Improvement of the Mechanical Consistometers for Paper Pulp

Oleksandr Romaniuk, Bohdan Kril, Oleksandr Kril

Automation and Computer – Integrated Technologies Department, Lviv Polytechnic National University, UKRAINE, Lviv, S. Bandery street 12, E-mail: o.m.romaniuk@gmail.com

***Abstract* – The purpose of this work is to improve the rotational and blade type mechanical paper pulp consistometers for enhancement of their metering characteristics and reducing the influence of pulp flow velocity, friction torques in shaft sealing and bearings on the measured pulp consistency. These goals are achieved by algorithmic control of the sensor motion velocity and algorithmic processing of measured data. The designs of upgraded rotational and blade consistometers are presented.**

Keywords – paper pulp consistency measurements, viscosity, rotational consistometer, blade viscometer, paper stock, non-Newtonian liquids, magnetoelectric transducers.

I. Introduction

The papermaking industry in Ukraine begins to regenerate and the volume of production is growing. Prerequisite of the mentioned processes is the easiness of access of the raw materials – the paper pulp, which can be recycled till six times, and a sound liquidity of the manufactured articles – sanitary tissue products, cardboard articles, packaging materials.

The maintaining of the paper pulp preset concentration on the different stages of its preparation during the manufacturing process of the sanitary tissue products or cardboard articles significantly influence the quality and production cost. Continuing consistency control of the paper pulp is the most appropriate to realize by the mechanical consistometers. There exists two types of mechanical consistometers for the paper pulp – rotational, or mixer type, and blade type [1, 2, 3]. Both of them realize indirect consistency measurements by measuring of the paper pulp viscosity. Authors performed the scientific research works to improve the rotational and blade type mechanical paper pulp consistometers for development and further small-quantity production. These goals are achieved by algorithmic control of the sensor motion velocity and algorithmic processing of measured data.

II. Rotational consistometer design

The main difference of the paper pulp rotational consistometer [4, 5], which mechanical scheme is sketched on the Fig. 1 is application of the disk-like form sensitive element with the radial wave – like fins, which can rotate in opposite directions.

By rotation of the sensitive element in turn in the clockwise and anticlockwise directions, and the following algorithmic processing it is possible to decrease the influence of the torque caused by the sensor shaft sealing, by sensor shaft bearings and by additional torque caused by deformation of flow profile in the pipeline on the measured value of the paper pulp viscosity, and associated with it paper pulp consistency. The reversing of direction of the sensitive element rotation and the accurate controle of the sensitive element angular velocity of rotation and associated with it shear rate, at which the viscosity measurements are carried out, is provided by means of the variable speed controller.

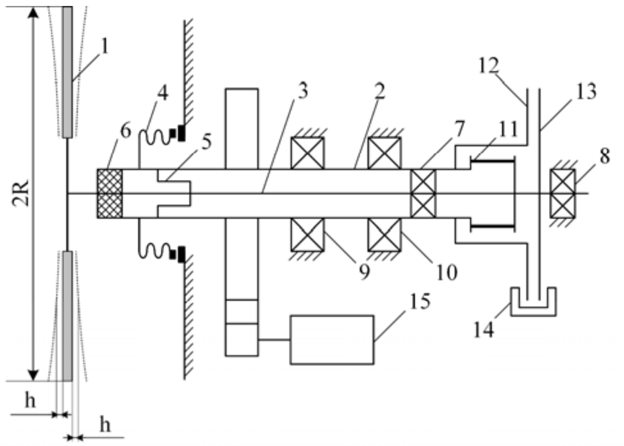

Fig.1 Mechanical scheme of the rotational type paper pulp consistometr. 1 – disk – like sensitive element, 2 – the main hollow shaft, 3 – the sensitive element shaft, 4 – the moving sealing of the main hollow shaft, consisting of bellow and two ring tungsten carbide – cobalt alloy inserts, 5 – elastic sealing in the form of longitudinally goffred thin walled tube, 6 – elastic sealing for protection against loading of the sealing 5, 7,8 – bearings supporting the sensor element shaft, 9,10 – bearings of the main hollow shaft, 11 – torsional spring made of cylindrical rods positioned around the circle, 12 – disc with perforations on the main hollow shaft, 13 – disk with perforations on the shaft of the sensitive element, 14 – optical transducer of the discs displacement angle between the disks 12 and 13, 15 – motor driven by the variable speed controller.

The general feature of the suggested measurement cycles is measurement of the viscous friction torque with gradual approach of the rotation frequency of the sensitive element to the set rotation frequencies. As the frequency increases (approach from below) the torque $M_{\uparrow t}$ is measured. And when the rotation frequency of the sensitive element is decreasing (approach from above) the value of torque $M_{\downarrow t}$ is measured for selected rotation frequency. With this purpose after the measurement is completed and the frequency approaches the rotation frequency Ω from the lower range, the rotation frequency insignificantly increases and stays permanent for a short time after which it decreases back to Ω and the torque value $M_{\downarrow t}$ is measured. The measured torque values are recorded and averaged by applying equation (1).

$$M = \frac{M_{\uparrow t} + M_{\downarrow t}}{2} = M_{cep} \quad (1)$$

The viscous friction torque values that were measured with changing rotation directions and obtained for two different rotation frequencies are averaged with results obtained for direct sensitive element rotation. And then the paper pulp parameters K and n are defined and subsequent conversion of the viscosity value into the measurement units of paper pulp consistency is done.

III. Blade consistometer design

The distinguishing characteristic of the blade paper pulp consistometer, which mechanical scheme is sketched on the Fig. 2 is that the blade 2, fixed on the shaft 4, swings straight and forth in reference for center position across the flux of the paper pulp. The mode of blade motion is defined by the triangle-shape pulse generator 7, and is provided by the following system with the magneto electric transducer 5 as actuating device. If the blade moves in the vicinity of the central blade position, the current over the winding of the magnetoelectric transducer is proportional to viscosity, and appropriately to consistency of the paper pulp. The blade rotates by the shaft in the plane of the paper pulp flux symmetry across the flux, what affords to take into account the paper pulp flow velocity, and to apply the corrections of determined values of viscosity and consistency by algorithmic method.

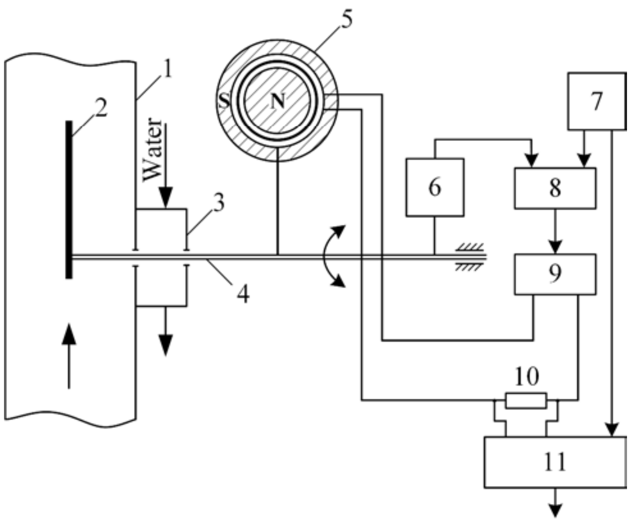

Fig. 2. Schematic diagram of the blade paper pulp consistometer with the paper pulp flow velocity compensation, 1 – the pipe, where the paper pulp flows, 2 – moving blade, 3 – “wet” shaft sealing, 4 – shaft, on the left side of which sensitive blade is fixed, and on the right – the lever arm with winding of the magnetoelectric transducer, 5 – magnet system of the magnetoelectric transducer, 6 – sensing shaft rotation angle transducer, 7 – triangle – shape pulse geneator, 8 – differential amplifier, 9 – power amplifier, 10 – resistor for measuring the strength of current throught the winding of magnetoelectric transducer, 11 – the microcontroller system for information processing, and connections with display system and industrial process control system.

The sheet-oriented realization on the electronic assembly units of the measuring circuit has no special features. Triangular pulse generator can generate one constant frequency or, for broadening of the functionality two or three preset frequencies that can be switched by a microcontroller. Two preset frequencies are used to extend the measuring range and the last, much higher value – is used for service operation – periodical blade shake – up to clean the blade from possibly adhering long fibered materials.

Conclusion

In designed rotational and blade type paper pulp consistometers the same values of shear rate can be set for measuring of viscosity of the non-Newtonian liquids, to which the paper pulp belongs. As a result, the calibration curves on consistency dependence and fiber composition dependence becomes as nearly as possible, and the same calibration curves can be used for temperature compensation. Together with the mentioned above compensation of the influence of the flow velocity and influences of torques, arisen by sealings, this allows to enhance the precision of the paper pulp consistency measurements.

The reversing of direction of the sensitive element rotation allows to reduce additional torque caused by deformation of flow profile in the pipeline on the measured value of the paper pulp viscosity, and associated with it paper pulp consistency. The reversing of direction of the sensitive element rotation and the accurate controle of the sensitive element angular velocity of rotation and associated with it shear rate, at which the viscosity measurements are carried out, is provided by means of the variable speed controller.

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