CHAPTER 6
DISCUSSION AND CONCLUSION

6.1 Discussion

6.1.1 Batch exeperiment

6.1.1.1 Manufacturing Condition and Procedure

Prior to the experiment which gives the results in Chapter 5, preliminary experimental study was done in order to set up exact manufacturing procedure. The experiment used in this work study was simplest and comfortable to use or apply for paving sportsground. The mechanical properties of polyurethane used for paving sportsground should be in a range of standard of patent pol.P.L. No. 141,631.

The best condition and procedure were obtained as discribed in Chapter 4. Reacting mixture of less than 200 g. was used in each batch.

6.1.1.2 Suitable composition of filled - polyurethane

The raw materials used in this study were supplied by TPU(Thai Polyurethane Industry Co.,Ltd.).

First , the NCO/OH ratio is chosen based on the best mechanical properties. From Table 5.1, a value of NCO/OH ratio at 1.02 and 1.11 were chosen because maximum percentage of elongation at break was obtained at NCO/OH ratio of 1.02 and maximum tensile strength and maximum hardness were obtained at NCO/OH ratio of 1.11 which could be described that while NCO/OH ratio increases, concentration of soft segment given from polyol also increases. Thus elongation at break had been influenced by concentration of soft segment increases to maximum value at NCO/OH ratio of 1.02. After that, effect of hard segment given from MDI and DEG on tensile strength and hardness had influenced over soft segment. The excess of isocyanate group is able to take part in crosslinking reactions through formation of allophanate or biuret linkages. By this reason a value of hardness increases with NCO/OH ratio.

Then, at NCO/OH ratio of 1.02 and 1.11, molar ratio of polyol:MDI:DEG of 1:4:3 was chosen because tensile strength and percentage of elongation at break were given maximum value (Table 5.2 and Table 5.3).

After the composition of unfilled polyurethane is obtained, brick was used as filler in this work study to find suitable composition of filled polyurethane. Brick powder do not paticipate in the reaction. From Table 5.4 and Table 5.5, brick powder had effect on decrease tensile strength and percentage of elongation at break but it increases hardness.

The percentage of brick in the filled-polyurethane was then determined. According to the standard of patent pol.P.L. No. 141,631, synthetic running surface should have a tensile strength in excess of 1.5 N/mm^2, % of elongation at break in excess of 100 and a hardness shore ^{o}A of 45-60. These values of the properties will be used as a standard in determining the suitable composition. Thus, based on Table 5.4, a 10% of brick was chosen because it had mechanical properties in standard of patent pol.P.L. No. 141,631 and at NCO/OH ratio of 1.11, a 5 % of brick was chosen for the same reason.

6.1.1.3 Cost of filled-polyurethane

Table 6.1, Figure 6.1 and 6.2 shown estimation material cost and mechanical properties of filled-polyurethane at NCO/OH ratio of 1.02 for paving sportsground.

Table 6.2, Figure 6.3 and 6.4 shown estimation material cost and mechanical properties of filled-polyurethane at NCO/OH ratio of 1.11 for paving sportsground.

Material cost :	Polyester polyol	70	Baht/kg
	Polymeric MDI	75	Baht/kg
	Diethylene glycol	30	Baht/kg
	Brick	2.0	Baht/kg
	Dibutyltin diluarate	320	Baht/kg

Composition of 10% brick-polyurethane at NCO/OH ratio of 1.02.

Polyester polyol	52.85	weight percent
Polymeric MDI	28.70	,,
Diethylene glycol	8.39	,,
Brick	10.00	,,
Catalyst	0.06	,,

Composition of 5% brick-polyurethane at NCO/OH ratio of 1.11.

Polyester polyol	54.26	weight percent
Polymeric MDI	32.06	,,
Diethylene glycol	8.62	,,
Brick	5.00	,,
Catalyst	0.06	,,

Table 6.1 Relation between mechanical properties and estimate cost by various weight percent brick at NCO/OH ratio of 1.02

% Brick	Tensile strength (MPa)	Elongation at break (%)	Hardness (Shore °A)	Cost (Baht/kg)
0	10.668	150	70	68.02
5	9.952	118	73	64.72
10	9.383	107	75	61.43
15	8.953	94	79	58.13
20	8.114	81	80	54.84
25	7.895	79	81	51.55

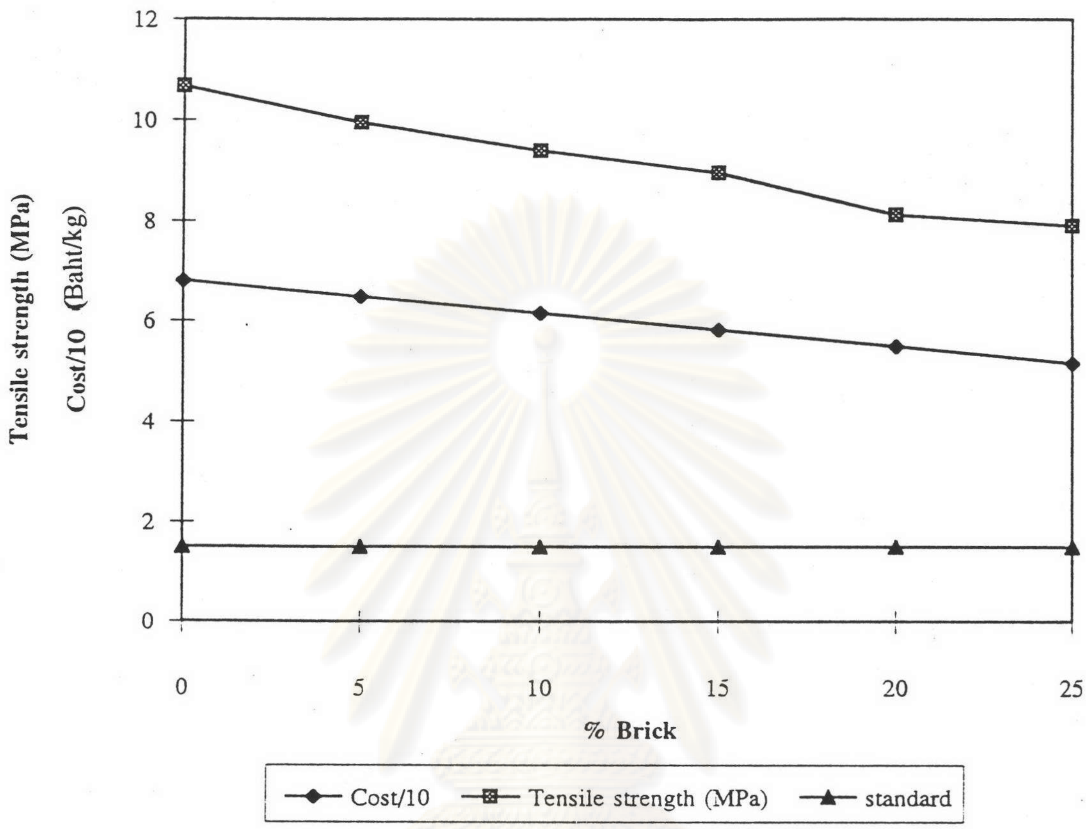

Figure 6.1 Relation between tensile strength, cost and standard value of filled-polyurethane at NCO/OH ratio of 1.02

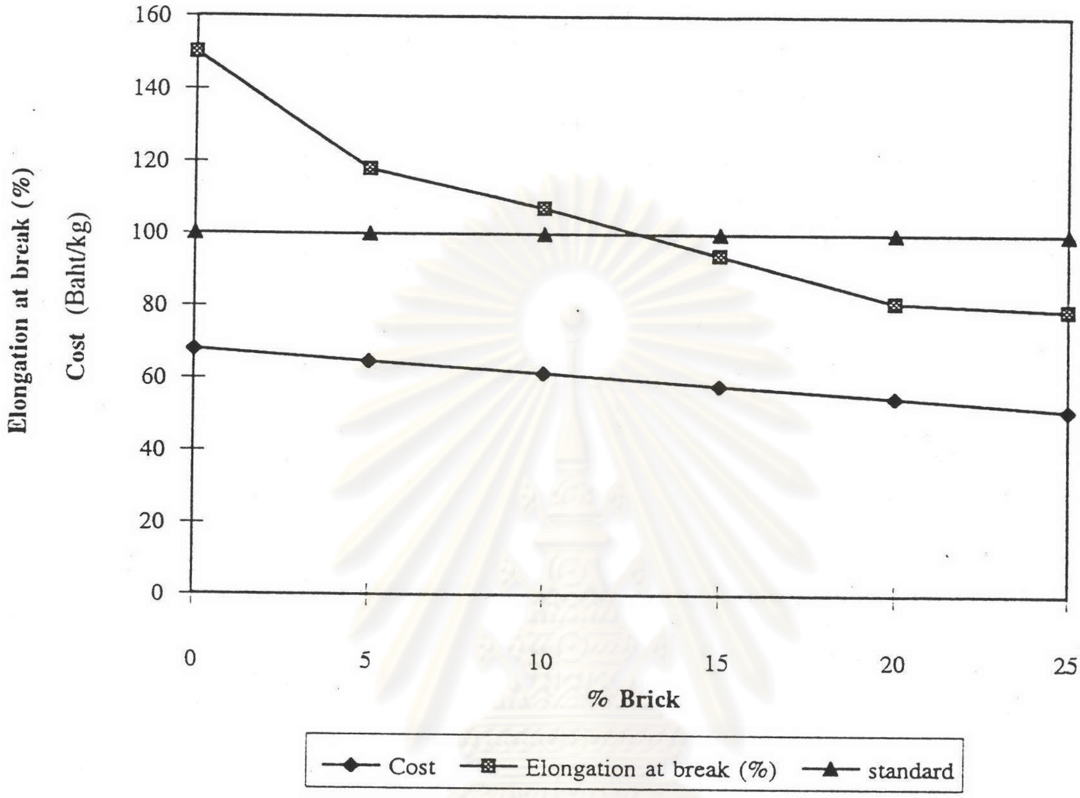

Figure 6.2 Relation between % elongation at break, cost and standard value of filled-polyurethane at NCO/OH ratio of 1.02

Table 6.2 Relation between mechanical properties and estimate cost by various weight percent brick at NCO/OH ratio of 1.11

% Brick	Tensile strength (MPa)	Elongation at break (%)	Hardness (Shore °A)	Cost (Baht/kg)
0	11.977	127	78	68.21
5	11.083	108	80	64.91
10	9.832	92	81	61.61
15	8.952	87	83	58.30
20	7.845	81	83	55.00
25	7.103	78	84	51.70

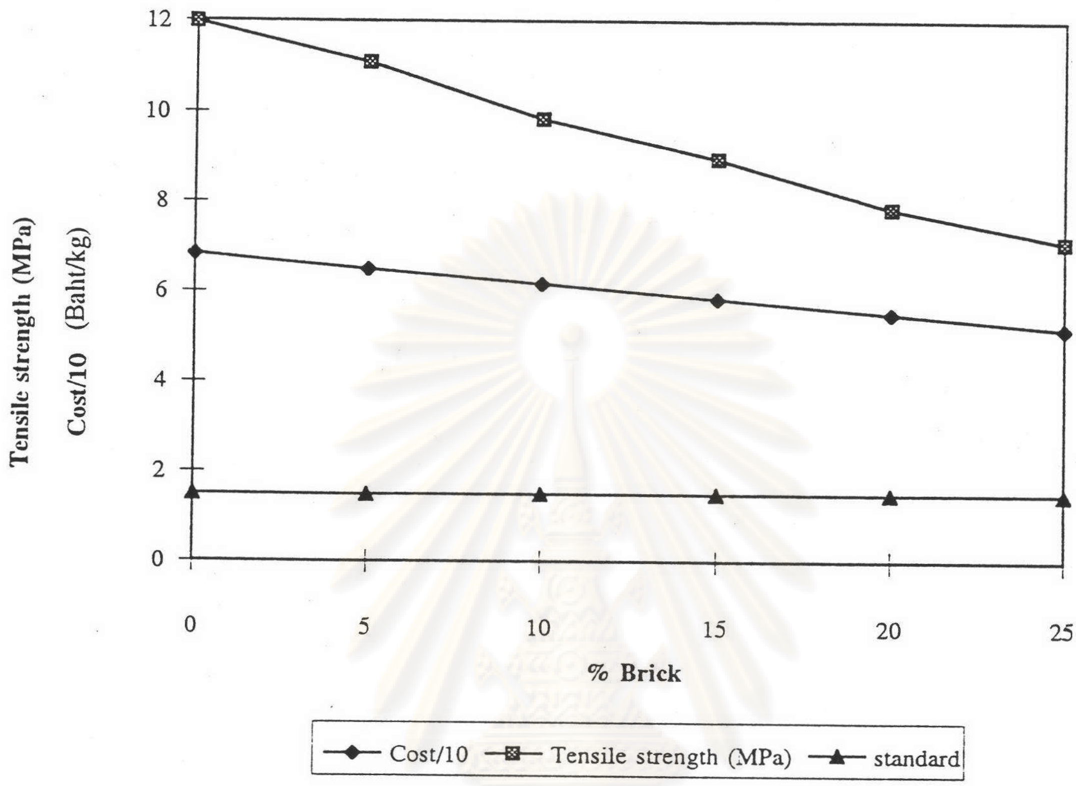

Figure 6.3 Relation between tensile strength, cost and standard value of filled-polyurethane at NCO/OH ratio of 1.11

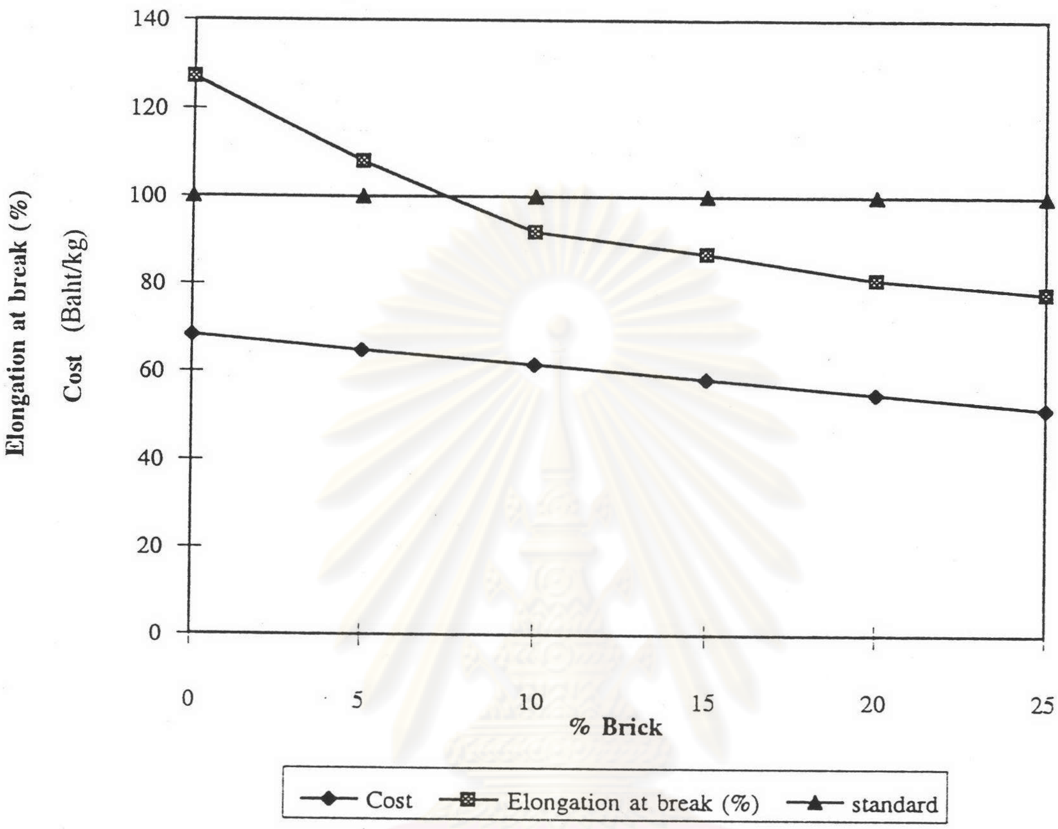

Figure 6.4 Relation between % elongation at break, cost and standard value of filled-polyurethane at NCO/OH ratio of 1.11

At 10% brick of NCO/OH ratio of 1.02 and 5% brick of NCO/OH ratio of 1.11, both products had mechanical properties in standard of patent pol. P.L. No. 141,631. But cost of paving surface at 10% brick of NCO/OH ratio of 1.02 is cheaper than at 5% brick of NCO/OH ratio of 1.11.

Then at 10% brick of NCO/OH ratio of 1.02 is chosen by this reason.

6.1.1.4 Effect of chain-extender on properties of polyurethane

Table 5.2 and 5.3 could be transfromed to Table 6.3 and Table 6.4, respectively, for showing the effect of diethylene glycol on mechanical properties of polyurethane.

From Table 6.3-6.4 and Figure 5.2-5.3, trends of the tensile strength and percentage of elongation at break increase to maximum value at molar ratio of diethylene glycol to polyester polyol of 3:1.

After that, a value of tensile strength and percentage of elongation at break begin to decrease while molar ratio of diethylene glycol to polyester polyol increases further. But when molar ratio of diethylene glycol to polyester polyol increases, trend of a value of hardness increases because size of the rigid block increases.

Table 6.3 Effect of DEG on mechanical properties of polyurethane at NCO/OH ratio of 1.02

Molar ratio		Mechanical properties		
DEG to polyol	MDI to polyol	Tensile strength (MPa)	Elongation at break (%)	Hardness (Shore °A)
1:1	2:1	1.750	112	40
2:1	3:1	6.428	129	46
3:1	4:1	10.668	150	70
4:1	5:1	9.384	125	78
5:1	6:1	8.037	117	80

Table 6.4 Effect of DEG on mechanical properties of polyurethane at NCO/OH ratio of 1.11

Molar ratio		Mechanical properties		
DEG to polyol	MDI to polyol	Tensile strength (MPa)	Elongation at break (%)	Hardness (Shore °A)
1:1	2:1	2.827	118	44
2:1	3:1	6.849	121	53
3:1	4:1	11.977	127	78
4:1	5:1	10.214	113	84
5:1	6:1	8.732	108	82

6.1.2 Continuous experiment

In this study, ratio by weight of reagent part A(polyester polyol, diethylene glycol and dibutyltin diluarate) to react with reagent part B(polymeric MDI) was controlled at NCO/OH ratio of 1.02 as indicated in Table 4.1.

The result of continuous experiment shown in Table 5.6 and Figure 5.6. A value of tensile strength, percentage of elongation at break and hardness are lower than a value which was given by the batch experiment.

Figure 6.5 shows the relation of a value of tensile strength from continuous experiment with a value of tensile strength from batch experiment.

Figure 6.6 shows the relation of a value of percentage of elongation at break from continuous experiment with a value of percentage of elongation at break from batch experiment.

Figure 6.7 shows the relation of a value of hardness from continuous experiment with a value of hardness from part batch experiment.

The values of mechanical properties which lower and variant could be explained as follows.

- Pump

Pump used in these experiment is gear pump. A gear pump is usually used in pumping viscous liquid but it is hard to control volumetric flowrate at a fixed value. Volumetric flowrate of gear pump could be adjusted by changing the size of pulley or speed of motor.

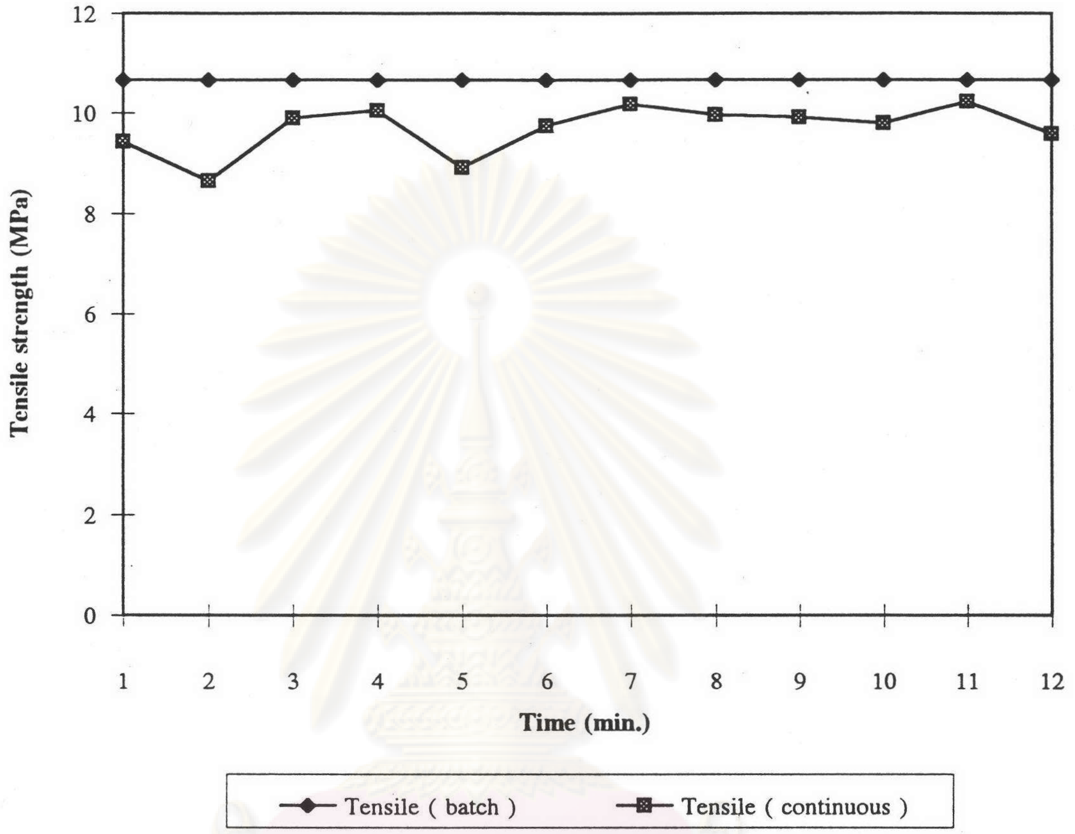

Figure 6.5 Relation of a value of tensile strength from continuous experiment with a value of tensile strength from batch experiment

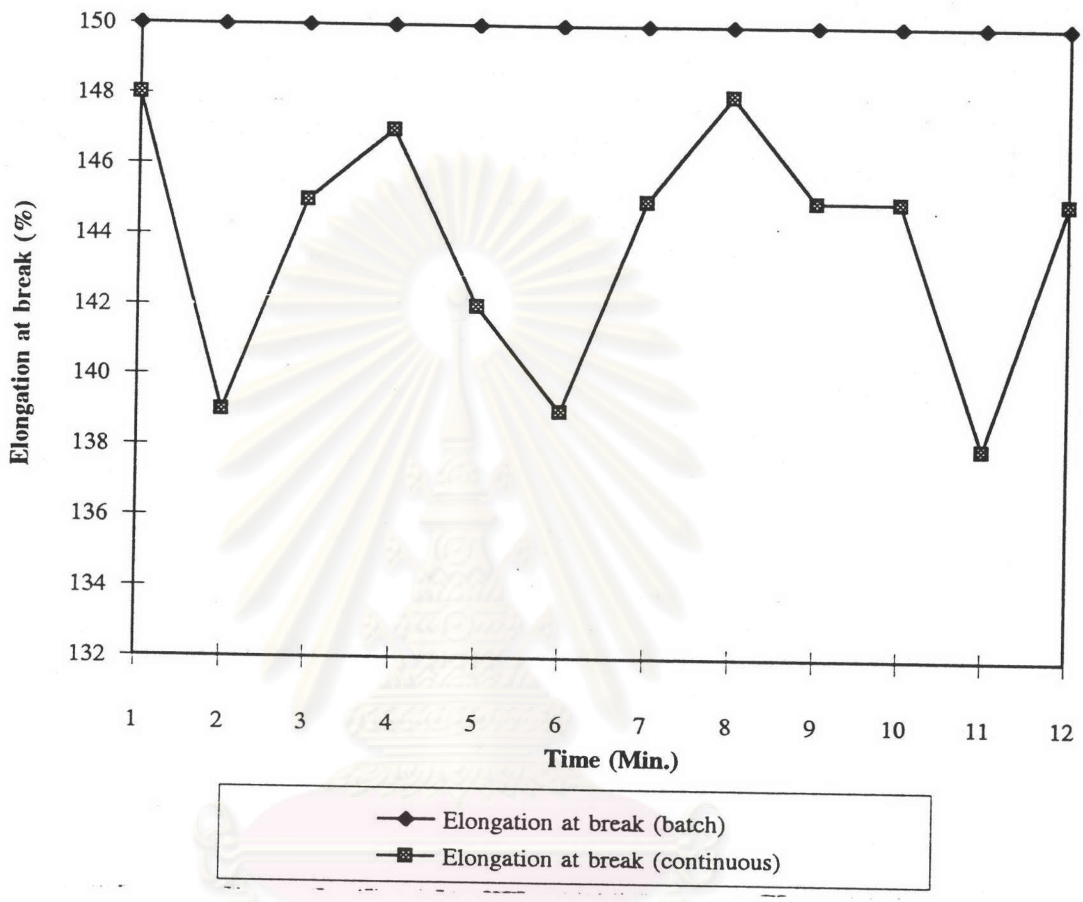

Figure 6.6 Relation of a value of % elongation at break from continuous experiment with a value of elongation at break from batch experiment

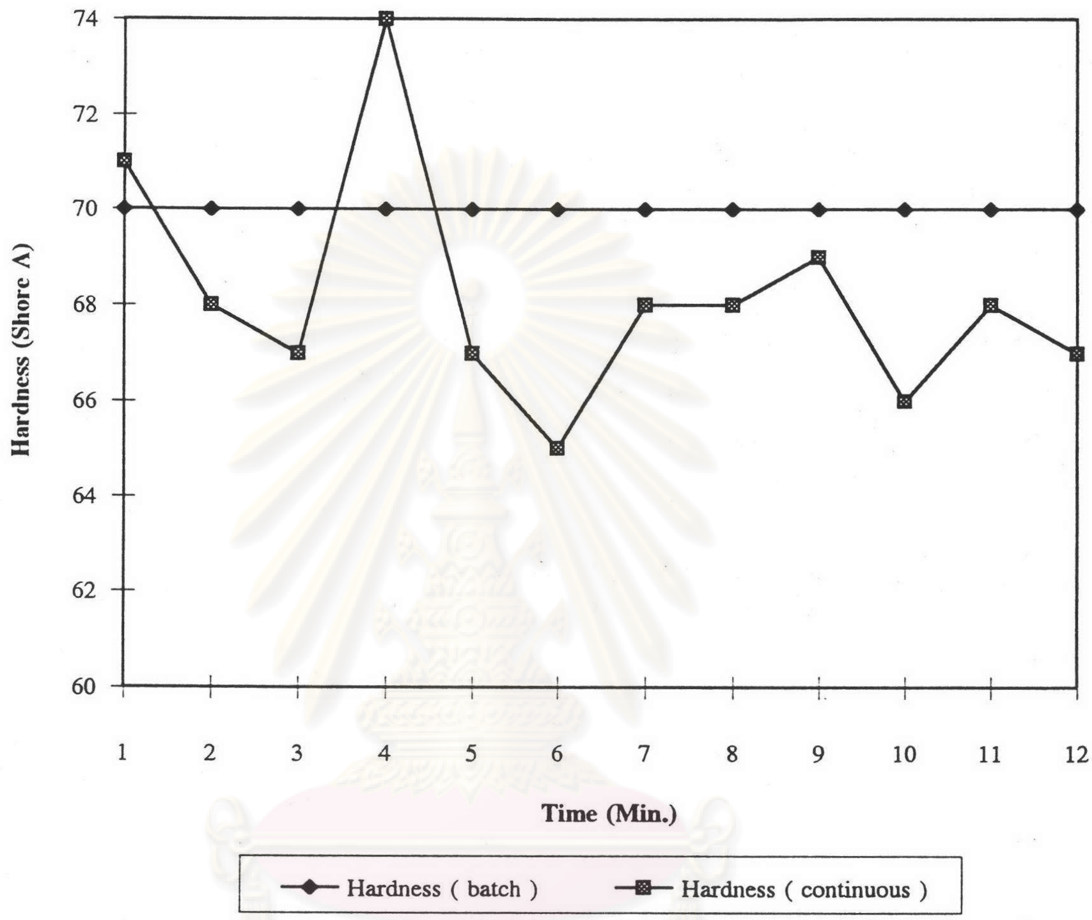

Figure 6.7 Relation of a value of hardness from continuous experiment with a value of hardness from batch experiment

- Static Mixer

Static mixer of kenic type was built to use in this experiment by Mr. Manut Artayapan of Thailand Institute of Scientific and Technological Rereach. In pipe line of static mixer consists of a series of mixing element aligned at 90°, each element being a short helix of one and half tube diameter in length. Each element has twist of 180° and right-hand and left-hand elements are arranged alternately.

Mixing element may not be aligned at 90° when put the element in pipe line, so liquid mixing of reagent part A and reagent part B may not be completed.

- Reagents used in these experiment

These experiment required a lot of volume of polyester polyol, diethylene glycol and polymeric MDI. The reagents must have a water content which shown in Chapter 4 (Table 4.1- 4.3). While polyester polyol, diethylene glycol and dibutyltin diluarate were mixed to serve as reagent part A, water content was over 0.03 phr. Thus, when reagent part A reacted with reagent part B, carbondioxide ocoured, resulting porous in product. The porosity made the value of tensile strength, percentage of elongation at break and hardness lower than the value given from batch experiment.

6.2 Conclusion

The suitable composition for unfilled-polyurethane had the molar ratio of polyester polyol : polymeric MDI : DEG of 1:4:3 at two NCO/OH ratios; one was at 1.02 and the other was at 1.11.

The suitable composition in filled-polyurethane was 10 w% brick powder used as a filler which was passed US. sieve No. 325 at the NCO/OH ratio of 1.02 and the molar ratio of polyester polyol : polymeric MDI : DEG at 1:4:3. The chain-extender(Diethylene glycol) has effects on mechanical properties as increasing the hardness when the molar ratio of diethylene glycol to polyester polyol increased. This is because the size of rigid block increases. Furthermore, at the molar ratio of diethylene glycol to polyester polyol of 3 : 1, the value of tensile strength and percentage of elongation at break was increased to maximum value. When the molar ratio exceeded this maximum value, the tensile strength and the elongation at break began to decrease.

In the continuous experiment, static mixer could be used for mixing reagent part A and reagent part B to produce polyurethane. However, it is noted that the value of mechanical properties fluctuated.