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# INFLUENCE OF UREA-FORMALDEHYDE OLIGOMER COMPOSITION ON TECHNICAL PAPER PROPERTIES

The article studies the influence of urea-formaldehyde oligomers on technical properties of paper types. The influence of the studied oligomers on the electrokinetic properties and the ability to dehydrate water-fibrous suspensions. Shows the effect of modified oligomers on the hydrophobic and physical-mechanical properties of the paper samples. It was established that the modification of the amino-formaldehyde oligomer lactams ε-aminocaproic acid affects the efficacy of the products obtained for improving the strength of paper.

**Introduction.** Currently urea-formaldehyde oligomers (UFO) are widely used in the pulp and paper industry [1]. Their main task is to give strength to technical types of paper. The main advantages of these oligomers as compared to other synthetic additives are high curing speed, low viscosity under high concentration, storage stability, colorlessness, low cost and abundant resource base. However, UFO are characterized by insufficient solubility in water, slight toxicity and insufficiently high adhesion strength.

Modification of these polymers makes it possible to eliminate such drawbacks. When selecting the modifying agent it's necessary to consider the following: water solubility, non-toxicity, additives availability and chemical nature which makes it possible to participate in chemical interactions with these oligomers. ε-amino caproic acid lactam (ε-aminocaproic lactam) satisfies the above requirements, namely: it is easily soluble in water, has reactive groups, and is neither a carcinogenic nor a toxic substance.

Therefore, the aim of this work was to investigate and to determine the influence of the ε-aminocaproic lactam modified UFO composition on the electrokinetic properties, as well as on hydrophobic and strength properties of the technical paper. It was also necessary to determine the UFO composition drainage capacity of paper pulp.

**Main part**. ε-Aminocaproic lactam modified UFO synthesis was carried out at a constant molar ratio of carbamide to formaldehyde 1 : 2. The quantitative ratio of carbamide to ε-aminocaproic lactam varied in the range of (3 : 1) ... (5 : 1). UFO modification was performed at the last stage of the synthesis at a temperature (40 ± 2)°C. The resulting products had a viscosity of VZ-4 22-25 s at a concentration (57 ± 1)% and a weak-base medium (pH 7.3-8.0), the refractive index being 1.43801.4475.

Samples of the aqueous fibrous slurry from waste paper MC-5B have been obtained to assess the effect of the produced UFO on the properties of paper pulp. These samples contained in their composition a sizing agent based on alkyl ketenes dimers (AKD) (Hydrores 225YP) in the amount of 0.4% of a. d. f. in the combination with a cationic starch (Hi-Cat C 323 A) 0.8% of a. d. f. 1% work solution dosing of the tested oligomer was performed following the continuous cationic starch and sizing component dosing. Contents of the tested oligomer in the aqueous fibrous slurry composition varied from 0 to 2% of a. d. f.

The nature of interaction between the components of the paper pulp was evaluated by the change in ξ - fibre potential, cationic demand (CD) and the drainage capacity of an aqueous fibrous slurry [2], depending on the composition and content of the tested UFO in its composition. Defining ξ-potential and CD was performed using FPA and CAS apparatuses (Germany) respectively.

As is seen from Fig. 1, the change in zeta potential of an aqueous fibrous slurry essentially depends on the content of chemicals in its composition and is of an extreme nature. The negative charge of the fibers is reduced by the action of cationic starch.

Adding the AKD based sizing agent to an aqueous fibrous slurry results in further reduction to the values of isoelectric state (–10 mV) in the fiber surface electronegativity. Subsequent addition of the tested UFO samples, differing by the ε-aminocaproic lactam content in their composition, leads to a slight increase in the negative value of ξ-potential.

It's a good practice to evaluate the effectiveness of auxiliary chemical additives at the mass preparation stage both by the fibre ξ-potential and by the cationic demand indicator. Cationic demand of the paper pulp was assessed in ml of standard cationic polyelectrolyte (Poly-Dadmac), consumed while titrating the filtrate to the endpoint.

Reducing cationic demand of the paper pulp (Fig. 2) on a step by step addition of a cation starch and a sizing agent indicates a decrease of the dissolved and negatively charged particles in the aqueous fibrous slurry, the reduction being accompanied by acceleration of drainage (Fig. 3). This is caused by the system isoelectric state in conditions of the above mentioned chemicals content in the aqueous fibrous slurry composition (Fig. 1).

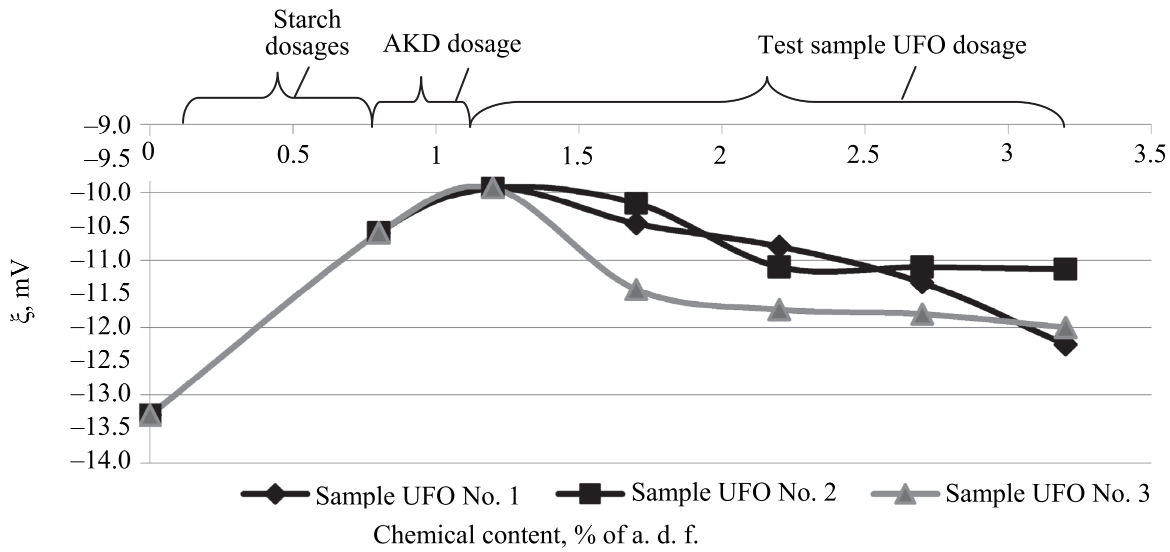


Fig. 1. ξ-potential change of fibres depending on content and UFO composition

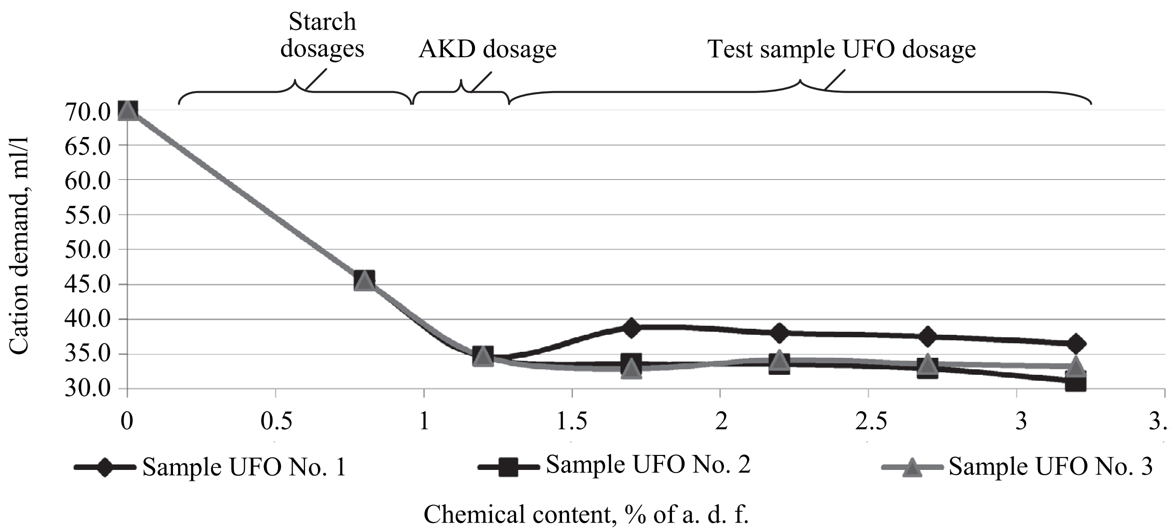


Fig. 2. Cation demand change of the paper pulp depending on the content and UFO composition

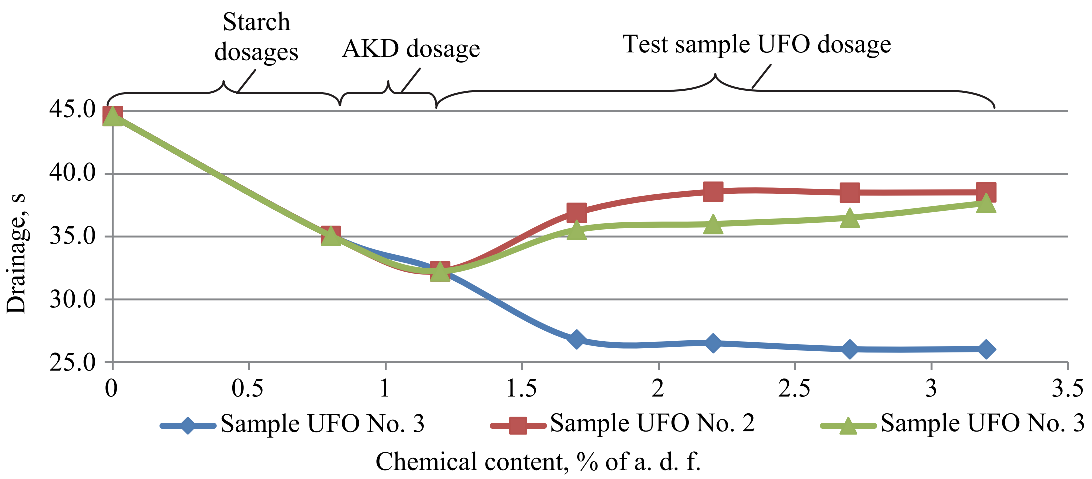


Fig. 3. Change of the paper pulp capacity to drainage depending on the content and UFO composition

**Hydrophobic and physico-mehcanical properties of paper samples containing 0.5% of a. d. f. the tested UFO in the composition**

| Parameter | Tested UFO samples | | |
|---|---|---|---|
| | Sample UFO No. 1 | Sample UFO No. 2 | Sample UFO No. 3 |
| Absorbency, g/m$^2$ | 13.2 | 13.4 | 12.3 |
| Wet strength, % | 13.2 | 9.9 | 8.9 |
| Force, N | 48.0 | 49.4 | 44.3 |
| Tensile strength, kN/m | 3.20 | 3.29 | 2.95 |
| Breaking length, km | 4.41 | 4.73 | 4.30 |
| Tensile energy absorption, J/m$^2$ | 29.6 | 32.3 | 34.1 |
| E-modulus, GPa | 3.434 | 3.309 | 3.005 |
| Tensile stiffness, kN/m | 420.6 | 416.6 | 369.70 |

Subsequent addition of the tested UFO into the paper pulp composition has little influence on the cationic demand parameter. However, this addition provides further acceleration of drainage while using modified UFO, the carbamide- to- ε-aminocaproic lactam ratio being 3 : 1 (sample UFO No. 1).

Comparative analysis of the obtained results showed that the preferred content of the investigated UFO in a paper pulp composition should be 0.5% of a. d. f.. Such content of chemicals provides isoelectric state of the system and a high capacity of paper pulp drainage.

Accordingly, to assess the effect of the investigated UFO on paper properties special samples have been prepared in compliance with the standard technique using sheet-making apparatus Rapid-Ketten. The obtained results characterizing the properties of paper samples are shown in a Table.

As is seen from the table, ε-aminocaproic lactam UFO modification influences the change of breaking length, tensile stiffness, wet strength and other strength characteristics of paper samples. Thus, the largest value of the breaking length 4.73 km is observed with carbamide -to- ε-aminocap roic lactam ratio of 4:1 (sample UFO No. 2). The maximum tensile stiffness is 420.6 kN/m, and wet strength is 13.2% with carbamide -to- ε-aminocaproic lactam ratio of 3 : 1.

**Conclusion.** Thus, the effect of UFO composition on electrokinetic properties, capacity to paper pulp drainage, hydrophobic and strength properties of the technical paper types has been studied.

It was established that UFO modification by ε-amino caproic acid lactam influences the application efficacy of the products obtained to enhance the strength of paper. Apparently, the use of ε-caprolactam in the preparation of urea-formaldehyde oligomers leads to the increase of their reactivity, the formation of a stronger oligomer adhesive bond with the fibers and, hence, the formation of a stronger paper.

## References

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