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OPTICAL IDENTIFICATION OF TRACTOR ENGINE FINITE ELEMENT MODEL

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ABSTRACT: A hybrid method was used to predict engine deformation induced by assembling crankcase and cylinder head. The core of method consists in identification process based on the multi-dimensional correlation analysis. By means of this method the results of holographic and speckle interferometry and preliminary finite element analysis (FEA) are compared. This comparison removes uncertainties of both the holographic interferometry and the finite element method.

INTRODUCTION

The development in engineering evokes the need for a complex stress or strain analysis of technical systems which are stressed by assembling or operating loads. A partial solution is possible to obtain by various measurement methods or by computer aided modelling (CAM). However, these different methods have some disadvantages. The measurement methods give results only from the specific parts of investigated object and the modelling methods are very sensitive to the accuracy of estimation of boundary conditions.

These problems occurred during the investigation of the tractor engine UR-IV M2 deformations which were caused by engine assembling. The partial results were obtained by holographic interferometry measurements that were reported in several papers (Brozman,Kubik 1991; Brozman,Kubik 1994; Brozman 1996). As followed from these works the results gave information about the part of engine surface and about three of six cylinder liners. This is given by visibility of these parts from observation and illumination points. The needs of development require to determine deformation state of all engine parts. For this purpose the hybrid method was used which was developed in the framework of the project LINDA (Laser Interferometry and Numerical Deformation Analysis) (Brozman 1996).

METHOD

Each experimental analysis can be considered for hybrid method because a mathematical algorithm for evaluation is usually used. In next the hybrid method will be called a combination of holographic interferometry and finite element method

(FEM). The finite element analysis belongs to those mathematical methods which assume certain presumed boundary conditions. The estimation of correct boundary conditions is very difficult in the real conditions and an incorrect estimation can cause the deterioration of numerical results. Convenient combination of the FEM and holographic interferometry can give the significant reduction of the mentioned uncertainties because the results of both methods can be represented by lines of constant displacements and thus they can be compared. The input values (boundary conditions) of numerical solution performed by the FEM are chosen so that the results satisfied the experimental values obtained by holographic interferometry on the measurable parts of an investigated object. These boundary conditions provide acceptable results on the non-measurable parts of object.

If we consider displacement values on the loaded object for random data, the resolution if FEM results satisfied the results from holographic interferograms can be processed by statistical methods. The considered random data create 3-D surfaces representing deformation of the part of object surface. For the comparison of both experimental and modeled 3-D surfaces a multi-dimensional identification parameter was derived in the following way.

The distribution of light intensity in the holographic interferogram is given by 2-D function z(x,y), where x,y are coordinates in the evaluated object surface. Intensity values in two different points of the compared contour fields we denoted as $z_1(x,y)$ and $z_2(x',y')$. The correlation function expressing the correspondence rate of two compared random functions is defined as a mean value of the product of these functions. One of these functions has shifted the interval origin of independent variable by t (Bendat, 1971). So, we can write according to the coordinate y

$$R_{1,2(x,x',t)} = \lim_{n \to Y} \frac{1}{n} \int_{-n/2}^{n/2} z_1(x,y) z_2(x', y+t)\, dy \tag{1}$$

where: x,y - dimensions of investigated area

$t = y' - y$

Analogically for the cross-correlation function according to the coordinate x can be written as

$$R_{1,2(k,y,y')} = \lim_{m \to X} \frac{1}{m} \int_{-m/2}^{m/2} z_1(x,y) z_2(x+k, y')\, dx \tag{2}$$

where $k = x' - x$.

From the equations (1) and (2) for the two dimensional cross-correlation function follows that

$$R_{1,2(k,t)} = \lim_{\substack{n\to Y \\ m\to X}} \frac{1}{nm} \int_{-n/2}^{n/2} \int_{-m/2}^{m/2} z_1(x,y) z_2(x+k, y+t)\, dx dy \tag{3}$$

If the values $z_1(x,y)$ and $z_2(x,y)$ are identical or similar (correlated) the cross-correlation function $R_{1,2\ (k,t)}$ takes its maximum for a certain point (k,t). More convenient is a normalized cross-correlation function expressed as

$$R_N = \frac{R_{1,2(k,t)}}{R_{1,2(0,0)}} \tag{4}$$

where R_N - takes maximum of 1 in the case of total correlation.

On the basis of correlation coefficient definition (Dowdy,1983) the 2-D correlation coefficient according to the analogy for two-dimensional case can be written as

$$K_R = \frac{\sum (z_{1(m,n)} - \overline{z_{1(m,n)}})(z_{2(m,n)} - \overline{z_{2(m,n)}})}{\sqrt{\sum (z_{1(m,n)} - \overline{z_{1(m,n)}})^2 (z_{2(m,n)} - \overline{z_{2(m,n)}})^2}} \tag{5}$$

The coefficient defined by last equation takes values from interval of <-1,1>. The coefficient value that refers to the statistically significant correspondence of the compared function is depended on the range of m,n values and it is given for several significance levels. For the hybrid method the significance level of 0.01 is chosen. For this criterion the identification parameter is proposed by simple formula

$$I_P = K_R^2$$

For computer modelling the LUSAS FEA software ver.11 and computer Pentium 100MHz, 32MB RAM, 1.7GB HDD were used. Holographic interferograms were taken by double-exposure method (Vest,1979) using He-Ne laser of 100mW output. After preliminary analysis the results were compared with the results from holographic interferogram and the load was gradually changed untill the model satisfied the experiment. The finite element model of whole engine crankcase was created by 5700 20-nodal brick elements (shown in fig.1). On the base of holographic interferogram results from previous experiments (Brozman, 1989,1992; Kubik,1992;Brozman, 1996) the boundary conditions (loads and supports) were input and slidelines for the contact problem of cylinder liner seating were defined (FEA Ltd.1993).

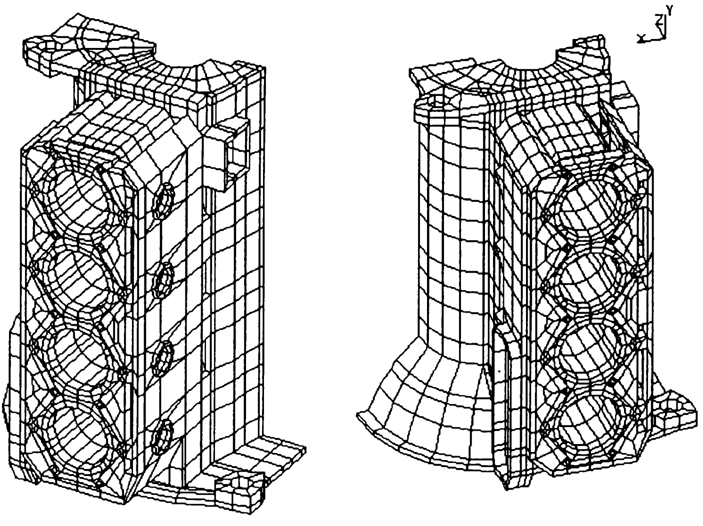

Fig.1

RESULTS AND DISCUSSION

The whole model of the engine crankcase was solved as a nonlinear contact problem. The solution of the complete crankcase structure was obtained with identification parameter value of 0.41 on significance level 0.01. The error of finite element analysis was determined as 3%. This value was obtained by means of verification examples (FEA Ltd.1993) and by determination of conditionality number. This number has in this case the value of 1.15 and it expresses the error transfer of input values into results. Mean square error of model was 18% in which the holographic interferometry errors, the FEA errors and the identification parameter are included. The relatively high value results from the low identification parameter. An improvement of parameter was not possible by any variations of boundary conditions. This condition was caused by unpredictable behaviour of the cylinder liners during deformation of crankcase. The probable reason was a wide range of cylinder liner tolerance on fit. All modelled cylinder liners have the mean tolerance value what is not possible to expect for manufactured liners. That is why the model has 23% error or it could be expressed as the crankcase was manufactured with various values of tolerance and the model performs product with the exact mean value of allowed tolerances.

CONCLUSION

The presented hybrid method enables to obtain the information about mechanical behaviour of machines or their parts after mechanical or thermal loading. This method performs computer aided experiment as one of CAD/CAM methods. The CAM methods, namely the finite element methods are included in the amendment of international standard ISO 9001. Reliable utilization of the FEM requires hybrid procedures including the experiment. The proposed hybrid method offers one of the possible solutions of CAM application.

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