CHAPTER VI

RESULTS AND DISCUSSIONS

After peel tension test , curve of load versus extension are obtained (Figure 6.1-6.5) . Because computer of tension machine cannot test 10 samples a time, so 5 samples are run each time and data are calculate as average mean load (table 6.2). Two times of 5 samples data then are calculated as average 10 samples. Average mean load of each formula is set into experimental table as in table 6.3 . Until all 16 formulas are found , then average value and other can be calculated according to experimental design.

6.1 EFFECT OF ADHESION AREA

In this experiment , method of coating hotmelt adhesive onto material surface is applied for adhesived samples , then adhesive can cover all surface area of testing film laminated paper. Because area of adhesion will effect load of peeling adhesive from adherend surface. General industry coating method , hotmelt adhesive is extruded from gun as small lining and freely spread of material surface. Then each time coating will have different area and the experiment will have one more error effect.
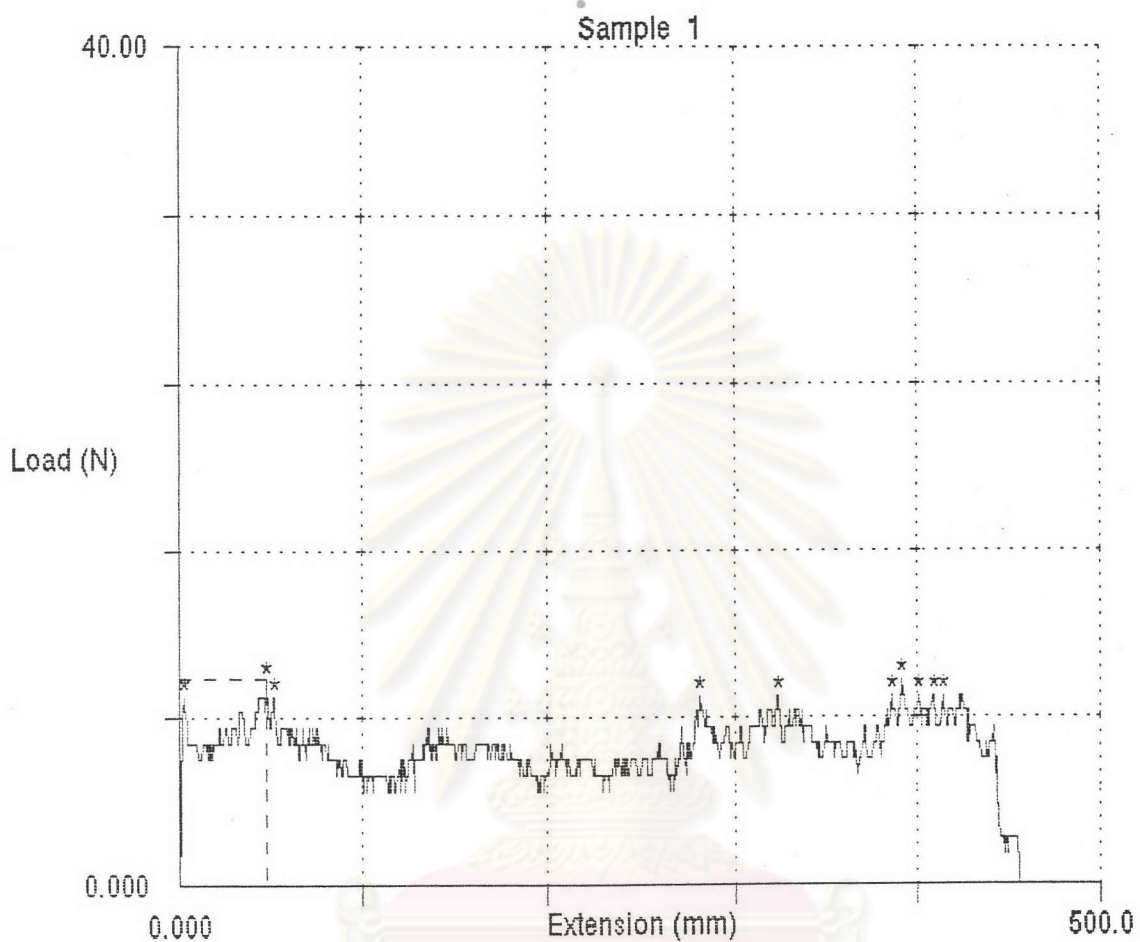
To eliminate this error , some more experiment is tested by adhering material surfaces using general gun to coat a lining adhesive . After tention peeling test method , the results are compared with the applied method.

Method	Mean load (N)
Small lining adhesive	3.12
Full cover adhesive	9.87

Table 6.1 Effect of adhesion area

Sample 1

Maximum Load (N)	Work Done (N-mm)	Mean Load (N)	Maximum Strength (N/mm)	Av Max Load (N)	Av Max Strength (N/mm)	Sample Width (mm)
9.918	3017	6.035	0.390	9.308	0.366	25.40

FIGURE 6.1 Peel tension graph of sample 1
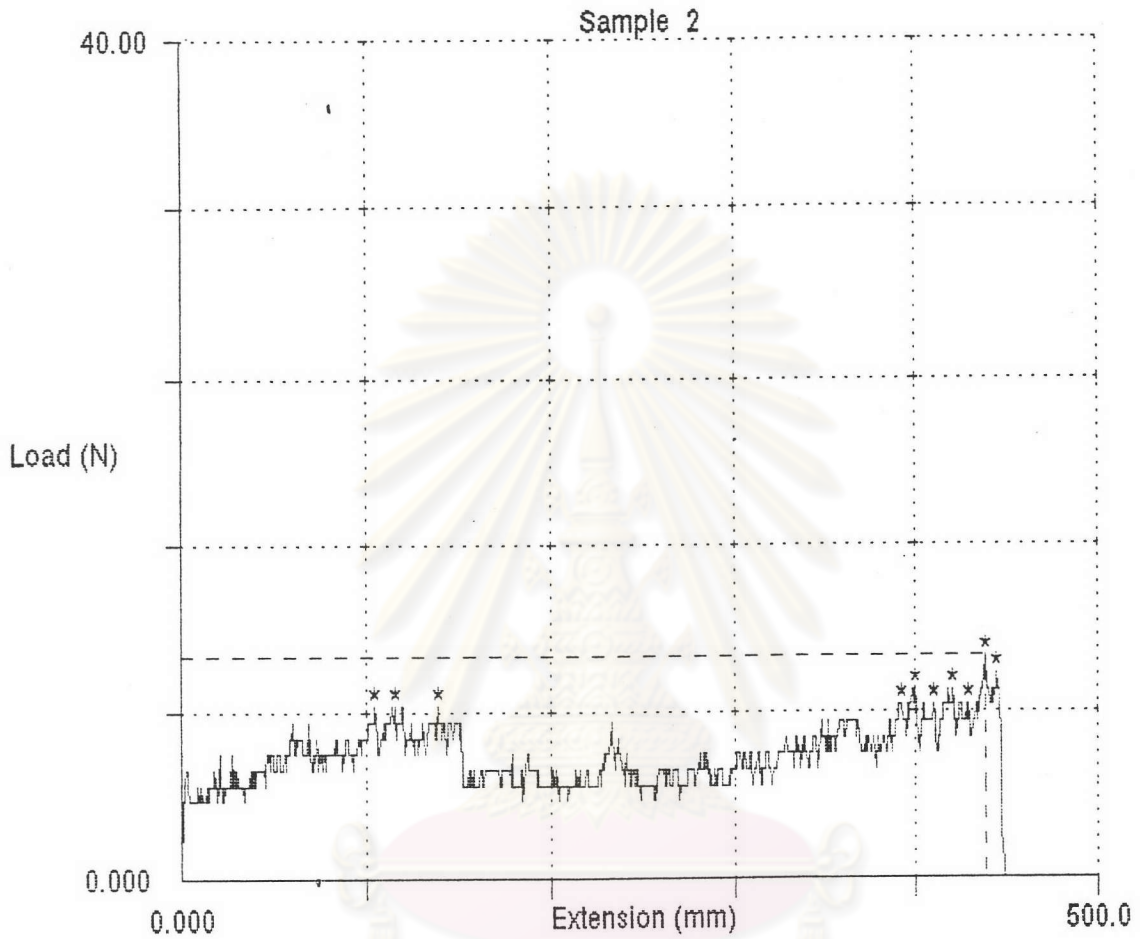
Maximum Load (N)	Work Done (N-mm)	Mean Load (N)	Maximum Strength (N/mm)	Av Max Load (N)	Av Max Strength (N/mm)	Sample Width (mm)
10.68	2696	5.392	0.420	8.926	0.351	25.40

FIGURE 6.2 Peel tension graph of sample 2

Maximum Load (N)	Work Done (N-mm)	Mean Load (N)	Maximum Strength (N/mm)	Av Max Load (N)	Av Max Strength (N/mm)	Sample Width (mm)
9.155	2288	4.577	0.360	7.706	0.303	25.40
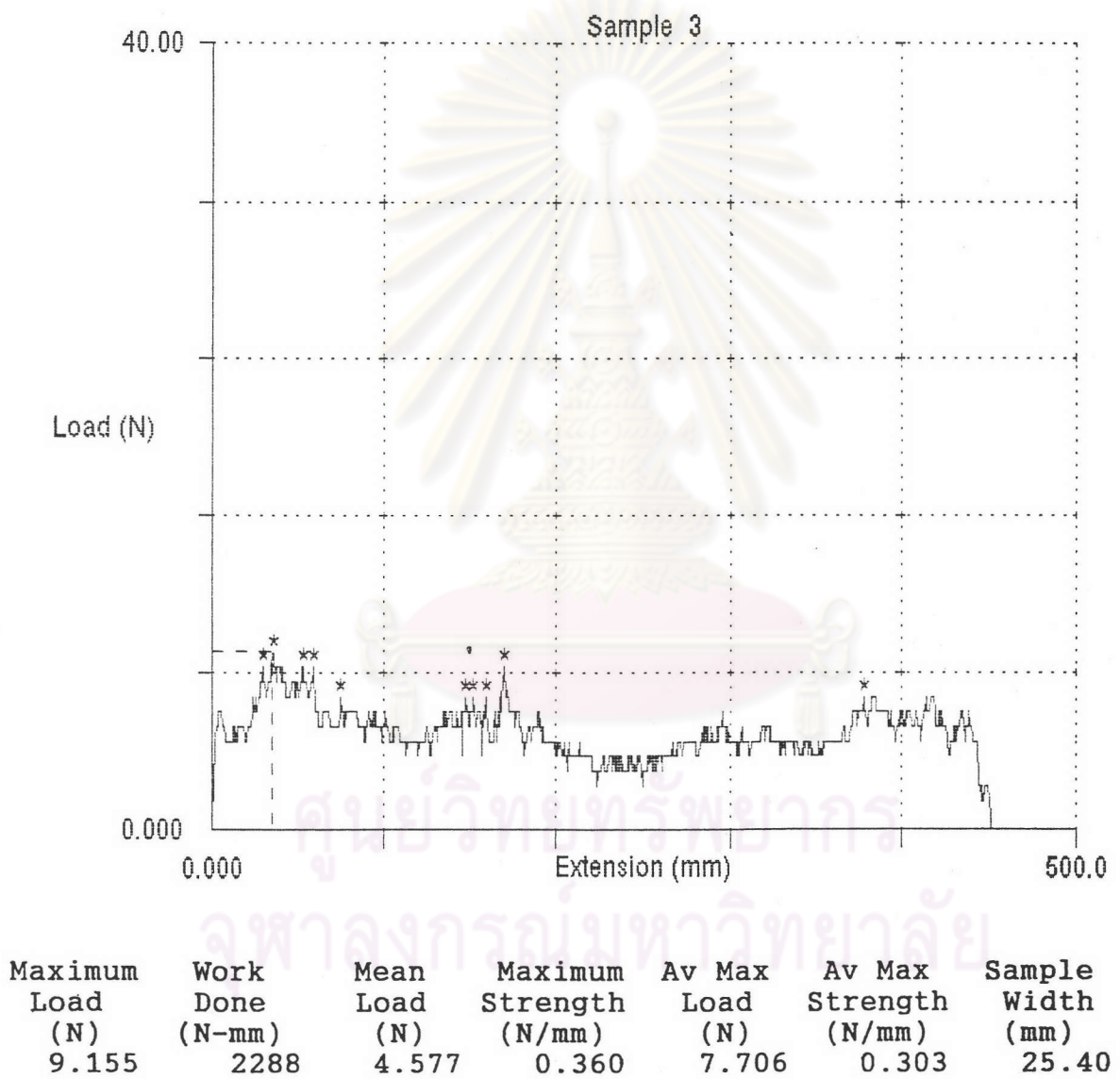
FIGURE 6.3 Peel tension graph of sample 3

Maximum Load (N)	Work Done (N-mm)	Mean Load (N)	Maximum Strength (N/mm)	Av Max Load (N)	Av Max Strength (N/mm)	Sample Width (mm)
11.44	2798	5.596	0.450	9.155	0.360	25.40
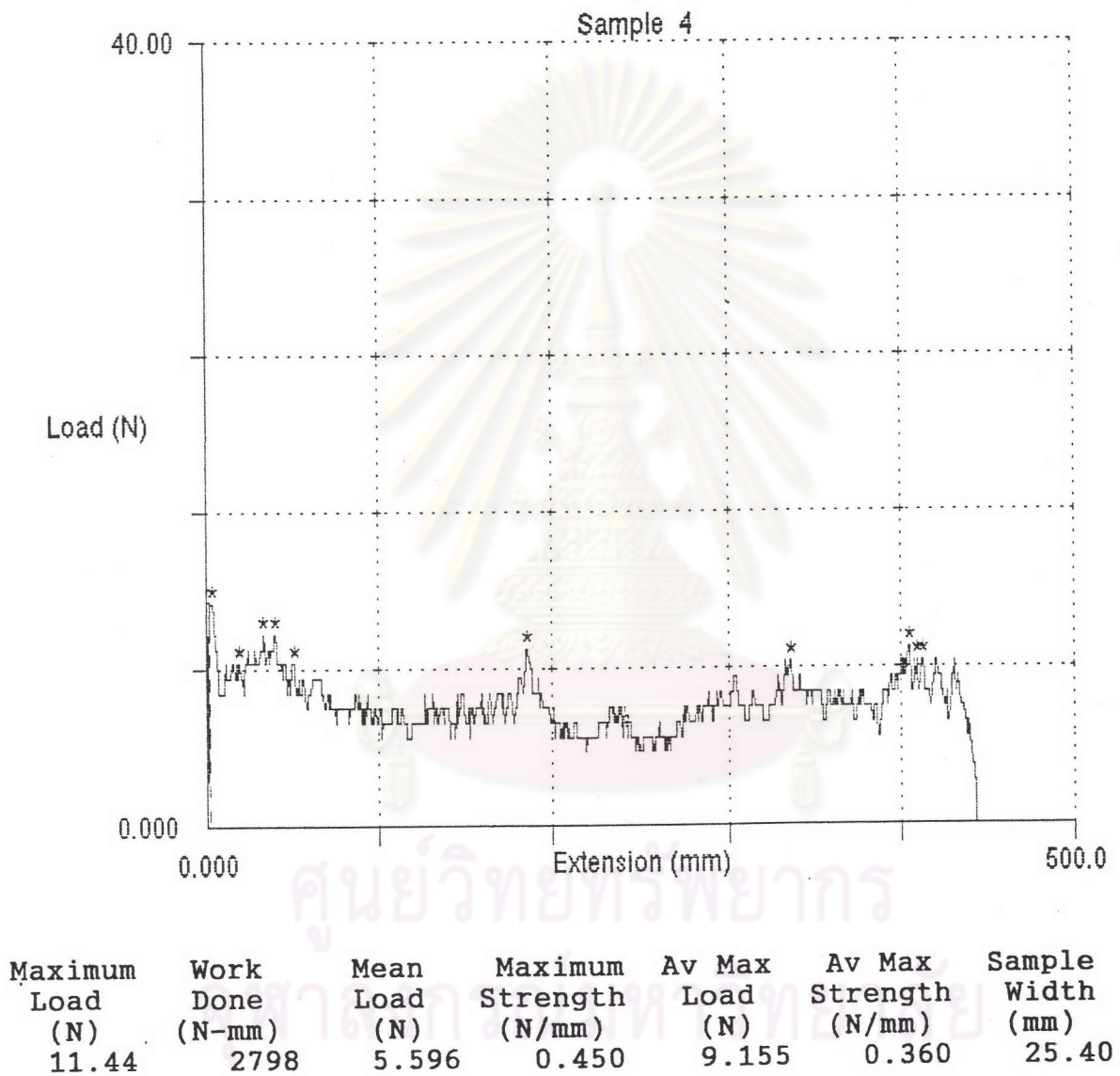
FIGURE 6.4 Peel tension graph of sample 4

Maximum Load (N)	Work Done (N-mm)	Mean Load (N)	Maximum Strength (N/mm)	Av Max Load (N)	Av Max Strength (N/mm)	Sample Width (mm)
10.68	2043	4.086	0.420	7.248	0.285	25.40

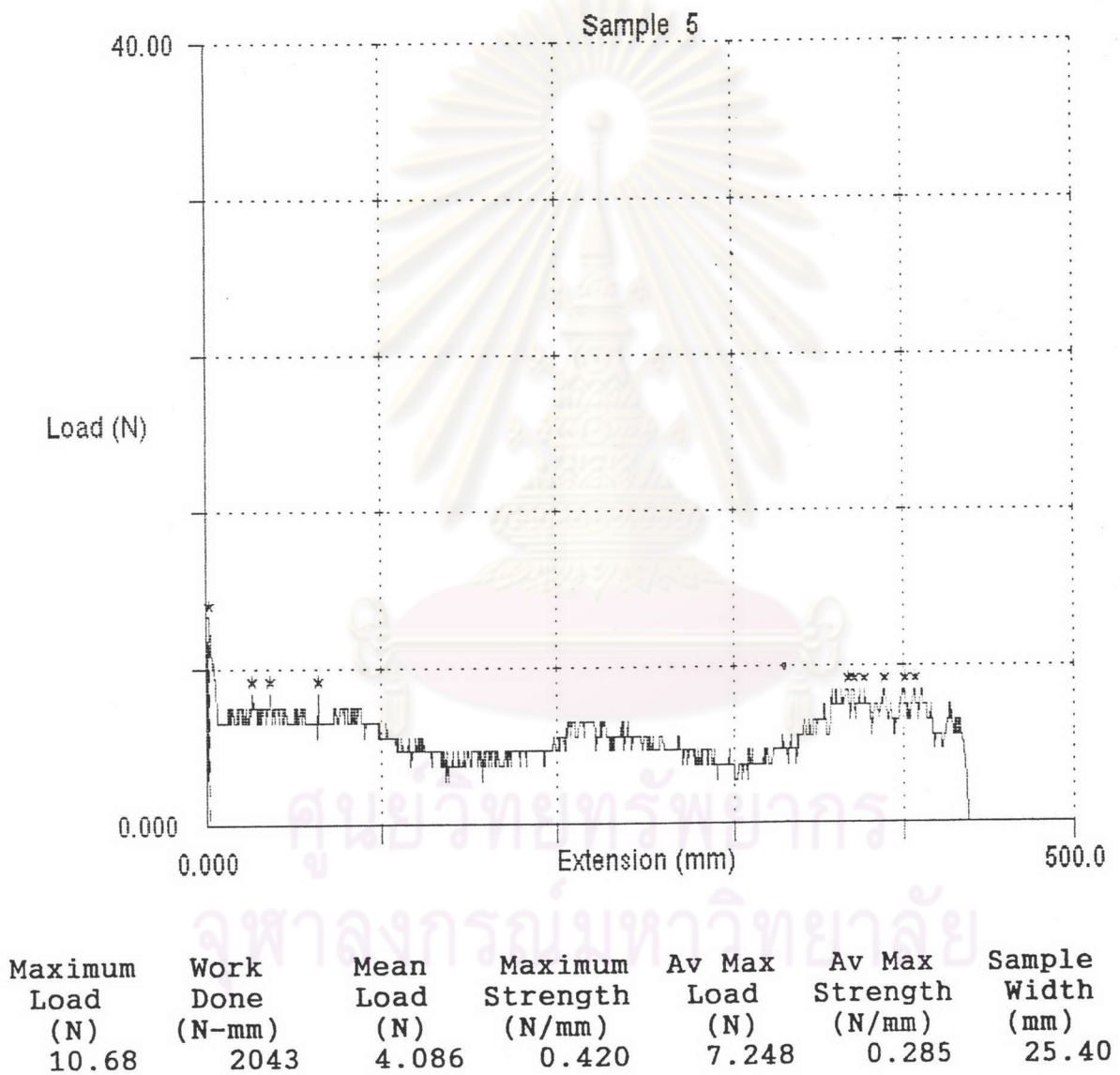FIGURE 6.5 Peel tension graph of sample 5

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Name of person      : wichian
Sample description  : hotmelt
Sample form         : strip
Temperature         :  23 Deg C
Date                : Sat 21 Dec 1996
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sample	Maximum Load (N)	Work Done (N-mm)	Mean Load (N)	Maximum Strength (N/mm)	Av Max Load (N)	Av Max Strength (N/mm)	Sample Width (mm)
1	9.918	3017	6.035	0.390	9.308	0.366	25.40
2	10.68	2696	5.392	0.420	8.926	0.351	25.40
3	9.155	2288	4.577	0.360	7.706	0.303	25.40
4	11.44	2798	5.596	0.450	9.155	0.360	25.40
5	10.68	2043	4.086	0.420	7.248	0.285	25.40
mean	10.38	2569	5.137	0.408	8.469	0.333	25.40
standard deviation	0.87	395.4	0.791	0.034	0.930	0.037	0.00

TABLE 6.2 Data of average mean load of sample 1-5

From table 6.1 the average load of applied method adhere by hotmelt of formula 10 is more than the load from general method that also use the same hotmelt.

6.2 EFFECT OF EACH COMPONENT

To know the effect of each component, two way of comparing data may be done. First compare from load results of low and high of a component variable while fixing other components. If the high give higher load mean that component has positve effect to hotmelt adhesion. And if the low give the higher load, that mean negative effect. Secondary way, also can compare from AVG- with AVG+ or Delta (see table 6.3). As the same, if Delta is higher than zero the component has positive effect. If lower than zero mean negative effect.

However AVG-, AVG+ comparing method is expected for more accurate result because it is average load differential.

6.2.1 Wetting agent

Delta value of wetting agent coloum (see table 6.3) is 40.0. It is higher than zero which mean that wetting agent has positive effect to hotmelt adhesion if quantity is increase from 12.5% (lower limit) to 25% (higher limit). And from experimental design we can forecast that the peel load will increase according to every percentage of wetting agent increase (see table 6.3, 6.4).

Formula	EVA	Wet	Wax	Plac	BHT	Mean Load
1	85.0	12.5	1	1	0.5	5.15
2	83.5	12.5	1	1	2.0	4.86
3	81.0	12.5	1	5	0.5	1.10
4	79.5	12.5	1	5	2.0	0.34
5	81.0	12.5	5	1	0.5	0.70
6	79.5	12.5	5	1	2.0	0.40
7	77.0	12.5	5	5	0.5	0.46
8	75.5	12.5	5	5	2.0	0.48
9	72.5	25.0	1	1	0.5	9.15
10	71.0	25.0	1	1	2.0	9.87
11	68.5	25.0	1	5	0.5	8.46
12	67.0	25.0	1	5	2.0	7.12
13	68.5	25.0	5	1	0.5	3.78
14	67.0	25.0	5	1	2.0	4.64
15	64.5	25.0	5	5	0.5	5.75
16	63.0	25.0	5	5	2.0	4.73
AVG-		13.5	46.05	30.14	34.5	4.19
AVG+		53.5	20.94	28.43	32.4	
Delta		40.0	-25.1	-1.7	-2.1	
Delta/2		20.0	-12.6	-0.9	-1.0	
Amout	85.0	12.5	1	1	0.5	
Calculation	4.2	2.5	-0.1255	-0.0085	0.0	6.6

TABLE 6.3 Experimental calculation 1

Formula	EVA	Wet	Wax	Plac	BHT	Mean Load
1	85.0	12.5	1	1	0.5	5.15
2	83.5	12.5	1	1	2.0	4.86
3	81.0	12.5	1	5	0.5	1.10
4	79.5	12.5	1	5	2.0	0.34
5	81.0	12.5	5	1	0.5	0.70
6	79.5	12.5	5	1	2.0	0.40
7	77.0	12.5	5	5	0.5	0.46
8	75.5	12.5	5	5	2.0	0.48
9	72.5	25.0	1	1	0.5	9.15
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Delta		40.0	-25.1	-1.7	-2.1	
Delta/2		20.0	-12.6	-0.9	-1.0	
Amout	72.5	25.0	1	1	0.5	
Calculation	4.2	5.0	-0.1255	-0.0085	0.0	9.1

TABLE 6.4 Experimental calculation 2

But it I s not mean that formulation of hotmelt adhesive contain wetting agent more than 25% will give only positive effect. From pretest experiment, load of hotmelt adhesive contain 75% wetting agent will lower than 25%. Because wetting agent cannot adhere with material surface itself . It only help EVA polymer side group to close to the film surface . And it is a hard brittle resin that is not tacky itself.

6.2.2 Wax

In wax column , value of delta is -25.1 (see table 6.3), it is lower than zero. It means that wax has negative effect to adhesion of hotmelt formulation. Because Sasol wax is low molecular weight polyolefin , so it has no side group to adhere to material surfaces , it is not like EVA which has acetate side group to bond with material surface. But percentage of wax composition will make percentage of EVA to lower then adhesion is lower too.

The another reason of wax negative effect is its low molecular weight . In coating step , when hotmelt is heated and applied onto material surface , wax may transfer to the adhesive layer surface to block adhesive from PP laminated paper surface . Must be understand that wax is simple additive always use in hotmelt adhesive to reduce viscosity because it is not disadvantage to adhere to ordinary paper or wood with roughness surface by mechanical force . But it is different for smooth PP laminated paper . It has low roughness , and mechanical force is not importance as side group bond.

6.2.3 Plasticizer

Result of plasticizer is same as wax , value of Delta is -1.7 in table 6.3, it is lower than zero. It also has negative effect to hotmelt adhesive formulation . As mentioned before , it is expected that plasticizer will make EVA to softer and adhesive formulation will has higher tacky property . Then adhesion may increase.

Result is negative show that although plasticizer may soften the adhesive but there are some reason to argue the expectation. Refer to pretest , when used high percentage of plasticizer as 50% , plasticizer will diffuse to adhesive layer surface. It can be easy seen that surface is wet with plasticizer liquid. So although low percentage is used , it may cause the same reason (but it cannot be seen that surface is wet) .

6.2.4 Antioxidant

Delta value of antioxidant is -2.1 in table 6.3, it is lower than zero . It also has same negative effect as two additives before. Higher percentage give lower adhesion. Antioxidant is added to prevent hotmelt adhesive to decompose at high temperature , so it is easy to decide to use small amount as 0.5% if it is enough to prevent oxidation in this process.

6.3 EFFECT OF COMBINATION OF INGREDIENT

Delta value that mention above can be use to calculate to forecast strength or load by

$$\overline{Y} = \frac{(AVG) + (\Delta/2)(A) + (\Delta/2)(B) + (\Delta/2)(C) + (\Delta/2)(D)}{100}$$

$\overline{Y}$ = Forecast load

AVG = Average of mean load

Δ = Delta value

A = Amout of wetting agent

B = Amout of wax

C = Amout of plasticizer

D = Amout of antioxidant

6.3.1 Predict of Formula and Strength

From table 6.3 , amout of wetting agent is 12.5, amout of wax is 1, amout of plasticizer is 1 and amout of antioxidant is 0.5. After calculation , forecast mean load is obtain as 6.6 N , compare to real mean load of formula 1 (same amout of additives) is 5.15 N.

From table 6.4 , amout of additives for calculation are same as formula 9. Forecast load is 9.1 and real mean load is 9.15.

It is shown that any amout of additives is chosen to formulate the hotmelt adhesive , and can forecast the load before real test by using data from experimental design. If AVG and delta values of each component are filled to equation of $\overline{Y}$, then equation for forcasting the peel strength is obtained as,

$$\overline{Y} = 4.2 + (20A - 12.6B - 0.9C - D)/100$$

6.3.2 Limit of Prediction

However this method has limit. The first limit is the boudary of amout of additive used for experimental design. It cannot be expected to forecast load of adhesive using wetting agent more than 25% or less than 12.5%, wax more than 5% or less than 1%, plasticizer more than 5% or less than 1%, antioxidant more than 2% or less than 0.5 %.

Second limit if upper boudary of wetting agent is raise to 75% . As mention above too high amout of wetting agent not give better adhesion. While this method will give high load as using high amout of wetting agent.

6.3.3 Price of adhesive

Cost is one important part of product. While forecasting the good hotmelt adhesive formula , it can be forecast its cost that optimum for business or not? First step of cost calculation, raw materials price have to found before.

Price of EVA is 45 bath/kg, wetting agent is 42 bath/kg, wax is 20bath/kg, plasticizer is 40 bath/kg and antioxidant is 120 bath/kg. Price of product is obtained by using

Product price = priceA(A) + priceB(B) + priceC(C) + priceD(D) + priceE(E)

100

As shown in table 6.5 ,adhesive formula 2 has cost of 45.80 bath/kg. And table 6.6 , adhesive formula 10 has cost of 45.50 bath/kg.

6.4 APPLICATION INVOLVE

This experiment is base on paper packaging industry , so method of experiment , material, and testing is optimum for this work. However hotmelt adhesive is convenient to many other industry.

Toy is one industry that consume large amout of hotmelt adhesive especially by glue gun. It can be imagined that if the worker want to stick an accessory bow onto doll blouse . If he use latex to adhere , how long he will wait until it dry and fix on. And how many doll will stop in this process. But for hotmelt adhesive after few second of adhering , it can be sent to next process.

Shoe industry is also use hotmelt adhesive to adhere accessory and any parts. Wood furniture industry can use hotmelt adhesive too especially new type hotmelt that can be crosslink cure to give more durable.

Formula	EVA	Wet	Wax	Plac	BHT	Mean Load
1	85.0	12.5	1	1	0.5	5.15
2	83.5	12.5	1	1	2.0	4.86
3	81.0	12.5	1	5	0.5	1.10
4	79.5	12.5	1	5	2.0	0.34
5	81.0	12.5	5	1	0.5	0.70
6	79.5	12.5	5	1	2.0	0.40
7	77.0	12.5	5	5	0.5	0.46
8	75.5	12.5	5	5	2.0	0.48
9	72.5	25.0	1	1	0.5	9.15
10	71.0	25.0	1	1	2.0	9.87
11	68.5	25.0	1	5	0.5	8.46
12	67.0	25.0	1	5	2.0	7.12
13	68.5	25.0	5	1	0.5	3.78
14	67.0	25.0	5	1	2.0	4.64
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16	63.0	25.0	5	5	2.0	4.73
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AVG+		53.5	20.94	28.43	32.4	
Delta		40.0	-25.1	-1.7	-2.1	
Delta/2		20.0	-12.6	-0.9	-1.0	
Amout	83.5	12.5	1	1	2.0	
Calculation	4.2	2.5	-0.1255	-0.0085	0.0	6.5
Price	45.0	42.0	20	40	120.0	
45.8	37.6	5.3	0.2	0.4	2.4	

TABLE 6.5 Price calculation 1

Formula	EVA	Wet	Wax	Plac	BHT	Mean Load
1	85.0	12.5	1	1	0.5	5.15
2	83.5	12.5	1	1	2.0	4.86
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6	79.5	12.5	5	1	2.0	0.40
7	77.0	12.5	5	5	0.5	0.46
8	75.5	12.5	5	5	2.0	0.48
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10	71.0	25.0	1	1	2.0	9.87
11	68.5	25.0	1	5	0.5	8.46
12	67.0	25.0	1	5	2.0	7.12
13	68.5	25.0	5	1	0.5	3.78
14	67.0	25.0	5	1	2.0	4.64
15	64.5	25.0	5	5	0.5	5.75
16	63.0	25.0	5	5	2.0	4.73
AVG-		13.5	46.05	30.14	34.5	4.19
AVG+		53.5	20.94	28.43	32.4	
Delta		40.0	-25.1	-1.7	-2.1	
Delta/2		20.0	-12.6	-0.9	-1.0	
Amout	71.0	25.0	1	1	2.0	
Calculation	4.2	5.0	-0.1255	-0.0085	0.0	9.0
Price	45.0	42.0	20	40	120.0	
45.5	32.0	10.5	0.2	0.4	2.4	

TABLE 6.6 Price calculation 2