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Study on Adhesive Mechanism and Sizing Process of Wheat Straw Board in Interior Decoration

Xuejiao Bai¹ and Xufang Liang^{1*}

¹ School of Chinese Literature, Changchun University of Science and Technology, Changchun, Jilin, 130022, CHINA

* baixuejiao16@163.com

Corresponding Author: Xufang Liang, School of Chinese Literature, Changchun University of Science and Technology, Changchun, Jilin, 130022, CHINA

Abstract. Wheat straw wood-based panels are widely used as environmental protection materials in indoor building decoration. In this paper, the selection of adhesives for wheat straw based panels was studied, the bonding mechanism was analyzed, and built bonding model. The results showed that: (1) adhesive isocyanate has excellent bonding properties to wheat straw surface, but its price is expensive, the wheat straw wood-based panels have no market advantage. (2) separate sizing, i.e. applying isocyanate glue first and then urea-formaldehyde resin glue, can effectively ensure the bonding strength, reduce production costs, can produce wheat straw wood-based panels that meet international standards and have market competitiveness. (3) In the process of adhesive bonding, the main function of isocyanate adhesive is to contact the hydroxyl group on the surface of straw through its high activity isocyanate group, and produce chemical effect, and then form a high efficient combination; the effect of urea-formaldehyde resin adhesive is to react with isocyanate group and promote the formation of adhesive layer.

1. Introduction

Crop straw is crushed by hot pressing and gluing to form a new decorative plate to meet the functional needs of modern society. Wheat straw board explain the concept of modern green environmental protection, in the indoor and construction field has a wide range of applications [1, 2]. According to the analysis of biological structure and surface chemical composition of wheat straw, it is considered that isocyanate adhesive is a more reasonable choice, however, only applying urea formaldehyde adhesive can hardly obtain wheat straw artificial board with international standard [3]. According to the literature, when the isocyanate sizing amount is about 5%, we can get the standard wheat straw board, but if we consider the market price of isocyanate, the advantage of raw material price of wheat straw board will be exhausted with the high price loss of adhesive, so that the wheat straw board will lose its market competitiveness.

According to the theory of gum rationality and the analysis of wheat straw surface structure and chemical properties, we think that the contradiction can be solved by applying isocyanate gum and urea-formaldehyde gum one after another. In the process of adhesive bonding, the main function of isocyanate adhesive is to contact the hydroxyl group on the surface of straw through its high activity isocyanate group, and produce chemical effect, and then form a high efficient combination. The effect of urea-formaldehyde resin adhesive is to react with isocyanate group and promote the formation of adhesive layer.



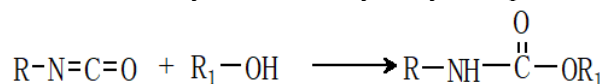
2. Bonding mechanism of isocyanates

There are three main types of isocyanates: TDI, MDI and PAPI. Although isocyanates are diverse, but the reaction is mainly isocyanate group.

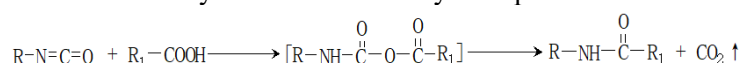
2.1. Chemical reaction of isocyanate group

Isocyanate group ($-NCO$) is a very active group, the most important chemical reaction is the addition reaction with compounds containing active hydrogen ($H - Y$, Y are different groups).

- Reaction of isocyanates with hydroxyl compounds:



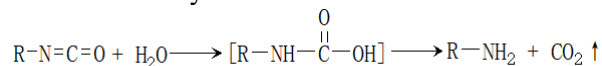
- Reaction of isocyanates with carboxyl compounds:



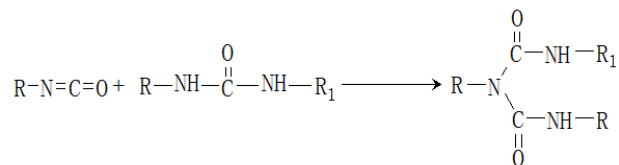
- Reaction of isocyanates with amino compounds:



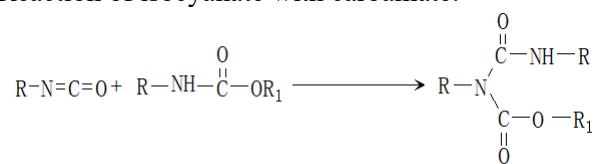
- Reaction of isocyanates with water:



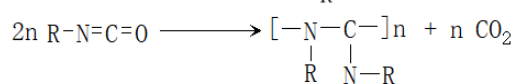
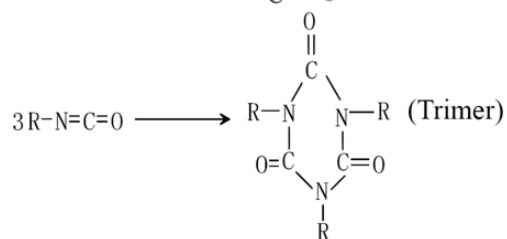
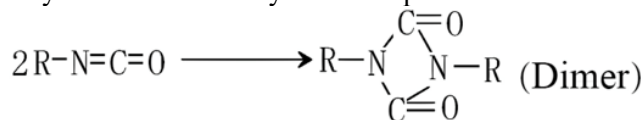
- Isocyanate and reaction with urea compounds:



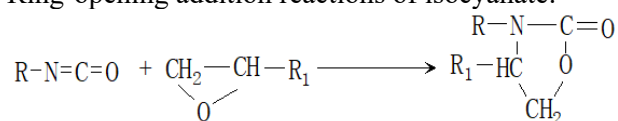
- Reaction of isocyanate with carbamate:



- Polymerization of isocyanate compounds:



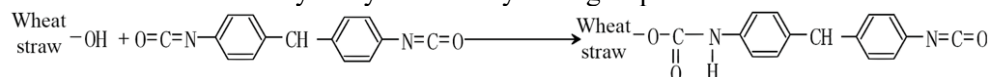
- Ring-opening addition reactions of isocyanate:



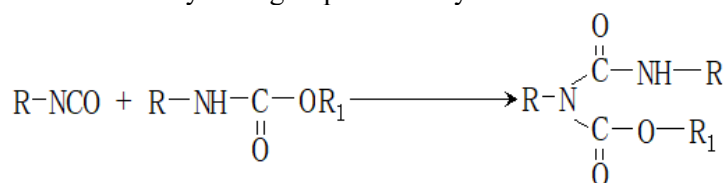
2.2. Chemical reaction between isocyanate gum and wheat straw surface

According to the analysis of chemical characteristics of wheat straw raw materials, wheat straw raw materials have a large number of hydroxyl functional groups, that is, smooth wax layer, which hinders the traditional urea formaldehyde adhesive from contacting with hydroxyl functional groups, directly affecting the bonding effect. Isocyanate has a high activity isocyanate group; the group can react not only with hydroxyl groups but also with unreactive ester bonds [4, 5]. Take the reaction of isocyanate group in 4, 4'-two phenyl methane isocyanate (MDI) as an example:

- Reaction between active hydroxyls and isocyanate groups of wheat straw:



- Reaction of isocyanate group with waxy substances on wheat straw surface:

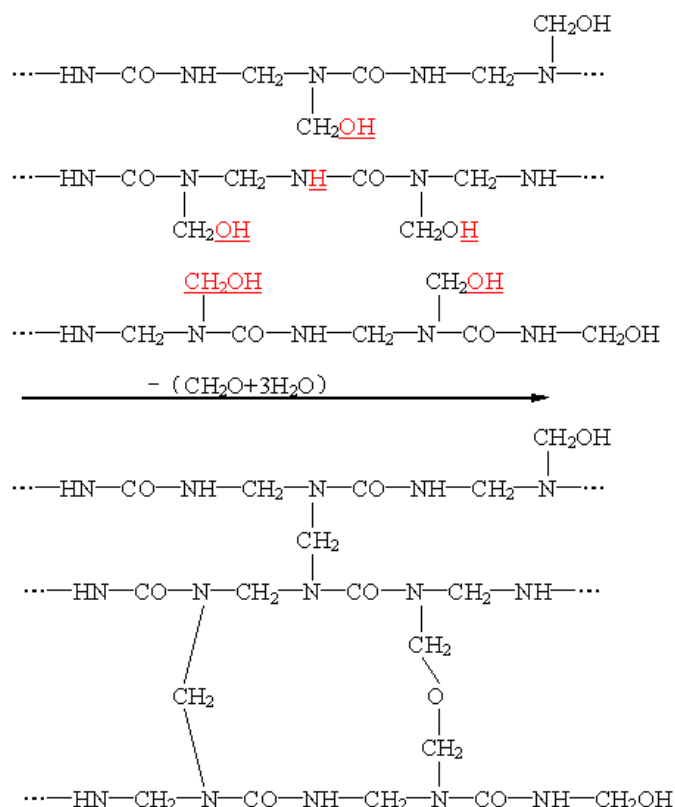


3. Bonding mechanism of urea formaldehyde resin

3.1. Gel reaction of urea formaldehyde adhesive

The curing process and curing mechanism of urea formaldehyde adhesive have important influence on the sizing method of wheat straw artificial board and the hot-pressing process of artificial board, so it is necessary to analyse the gel mechanism of urea formaldehyde adhesive.

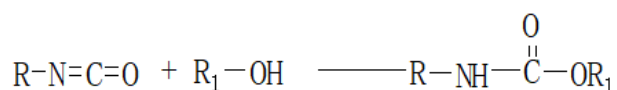
- Gelation mechanism of urea formaldehyde adhesive:



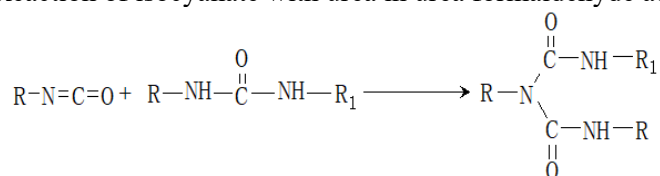
3.2. Reaction process between urea formaldehyde adhesive and isocyanate adhesive

There are many functional groups reacting with isocyanate group in urea-formaldehyde adhesive. Based on the main functional groups in urea-formaldehyde adhesive, the reaction between urea-formaldehyde adhesive and isocyanate adhesive was analysed.

- Reaction of isocyanates with hydroxyl groups in urea formaldehyde adhesive:



- Reaction of isocyanate with urea in urea formaldehyde adhesive:



4. Selection of sizing method and gluing process of adhesive

According to the analysis of the biochemical characteristics of wheat straw and the bonding mechanism of adhesive, we think that the method of separate sizing can achieve better bonding. The process of separate sizing is to apply isocyanate adhesive first, then urea-formaldehyde resin adhesive. The sizing process and gluing process were demonstrated through the model.

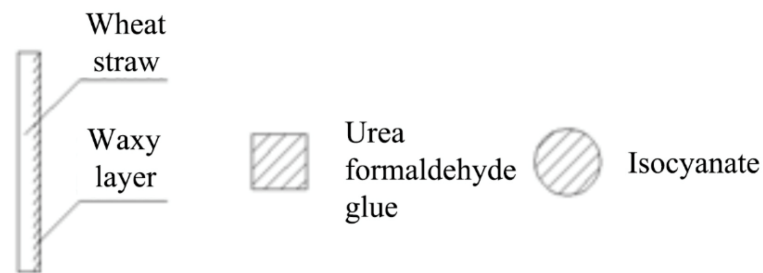


Figure 1. Schematic diagram



Figure 2. Gluing process of Wheat Straw Particleboard (urea formaldehyde adhesive)

Figure 2 shows gluing process of Wheat Straw Particleboard (urea formaldehyde adhesive), the chemical reaction between urea-formaldehyde adhesives formed a strong chemical bond, but the waxy layer on the surface of wheat straw made it difficult for water-soluble urea-formaldehyde adhesives to form a good chemical bond with the wheat straw interface, which made the bonding quality unsatisfactory.

Figure 3 shows gluing process of Wheat Straw Particleboard (isocyanate), isocyanates can react with the active functional groups on the surface of wheat straw or even the functional groups of wax layer, and the isocyanate itself can polymerize well, so it can get better bonding interface and bonding quality. However, considering the price of isocyanate, this adhesive bonding method is not competitive in the market.



Figure 3. Gluing process of Wheat Straw Particleboard (isocyanate)

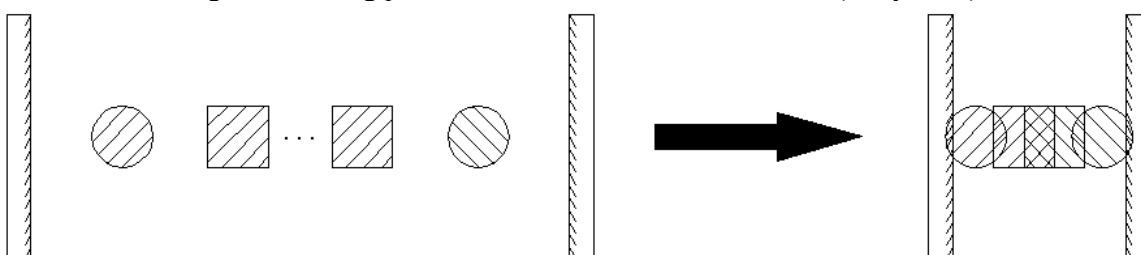
Figure 4. Gluing process of Wheat Straw Particleboard
(First use isocyanate gum, then use urea formaldehyde glue)

Figure 4 shows gluing process of Wheat Straw Particleboard (First use isocyanate gum, then use urea formaldehyde glue), When the isocyanate adhesive is applied, the highly active isocyanate group reacts with the hydroxyl groups on the wheat straw surface first, and then forms a firm bond with the wheat straw surface, at this time, the chemical reaction process of Fig. 3 occurs. When urea formaldehyde resin is applied, the isocyanate group of isocyanate can form chemical bonds with functional groups in urea formaldehyde adhesive, and produce gel effect under the action of curing agent and hot pressing, so that the straw stalk can be firmly combined.

5. Conclusion

With the aid of theory and bonding model, the bonding mechanism of isocyanate and urea formaldehyde adhesive was analysed. Among the many adhesives, isocyanate has better adhesive properties to wheat straw surface. According to the bonding model and chemical reaction process analysis, applying isocyanate adhesive first and then urea-formaldehyde adhesive can effectively guarantee bonding strength and reduce production cost.

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