Experimentální Analýza Napětí 2011
Experimental Stress Analysis

The Creation of Finite Element Model by Using the Digital Image Correlation Method

František Trebuňa[1] & Róbert Huňady[2]

Abstract: The paper deals with possibilities of using DIC method for creating of spatial finite element models for needs of numerical analysis. A process of creation of a spatial geometry is presented on the example of a fan blade. Its geometry was obtained by correlation system Q-450 Dantec Dynamics. Model of the blade was subsequently used for determination of its eigen frequencies by numerical modal analysis in SolidWorks software.

Keywords: Digital image correlation, Finite element model, Numerical analysis

1. Introduction

The digital image correlation method [1, 2] is a modern contactless optic method, which uses digital image registration technique to precise measurements of plane and spatial deformation. Thanks to high resolution cameras, system is able to observe a wide range of an object's surface points with variable contrast. It allows to visualize measured parameters in the whole observed area. The principle of method is based on observation of stochastic speckle pattern, which is created on the surface of the tested object, e.g. by spattering black color on a white base. An area observed by cameras is divided into smaller subareas called facets (Fig. 1) in such a way, that every one of them contains characteristic part of the pattern. Surface speckles represent material points of a solid. If a relative position of both cameras is known, then it is possible to calculate an absolute threedimensional coordinates of every surface point and create spatial contour of the model. Displacements and strains of the individual points are subsequently determined by correlation of corresponding facets on digital images in state before and after deformation of a solid.

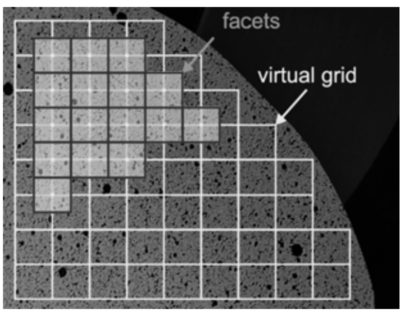
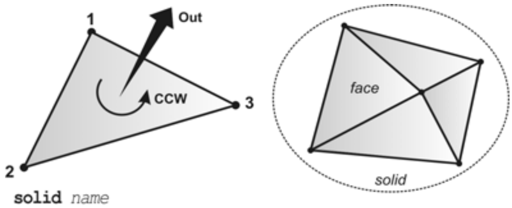


Fig. 1. A dividing of stochastic speckle pattern to the facets

[1] *Dr.h.c. mult. prof. Ing. František Trebuňa, CSc.; Department of Applied Mechanics and Mechatronics, Faculty of Mechanical Engineering, Technical university; Letná 9, 042 00 Košice, Slovakia; frantisek.trebuna@tuke.sk*
[2] *Ing. Róbert Huňady, PhD.; Department of Applied Mechanics and Mechatronics, Faculty of Mechanical Engineering, Technical university of Košice; Letná 9, 042 00 Košice, Slovakia; robert.hunady@tuke.sk*

2. The creation of spatial geometry

Stereoscopic observing of the object’s surface by two cameras is a condition of full-value reconstruction of their contour in threedimensional space. System Q-450 [3, 4] allows obtained geometry to export to STL (STereoLithography) file format developed by 3D SYSTEMS company. This format is supported by most CAD and FEM programs and it is massively used for 3D plottering and modeling. STL interprets unprocessed surface by its points and normals. Spatial surface is represented by triangular plates (faces) that are described by twelve values. ASCII structure of STL file is shown in the Fig. 2.




```
solid name
    facet normal ni nj nk
        outer loop
            vertex v1X v1Y v1Z
            vertex v2X v2Y v2Z
            vertex v3X v3Y v3Z
        endloop
    endfacet
    ⋮
endsolid name
```

definition of one face

Fig. 2. Syntax for an ASCII STL file

In the Fig. 3a there is shown fan blade, which geometrical model was created by DIC method. Speckle pattern on the blade’s surface was created by spraying and subsequently recorded by cameras from two different directions. The final contour of surface obtained by correlation of images is in the Fig. 3b.

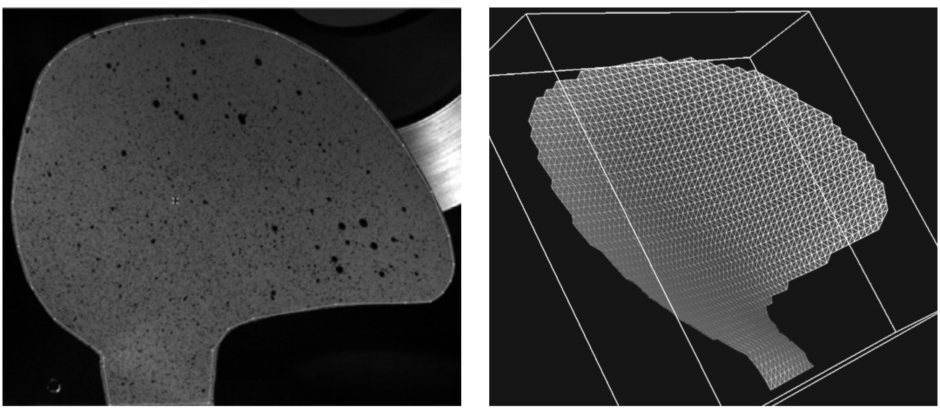


Fig. 3. a) fan blade, b) final contour of the blade surface

An accuracy of contour depends on an adjusting of the correlation parameters. Width of the grid defines a density of surface points, which coordinates may be calculated. Too big width can cause a distortion of curved parts and a decreasing of an accuracy of approximation of contour boundary (Fig. 4). On the other side, too dense mesh can result in rising of correlation errors caused by decreasing of a facet size.

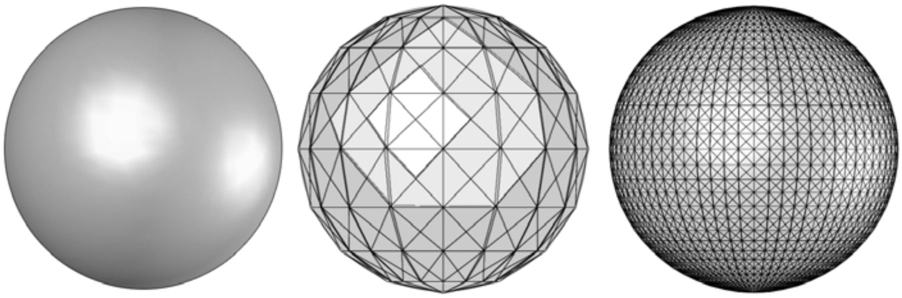


Fig. 4. Approximation of contour depending on a mesh density

3. Modal analysis of the fan blade

Spatial contour was imported to the SolidWorks program as an object of the type “surface”. There were defined material properties and thickness of the imported surface. SHELL elements were used to meshing. Model created by this way was prepared for a numerical analysis after defining of boundary conditions (Fig. 5).

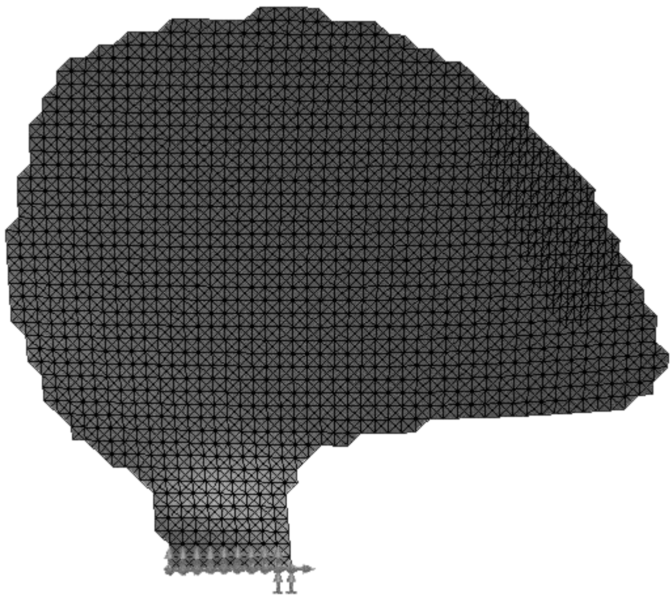


Fig. 5. Meshed model of the fan blade

Eigen shapes and eigen frequencies determined by the finite element method are shown in Fig. 6.

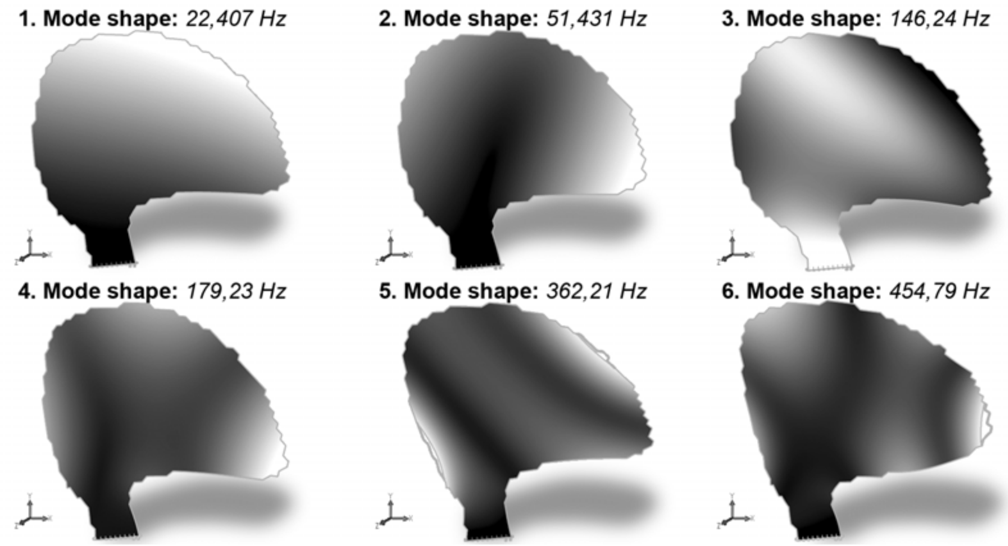


Fig. 6. The first six eigen frequencies and eigen shapes of the blade

Eigen frequencies of the fan blade determined in SolidWorks program were verified by experimental measurement, in which the blade was excited acoustically – by powerful sound equipment with software generator of white noise signal [5]. Speed of acquisition of cameras was 1000 fps, what allowed to evaluate frequency spectrum of vibration up to 500 Hz. Configuration of the experiment is shown in Fig. 7.

Fig. 7. A measuring of eigen frequencies of the fan blade by Q–450 system

The average frequency spectrum of absolute displacements obtained under the excitation by white noise is shown in Fig. 8.

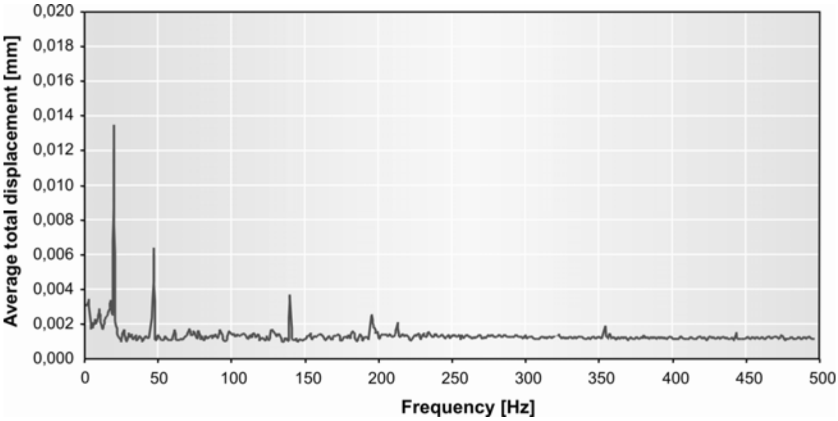


Fig. 8. The average frequency spectrum of absolute displacements of the blade measured by Q-450

There was possible to identify the first six eigen modes in given frequency range. Eigen frequencies subtracted from the graphical chart in the Fig. 8 are mentioned in Tab. 1 together with the eigen frequencies determined by FEM analysis.

Table 1. Eigen frequencies of the fan blade and its numerical model

	1.	2.	3.	4.	5.	6.
Q–450	20.96 Hz	48.95 Hz	141.08 Hz	193.12 Hz	355.08 Hz	441.85 Hz
FEM	22.407 Hz	51.431 Hz	146.24 Hz	179.23 Hz	362.21 Hz	454.97 Hz
Difference [%]	6.5	4.8	3.5	7.2	1.9	2.9

From comparison of frequencies mentioned in Tab. 1 it is obviously that values determined by numerical analysis on the model created by the digital image correlation method are similar to values obtained by experimental measurement. Differences are in allowable bounds with respect to different stiffness of real and ideal restrains. The results show that DIC method was suitable applied to creation of blade model and this model was correct.

4. Conclusion

Although the digital image correlation method is priority aimed at deformation measuring, possibilities of some correlation systems extend its applications even to other areas. One of them is a scanning of shape of a component. It can be used in case, when an object’s surface is too complicated to easily modeling in CAD software. In this paper specific example of creation of model was described by Q-450 system.

Acknowledgement

This contribution is the result of the project implementation: Center for research of control of technical, environmental and human risks for permanent development of production and products in mechanical engineering (ITMS: 26220120060) supported by the Research & Development Operational Programme funded by the ERDF.

References

[1] TREBUŇA, F. – ŠIMČÁK, F. 2007. Príručka experimentálnej mechaniky, TypoPress, Košice, ISBN 970-80-8073-816-7

[2] SIEBERT, T. – SPLITTHOF, K. – STECKLUM, S. – HERBST, Ch. 2005. New features in digital image correlation techniques, 22nd DANUBIA-ADRIA Symposium on Experimental Methods in Solid Mechanics
[3] DANTEC DYNAMICS 2010. High Speed 3D Digital Image Correlation System. Publication No.: PI-Q-450_10_01, [online] http://www.dantecdynamics.com/Default.aspx?ID=1521
[4] DANTEC DYNAMICS GmbH. 2008. Istra4D / Software Manual Q-450 System
[5] TREBUŇA, F. – HUŇADY, R.: Using of digital image correlation for determination of eigenshapes and eigenfrequencies, In: Fine mechanics and optics, vol. 55, no. 10 (2010), p. 276-279, ISSN: 0447-6441