AIRBUS A320 NEO GVT AND FEM UPDATING

STATE-OF-THE-ART TECHNIQUES TO PERFORM AN INDUSTRIAL VIBRATION TEST CAMPAIGN AND A RAPID PROCESS TO UPDATE RENEWED FEM FOR CLEARANCE OF FIRST FLIGHT TEST

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Abstract: After the realization of the GVT (Ground Vibration Testing) campaigns on the AIRBUS A350 XWB 900 in 2013, the ONERA-DLR specialized joined team performed the GVT of the A320 NEO Pratt & Whitney powered in July 2014. The specifications of this test were particularly oriented to the updating of a renewed FEM (Finite Element Model) of this new version of the A320. Concerning the GVT, the latest improvements on developed methods and tools were applied, making the completion of the test successful in 7 measurement days for 2 mass configurations.

Concerning the GVT, the very short time devoted to this campaign imposed by a strict and busy planning from the program leaders required to reinforce in one hand the test techniques and methods, mixing PSM (Phase Separation Methods) and PRM (Phase Resonance Methods) and to optimize in the other hand the workflow and the data deliveries to meet the challenging test requirements. This paper describes the processes followed and the methods used in this particularly hard context and how those contributed to the successful achievement of this challenging test campaign.

Concerning the FEM updating, an optimized process has been applied to update the renewed FEM, especially focusing on the updated components such as pylons, engines, wings and sharklets. This process - including correlation analysis, tuning FEM then validating tuned FEM w.r.t GVT - has provided a means to tune FEM within a short time to support clearance of first flight test.

1 INTRODUCTION

In July 2014, the ONERA-DLR specialized team did the GVT (Ground Vibration Testing) campaign of the AIRBUS A320 NEO (New Engine Option), powered by new Pratt & Whitney 1100G-JM engines. The GVT was performed on the MSN 6101 aircraft, for a period of 7 measurement days, in the AIRBUS facilities of Saint Martin du Touch (France).

The very short time devoted to this test campaign, imposed by a strict and busy planning from the A320 NEO program management, required to improve the ONERA-DLR test techniques and methods (ref. [1], [2] and [3]) and to define an optimized workflow to meet the challenging test requirements in this time frame. If the PSM (Phase Separation Method) was the main used method, some specific modes were also identified with PRM (Phase Resonance Method).

Continuous exchanges with AIRBUS on the modal models built in “live” allowed adjusting the test program in “real time” in function of results and requirements.

The FEM updating is traditionally used for supporting first flight clearance, for opening flight domain and finally for flutter certification. This paper deals with rapid and preliminary FEM updating for supporting flutter clearance of first flight (2 months after GVT).

Figure 1: GVT campaign of the A320 NEO PW MSN 6101 in AIRBUS facilities (Toulouse, France)

2 A320 NEO DESCRIPTION

As the world’s best-selling product line, the A320 NEO family continues AIRBUS reputation for non-stop innovation – incorporating two new engine choices, sharklets fuel-saving wingtip devices and a further optimized cabin to deliver unbeatable efficiency and comfort.

These improvements result in a per seat fuel burn saving of 20 per cent compared to current engine option (CEO) jetliners, along with additional range, reduced engine noise and lower emissions.

A320 NEO family consists of 3 versions (A319 neo, A320 neo & A321 neo), powered with new engines (the 1100G-JM engines from Pratt and Whitney or the LEAP from CFM).
The current paper deals with the GVT of the first A320 NEO, powered with 2 engines PW1100G-JM. This aircraft performed its maiden mission from Toulouse (France) on the 25th of September, 2014.

Figure 2: A320 NEO PW MSN 6101

3 GVT ORGANIZATION

3.1 Technical specifications

The objective of the A320 NEO GVT campaign was the following:

- A/C test - to determine the modal characteristics of the complete A/C (and its control surfaces) for FEM validation:
    - Resonance frequencies
    - Mode shapes
    - Generalized mass & damping
    - FRFs (Frequency Response Functions)
    - Structural nonlinear behaviour

Ground Vibration Test is an essential milestone in the aircraft development process for aeroelasticity and supports load certification.

Practically GVT:

- Supports first flight clearance and flight domain opening
- Is used as a means of compliance for Airworthiness Authorities due to the aircraft certification process

Tests were on the critical path of the program. Impact on planning was reduced to the very minimum thanks to an optimized workflow and to an enhanced integration with Final Assembly Line (FAL).

Measurement and excitation strategies had both:

- To be optimized to fit with the strong time constraint
- To be adjusted in "live" taking into account encountered structural specificities:
  - To remain in acceptable levels versus structural and material limitations
  - To provide the best measurement quality

Modal data were directly post-processed and were analyzed on site to allow "live" trouble shooting and early model calibration.

3.2 Aircraft configurations

During this reduced and fixed time frame, the GVT had to address two fuel mass configurations:

- Structural configuration 1 (C1) – main configuration - light A/C, empty of fuel
- Structural configuration 2 (C2) – partial configuration - outer wing tanks fully filled of fuel

The control surfaces were set in neutral position (normal law with no feedback).

The aircraft was put on suspensions to uncouple rigid body modes from flexible modes. In order to reduce the lead time, a new suspension device was designed using air-spring to achieve low stiffness and straightforward industrial implementation.

3.3 Equipment

For conducting such a GVT, it is mandatory to have enough equipment for vibration excitation and for measurement of vibration responses. Due to the size and weight of an aircraft, the considered frequency range is typically low. The upper frequency limit of excitation was in this case not higher than 50 Hz. The lower limit of the frequency range depended on the suspension characteristics. Except for dedicated identification of resonance frequencies of rigid body motions, the lower frequency limit of measurement was around 1.5 Hz. In order to address as far as possible structural nonlinear behaviours, even for the very first elastic modes, it is recommended to use shakers having a long coil stroke to excite at such low resonance frequencies and with sufficient excitation force. It has also to be noticed that current-controlled power amplifiers were used with shakers.

Tripods excitation devices were required to locate shakers at specific positions on the aircraft. These tripods must be stable enough to carry shakers and to compensate excitation force. In addition, they must be capable of fine tuning the relative position of shakers with respect to aircraft. On the other hand, the tripods must include an elastic degree of freedom propitious to avoid the undesirable motion of shaker bodies due to the possible flexibilities of platforms and scaffoldings on which they are installed.

Figure 3: View of the Z excitation of the left-hand side engine

Figure 4: View of the Z excitation of the right-hand side wing

For risk mitigation purposes, excitation forces were measured twice with different measurement principles. Primarily, excitation forces were measured using piezoelectric force sensors installed at each excitation point between the structure and each exciter coil. In addition, excitation forces were measured using coil currents provided by power amplifiers. Displacement sensors, permanently installed inside shakers, were used to measure the relative displacement of shaker armature in its housing. It was useful for optimization of excitation force signals in the very low frequency range, where the limitation is not the peak force of shaker, but the driving point displacement response, and to avoid any damage on shakers and their connections with the aircraft.

The vibration responses were mainly measured in terms of acceleration response using accelerometers qualified for the very low frequency range. A total of 490 accelerometers were installed for the GVT on A320 NEO and were measured simultaneously.

The whole data acquisition system was based on ONERA’s and DLR’s combined LMS Scadas III frontends controlled by the LMS Test.Lab software. Distributed data acquisition was realized by placing the 8 LMS Scadas III frontends at different locations around the aircraft. These frontends were connected together by optical fiber cables to synchronize and transfer data. V12L modules were used due to their very low cut-off frequency of analog high-pass filter. As these modules provide a 24 bits resolution, the time-consuming process of acquisition channels autoranging is useless.

A total of 20 excitation locations were applied for C1, and then 8 for C2.

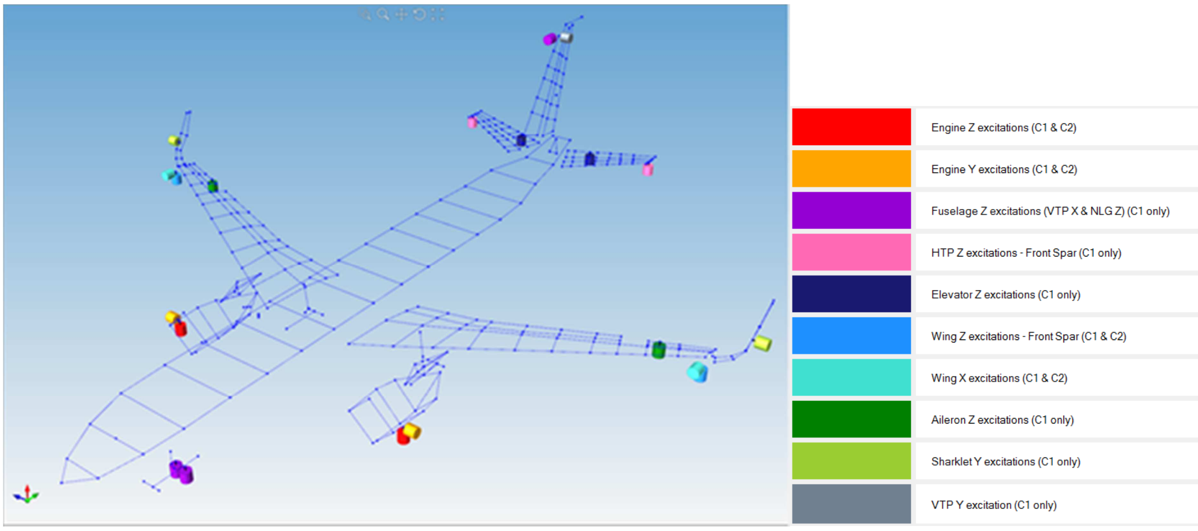

Figure 5: Excitation configurations with exciter locations

3.4 Teams

The work was organized in two shifts with 8 people per shift. A single team consists of several positions:

- An engineer team leader
- Technicians for shaker handling and connections
- Technicians and engineers for excitation control and data acquisition
- Engineers for data checking, modal identification and model correlation

This kind of team setup guarantees a highly efficient GVT performance, which is especially relevant because of the short time slot offered by aircraft manufacturers to conduct such a GVT.

The work rate was 6 days a week, from 7 a.m. to 12 p.m. during the 7 days of measurement.

Figure 6: GVT command rooms

4 METHODS

Two complementary kinds of excitation methods were applied during the tests. The Phase Separation Method was mainly used to identify the global structural behaviour. Additionally some specific modes have been analyzed by the Phase Resonance Method.

4.1 Phase Resonance Method (PRM)

PRM, the standard method used by ONERA and DLR for aircraft GVTs before 2000, is sometimes considered as an outdated method. Nevertheless PRM is up to now the most accurate and robust method for modal analysis, especially when nonlinear structural behaviour is encountered. Contrary to PSM, PRM aims to make a structure vibrate as a purely real mode by finding the best excitation force pattern; then it gives a snapshot of a mode and does not need any complex mathematical algorithms for post-processing. Methods such as Force in Quadrature and/or Complex-Power are applied to evaluate both structural damping coefficients and generalized mass values. Even if PRM could be very time-consuming, it is still mandatory to keep the ability to apply it during a test since its precision is worth the effort.

4.2 Phase Separation Method (PSM)

PSM was used most of the time since it has the best compromise between time-consuming and modes providing. FRFs are obtained from applying random or swept-sine excitations using electro-dynamic shakers. The majority of exciter configurations consists of two shakers that are operated simultaneously due to the symmetry of the aircraft structure.

Preliminary swept-sine excitations at low force or random excitations give a first series of FRFs. First, low level information of structural response is needed to not exceed predefined threshold levels for maximum acceleration on dedicated components during high level excitation runs. Based on the low level FRFs, the Force Notching process, introduced for the AIRBUS A380-800 GVT in 2005, is applied. Frequency dependent excitation forces are calculated without exceeding the maximum levels of acceleration required by AIRBUS and the maximum coil strokes available in each exciter.

4.2.1 Data workflow for PSM

In the last 15 years, the switch from PRM to PSM for aircraft GVTs was completely performed. One of the main reasons is to save testing time. Nevertheless the effort for post-processing has risen significantly. Using PRM it was quite simple to establish a modal model of the structure with high quality and perfectly excited modes. It was also easy to identify problems or even mistakes during excitation. To achieve a comparable quality using broad band excitation, advanced testing strategies starting from exciter signal generation, over signal processing to data delivery are needed. By PRM, each mode was excited using different force levels if requested just from a single exciter configuration. Directly after acquisition, the captured mode could be delivered to the customer. For PSM, modes are identified multiple times from different exciter configurations and a selection process for the “best” modes needs to be carried out afterwards.

The workflow related to the application of PSM on an aircraft structure is shown in Figure 7. The ONERA-DLR GVT team relies on an LMS SCADAS III system with LMS Test.Lab software. Efficient tools that interact with the LMS Test.Lab environment optimize the processes from data acquisition with user defined signals, signal processing, modal identification and modal model correlation.

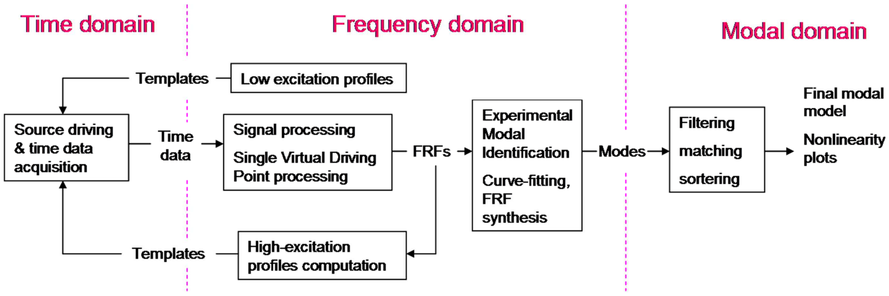

Figure 7: Data workflow for PSM

Basically there are three important tools to mention that improve the efficiency and the data quality achieved by the ONERA-DLR team during the GVT with the Phase Separation Technique:

1. *Force notching:* User defined and perfectly optimized excitation signals for single and multipoint swept sine excitation
2. *Single virtual driving point processing:* Processing of data from correlated multipoint swept sine excitation runs directly into a single column of frequency response functions
3. *Correlation tool:* SQL-based database software environment for storage, visualization, interpretation and correlation of all identified modes before the final delivery to the customer

On-site signal processing and modal identification process is an essential pre-requisite; otherwise problems and mistakes in a setup with hundreds of sensors can neither be identified nor corrected. Through on-site analysis, results can be delivered to the customer immediately. In fact, the customer has a view-client access to the permanently growing GVT database which enables him to monitor the test progress and to put emphasis on identification of specific modes of interest.

4.2.2 SVDP

For an aircraft, swept-sine excitations are either symmetric or antisymmetric force patterns applied with two shakers also installed in a symmetric setup. As forces are in this case by definition correlated, it is not possible to use the H_1 estimator on the acquired time data directly:

$$\left[H_1(\omega)\right] = \left[P_{XX}(\omega)\right]\left[P_{XF}(\omega)\right]^{-1} \tag{1}$$

Where $[P_{XX}(\omega)]$ and $[P_{XF}(\omega)]$ are respectively the output and input-output power spectral densities.

One solution consists to build augmented matrices from the combination of all runs, for instance two runs in the case of symmetric and anti-symmetric excitations. The Single Virtual Driving Point (SVDP) process is preferred for several reasons (ref. [4] and [5]). First, it allows the use of existing single input multiple outputs (SIMO) processing on each run. The

FRFs are obtained much faster than waiting for the complementary run. Second, the modal density is only half of the modal density from uncorrelated excitation. Symmetric sine sweeps only excite symmetric modes which allows for an easier modal identification.

The SVDP process defines a mathematical construction of a virtual driving point, which would have given rise to vibratory responses strictly similar to those obtained with correlated forces. SVDP relies on the equivalent complex power:

$$\{P(\omega)\} = \sum_{shakers} \{F_s(\omega)\}\{\dot{X}_s(\omega)\} = \{F_V(\omega)\}\{\dot{X}_V(\omega)\} \tag{2}$$

Where $\{F_s(\omega)\}$ is an excitation force acting on a driving point *s*, $\{\dot{X}_s(\omega)\}$ the velocity at driving point *s*, $\{F_V(\omega)\}$ the virtual force and $\{\dot{X}_V(\omega)\}$ the velocity response of the virtual driving point. The virtual driving point does not exist physically. It is just an imaginary driving point of the virtual force. It is important to note that the single virtual force acting on this single virtual point has exactly the same excitation energy as the multi-shaker setup and produces exactly the same response. Once the SVDP process has been applied, SIMO FRFs with regard to the virtual driving point are obtained and classical curve-fitting can be directly used on them. The additional degree of freedom of the mode shape vector related to the virtual driving point can be removed after modal analysis and normalization can be applied to the mode shape vector and the generalized mass.

4.2.3 Force Notching

The classical broad band excitation signals for electro dynamic shakers are random and swept sine signals. Random signals can be used to get a fast insight of the structural dynamic behavior at a very low level of input energy. Indeed, the total energy is distributed in all the frequency range of excitation.

Swept sine excitation signals are more appropriate to achieve higher response levels of energy. Nevertheless, it is necessary for aircraft vibration testing not to exceed predefined thresholds of response levels that are either given by the customer (typically max. g level per component of the structure) or that are physically given by the maximum stroke and the maximum force limit of the electro dynamic shaker.

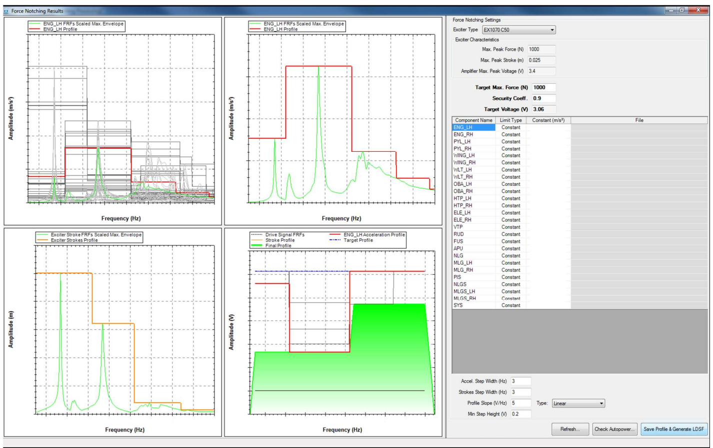

Figure 8: Force notching results on the engine Z excitation configuration

4.2.4 Modal identification and quality assessment

From a theoretical point of view it would be sufficient to use only very few excitation points to excite all modes of an aircraft, but the practical application shows that several excitation configurations are needed during GVT: vertical and lateral engine excitations, vertical and axial wing excitations, HTP excitation, VTP excitation, and possibly many others as well. The general goal is to put as much energy as possible per mode, i.e. to increase the level of generalized force until maximum per mode, as it is typically performed when using PRM. These numerous tests are mandatory for optimizing the reliability of experimental modal model and taking into account nonlinear structural behavior. In practice, for each excitation configuration, several runs are performed at different levels of excitations. From all these runs, each structural mode can be identified a significant number of times. During the modes sorting and filtering process, the whole set of modes identified by curve-fitting is carefully analyzed by structural engineers and sorted by nature.

All identified modes are stored into a database system with multi user access. Each mode is stored not only with its modal properties but also with numerous fields containing meta-information and other mode shape describing qualifiers. A specially designed software tool called “Correlation Tool” was developed to review the modes in the database. The Correlation Tool uses an SQL database that is running on a server PC. Graphical user interfaces for database access, e.g. for correlation or visualization purposes, can be installed on different computers, even on the customer computer to give online access (read only) to the current modal data.

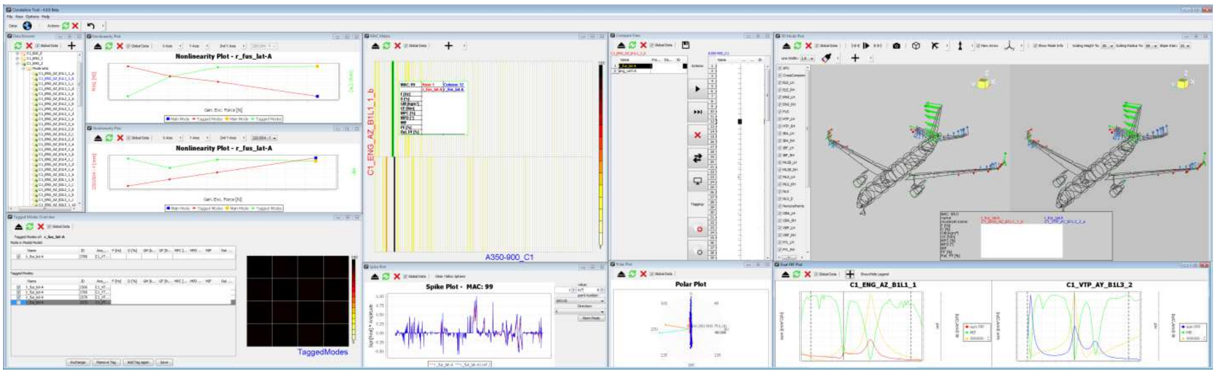

Figure 9: Correlation tool

A typical view of the Correlation Tool is shown in Figure 9. Several windows showing modal properties of the correlated modes can be plugged in.

One feature of this database software is that modes which have been identified from different FRF datasets with almost identical properties can be grouped in a mode family based on the Modal Assurance Criterion (MAC). For each family, the most representative mode is selected as a member of the final modal model delivered to the customer. To support the process of correlation of modal datasets and finally the generation of the final modal model different quality indicators and other criteria are applied, for example, level of excitation, generalized force and value of Mode Indicator Function (MIF) are used here. The concept of mode families can also be applied to evaluate variability on test results or even to analyze the results in terms of nonlinear behavior. If the members of a mode family are considered to be reliable enough (i.e. confidence in the results assessed by quality indicators), they can become affiliated to a "master mode" and their damping ratios and resonance frequencies can be plotted as a function of force level or other parameter of the database.

After correlation of all identified modes specific modal model modes can be analyzed for nonlinear effects. The correlated family can be visualized by frequency and damping over generalized force.

Since the SQL database has the capability of multi user access, the GVT manager can control the current status of the analysis from any PC in the network. Even the customer gets a “read only” account from which an export of the current modal model in the Universal File Format is possible. This enables the customer for on site model correlation.

During the A320 NEO GVT, the work of modal correlation was a specific challenge. Finally, the huge amount of data was condensed down from about 3321 poles identified from all FRF datasets to only 78 master modes in the final modal model for the main configuration. For sure, this correlation work had to be performed in a short period of time leading to specific requirements of the graphical user interface ergonomics.

4.2.5 "Live" feedback from AIRBUS

The correlation tool with its multi user access database offers the customer utmost transparency of the modal data. In addition ONERA and DLR share the work progress table of all individual working stations (exciter preparation, data acquisition, modal identification and modal correlation) in an online multi user access worksheet presented in Figure 10.

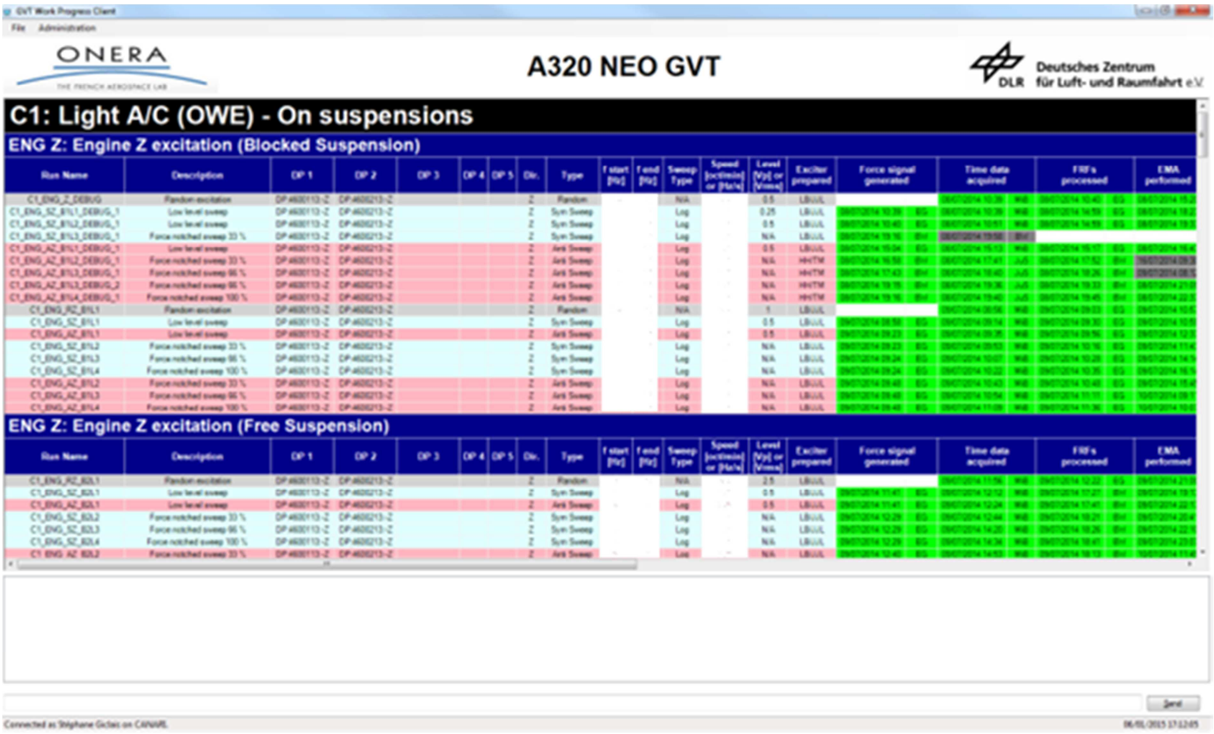

Figure 10: “Live” work progress of the test

The status of data acquisition and processing can be tracked easily by everybody in the team. This tool is available for the customer. In combination this visibility allows instantaneous decisions from the customer for next exciter configurations. Access to analysis results significantly contributed to achieve this GVT half a day in advance.

5 GVT RESULTS

5.1 Structural configuration 1 (C1)

5.1.1 PSM

During structural configuration 1, 147 runs were performed for 10 exciters configurations. For each excitation configuration, a first random excitation was done, to quickly define the frequency ranges of interest. Then, swept-sine excitations with constant or notched amplitudes were done in different frequency bands.

In fact the frequency range was divided in 2 bands due to mechanical reasons:

- For low frequencies (below 10 Hz), the bungees of the exciters suspension devices were blocked
- For high frequencies (above 8 Hz), the exciter suspension devices and the push-pull rods were stiffer than the ones used for low frequency bands

A total of 3321 modes were identified during the post-processing of C1. From this whole set, 1346 were kept to form 78 family of modes. Finally, 78 modes were considered as master modes (one per family mode) and formed the modal model that should be used for FEM updating and flutter computation. More specifically, all main structural modes were selected up to 20 Hz, and control surface modes were identified up to 50 Hz.

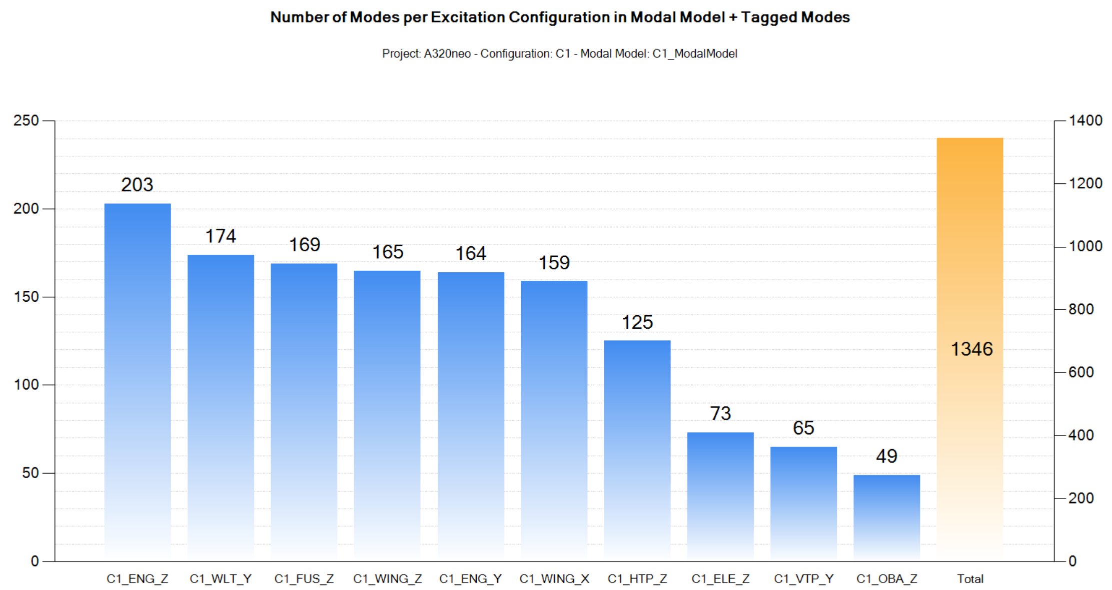

Figure 11: Distribution of selected modes per exciters configuration

On Figure 11, the distribution of these 1346 modes is presented as a function of exciters configuration. It could be noticed that most of modes were obtained by excitations on the engines, the wings and the fuselage.

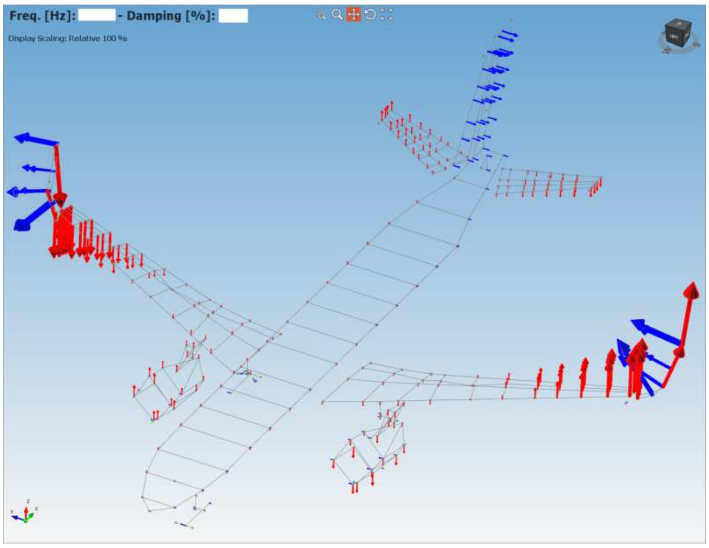

Figure 12: Shape of the 3 nodes wing bending mode of the structural configuration 1

For each mode of the modal model, mode shape, nonlinearity plot, MIF by component and scatter plots were provided. An example of such information is depicted on Figure 12, Figure 13 and Figure 14 for the 3 nodes wing bending mode.

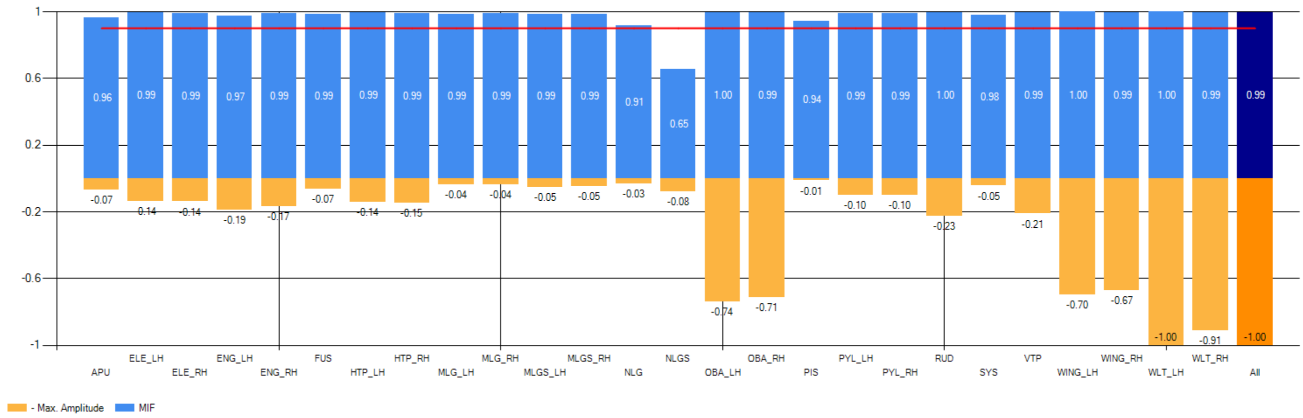

Figure 13: MIF per component of the 3 nodes wing bending mode

Introduced in 1994, the Mode Indicator Function (MIF) per component is very valuable because it gives a clear idea of the quality of identification in terms of mode complexity. For example, on Figure 13 it can be observed that one sub-part (here the nose landing gear NLGS) was not purely in-phase (or out-of-phase) for this particular mode, because its MIF was about 0.65, while other MIFs were all above 0.9 (blue bars). Nevertheless, its maximum amplitude ratio (orange bar) was weak compared to other parts.

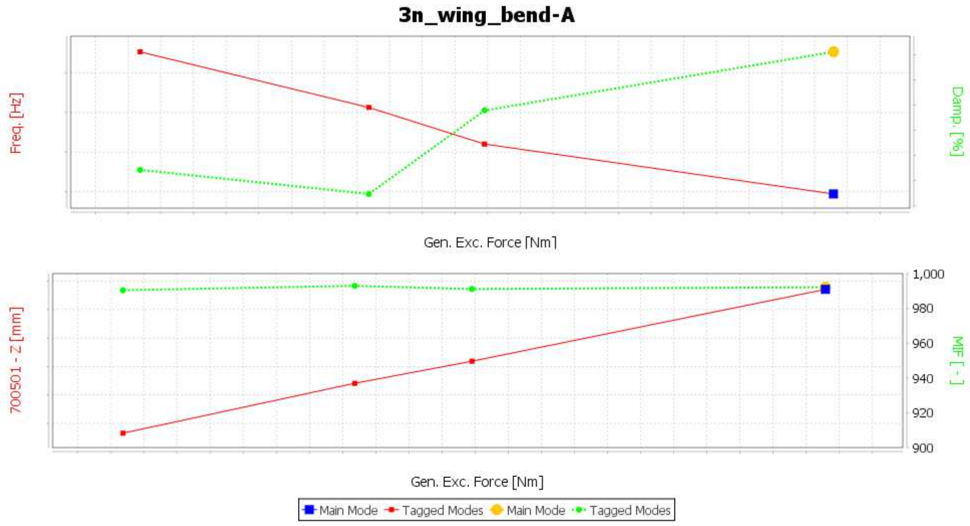

Figure 14: Nonlinearity plots (frequency, damping and displacement as a function of generalized force) of the 3 nodes wing bending mode

The evolution of resonance frequency and damping ratio as a function of force level is given by nonlinearity plots (see an example on Figure 14). In general, frequency decreases as a function of force, while damping increases. But indeed each mode can show a different pattern, because these evolutions are very case-dependent.

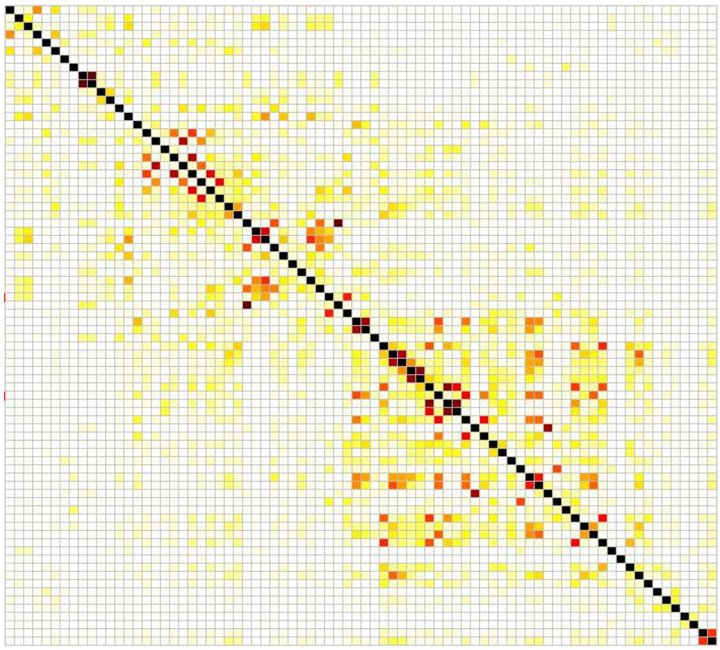

Figure 15: Auto-MAC of structural configuration 1

The auto-MAC of structural configuration 1 is depicted on Figure 15. The matrix is mainly diagonal, with few noticeable extra-diagonal terms. They are due to modes whose shapes are very similar. For such modes, in general the movement of a sub-part (a landing gear for example) can help an analyst to distinguish between them.

5.1.2 PRM

As requested during the follow-up of the GVT, the Phase Resonance Method (PRM) was performed on the two vertical symmetrical and anti-symmetrical engines modes for structural configuration 1. Two exciters located on the two engines were sufficient to guaranty a very acceptable MIF value for the targeted modes.

The PRM has been applied with respect to the forces introduced in the exciter coils with current controlled power amplifiers, force cell sensor responses being acquired for possible backup processing. Due to very small friction in the coil control and due to the absence of springs inside exciter, only the coil mass (3 kg per coil for those exciters connected to the engines) impacts the modal identification.

Views of these two mode shapes are given on Figure 16 and Figure 17.

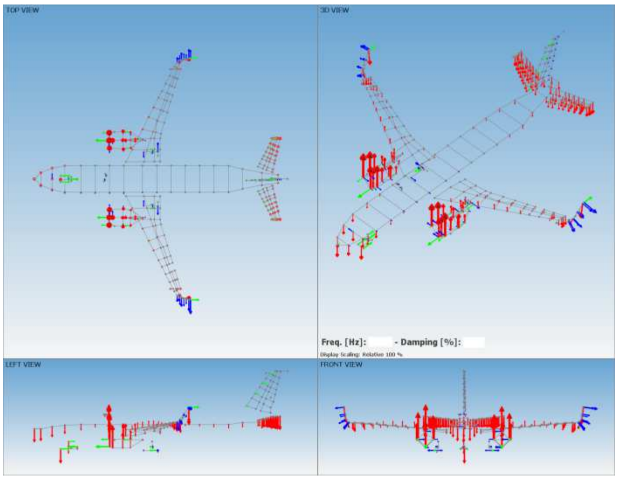

Figure 16: Shape of the symmetrical vertical engines mode obtained by PRM

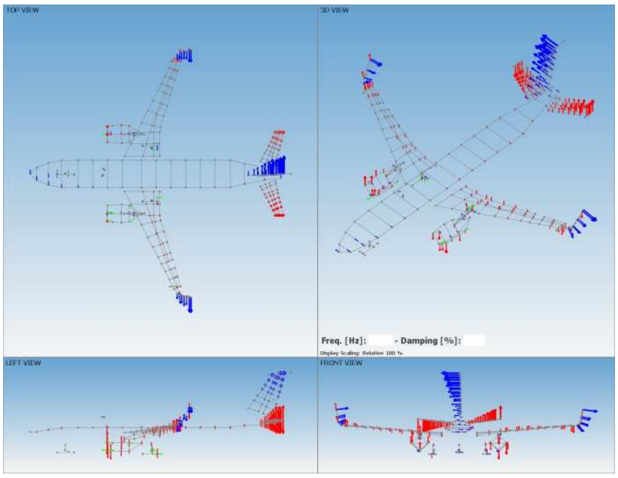

Figure 17: Shape of the anti-symmetrical vertical engines mode obtained by PRM

5.1.3 PSM vs. PRM

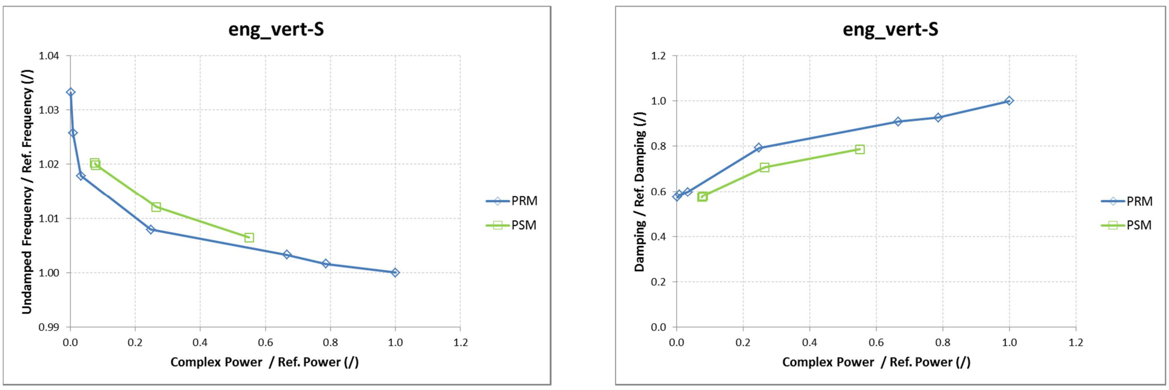

Figure 18: Comparison of nonlinearity plots for the symmetrical vertical engines mode

Nonlinearity plots are really similar when we compare the symmetrical vertical engines mode identified by PRM and PSM (see its shape on Figure 16 and the comparison on Figure 18). Less than 0.01 Hz of difference is observed on undamped resonance frequency and less than 0.2 % on damping ratio. These differences are really small and are considered as acceptable.

5.2 Structural configuration 2 (C2)

In structural configuration 2, 29 runs have been acquired with 4 exciters configurations corresponding to 8 exciter locations.

A total of 506 modes were identified during the post-processing of C2. From this whole set, 316 were kept to form 45 family of modes. Finally, 78 modes were considered as master modes (one per family mode) and form the modal model that should be used for FEM updating and flutter computation.

The Auto-MAC of C2 is depicted on Figure 19.

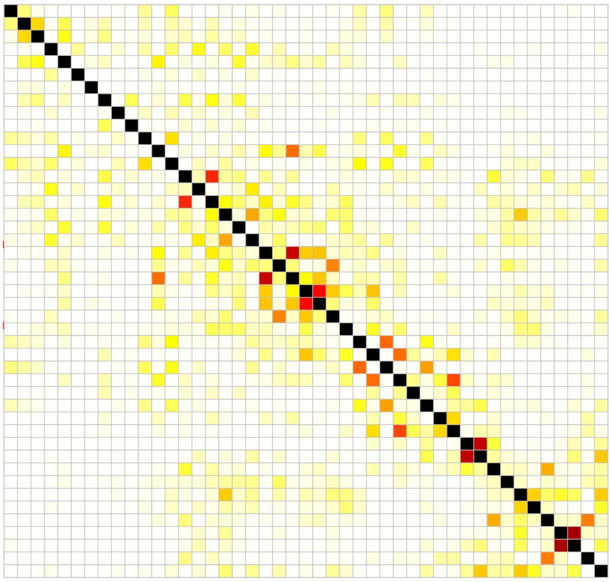

Figure 19: Auto-MAC of structural configuration 2

Differences between auto-MACs of C1 and C2 can be explained by two points.

First, frequency ranges of analysis were different: 15 Hz for C1 and 20 Hz for C2. Then it is normal that although C1 has 78 master modes, C2 basis is limited to 45 modes.

The second point deals with the modes quality identification. There is a strong link between the richness and quality of modal bases and the number of exciters configuration. In fact, when more exciters configurations are used (10 for C1 compared to 4 for C2), modes involving complex movements of several sub-parts are more likely highlighted and then better identified. Moreover, specific sub-parts such as control surfaces can only be identified with dedicated exciter configurations, because they have an inherently nonlinear behaviour.

6 FE MODEL UPDATING FOR FLUTTER CLEARANCE

After performing GVT in July 2014, in order to reduce the lead time, AIRBUS requested ONERA-DLR to deliver the final results of a reduced list of modes in priority, those involved in main flutter coupling. A rapid FEM updating to those GVT results was then performed to create preliminary FEM for supporting flutter clearance of First Flight test.

The principle of rapid process is described in the following steps:

1. Renewed FEM of A320NEO has been created based on certified FEM of A320 Sharklet, with updated pylon and NEO PW engine. This FEM has
    - Mass model validated by GVT weight control
    - Suspension model validated by comparing rigid body modes between FEM & GVT
    - Stiffness model to be adjusted

2. Frequency comparison and correlation analysis between FEM & GVT have been processed with the reduced list of modes to qualify the FEM w.r.t GVT results.

3. "Trial and error" method
   Based on analyzing results from previous step, combined with engineering judgment, a quick process for adjusting FEM has been defined. In this process, Power Plant System (renewed parts of FEM) was focused for updating.

   "Trial and error" method consists of two repeated steps:
   - adjusting FEM: engineering judgment was applied to define group of elements to be adjusted and amount of materials properties to be varied.
   - step 2 was then performed for adjusted FEM

   After two iterations, the preliminary updated FEM better matches GVT results (both C1 and C2 configurations), especially for engine modes. It was then used for supporting flutter clearance of First Flight Test.

   As shown in the following figures, the FEM updating has improved the frequency correlation without significant degradation of mode shape.

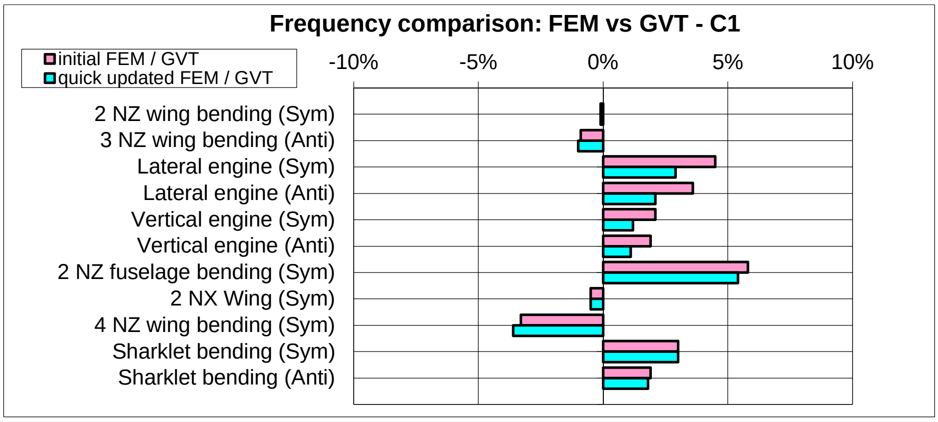

Table 1: Frequency comparison of initial FEM vs. GVT and updated FEM vs. GVT (main configuration)

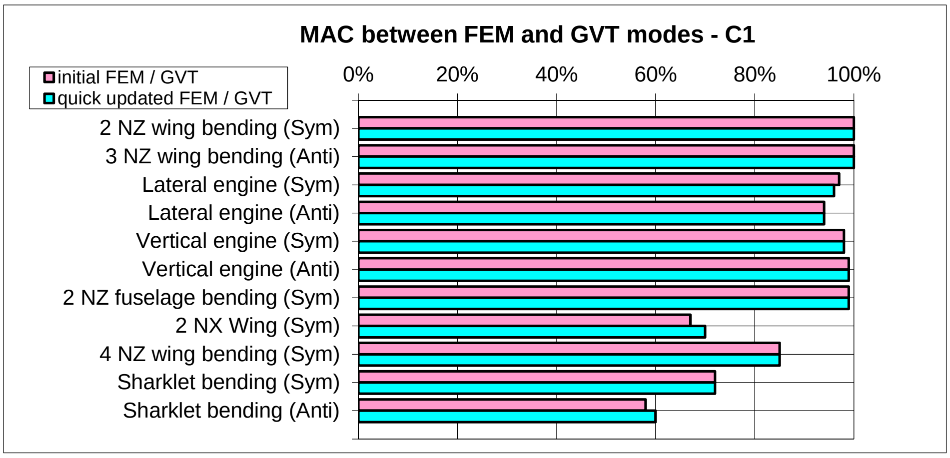

Table 2: Correlation of initial FEM vs. GVT and updated FEM vs. GVT (main configuration)

Frequency deviation (%) = (Freq_FEM - Freq_GVT)/Freq_GVT
Sym : Symmetric
Anti : Anti-Symmetric

7 CONCLUSIONS

Ground Vibration Test is a major milestone on the critical path of aircraft development process. It is performed for several goals. First of all, it delivers the modal model which can be used for flutter predictions and FE model updating. The results of computation are then a support for first flight safety and allow a fast flight domain opening. And finally, they serve as means of compliance in front of Airworthiness Authorities.

The success of such a test relies on several complementary aspects. High-end test hardware and best in class customized software were developed, implemented and used for productivity and quality. Innovative methods and optimized workflow inspired from production line enables a time reduction without decreasing the amount of data. Of course, the human factor is also a strong feature during a test. Highly skilled, integrated and flexible teams (AIRBUS and its subcontractors, DLR and ONERA) were particularly involved during this test, and their work is directly linked to the quality of delivered results. Thanks to all these elements, the A320 NEO GVT was fulfilled in a record time (half a day in advance), with respect to very challenging specifications and with all expected results delivered in required quality.

During GVT campaign, continuous exchanges between ONERA-DLR & AIRBUS on the modal models built in “live” allowed

- GVT teams to adjust the test program in ”real time” in function of results and requirements.
- AIRBUS to anticipate the correlating & updating of preliminary FEM for supporting First flight clearance as well as to accelerate flight domain opening

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9 COPYRIGHT STATEMENT