Development of Analyzer for Paper Stock Concentration Measurement

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Abstract – Measurement and regulation of paper stock concentration is of great importance in pulp and paper industry Deviations of concentration from the optimal value lead to deterioration of the product quality and can damage technological equipment of the factory. As a result a necessity of paper stock concentration measurement arises. In this article the improved rotational method of paper stock concentration measurement is examined, that is based on indirect measurement of concentration by viscosity. The influence of temperature on the measurement results was studied. The main sources of errors in concentration measurement by means of viscometer method were analyzed. A principle of improving accuracy of a paper stock rotational consistency meter is presented and a structural scheme of its realization is designed.

Key words – concentration, viscosity, consistency meter, rotational viscometer, paper stock, non-Newtonian fluid.

I. Methods of the Pulp Concentration Measurements

The condition of pulp and paper industry is inseparably associated with the general industrial level of countries, when one of the indicators is the multiplicity of paper stock use in this recycling production. It is recognized that paper stock can be recycled up to six times. The approximate relationship between the major components of raw materials in recent years in world production of paper and paperboard following: waste paper is up to 50 % of raw materials for the paper industry and cellulose – only 27.5 %.

One of the important parameters in pulp and paper industry is paper stock concentration measurement. This measurement is employed at all stages of paper manufacturing from waste paper dissolving to paper-making machine [1]. Deviations of concentration from the set values leads to technological process failures, affects quality of the product and economic performance of manufacture.

The main methods of measuring paper stock concentration include blade, rotational, optical and ultrasound methods [2]. The most widespread consistency meters are blade and rotational ones that work on the principle of measuring paper stock viscosity. This is one of the known cases of indirect measurement of fluid concentration by its viscosity. Instruments, operating by above mentioned methods, can be used as a pulp consistency meters only when some special condition is realized.

Rotational methods based on measurement of torque that occurs on the rotor axis (cylinder, disk, cone etc.) that is rotating in the medium measured. There are constructions of devices with one rotating element, but those with two elements are more promising. One of them has a propeller that constantly rotates and pulls the other element - impeller - through the measured medium. The impeller's turning angle depends on viscosity, and correspondingly on pulp concentration.

II. Structural Scheme of Paper Stock Concentration Meter

The following factors impact the result of viscosity measurements: pressure, temperature, flow type (laminar or turbulent). Fluid viscosity undergoes little change with pressure growth, but strongly depends on the temperature [3].

Viscosity of non-Newtonian liquids decreases exponentially as the absolute temperature T increases:

$$\mu = A\exp\left(\Delta U/kT\right), \qquad (1)$$

where A – is a pre-exponential factor (it's value has a little dependence on shear stress and temperature), ΔU – energy of viscous flow activation, that relates to one kinetic unit. It depends not only from the system structure but also from share stress and shear rate, $k = 1.3806488\times10^{-23}\ J/K$ – Boltzmann constant [4]. Change of viscosity value may be up to few percent per one degree. Thus for viscosity measurement temperature should be accurately defined and stabilized.

Fluids which viscosity does not depend on flow speed gradient are known as perfectly viscous or Newtonian fluids. Viscosity of non-Newtonian fluids depends on the gradient of the flow speed (shear rate). Depending on the character of flow properties non-Newtonian fluids are divided into pseudoplastic, plastic, dilatant, thixotropic and rheopectic. Paper stock belongs to pseudoplastic fluids that are characterised by reduction of viscosity and increase of shear stress. The typical diagram of shear stress on shear rate for Newtonian and non-Newtonian pseudoplastic fluids is presented on Fig.1.

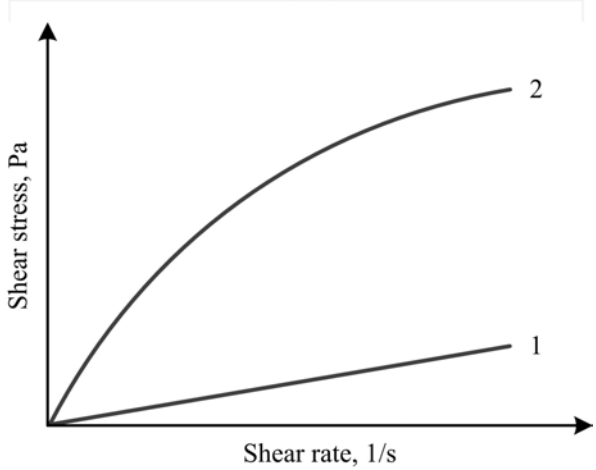

Fig. 1. Dependence of shear stress on shear rate for Newtonian fluids (1) and non-Newtonian pseudoplastic fluids (2)

Let's examine the main sources of errors in measurement of paper stock concentration by means of rotary viscometer. Viscosity depends to a great extent on temperature E. 1, therefore temperature changes cause significant measurement errors. Presence of fine gas

bubbles significantly increases viscosity. Fibrous inclusions and paper stock structures wrap around rotor and drive axis. At significant fluid flow speed gradients certain flow laminarity failures are possible in rotary viscometers. It is recommended not to use rotary viscometers in flows with Reynolds number higher than 1000. Also, during viscosity measurement of a fluid with a high flow speed gradient by means of a rotary viscometer heating occurs, created by internal friction of the substance. Rotary method belongs to mechanical measurement methods to which instrumentation error is appropriated. Due to these errors the sensor element can't determine small changes of concentration in mechanical methods of viscosity measurement.

III. Structural Scheme of Paper Stock Concentration Meter

To measure paper stock concentration by its viscosity it is most reasonable to measure temperature and make correspondent correction in algorithmic way.

Fig. 2 shows the structural scheme of a paper stock consistency meter.

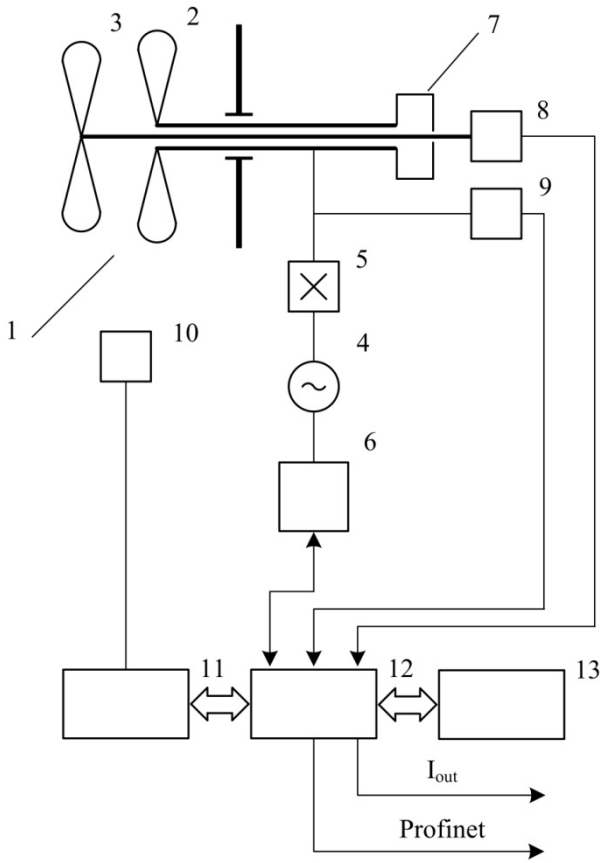

Fig. 2. Structural scheme of paper stock concentration meter
1 – medium measured; 2 – propeller; 3 – impeller; 4 – engine; 5 – toothed belt transmission; 6 – frequency converter; 7 – resilient torsion element; 8, 9 – rotary encoder; 10 – resistance thermometer; 11 – temperature measuring module; 12 – controller; 13 – operator panel

We studied an analyzer for paper stock concentration measurement that realizes rotational method with two rotating elements – propeller and impeller. The main difference between this option and known designs is that measurements are done with two different values of propeller rotation speed and two different directions of rotation. Such decision allows to reduce errors in measurement of non-Newtonian fluids viscosity value, to which paper stock belongs. Non-Newtonian fluids have non-linear character of rheogram, i.e. dependence of share stress on shear rate. Therefore in order to increase accuracy of viscosity assessment shear stress should be measured with at least two different values of shear rate. For this purpose a frequency changer is used to power the engine that rotates propeller through the belt transmission. Measurement is done at 30 and 60 Hz frequencies of engine power both in direct and reverse directions of rotation. This option also allowes to take into account errors caused by mechanical elements of the machine, e.g. sealing glands of the rotating elements, hysteresis of the resilient torsion element that creates the opposing torque.

The most reasonable is realization of similar short-batch devices with a high volume of algorithmic processing of measurement results based on low-power free-programmable logical controllers. This design is done using a S7-1200 Siemens controller. Such solution enables reducing costs of short-batch device and streamlining its design for specialists who are specialised in technological measurements and technological process automatization.

Conclusion

A principle of improving accuracy of a paper stock rotation consistency meter was proposed and a structural scheme of its realization on a low-power free-programmable logical controller was designed. A paper stock consistency meter based on this principle can be used in automatized control systems for technological processes in pulp and paper industry.

References

[1] Tehnologija celjulozno-bumazhnogo proizvodstva [Technology of pulp and paper production], vol. 1. Syr'e i proizvodstvo polufabrikatov [Raw materials and production of semi-finished products], Politehnika Publ., Saint Petersburg, 2004.

[2] Instrument engineers handbook: Process Measurements and Analysis, 4th ed., vol. 1. Bela G. Liptak. ISA, The Instrumentation, Systems, and Automation Society, 2003.

[3] P. Profos, "Izmerenija v promyshlennosti" ["Measurements in the industry"], vol. 2, "Sposoby izmerenija i aparatura" ["Measuring methods and instruments"], Moscow: Metallurgija Publ., 1990.

[4] V. V Nyzhnyk and T.Iu. Nyzhnyk, "Fizychna khimiia polimeriv" ["Physical chemistry of polymers"], Kyiv, Ukraine: Fitosotsiotsentr Publ., 2009.