Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Volume 21, No. 1, ISSN 1726-9679
ISBN 978-3-901509-73-5, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2010
Make Harmony Between Technology and Nature, and Your Mind will Fly Free as a Bird
*Young Researches and Scientist Paper / * Supervisor, Mentor*

MEASURING THE NIP FORCES IN ROLLER SYSTEMS USING PIEZOELECTRIC PAINT

VOICU, M[ariana] - C[laudia]; SCHMIDT, R[einhard]*; LAMMEN, B[enno]* & MANIU, I[nocentiu]

Abstract: *To improve the efficiency of printing or coating processes for paper products the velocity of the web and the roller width can be increased. However, these measures bring about deformations of the rollers, heating effects and streak print defects due to undesirable oscillations. This paper describes a new sensor technology for measuring the nip pressure for an optimal adjustment of special rollers in a roller system. The sensor is made of piezoelectric paint. It is applied underneath the elastomer covering of the rollers and does not affect mechanical features or cause a fall off in the quality of the product.*
Key words: *piezoelectric paint, pressure sensor, rollers*

1. INTRODUCTION

This paper presents new sensor technology for measuring the axial and circumferential distribution of contact pressure along the nip. The sensors are applied underneath the elastomer covering of the rollers and must affect mechanical features or cause a fall off in the quality of the product. In the paper a new measurement technique, the piezoelectric paint, is described and test results are presented. The piezoelectric paint seems to fulfil all requirements in an ideal way.

The work presented in this paper contributes to a research project which aims to enhance the productivity of printing and coating processes at equal or improved quality standards by means of innovative technology.

In the industry, there are not efficient methods for online monitoring and optimal adjustment of roller systems. Fuji sells pressure paper that becomes color gradations by pressing of it. (CMV, 2010) describes a system to measure distribution of the pressure in the nip by contacting of two rollers. Both methods are applicable for a single test but not for online monitoring of nip pressure.

On the market there are piezoelectric film sensors that consist of rectangular piezoceramic rods sandwiched between layers of adhesive and electroded polyimide film (smart-material, 2010). They measure distributed solid-state deflection. The film can be a sensor as well as an actuator. The disadvantage is that they are quiet expensive and cannot be bended in a tight radius.

2. PRESSURE SENSORS APPLICABLE UNDER ELASTOMER COATING

The sensor described in this paper is not directly available on the market. It shall measure the rapid change of pressure along the nip during operation. The sensor must be thin and applicable to curved surfaces underneath the flexible plate without affecting the quality of printing image in the flexography and it should be easy to produce, inexpensive and robust.

3. PIEZOELECTRIC PAINT SENSORS

The piezoelectric paint contains a piezoelectric material, which creates a measurable charge under force or deformation. Piezoelectric sensors are limited to dynamical measurements because their output signal decays in milliseconds.

Piezoelectric paint is a thick-film material used to make dynamic strain sensors to measure vibration (Hale et al., 2005) or to measure pressure. A high quantity of lead zirconate-titanate (PZT) particles 1 μm in diameter was mixed into a water-based paint (Raptis et al., 2004), which can be sprayed or coated on any conductive flat or uneven surface. Successful laboratory tests of the piezoelectric paint have already been realized at the University of Newcastle upon Tyne supervised by Prof. J.M. Hale.

Some problems had to be overcome when applying the water-paint directly on the steel surface. The steel rusted and the paint lost contact. So the piezoelectric paint has been coated by a copper film as shown in fig. 1. The paint creates a dielectric substrate of the piezoelectric sensor, which is actually a plane capacitor. The thickness of the piezoelectric paint is 90 μm, and it is important to achieve a uniform substrate thickness in order to obtain a sensor with a homogeneous sensitivity. The sensor will be poled by applying a high-voltage source onto sensor's wires to orientate the crystal structure of piezoelectric material. Good results are obtained by using a 300 V electrical voltage by a room temperature of 25°C.

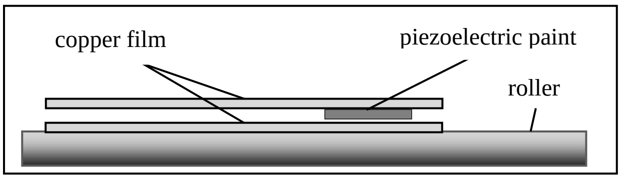

Fig. 1. Piezoelectric paint sensor

4. TESTS OF THE PIEZOELCTRIC SENSORS

Piezoelectric sensors have been tested in several ways:

The dynamic behaviour of piezoelectric sensors has been tested with the test set-up shown in fig.2. An electrodynamik shaker loads the piezoelectric sensor with sinusoidal forces. The amplitude and the frequency of the sinus functions have been varied. Between shaker and piezoelectric paint there is a calibrated force sensor, that measures the same forces as the piezoelectric paint.

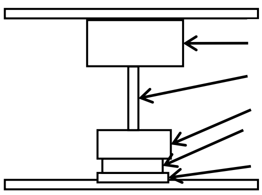

Fig. 2. Test set-up for dynamic measurement

The second test rig presented in fig. 3 simulates a coating or printing machine and is used to investigate the sensor's efficiency when it is applied under the elastomer covering. It contains a pneumatic cylinder (4) which presses the load roller (anilox roll) (1) against the rubber coated roller (plate cylinder) (2) by applying a defined force to (1). Both move to the supporting roller (impression cylinder) (3) until desired contact pressure is achieved. The force sensor (5) is the reference for sensor's calibration.

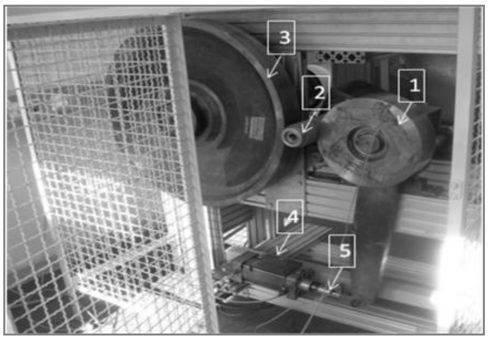

Fig. 3. Test rig with sensor under elastomer covering
1-load roller, 2-rubber roller, 3-supporting roller, 4-pneumatic cylinder, 5-force sensor

5. TEST RESULTS

Dynamical tests with sinus wave forces show a good correlation between the normalized amplitudes from the calibrated sensors and the piezoelectric paint. Fig. 4 shows examplarily the results for a shaker excitation with 7 Hz frequency and 1 V electrical voltage.

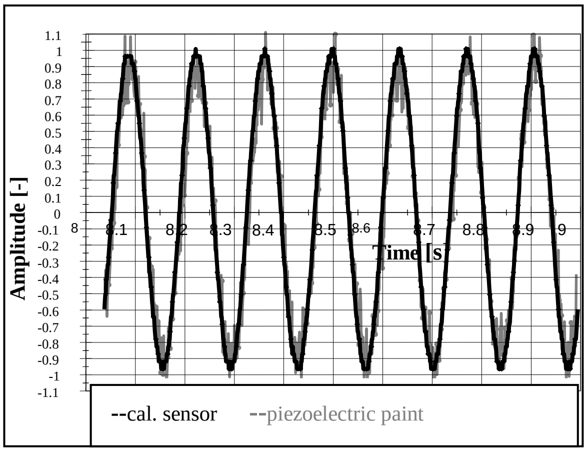

Fig. 4. Correlation between calibrated sensor and piezoelectric paint

Tests had been carried out with different frequencies up to 500 Hz and different amplitudes. All measurements show a very good correlation between the calibrated force sensor and the new piezoelectric paint sensor. As shown in table 1, the amplitude increases linear with force sensors signals.

	20 Hz		
Excitation	1V	2V	2.5V
calib. sensor	1.32	2.76	3.57
piezoel. paint	3.86	8.05	10.47

Tab. 1. Test results of dynamic measurements

Measurements on the test rig presented in fig. 3 indicate that the sensor is able to measure the rapid change of the pressure in the nip.

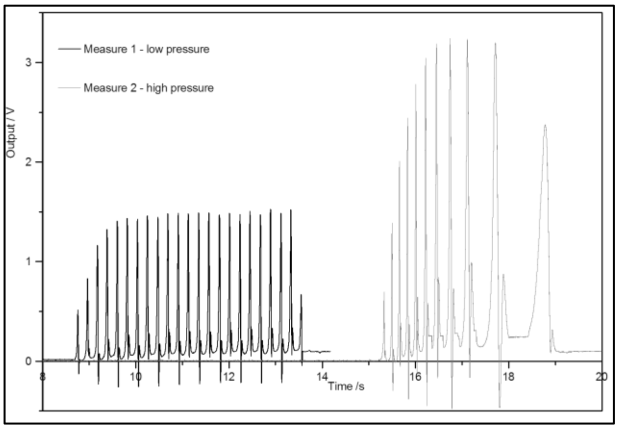

Fig. 5. Piezoelectric paint under elastomer coating– the nip pressure is first increasing and then decreasing

Each time the sensor passes the nip a rapid increase of pressure can be identified and the amplitude of the nip pressure is increasing by bringing the three rotatable rollers in contact and decreasing when the pressure disappears.

6. CONCLUSION AND OUTLOOK

Starting from a set of special requirements for developing an adequate sensor in order to measure the pressure distribution in the nip of a system of rubber coated rollers, a new sensor technology is presented in this paper. It could be demonstrated that the piezoelectric paint shows promising results and good correspondence with the control measurements with a calibrate force sensor for the test set-up with the dircet force application as well as for the test set-up with sensors applied under the rubber coating. So a solution has been found for an application of the sensor without affecting the printing image.

The next steps will be the improvement of the new developed sensors and of the calibration procedure for the sensors after implementation in the rubber coated roller. The sensor signals will be implemented in an active control loop (Gabbert et al., 2008) to damp the vibrations of coated rollers.

7. ACKNOWLEDGEMENTS

The authors wish to thank EFRE with the Ministry for Science and Culture of the land Lower Saxony for the granted sponsorship. Furthermore the authors thank Prof. Hale for providing the piezoelectric paint.

8. REFERENCES

Gabbert, U.; Nestorovic´, T.; Wuchatsch, J. (2008). Methods and possibilities of a virtual design for actively controlled smart systems, *Computers and Structures*, Vol. 86, pp. 240–250

Hale, J. M.; White, J. R.; Stephenson, R & Liu, F. (2005). Development of piezoelectric paint thick-film vibration sensors, *Proceedings of IMechE*, Vol. 219 Part C: J. Mechanical Engineering Science 2005

Raptis, P.N.; Stephenson, R.; Hale, J.M.; White, J.R. (2004). Effects of exposure of piezoelectric paint to water and salt solution, *Journal of Materials Science*, Vol. 39, pp. 6079-6081

*** (2010) http://www.smart-material.com, *Accessed on: 2010-05-10*

*** (2010) http://www.cmv.de/iscan.php, *Accessed on: 2010-06-13*