faster than the rear	7	Low speed of inject resin	4	The production personnel read and check inject speed program in injection machine	3	84						
				Inject nitrogen gas at the needle of shut off valve	6	The production personnel connect the path of gas injection depends on the mould design, which is the customer's property	7	294						
				Shut off valve quickly open but slowly close	6	Use hydraulic system to control open and close speed of shut off valve	7	294						

Table 4.2: FMEA of silver streaks defect (continued)

				Delayed time of gas injection is unstable	6	The production personnel read and check the delayed time program in gas injection machine	7	294						
	Stop machine	Cannot reach the target and/or drain resin in machine	4	Oil leaks at shut off valve (O-ring damaged)	5	3 months checking	4	80						
4.Inspection	Defects pass to the next process	Waste of money and time, causing customer dissatisfaction , document errors	6	Without real action, insufficient, ignorance, work load	3	The production personnel check every pieces visually and PQC sampling 2 pieces per hour for checking visually as well	5	90						

Table 4.2: FMEA of silver streaks defect (continued)

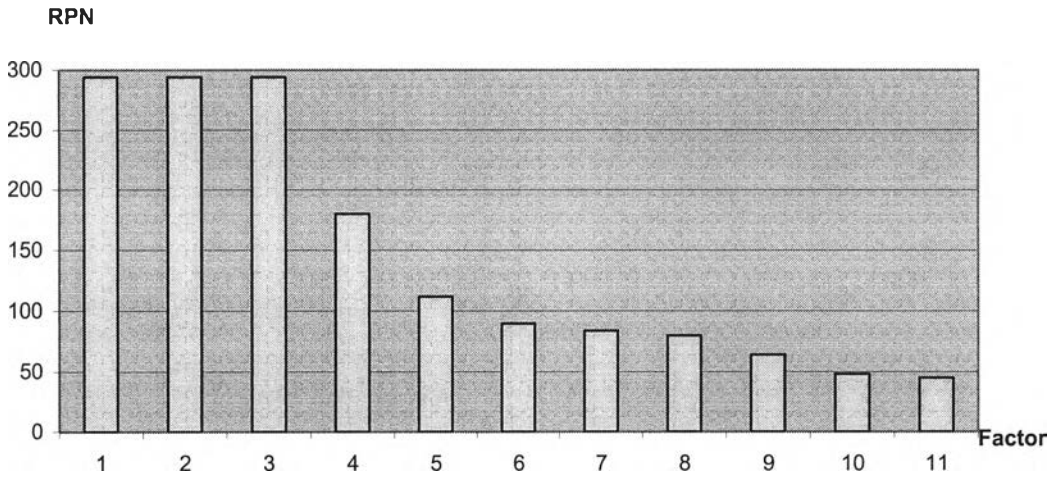

Figure 4.3: Pareto diagram of silver streak defect

The implementation team set the RPN at 100, which is acceptable. If the failures have RPN over 100, it should be a recommendation for improvement. We can see the high priority number easier in the Pareto diagram (see figure 4.3). All factors are following.

1. Inject nitrogen gas at the needle of shut off valve.
2. Shut off valve quickly open but slowly close.
3. Delay time of gas injection.
4. Heater out of order.
5. No strict quality testing of raw material.
6. Man factor.
7. Low speed of injected melted resin.
8. The leakage at shut off valve.
9. A lot of raw material grade A in the mixing ratio
10. Low speed of screw rotation.
11. Improper condition of heating raw material.

4.4 Relation diagrams

From brainstorming, all factors have a relation between one or more factors. If we can solve the main factor, the rest factors between the main factors can be solve as well. For instance, we determine to solve the qualification of raw material, which is vague by increasing the sample of quality test and request the supplier to specify the qualification. These can solve the rest factors; if we know the clearly qualification, and we can set a proper heating condition and plastic injection condition in the further study. All of these will reduce the number of silver streaks defect.

However, we cannot solve all of main factors in this research because the time limitation. We can focus on some factors as sample way for the further study. In addition, we plan to spend more time and come up with the best solution for every main factor in the future. Figure 4.4 shows the relation of all factors that affects to the silver streaks defect. The direction between them leads from the cause to the result.

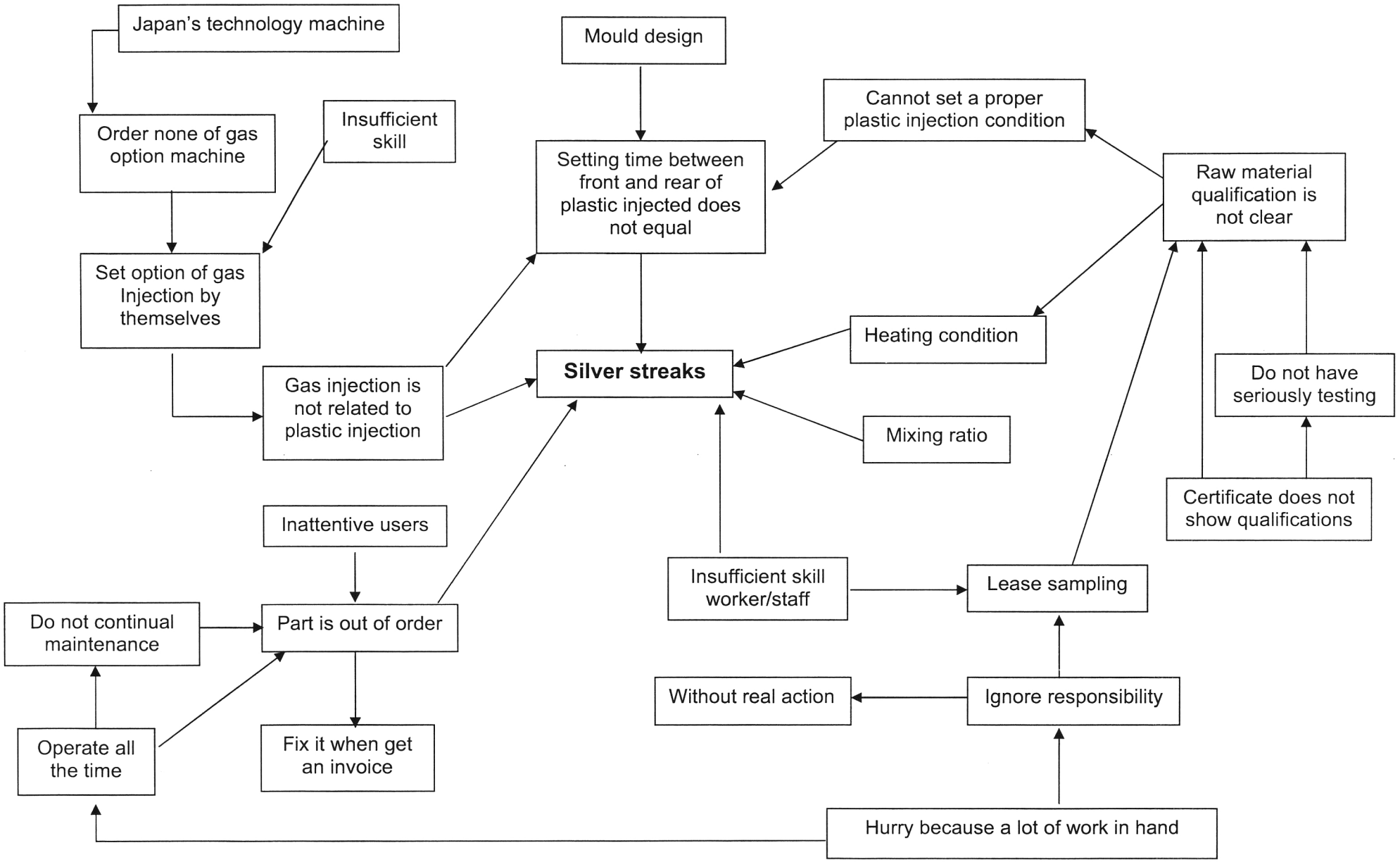

Figure 4.4: Relation diagrams of silver streaks

4.5 Why-Why analysis and decision tree diagrams

The implementation team uses the "Why-Why analysis and decision tree diagrams" to find the root cause of the first five priorities RPN and find the solution before we make suggestions. Since the real root cause can be got rid of by a suitable advice and the quality problems will be reduced.

First, we start at the asking 'why do the silver streaks happen?' It is because we cannot adjust a proper heating condition matching raw material qualification. The proper heating condition can eliminate all humidity from the raw material. Then, we ask why we cannot adjust a proper heating condition to match raw material qualification. However, the problem is the qualification is vague. If we know the clear qualification, we think we can tune the engine to a proper condition. Next, we ask why we do not know precise qualification. The answer is we have never tested it solemnly. It is resulted from we pick up one bag per one lot for quality testing and we test only one issue in this test that is an inflammable testing. Finally, we ask why we select just one bag out of million, thus the root cause is we believe in the supplier's certificate too much.

Second, we start at the same question again 'why do the silver streaks happen?' Since the heater temperature cannot reach the set point, the melted resin becomes thick if the heater temperature cannot reach the set point and it difficult to inject. Moreover, the vapor in the machine can condense into the melted resin. On the other hand, the melted resin becomes thin if the heater temperature is over the set point. Then, we ask why the heater temperature cannot reach the set point for which the heater is out of order. The answer to the question is non-stop operation. The inattentive users are the cause of non-stop operation. They are too concerned in the customer's order that forget the machine limitation. Due to non-stop operation, the heater is damaged. However, the heater or equipment will not be in this situation if it receives a continually maintenance. Thus, the root cause of the heater cannot reach the set point is irregular maintenance.

As same as the previous stage, we begin by asking 'why do the silver steaks happen?' Because of the setting time of the front injected resin is not equal to the rear injected resin. The lack of time between the front and the rear is too high. Then, we ask why it is not correlative to the rear injected resin and the cause is the temperature of the front injected resin is decreased sooner than the rear injected resin. It is because of the front injected resin will meet the nitrogen gas before the rear injected resin. These come from three causes:

a) The shut off valve quickly opens but slowly closes; the company uses the hydraulic-shut off valve system, which use a cushion for bump against of piston. The shut off valve will close slowly than its opening. Also, some of nitrogen gas might leak to meet the front melted resin in the shut off valve.

b) Inject nitrogen gas at the needle of shut off valve. There are two ways of gas injection. It depends on the mould design, which is a customer's

property. The first one injects gas at the needle of shut off valve and the last one injects gas directly at the mould. The first type is easy that the nitrogen gas can meet the melted resin in the needle and also in the shut off valve, which slowly close. On the other hand, the last type is better for the gas is difficult to leak. However, the front cabinet of 14-inches television can only use the first type of shut off valve because there is no connecting path of gas injection at the customer's mould design.

c) The delayed time of gas injection. The machine of research's product does not have a gas injected option. The company needs to reduce cost, so we order it than a full option machine. They think they can set the gas option match to the machine by themselves. Finally, even though they can set it. It is not compatible with the Japanese's technology machine because it has a delayed time.

The figure on the next page illustrates the why-why analysis of the first five priorities RPN number of silver streaks.

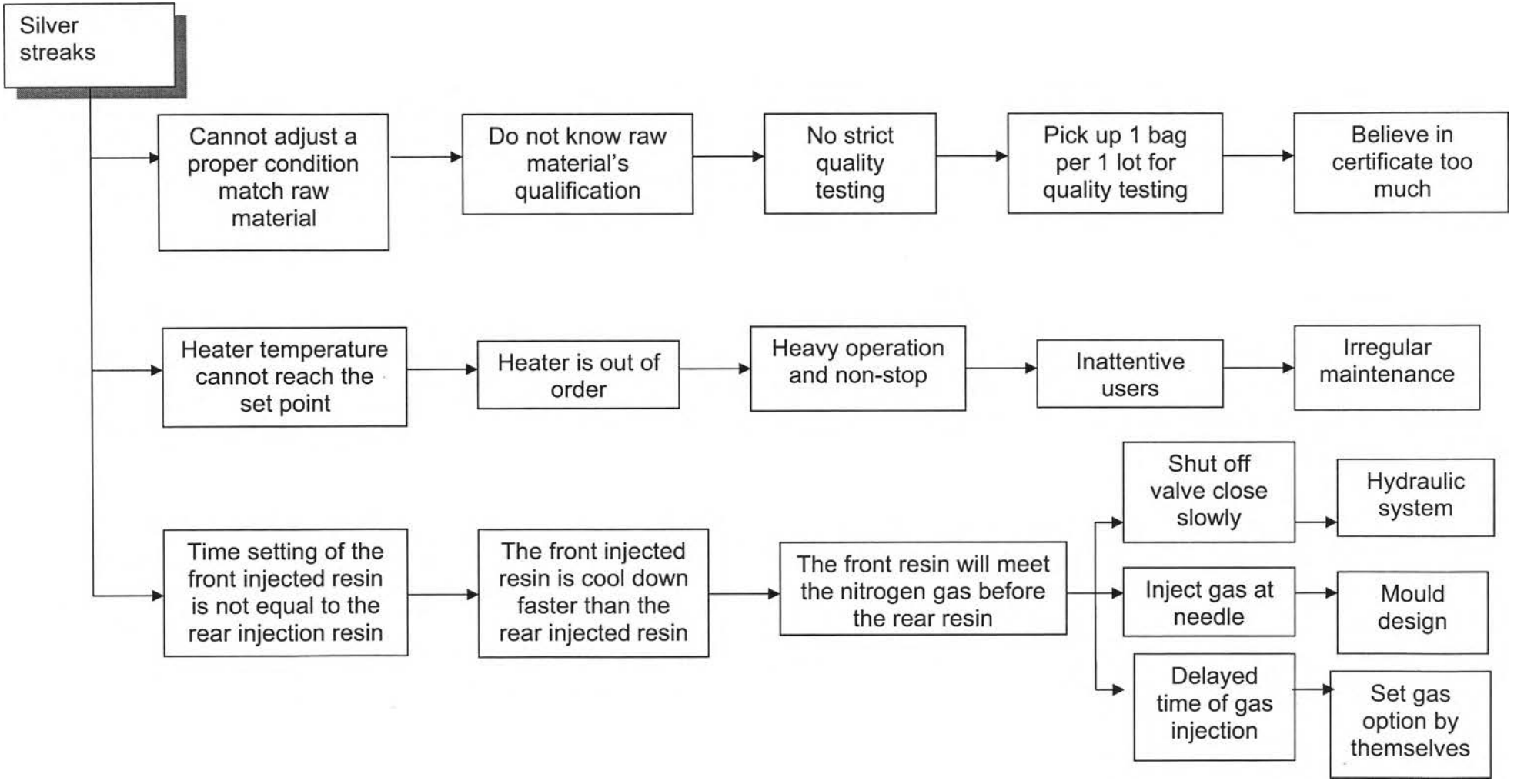

Figure 4.5: Why-Why analysis of silver streaks

After we know the root cause of each flaw, the implementation team needs to make a suitable recommendation. It can reduce the RPN number and can solve the failure of quality problems. Therefore, the team uses the decision tree diagrams to determine the best decision at each point. The first is strategy for believing certificate too much, the second is for no continually maintenance, and the last is for three root causes of resin time setting. The following diagram shows the decision tree diagrams for the silver streaks.

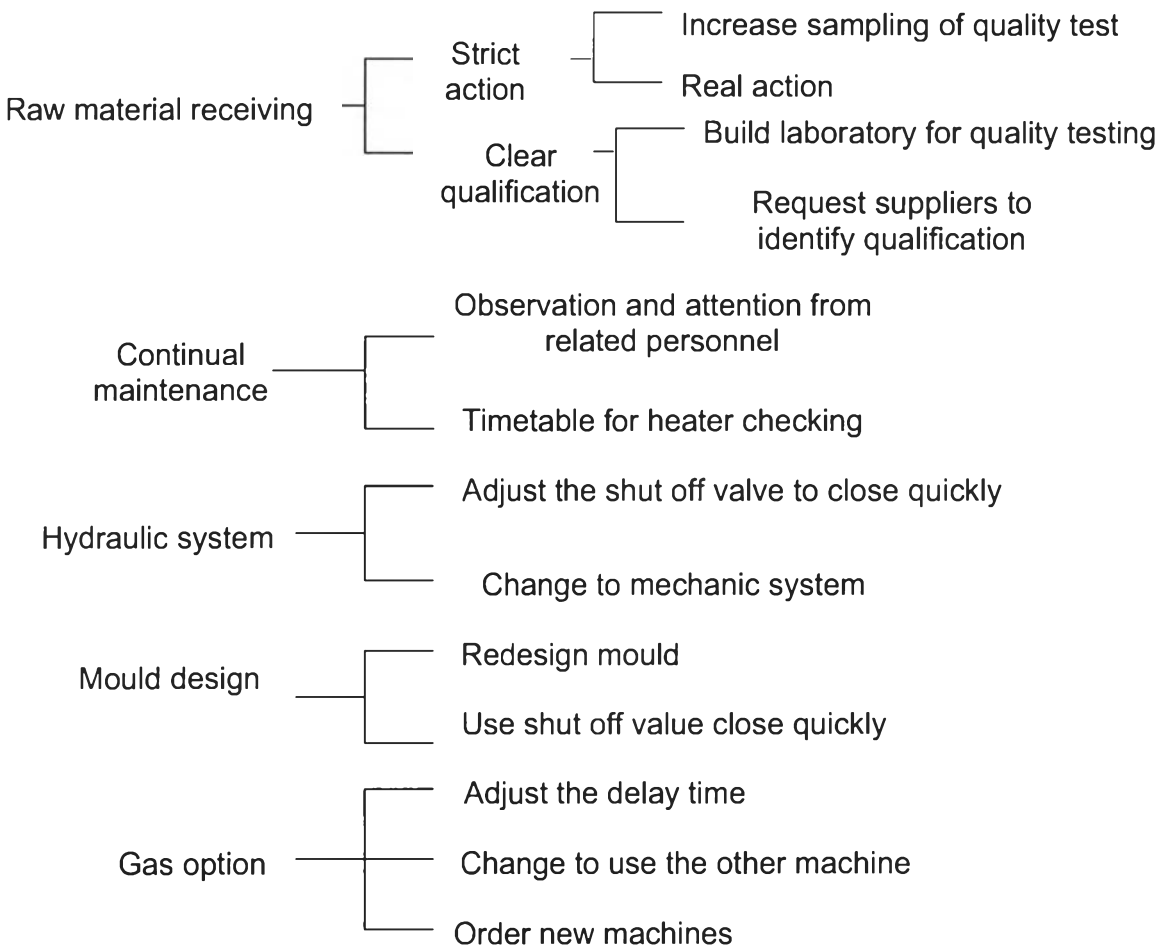

Figure 4.6: Decision tree diagrams of silver streaks

From the brainstorming of implementation team, we decide the first strategy to improve the certificate's confidence at raw material receiving stage by more strict action and clear qualification. On the first way, the sampling of quality test is not according to the switching sampling plan. Also, we need to increase the sampling of quality test followed by the sampling plan and design a new check sheet to support this action. However, this action will not be successful without taking action. Therefore, we need to train the worker, who checks the raw material. It should be in the ethic training, including the responsibility and work attention, for the workers.

On the second way, we need to build a laboratory for raw material's quality testing. We think we know a more specific qualification and adjust a proper machine's condition immediately if we have the laboratory. However, we know it by requesting the suppliers to show these qualifications in their certificate. Therefore, we should choose the best decision from these strategies by using an estimation, which can see from the investment and benefit impact. We set the point of ranking as one to three. If which factor can make higher benefit or profit to the company, it get three points. In contrast, it gets one point if it cannot make the profit for us. For example, the low investment gets the higher score than high investment. The following estimation will show the best decision for the raw material receiving.

	Cost	Benefit impact	Result
Increase sampling of quality test	3	2	6
Real action by ethic training	2	2	4
Laboratory for quality test	1	2	2
Request supplier of more specific qualification	3	2	6

From the estimation above, we can see the best two actions: increase sampling of quality test, and request supplier for more specific qualification. Both of them become a recommendation for raw material obtaining in the table 4.3: FMEA of silver streaks defect and recommended action

According to the brainstorming, we decide the second strategy by using the continual maintenance. There are two ways of doing. First, the related personnel should pay attention and observation to the component and machine. If all related personnel pay attention, it can reduce the part or machine out of order, especially the heater. If the heater is ready to operate, the temperature of the melted resin will be easy to reach the set point. In addition, it should pay attention to all machines. For example, the production personnel see the resin leak at the shut off valve and invoice to the maintenance immediately. The shut off valve will receive maintenance before it is damaged while the RPN number is still lower 100. Therefore, the heater should receive the observation as same as the shut off valve. Figure 4.7 shows the sample of resin leakage at the shut off valve, which does not receive the observation and is lack of attention form the production and maintenance personnel.

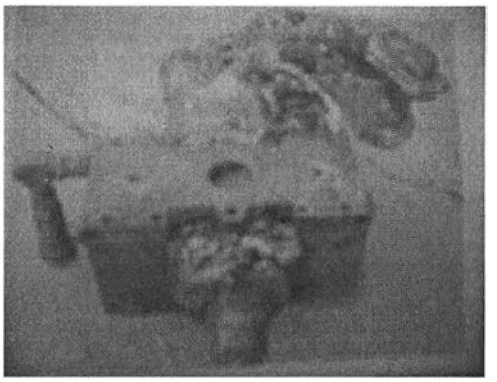

Figure 4.7: The shut off valve out of order

Secondly, do the timetable for heater checking. The part and machine should receive a regular maintenance, especially the heater. Since the quality of work is not continuous if we often stop machine for changing heater. As same as the shut off valve in the previous stage, the heater was not out of order and the RPN number will be reduced if it receives the monthly checking. In the improvement's view, this is a correct action for improvement because it is a protection of error. The following estimation will show the best decision for the continual maintenance.

	Cost	Benefit impact	Result
Observation and attention from the related personnel	3	2	6
Timetable for heater checking	2	2	4

From the estimation above, we can see the best action that is the related personnel should pay attention and observation to the part and machine. Therefore, it becomes a recommendation for fourth priority RPN number in the table 4.3.

Next, we decide the strategy for the shut off valve close slowly, which is a hydraulic system. First, we determine to adjust the shut off valve to close quickly. In this way, it is still the hydraulic system and nitrogen gas cannot leak to meet the melted resin in the shut off valve. Second, the hydraulic system will change to the mechanic system if it cannot adjust the close speed. The following estimation will show the best strategy for the closing speed of shut off valve.

	Cost	Benefit impact	Result
Adjust the shut off valve to close quickly	2	3	6
Change to mechanic system	1	3	3

From the estimation, we can see the best action that is to adjust the shut off valve to close quickly. Therefore, it becomes a suggestion for second priority RPN number in the table 4.3.

The mould design is affect on the nitrogen gas leakage. According to the Why-Why analysis, the research's product use the first type of shut off valve, which injects gas at the needle of shut off valve. This type is easy that the nitrogen gas can meet the melted resin in the needle and also in the shut off valve, which close slowly. Therefore, we decide two strategies for the mould design. First, we decide to redesign mould by contacting the customer because the mould is a customer's property. The cost of redesign mould gets the three scores because we do not spend money to new design, just contacts the owner. Second, we decide to use the shut off valve that close quickly. The following estimation will show the best strategy for the mould design.

	Cost	Benefit impact	Result
Redesign mould	3	3	9
Use shut off value close quickly	1	3	3

From the estimation above, we can see the best action that is to redesign mould. Therefore, it becomes an advice for first priority RPN number in the FMEA (table 4.3).

Eventually, we resolve the strategy for the delay time of gas option. There are three approaches for improving: adjust the delay time, change to use the other machine, and order new machine. First approach, we try to adjust the delayed time in the old gas injection machine. After that, the product is undertaken by the trail condition and records the errors for an enhancement. Second approach; determine to employ other machines with a gas option. However, we decide to order new full option machine if the machine is not enough for the production. The following estimation will show the best strategy for the delayed time of gas injection.

	Cost	Benefit impact	Result
Adjust the delay time	2	2	4
Change to use the other machine	3	2	6
Order new machine	1	3	3

From the estimation, we can see the best action that is to use the other machine with a gas option. Therefore, it becomes a recommended action for third priority RPN number in the FMEA. Every significant action becomes a recommendation and shows in the FMEA (table 4.3) again.

Process	Potential failure mode	Potential effect of failure	S	Potential cause	O	Current control	D	RPN	Recommended action	Action result				
										Action taken	S	O	D	RPN
1. Raw material receiving	Raw material qualification is vague such as melting temperature or melting point and humidity.	The company cannot set a suitable heating condition between it and that raw material lot.	4	The company did not have a strict inspection of raw material's qualification one reason is they believe a certificate too much.	4	Check colour and dimension by visual, test inflammably by the lighter that they do not know an exact melting point. They pick 1 bag per lot for quality checking (dimension and inflammable). They do not pay attention to receive quantity in addition, they are not cautious about a mistake in supplier's certificate	7	112	Increase sampling of quality test Request supplier to specify qualification					
2. Raw material heating	Hopper machine cannot get rid of humidity.	Raw material still has humidity and pass to the next process.	5	Time duration and temperature do not match to raw material	3	Hopper machine has an alarm alert for an error	3	45	None					
	Improper mixing ratio	Wrong colour and high stress	4	A lot of raw material grade B in the mixing ratio	4	The production personnel measure the mixing raw material follow by UL standard	4	64	None					

Table 4.3: FMEA of silver streaks defect and recommended action

3.Injection	Incomplete mixing	Compound not together	4	Low speed of screw rotation	4	The production personnel read and check rotation speed program in injection machine	3	48	None					
	Sticky melted resin	Stop machine for changing heater	6	Temperature cannot reach the set point	6	The production personnel read and check temperature program in injection machine	5	180	Observation and awareness from the related personnel					
	Time setting at the front injected resin is not equal to the rear injected resin	The front injected resin will meet the nitrogen gas before the rear injected plastic. Therefore, the front is cool down faster than the rear	7	Low speed of inject resin	4	The production personnel read and check inject speed program in injection machine	3	84	None					
				Nitrogen injection at the needle of shut off valve	6	The production personnel connect the path of gas injection depends on the mould design, which is the customer's property	7	294	Redesign mould					
				Shut off valve open quickly but close slowly	6	Use hydraulic system to control open and close speed of shut off valve	7	294	Adjust the shut off valve to close quickly					

Table 4.3: FMEA of silver streaks defect and recommended action (continued)

				Delay time of gas injection is unstable	6	The production personnel read and check the delayed time program in gas injection machine	7	294	Change to use the other machine					
	Stop machine	Cannot reach the target and/or drain resin in machine	4	Oil leakage at shut off valve (O-ring damaged)	5	3 months checking	4	80	None					
4.Inspection	Defects pass to the next process	Waste money and time, customer dissatisfy, document errors	6	No action taken, insufficient, ignorance, workload	3	Chief and/or manager	5	90	None					

Table 4.3: FMEA of silver streaks defect and recommended action (continued)