# CHAPTER V
# RESULTS AND DISCUSSION

## 5.1 Results

From inspections and analysis of the impact of implemented corrective actions, it can be concluded that:

- No bubbles in chilled water of quenching bath of the study line.
- Breakage times of the study line dramatically reduced (see table 5.1, 5.2, 5.3 and 5.4) after bubbles in chilled water of quenching bath of the line study were eliminated.

The results of this study are discussed into two parts: the results of sample study in the study line and results of other types of PP bands of the study line. Breakage times of sample study have satisfactorily reduced after implementing corrective actions. Therefore, further implementation has done on other type of PP bands to see whether the corrective actions can be implemented to solve the breakage problem in other type of PP bands in the study line.

### 5.1.1 Results of Sample Study in the Study Line

In order to see the difference of implementing corrective action in the sample study in the study line, information regarding breakage times and breakage losses were collected before and after chillers maintenance. Before chillers maintenance, the breakage times of sample study in the PP-band line found in September 2004 to December 2004 are identified in the following table.

**Before chillers maintenance**

From table 5.1, the trend of breakage per production of sample study increased from 2.3 % to 7.62 % from September to December, 2004. This means that if the company does not have any solution to solve breakage problem, this production line of PP bands will be shut down soon and the company will loss of opportunity for selling.

**Table 5.1: Breakage Times per Production before Chillers Maintenance**

| Month | PP-band type: A15-18W | | | | |
|---|---|---|---|---|---|
| | Rolls | Total Weight(Kg.) | Breakage (Times) | Breakage Loss (Kg.) | Breakage/ Production |
| Sep | 391 | 3026.34 | 8 | 69.74 | 2.3 % |
| Oct | 280 | 2167.2 | 9 | 108.35 | 3.21 % |
| Nov | 222 | 1718.28 | 11 | 163.45 | 4.95 % |
| Dec | 105 | 812.7 | 8 | 76.55 | 7.62 % |

**After chillers maintenance**

After chillers maintenance which was done by changing O-ring seal at water pump, we found that the percentage of breakage per production has been reduced by 0.44 % (as shown in table 5.2) from January to April, 2005.

**Table 5.2: Breakage Times per Production after Chillers Maintenance**

| Month | PP-band type: A15-18W | | | | |
|---|---|---|---|---|---|
| | Rolls | Total Weight(Kg.) | Breakage (Times) | Breakage Loss (Kg.) | Breakage/ Production |
| Jan | 451 | 3490.74 | 2 | 17.87 | 0.44 % |
| Feb | 515 | 3986.1 | 1 | 18.84 | 0.19 % |
| March | 325 | 2515.5 | 0 | 0 | 0 % |
| April (8days) | 100 | 774 | 0 | 0 | 0 % |

### 5.1.2 Extension of the Solution to Other Production Types

To see whether chillers maintenance can help reduce breakage times in other production types of PP bands of the study line, information about breakage times and losses are collected before and after chillers maintenance in various types of PP bands. Breakage per production is then calculated to see the trend of improvement or deterioration.

**Before chillers maintenance**

Before chillers maintenance, the breakage times of other type of PP bands in PP-band line found in September 2004 to December 2004 are identified in table 5.3. The breakages per production of almost all types of PP bands are high in December 2004. The productivity of the line is going down. The result reveals that all types of PP bands are reducing in production from September to December 2004.

**Table 5.3: Breakage Times per Production of Other Type of PP Bands before Chillers Maintenance**

| Year 2004 | | | | | | |
|---|---|---|---|---|---|---|
| Type | Month | Rolls | Total Weight (Kg.) | Breakage (Times) | Breakage Loss (Kg.) | Breakage /Production |
| AU15-20W | Sep | 256 | 2304 | 7 | 110.79 | 2.73 % |
| | Oct | 264 | 2376 | 10 | 152.43 | 3.79 % |
| | Nov | 165 | 1485 | 6 | 108.35 | 3.64 % |
| | Dec | 105 | 945 | 8 | 99.78 | 7.62 % |
| AU15-18B | Sep | 380 | 3078 | 8 | 108.35 | 2.11 % |
| | Oct | 102 | 826.2 | 4 | 53.42 | 2.05 % |
| | Nov | 82 | 664.2 | 4 | 44.78 | 4.88 % |
| | Dec | 65 | 526.5 | 4 | 55.66 | 6.15 % |
| A15-18B | Sep | 235 | 1818.9 | 8 | 82.25 | 3.4 % |
| | Oct | 208 | 1609.92 | 5 | 75.86 | 2.4 % |
| | Nov | 78 | 603.72 | 3 | 38.95 | 3.85 % |

| Year 2004 | | | | | | |
|---|---|---|---|---|---|---|
| Type | Month | Rolls | Total Weight (Kg.) | Breakage (Times) | Breakage Loss (Kg.) | Breakage /Production |
| A15-18B | Dec | 45 | 348.3 | 3 | 40.45 | 4.44 % |
| A15-18Y | Sep | 208 | 1609.92 | 6 | 80.68 | 2.88 % |
| | Oct | 201 | 1555.74 | 6 | 83.18 | 2.99 % |
| | Nov | 101 | 781.74 | 5 | 80.76 | 4.95 % |
| | Dec | 51 | 394.74 | 4 | 59.56 | 7.84 % |
| AU15-18C | Sep | 100 | 810 | 3 | 34.94 | 3 % |
| | Oct | 110 | 891 | 2 | 24.89 | 1.82 % |
| | Nov | 60 | 486 | 2 | 25.47 | 3.33 % |
| | Dec | 30 | 243 | 2 | 23.34 | 6.67 % |
| AU15-25W | Sep | 250 | 2812.5 | 5 | 55.88 | 2 % |
| | Oct | 100 | 1125 | 4 | 50.77 | 4 % |
| | Nov | 50 | 562.5 | 1 | 20.88 | 2 % |
| | Dec | 50 | 562.5 | 3 | 54.04 | 6 % |
| AU15-16W | Sep | 200 | 1600 | 5 | 51.73 | 2.5 % |
| | Oct | 115 | 920 | 2 | 36.53 | 1.74 % |
| | Nov | 105 | 840 | 4 | 50.26 | 3.81 % |
| | Dec | 75 | 600 | 5 | 86.89 | 6.67 % |
| A15-18G | Sep | 238 | 1842.12 | 5 | 76.55 | 2.1 % |
| | Oct | 80 | 619.2 | 3 | 34.98 | 3.75 % |
| | Nov | 90 | 696.6 | 3 | 44.33 | 3.33 % |
| | Dec | 60 | 464.4 | 2 | 43.66 | 3.33 % |
| AU15-18Y | Sep | 116 | 939.6 | 3 | 39.77 | 2.59 % |
| | Oct | 55 | 445.5 | 1 | 19.43 | 1.82 % |
| | Nov | 85 | 688.5 | 2 | 17.64 | 2.35 % |
| | Dec | 45 | 364.5 | 2 | 32.23 | 4.44 % |

**After chillers maintenance**

Table 5.4 shows breakage times, losses and breakage per production after chillers maintenance from January 2005. The breakage per production of almost all types of PP bands is reduced to 0 %, meaning that the study line is coming back to normal state of producing of PP-band product.

**Table 5.4: Breakage Times per Production of Other PP-band Type after Chillers Maintenance**

| Year 2005 | | | | | | |
|---|---|---|---|---|---|---|
| Type | Month | Rolls | Total Weight (Kg.) | Breakage (Times) | Breakage Loss (Kg.) | Breakage /Production |
| AU15-20W | Jan | 473 | 4257 | 1 | 17.55 | 0.21 % |
| | Feb | 302 | 2718 | 0 | 0 | 0 % |
| | Mar | 412 | 3708 | 0 | 0 | 0 % |
| AU15-18B | Jan | 201 | 1628.1 | 0 | 0 | 0 % |
| | Feb | 264 | 2138.4 | 0 | 0 | 0 % |
| | Mar | 174 | 1409.4 | 0 | 0 | 0 % |
| A15-18B | Jan | 282 | 2182.68 | 0 | 0 | 0 % |
| | Feb | 150 | 1161 | 1 | 11.71 | 0.67 % |
| | Mar | 180 | 1393.2 | 0 | 0 | 0 % |
| A15-18Y | Jan | 182 | 1408.68 | 0 | 0 | 0 % |
| | Feb | 278 | 2151.72 | 0 | 0 | 0 % |
| | Mar | 282 | 2182.68 | 0 | 0 | 0 % |
| AU15-18C | Jan | 371 | 3005.1 | 1 | 23.22 | 0.27 % |
| | Feb | 233 | 1887.3 | 0 | 0 | 0 % |
| | Mar | 230 | 1863 | 1 | 0 | 0.43 % |
| AU15-25W | Jan | 150 | 1687.5 | 0 | 0 | 0 % |
| | Feb | 300 | 3375 | 2 | 30.89 | 0.67 % |
| | Mar | 190 | 2137.5 | 0 | 0 | 0 % |
| AU15-16W | Jan | 220 | 1760 | 0 | 0 | 0 % |
| | Feb | 116 | 928 | 0 | 0 | 0 % |

| Year 2005 | | | | | | |
|---|---|---|---|---|---|---|
| Type | Month | Rolls | Total Weight (Kg.) | Breakage (Times) | Breakage Loss (Kg.) | Breakage /Production |
| AU15-16W | Mar | 267 | 2136 | 0 | 0 | 0 % |
| A15-18G | Jan | 238 | 1842.12 | 0 | 0 | 0 % |
| | Feb | 153 | 1184.22 | 0 | 0 | 0 % |
| | Mar | 121 | 936.54 | 0 | 0 | 0 % |
| AU15-18Y | Jan | 80 | 648 | 0 | 0 | 0 % |
| | Feb | 171 | 1385.1 | 1 | 20.78 | 0.58 % |
| | Mar | 198 | 1603.8 | 0 | 0 | 0 % |

### 5.1.3 Summary of FMEA Process at Stretching Process

After the corrective action has been implemented till 8 April 2005 by changing O-ring seal of water pump in chillers to prevent the leakage, Severity of effect is equal to 8 (refer to Appendix A), Occurrence ranking is equal to 1 (refer to Appendix B) and Detection ranking is equal to 8 (refer to Appendix C). Risk Priority Number (RPN) (8*1*8) is equal to 64. Summary of process FMEA form can be shown as table 5.5.

**Table 5.5: Summary of Process FMEA with RPN**

| | | | | | |
|---|---|---|---|---|---|
| The Case Company | Item | : PP bands | Failure Mode and Effects Analysis | | FMEA No.PP-001 |
| | Process Responsibility | : Production Line | | Design FMEA | Original Date 7-1-05 |
| | Prepared by | : Sunya S.(Production Engineer) | | Process FMEA | Revised Date |
| | Key Date | : 07-Jan-05 | | Service FMEA | Page 1 of 1 |
| | Core team | : PM(Production Manager),PE(Production Engineer), PS(Production Supervisors),LO(Line Operators) | | | |

| Process Functional Requirement | Potential Failure Mode | Potential Effect(s) of Failure | SEV | Potential Cause(s) of Failure | OCC | Current Process Controls Prevention | Current Process Controls Detection | DET | RPN | Recommended Corrective Action(s) | Person Responsible and Target Completion Date | Action Results: Action Taken | SEV | OCC | DET | RPN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stretching Process | Breakage | Intermittent operation and scrap | 8 | Bubbles in chilled water of quenching bath, band speed and temperature in stretching oven | 10 | None | Surface of bands after quenching process | 8 | 640 | Use Design of Experiments (DOE) on bubbles vs. band speed vs. oven temperature | PM,PE,PS and LO/15-3-05 | Eliminated bubbles by changing O-ring seal at water pump Done/8-4-05 | 8 | 1 | 8 | 64 |

## 5.2 Discussion

Based on the experimental results, bubbles in chilled water of quenching bath influenced breakage failure of the study line. Data collection after changed O-ring seal in electric centrifugal pump of chillers (table 5.2 and 5.4) shows that breakage times of the sample study (PP-band type: A15-18W) and other types of PP bands dramatically reduced. As a result, bubbles in chilled water of quenching bath are the real cause of breakage failure in stretching process at stretching oven of the study line.

This indicated that the company could forego preventive maintenance in the factory to prevent unforeseen impact as this cause of failure. Maintenance can be defined as actions to control the deterioration process leading to failure of a system and restore the system to its operational state through corrective actions after a failure.

### 5.2.1 Conclusion of Results

The results from using FMEA techniques to solve the problem of breakage in PP-band line of the case company can be concluded as follows:

#### 5.2.1.1 Causes of PP-band Breakage Problem

Bubbles in chilled water of quenching bath were cause of breakage in stretching oven because PP bands from extruder were extruded with high temperature before directly cooled down in quenching bath for band setting. At this sensitive situation, small bubbles particles formed into big bubbles particles directly destroyed surface of PP bands during band of PP flow into chilled water of quenching bath (as figure 5.1) or sometimes small bubbles particles can destroy PP bands surface as well (as figure 5.2). Deforming of PP bands for quenching process in quenching bath is quite sensitive for any particles including bubbles which can destroy surface of PP bands. The result is that abnormal physical form of PP bands which is stretched in stretching oven will break during stretching process as figure 5.3.

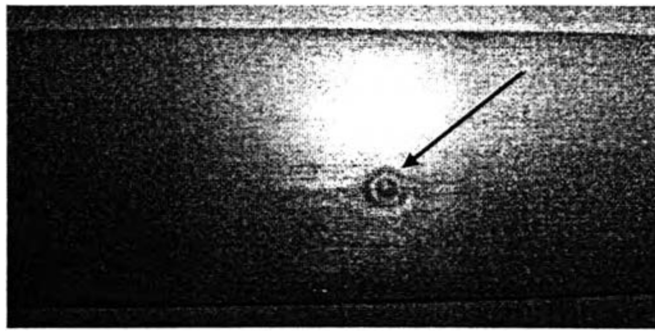

**Figure 5.1: Surface of PP Band Affected by Big Bubble**

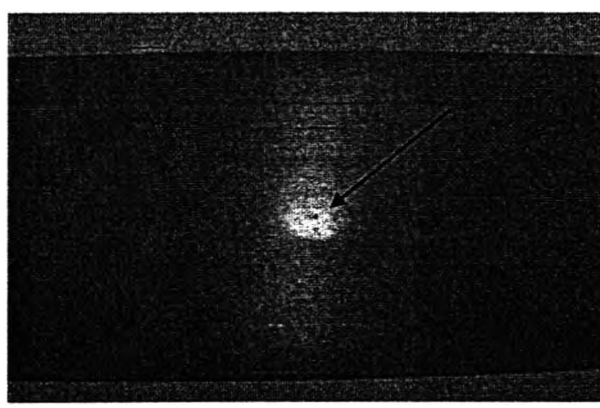

**Figure 5.2: Surface of PP Band Affected by Small Bubble**

**Figure 5.3: Abnormal PP Band after Breakage**

#### 5.2.1.2 Solution to Reduce Breakage Problem

In order to solve PP-band breakage problem, it is required to eliminate bubbles in chilled water of quenching bath to prevent bubbles particles destroy PP-band physical surface in quenching process. This can be accomplished by changing O-ring seal at water pump to prevent leakage which causes bubbles in the water flow system. In addition, in order to reduce the breakage problem in the future, the case company should implement preventive maintenance in chillers by regularly changing O-ring seal at water pump to prevent unforeseen impact which can cause of bubbles in the chilled water system.

#### 5.2.1.3 Other Breakage Problems

Tables 5.2 and 5.4 reveal that after eliminating bubbles in quenching bath which is the real cause of breakage, however, there are still a small number of breakages. Some are uncontrollable but rare situations such as electricity breakdown. Nevertheless, there may be other causes, such as irregular cleaning of filter in the extruder, which could be eliminated with proper preventive maintenance.

### 5.2.2 Benefits

The benefits of the research can be divided into tangible benefits and intangible benefits which are discussed below.

#### 5.2.2.1 Tangible Benefits

There are several tangible benefits that can be obtained from this study. They are as follows:

- **Reduced production cost:**

  In the last year from January to December 2004, the case company has suffered total breakage loss more than 5,700 kg of material (table 3.1), mostly Polypropylene, which is cost around 265,000 baht (PP no.1102H: 46 baht per kg in April 2005). Actually, breakage loss of material (PP) can be recycled by outside supplier but the recycled PP can produce only low grade of PP bands which the value of scrapped PP was reduced. This forces the company to produce only low grade PP bands as B grade. If PP-band breakage can be reduced, the production cost of A grade, Auto grade and Heavy grade will be saved dramatically. As a result, company's competitive advantage can be increased.

- **Increased machine productivity:**

  The productivity of machine can be increased because the company does not need to waste time to set up the machine after the production breakdown from the breakage. Machine can be utilized effectively.

- **Reduced machine maintenance time:**

  When there is no breakage of PP bands in the production line, maintenance time of machine will be reduced because there is no need to set up or adjust the machine.

**5.2.2.2 Intangible Benefits**

Other several benefits from this study are intangible which can be explained in detailed as follows:

- **Case study of FMEA:**

  This study adds the new dimension of using FMEA technique to solve the production problem. Since this study deals only with the breakage problem which is the main problem of production in the case company, however there are numerous problems which FMEA technique can be applied to solve the problem. Therefore, this study is a case study of FMEA for other researcher or other companies who are interested in applying FMEA techniques.

- **Build awareness:**

  By using FMEA technique in the case company, it captures collective knowledge of a team and builds awareness for the case company's employees in employing FMEA technique to improve process in the other production line or department of the company.

- **Meeting production target schedules**

  Improvement in machine performance, machine productivity and maintenance time has greatly contributed to the company targets of reducing cycle time in production. Production schedules can be met.

- **Support of Preventive Maintenance**

  The case company has not implemented preventive maintenance program. Applying FMEA methodology in the organization also supports preventive maintenance by using PP-band breakage failure as the example for preventive maintenance which the company is considering to implement in the future in order to improve quality, reliability, and safety of the process in the company. However, the cost of implementing of Preventive Maintenance must be taken in consideration because for SME companies normally supporting money from top management is limited.