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VIBRATION TESTING OF A HELICOPTER MAIN ROTOR COMPOSITE BLADE

Maciej Parafiniak, Paweł Skalski

Institute of Aviation

Abstract

The research presented in this paper focuses on a composite structure test. The object of the investigation is a blade from main rotor of the IS-2 helicopter. 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 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.

INTRODUCTION

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.

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.

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.

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.

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 nosie and vibration testing, including solutions for acoustic, rotating machinery, structural testing, environmental testing, vibration control, reporting and data management.

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.

1. 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). The blade is made of a composite material. Dimensions of the investigated object are: length 3,25 [m], width 0,20 [m]. Approximate weight of the structure is 12,60 [kg].

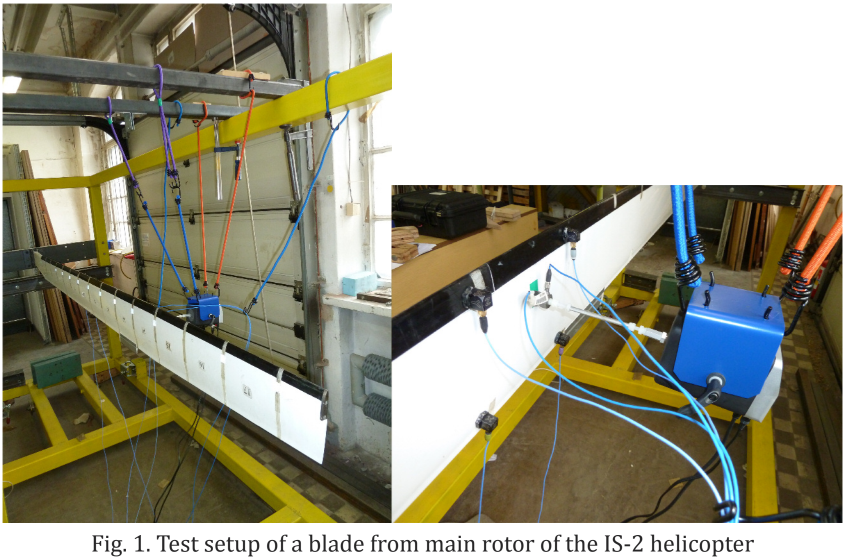

Fig. 1. Test setup of a blade from main rotor of the IS-2 helicopter

In a test campaign the following measurement and analysis tools were used:
- 1 main rotor composite blade of the IS-2 helicopter .
- 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].

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. 2. It consists of 39 points, 38 of which are acquisition locations and the remaining 1 is the reference point.

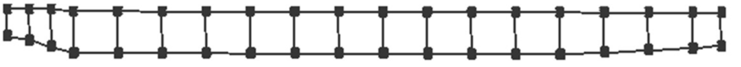

Fig. 2. Cartesian coordinate system for piezoelectric sensors in LMS Test.Lab Geometry

2. 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. Modal models have to be validated to provide confident information about the structural dynamics of a research object.

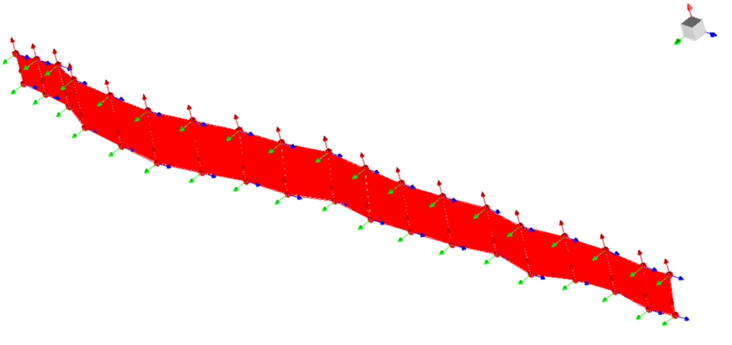

Fig. 3. View of measured blade in LMS Test.Lab Geometry

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. 4 presents a window of PolyMAX in LMS Test.Lab.

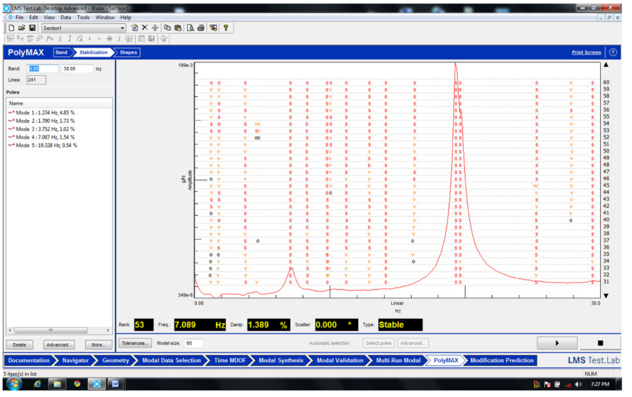

Fig. 4. Window of a stabilization diagram in LMS Test.Lab PolyMAX

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.

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

Visual inspection of the mode shapes is presented on Fig. 5, in this case its present the flapwise 2^{nd}.

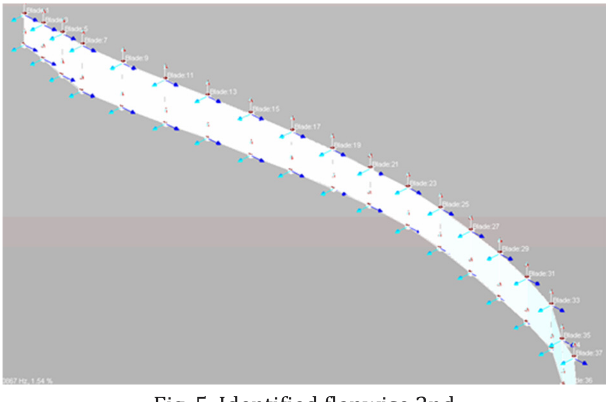

Fig. 5. Identified flapwise 2nd

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. 6.

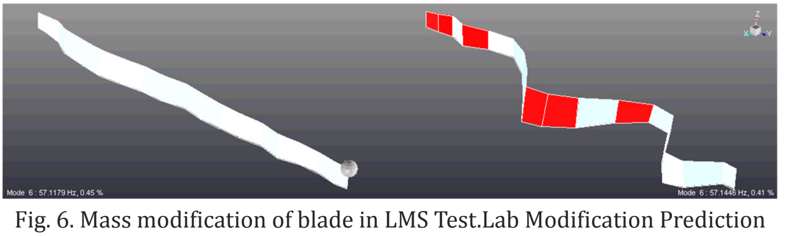

Fig. 6. Mass modification of blade in LMS Test.Lab Modification Prediction

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.

The dynamic characterization of the blade is particularly complex as the impact of the weight of sensors and instrumentation (cables, mounting of exciters) can distort the results.

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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MACIEJ PARAFINIAK, PAWEŁ SKALSKI

PRÓBY WIBRACYJNE KOMPOZYTOWEJ ŁOPATY WIRNIKA ŚMIGŁOWCA

Streszczenie

Badania przedstawione w pracy odnoszą się do prób struktury kompozytowej. Badany obiekt to kompozytowa łopata wirnika śmigłowca IS-2. Metoda badawcza jaka została użyta w próbach to eksperymentalna analiza modalna (ang. EMA). Technika ta jest uznanym narzędziem do identyfikacji własności dynamicznych konstrukcji. Na podstawie danych eksperymentalnych, własności dynamiczne zostały wyznaczone, za pomocą PolyMAX – modułu programu LMS Test.Lab.