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〔*Mokuzai Gakkaishi* Vol. 20, No. 11, p. 538～540 (1974) (Original article)〕

Reaction Catalysts of Urea-formaldehyde Resin, as Related to Strength Properties of Southern Pine Particleboard[*1]

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サウザンパイン・パーティクルボードの材質におよぼすユリア・ホルムアルデヒド樹脂の触媒の影響[*1]

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パーティクルボード材質におよぼすユリア・ホルムアルデヒド樹脂のアルカリ性触媒（3水準）と酸性触媒（4水準）の組合わせによる効果について検討した。その結果，アルカリ性触媒のうち水酸化ナトリウムを使用した樹脂がより高い接着強度を示し，水酸化ナトリウム触媒と組合わせた酸性触媒の樹脂は4種とも，ヘキサメチレンテトラミンとの組合わせでは塩酸とリン酸触媒の樹脂が，またトリエタノールアミンとの組合わせでは酸性触媒のうち酢酸を使用した樹脂だけが，それぞれ良好な接着強度を示した。

Twelve resins were formulated with factorial combinations of three alkaline catalysts (*i.e.*, sodium hydroxide, hexamethylenetetramine, and triethanolamine) and four acidic catalysts (*i.e.*, acetic acid, hydrochloric acid, ammonium chloride, and phosphoric acid). The resins were replicated.

Resins catalyzed with sodium hydroxide in general had higher internal bond and modulus of rupture than resins prepared with hexamethylenetetramine or triethanolamine. All acidic catalysts in combination with sodium hydroxide as alkaline catalyst yielded strength values in excess of those called for by U.S. Commercial Standard CS 236-66. With hexamethylenetetramine as alkaline catalyst, hydrochloric acid and phosphoric acid yielded resins meeting the standard. With triethanolamine as the alkaline catalyst, only acetic acid gave adequate bonds.

1. INTRODUCTION

As observed in the preceding paper,[1)] pH during the initial phase of resin formulation significantly affected quality of particleboards made from southern pine wood. Because a wide variety of chemicals can be used as catalysts to adjust reaction pH, an attempt was made to optimize the catalyst selection.

2. PROCEDURE

Procedures for resin and particleboard preparation were the same as those described in the first paper of this series,[2)] except that the initial alkaline phase was adjusted to pH 7.6 and the acidic phase to 5.0. Data in the second paper[1)] indicated that these values would give a reasonable compromise between formulation time and board quality.

Strength properties were evaluated by measuring internal bond strength, modulus of rupture (MOR), and modulus of elasticity (MOE) of boards assembled with these resins. Catalysts were:

- Alkaline phase
  - Sodium hydroxide
  - Hexamethylenetetramine (HMTA)
  - Triethanolamine (TEA)
- Acidic phase
  - Acetic acid
  - Hydrochloric acid
  - Ammonium chloride
  - Phosphoric acid

Thus, 12 resins were formulated; as each was replicated, 24 batches were prepared.

Data were tested by analysis of variance at the 95 % level of probability.

3. RESULTS AND DISCUSSION

Strength properties of particleboards varied widely; ranges for the boards assembled with all 24 resin batches were: IB, from 2.46 to 10.9

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kg/cm^2; MOR, from 75.5 to 187.5 kg/cm^2; and MOE, from 16.5×10^3 to 26.7×10^3 kg/cm^2. Averages for the 12 resins are shown in Table 1.

Internal bond and MOR differed with alkaline catalyst, and interactions of alkaline and acidic catalysts were significant. Resins catalyzed with sodium hydroxide in general had higher internal bond and MOR than resins prepared with HMTA or TEA (Table 2).

Of the acid phase catalysts, acetic acid yielded the best internal bond. It was followed in order by hydrochloric acid, phosphoric acid, and ammonium chloride.

All acid-phase catalysts in combination with sodium hydroxide as alkaline catalyst yielded internal bond and MOR values in excess of those called for by U. S. Commercial Standard CS 236-66, which specifies internal bond of 4.9 and MOR of 112. Only three out of the four acid-phase catalysts (*i. e.*, hydrochloric, phosphoric, and acetic acid) in combination with HMTA as alkaline catalyst yielded resins meeting this standard. With TEA as the alkaline catalyst, only acetic acid yielded strong resin bonds.

Resin viscosity as a function of reaction time is plotted in Fig. 1. The curves for TEA in combination with two acid-phase catalysts (ammonium chloride and phosphoric acid) and for HMTA with three of the four acid-phase catalysts (acetic acid, ammonium chloride, and phosphoric acid) are not shown; they are in general similar to the curve for HMTA with hydrochloric acid. The rates of condensation for many formulations were so fast that the control would be difficult during resin manufacture.

Table 1. IB, MOR, and MOE of particleboard assembled with resin formulated at combination of alkaline and acidic catalysts.

Alkaline and acidic catalysts	Internal bond	MOR	MOE
	kg/cm^2		100 kg/cm^2
Sodium hydroxide			
Acetic acid	8.37	127.8	22.1
Hydrochloric acid	7.73	121.0	20.4
Ammonium chloride	7.66	144.6	22.7
Phosphoric acid	7.59	128.5	21.9
Hexamethylenetetramine			
Hydrochloric acid	8.65	129.1	20.4
Phosphoric acid	6.82	116.6	21.1
Acetic acid	6.61	112.1	20.2
Ammonium chloride	3.30	93.0	18.0
Triethanolamine			
Acetic acid	8.51	135.8	24.5
Hydrochloric acid	4.64	99.3	20.5
Ammonium chloride	4.42	97.2	20.9
Phosphoric acid	3.59	84.9	18.6

Table 2. Effect of alkaline and acidic catalysts on strength properties of particleboard.

Catalyst	IB	MOR
	kg/cm^2	
Alkaline catalyst		
Sodium hydroxide	7.80	130.3
Hexamethylenetetramine	6.33	112.6
Triethanolamine	5.27	104.3
Acid catalyst		
Acetic acid	7.87	
Hydrochloric acid	7.03	—
Phosphoric acid	5.91	—
Ammonium chloride	5.13	—

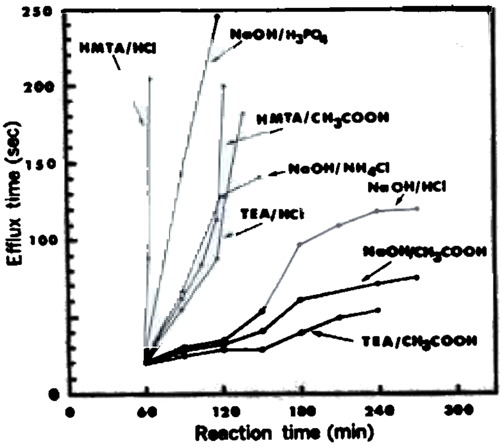

Fig. 1. Relationship between resin viscosity and reaction time with various alkaline and acidic catalysts.

Of the six resins with adhesive strength in excess of the U. S. Commercial Standard, NaOH/HCl gave the most desirable viscosity curves. Very strong bonds were made, however, with the two resins having either uncontrollably fast or intolerably slow reaction times—HMTA/HCl and TEA/CH_3COOH. It is highly probable that an alkaline catalyst system combining NaOH, HMTA, and TEA may provide the means for further improvement of resin performance.

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