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IMPROVING THE MOISTURE RESISTANCE OF RECYCLED PAPER

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Abstract

Wet strength is a critical property of paper, ensuring structural integrity under moist conditions. A modified cationic polyacrylamide was synthesized to enhance fiber bonding. Laboratory paper sheets treated with modified product with dosages of 2.10–2.52 kg/t showed optimal dry and wet tensile strength. However, pH variations in recycled pulp, especially alkaline conditions caused by calcium carbonate fillers, can reduce additive effectiveness by hydrolyzing aldehyde groups. The study found product performs best at pH 5.5–6.5, without altering the pulp's initial pH. It shows potential for temporary moisture resistance, with further improvements needed for high-pH environments.

Key words: glyoxal, polyacrylamide, paper, polymer, water resistance.

One of the most valued properties of paper products is their wet strength, which refers to the paper's ability to retain its structure and mechanical integrity when exposed to moisture. This property is especially crucial for products like tissues, packaging materials, labels, and technical papers that are expected to perform under humid or wet conditions. Without adequate wet strength, paper tends to weaken, disintegrate, or lose its original form when moistened. To achieve the desired wet strength, special polymeric additives are incorporated during the papermaking process, primarily at the “wet end,” where the pulp is still in a slurry form. These wet-strength agents function by forming strong chemical bonds - often covalent - between the cellulose fibers, reinforcing the internal structure of the paper. As a result, the finished product gains not only water resistance but also improved dimensional stability and mechanical durability [2].

The reinforcing mechanism is primarily based on the agent's ability to chemically interact with cellulose or hemicellulose, forming strong covalent bonds between the polymer molecules and the fibers. These bonds complement the natural hydrogen interactions present in dry paper, significantly enhancing the overall wet strength. Because covalent bonds are not disrupted by water, they provide lasting resistance to moisture. This mechanism likely also involves some degree of polymer crosslinking, which creates an additional internal network that further reinforces the paper structure.

Within the protective mechanism, the polymer disperses across the fiber surfaces and crosslinks to form a water-insoluble three-dimensional network. This network envelops fiber contact points,

penetrates the interfiber spaces, and prevents fiber separation upon rewetting. As a result, the paper retains a portion of its original strength even after exposure to water.

In a study conducted at the Department of Ecology and Plant Polymer Technologies, Igor Sikorsky Kyiv Polytechnic Institute, a modified cationic polyacrylamide (MCP) was synthesized using glyoxal, sodium hydroxide, sulfuric acid, and deionized water. The resulting polymer had a high molecular weight and a moderate cationic charge density, making it suitable for improving fiber bonding in paper. Laboratory paper sheets weighing 75 g/m² were produced and treated with various dosages of MCP: 1.05, 2.10, 2.52, 3.15, and 4.20 kg per ton of absolutely dry fiber. These dosages were introduced directly into the pulp suspension to ensure even distribution and interaction with the cellulose fibers. The mechanical properties of the paper were then tested, both in dry and wet conditions. The findings showed that the best results in terms of tensile strength, both in dry and wet states, were achieved at dosages of 2.10 and 2.52 kg/t. At higher dosages (3.15 and 4.20 kg/t), the improvements plateaued, indicating that the polymer's bonding potential had reached its limit. This highlights the importance of optimizing additive levels-not only for performance but also for cost-effectiveness.

The pH level of recycled paper pulp can vary significantly depending on the chemicals used in the original paper production. For instance, the use of calcium carbonate as a filler in primary paper manufacturing often results in an alkaline pH in the recovered fibers. These pH fluctuations are not merely a byproduct of recycling - they can have a profound impact on the effectiveness of chemical additives, particularly those aimed at improving wet strength.

When the pH becomes too high, hydrolysis of aldehyde groups within the additives, such as modified polyacrylamides, may occur. This reaction reduces their ability to form stable covalent bonds with cellulose fibers, weakening the fiber network and undermining the desired reinforcement. Therefore, the ability of wet-strength agents to perform optimally depends strongly on the pH of the pulp suspension during processing.

To better understand this effect, a study was conducted to evaluate the influence of environmental pH on the physical and mechanical properties of paper produced with MCP (Fig.1).

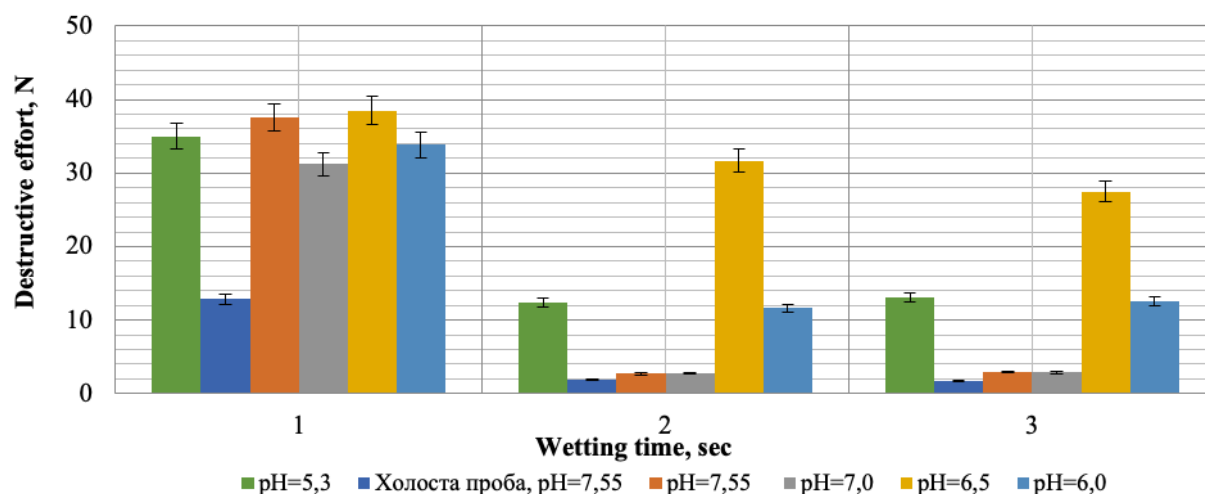


Figure 1. Effect of pH on the mechanical strength of paper samples

Thus, the effectiveness of MCP depends on the pH of the medium and is optimal in the range of 5.5–6.5. Adding the polymer to the waste paper pulp in a given amount does not change the hydrogen index of the waste paper pulp. MCP is a promising agent for providing temporary moisture resistance of paper, especially when produced from waste paper. Further research should be aimed at improving

the polymer structure (crosslink density, molecular weight) to achieve better characteristics at pH > 7, which is relevant for paper and grades containing calcium carbonate filler.

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ПОКРАЩЕННЯ ВОЛОГОСТІЙКОСТІ МАКУЛАТУРНОГО ПАПЕРУ

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Анотація

Влогостійкість є критично важливою властивістю паперу, що забезпечує структурну цілісність у вологих умовах. Для покращення зв'язування волокон було синтезовано модифікований катіонний поліакриламід. Зразки лабораторного паперу, оброблені модифікованим продуктом у дозуванні 2,10–2,52 кг/т, показали оптимальну міцність на розтяг у сухому та вологому стані. Однак коливання рН макулатурної маси, особливо лужні умови, спричинені наповнювачами на основі карбонату кальцію, можуть знизити ефективність добавок шляхом гідролізу альдегідних груп. Дослідження показало, що продукт найкраще працює при рН 5,5–6,5, не змінюючи початкового рН маси. Він демонструє потенціал для забезпечення тимчасової влогостійкості, з подальшими покращеннями, необхідними для середовищ з високим рН.

Ключові слова: гліюксаль, поліакриламід, папір, полімер, водостійкість.