CHAPTER 4

RESEARCH METHODOLOGY

The methodology of research is divided into four steps follwing.

1. To study rinsing process in recycled plastic plant.

2. To formulate a mathematical model for rinsing of recycled plastic rinsing process.

3. To do the experiment to collect data for validating model.

4. To optimize a rinsing model.

4.1 Rinsing process in recycled plastic plant

Recycle process of plastic can be described with process flow diagram (Figure 4.1) as follows. First step of the recycle process, plastic garbage, which is purchased from supplier, is sorted by type of plastic such Polypropylene (PP), Polyethelene (PE), Poly Ethly Thalethalene (PET), etc. because each type has a different properties such as melting point, density and transparence. It effects to the quality of recycled plastic gains. Second step, steel scrap and paper are separated from these plastic, after it is sorted by color appearance. Third step, plastic is grinded to small particle size, washed in a machine and rinsed with fresh water in a pit . Next step, the plastic is dried by hot air and the label on the plastic is removed. Then, the plastic is melted and extruded to a bar of plastic. Final step, these plastic is cut off to a grain and formed to a product. The product that is made form the recycle plastic has poor properties. Sometime the recycle plastic grain is blended with new plastic grain to improve the properties.

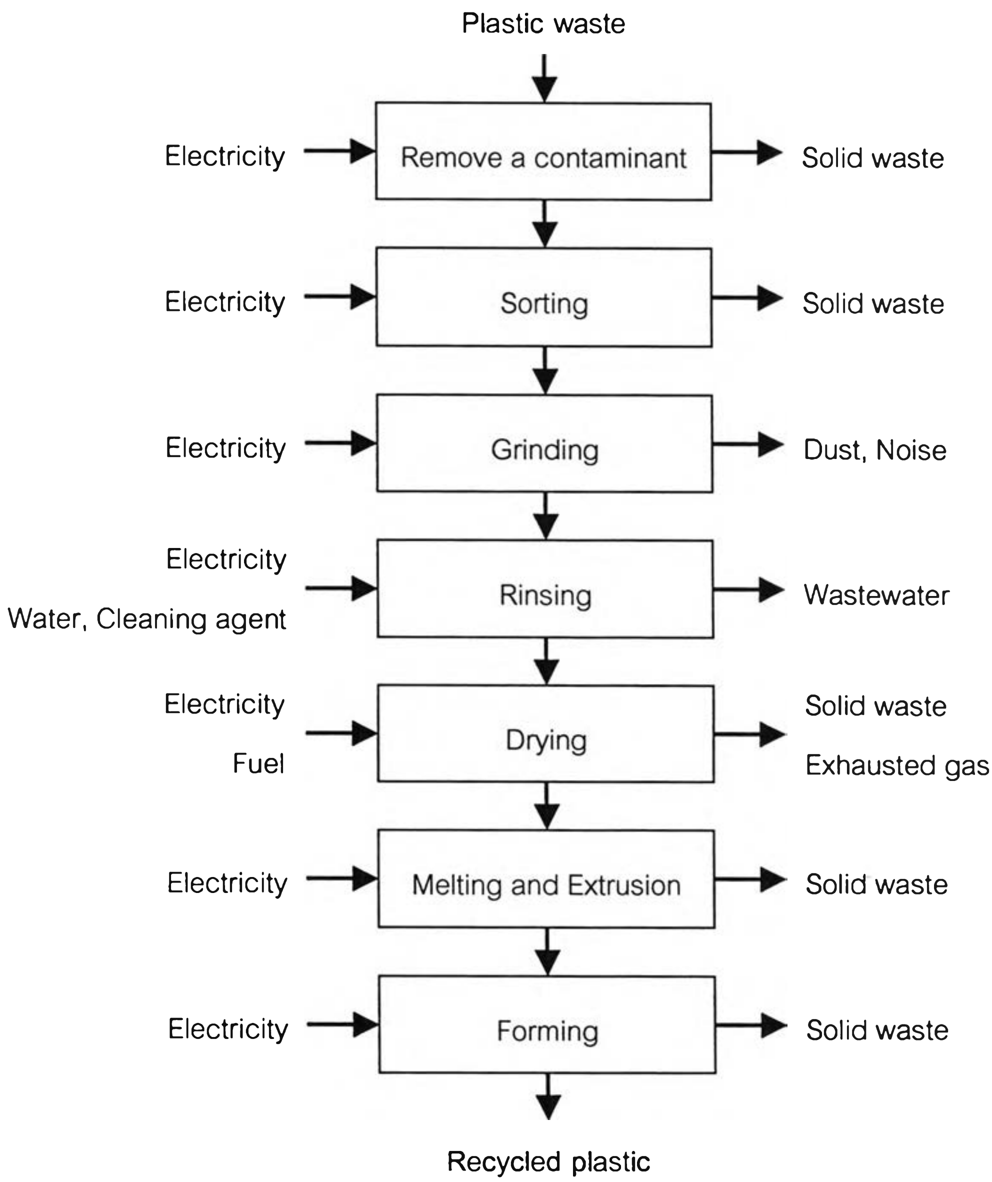

Figure 4.1 A process of recycling plastic

In the rinsing process, the objective of is removal contaminant in a plastic before plastic is recycled to grains. This process has several water consumption and occurs high volume of wastewater. The process is comprised two part. First part is washing by machine (Figure 4.2) and second part is rinsing with fresh water in a pit (Figure 4.3). The function of washing by machine is removal a contaminant on plastic such as dust, oil etc and the cleaning agent is used to remove it. This machine has a propeller to create turbulent flow, which the contaminant in recycled plastic is removed easily. After finished of washing by machine, the water is discharged and the worker use fresh water to wash the cleaning agent which trap on the plastic. Then the plastic is moved to a pit for rinsing cleaning agent contaminant. Now, the rinsing is one drag out rinse type. Plastic is submerged in a pit, before it is put in dewatering machine.

Figure 4.2 Washing machine

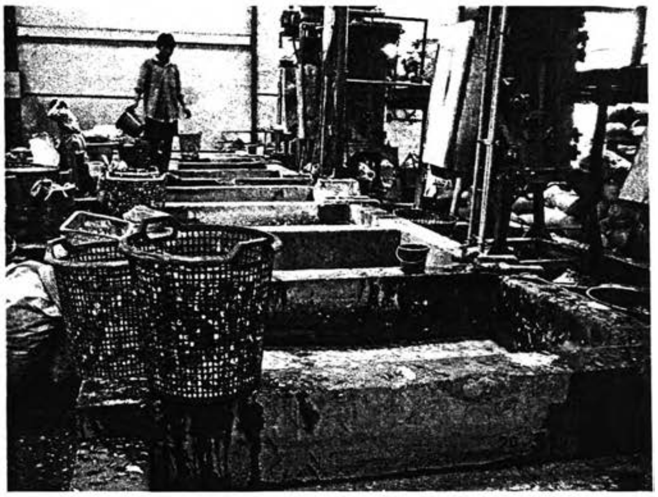

Figure 4.3 Rinsing pit

4.2 Model for rinsing of recycled plastic

In this research, we interest to study rinsing process with three drag out rinse. This type is appropriate for available number of pit in factory. We apply rinsing model in previous chapter for rinsing system as follows

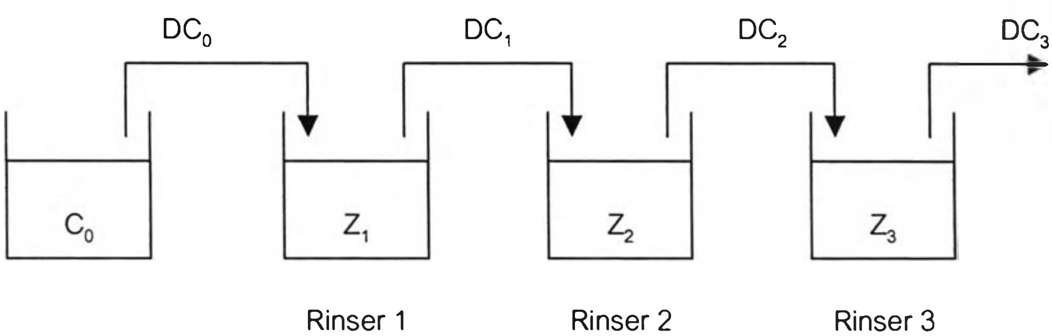

Figure 4.4 Rinsing system in this research

From the equation of rinsing system (3.6) in previous section, we apply the asumption based on equal of volume of each rinser and drag out and can express a mathematical model, which used to determine concentration of cleaning agent in rinse water for each rinser as follows

$$Z_1 = C_0\left[1 - \beta_1^1 \exp(-kb_1t)\right] \tag{4.1}$$

$$Z_2 = C_0\left[1 - \beta_2^1 \exp(-kb_1t) - \beta_2^2 \exp(-kb_2t)\right] \tag{4.2}$$

$$Z_3 = C_0\left[1 - \beta_3^1 \exp(-kb_1t) - \beta_3^2 \exp(-kb_2t) - \beta_3^3 \exp(-kb_3t)\right] \tag{4.3}$$

Where $\beta_1^1 = 1$

$$\beta_2^1 = \frac{b_2b_1}{b_2 - b_1} \qquad \beta_2^2 = 1 - \frac{b_2b_1}{b_2 - b_1}$$

$$\beta_3^1 = \frac{b_3}{b_3 - b_1} \times \left[a_2 b_1 + \frac{b_2{}^2 b_1}{b_2 - b_1} \right] \qquad \beta_3^2 = \frac{b_3 b_2}{b_3 - b_2} \times \left[1 - \frac{b_2 b_1}{b_2 - b_1} \right]$$

$$\beta_3^3 = 1 - \left[\frac{b_3}{b_3 - b_1} \times \left(a_2 b_1 + \frac{b_2{}^2 b_1}{b_2 - b_1} \right) + \frac{b_3 b_2}{b_3 - b_2} \times \left(1 - \frac{b_2 b_1}{b_2 - b_1} \right) \right]$$

$b_n = 1 - a_n$ for n=1,2,3

The coefficient (b_1, b_2 and b_3) in equation (4.1) to (4.3) can be obtained from fitting curve between model and the experimental point.

4.3 The experiment

The experiment in this research can be described following. First, prepare a calibration curve, which is a relationship between the cleaning agent concentration and a value of pH. We use this curve to determine the cleaning agent concentration in each tank after rinsing. Second, set up the three rinsing tanks as Figure 4.5 and fix twenty liters of fresh water in each tank. Two hundreds grams of recycled plastic from the factory in the basket as shown in Figure 4.6 to 4.7 is be determined the workpiece for rinsing. Third, prepare the cleaning agent tank with five gramperlitre of initial cleaning agent concentration. We sets as cleaning agent concentration of plastic after washing with machine.

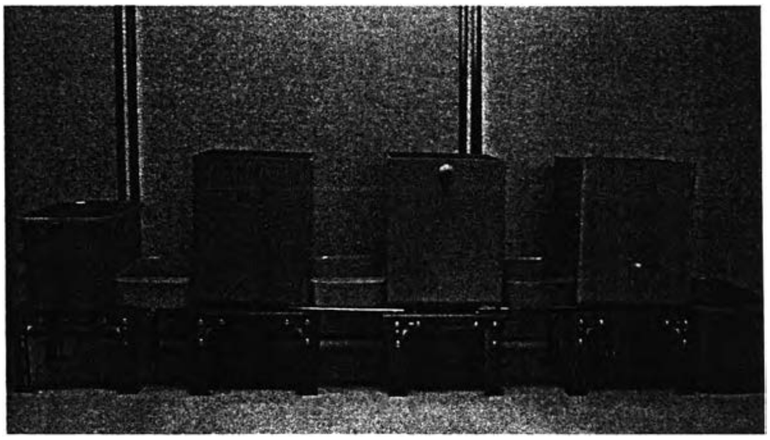

Figure 4.5 Set of the experiment.

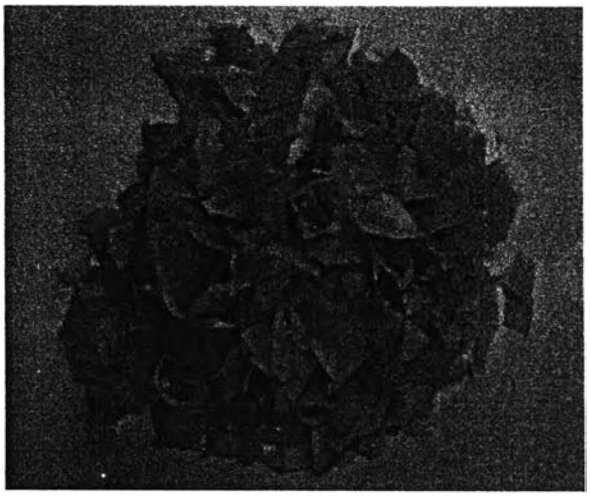

Figure 4.6 Sample of recycled plastic in the experiment.

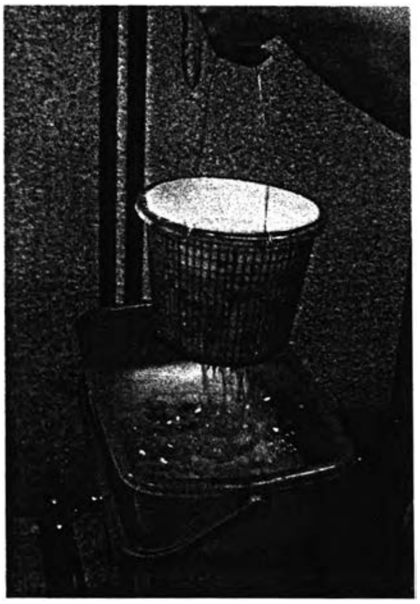

Figure 4.7 Container of recycled plastic for rinsing.

Next, dip the container to cleaning agent tank, we hold it in five seconds after move it to immerse in the fresh water at the first tank, second tank and the last tank respectively under determined rinsing time as Figure 4.8. Measure pH value of rinse water in each rinsing tank at 2, 4, 6, 8, 10, 12, 14, 16, 18 and 20 of cycle time of rinsing. We set six sets experments of 5, 10, 15, 20, 25 and 30 the rinsing time in each tank.

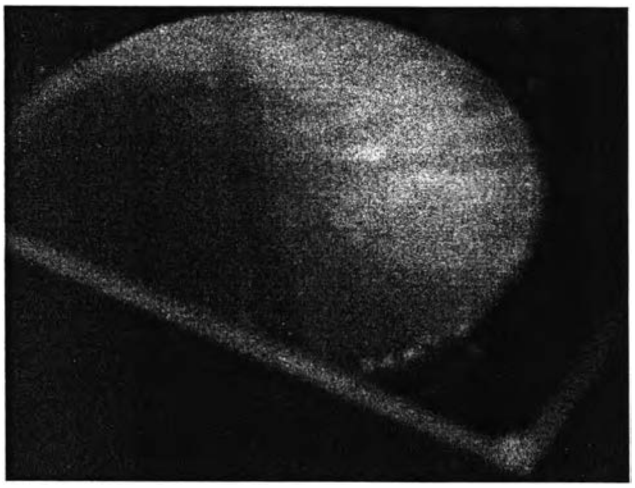

Figure 4.8 Rinsing of plastic in the experiment.

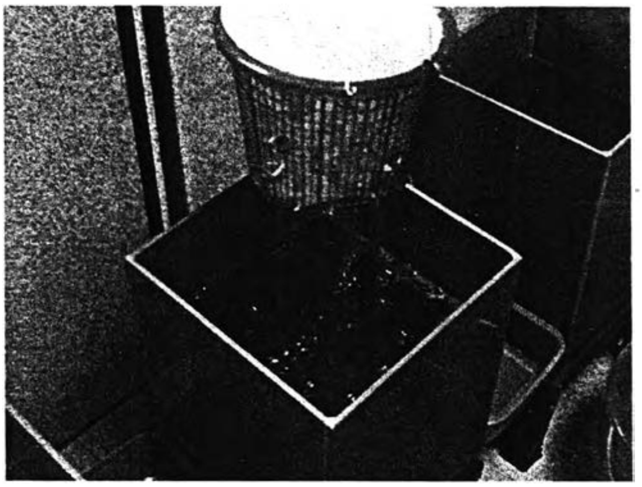

Figure 4.9 Drag out of rinse water after rinsing in each tank.

Finally, convert the measured pH value of rinse water in each tank at various of cycle time of rinsing to the cleaning agent concentration based on the calibration curve and plot this data between concentration of cleaning agent and cycle time of rinsing on the semilog graph.

4.4 Optimization

Since the mathematical model at steady state can't be expressed, dynamics optimization technique is applied to find an optimum value. In this research, we interests to find the optimum volume of rinsing water in each stage and an optimum volume of drag out under constraint with number of rinsing and limitation of cleaning agent concentration in the last of rinsing stage. We can generate the optimization problem as following.

$$\min_{V \text{ or } d} C_3 = a_2 C_2 - (1-a_2) Z_2 \quad (4.4)$$

$$\textit{Subject to} \quad V\frac{d}{dt}Z_1 = (D - a_1 D)C_0 - (1-a_1)DZ_1 \quad (4.5)$$

$$V\frac{d}{dt}Z_2 = (D - a_2 D)C_1 - (1-a_2)DZ_2 \quad (4.6)$$

$$V\frac{d}{dt}Z_3 = (D - a_3 D)C_2 - (1-a_3)DZ_3 \quad (4.7)$$

$$Z_3^L \le Z_3 \quad (4.8)$$

$$Z_3 = Z_3(t_N) \quad (4.9)$$

$$V^L \le V \le V^U \quad (4.10)$$

$$d^L \le d \le d^U \quad (4.11)$$

This problem is a dynamic optimization with end points constraints. The objective function is formulated from the relationship between the cleaning agent concentrations on plastic at the last stage and the cleaning agent concentrations in the last tank (3.13). The constraints consist of mathematical model of concentration response in each stage (3.14), limitation of cleaning agent concentration in the last tank at final of rinsing cycle and lower-upper bound of the optimized variable (volume of rinsing water or drag out volume).