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*Professional paper*

# EFFECT OF ADDITION OF WET-STRENGTH AGENT ON TENSILE STRENGTH OF PAPER

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**ABSTRACT**

Wet-strength paper production is of great significance due to its prominent importance in everyday consumer activities. Recently, market demands for paper with specific properties and purposes are increasing. Production of these paper types is very challenging for the manufacturer since they have to meet very specific demands. Wet-strength paper products include bags that come in contact with moisture and wet products, hygienic and kitchen towels, paper towels, packaging products (packages for liquids, aseptic dishes, and a variety of packaging for food), and other special purposes items (tea bags, coffee filters, paper money, etc.) Throughout this research, the focus was on the effects a wet-strength agent has on the tensile strength of paper. The wet strength property of paper is the ratio between the strength of paper in the wet and dry state. The strength in the dry state comes from the hydrogen bonds present in natural cellulose, while the strength of paper in the wet state requires waterproof (covalent) bonds created by the use of a wet strength agent. The wet strength agent used is a cationic PAE resin. The aim of the work is to determine the optimal amount of agent needed in relation to the required value of the tensile strength property of the paper. The investigation of these influences was carried out on Semi Extensible Standard Kraft type of paper in Natron-Hayat.

**Keywords**: paper, wet strength additive, tensile strength

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## 1. INTRODUCTION

Wet strength paper is paper that holds a significant portion of its original strength (strength in the dry state) after being completely saturated with an aqueous solution. In order to produce this type of paper, which needs to maintain its strength after being made and in a wet state, chemical agents are used. Wet-strength chemicals such as UF-urea formaldehyde, MF-melamine formaldehyde, PAE-polyaminoamide epichlorohydrin, and others are used to develop and maintain the mechanical strength of paper when the paper comes in contact with moisture. According to the chemical composition of these agents, they act either as protective agents by preventing fiber swelling and protecting existing bonds or form new and waterproof bonds through reinforcement mechanisms. In order for the paper to be used for the production of bags, it needs to have extremely good physical and mechanical properties, both in the longitudinal and transverse directions [1]. The need for such high mechanical performance of paper is based on the fact that modern technologies for filling bags and transporting them require high durability of bags [2]. On the other hand, one must always look at the financial viability of the product, which means that the goal is to produce the best possible product with as

little cost as possible. Thus, in order to be competitive in the market, some other subtypes of sack kraft paper have been developed from the basic offer of sack kraft paper, which has its advantages in the production of bags. The wet strength property of paper is the ratio between the strength of paper in the wet and dry state. Unlike the strength in the dry state, which comes from the hydrogen bonds present in natural cellulose, the strength of paper in the wet state requires waterproof (covalent) bonds. Naturally, cellulose contains few covalent bonds, so additives are needed that will affect the formation of these bonds. Polymer resins are most commonly used to increase the strength of wet paper. There are two different Wet strength mechanisms, the protection mechanism, and the amplification mechanism, which are shown in Figure 1 [3].

**Figure 1**. Representation of wet strength mechanism of action: a) protection mechanism, b) amplification mechanism [3]

The protection mechanism involves the diffusion of the wet-strength polymer to the fiber surface where it binds through and around the fibers. In this way, they prevent swelling of the fibers and help preserve covalent bonds when the paper is exposed to water. In contrast, the reinforcement mechanism means that new bonds are formed between the wet-strength polymers and the fibers. Since the dry strength of different types of paper varies according to different parameters such as weight, density, and forces between the fibers, it is difficult to determine the strength in the wet state. Therefore, the wet strength property of paper is usually represented by the ratio between the strength of the paper in the wet and dry state. When paper comes in contact with water, water molecules increase the distance between individual cellulose fibers, so that much of the strength is lost. The paper strength is then only about 10% of the dry strength. This percentage is usually considered to represent the friction force between the residual pulp forces [4].

### 1.1 The Basic Mechanism of Fiber Strength

The strength of the paper depends on the strength of the bond between the individual fibers, the fiber distribution, and the bond (formation).

In the paper, fibers are joined by Van der Waals bonding forces and hydrogen bonds that give the paper mechanical and essential structural strength. Figure 2 shows the hydrogen bonds within and between cellulose fibers [5].

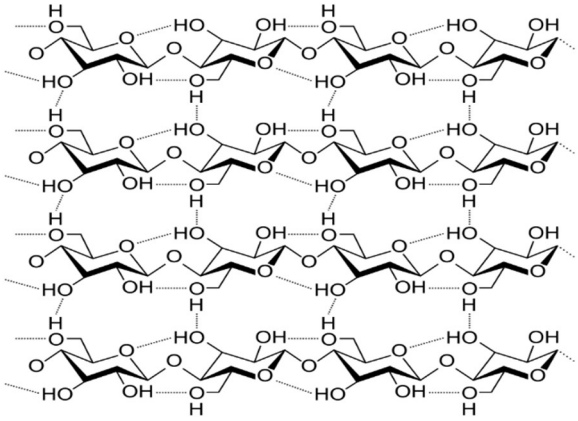

**Figure 2.** Cellulose fiber with hydrogen bonds (dashed lines) within and between cellulose molecules [6]

Binding affects both the development of the structure and the final structure of the paper. The bond between the fibers can be viewed as a zone in which two fibers are so close to each other that molecular entanglement or chemical bonding can occur. Bonds hold the fibers together and therefore contribute to the internal cohesion of the paper [6].

When paper is in contact with water, the hydrogen bonds between the fibers get broken. In this way, the paper loses its mechanical strength. The strength of normal paper after wetting is small, usually 4-10% of its strength when dry. Therefore, additives can be added to cellulose, chemicals for wet strength, which protect the bonds between the fibers and increase the strength of wet paper. The most commonly used agents are polymer resins [7].

## 2. ANALYSIS OF THE IMPACT OF "WET STRENGTH" CHEMICALS ON THE PHYSICAL AND MECHANICAL PROPERTIES OF PAPER

The influence of Wet strength chemicals on the mechanical properties of paper was investigated and the data of 33 reels (460 tons of paper) to which the chemical was added were processed. An individual analysis of each reel of paper was performed. Analysis of NH Wet Strength semi-extensible paper was performed in the internal laboratory at Natron-Hayat in Maglaj using the following methods:

- The standard method of Natron-Hayat NH F 6: Determination of tensile properties, constant load speed method (ISO 1924-1), and constant stretch speed method (ISO 1924-2 and ISO 1924-3) [8,9].
- The standard method of Natron-Hayat NH F 21: Determination of tensile strength after immersion in water [10].

The addition of chemicals to the system was done gradually from a larger amount to a smaller one in order to find the optimal consumption for the required percentage of wet paper strength. The amount of chemical dosed at the pump, at the time of completion of the reel of paper was monitored, after that the paper on the given reel was analyzed according to the previously mentioned methods, and from the obtained data a comparison of the mentioned parameters was made.

Figure 3 shows the amount of added chemical and the direct impact on the property of wet strength paper (md direction of measurement) on the analyzed paper reels.

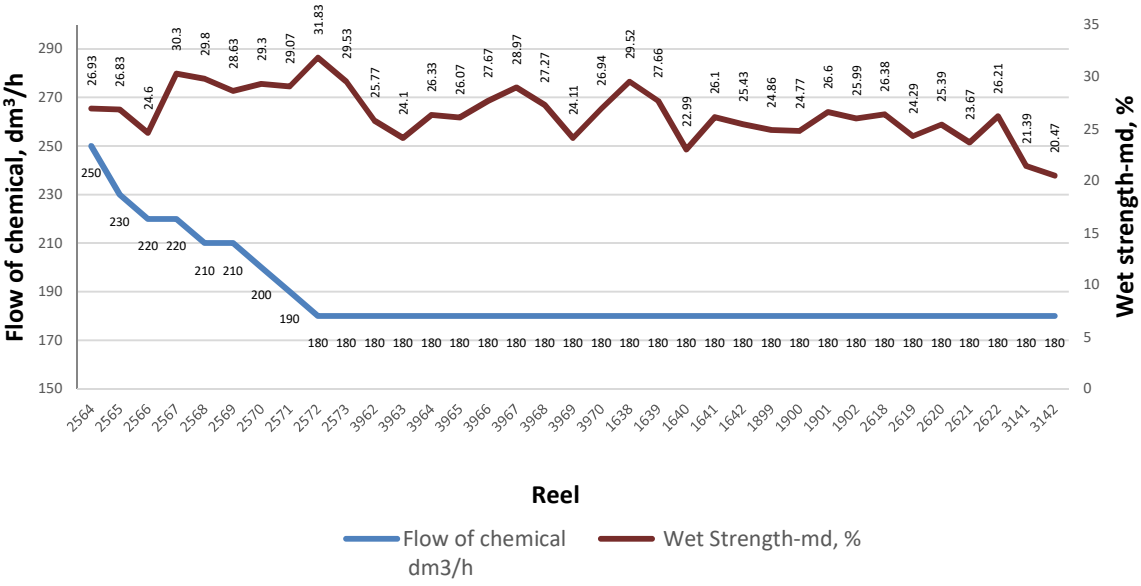


**Figure 3.** Effect of the addition of wet strength chemicals - md paper direction

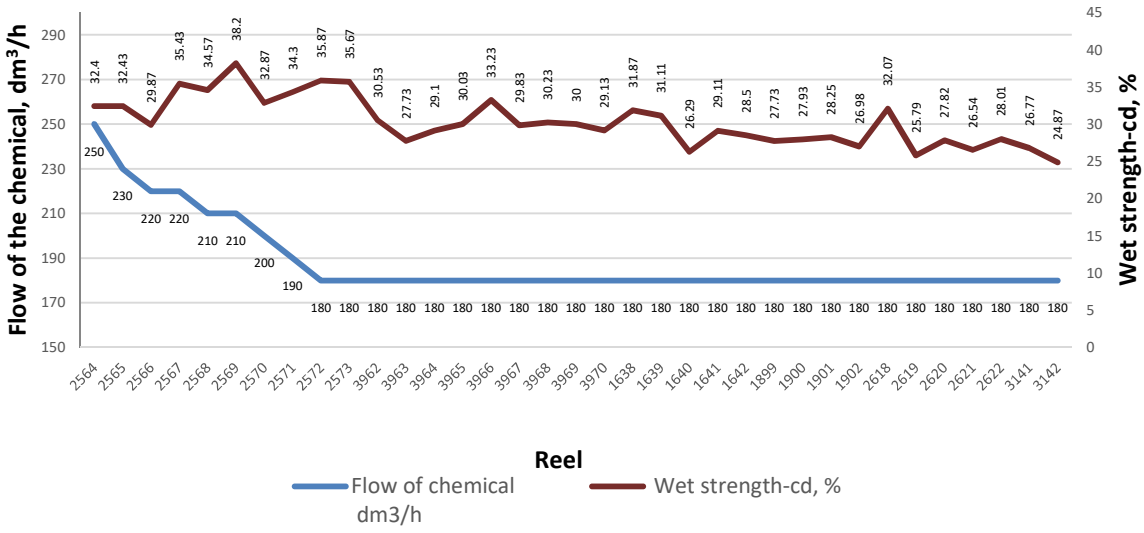


**Figure 4.** Effect of the addition of wet strength chemicals - cd paper direction

Figure 4 shows the amount of added chemicals and the direct impact on the property of wet strength paper (cd direction of measurement) on the analyzed paper reels.
Figures 3 and 4 show how much of an effect adding the chemical has on the wet strength of paper in the machine direction and cross direction. From the presented results the optimal amount of chemical consumption that meets the required wet strength value can be seen. Due to the need to saturate the system, a larger amount of agents was added at the beginning. The measured values of wet strength (in the cd and md direction) were lower on the first analyzed tambourines because it is necessary to saturate the system with the added wet strength additive. Then, smaller amounts of the agent were added and higher values of the wet strength cd and md properties were obtained on the following reels. In order to find the optimal ratio of the amount of added agent and the required value of wet strength, the amount was reduced to 180 dm3/h or 5 kg/t of paper, whereby the required wet strength value was obtained.
In order to have an insight into the influence of chemicals on the physical and mechanical properties of paper, the analysis of semi-extensible paper without the addition of wet-strength chemicals was performed. Figure 5 compares the values of tensile strength, measured in the MD and CD directions of the paper, in the dry and wet state in the case when no wet Strength chemical was used during production.

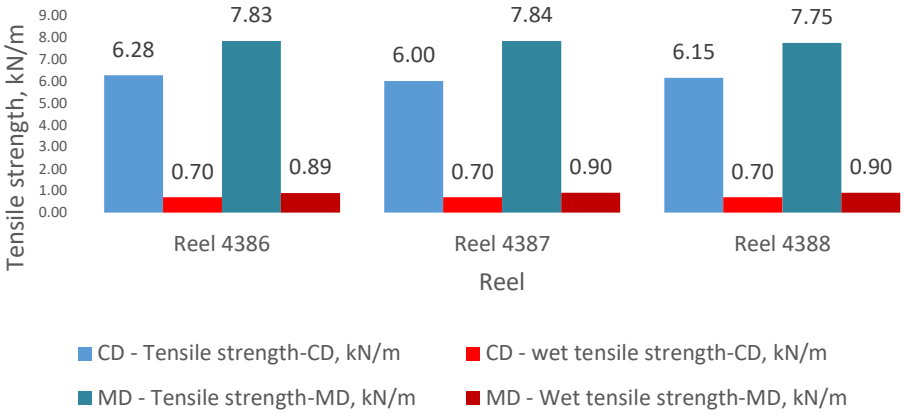


**Figure 5.** Tensile strength in dry and wet state in cd and md direction

Figure 5 shows the measured value of tensile strength in the dry and wet state in two directions of the paper to which no chemicals for wet strength were added. The same analysis was performed on three paper reels (42t paper). The diagram shows that the value of tensile strength in the wet state decreases sharply compared to the value of tensile strength in the dry state. On Figure 5, it can be seen that the mechanical properties of the paper in the dry state are at a high level, but after immersion in water, these values decrease. The reason for the high values of mechanical properties in the dry state for this type of paper is related to the raw material from which it is obtained, long cellulose fibers and their processing by grinding processes, and also with the help of machine orientation. The obtained values of the comparison of tensile strength in the wet and dry states shown in Figure 5 show that there is a decrease in the value by about 90% when the paper is in the wet state.

## 3. CONCLUSION

In this paper, theoretical research was conducted on the production of wet-strength paper and the mechanism of action of wet-strength chemicals. Based on the results of this research and research conducted in the laboratory and industrial conditions in the pulp and paper factory Natron - Hayat, the following conclusions were reached:

- Wet strength semi extensible paper as a paper with strong mechanical properties in the wet state is a sought-after product for all purposes in which the paper comes as packaging for products with a higher percentage of moisture;
- In order to obtain good physical and mechanical properties of paper in the wet state, the use of additional chemicals is required. In order to find the optimal consumption of the chemical, but also to meet the required value of paper strength in the wet state, it was concluded that the optimal value of consumption is 180 $dm^3/h$ or approximately 5 kg/t of paper. The use of new chemicals in each production process further increases the cost of production itself, so the optimal balance must be found between the consumption of funds and the cost-effectiveness of the product.
- In order to prove the impact of chemicals on the product, an analysis of paper without the addition of chemicals was performed. Such a product does not have the strength in the wet state that is needed. By saturating the paper with water, the paper loses its physical and mechanical properties, which is proven by the analyzes in this paper. Chemicals for wet strength are those that lead to the creation of new bonds with fibers and the preservation of physical and mechanical properties when the paper is wet. Analyzes showed that the value of wet paper strength in paper to which wet strength chemicals were not added was 10%, while in paper with the addition of wet strength chemicals, depending on the amount added, this value is 20-35%;
- The impact of the amount of chemicals, i.e. the amount of chemicals consumed in relation to paper production was investigated in this paper and the results were obtained on the optimal amount of consumption per ton of paper, following the internal standard on physical and mechanical properties of paper and economic aspect;
- In order to be competitive with the market, paper mills must follow new trends in production and have papers for specific purposes in their product portfolio, such as wet strength paper.

**Conflicts of Interest**

The authors declare no conflict of interest

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