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A. Bojtos / A. Huba

Transparent Silicone Rubber Used for Optical force transducer

Abstract. The paper shows the newest result of our optical research in connection with silicone rubber and shows the possibility of its usage for optical strain and force sensor, using its birefringence.

Optomechanical sensors for force, strain, and torque, work usually on the basis of the optogate. The measurement of the mechanical quantities in case of these sensors can be lead back to the measurement of the light intensity.

Over the usage of silicone rubber as structural material, the “intelligent” behaviour becomes more and more important. In this case the question arises whether its optical properties change by the effect of mechanical load or deformation?

We support in this paper with practical results that the high elastic optical silicon rubber material is suitable for the application as strain or force sensor for special tasks like in case of large deformations.

Keywords: sensor, silicone rubber, birefringence, optical stress analysis.

Introduction

The conceptual possibility of the usage of the photoelastic effect for mechanical load (force, strain) sensor [3] is long known. But its usage has been put into the background by the better parameters of the alternative solutions. More and more publication appeared lately discussing the application of the optical fibre as a mechanical load sensor. There are experiments among them, which use the birefringence of the optical fibre for the measurement of the force [4, 5].

The common feature of the above mentioned devices is, that their construction is rather stiff and they can not be applied in case of large deformations.

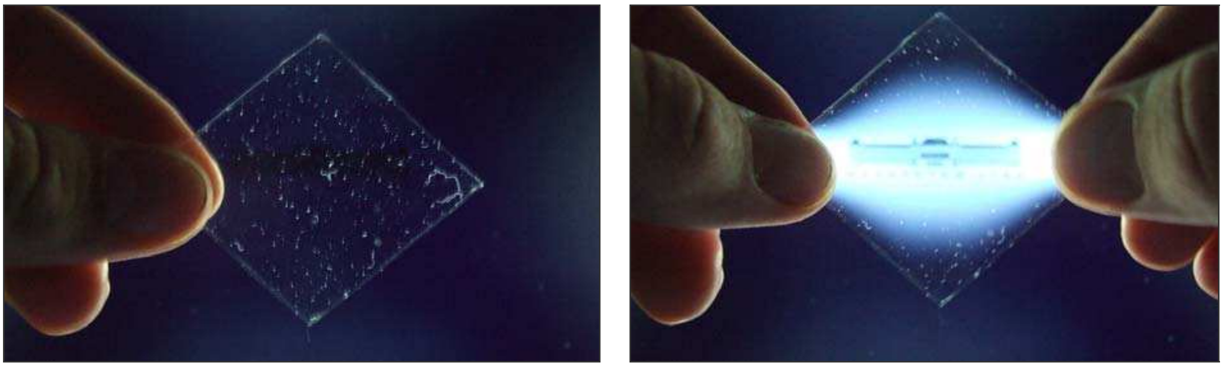
Our aim is to develop a flexible strain and force sensor from silicone rubber, that is suitable – using its special flexibility – for applications which traditional sensors can not fulfil. For example for the measurement of strain of elastic materials.

Some translucent and transparent silicon rubber types were tested to understand their optical properties. As the first step the properties of these materials were examined without mechanical load. As the second step the properties were measured with various amount of deformation. Transmission, reflection and photostress analysis were performed. And a new method and an instrument were developed to measure the value of the birefringent of the deformed material.

The following silicone elastomer was examined: NUSIL® MED-6755, 35 Sh A hardness, optically clear, two-componentsilicone with addition cure, refractive index: 1.462. It was observed that the birefringence effect of the NUSIL® MED-6755 optically clear silicone rubber makes this material applicable as a strain sensor. NUSIL® MED-4020, /4035 materials were also tested but their optical properties do not allow them to be applied as strain sensor according to the test results. For this reason the paper only points out the result of the NUSIL® MED-6755.

Measurement of the optical activity of the silicone rubber

The principle of photostress analysis is the birefringence of the amorphous structured transparent materials [1, 2]. Between two crossed polar filters the colour of silicone rubber changes by deformation. Its birefringence made the polarized light in the background visible (*Fig. 1,*). This experience showed that the deformed silicone rubber is birefringent.



a.) *b.)*

Fig. 1, Between two crossed polarisation state polar filters the colour of silicone rubber is changed by deformation. b.) Its birefringent made to visible the polarized light emitter background.

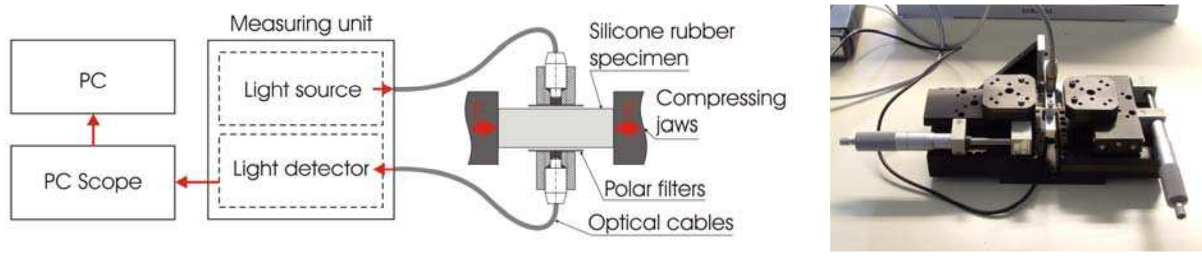


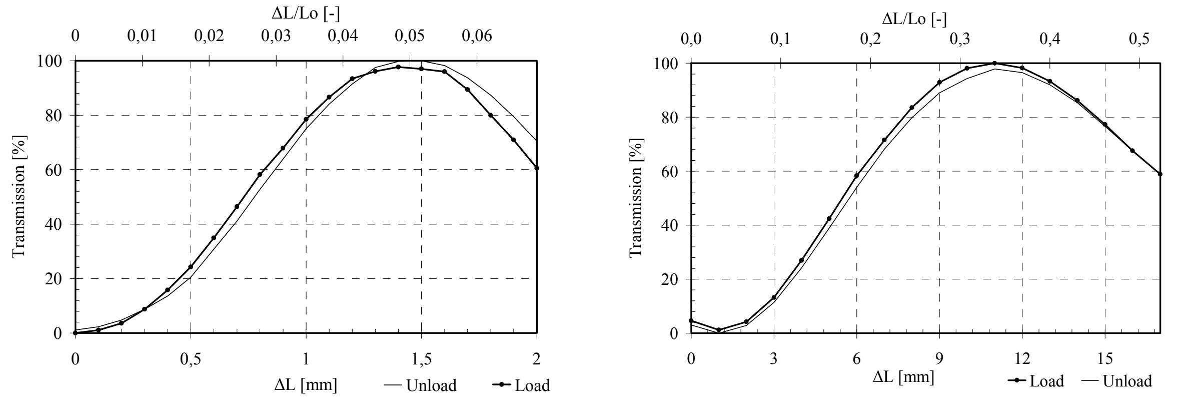
Fig. 2, Measurement set and the instrument to measure the optical activity of the specimens.

An equipment was designed (*Fig. 2*) which ensured the measuring of transmission in a small area where the stress was relatively homogeneous. And the change of transmission as a function of time also could be measured. Contrary to the spectrophotometer it could not be measured in a range of wavelength continuously, but at some discrete wavelengths. As light source we used white and colour LEDs *(Blue 470, Green 520, Yellow 588, Red 632 nm)*. Colour LED has a very narrow spectral emission, its half-width about *25-40 nm*, this light is almost monochromatic. We also used a LASER light source *(647 nm)*, it is theoretically monochromatic and coherent. The photodiode that we used can detect the light intensity in range of visible light.

The deforming of the specimens was performed by the instrument used which includes a fine positioning platform.

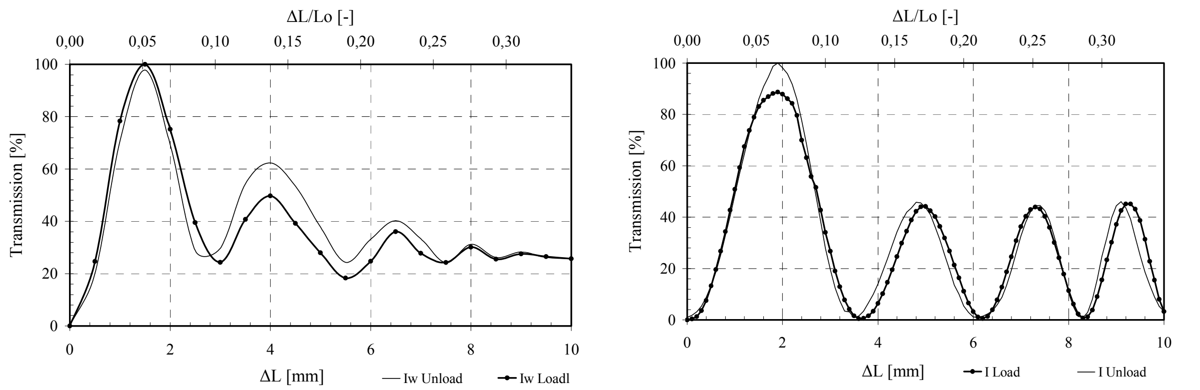
Compressed *(10x10x29 mm)* and stretched specimens *(40x40x3 mm)* were examined. Both test showed similar results, the deformation of silicone rubber caused the increasing of the light intensity. Behind the maximum point the intensity decreased. When increasing the deformation it was observed that this effect cyclically repeated *(Fig. 4)*.

The tests show that the photoelasticity of the transparent silicone rubber is applicable for the measure of external mechanical load like deformation, force or torque (with an applicable transducer). The first – almost linear – section of the characteristics should be used to measure. The measuring instrument has to be calibrated.



a.) *b.)*

Fig. 3. Relative intensity of the transmitted light as a function of deformation. The light source was a white LED. a.) Detail of the transmission of the specimen from the compression test. b.) Transmission of the specimen from the tension test.



a.) *b.)*

Fig. 4, Transmission of the specimen from the compression test. Relative intensity of the transmitted light as a function of deformation. The light source was a white LED (a.) and a red LASER(b.)

Cyclic test with deformation exciting

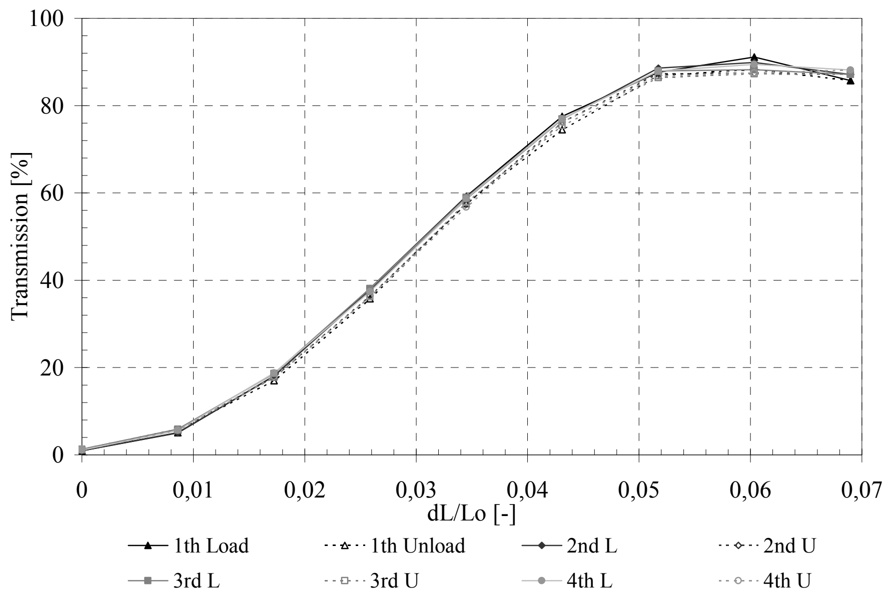


Fig. 5. Cyclic measurement of the light intensity as a function of deformation.

A cyclic test was performed to find out whether the material has optical hysteresis, drift or other measurement errors. The measurement showed that the largest standard deviation was *1.38 %* at the maximum point, and we can see that the reason for the deviation is the separation of the upload curves (continuous) and the unload curves (dotted). The reason of this separation is the friction between the specimen and the measuring frame. To reduce the friction we applied silicone oil to lubricate.

To build a deformation or force sensor we should avoid the friction in the system and we should use the first (almost linear) section of the curve. We can configure the sensor for a wide measurement range by the changing of the dimension of the silicone rubber part.

Force transducer design

A force transducer was designed *(Fig. 6)* by using transparent silicone rubber. The transducer consists of two main parts. The first one is the measuring head, this contains the silicone rubber deformation element and the covering for leading the force in. The other part is the measuring adapter which contains the light source *(647 nm LASER diode)*, photodiodes and a beam splitter prism to make reference beam. The two parts are connected to each other with a multimode optic fibre *(62.6 / 125 nm)*. This set makes the transducer suitable for some special application, which does not allow the usage of metal parts or electric current.

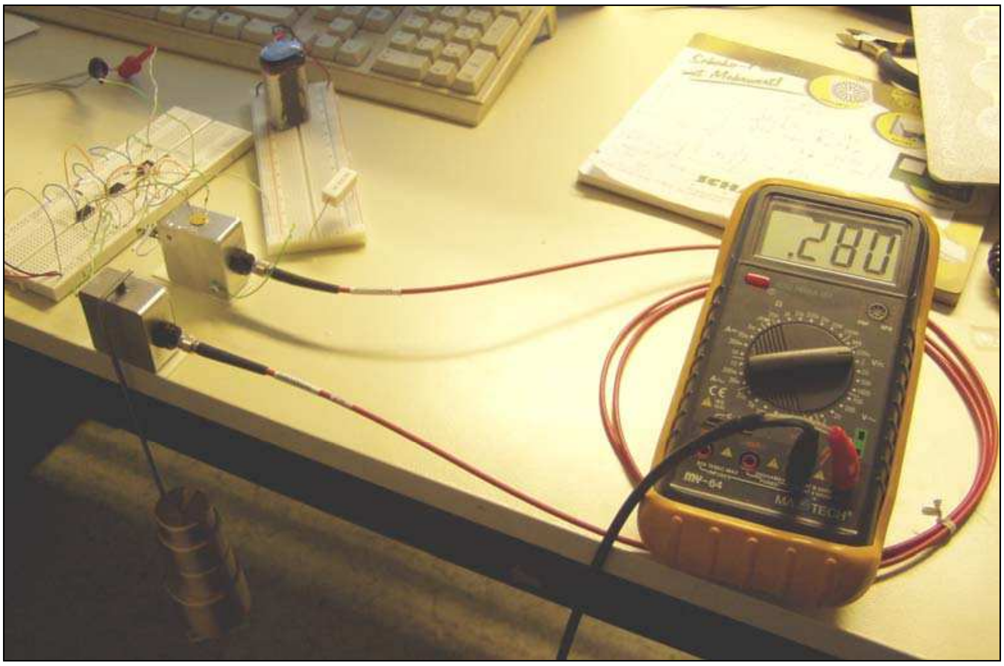
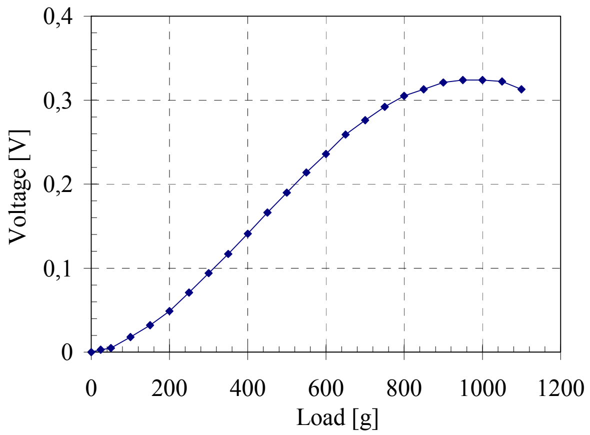
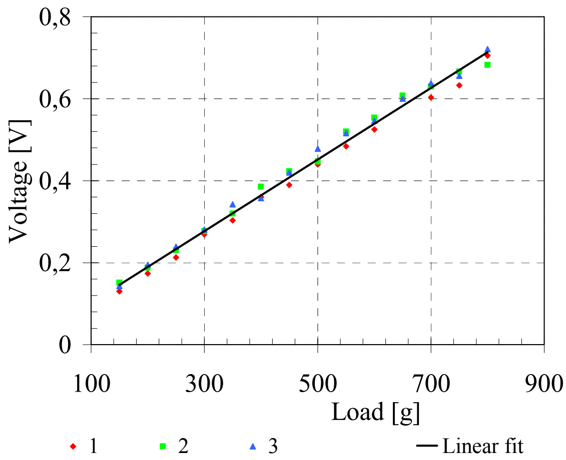


Fig. 6, Verification of the force sensor with calibrated masses.

Some tests were performed with the force transducer to understand its statistical parameters, like the standard deviation and the repeatability. The tests were performed in three series with random load *(Fig. 7/b)*. The graph shows that the standard deviation is larger than in the case of deformation exciting *(Fig. 5)*. The reason of this might be the creep of the rubber, to find the reason for this the investigation is still in process.



a.)



b.)

Fig. 7, Result of the validation of the force sensor. a.) Ordered loading. b.) Random loading in three series.

Conclusions

Some experiments were performed with the optically clear silicone rubber and we found that the changing of the transmitted and the reflected light is not significant (10 – 15 %) by deformation.

In polariscope the deformed silicone rubber showed a more significant change of the transmitted light. Its cyclical characteristics *(Fig. 5/b)* need further evaluation.

According to the tests the examined silicone rubber is an optically active material and it shows photoelasticity. This effect makes this material applicable to be used as a load sensor. An instrument was designed for measuring the photoelasticity of the silicone rubber.

A force transducer was designed by using transparent silicone rubber. Some tests were performed with the force transducer which show that the standard deviation is larger in the case of force exciting than in the case of deformation exciting, to find the reason for this the investigation is still in process.

Acknowledgement

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References:

[1] Thamm , Ludwig, Huszár, Szántó. *Experimental Methods of the Mechanics (in Hungarian)*, Műszaki Könyvkiadó, Budapest: 1968, PP: 218-296

[2] F. Thamm Photostress Examination of Transparent Polymer Parts (in Hungarian), Műszaki Kiadványsorozat / Gépipari Tudományos Egyesület, Budapest: 92/1972

[3] G. Halász, A. Huba. Műszaki mérések. Budapest: Műegyetemi Kiadó 2003.

[4] K. T. V. Grattan, B. T. Mggitt. Optical Fiber Sensor Technology. London: Chapman-Hall 1995.

[5] Dr. Ábrahám György. Optika. Budapest: Panem-McGraw-Hill 1997.

[6] Bárány Nándor, Mitnyán László. Optimechanikai Műszerek. Budapest: Műszaki Könyvkiadó 1961.

[7] Dr. Bodor Géza: A polimerek szerkezettana. Budapest: Műszaki könyvkiadó 1982.

[8] G. Liu, S.L. Chuang. Polarimetric optical fiber weight sensor. Sensors and Actuators 1998;69:143-147

[9] B.-J. Peng, Y. Zhao, J. Yang, M. Zhao. Pressure sensor based on a free elastic cylinder and birefringence effect on an FBG with temperature-compensation. Measurement 2005;38:176–180 [14] Huba A., Molnár L., Valenta L. Szilikon-elasztomer anyagok tulajdonságai és konstrukciós célú alkalmazásai a finommechanikában és a gyógyászatban. OGÉT 99., Oradea-Baile Felix, 1999.

Authors:
Attila Bojtos
Dr. Antal Huba
BME-MOGI, Egry J. 3.
H-1111, Budapest
Phone: +36 1 463-2602
Fax: +36 1 463-3787
E-mail: bojtos@mogi.bme.hu