25th International Conference on Noise and Vibration Engineering 2012, ISMA 2012, including USD 2012:
4th International Conference on Uncertainty in Structure Dynamics. pp. 2039 - 2043.

Model updating of a helicopter stub wing

C. Mares[1], **M. Esperon Miguez**[2]
Brunel.University, School of Engineering and Design, Mechanical Engineering
Kingston Lane, Uxbridge, Middlesex, UB8 3PH, United Kingdom
e-mail: **cristinel.mares@brunel.ac.uk**

[2] Cranfield University, IVHM Centre
University Way, Cranfield Technology Park, MK43 0FQ, United Kingdom
e-mail: **m.esperonmiguez@cranfield.ac.uk**

Abstract

In this paper we describe the process of optimization for the structural model of a helicopter stub-wing based on experimental data. The wing dynamics is updated using the ground vibration tests within the

0-80Hz frequency range and a detailed discussion is carried out to present the modeling errors and the specific finite element analysis leading to an improved dynamic behaviour. Because the main objective for model updating exercises of aeronautical structures is the prediction of the dynamic behavior in flight, as well as the effect of configuration changes, a set of in-flight measurements is determined with the objective to be used for the derivation of a representative model. A preliminary analysis of the model quality to be used subsequently in flight test conditions is carried out.

1 Introduction

In complex structural dynamics applications, considerable discrepancy between analytical prediction and experimental data is usually encountered, requiring modifications of the models based on a better understanding of the physical behaviour, mitigation of the modeling assumptions followed by model adjustments and finally by model validation through predictions of systems behavior in other test conditions or modified configurations.

The model updating procedures are described in detail in [1-3] and among different approaches, the sensitivity method has been applied successfully to large industrial problems for finite element model updating based on vibration data. A tutorial describing the most specific aspects of the sensitivity method is presented in [4].

In aeronautical applications the main objective for model updating exercise is the prediction of the dynamic behavior in flight, as well as the effect of configuration changes. The level of vibration in helicopter applications represents a main concern due to its impact on the life and operational costs. The design cycles can be reduced by building appropriate models allowing further optimization, structural changes, smooth flying qualities and increased flight performance. The prediction of airframe vibration levels and performance must take into account the dynamic in-flight loads. For the specific case of helicopter dynamics, these include the effects of aerodynamic loads and rotor harmonic excitation and the modal parameters should be determined using an operational modal analysis technique leading to the discrimination of the rotor harmonics. The complexity of model updating for helicopter airframes has been addressed previously in [5] and in [6] the model updating loop was complemented by the clustering of the updating parameters spread over different parts of the model using the sensitivity matrix. In this paper, some difficulties in modeling and their effect upon the dynamics in the analysed frequency range are presented, the updated model presenting reduced errors between analytical prediction and test results.

2 Model Correlation

2.1 Finite element model

The stub wing structure is bolted to the vehicle airframe at four points and the structural layout is that of a standard tapered wing structure with three spars and four ribs aligned with the vehicle axis and skin panels covering the internal frame. The structure is modeled in MSC-NASTRAN using CQUAD4 elements. The pylons connect the external payload and are modeled using CBAR elements with spring and rigid elements (CELAS and RBAR). Inertial properties are correlated with the real hardware and concentrated masses are assigned at specific nodes in order to model the mass distribution correctly, Figure 1.

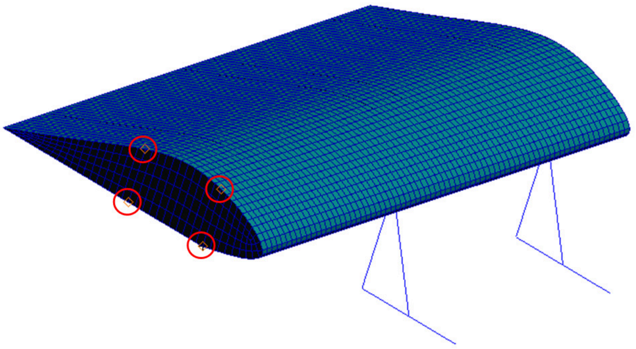

Figure 1: Finite element model (wing and connection points).

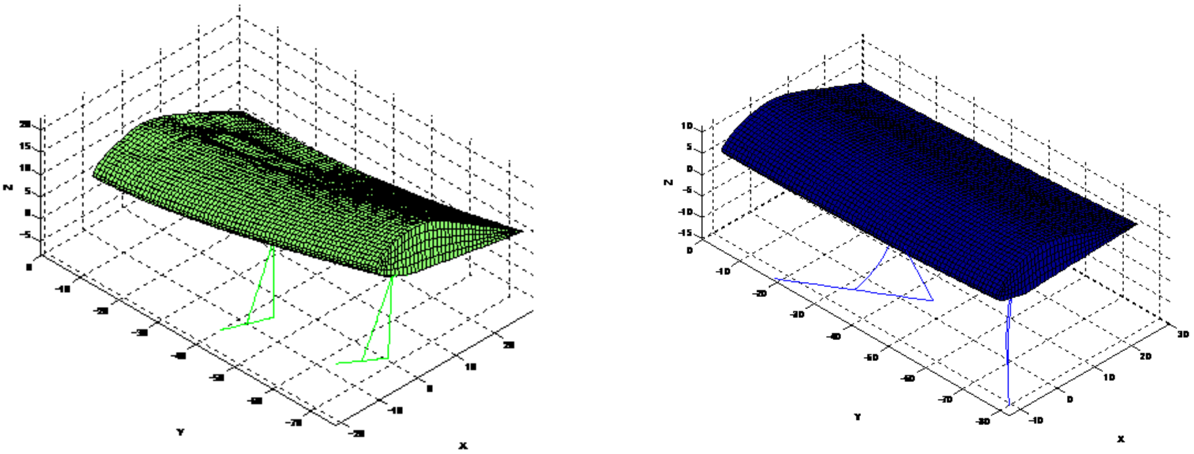

Figure 2: Mode shapes: bending @ 3.34 Hz and pylon torsion @ 4.57Hz .

The dynamic analysis identified a set of modes up to 80Hz, these corresponding to the bending and torsion of the wing or pylon as well as more complex dynamics. The natural frequencies are shown in Table 1 with two representative mode shapes in the lower frequency range presented in Figure 2. These were later used for model correlation in an updating loop using the identified experimental modes.

2.2 Experimental analysis

The structure was tested in a hammer test and 23 accelerometers were used to measure the response at different points. The reciprocity of the measured responses was verified on 16 different points (with some measurements in more than one direction). The sampling frequency was 256 Hz the data was collected with a resolution of 0.125 Hz getting 1024 measurement lines for each FRF. The experimental wireframe is presented in Figure 3, this being matched with the closest finite element nodes.

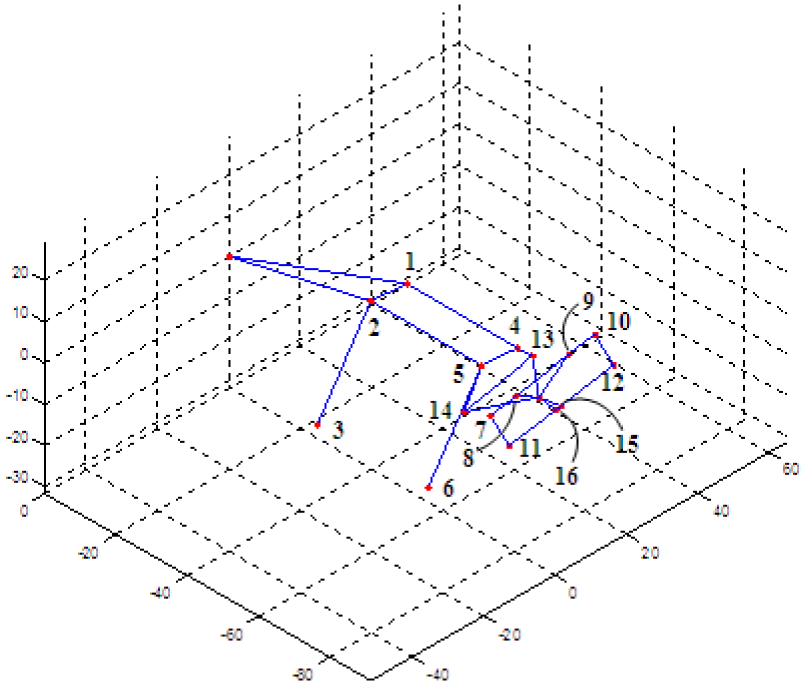

Figure 3: Experimental wireframe.

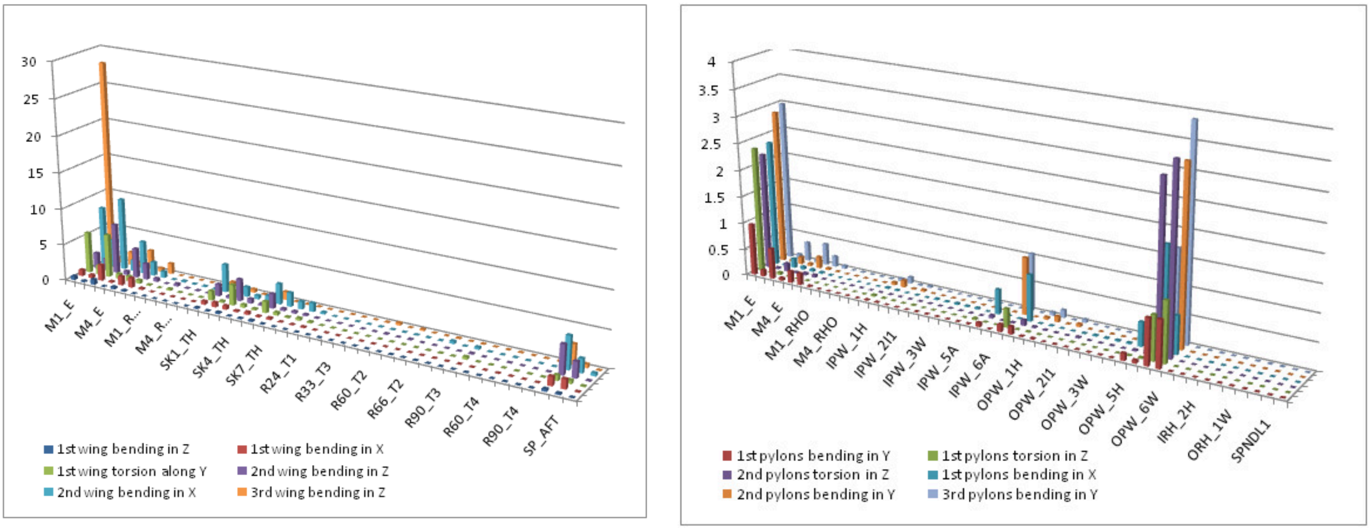

Figure 4: Eigenvalue sensitivity for most important updating parameters.

2.3 Model Updating

Different material properties were used to parameterize the baseline model and a set of 82 parameters were analysed to determine their effect on the wing dynamics. These were material and geometric properties such as Young's modulus, density and dimensions for the cross sections of the bars and thickness of the plates. The normalized sensitivity for the groups of modes describing the wing and pylon dynamics are presented in Figure 4. It was determined that 11 respectively 9 variables could be used for improvement of the wing respectively pylon's dynamics. The finite element analysis showed discrepancies in modeling with respect to the actual hardware and allowed to understand the need for an equivalent model and generation of large sensitivities with respect to some variables. Construction details such as just only two ribs connecting the leading edge with the trailing edge, the existence of operational access panels located on the wing, specific joints within the wing and between the pylons and the wing as well as the taper ratio of the wing, allowed to determine a correspondence between the nature of the parameters with large sensitivity and the errors presented in the actual model [7]. The model was updated using these two groups of modes and the parameters discussed above using Solution 200 for the reduction of the errors in natural frequencies between the correlated modes. The results are presented in Table 1, and it can be seen that the average error was reduced from 11.5% to 2%. Although the torsion mode presents a final error of 11%, the overall dynamics is better correlated.

3 Conclusions

In this paper some results of a model updating exercise for the improvement of the dynamic behavior of a helicopter stub wing are presented. The model updating loop is carried out by correlating the updating parameters with modeling errors of the actual hardware. In the analysed frequency range, the updated model presents a better correlation with the test results for the two main groups of modes with localized dynamics of the pylons and torsion/bending of the wing.

Acknowledgements

This work has been carried out within the program GARTEUR AG-19, "Methods for Improvement of Structural Dynamic Finite Element Models using In-Flight Data".

Mode	**Test (Hz)**	**Initial (Hz)**	**Error (%)**	**Updated(Hz)**	**Error (%)**
Wing 1st Z bending	3.41	3.87	13.24	3.34	-2.25
Pylons 1st Y bending	4.31	4.32	0.28	4.27	0.90
Pylons 1st Z torsion	4.54	4.89	7.59	4.57	0.60
Pylons 2nd Z torsion	5.21	4.94	-5.24	5.22	0.10
Pylons 1st X bending	5.62	5.36	-4.79	5.64	0.18
Pylons 2nd Y bending	6.62	6.69	0.94	6.64	0.29
Pylons 3rd Y bending	9.29	8.14	-12.36	9.23	-0.64
Wing 1st X bending	13.15	12.50	-7.56	12.98	-3.98
Wing 1st Y torsion	28.08	29.36	4.54	31.21	11.13
Wing 2nd Z bending	30.35	34.84	14.78	30.44	0.28
Wing 2nd X bending	39.35	61.46	56.20	40.33	2.49
Wing 3rd Z bending	61.82	68.90	11.43	62.93	1.77
Average	-	-	11.58	-	2.05

Table 1: Model updating results.

References

[1] H. G. Natke, *Einfuhrung in Theorie und Praxis der Zeitreihen und Modalanalyse*, Vieweg Verlag, Branschweig/Wiesbaden, Germany, (1992).

[2] J. E. Mottershead, M. I. Friswell, *Model updating in structural dynamics: a survey,* Journal of Sound and Vibration, Vol. 167, No. 2, Academic Press (1993), pp. 347-375.

[3] M. I. Friswell, J. E. Mottershead, *Finite Element Model Updating in Structural Dynamics*, Kluwer Academic Publishers, Dordrecht, (1995).

[4] J. E. Mottershead, M. Link, M. I. Friswell, *The sensitivity method in finite element model updating: a tutorial,* Mechanical Systems and Signal Processing, (2011), Vol 25, pp. 2275-2296.

[5] G. W. Skingle, G. H. Graves, C. Hatch, J. E. Mottershead, D. Goege, M. Link, N. Lieven, A. McLughlin, A. Piet, H. Rottmayr, R,. Van Routen, *GARTEUR AG-14: Methods for refinement of structural dynamic finite element models*, GARTEUR LTd, (2003).

[6] H. Shaverdi, C. Mares, W. Wang, J. E. Mottershead, *Clustering of parameter sensitivities: examples from a helicopter airframe model updating exercise,* Shock and Vibration, Vol. 16, No.1, (2009), pp. 75-88.

[7] M. Esperon, *Improvement of a Structural Dynamic Finite Element Model for a Helicopter Stub Wing*, MSc Dissertation, School of Engineering and Design, Brunel University, (2010).

2012-09-19

Model updating of a helicopter stub wing

Mares, Cristinel

International Stress Management Association (ISMA)

Mares C, Miguez ME. (2012) Model updating of a helicopter stub wing. In: 25th International Conference on Noise and Vibration Engineering 2012, ISMA 2012, including USD 2012: 4th International Conference on Uncertainty in Structure Dynamics, 17-19 September 2012, pp. 2039-2046

https://past.isma-isaac.be/downloads/isma2012/papers/isma2012_0729.pdf