

CHAPTER IV

RESULTS AND DISCUSSIONS

4.1 Solid Content of Non-Dehydrated Adhesive

Table 4.1 Solid content (%) of resol adhesive from CNSL

Refluxing Time Formalin	Solid Content (%)			
	10 min	20 min	30 min	40 min
20%	61.42	61.86	62.15	63.19
25%	58.91	59.61	60.91	62.57
30%	59.71	59.56	59.06	60.68
35%	54.62	56.57	56.90	57.56

From Table 4.1 and Figure 4.1, the solid content decreased with increasing of the mole ratio of formaldehyde and anacardic acid eventhough the concentration of formaldehyde was raised. In addition, when refluxing time was raised, the solid content did not changed significantly.

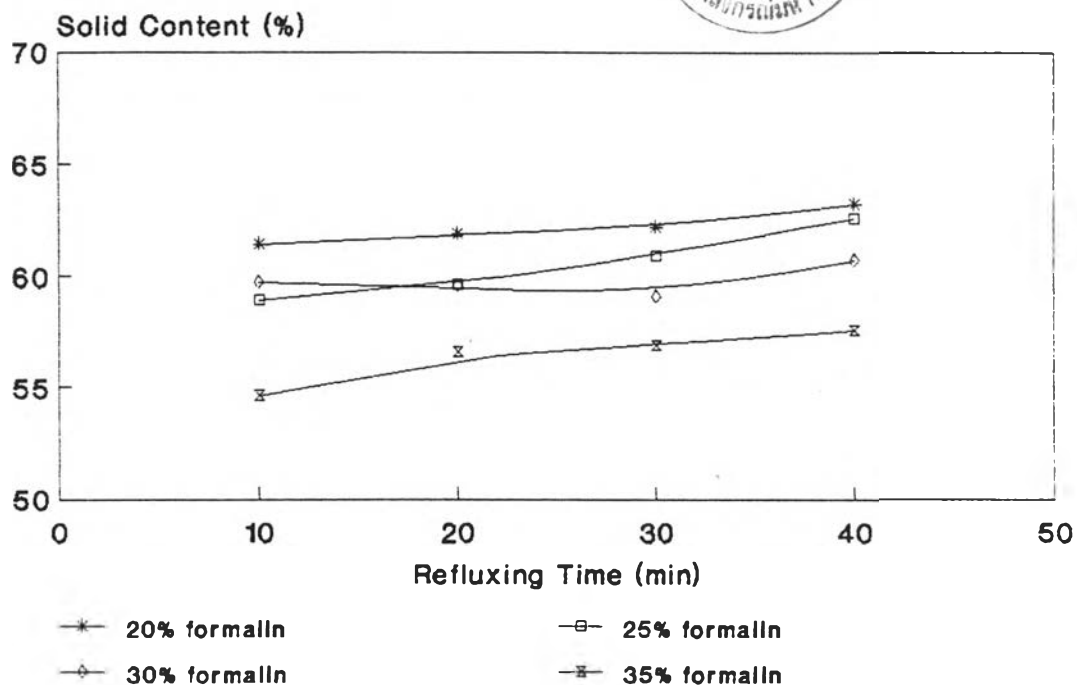


Figure 4.1 Solid content of resol adhesive from CNSL.

4.2 Viscosity of Non-Dehydrated Adhesive

Table 4.2 Viscosity (poise) of resol adhesive from CNSL

Refluxing Time Formalin	Viscosity (poise)			
	10 min	20 min	30 min	40 min
20%	19.20	60.24	288.80	799.20
25%	15.51	105.80	88.88	924.25
30%	12.79	54.51	38.56	544.80
35%	3.21	5.07	26.12	96.88

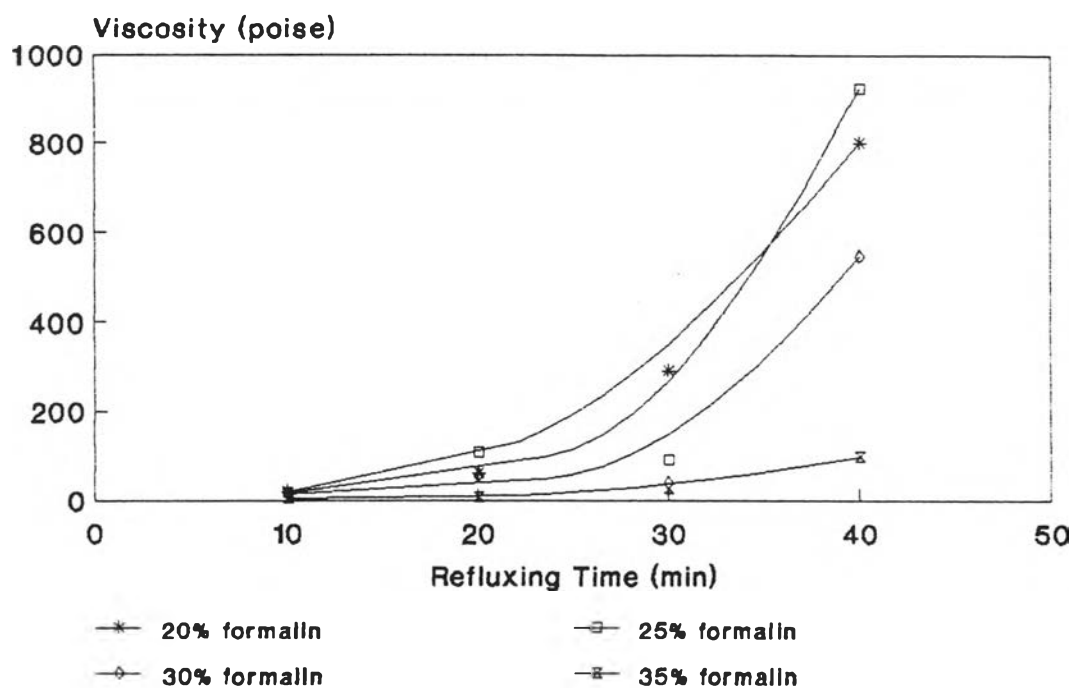


Figure 4.2 Viscosity of resol adhesive from CNSL.

Figure 4.2 showed the viscosity of a non-dehydrated adhesive from CNSL. In the early stage at 10-20 minutes refluxing the viscosity increased a little bit but when refluxing time was raised, the viscosity increased sharply. This could be explained that the reaction between anacardic acid and others compositions of CNSL and formaldehyde was condensation or step polymerization. The size of the polymer molecules increased at a relatively slow rate. One proceeded slowly from monomer to dimer, trimer, tetramer, pentamer, and so on, until eventually large polymer molecules had been formed. Any two molecular species could react with each other throughout the course of the polymerization [34]. In addition, the intrinsic viscosity $[\eta]$, could be related to the molecular weight, M , as shown below [35]:

$$[\eta] = K'M^a \quad (4.1)$$

K' and a - constant

It was obviously seen that at 35% formalin the viscosity was the lowest. For the same refluxing time, the highest viscosity was obtained at 25% formalin. These results could be explained from the effect of increasing water quantity associated with increasing of the formalin concentration caused the rate of polymerization to occur slower. The highest viscosity, 924.25 poise, was attained when the quantities of formalin was 25 per cent and refluxing time was 40 minutes.

4.3 Relation between Viscosity and Dry-to-Touch Time of Resol Adhesive from CNSL (Non-Dehydrating)

Table 4.3 Dry-to-touch time (min) of resol adhesive from CNSL

Refluxing Time Formalin	Dry-To-Touch Time (min)			
	10 min	20 min	30 min	40 min
20%	60.00	20.00	2.00	1.50
25%	62.00	3.00	3.50	1.50
30%	62.50	28.00	12.50	1.50
35%	106.00	100.00	17.00	3.00

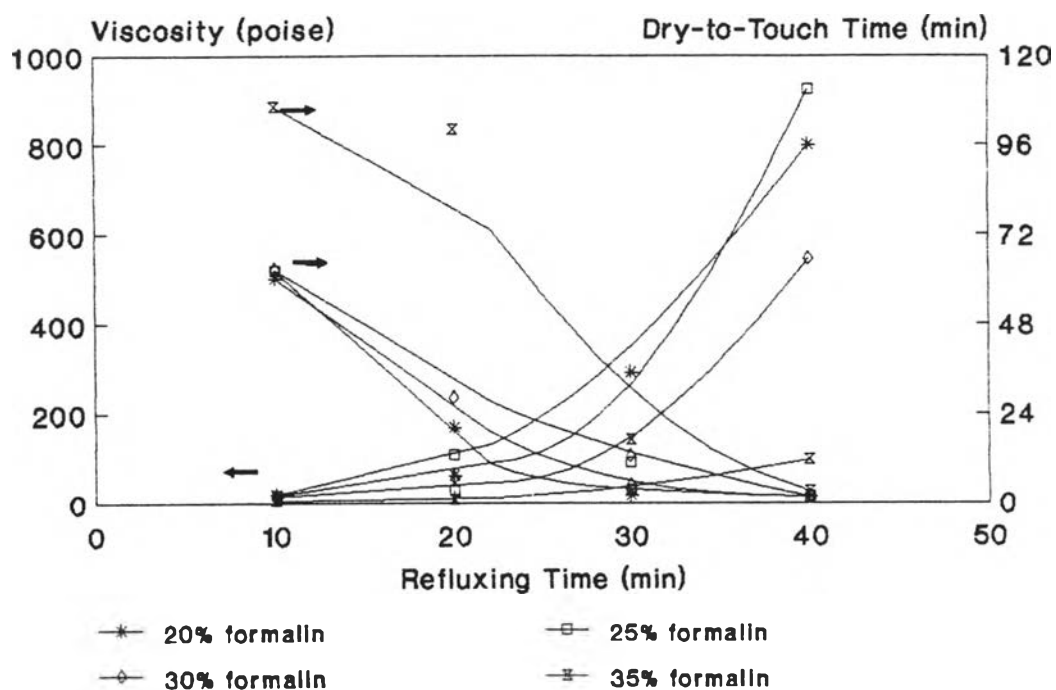


Figure 4.3 Viscosity and dry-to-touch time of resol adhesive from CNSL (non-dehydrating).

From Table 4.3, the dry-to-touch was faster with increasing of the refluxing time.

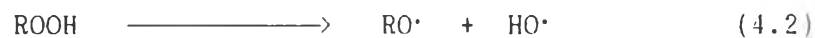
The relation between viscosity and dry-to-touch time were shown in Figure 4.3. The dry-to-touch time was faster when the polymer molecules were bigger (high viscosity) because of the formation of an oxidative crosslinked matrix after air exposure of an adhesive film. The crosslinked matrix of the high molecular weight or long molecules occurred more rapidly than the short one. The reaction between unsaturated long chain hydrocarbon of anacardic acid and other compositions of CNSL and oxygen, was initiated by light and hydroperoxides as illustrated in (4.1):



Decomposition of hydroperoxides yielded two free radicals which propagated the chain reaction of autooxidation.

From a kinetic standpoint, there were three stages in autooxidation:

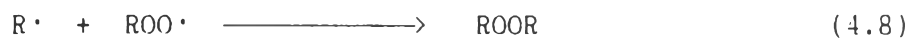
Initiation production of R^\cdot and ROO^\cdot



Propagation



Termination



The termination step was primarily importance in the film forming process (dry-to-touch) [14, 22, 36].

4.4 Shear Strength of Resol Adhesive from CNSL (Non-Dehydrating)

Table 4.4 Shear strength of wet-laminating and cold pressing of resol adhesive from CNSL (T = Pressing Time)

Batch No. \ T	Shear strength (kg/cm ²)			
	0 min	10 min	20 min	30 min
20/10	3.2	6.4	7.8	5.0
20/20	4.7	7.6	9.6	5.2
20/30	12.7	14.4	15.8	8.7
20/40	14.0	18.0	15.2	16.2
25/10	3.3	5.7	5.9	6.7
25/20	11.2	11.4	4.4	4.6
25/30	7.2	3.7	1.4	1.6
25/40	13.9	8.0	7.9	8.0
30/10	1.4	2.3	2.0	1.8
30/20	6.2	1.7	1.1	1.8
30/30	4.6	1.5	2.7	1.4
30/40	10.6	4.3	6.1	3.3
35/10	0.1	0.6	0.3	0.4
35/20	1.3	1.2	0.8	0.9
35/30	4.0	1.7	2.5	1.6
35/40	6.3	3.2	2.2	1.9

Table 4.5 Shear strength of dry-laminating and cold pressing
of resol adhesive from CNSL (T = Pressing Time)

T Batch No.	Shear strength (kg/cm ²)			
	0 min	10 min	20 min	30 min
20/10	2.9	7.7	6.7	8.4
20/20	6.5	8.8	8.0	7.8
20/30	12.6	14.0	18.0	13.4
20/40	10.4	18.6	18.4	18.0
25/10	3.2	1.2	3.9	9.3
25/20	10.5	17.1	8.5	5.4
25/30	7.3	3.4	1.8	5.2
25/40	14.2	10.8	6.5	4.8
30/10	1.5	2.6	2.2	2.7
30/20	6.0	0.9	0.8	3.0
30/30	4.8	11.3	1.0	1.0
30/40	10.8	9.1	5.4	7.3
35/10	0.3	0.8	0.7	0.6
35/20	2.2	1.1	1.2	1.1
35/30	4.1	2.0	1.9	1.7
35/40	8.7	2.4	2.8	2.4

Table 4.6 Shear strength of dry-laminating and hot pressing of
resol adhesive from CNSL (T = Pressing Time)

T Batch No.	Shear Strength (kg/cm ²)		
	10 min	20 min	30 min
20/10	1.0	2.0	6.9
20/20	1.2	2.5	8.4
20/30	1.2	3.5	10.9
20/40	2.4	6.8	7.3
25/10	4.2	7.8	12.9
25/20	1.9	7.8	9.5
25/30	0.8	3.7	6.7
25/40	0.8	1.4	8.0
30/10	2.6	13.4	13.9
30/20	2.9	11.7	13.3
30/30	4.0	6.8	11.2
30/40	5.2	10.6	14.4
35/10	6.9	15.0	18.0
35/20	7.0	12.9	15.1
35/30	10.5	12.9	14.4
35/40	9.6	12.6	14.1

Shear strength of wet-laminating and dry-laminating and cold pressing assembly of resol adhesive from CNSL (non-dehydrating) were shown in Table 4.4 and 4.5, respectively. It was obviously seen that when the per cent of formalin was 20% (mole ratio of formaldehyde/anacardic acid : 1.04), the obtained shear strength was higher than other concentrations. This result was also observed in dry-laminating and cold pressing assembly. There were some reasons to support these results. First, the molecular weight of resol resin at 25, 30 and 35% formalin were less than at 20% formalin. Although the viscosity of 25% formalin and 40 minutes refluxing was the highest (924.25 poise), it was more difficult to wet the plywood surface than resol resin from 20% formalin at the same refluxing time (799.20 poise). Finally, the higher concentration of formalin provided higher concentration of water which in turn affected the adhesion between adhesive and plywoods surface. The strength of the adhesive was reduced because it was plasticized by water.

From Table 4.6, higher concentration of formalin provided the higher shear strength. This could be explained that on heating, when the quantity of the reactant was raised the degree of polymerization increased, resulted in high degree of crosslinking. The optimum condition of wet-laminating and cold pressing and dry-laminating and cold pressing assembly were attained at 20% formalin, 40 minutes and 10 minutes press at 18.0 and 18.6 kg/cm², respectively.

4.4.1 Shear Strength of 20 % Formalin Concentration of The Resol Adhesive from CNSL

Shear strength of three different methods, wet-laminating and cold pressing, dry-laminating and cold pressing and dry-laminating and hot pressing were shown in Figure 4.4-4.6.

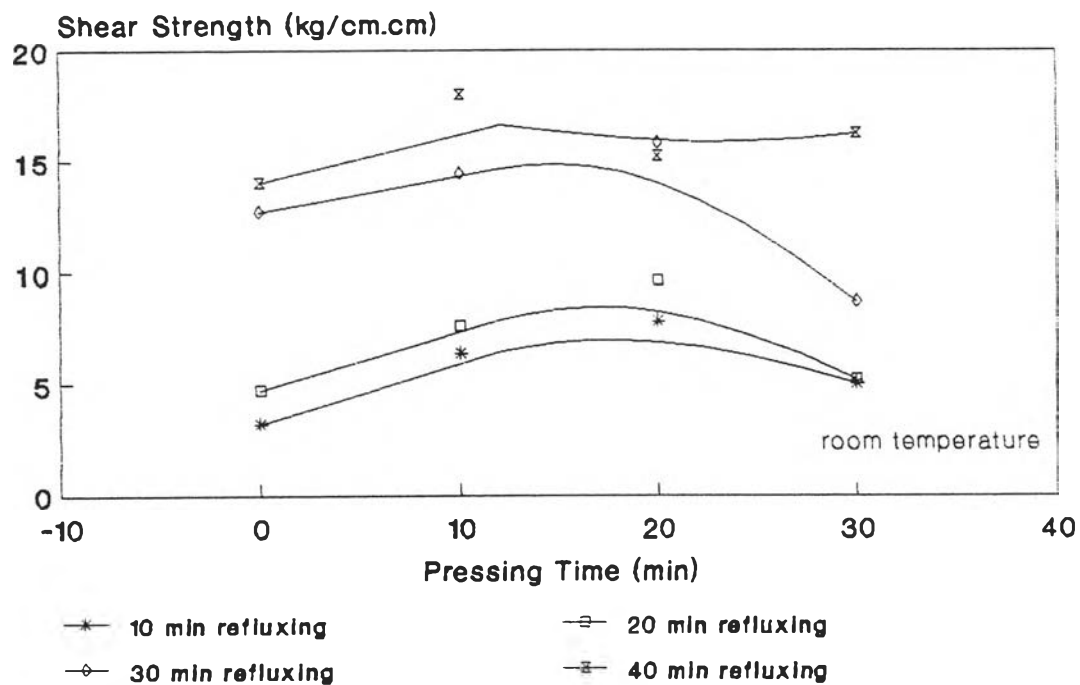


Figure 4.4 Shear strength of wet-laminating and 0-30 minutes cold pressing of 20% formalin of the adhesive from CNSL.

From Figure 4.4, the shear strength increased with increasing of pressing time and it dropped when the pressing time was about 30 minutes. The optimum condition of 10, 20 and 30 minutes refluxing adhesive was attained at 20 minutes pressing time. Whereas at 40 minutes refluxing adhesive and 10 minutes pressing time gave the highest shear strength (18.0 kg/cm^2). The shear strength of 40 minutes refluxing adhesive was the highest.

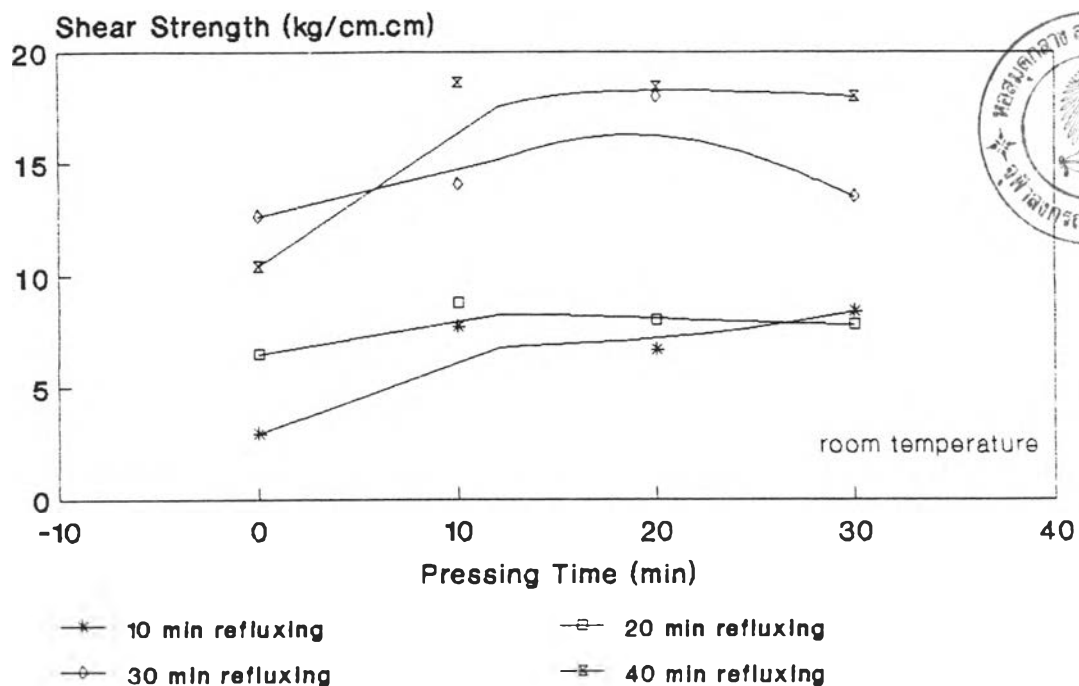


Figure 4.5 Shear strength of dry-laminating and 0-30 minutes cold pressing of 20% formalin of the adhesive from CNSL.

The shear strength of dry-laminating and cold pressing was shown in Figure 4.5. It increased with increasing of the refluxing time. When the pressure was not applied the shear strength of 40 minutes refluxing was lower than that of 30 minutes refluxing, although the viscosity of its resol resin was higher. This was not observed in wet-laminating and cold pressing. It was speculated that the adhesive of 40 minutes refluxing gels rapidly when it was exposed to the air. The fusion of the two adhesive films was less completed and the air was entrapped into the adhesive layer [16,37]. At 30 minutes pressing, the shear strength of 10 minutes refluxing was closed to 20 minutes refluxing. The highest shear strength was 18.6 kg/cm^2 . The optimum condition was as same as the wet-laminating and cold pressing.

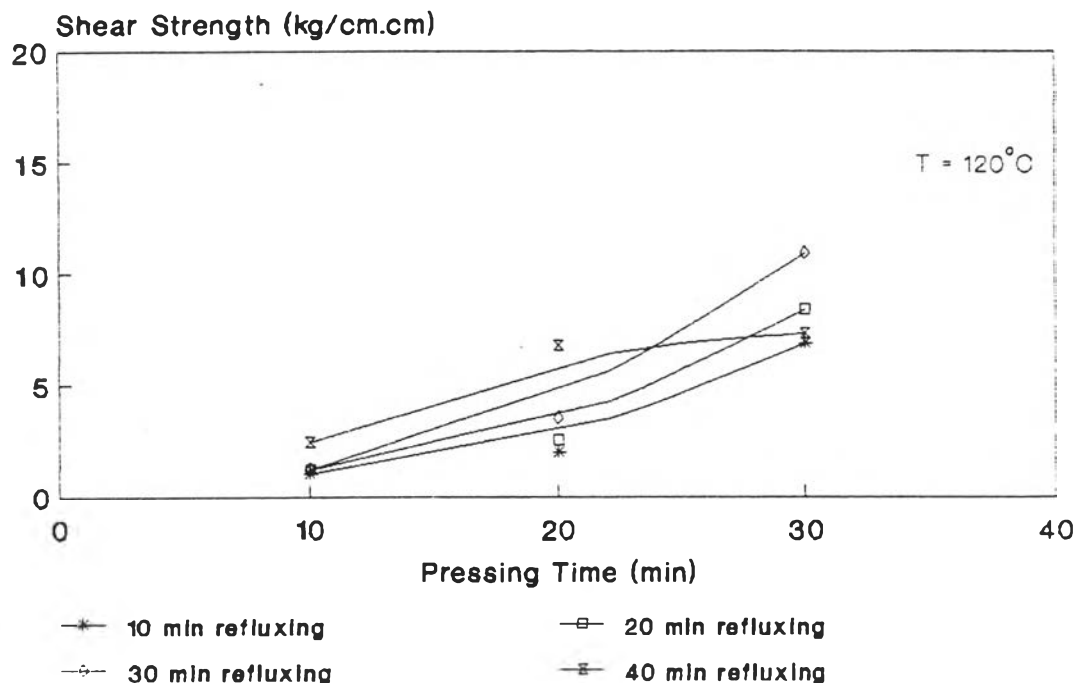


Figure 4.6 Shear strength of the resol adhesive from CNSL of 20% formalin concentration and dry-laminating and hot pressing assembly.

Figure 4.6 showed the shear strength of dry-laminating and hot pressing. It increased with increasing of refluxing time and pressing time except when the pressing time was 30 minutes, the shear strength dropped to 7.3 kg/cm² when the refluxing time was 40 minutes. It closed to the shear strength of 20 minutes refluxing (6.9 kg/cm²).

Shear strength of 3 different methods to cure the resol adhesive from CNSL at 20% formalin and 40 minutes refluxing were shown in Figure 4.7. For no press assembly, the wet-laminating was indeed better. This was explained by the ability of the polymer molecules to diffuse across the adhesive interface of wet-laminating was better than the dry-laminating. Therefore

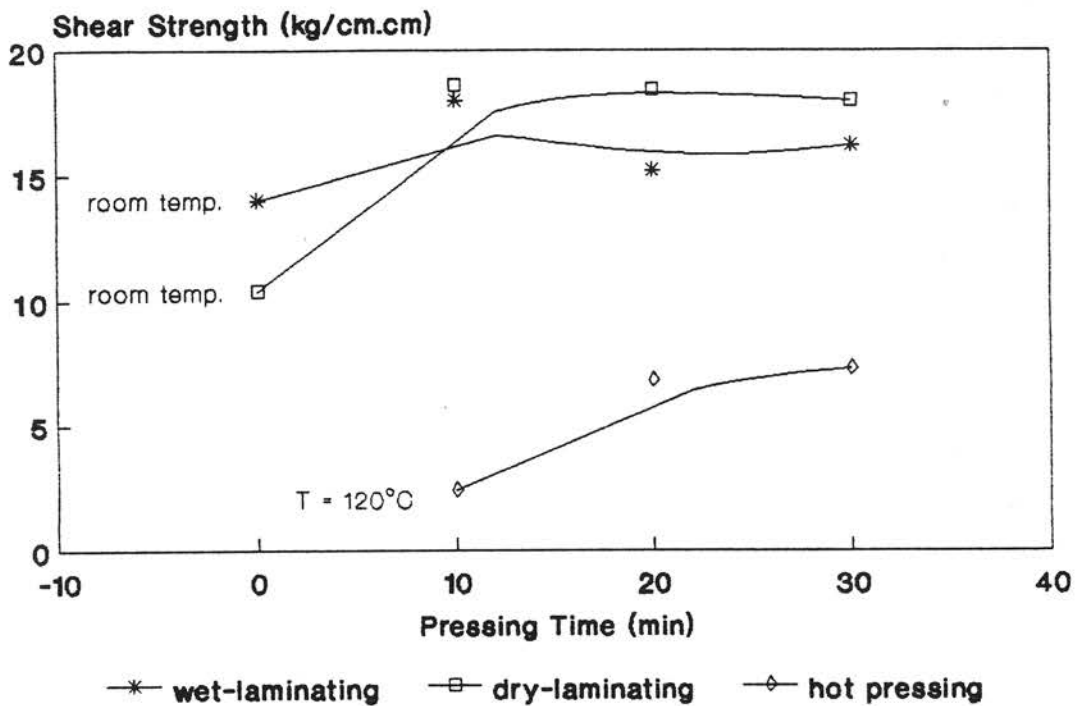


Figure 4.7 Comparing shear strength between wet-laminating and cold pressing, dry-laminating and cold pressing, and dry-laminating and hot pressing of 20% formalin concentration and 40 minutes refluxing.

the fusion of the two adhesive films on each adherend of dry-laminating was less completed [16, 37]. When the pressure was applied reversal occurred and the dry-laminating had some advantages. This could be explained that the adhesives containing water or solvent were often improved in strength if it was allowed to dry partially [38]. The shear strength of no pressing assembly was lower than that of the pressing one because the air was trapped between the interface causing the reduction of the adhesion. Moreover, by pressing the adhesive diffused into the pores of the wood which improved the mechanical interlocking and preserved good adhesion [16]. It was noticed that the strengths

at 120°C pressing were lower than cold pressing because on heating the gels produced rapidly and water was trapped in the adhesive bulk resulted in the porous adhesive film. The highest shear strength of 18.6 kg/cm² was obtained from dry-laminating at 10 minutes cold pressing which was not significant difference from the wet-laminating at the same condition (18.0 kg/cm²).

4.4.2 Shear Strength of Dry-Laminating and Cold Pressing of 20-35% Formalin and 40 Minutes Refluxing Time

Figure 4.8, The shear strengths obtained from 20-35% formalin were compared. It was found that, when the pressure was employed the quantity of formalin was raised while the shear strength decreased. This could be caused by the water content that remained within the adhesive matrix. When the

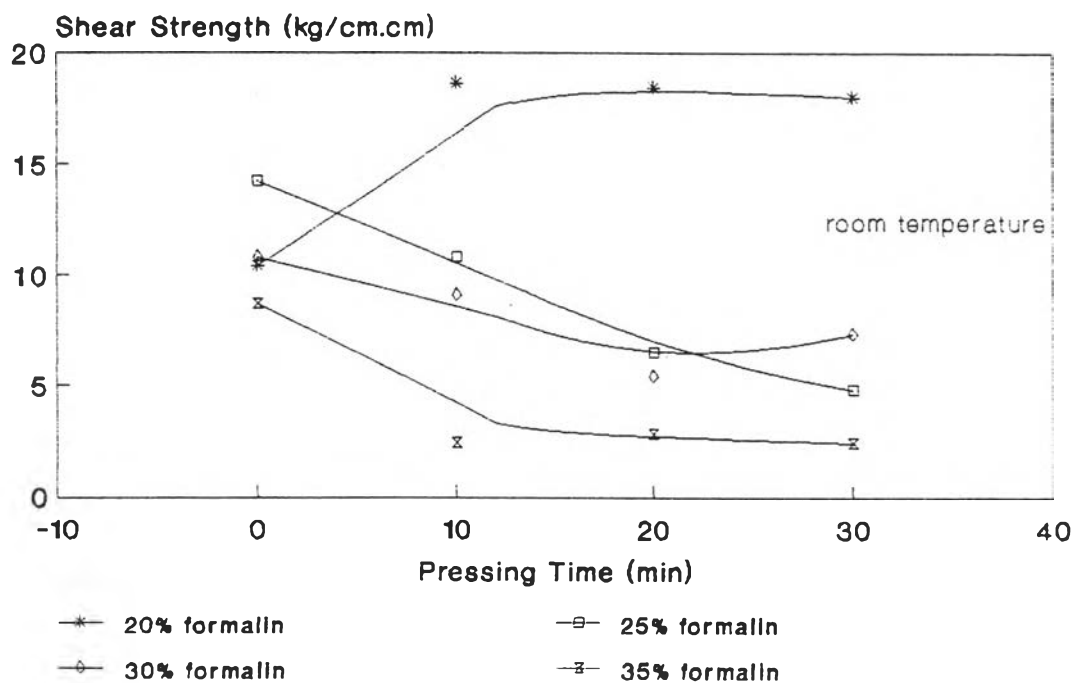


Figure 4.8 Shear strength of dry-laminating and cold pressing of 20-35% formalin of 40 minutes refluxing.

concentration of formalin was increased the quantity of water was also increased, resulted in decreasing of adhesion between the wood surface and the adhesive. In case of non-pressing, the shear strength depended on the viscosity of resol adhesive. When the pressure was applied the shear strength of 20% formalin adhesive was the highest.

4.5 Properties of Dry-Laminating and Cold Pressing of The Adhesive Batch No.20/40 and D20/40

Table 4.7 Properties of dry-laminating and cold pressing of the adhesive batch no.20/40 and D20/40

Properties	Non-Dehydrating	Dehydrating
Shear strength (kg/cm ²)		
0 min pressing	10.4	12.2
10 min pressing	18.6	18.0
20 min pressing	18.4	18.7
30 min pressing	18.0	16.2
*Lost shear strength (%)		
0 min pressing	17.3	37.7
10 min pressing	16.1	44.4
20 min pressing	29.9	26.7
30 min pressing	30.6	24.1

Table 4.7 (Continued)

Properties	Non-Dehydrating	Dehydrating
Solid content (%)	63.19	51.60
Viscosity (poise)	799.20	94.85
Dry-to-touch time (min)	1.50	1.50

* After 3 days submerged in water

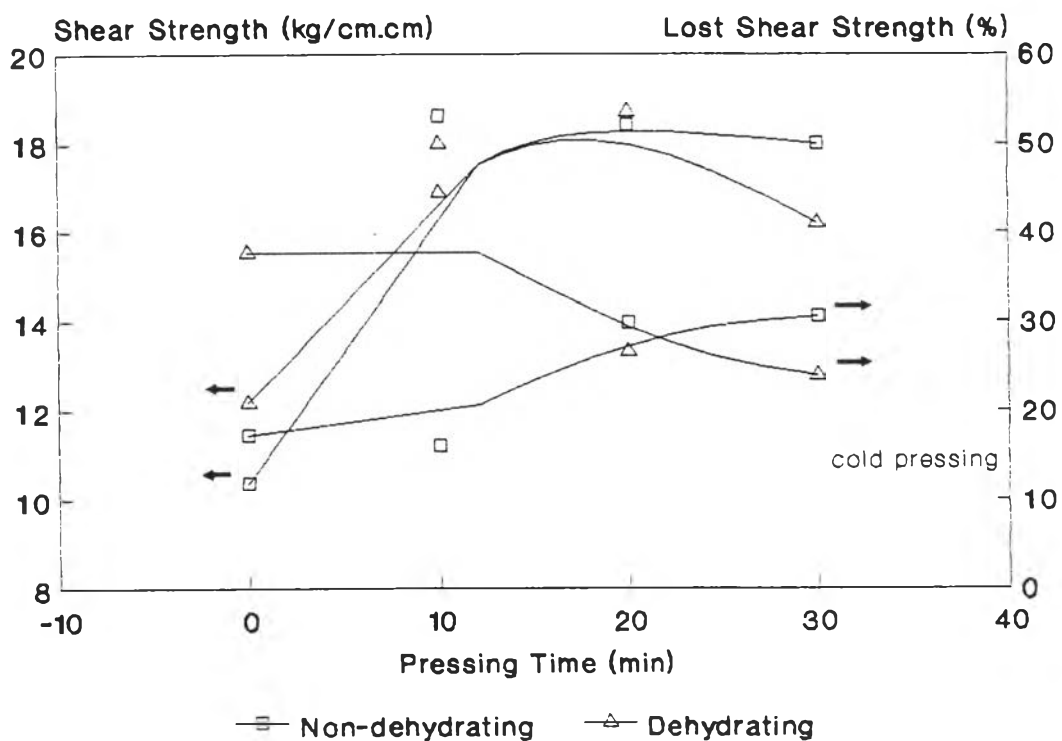


Figure 4.9 Shear strength and lost shear strength after 3 days submerged in water of dry-laminating and cold pressing of the adhesive batch no.20/40 and D20/40.

From Table 4.7, the dry-to-touch time of non-dehydrated and dehydrated adhesive were equal.

Shear strength of 20% formalin and 40 minutes refluxing of non-dehydrated and dehydrated adhesive were compared in Figure 4.9. Optimum condition of non-dehydrated adhesive was attained when pressing time was 10 minutes (18.6 kg/cm^2), while the dehydrated adhesive at 20 minutes gave 18.7 kg/cm^2 . For considering lost shear strength after 3 days submerged in water, the optimum condition of non-dehydrated adhesive had % lost lower than that of dehydrated adhesive. Therefore, the non-dehydrated adhesive were more practical than the dehydrated one.

4.6 Effect of Linseed Oil on Properties of The Adhesive Batch No.20/40

Table 4.8 Properties of dry-laminating and 10 minutes cold pressing of the adhesive batch no.20/40 after adding linseed oil

Properties	Linseed Oil (%)			
	0	5	10	15
Shear strength (kg/cm^2)	18.6	17.2	16.6	14.2
Shear strength (kg/cm^2) after 3 days in water	15.6	15.8	12.3	13.2
lost shear strength (%)	16.1	8.1	25.9	7.0
Solid content (%)	63.19	64.98	66.87	69.92
Viscosity (poise)	799.20	511.56	307.10	203.68
Dry-to-touch (min)	1.50	3.80	8.00	16.30

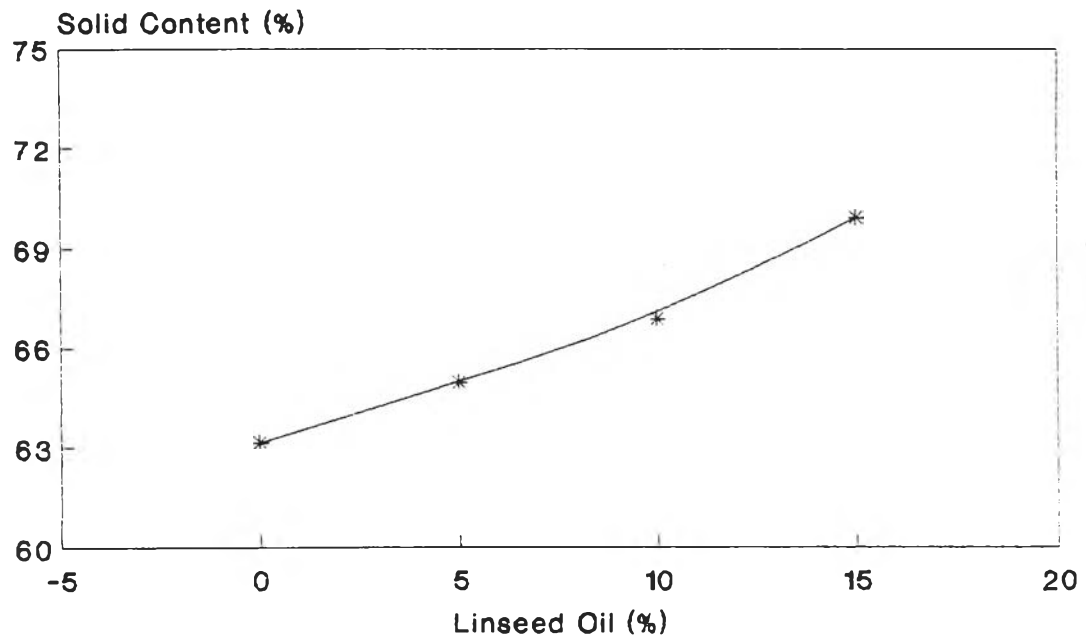


Figure 4.10 Effect of linseed oil on solid content of the adhesive batch no.20/40.

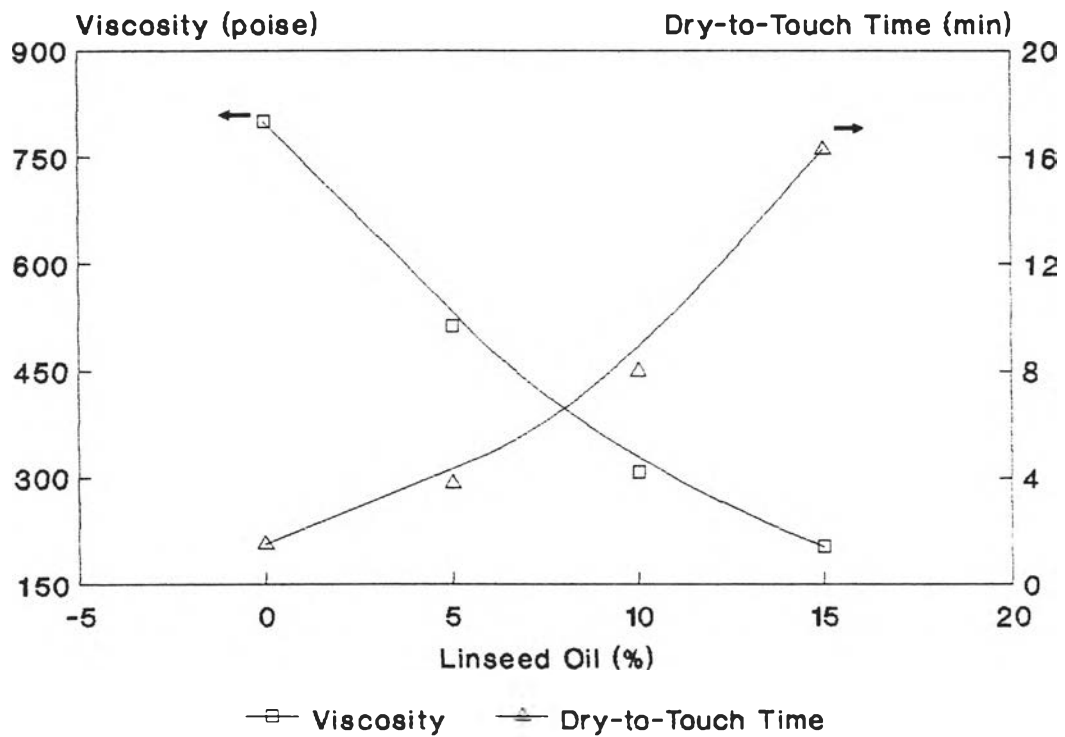


Figure 4.11 Effect of linseed oil on viscosity and dry-to-touch time of the adhesive batch no.20/40.

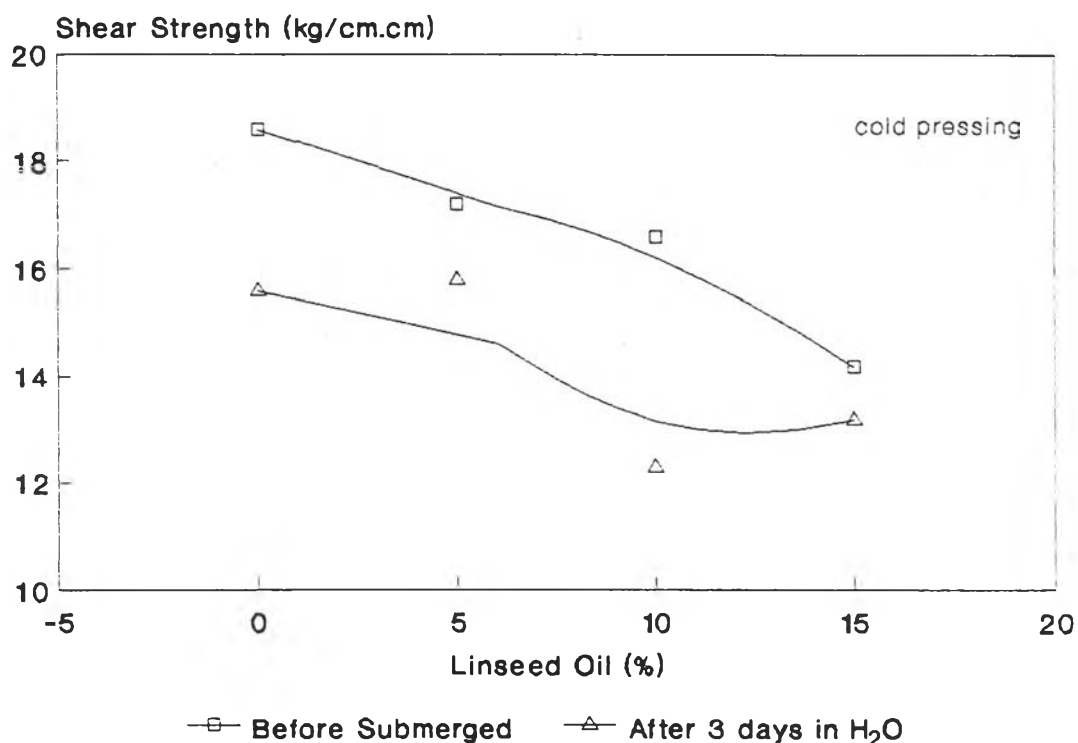


Figure 4.12 Effect of linseed oil on shear strength of dry-laminating and 10 minutes cold pressing of the adhesive batch no.20/40.

The effect of linseed oil on solid content and viscosity and dry-to-touch time of the adhesive bath no.20/40 were shown in Figure 4.10 and 4.11, respectively.

When the linseed oil was employed the solid content increased but the viscosity decreased resulted in increasing of the dry-to-touch time. There were some reasons to support these behavior. First, the constitutions of linseed oil is non-volatile matter. Secondly, It acted as a diluent. Finally, the main compositions (more than 80%) was unsaturated long chain fatty acid could be oxidized and converted into the saturation state [22].

The shear strength and lost shear strength of the adhesive batch no.20/40 after adding linseed oil was illustrated in Figure 4.12. The shear strength decreased with increasing amount of linseed oil. Because the oil had unsaturated long chain fatty acid moiety, therefore it could be oxidized and converted into an elastic solid which caused the adhesive to be soften.

4.7 Effects of Stannous Octoate on Properties of The Adhesive Batch No.20/40

Table 4.9 Properties of dry-laminating and 10 minutes cold pressing of the adhesive batch no.20/40 after adding stannous octoate

Properties	Stannous octoate (%)					
	0.0	0.1	0.2	0.3	0.4	0.5
Shear strength (kg/cm ²)	18.6	22.0	25.9	18.0	13.0	8.4
Shear strength (kg/cm ²) after 3 days in water	15.6	18.1	21.8	14.9	11.9	4.0
lost shear strength (%)	16.1	17.7	15.8	17.2	8.5	52.4
Solid content (%)	63.19	62.72	63.09	63.08	63.24	63.04
Viscosity (poise)	799.20	-	-	-	-	-
Dry-to-touch (min)	1.50	1.00	0.58	0.67	0.67	0.75

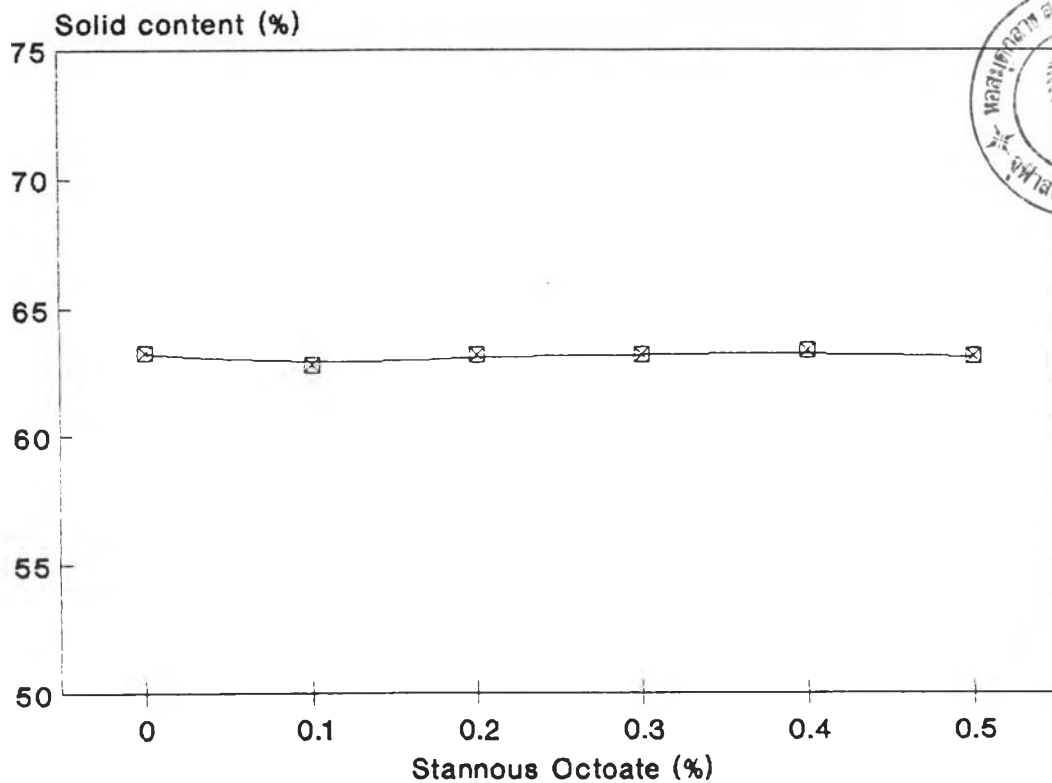


Figure 4.13 Solid content of the adhesive batch no.20/40 at various stannous octoate concentration.

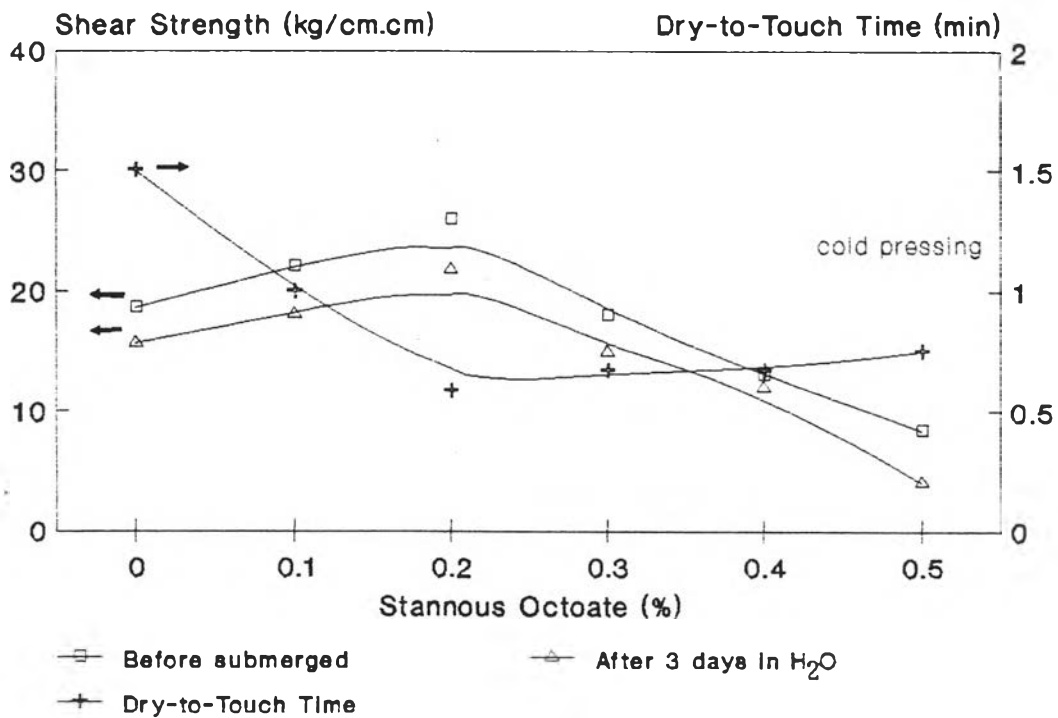
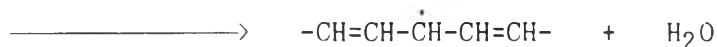
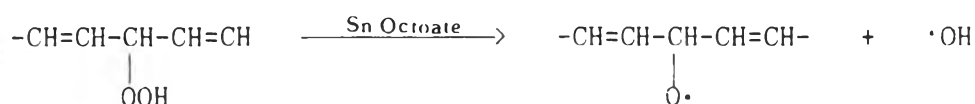


Figure 4.14 Dry-to-touch time and shear strength of dry-laminating and 10 minutes cold pressing of the adhesive batch no.20/40 at various stannous octoate.

The effect of stannous octoate on solid content, dry-to-touch time and shear strength of the adhesive batch no.20/40 were shown in Table 4.9 and Figure 4.13 and 4.14.

The increasing amount of stannous octoate (0-0.5% of adhesive, g/g) was not affected the solid content whereas it reduced the dry-to-touch time. The optimum concentration was at 0.2% by weight to weight of an adhesive, resulted in the maximum shear strength of 25.9 kg/cm², but the dry-to-touch time was reduced to be 0.58 minutes. After 3 days submerged in water the shear strengths was 21.8 kg/cm² (15.8% lost).

Stannous octoate catalyzed oxidative reaction when the adhesive film was exposed to the air as illustrated below (scheme 4.1) [14]. This speeded up dry-to-touch time.



Scheme 4.1 Catalyzed oxidative reaction by stannous octoate.

From Table 4.10, the shear strength of the adhesive batch no.20/40 without stannous octoate was in the range of the shear strength of the adhesive from Wanapan Th Thailand Co.,Ltd.,

Table 4.10 Shear strength and storage/pot life of resol adhesive
from CNSL and others

Adhesive	Shear Strength (kg/cm ²)		Storage/Pot Life (month)
	before [#]	after ^{##}	
20/40	18.6	15.6	1.5 (storage)
20/40 (0.2% Sn octoate)	25.9	21.8	1/4 (pot)
*DYNO	8.2-20.4	-	3.0 (storage)
**UDC 668.395: 678.632.652	-	17.0 [@]	-

* Wanapan Th Thailand Co.,Ltd.

** Thai Industrial Standards Institute, Ministry of Industry

Before submerge in water

After 3 days submerged in water (room temperature)

@ After 1 day submerged in water (27±2°C)

DYNO. Whereas the one with the stannous octoate gave the shear strength higher than that of DYNO. The resistance of the adhesive without stannous octoate was lower than that of the UDC standard but the one with the stannous octoate was higher. For the fact that, the number of days in water of the adhesive from CNSI was longer than the standard of Thai Industrial Standards Institute. The storage life was shorter than the DYNO.

4.8 Resol Adhesive from CNSL as The Hot-Setting Adhesive

From Figure 4.6, the maximum shear strength of dry-laminating and hot pressing, 10.9 kg/cm^2 was attained at 30 minutes refluxing and 30 minutes pressing, and the temperature was 120°C .

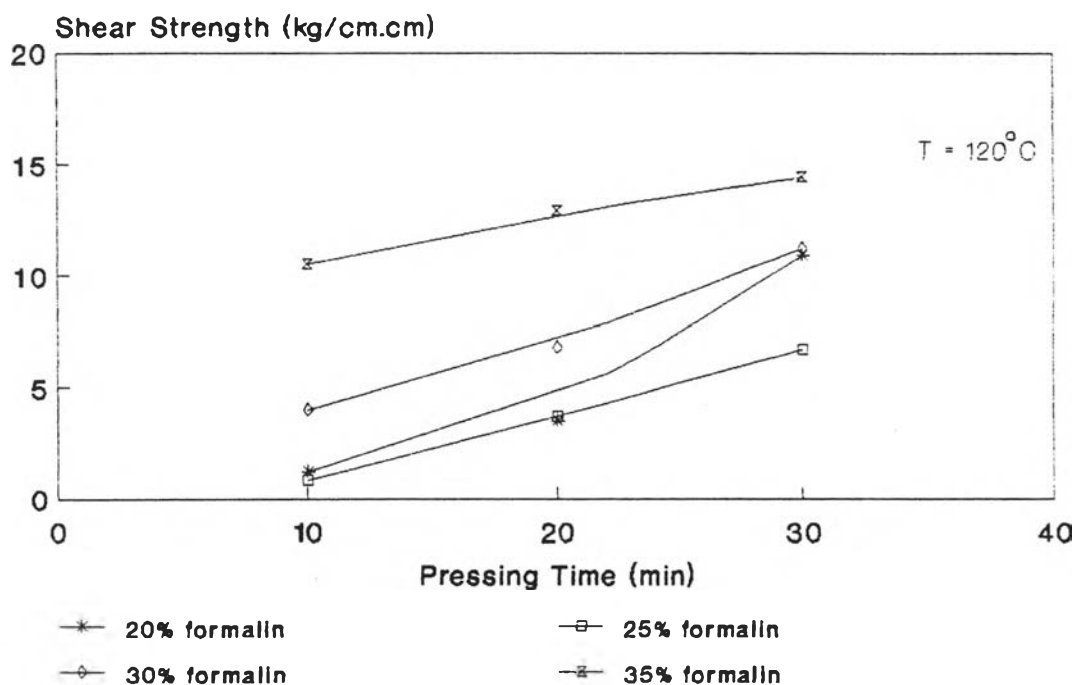


Figure 4.15 Shear strength of dry-laminating and hot pressing of 20 - 35% formalin, 30 minutes refluxing and non-dehydrating.

Shear strength at 20-35% formalin and 30 minutes refluxing after pressing at 120°C was shown in Figure 4.15. The strength was directly proportional to pressing time and formalin concentration. This indicated that more pressing time and formalin induced more curing reaction. The shear strength of 25% formalin was lower than that of 20% formalin. The maximum shear

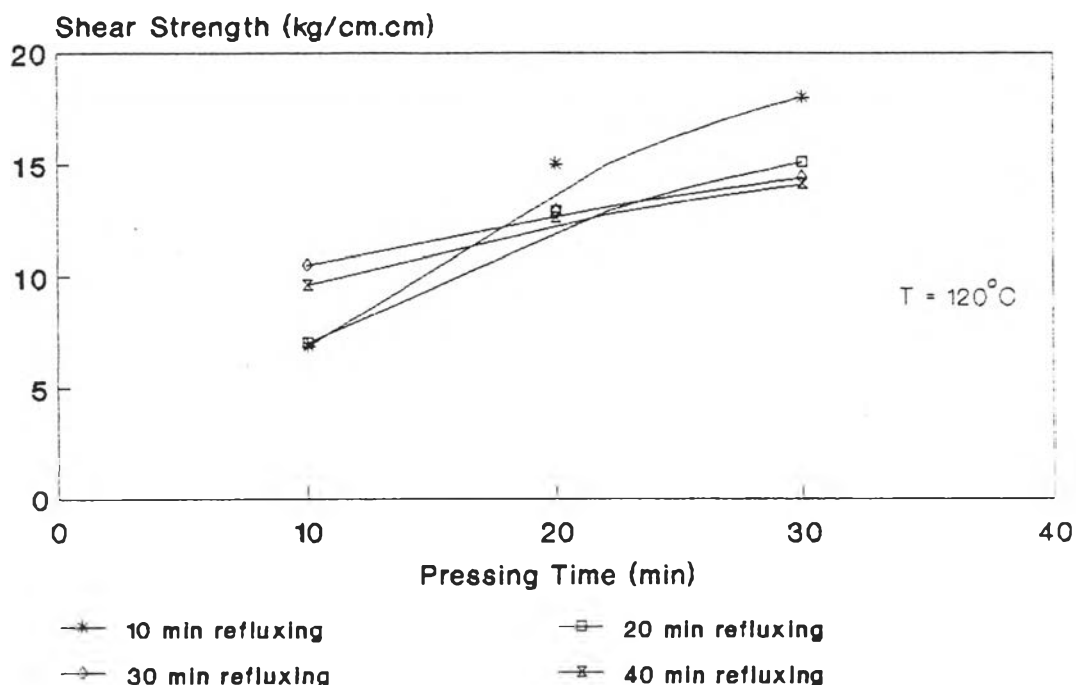


Figure 4.16 Shear strength of dry-laminating and hot pressing of 35% formalin and 10-40 minutes refluxing and non-dehydrating.

strength of 14.4 kg/cm^2 was obtained when the concentration of formalin was 35% with 30 minutes pressing time and 30 minutes refluxing.

The shear strengths of 35% formalin at several refluxing and pressing time were illustrated in Figure 4.16. The shear strength increased with pressing time. When the pressing time was 10 minutes, the adhesive with 30 minutes refluxing gave the best shear strength. The highest shear strength, 18.0 kg/cm^2 , was obtained when the refluxing time was 10 minutes with 30 minutes pressing time and 35% formalin concentration.

4.9 Properties of Dry-Laminating and 30 Minutes Hot Pressing of
The Adhesive Batch No.35/10 and D35/10

Table 4.11 Properties of dry-laminating and 30 minutes hot pressing of the adhesive batch no.35/10 and D35/10

Properties	Non-dehydrating	Dehydrating
Shear strength (kg/cm ²)		
10 min pressing	6.9	9.3
20 min pressing	15.0	13.5
30 min pressing	18.0	14.8
*Lost shear strength (%)		
10 min pressing	81.2	92.5
20 min pressing	46.7	83.0
30 min pressing	38.9	77.0
Solid content (%)	54.62	49.50
Viscosity (poise)	3.21	54.32
Dry-to-touch time (min)	106.00	1.50

* After 3 days submerged in water.

From Table 4.11, The dry-to-touch time of dehydrating adhesive was faster than non-dehydrating since in the dehydration step, anacardic remained active to undergo polymerization with formaldehyde and produced the larger molecules.

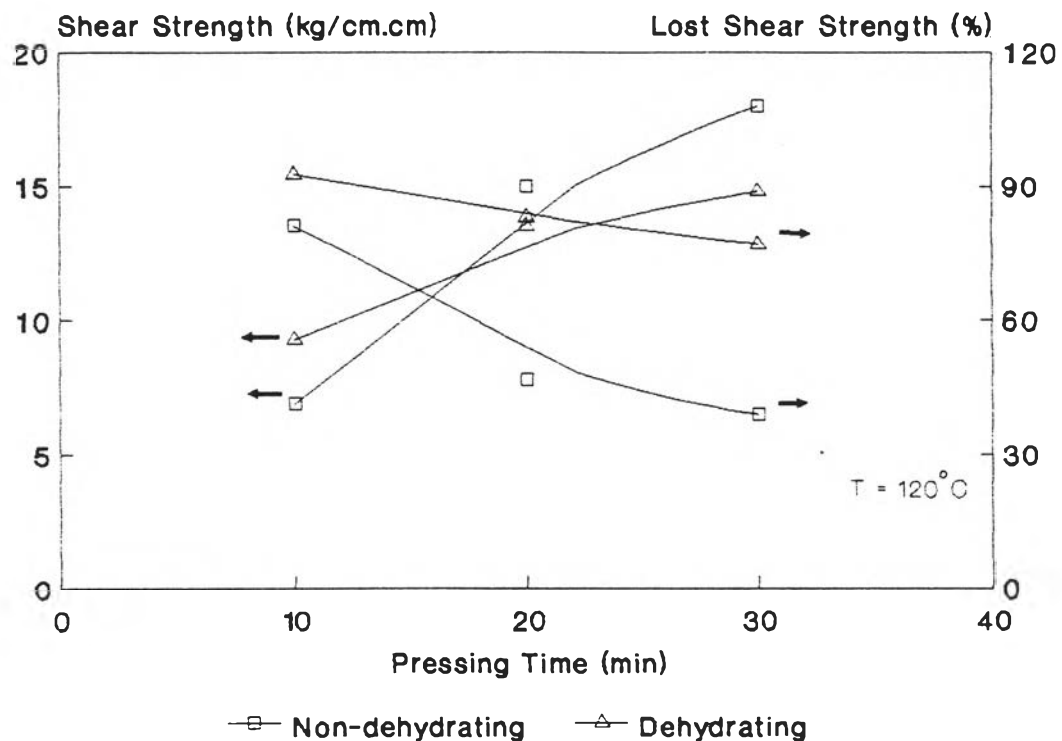


Figure 4.17 Shear strength and lost shear strength of dry-laminating and hot pressing of the adhesive batch no. 35/10 and D35/10.

In Figure 4.17, it was found that at 10 minutes pressing, non-dehydrating adhesive was preferable. However, when the time was increased to be 20 and 30 minutes, it was found that a reversal occurred and the non-dehydrating had an advantage. It was speculated that at 10 minutes pressing time the dehydrating adhesive cured faster because it contained less water. When the time increased it cured slower since the concentration of formaldehyde was lower. The dehydrating adhesive lost some formaldehyde during dehydration step. It was seen that non-dehydrating adhesive had better water resistance than dehydrating one.

4.10 Application of The Adhesive Batch No.35/10 and Resorcinol-Formaldehyde Adhesive in Bonding Nylon-6 Fabric and Compounded Natural Rubber

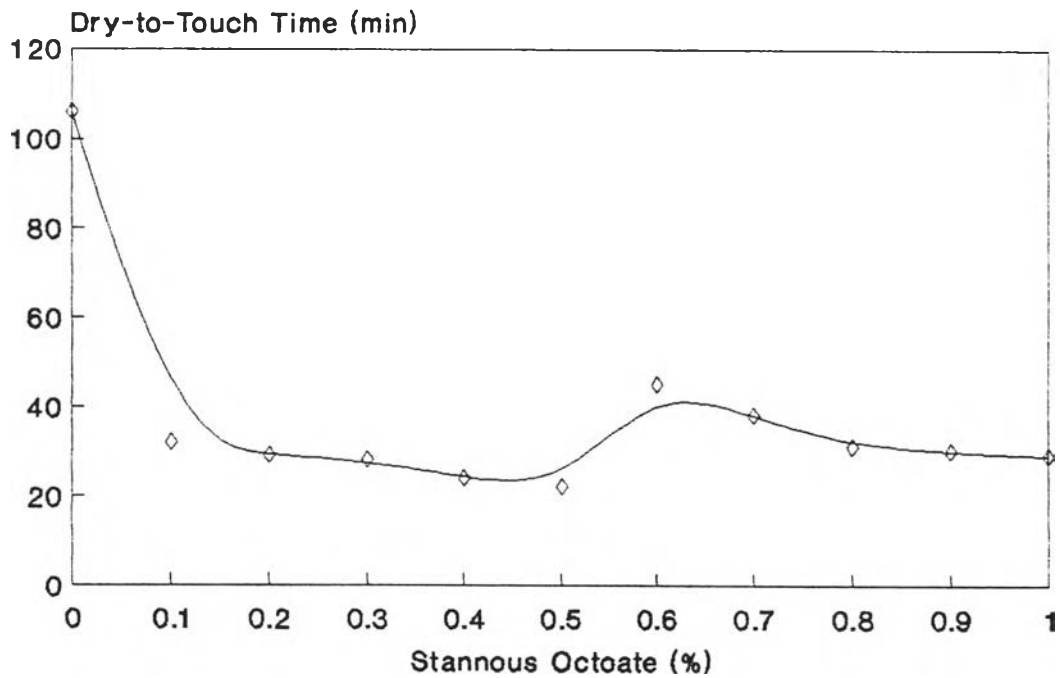


Figure 4.18 Effect of stannous octoate on dry-to-touch time of the adhesive batch no.35/10.

The effect of stannous octoate on dry-to-touch time of 35% formalin and 10 minutes refluxing adhesive was shown in Figure 4.18. It showed that 0.5% stannous octoate was the optimum concentration. The dry-to-touch time was improved to be 22 minutes instead of 106 minutes.

Table 4.12 Peel strength of the adhesive batch no.35/10 in bonding nylon-6 fabric to compounded natural rubber

Adhesive	Sn octoate (%)	Temp. (°C)	Peel Strength (kg/cm)			
			Pressing Time (min)			
			30	40	50	60
-	-	150	7.9	6.4	3.0	7.0
35/10	-	150	0.5	0.6	1.0	0.6
35/10	0.5	150	1.0	0.8	0.6	1.2

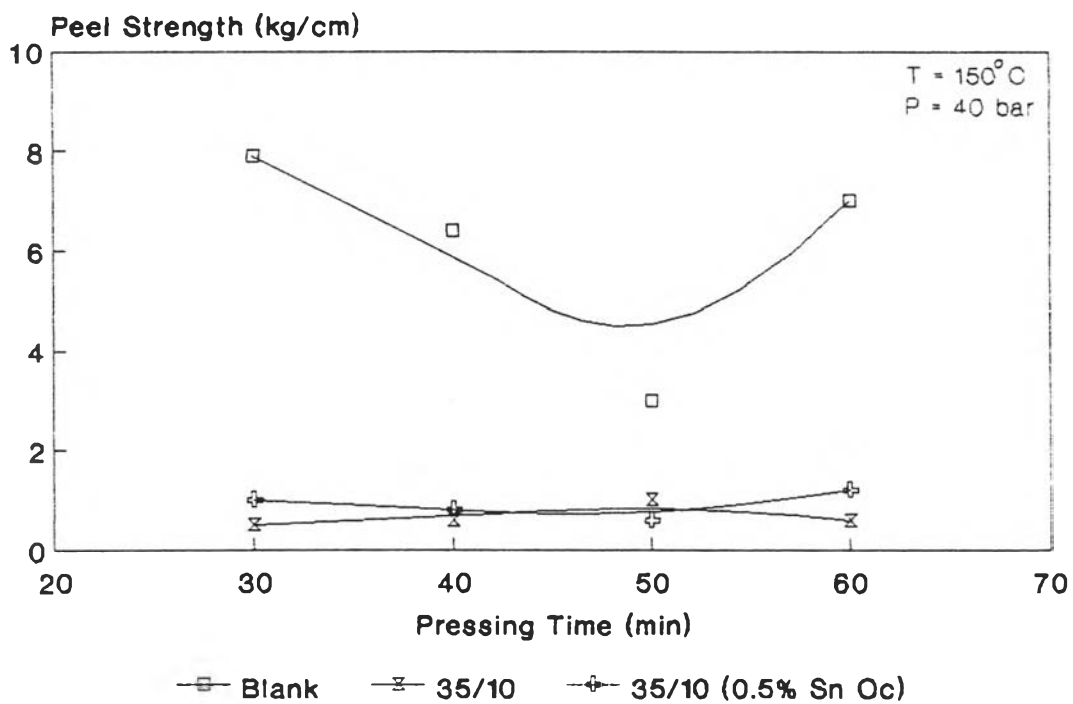


Figure 4.19 Peel strength between nylon-6 fabric and compounded natural rubber (Sn Oc = Stannous Octoate).

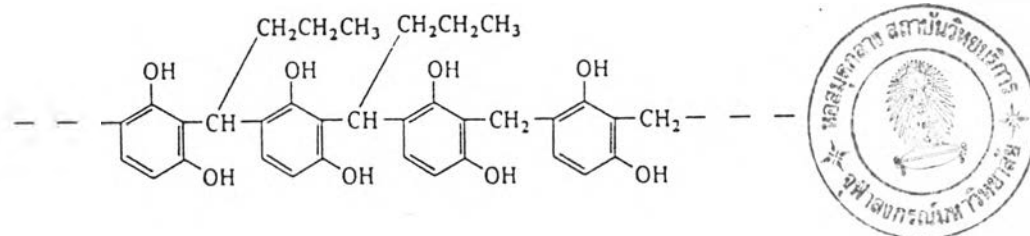
Peel strength of adhesive bonded and non adhesive bonded nylon-6 fabric to natural rubber compound were shown in Figure

4.19. It was obviously seen that, the adhesive from CNSL did not improve the adhesion between nylon-6 fabric and compounded natural rubber. By the way, although 0.5% stannous octoate made the dry-to-touch time faster, the shear strength improved very little. This could be explained by considering solubility parameter (Table 2.1). The solubility parameter of phenolic resin and nylons were very closed, but of phenolic and natural rubber were different, 11.5 and 7.9-8.3, respectively. Therefore, the adhesive from CNSL, a phenolic type, was not compatible to compounded natural rubber. In the case that the adhesive was employed the peel strength was lower than that of the one without adhesive since the rubber matrix penetrated the interstices of nylon-6 fabric to give a greater strength [39].

Table 4.13 Properties of the resorcinol-formaldehyde adhesive

Properties	Values
Solid content (%)	87.5
Viscosity (poise)	57.37
Dry-to-touch time (day)	>1

Table 4.13 showed the properties of resulting resorcinol-formaldehyde adhesive. Its speculated structure was shown in scheme 4.2. The resin would have improved solubility in hydrocarbon mixtures such as rubber and were less polar by $-\text{CH}_2\text{CH}_2\text{CH}_3$



Scheme 4.2 Chemical structure of resorcinol-formaldehyde resin with butyraldehyde in a first stage and completed with formaldehyde.

Table 4.14 Peel strength of the adhesive batch no.35/10 and resorcinol-formaldehyd adhesive

Adhesive	Hexamine (%)	Peel strength (kg/cm)
-	-	7.9
35/10 (0.5% Sn octoate)	-	1.2
RF	0	1.4
RF	5	1.7
RF	10	1.1
RF	15	1.2

RF = Resorcinol-Formaldehyde Adhesive from section 3.4.2

branch chain. Thus its surface tension would be lower, made the resin more soluble in rubbers [39].

From Table 4.14, the optimum concentration of hexamethylenetetramine was 5 per cent by weight to weight of the resorcinol-formaldehyde adhesive. The peel strength of 5% hexamine-modified resorcinol-formaldehyde adhesive was a little better than the adhesive from CNSL with 0.5% stannous octoate.

The peel strength of both CNSL adhesive and resorcinol-formaldehyde adhesive were lower than those without adhesive. Therefore, it was speculated that no chemical bonding occur between these adhesive and compounded natural rubber.

4.11 Scanning Electron Microscope

The scanning electron microscope (SEM) was employed to investigate the surface of the shear area after the shear test and that of the nylon-6 fabric and compounded natural rubber.

From Figure 4.20-4.23, they showed that the adhesive was in the interstics of plywood surface. When the adhesive was dehydrating, its film on the plywood surface was more continuous than that of the non-dehydrating one. The adhesive was the porous film when the curing was employed at 120°C.

Figure 4.24 showed the scanning electron micrograph of nylon-6 fabric surface. Figure 4.25 and 4.28 showed that when the adhesive was not employed, the rubber matrix penetrated into the space between the filaments of nylon-6 fabric. On the other hand, it could not penetrate into the nylon-6 fabric (Figure 4.26, 4.27, 4.29 and 4.30) when the adhesives were employed. The adhesive was better more compatible to the nylon-6 fabric than compounded natural rubber.

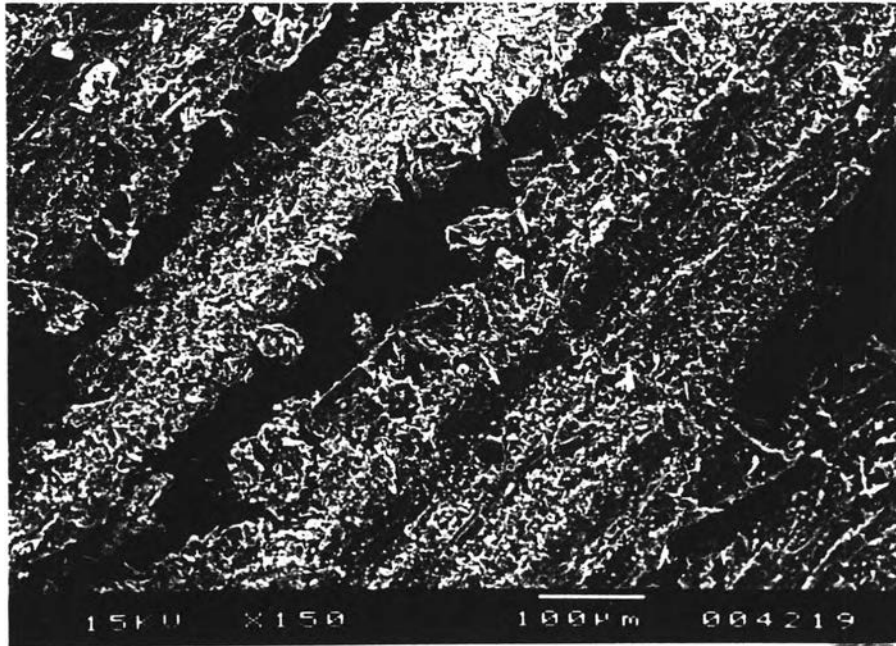


Figure 4.20 Scanning electron micrograph of the plywood surface.

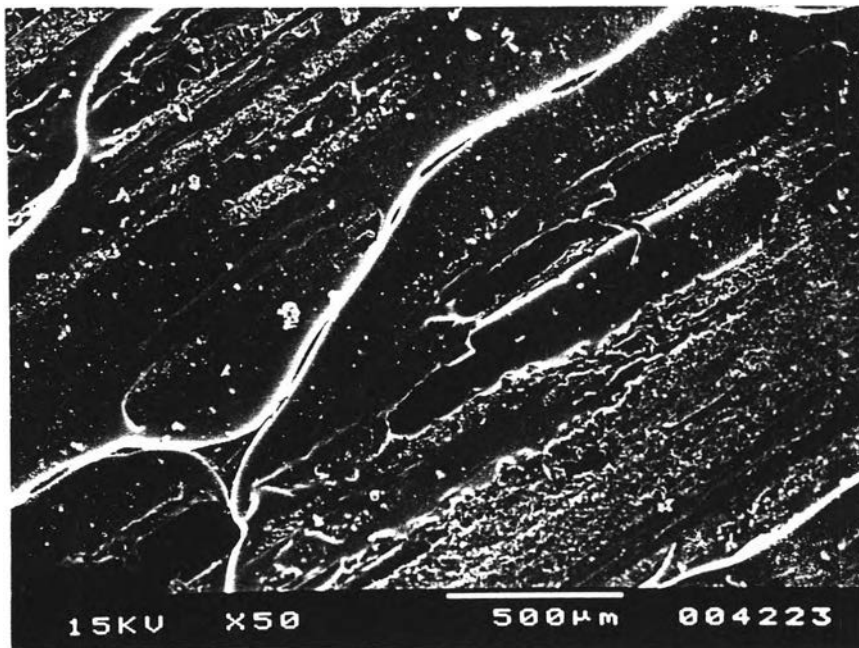


Figure 4.21 Scanning electron micrograph of shear area after fracture of dry-laminating and 10 minutes cold pressing of the adhesive batch no.20/40

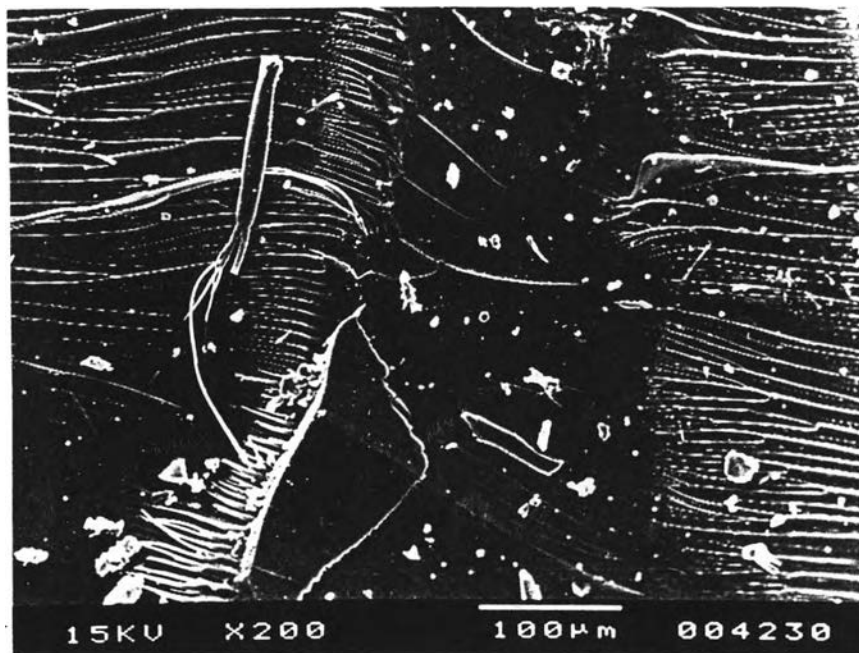


Figure 4.22 Scanning electron micrograph of shear area after fracture of dry-laminating and 10 minutes cold pressing of the adhesive batch no. D20/40.

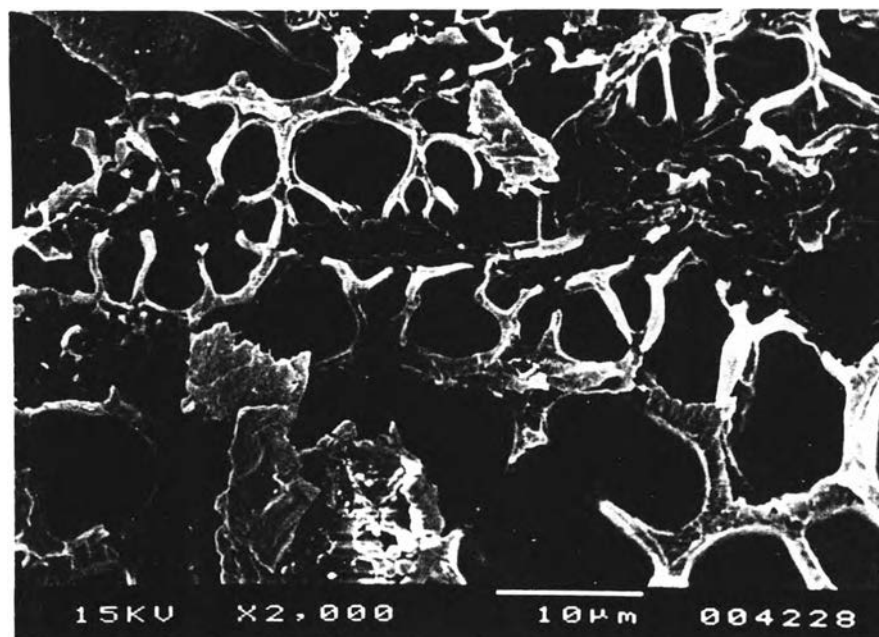


Figure 4.23 Scanning electron micrograph of shear area after fracture of dry-laminating and 30 minutes hot pressing (120°C) of the adhesive batch no. 35/10.

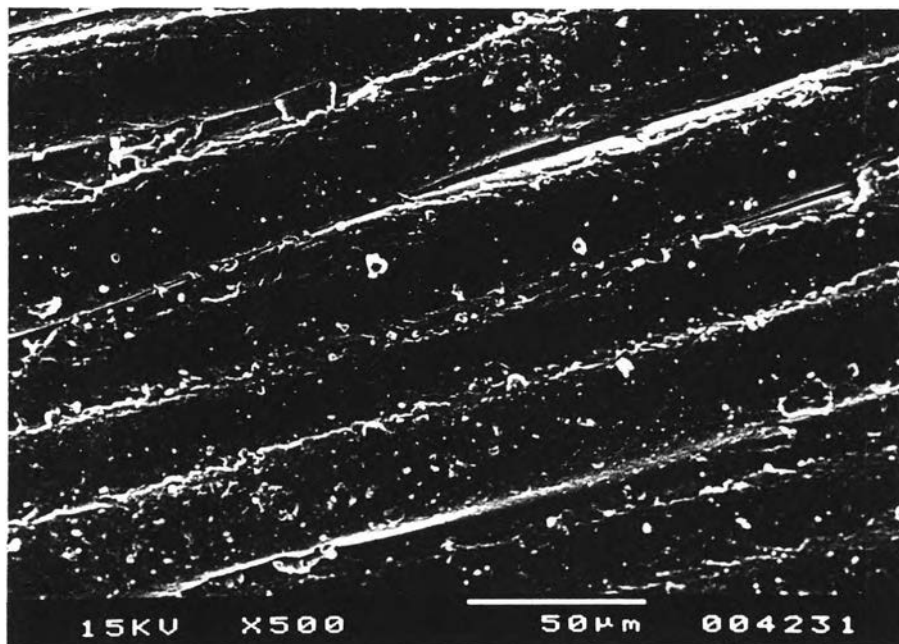


Figure 4.24 Scanning electron micrograph of nylon-6 fabric surface.

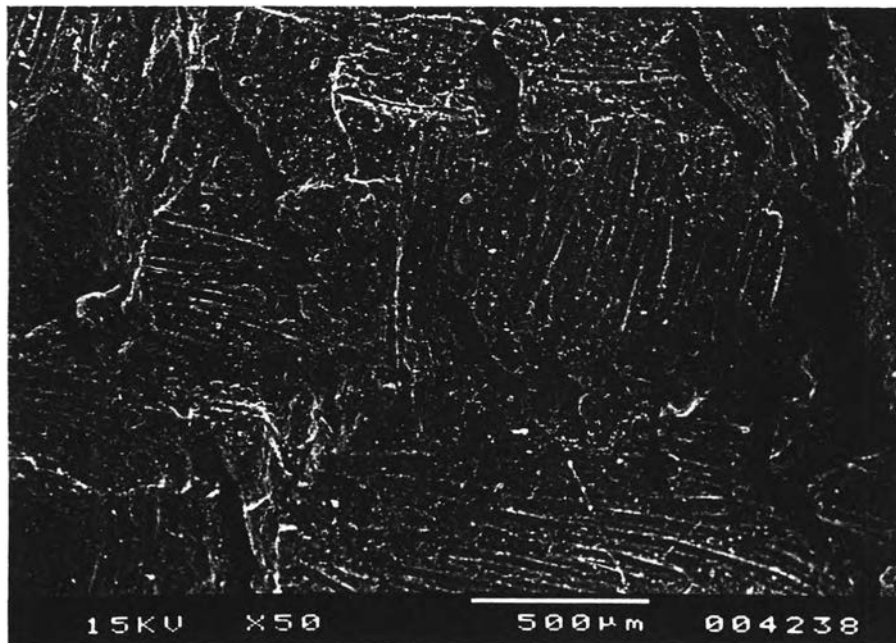
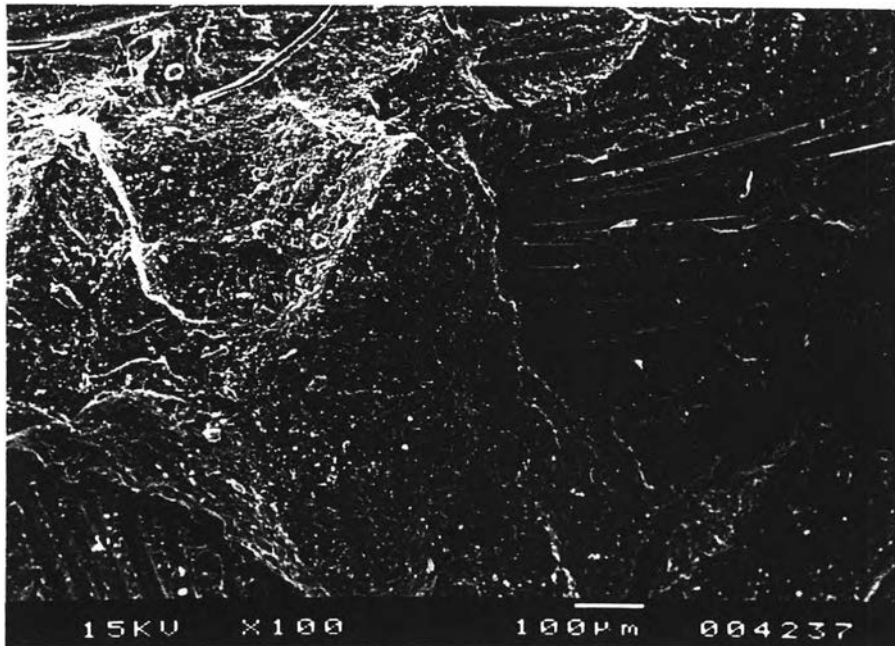


Figure 4.25 Scanning electron micrograph of (a) nylon-6 fabric surface and (b) compounded natural rubber surface after the peel test without adhesive.

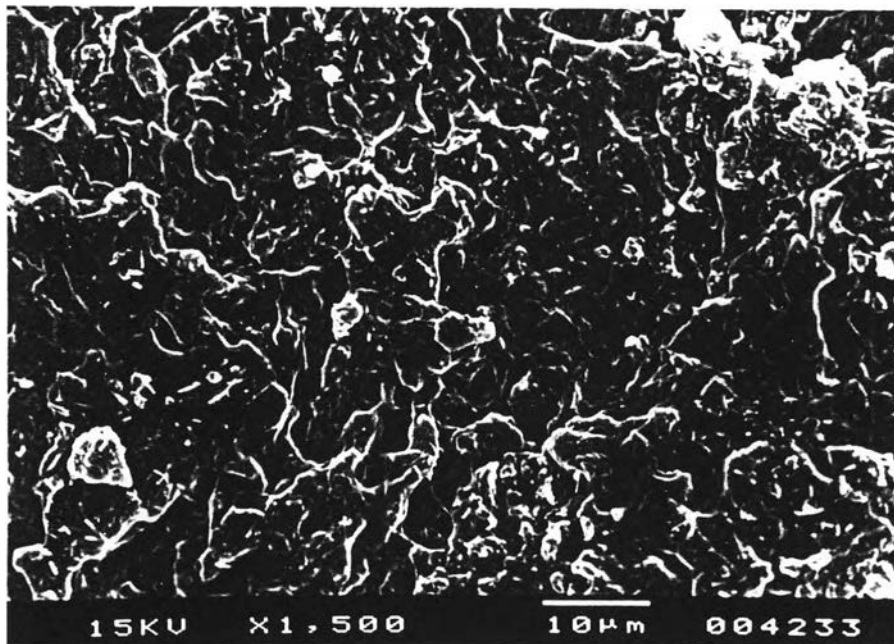
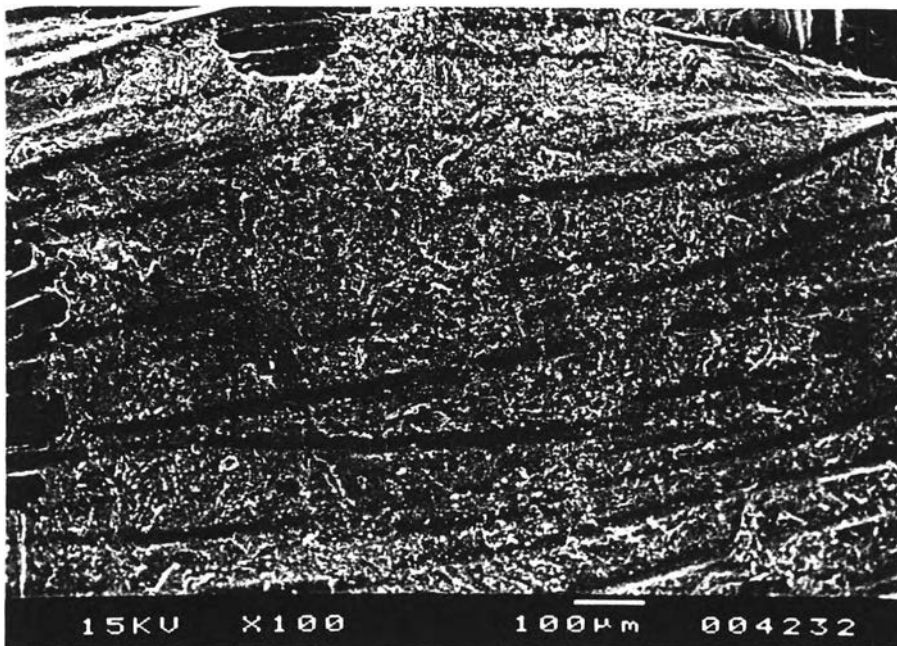


Figure 4.26 Scanning electron micrograph of (a) employed nylon-6 fabric surface and (b) compounded natural rubber after the peel test with adhesive batch no. 35/10 and 50 minutes pressing time at 150°C.

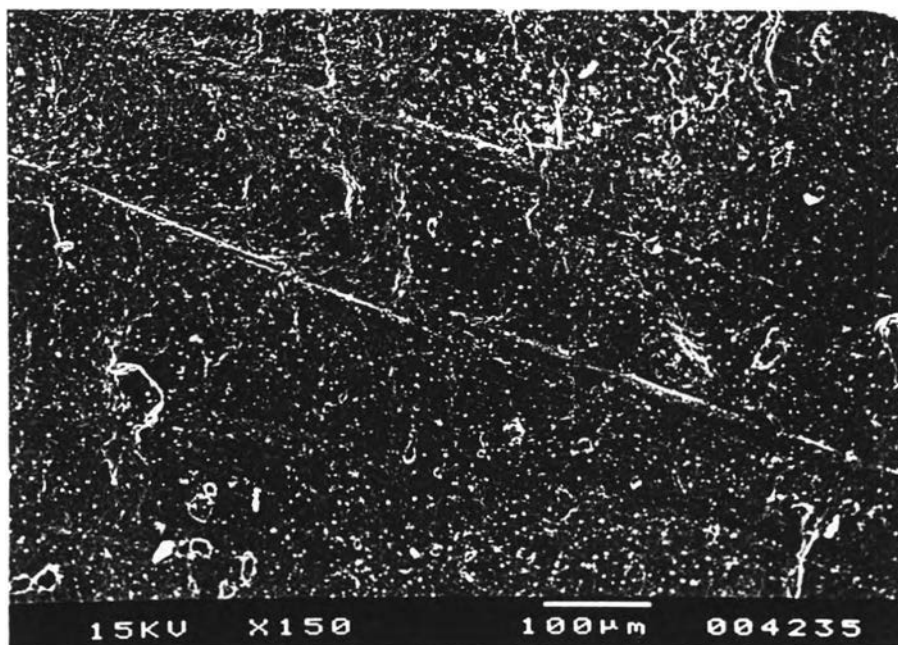
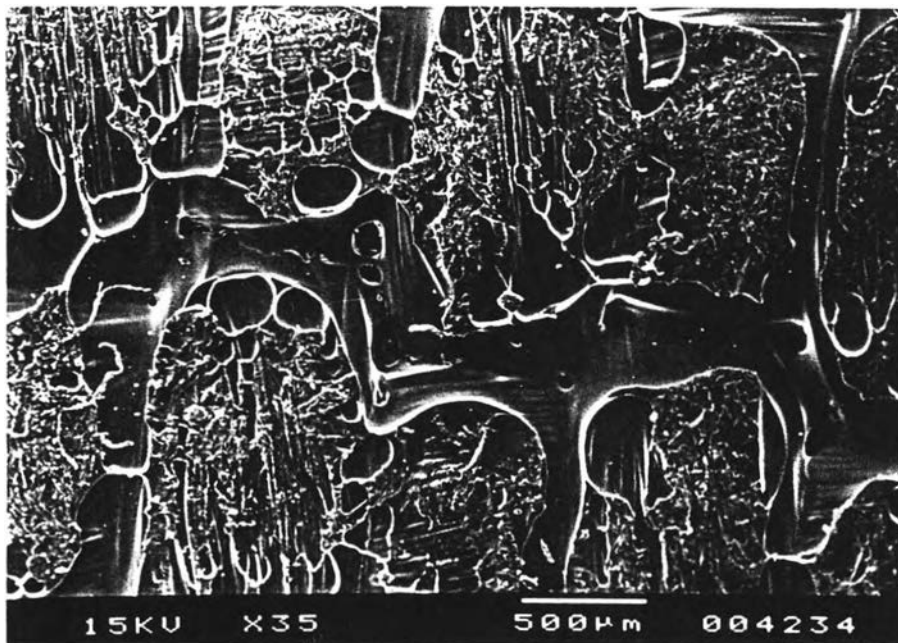


Figure 4.27 Scanning electron micrograph of (a) nylon-6 fabric surface and (b) compounded natural rubber surface after the peel test with 0.5% stannous octoate-modified adhesive batch no. 35/10 and 60 minutes pressing time at 150°C.

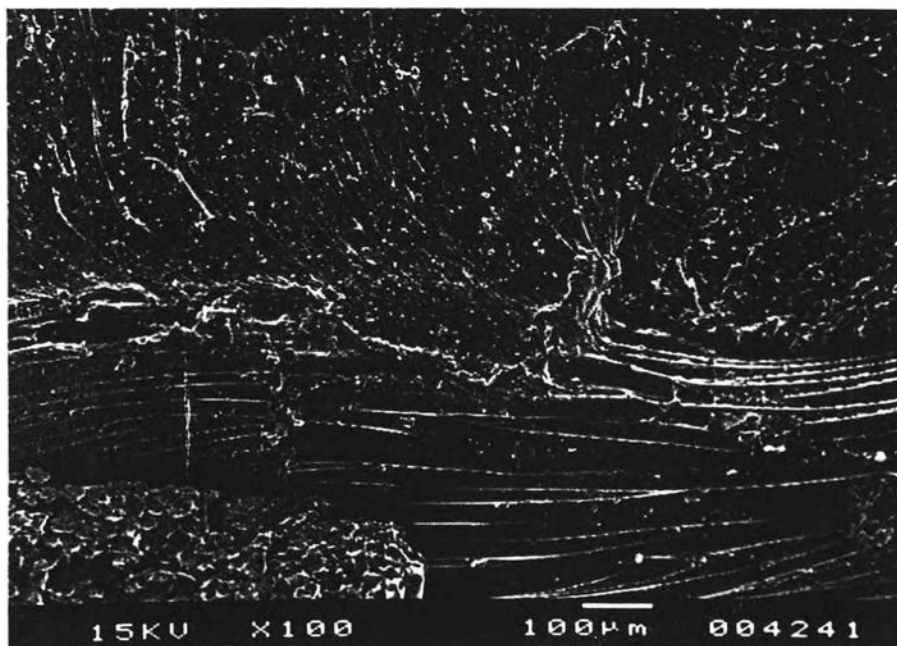


Figure 4.28 Scanning electron micrograph of longitudinal section of the test panel without the adhesive.

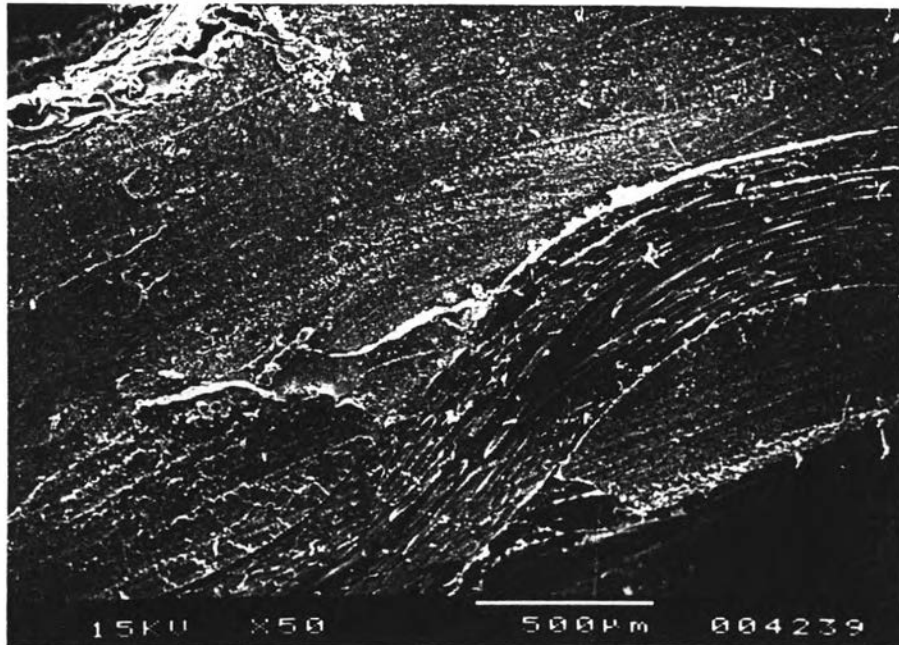


Figure 4.29 Scanning electron micrograph of longitudinal section of the test penal with the adhesive batch no. 35/10 with 50 minutes pressing time at 150°C.

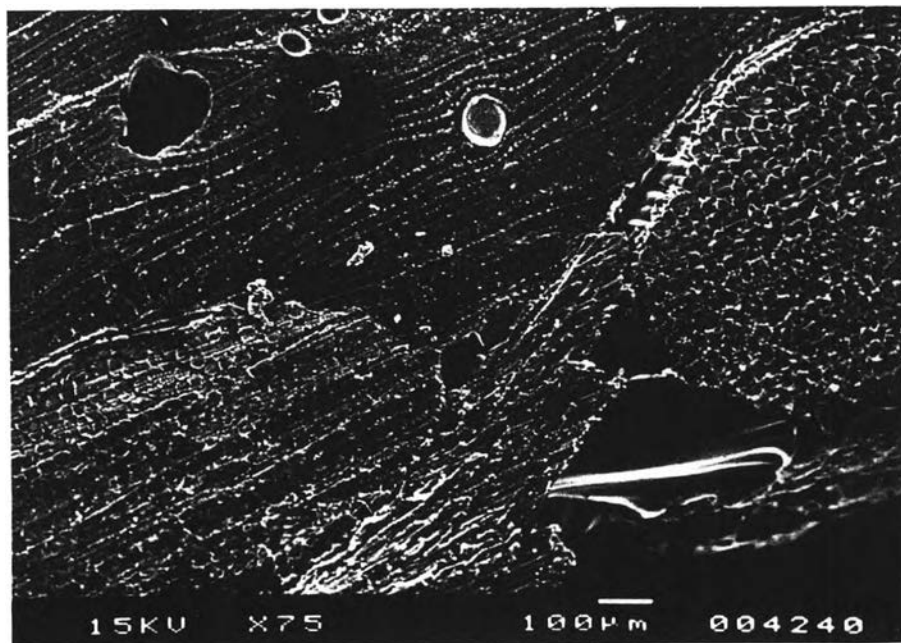


Figure 4.30 Scanning electron micrograph of longitudinal section of the test penal with 0.5% stannous octoate-modified adhesive batch no. 35/10 and 60 minutes pressing time at 150°C