PRODUCTION ENGINEERING ARCHIVES

2015,Vol. 7, No 2, pp 16-19
ISSN 2353-5156 (print version)
ISSN 2353-7779 (online version)

Article history: Received: 15.12.2014 Accepted: 30.03.2015 Online: 30.04.2015

Available online on: http://www.qpij.pl **Exist since 4rd quarter 2013**

Usage of 3D printing in photostress investigation

Peter Ficzere[1]

[1] PhD., Budapest University of Technology and Economics Department of Vehicle Elements Vehicle-Structure Analysis, e-mail: ficzere@kge.bme.hu

Abstract. In this paper a theoretical analysis of load cases will be constructed, which are the most difficult to be determined during numerical simulations. The development of the design principles and methods are significantly influenced by technology development. Inappropriate design procedures and incomplete knowledge of the loads presents a significant risk factor. A strong emphasis should be put on determining the applicable conditions of coating layered optical photostress investigations for simplification of product validation. Future research should be focused on the views of industry representatives. Particular attention should be paid to the further clarification of the used 3D printing material properties and characteristics because these determine the conditions and limits of applicability. This would be a new application field of 3D printing.

Key words – material science, 3D printing, photostress investigation

1. Introduction

The numerical simulation software have a significant development and spread thanks to 3D CAD modeling methods (Fig. 1.):

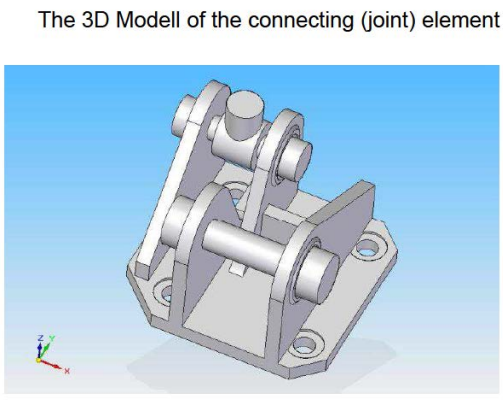

Fig. 1. 3D model.

Today almost all 3D CAD software uses the finite element method (Fig. 2):

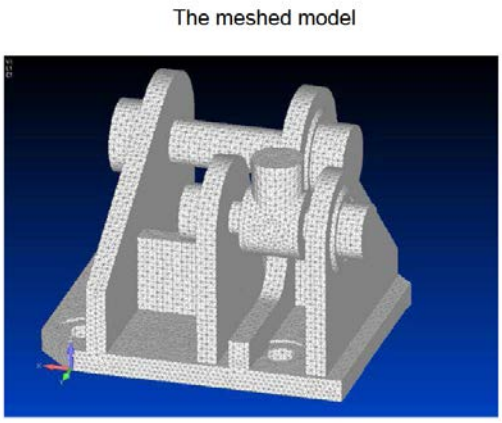

Fig. 2. 3D meshed model (finite elements).

For proper modeling loads and boundary conditions of the planned parts need to be known (KRYNKE, BORKOWSKI, SELEJDAK, 2013). These are the input data for calculations. The definition of the loads and constraints are often very difficult (Fig. 3):

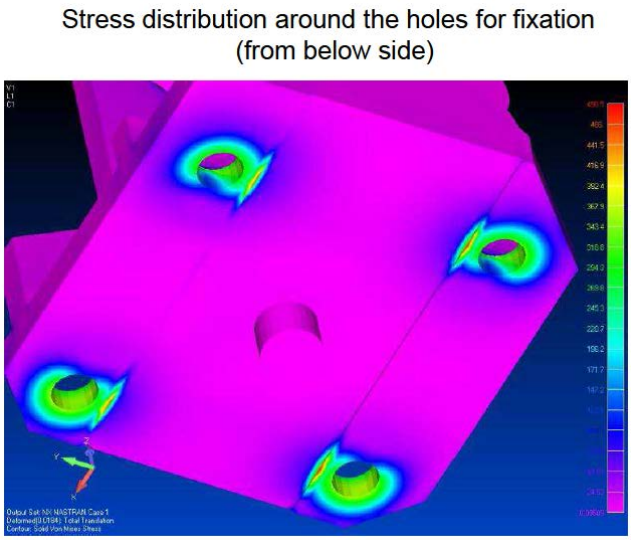

Fig. 3. 3D results of loaded and constrained element.

Precise estimation of these specified parameters are essential. One of the most reliable means to determining the exact stresses is the coating layered optical photostress investigation (DALLY, RILEY, 1991, BURGER, 1993, FICZERE, BORBAS, 2013, BORBAS, FICZERE, 2012). Preparation and parameterization of the appropriate coating layers is difficult and time-consuming (MARKOVITS, BAUERNHUBER, MIKULA, 2013). For the measurement, high competence and professional experience is required. The industrial aim would be to simplify and accelerate this method. This coating layer can be prepared quickly and easily by 3D printing methods (FICZERE, BORBÁS, TÖRÖK, 2013). The material must be suitable for this examination in order for optical photostress to use these 3D printed layers (BORBAS, 2000). The goal is to develop such materials and determining the material parameters necessary for the test. BME Department of Vehicle Elements Vehicle-Structure Analysis (Former: BME Dept. of Machine Elements) has a strong historical connection with material sciences and 3D printing. Optical photostress methods has been used formerly in several industrial contracts. This method has been widely used for investigation of real loads and stresses of bones cooperatively with Research Center for Biomechanics at Budapest University of Technology and Economics (BORBAS, THAMM, OLAH, 2006). It has been proved that the joint use of the photoelastic coating technique and numerical finite element analysis is suitable for the validation of static strength properties of earlier unknown materials determined in an experimental way (FICZERE, BORBAS, TOROK, 2012). In addition, in my PhD thesis I dealt with the testing of 3D printed materials and a significant discovery was born from this. (FICZERE, 2014, Fig. 4.):

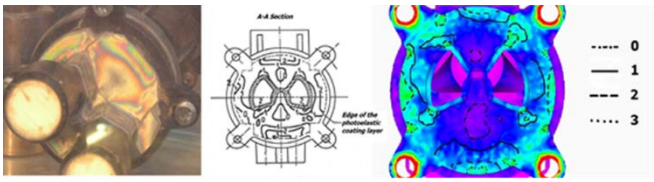

Fig. 4. The result of coating layered photostress method and numerical analysis (in case of m=1, σ_1-σ_2=8.1 MPa).

2. Hypothesis – Research question

The basic interest of this paper is the adaptation and improved methods of new approaches, methods used in 3D printing. The investigation can only be done to a given load in the case of the real material properties known (Fig. 5):

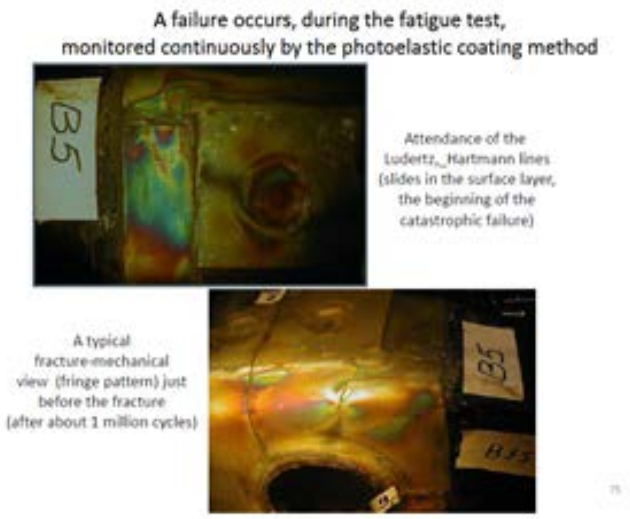

Fig. 5. Photostress visualisation of fatigue test.

In many cases the load and therefore, the answer as well can only be estimated and therefore the simulation is also not reliable. Thanks to improvement in methods, the stresses in these cases can easily be determined precisely. With the knowledge of the loads and constraints we can make numerical simulations and optimization on the model of the given parts. Can 3D printing be used as photoelastic coating technique? Can 3D printing as photoelastic coating technique be validated with computer aided modelling and finite element method? How can it be made faster with cheaper measurements on real parts? and finally, how to simplify it ?

3. Theoretical results

The load cases can be identified, which are the most difficult to be determined during numerical simulations. The development of the design principles and methods will be significantly influenced by these results. Inappropriate design procedures and incomplete knowledge of the loads presents a significant risk factor. A strong emphasis needs to be put on determining the applicable conditions of coating layered optical photostress investigations. Future research should be focused on the views of industry perspectives. Particular attention should be paid to the further clarification of the used 3D printing material properties and characteristics because these determine the conditions and limits of applicability (THAMM, BORBÁS, DEVECZ, 2001). This would be a new application field of 3D printing.

4. Measurement setup

Research infrastructure is provided by BME Department of Vehicle Elements Vehicle-Structure Analysis. For the investigations, 3D printed coating layers are needed. The fixation of the coating layers need special multicomponent glue and for the investigation need a special reflecting layer. In addition it is essential to purchase good quality high resolution picture and data recording devices (camera) as well as a portable computer (Notebook) which is capable of running the latest engineering software. To perform the tests an appropriate polariscope and polarization filters are required.

4. Summary

The numerical simulation software have significant development and spread thanks to 3D CAD modelling methods. For proper modelling loads and boundary conditions of the planned parts need to be known. The definition of the loads and constraints are often very difficult. Precise estimation of these specified parameters are essential. One of the most reliable means to determine the exact stresses is the coating layered optical photostress investigation. The basic idea behind the methodology is the following: in an optically transparent material the stresses will cause birefringence. The difference in optical property is linear to the stress that has been caused. Photostress management is done by an optically active coating on the real surface. The resulting principal directions of birefringence are equal to the principal direction of stress state. The measurement results immediately show the real stress-state and stress distribution under real loading conditions. Preparation and parameterization of the appropriate coating layers is difficult and time-consuming. For the measurement high competence and professional experience is required. The simplification and acceleration of this method is essential. Today, almost all parts have 3D CAD model. An offset surface with a given thickness can be attached to the outer surface of this model. This will be the coating layer which can be prepared quickly and easily by 3D printing methods. The material must be suitable for this examination in order for optical photostress to use these 3D printed layers.

References

1. BORBÁS L., FICZERE P. 2012. *Validation Of Numarical Analysis Results In Case Of Rapid Prototyping By Experiments Using Optical Techniques*. Proceedings of the 29th Danubia-Adria-Symposium on Advances in Experimental Mechanics, Belgrad, Serbia, 2012.09.26-2012.09.29. Belgrad: Belgrade University-Mechanical Engineering Faculty, pp. 68-69. (ISBN:9788670837621).
2. BORBÁS L. 2000. *Course on: Engineering Design and Industrial Design Interaction*. Bologna University International Ceentre – Bertinoro (Forli) Italy. Investigation of structural components by

photoelstic coating technique. Chapter II. p.: 18...37.
3. BORBÁS L., THAMM F., OLÁH L. 2006. *Comparison of strain gauge technique and photoelastic coating method in the investigation procedure of femur prostheses*. Journal of Computational and Applied Mechanics, Vol.7, No. 1. (2006.), pp. 3-12.
4. BURGER C. P. 1993. *Photoelasticity* Handbook on Experimental Mechanics, SEM, 2nd Revised ed. Ed. A.S. Kobayashi.
5. DALLY J. W., RILEY W. F. 1991. *Experimental Stress Analysis*, 3rd ed. McGraw-Hill, New York.
6. FICZERE P. 2014. *Material and numeric analysis of rapid prototypes*, PhD thesis. Supervisor: Lajos Borbas.
7. FICZERE P., BORBAS L., TOROK A. 2012. *Theoretical And Practical Investigation Of Rapid Prototyping*, Toyotarity. Standarizations' Kinds. Dnepropetrovsk: Yurii V Makovetsky, pp. 139-150. (ISBN:978-966-1507-77-6)
8. FICZERE P., BORBAS L. 2013. *Rapid prototyping products material law validation by optical photoelastic coating method*. 30th Danubia-Adria Symposium on Advances in Experimental Mechanics. Primošten, Croatia, 2013.09.25-2013.09.28.pp. 51-52.
9. FICZERE P., BORBÁS L., TÖRÖK Á. 2013. *Economical Investigation Of Rapid Prototyping*, International Journal For Traffic And Transport Engineering 3:(3):344-350., Doi: 10.7708/Ijtte.2013.3(3).09.
10. KRYNKE M., BORKOWSKI S., SELEJDAK J. 2014. *Analysis of influence of bearing clearance on the static carrying capacity of multi-row slewing bearings*, Periodica Polytechnika Transport Engineering, 42(1):43-48, 2014, doi: 10.3311/PPtr.7261.
11. MARKOVITS T., BAUERNHUBER A., MIKULA P. 2013. *Study on the transparency of polymer materials in case of Nd:YAG laser radiation*, Periodica Polytechnika Transportation Engineering, 41(2):149–154, doi: 10.3311/PPtr.7117.
12. THAMM F., BORBÁS L., DEVECZ J. 2001. *Newer coating layers for photstress investigation* [in Hungarian: Újabb réteganyagok kifejlesztése a felszíni réteges optikai feszültségvizsgálathoz]. Rubber & Plastics [in Hungarian: Műanyag és Gumi], HU ISSN 0027 – 2914.