American Journal of Mechanical Engineering, 2016, Vol. 4, No. 7, 353-356
Available online at http://pubs.sciepub.com/ajme/4/7/21

DOI:10.12691/ajme-4-7-21

Modern Trends in the Field of Measurement of Residual Stresses Using Hole-Drilling Method

Patrik Šarga[1,*], František Trebuňa[2]

[1]Department of Mechatronics, Faculty of Mechanical Engineering, Technical University of Košice, Letná 9, 042 00 Košice, Slovak Republic
[2]Department of Applied Mechanics and Mechanical Engineering, Faculty of Mechanical Engineering, Technical University of Košice, Letná 9, 042 00 Košice, Slovak Republic
*Corresponding author: patrik.sarga@tuke.sk

Abstract Residual stresses in the constructions have in most cases a negative effect on their overall life. Large numbers of investigations have been carried out to study this phenomenon and its effect on the mechanical characteristics of these constructions or their components. Hole-drilling method is one of the most used methods used for the determination of residual stresses. This method typically uses strain gauges. This article describes options of using optical methods instead of strain gauge in the process of evaluation of residual stresses by hole-drilling method.

Keywords: *residual stresses, hole-drilling method, optical methods*

Cite This Article: Patrik Šarga, and František Trebuňa, "Modern Trends in the Field of Measurement of Residual Stresses Using Hole-Drilling Method." *American Journal of Mechanical Engineering*, vol. 4, no. 7 (2016): 353-356. doi: 10.12691/ajme-4-7-21.

1. Measuring Residual Stresses by Hole-drilling Method Together with Optical Methods

In the 1980s and 1990s were for the first time used optical methods for measuring strains together with the hole-drilling method. In comparison with strain gauges the optical methods provide more comprehensive data. Strain gauge rosettes (Figure 1) gives the deflections in just three directions, in contrast, optical methods provide full-field data, which enable the possibility for data averaging, error checking and extraction of detailed information (Figure 2).

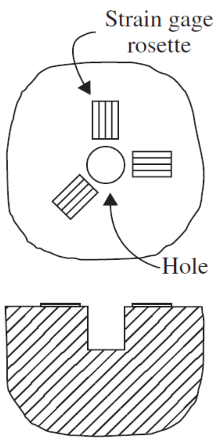

Figure 1. a) Conventional hole-drilling method with the strain gauge rosette

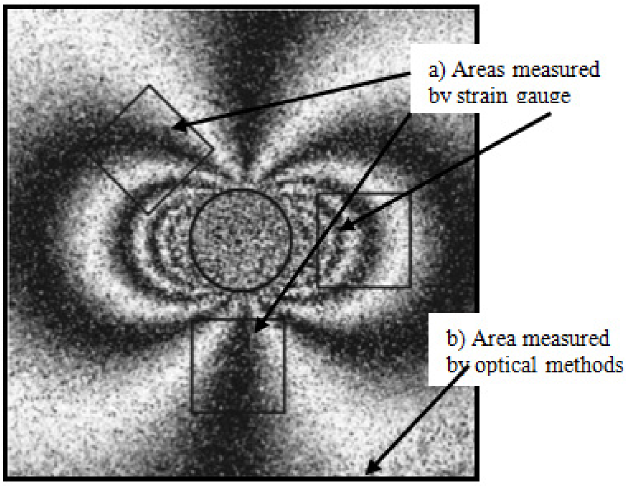

Figure 2. Comparison of areas measured by a) strain gauge, b) optical methods [7]

Currently, in the hole-drilling method is examined the use of three different optical methods, namely: Holographic Interferometry, Digital Image Correlation (DIC) and PhotoStress.

1.1. Holographic Interferometry

Holographic Interferometry (Figure 3) is a method that is used for measuring surface displacements around drilling hole. Its modern variant, Electronic Speckle Pattern Interferometry (ESPI) [1], has become popular because it uses a digital camera that displays real-time image of the fringe patterns.

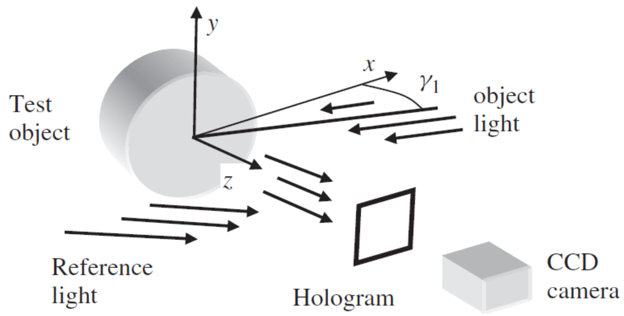

Figure 3. Holographic interferometry set-up [7]

With the ESPI is possible to measure the plane or spatial displacements of the surface, and also the slope of the surface, depending on the optical configuration used. An important advantage of ESPI is the fact that it allows to realise the measurement of the specimen surface without a diffraction grating. This makes measurements by ESPI faster than the method using the diffraction grating. This advantage gives ESPI a better preconditions as a tool for industrial quality control.

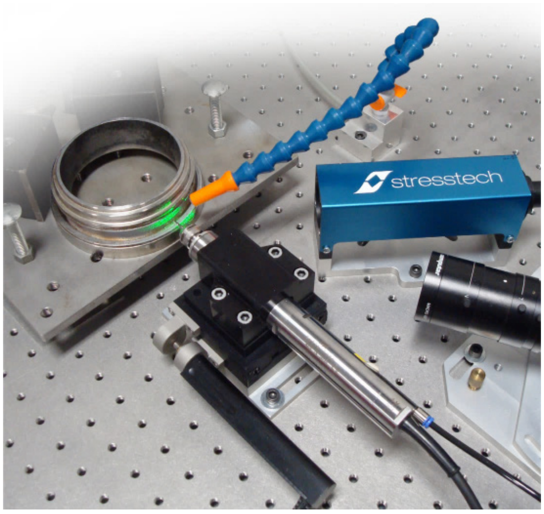

Figure 4. Measurement of the residual stresses by the PRISM system [2]

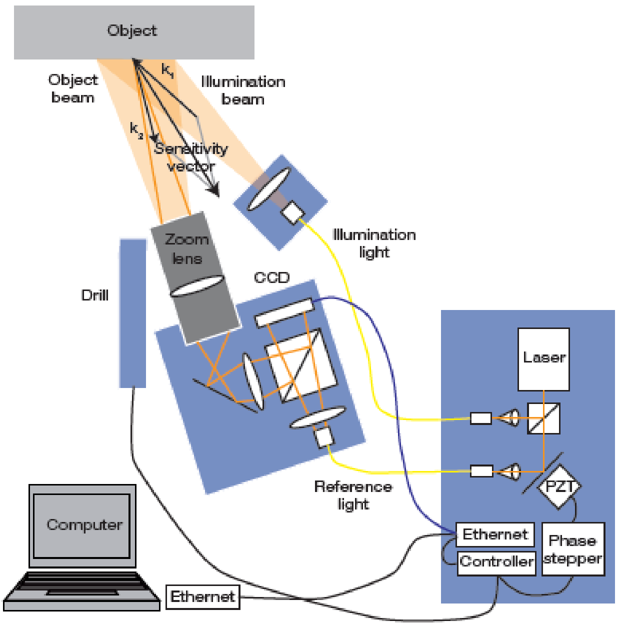

Figure 5. Schema of the measuring system PRISM [2]

An example of ESPI with hole-drilling method is displayed on Figure 4. It is the automatic, computer controlled measuring system PRISM developed by Stresstech. It is able to realise the measurement of the residual stresses in a very short time, on any material, with accuracy of 7 MPa. Figure 5 schematically shows the measuring system PRISM [2].

1.2. Digital Image Correlation

Digital Image Correlation (DIC) is another optical measuring method used with hole-drilling method for measuring the residual stresses (Figure 7). In DIC method is created a random black and white pattern on the surface of the specimen that is observed by one or several digital cameras with high resolution. If only one camera is used, it must be perpendicularly directed to the investigated surface, and it records the image of the surface before and after the deformation. In correlation process the images before and after deformation are compared. Based on the differences between both images, relative displacements in the two in-plane directions are determined. The combination of the appropriate algorithms and appropriately calibrated optical system, allows to resolve displacements of ± 0.02 pixels.

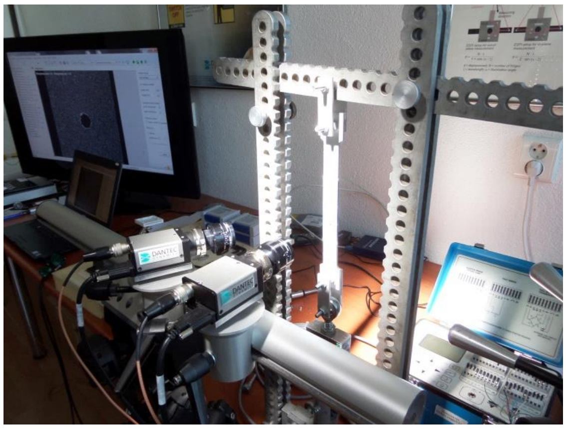

Figure 6. Example of measuring the deformation by DIC with two cameras

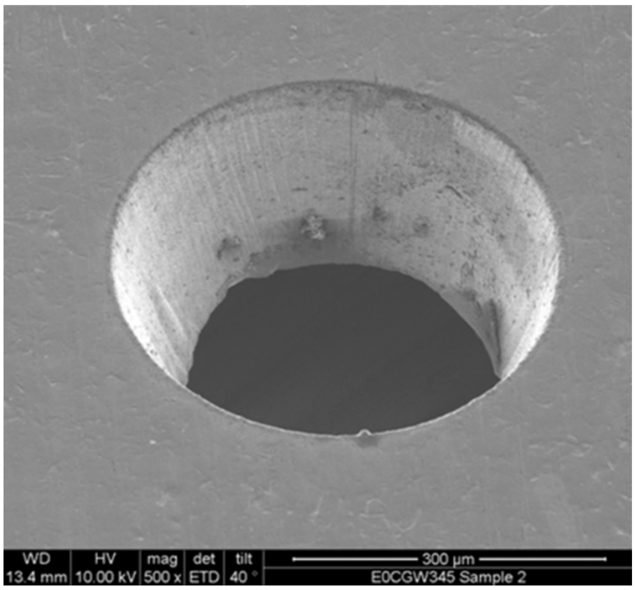

Figure 7. Example of measuring DIC and hole-drilling method

Usage of two cameras allows DIC to get a 3D image of displacement (Figure 6). Such 3D image provides more detailed information on the out-of-plain deformation of the surface, which can help to increase the accuracy of residual stress measurement [3].

1.3. PhotoStress Method

PhotoStress method is a widely used technique for measuring surface deformations and stresses on specimens during static or dynamic loads. It is used either on transparent materials, or the special stick-optically sensitive photoelastic coating is applicated to the surface of the observed specimen. This layer after loading of the specimen and subsequent illumination with polarised light from the reflecting polariscope shows the distribution of stresses and deformations in the form of colored photoelastic stripes.

PhotoStress method uses optical-mechanical properties of photoelastic materials to determine the main direct stresses respectively major strains on the tested specimen´s surface. The measurement is taken by reflective polariscope such as LF / Z-2 (Figure 8). Quantitative values of major strains or stresses can be obtained by software applications, e.g. PSCalc ™.

Reflective polariscope LF/Z-2 is a complex optical instrument to perform quantitative measurement of the principal stresses or strains by PhotoStress method.

Figure 8. Reflective polariscope LF/Z-2

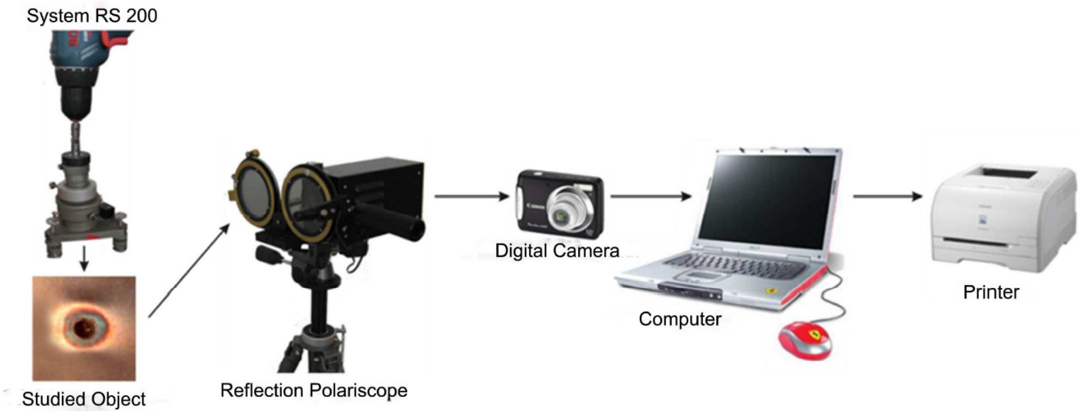

Figure 9. Measuring chain used for the measurement of residual stresses by the hole-drilling method and PhotoStress method

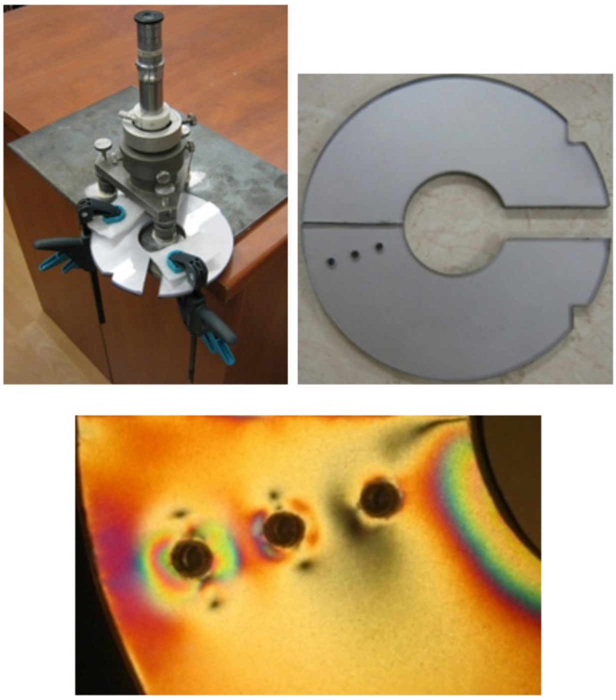

Figure 10. Example of measurement of the residual stresses by the hole-drilling method and PhotoStress method

Optical part of the polariscope consists of a linear polarizer and quarter-wave plate, which serves as a source of polarized light to illuminate the photoelastic coatings. The second optical unit includes a linear polarizer and the quarter-wave plate which functions as an analyzer through which photoelastic patterns on the coating under a load are observed [4].

PhotoStress method can be used in combination with the hole-drilling method, when unloaded photoelastic material is drilled and released residual stresses are observed by polariscope in the form of colored photoelastic stripes.

The measuring chain composed of the hole-drilling device RS – 200, the reflective polariscope LF/Z-2 and the evaluation parts is displayed in Figure 9 [4]. Figure 10 shows the example of the measurement of residual stresses that has been made on the author´s department [6].

1.4. Comparison of Strain Gauge and Optical Measurements

Residual stress measurement using optical methods compared to the strain gauge method has its advantages, but also disadvantages. In Table 1 summarizes the comparison of the two basic principles.

Table 1. Comparison of strain gauge and optical measurements [7]

Strain gauge measurements	Optical measurements
- moderate equipment cost, high per-measurement cost, - significant preparation and measurement time, - small number of very accurate and reliable measurements, - stress calculations are relatively compact, - modest capabilities for data averaging and self-consistency checking, - relatively rugged, suitable for field use, - sensitive to hole-eccentricity errors.	- high equipment cost, moderate per-measurement cost, - preparation and measurement time can be short, - large number of moderately accurate measurements available for averaging, - stress calculations often quite large, - extensive capabilities for data averaging and self-consistency checking, - less rugged, more suited to lab use, - hole center can be identified accurately.

Strain gauge methods for the measurement of residual stresses have been used for several decades and are accepted as a reliable technique for measuring deformations. Optical methods are relatively new and still improving. Optical methods are capable to provide much more data, which may increase the accuracy and reliability of evaluating residual stresses. On the other hand, optical methods have much more difficult implementation conditions than strain gauge methods that are commonly used in the field. There is also a significant difference in the cost of applying both methods. Strain gauge methods have lower initial investment, but the costs of each single measurement in terms are higher than in the optical methods.

2. Conclusions

Use of optical measuring method with hole-drilling method for analysis of residual stresses, is still in development. Currently there are no widely available commercial systems allowing to make such measurements. Challenging conditions that have to be ensured in optical methods, limit their usage for laboratory conditions mainly. Since measurement using strain gauges can be used without significant restrictions even in the field, therefore measuring residual stress by strain gauges will have a permanent place in practice.

University department where the authors works has rich experience in using strain gauges with hole-drilling method for measuring residual stress. It also researches the possibility of using optical methods for determining residual stresses with hole-drilling method.

Acknowledgements

This work was supported by grant projects VEGA No. 1/0751/16 and APVV 15-0435.

References

[1] Steinzig, M., Ponslet, E. (2003) “Residual Stress Measurement Using the Hole Drilling Method and Laser Speckle Interferometry: Part I.” Experimental Techniques 27(3):43-46.

[2] http://www.stresstech.com/en-fi/products/espi-hole-drilling-equipment/prism-equipment.

[3] Nelson, D. V., Makino, A., Schmidt, T. (2006) “Residual Stress Determination Using Hole Drilling and 3D Image Correlation.” Experimental Mechanics 46(1):31-38.

[4] Frankovský, P.: Využitie experimentálnych metód mechaniky pri určovaní zvyškových napätí, TU v Košiciach, September 2010, Košice.

[5] Frankovský, P., Kostelníková, A., Šarga, P.: The use of strain-gage method and PhotoStress method in determining residual stresses of steel console, In: Metalurgija. Vol. 49, no. 2 (2010), p. 208-212.

[6] Frankovský, P. a kol.: Utilisation Possibilities of PhotoStress Method in Determination of Residual Stresses, In: Applied Mechanics and Materials. Vol. 732 (2015), p. 3-8.

[7] Schajer, G. S.: Practical Residual Stress Measurement Methods, 2013.