SPMC Technical Review EN

Characteristics of PAE-Based Crepe Adhesives and Their Effect on Yankee Dryer Coatings

SEIKO PMC COROPORATION
Papermaking Chemicals Business Division Yukie Suzuki
Hiroshi Suzuki

1. Introduction

Household papers (sanitary papers), including toilet rolls, facial tissues, and paper towels are designed to have fine wrinkles or puckers called "crepes", unlike common printing papers and paperboard shown in Figure 1. Fine and uniform crepes impart desired textural characteristics, such as softness, superior handfeel, and bulk to household papers

Dry-crepe process is conventionally employed in most of the Japanese household paper manufacturers and this process is composed of the following three stages.

① Low-basis-weight wet sheet formed at high speed is transferred and adhered to a drying surface such as a rotating Yankee dryer.
② Dried sheet is compressed by applying a doctor blade against the surface, leading to formation of crepes.
③ Creped web sheet is dislodged from the dryer surface.

The runnability of a tissue machine varies depending on various factors such as papermaking conditions, feed stocks, and added chemicals, which also influence the final crepe properties. Therefore, in order to stabilize the creping process and obtain a good crepe properties, a combined use of crepe adhesive and release agent is commonly employed to optimize the balance of adhesion and release.

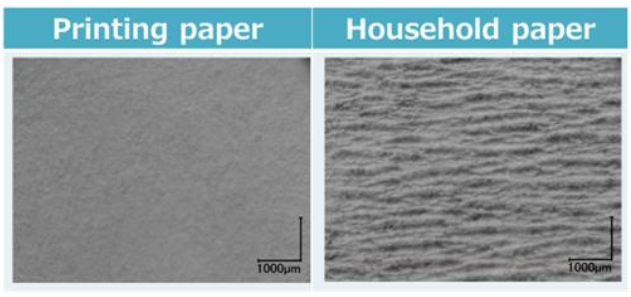

Figure 1. SEM images of the paper surface

The crepe adhesive is generally composed of polyamide-epichlorohydrin (PAE) resin as a main chemical ingredient. In 1974, one of our roots, DIC-Hercules Co., Ltd., launched the first crepe adhesive based on PAE in Japan market. Since then, we have been continuing to improve performance of PAE-based crepe adhesives[1]. This paper introduces the characteristics of PAE-based crepe adhesives and their effect on the coating film formed on the Yankee dryer surface.

2. Function of crepe adhesives

There are two types of chemicals for creping, mainly crepe adhesives (coating agents) and release agents. These chemicals are sprayed onto the surface of a Yankee dryer, forming a coating film on the dryer surface. It is thought that the coating film is composed of “protective layer” and “soft adhesive layer” depicted in Figure 2. The protective layer consists of thermally cured adhesives on a dryer surface and works as Yankee roll protection. The soft adhesive layer formed on the wet sheet side consists of mixture of the adhesive and the release agent, contributing to adhesion to the wet sheet.[2]

Crepe adhesives play an important role in determining the quality of crepes by forming a proper

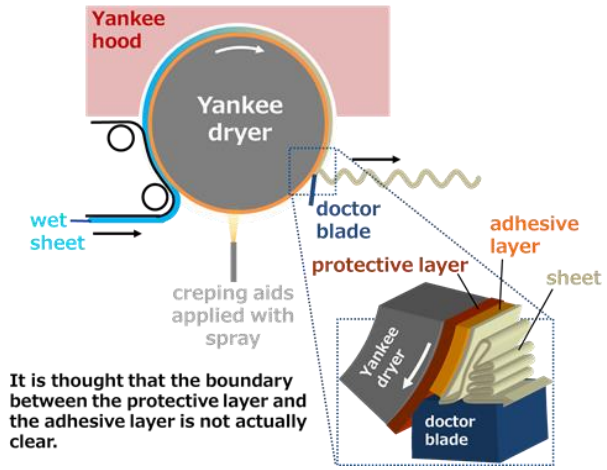

Figure 2. Image of creping process

coating film on the Yankee dryer surface. It is required to impart a high "wet sheet adhesive strength", a high "water resistance" and a moderate "hardness". Too lower water resistance of the coating film can lead to dissolution of it due to moisture of the wet sheet, leading to lack of durability. Excessively low hardness of the coating film can be scraped off by the doctor blade, impairing functions of the protective layer and the adhesive layer. Conversely, if the hardness of the coating film is too high, deposits accumulated on the Yankee dryer surface cause various machine and quality problems.

3. PAE-based creping adhesives

3-1. PAE characteristics

The chemical structure of the PAE is shown in Figure 3. PAE is obtained by reacting a polyamide resin with epichlorohydrin. By changing the amount of epichlorohydrin added and reaction condition, the molecular weight of PAE, the number of cross-linked sites, and the number of reactive sites can be easily controlled, making it possible to design crepe adhesives for various papermaking conditions.

PAE-based adhesives are broadly classified into reactive and non-reactive types based on the presence or absence of the reactive site, azetidium groups (AZR).

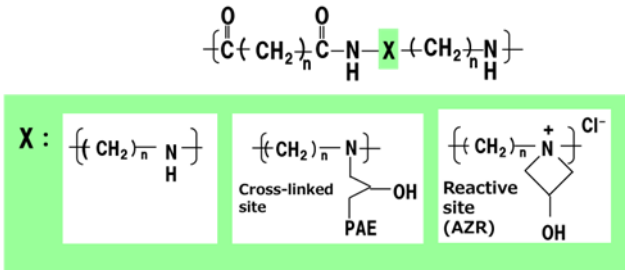

Figure 3. Chemical structure of PAE

The non-reactive type is a crepe adhesive without AZR groups, showing almost no change in molecular weight on the dryer. This adhesive type has excellent adhesion and provides a coating film with low hardness.

On the other hand, crepe adhesives having AZR groups are called "reactive types" and undergo a cross-linking reaction when applied and dried on the dryer surface. Compared to the non-reactive type, the reactive type can give the coating film with higher hardness and superior water resistance.

3-2. Optimal crepe adhesives for each papermaking condition

The choice of reactive or non-reactive adhesives is usually determined by wet end chemicals such as wet strength resins and softeners, and paper making speed. For production of tissue paper and towel paper, the addition of wet strength resin is imperative to impart wet strength. However, the use of wet strength resin tends to harden the coating film excessively, thus, non-reactive adhesives are preferably selected.

In the production of medium or premium tissues, softeners agents are added to the paper-making system to impart softness and good handfeel. However, the use of softeners lower adhesive strength of the coating film and soften the coating film, making it easier to be scraped off by a doctor blade. So, it is preferable to select reactive adhesives that provide more harder coating film.

For high-speed machines, the coating film tends to be

dissolved by moisture of the web sheet due to high moisture content of the web at the dryer part. Thus, reactive adhesives are usually selected to give good water resistance to coating film.

Recently, higher machine speed and new installation of high-speed machines are advancing to meet increased production and cost reduction goals.

In addition, the use of softeners and increased softener dosage are also being implemented to produce more higher quality household papers. Since both the higher speed machines and the use of softeners are factors inhibiting the coating film formation on the dryer surface, there are strong demands for crepe adhesives enabling to impart more superior adhesive strength and water resistance to the coating film.

3-3. Physical Properties and Design Concept of Newly Developed Crepe Adhesives

Although the coating layer composed of crepe adhesives with high molecular weight and higher number of AZR groups shows excellent adhesive strength and water resistance, there is a problem, the excess hardening of coating film. Accumulated hardened deposit on dryer surface edge leads to increase the loading pressure between the coating and the doctor blade. Higher loading pressure accelerates wear of the blade and causes more paper pinholes and sheet breaks.

One of the factors that increase the coating hardness is strong hydrogen bonding acting inner and inter molecules of PAE. Therefore, we studied how to weaken hydrogen bonding of PAE molecules, succeeding in development of novel creping adhesives A and B, which can suppress increase in coating hardness even if the molecular weight and the number of AZR groups in PAE molecules are increased.

Table 1 shows physical properties and characteristics of the novel crepe adhesives A and B, and the conventional ones a1, a2, b1 and b2. Crepe adhesives A, a1 and a2 are non-reactive types with no reactive sites, so the number of AZR groups in each product is “zero”. Crepe adhesives B, b1, and b2 are reactive types having AZR groups. The number of AZR groups and the molecular weight in the products are shown as relative values based on conventional reactive adhesive b1.

3-4. Evaluation method

Adhesion:

An adhesive was applied to the probe heated at 110 ℃ of the tacking tester, and the probe was pressed against the wet sheet. Peeling force was measured when the probe was pulled apart from the wet sheet (Figure 4). The higher value of the drag force, the higher adhesion.

Table 1. Physical properties and characteristics of crepe adhesives

	a1	a2	A	b1	b2	B
Type	Non-reactive			Reactive		
Appearance	Amber liquid			Amber liquid		
Solids (%)	30	10	10	30	15	15
Viscosity (mPa-s)	200	50	50	200	40	40
pH	4	9	9	4	3	3
Number of AZR group	0.0	0.0	0.0	1.0	1.3	1.3
Molecular weight of PAE	1.0	7.4	7.4	1.0	2.0	2.0
Weakened hydrogen bond	No	No	Yes	No	No	Yes

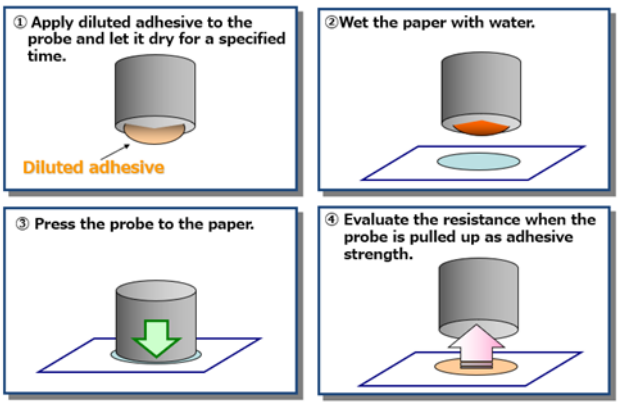

Figure 4. Evaluation method of adhesion

Water resistance of coating film:

A coating film of creping adhesive prepared on a petri dish was immersed in water for a fixed time, and a residue of an undissolved coating film was calculated from a change in dry-weight before and after immersion. The larger residue, the better water resistance of the coating film.

Hardness of coating film:

A coating film of creping adhesive prepared on a petri dish was scratched with pencils having various hardness. The higher hardness number, the harder coating film.

3-5. Evaluation results

Figures 5, 6 and 7 show the adhesive strength, water resistance, and hardness of coating film prepared from each sample. Conventional non-reactive crepe adhesive a1 impart better adhesive strength compared to conventional reactive adhesive b1, while b1 gives better water resistance than a1. Non-reactive adhesive a2, which has a higher molecular weight than a1, further enhances adhesive strength, and b2, which has a higher molecular weight than b1, further enhances the water resistance.

However, it is notable for conventional reactive adhesive b2 that the increase in molecular weight of PAE causes hardening of coating film hardness.

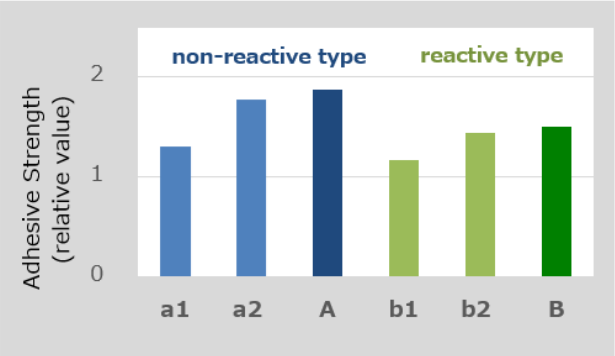

Figure 5. Adhesive Strength

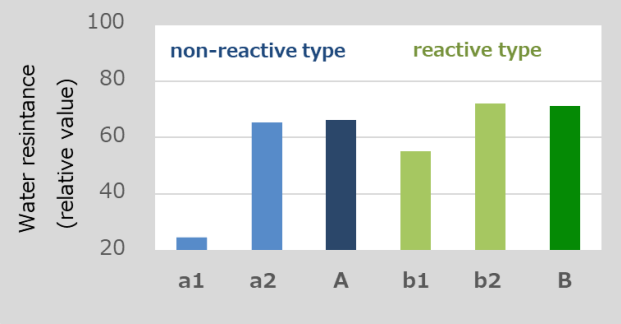

Figure 6. Water Resistance

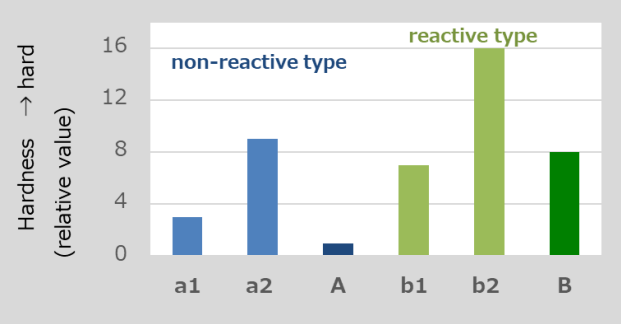

Figure. 7. Hardness

Excessive increase in hardness results in several problems due to deposit on the edge of Yankee dryer surface. The newly developed adhesives A and B impart superior adhesive strength and water resistance to coating films and succeed in avoiding excess hardening of the coating films by reducing hydrogen bonding strength of PAE.

3-6. Non-Reactive Type/Reactive Type Adhesives Combined Formula

Aiming to improve the performance of creping adhesives further, we investigated several combined

uses of non-reactive and reactive adhesives and obtained excellent results, which could be not reached by single use of non-reactive or active adhesive.

Figures 8, 9 and 10 show the test results of adhesive strength, water resistance, and hardness of coating film prepared from the combined formulation of the non-reactive type A and the reactive type B.

The combined use of adhesives A and B gives excellent adhesive strength and water resistance to the coating film compared with single use of adhesive A or B, while suppressing further hardening of it.

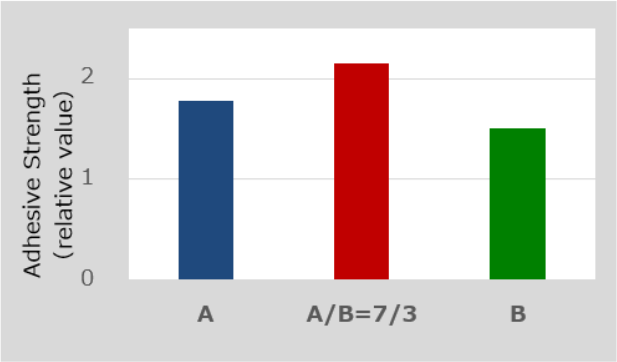

Figure 8. Adhesive strength

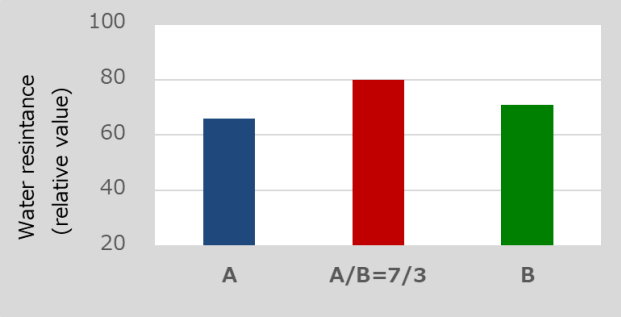

Figure 9. Water resistance

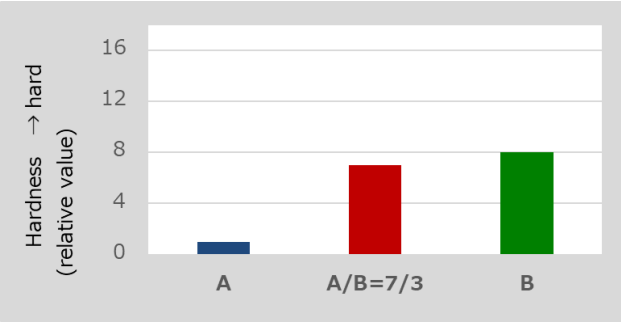

Figure 10. Hardness

The reason why the combined use gives superior results are presumably due to increase in molecular weight of PAE by cross-linking reaction of non-reactive type A with the reactive type B.

Desired adhesive strength, water resistance, and hardness of coating can be obtained by changing the ratio of non-reactive type and reactive type. Therefore, the combined formulation is quite effective for paper machines that manufacture multiple grades of household papers.

The combined formulations have already been employed in several paper mills, contributing to fewer operational troubles, longer life of doctor blade, higher productivity and improved paper quality.

4. Conclusion

Crepe adhesives play an important role to determine coating film properties, crepe quality, and runnability in the creping process. The PAE-based crepe adhesives are conventionally used for production of household papers due to enabling to adjust adhesion, water resistance, and hardness of coating films just by modifying chemical structures and molecular weight of PAE.

Novel adhesives A and B achieve excellent adhesive strength and water resistance while suppressing excess hardening of coating films. We also introduced that the combined use of non-reactive type and reactive type adhesives give superior adhesive strength and water resistance compared with the single use of non-reactive or active type.

We will continue to develop more advanced technologies for creping agents to meet various customers' requirements, changes of raw materials, paper machine conditions, and paper quality, thereby contributing to the development of household paper industries.

＜References＞

1) Yukie Suzuki, Koji Yoshitani, Paper Engineering Journal, Vol. 74 (No. 5), pp. 32-35

2) Yoshitani Koji Paper Pulp Technique Times, July 2010 issue, pp. 29-33

Profile

SEIKO PMC CORPORATION
Papermaking Chemicals Business Division
Technology Management Department
Chiba Laboratory
Yukie Suzuki

SEIKO PMC CORPORATION
Papermaking Chemicals Business Division
Technology Management Department
Chiba Laboratory
Manager
Hiroshi Suzuki