DIGITAL IMAGE CORELLATION TECHNIQUE AS A TOOL FOR KINEMATICS ASSESSMENTS OF STRUCTURAL COMPONENTS

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Abstract: The paper reports results of tests focused on determination of kinematic properties of components under cyclic loading. DIC system called 5M PONTOS was employed to follow variations of displacement and velocity versus time. It was conducted by a use of markers stuck on selected sections of components tested. Results are presented in 2D and 3D coordinate systems expressing behaviour of elements such as: car engine, boat frame and mechanical coupling device. These data enable to capture weak and strong sections of the component tested at various loading conditions.

Key words: digital image correlation system, cyclic loading, PONTOS, motion, displacement, 3D coordinate system

1. INTRODUCTION

Digital Image Correlation (DIC) method is non-contact technique, which has been developed in the last 15 years. Mathematical approach and CCD cameras progress have enabled designing DIC system. Equations and relationships for determination of solid bodies deformation are employed to follow differences on a sprayed grey background having black dots stochastically arranged (Chu et al. 1985). On the basis of these data a displacement can be reached directly and next strain full filled maps calculated. As it is noticed by a lot research groups this method can be employed for examination of various types of specimens such as: flat (Toussaint et al., 2008), tubular, hourglass (Kamaya and Kawakubo, 2011) and CT. DIC technique enables evolution of strain distribution close to artificial defects and reaching features appearing before material fracture (Szymczak et al., 2016a, b). Comparison of DIC results data from FEA and tensometer technique indicates on a good agreement between them. Young's modulus, yield point and ultimate tensile strength can be determined by the use of DIC technique.

This conception is also used for determination of kinematic properties of various elements. For this case DIC method uses markers stuck on selected zones of components tested, Fig. 1. Dimensions of markers (GOM) are within a range from 0.4 to 25 mm. Typical DIC system contains two cameras (stereo device), working stations and calibration equipment.

Application of the 5M PONTOS requires calibration stage, which should be directly conducted before main test. This part of experimental procedure employs cross (Fig. 1) or plate having measurements dots located at various orientation in 3D coordinate system. The equipment is positioned in the centre of a measurement zone and it is subjected to movement and rotation according to comments produced by the software. In the case of 5M PONTOS two various kind of markers can be applied. Typically, when lightening conditions are acceptable, black dots on a white background can be used. In an opposite case the markers with a fluorescence layer are recommended.

The PONTOS device was used to determine deformation and vibration of a large-volume tractor tyre during dynamic test (Brinkmann at al., 2007). Response of a wing of airplane is another DIC system external application (Berger et al., 2010).

Fig. 1. DIC technique details: distribution of markers for measurements and calibration cross

The DIC technique was also successfully applied for identification of shape mode of the wind turbine blade (Bagersada, 2012). DIC method is also used for kinematic capturing parameters of NASA conception vehicle called The Scarab (Creager, 2015). Tract of each wheel were followed applying PONTOS system.

2. EXPERIMENTAL PROCEDURE

Testing procedure was designed to check suitability of the 5M PONTOS for detection of displacement in 2D and 3D measurements of various components such as: mechanical coupling device, car engine, and boat frame. Various types of loading were used for movement of components tested. Symmetrical signal of cyclic force was applied for examination of a coupling device up to 2×10^6 cycles, Fig. 2. The most important feature of the experimental procedure is mounting the equipment in the same position as it appeared during exploitation. The coupling device was tested to check whether it can be mounted in the Sports Utility Vehicle (in this case Hyundai Tucson).

DIC system was also used to investigate vibration of 3.0 diesel engine of Porsche Cayenne (SUV). In this case markers were arranged on the engine cover and bumper of the car, Fig. 3. The major coordinate system was represented by the velocity up to 2500 RPM. The aim of this experiment was to determine vibration of the car engine with respect to exhaustion of gum-metal absorbers.

The PONTOS 5M was employed in all stages of the experimental procedure to follow variations of displacement versus time . It enabled to reach distribution of displacement vectors in 2D and 3D coordinate systems. These results were analysed to indicate characteristic features of the objects examined.

3. RESULTS

Data showing variations of displacement for the components tested are presented in Figs.2÷4. Looking at the results a distribution of displacement vector can be easily studied.

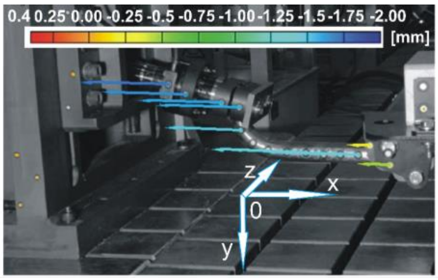

Fig. 2. Distribution of displacement in 0x axis direction for mechanical coupling device examined under cyclic loading

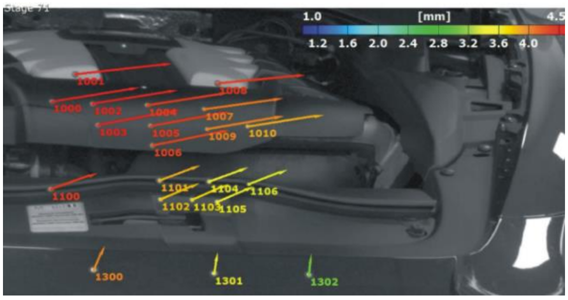

Fig. 3. Distribution of resultant displacement vector in 3D coordinate system for selected rotated velocity of the car engine of Porsche Cayenne

In the case of coupling device this data were represented by displacement in 0x direction because this magnitude is very important from engineering point of view, Fig. 2. Data for designing of this element can be very easy noticed basing DIC's results. Moreover, an analysis of these data enable to assess movement in the mounting zone.

Car engine behaviour was studied using variations of displacement resultant vector as indicator for vibration assessment, Fig. 3. The vectors were determined at different values of car engine rotational velocity. The results expressed a one direction of displacement vector. It was noticed for a whole range of velocity applied up to 2 500 RPM. In comparison to typical behaviour of car engine the vector distribution express difference in mechanical properties of gum-metal absorber. It is clearly illustrated in Fig. 3, 4. A maximum value of resultant vector reached of 4.5 mm. On the basis of these data engineers are able to assess exhaustion of the anti-vibration components.

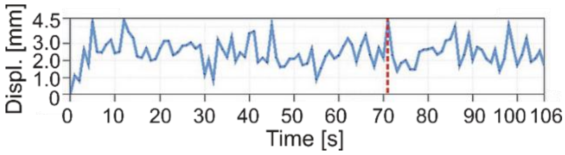

Fig. 4. Variations of resultant displacement vector in 3D coordinate system for various rotated velocity of 3.0 diesel car engine of Porsche Cayenne

4. SUMMARY

DIC technique can be used for determination of full-filed strain maps, stress-strain characteristics, mechanical properties as well as kinematics features such as: displacement, velocity and acceleration.

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