Suitable Methoxysilane and Its Oligomer for Tensile Strength Improvement in Treated Paper Using Titanium Butoxide as Reaction Accelerator

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Abstract
For investigating the suitable methoxysilane and its oligomer for improving the tensile strength of treated paper after its hydrolysis and poly-condensation, three methoxysilanes (tetramethoxysilane (TMOS), methyltrimethoxysilane (MTMS) and dimethyldimethoxysilane) and two oligomers (TMOS and MTMS oligomers) were impregnated into the base paper using titanium butoxide as the reaction accelerator. Among the three methoxysilanes, the highest impregnated weight (7.2 g/m²) was obtained when a TMOS solution was used. The highest tensile strength was obtained when an MTMS solution was treated (4.3 kN/m, 130 % increase compared to the base paper). On the other hand, for the two oligomers, the highest weight was 50 g/m² and the highest strength was 6.8 kN/m (200 % increase) when an MTMS oligomer solution was treated. These differences in the improvement of the weight and strength between the monomer solutions and the oligomer ones were due to the monomer’s high volatility. The reason why the MTMS oligomer produced the highest strength treated paper is attributed to its molecular characteristics. Because the MTMS has one unhydrolyzable group (methyl group) and three hydrolyzable groups (methoxy groups), it is assumed that the balance between the flexibility resulting from the methyl group and the hardness from the methoxy groups produced the moderate tension in the generated polymer. The MTMS oligomer has the same balance as the MTMS. Among the MTMS oligomers having different degrees (n = 3.1, 4.4, 6.3, 8.7, 12.4 and 26.1), there was only a slight difference in strength. The most suitable methoxysilane compound for improvement of the tensile strength was the MTMS oligomer.

Key-words : Methyltrimethoxysilane, Sol-gel method, Tensile strength, Titanium tetrabutoxide

1. Introduction
Paper has long been used as an environmentally friendly material. However, the range of its uses is limited because of its low tensile strength, water sensitivity, etc. If these disadvantages are eliminated by some treatment, such as a coating or impregnation by some material, the application range of paper can be extended.

A method of treating with an alkoxysilane to generate siloxane bonds after hydrolysis and its poly-condensates typically using an acidic catalyst, namely, the sol-gel method, has been widely applied to a glass or metal surface. This method produces many excellent properties, such as heat resistance and tensile strength improvement. Recently, the application of this method has been extended to wood surfaces, cotton fabrics and textiles. If this method is applied to paper, its disadvantages can be easily reduced.

In the typical sol-gel solution, the starting material is an alkoxysilane, such as tetramethoxysilane (TMOS) or tetraethoxysilane, and the catalyst is an acid, such as hydrochloric acid or nitric acid. For successfully applying this method to paper, a suitable alkoxysilane and catalyst must be determined.

It was reported that a treatment solution consisting of a methyltrimethoxysilane (MTMS) oligomer and titanium tetrabutoxide (Ti-Butoxide) without acidic materials was applied to paper to improve its tensile strength without cellulose degradation.

It was also reported that a treatment solution consisting of...