TESTING OF A COMPOSITE BLADE

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Abstract: The research presented in this paper focuses on the investigation of helicopter composite blade. The object of tests is a blade from main rotor of the IS-2 helicopter. The author describes briefly basic elements of composite blade manufactured at the Institute of Aviation in Warsaw. The composite blade was investigated by the Experimental Modal Analysis (EMA) to evaluate dynamic properties of tested structure. Based on the experimental data collection, dynamic properties of a research object were estimated. The modal parameters have been estimated using PolyMAX – module of LMS Test.Lab software.

1. INTRODUCTION

The helicopter blade is a very important part of main rotor. It is a light weight construction but has to sustain heavy loads and harsh environment conditions. There is a need to improve the characteristics of helicopter blades, accompanied by dynamic loads. Application of new methods for testing the dynamic susceptibility can divide a complex system into simpler components, allowing to analyze the impact of changes in susceptibility of individual items on the general characteristics of complex vibration system and the selection parameters of the system during its formation.

Modal analysis is a widely used technique in practice, the study of dynamic properties of the structure. As a result of modal analysis the modal model is obtained as a set of frequencies own form of vibration and damping coefficients. Knowing these parameters allows the prediction of the behaviour of an object due to any imbalances (Ewins, 2000; Heylen et al., 1998).

Modes are used as a simple and efficient means of characterizing resonant vibration. Resonant vibration is caused by an interaction between the inertial and elastic properties of the materials within a structure (Ewins, 2000; Heylen et al., 1998).

The research presented in this paper focuses on composite structure tests. The basic methodology which is used is the Experimental Modal Analysis (EMA). The EMA technique is an established tool for the identification of dynamic properties of structures (Luczak et al., 2010).

As in most practical applications of modal analysis is required for multi-channel experiment and the complex calculations associated with the processing of measured signals and estimation of model parameters. The first application of the method of modal analysis has already been documented in the late 40's, and their rapid development occurred in the 80's, due to the development of computer techniques (Ewins, 2000; Heylen et al., 1998; Kaczmarczyk et al., 2008).

In the present study performed a computer-aided measurement and subsequent analysis were used LMS Test.Lab software. LMS Test.Lab offers a complete portfolio for noise and vibration testing, including solutions for acoustic, rotating machinery, structural testing, environmental testing, vibration control, reporting and data management (LMS Company – marketing materials).

The software naturally follows the test campaign process, guiding for measurement and analysis parameters. Its includes a lot of different modulus, which are useful in a computer-aided design (CAD), like, LMS Test.Lab Geometry and LMS Test.Lab Modification Prediction. LMS Test.Lab Geometry provides fast wireframe generation and full 3D visualization of test and analysis results. Point coordinates are defined in Excel-like tables, while connections and surfaces are graphically defined in the display. The geometry can be copy/pasted. LMS Test.Lab Modification Prediction evaluates structural modifications (mass, stiffness and damping). Based on the modal model and on the modification element definition, a modal of the structure can be calculated. The effect of such a set of modifications on a modal model can be calculated and compared to the original situation (LMS Company – marketing materials).

2. RESEARCH OBJECT

The object of the investigation is a blade from main rotor of the IS-2 helicopter presented in a work stand (Fig. 1). Dimensions of the investigated object are: length 3,25 m, width 0,20 m. Approximate weight of the structure is 12,60 kg.

The tested blade was manufactured at the Institute of Aviation. The production process is very complicated. Blades are formed by combining two halves into one whole, which is followed is annealed in the oven (Fig. 5).

The basic instrumentation used in the manufacture of rotor blades are moulds (Fig. 2): a upper mould part and a lower mould part. Both moulds have a similar structure. A working surface of moulds is made of a rigid laminar coating of fiber-epoxy composite covered with gelcoat. The high rigidity of the surface of moulds ensures proper representation of the external geometry of blades in the cross-section (Fig. 6).

Composite blade base on carbon, fiber composites, roving, epoxy and lead (Fig. 3), (Fig. 4).

Fig. 1. Blade mounted in a test stand

Fig. 2. Moulds of blade

Fig. 3. Mould with fiber composite

Fig. 4. Mould with roving and carbon composite

Fig. 5. Upper and lower halves of a blade part in oven

Fig. 6. Cross-section of a composite blade

Performed helicopter blade is controlled by thermography system to detect defects such as a delamination, air bubbles (Kaczmarczyk et al., 2008; Meinlschmidt and Aderhold, 2006; Świderski, 2009). Proven blade structure is released for vibration testing, so as to exclude the effect of defects on the vibration tests. Thermography is one of the most common non-destructive testing method of composites. It is used to detect material defects and evaluate the structure of materials without having to change their performance (Kaczmarczyk et al., 2008; Meinlschmidt and Aderhold, 2006; Świderski and Vavilov, 2010). A result sample of the experiment with a thermography camera is presented in Fig. 7.

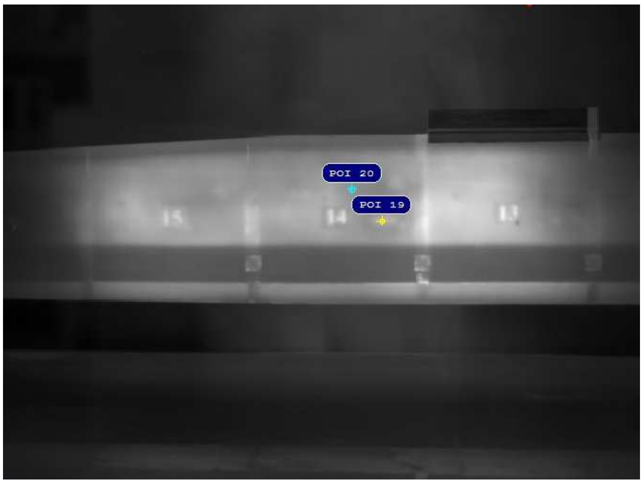

Fig. 7. Thermal image taken from thermography measurement

In a vibration test campaign the following measurement and analysis tools were used (Fig. 8):
- 1 electromagnetic shaker, with impedance heads incorporating acceleration and force sensor in the same housing to measure reference point FRF's;
- 4 triaxial modal piezoelectric accelerometers PCB;
- 16 channels in fronted LMS SCADAS Mobile with computer a Test.Lab acquisition and analysis suite;
- bandwidth 128 Hz, resolution 0,05 Hz.

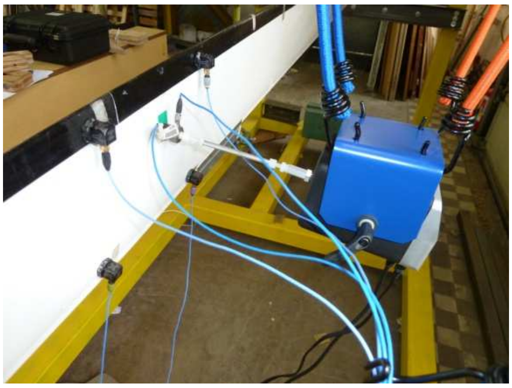

Fig. 8. Vibration test setup of a blade from main rotor of the IS-2 helicopter

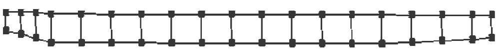

Fig. 9. Cartesian coordinate system for piezoelectric sensors in LMS Test.Lab Geometry

The shaker was attached to the structure using a stinger (long slender rod), so that the shaker will only impact force to the structure along the axis of the stringer, the axis of force measurement.

A dense grid of measurement points is defined all over the blade surface, in order to successfully identify the dynamic properties of this structure. Measurement points are set with distance of 0,20 m one from each other in the spanwise (X) direction and 0,20 m in the edgewise direction (Z). Geometry definition for blade is presented on Fig. 9. It consists of 39 points, 38 of which are acquisition locations and the remaining 1 is the reference point.

3. EXPERIMENTAL RESULTS AND ANALYSIS

The measurement was done in "sets" which means not all the points were measured at the same time. As a consequence a number of partial modal models were estimated for each of the set. Next the partial models were merged into a global model by means of multi-run modal synthesis (Luczak et al., 2010). Modal models have to be validated to provide confident information about the structural dynamics of a research object (Fig. 10).

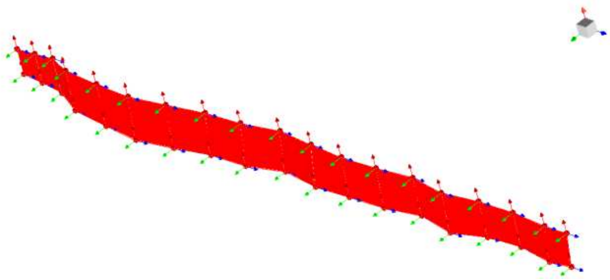

Fig. 10. View of measured blade in LMS Test.Lab Geometry

Due to a high number of measurement points and limited number of piezoelectric sensors applied to the structure (in order to reduce the mass loading phenomena), a large number of test was carried out. Random signal were applied.

Based on the experimental data collection, modal models were estimated. The modal parameters have been estimated using PolyMAX (Polyreference Modal Analysis eXtended) algorithm provided by LMS software. Fig. 11 presents a window of PolyMAX in LMS Test.Lab (LMS Company – marketing materials).

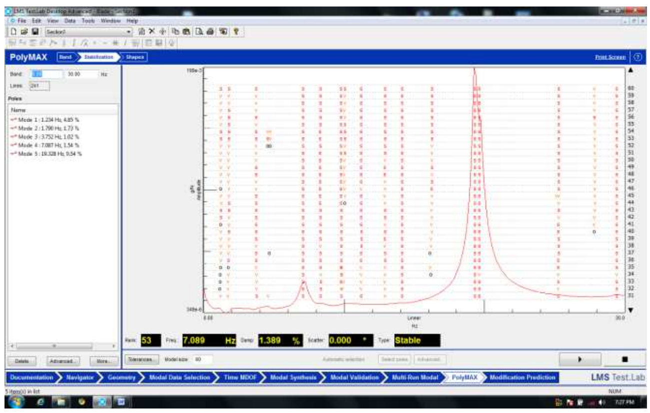

Fig. 11. Stabilization diagram obtained by LMS PolyMAX method

PolyMAX is an advanced modal parameter estimation technique that offers superior identification of modal parameters. Its main advantage consists in damped structure identification, where more modes can be identified into a higher frequency range (LMS Company – marketing materials).

During results analysis, the experimental natural modes and damping were estimated: flapwise 2nd – frequency 7,0 Hz and damping 1,54 %; flapwise 4th – frequency 19,0 Hz and damping 0,54 %; chordwise 1st – frequency 34,4 Hz and damping 0,44 %; torsion 1st – frequency 43,0 Hz and damping 0,60 %.

Visual inspection of the mode shapes is presented on Fig. 12, Fig, 13, Fig. 14.

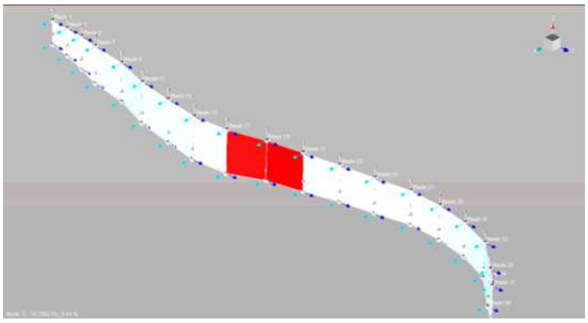

Fig. 12. Identified flapwise 4th

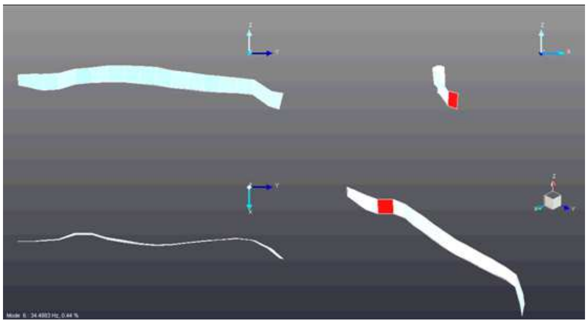

Fig. 13. Identified chordwise 1st

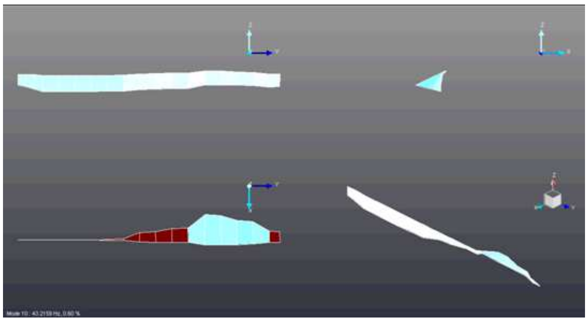

Fig. 14. Identified torsion 1st

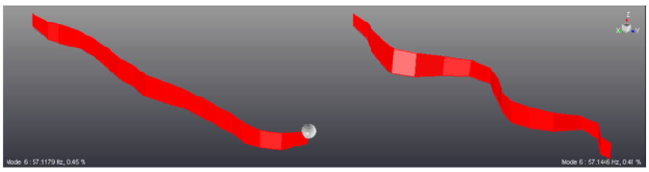

Fig. 15. Mass modification of blade in LMS Test.Lab Modification Prediction

Using LMS Test.Lab Modification Prediction we can change i.e. a mass of the blade in this case. We change the mass and we change the modal modes. A comparison between blade with additional mass and regular blade mass is presented on Fig. 15.

4. CONCLUSIONS

This paper presents some aspects of the multidisciplinary and interdisciplinary research oriented for the test data variability. It was presented a test campaign lead on the composite material main rotor helicopter blade. Test setup include measurement technique of contact type. Experimental test data examples are shown and used for modal models estimation.

Experimental Modal Analysis (EMA) is currently one of the key technologies in structural dynamics analysis. Based on the academic fundaments of system identification, it has evolved to become a “standard” approach in mechanical product development. The PolyMAX method brings a revolutionary modal parameter estimation technique that is easy to use, quick to perform, substantially reduces operator-dependent judgment, and that delivers high quality modal parameter estimation, even on complex data.

Varying mass loading or constraint effects between partial measurements may determine several errors on the final conclusions. Mass loading effect from adding piezoelectric accelerometers and instrumentation should be analysed In next tests, thought a comparison between the mentioned contact and non-contact measurement techniques (i.e. laser vibrometer).

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