FASTVIBE SW TOOL FOR RIDE-ALONG VIBRATION SURVEY ANALYSIS

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Abstract

During aircraft operational service life, airborne equipment is exposed to a wide range of mechanical stresses, like vibrations. Environmental vibrations may cause malfunctions or failures, or induce noise and vibrations in the aircraft cabin, threatening safe flight conditions, reducing equipment reliability and operational life. First estimations of an aircraft vibration levels are based on previous experience gathered from similar platforms and on published methods [1][2]. Once the project is mature, dedicated on-ground and flight tests are performed to determine the actual vibration environment and to compare it with the predictions made in the early design phase. Developing adequate qualification criteria for airborne equipment, that take account of these manifold environmental conditions, is not easy. Furthermore initial vibration predictions are affected by factorization criteria that are used to account for uncertainties due - for instance - to the limited number of sensors that can be installed or to the limited amount of experimental flights performed to carry out the vibration survey. Steps have been implemented in the past to determine realistic vibration environment predictions for airborne equipment and to improve the state-of-the-art in understanding what flight parameters and aircraft dynamic variables affect vibrations. With the aim of simplifying the aircraft vibration survey analysis and, at the same time, obtaining vibration data not affected by excessive scattering, an automated tool is created with the use of Machine Learning technique. This tool has been developed to cover equipment qualification needs of a high performance jet aircraft. However, being an automated tool, it can be easily adapted and used to analyse the vibration environment of other kind of platforms (e.g. transport aircraft, turbo-props, unmanned), each characterized by its own vibration sources.

Keywords: Flight tests, Vibration analysis, Machine learning, Equipment qualification, Ride along analysis

1. Introduction

The code development started during a thesis [3] internship taken at the Leonardo Aircraft Division within the Environmental and Vibration Qualification department.

It aimed to create an automated tool that, starting from an existing software (i.e.: “MatVibe” [9]) used in the department, simplifies aircraft vibration survey analysis. The tool uses Matlab™ as a computer language and allows for much faster times in aircraft experimental vibration analysis.

The tool, as it is automated, 'replaces' for much of the process the user (i.e.: the environmental specialist) who normally would be instead continually called upon, especially to identify, by means of several manual iterations, the origin of the vibration sources induced by pilot manoeuvring. As an alternative, the code “FastVibe” now developed makes use of basic Machine Learning algorithms that therefore allow the process to be more efficient and, at the same time analytical and self-learning. It helps to identify the origin of vibration trends and supports the environmental specialist to interpret any exceedances or anomalous vibration spikes should occur during a flight.

Another goal of this tool is reduce the possibility of manual errors during the experimental data analysis process, regardless the experience of who performs the vibration analysis but still maintaining the possibility of intervention of senior environmental specialists who can always evaluate the validity of the obtained results and introduce corrections as necessary.

2. Background

2.1 Vibration survey flight test campaign

Reasons for measuring platform vibrations lie in the uncertainty of predictions on vibration scenarios. Vibrations may arise from many different sources. Especially at the beginning of a new project, it is not easy to determine which source will be the most important one affecting a specific zone of the aircraft. Without experimental measurements, it is hard to evaluate accurately the frequency and the intensity of the vibration that a part of the structure or an airborne equipment will be subjected to.
Therefore, devoted flight trials are planned inside the flight envelope (Figure 1) to acquire vibration levels in a certain number of specific flight test points, enough to extract tendencies over the most relevant flight parameters, such as Mach number, altitude, angle of attack or load factor.

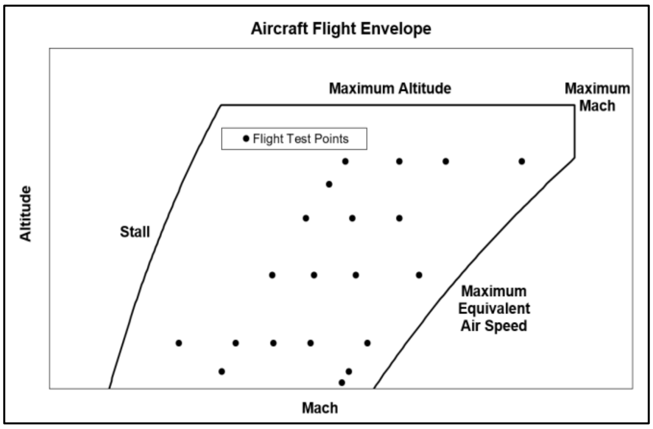

Figure 1 – Example of flight envelope and dedicated flight test points

This way the data to be analysed will be relatively few and the accuracy of the interpolations and extrapolations not so high, this meaning that a scatter factor on the results needs to be applied.

Another approach to gather data from many other flight test points (Figure 2) is to leverage those experimental flights planned for other testing needs. This way an automated tool is necessary to manage a huge amount of data and to allow correlating vibrations against the flight parameters.

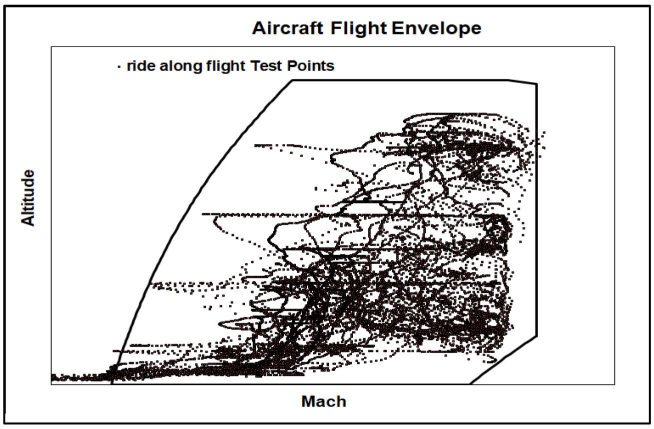

Figure 2 – Example of flight envelope and ride-along flight test points

2.2 Vibration sources

Equipment vibration requirement is normally defined considering MIL-STD-810 [1][2], Method 514 guidelines. Vibration predictions consider both the aircraft performances within the cleared flight envelope, that contribute to define the vibration functional requirement, and the service life - characterized by design mission profiles - that contribute to define the endurance vibration requirement. Specific vibration levels are derived from airframe structural motions, usually of low frequency range, induced by high load-factor manoeuvres, turbulence, dynamic landing, etc.. Figure 3 shows a general scheme of jet aircraft vibrations that, potentially, may affect equipment.

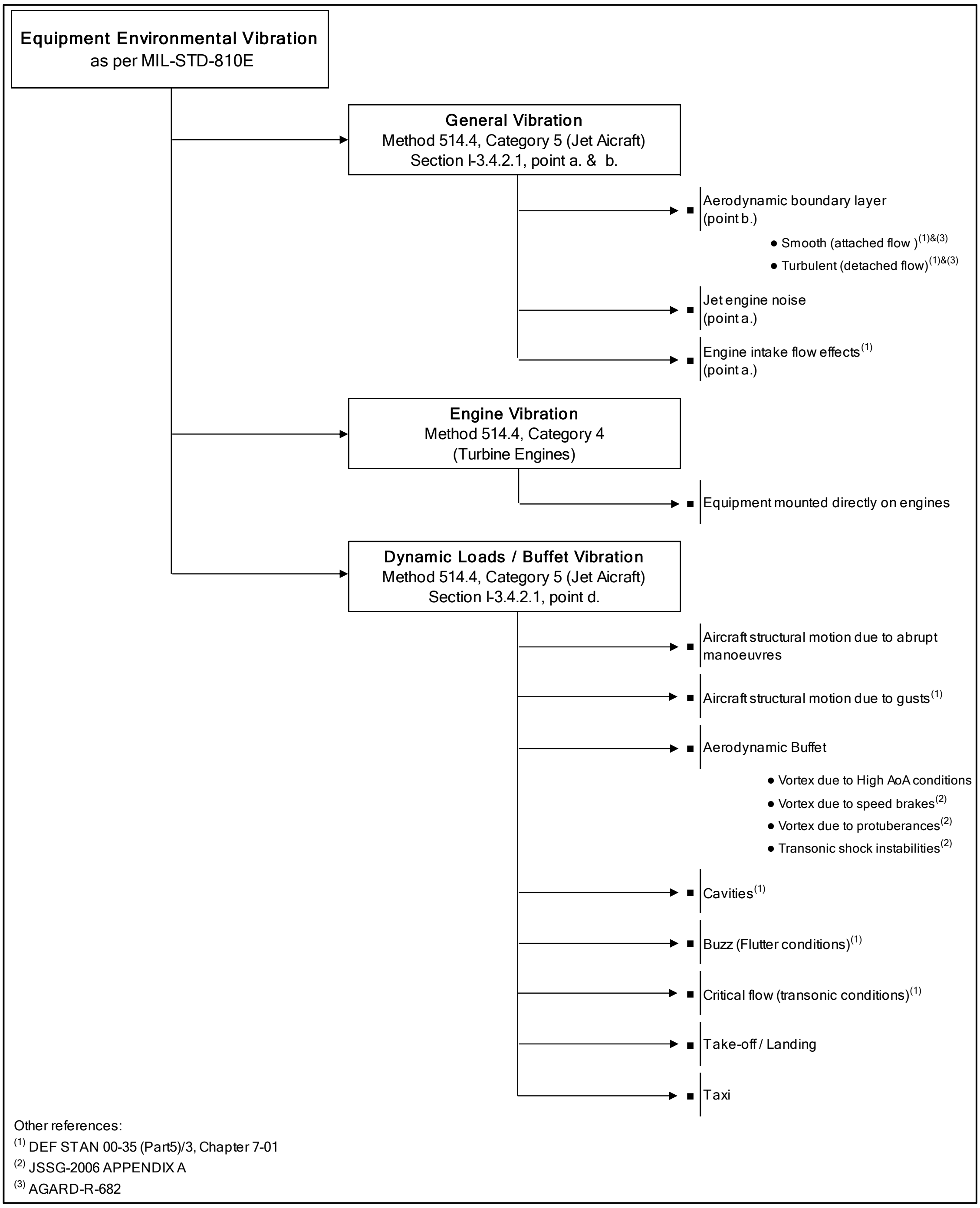

Figure 3 – General scheme of jet aircraft vibration sources

In the initial design stages, it is a common practice to use the published methods of Figure 3 as a reference, since there are not experimental data available. With reference to General Vibration environment, Figure 4 presents a typical broadband random vibration spectrum normally used to define an excellent yet conservative initial design reference for equipment qualification activity.

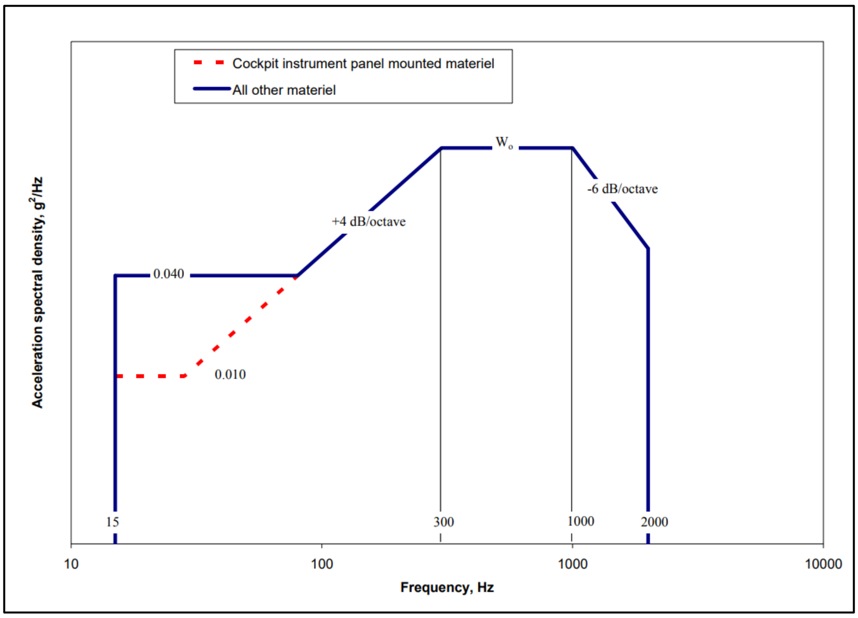

Figure 4 – MIL-STD-810G [1] general vibration qualification profile

When sufficient experimental data are available, it is possible to use them to create gradually the qualification spectra that will then be used for equipment de risking tests or to confirm the vibration qualification levels defined using published methods.
In fact, there could be a considerable difference between the vibration levels suggested by the standards and those that can occur in the reality. Furthermore, the modes of failure that could occur during laboratory tests are multiple, due to the diversity and complexity of the equipment under test and the materials involved, which can make the failure analysis sensitive to even small differences between the performed qualification test spectrum and the real vibration environment that will be experienced in service.
Finally, it could happen to face unexpected problems, like malfunctions or equipment failures that could arise during operations, despite the laboratory tests carried out in the qualification phase. In such cases, it may be necessary to carry out a series of measurements of the actual vibration environment. In fact, if the latter had been initially schematized according to regulations, or in any case measured only under particular flight test points (Figure 1) for reasons of time and cost, it will be now necessary to consider the vibrations pertaining to several flight phases, each characterized by Mach number, speed, altitude, engine setting, etc., with relative dwell times according to the mission profile and fraction of design life spent in each type of mission, to determine a spectrum, or a series of spectra, granting more reliability, with which to carry out re-qualification tests.

The vibratory stresses affecting airborne equipment may be very harsh in a high performance aircraft. These excitations in general are mainly due to these sources:

- aerodynamically induced vibrations from level flight at high Mach and/or high dynamic pressure [1];
- the effect of the unsteady aerodynamic field that occurs in high-incidence set-ups, which are required to increase manoeuvrability, with partially detached flow and strong turbulence that generates strong vibration levels [1][4];
- increasingly powerful engines, capable of exciting the adjacent structures, by fan and turbine rotation, with some specific harmonics or with the noise generated by fan exhaust velocities [1][2]

Vibration amplitude and frequency are the characteristics that describe the severity of the environment. The amplitude is important to determine the level of stress that an equipment can withstand; the frequency may highlight whether there could be equipment installation resonances that can amplify the response to a known input vibration. The quantification of vibrations may be seen in different ways:

- peak values are important for short duration events;
- PSD (Power Spectral Density) *or ASD (Acceleration Spectral Density)* vibration spectrum provides the amplitude of the vibration versus frequencies;
- Root Mean Square (RMS) value - also identified as Grms value – is calculated over a certain frequency range, typically from 15 to 2000 Hz for General Vibration, and is the most relevant, as it is directly related with the energy content of the applied vibrations.

Figure 5 present examples of vibration sources as measured from flight test points during experimental trials. one pertaining to low frequency structural response (buffet) and the other one to steady level flight.

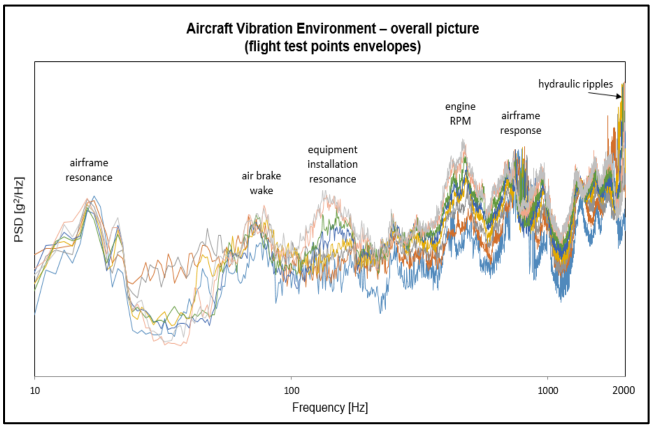

Figure 5 – Example of induced vibrations measured during level flight and manoeuvring conditions

Next figure (Figure 6) shows one of the engine vibration source.

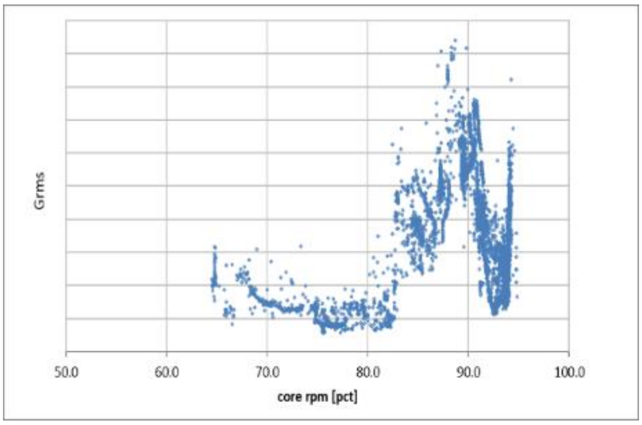

Figure 6 – Example of engine induced vibration in a selected frequency band

2.3 Vibration requirement definition

The distinction between the "functional" vibration test and the "endurance" one is very important. The purposes of the two laboratory tests is, in the first case, to demonstrate that the equipment is capable to perform correctly even up to the maximum vibration levels that are encountered at the flight envelope extremes; the second test that the equipment service life - generally equal to the life of the aircraft) – is covered as well. For this reason, it is required that the performance of the component fully satisfies its operative tasks whereas this is not a necessary verification to be held during the endurance test, assumed that, at the end, the equipment performance is still guaranteed.

The vibration analysis based of ride-along experimental data first of all makes it possible to obtain reliable trend curves, thanks to which vibration level extrapolations can be obtained up to the end limits of the envelope, reducing – at the same time – the need to apply too conservative scatter factors to the qualification requirement.

At the same time, however, this type of analysis is highly dependent on the vibration specialist expertise. As a consequence the analyst could tend to assume exaggerated factorizations if a full picture of the vibration sources has not been manually determined due to time constraint. Therefore, there is the risk of obtaining qualification requirements that overestimate the aircraft real vibration environment. Finally yet importantly, ride-along analysis is highly time-consuming. In fact, the procedure illustrated below is carried out for each aircraft accelerometers along each of the 3 spatial axes (X, Y, Z) for every sensor location.

Despite this, however, the ride-along analysis is the one that shows the highest accuracy and it is therefore adopted to analyse the vibration survey results of high performance aircrafts, whereas - for instance - for transport aircrafts some dedicated flight test points acquired during maximum two or three flights are normally sufficient to fulfil vibration characterization. In any case, the code can be easily adapted to carry on detailed analyses also for this kind of platforms.

3. FastVibe tool

As seen in the previous section, the aircraft vibration analysis methodology as it is currently used, is particularly long and difficult to handle. The FastVibe program aims to speed up the entire procedure through automation. To achieve good results it makes use of analytical methodologies, in particular basic statistical and Machine Learning tools. Figure 7 presents the block diagram of the vibration survey data analysis methodology implemented by FastVibe.

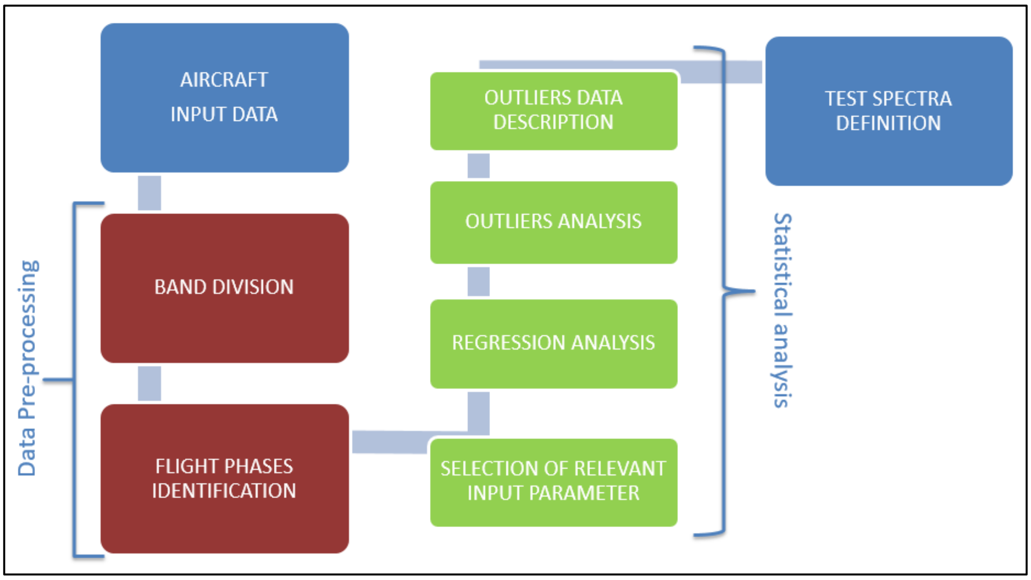

Figure 7 – FastVibe flow chart

The program takes as input vibration Power Spectral Density (PSD) values but also the flight parameters that characterize each flight phase.
The first step is to create a matrix, called “map”, which in fact constitutes a map for the gathered flight data. It is made up exclusively of ones and zeros and allow to identify which flight condition the aircraft experienced. It is made up of a number of rows equal to the gathered flight points and a number of columns equal to the number of possible flight conditions. The presence of a '1' therefore indicates that the selected flight point (identified by the row in which it is located) belongs to the flight phase indicated by the relevant column. The columns are ordered in such a way as to have, starting from the first, the following phases: ground operations / taxing, take off, landing gear down, landing gear up, climbing, airbrake deployment, level flight, manoeuvring, diving, approach and landing, etc. The last column is left for any other specific flight conditions that could be useful to investigate. As can be imagined, the most point-rich phases are those relating to the steady and level flight and the manoeuvring phase. Shown below is the graphic representation of the map thus created in one of the various cases analysed.

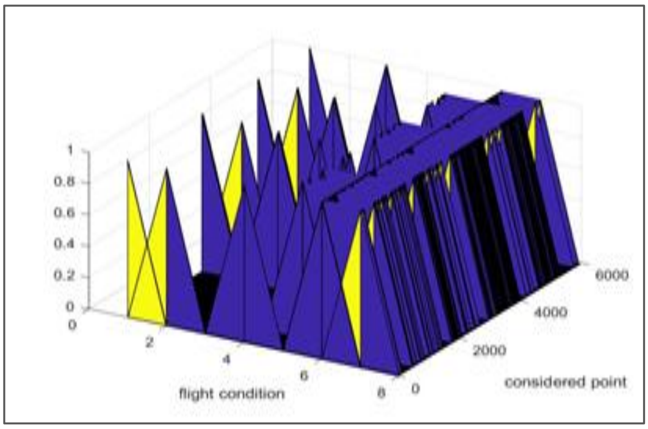

Figure 8 – Three-dimensional representation of the “map”

Considering the vibration Power Spectral Density (PSD) which envelopes all the measured data, it is necessary to perform the operation of dividing the entire frequency range into several and smaller frequency bands.

It is shown here, a plot of PSD values versus frequency in a double-logarithmic scale graph. Several peaks can be seen, which are unevenly distributed across the entire frequency domain.

The division into bands is done manually and an attempt is made to enclose only one peak within each band so that the analysis can then proceed by taking one peak at a time.

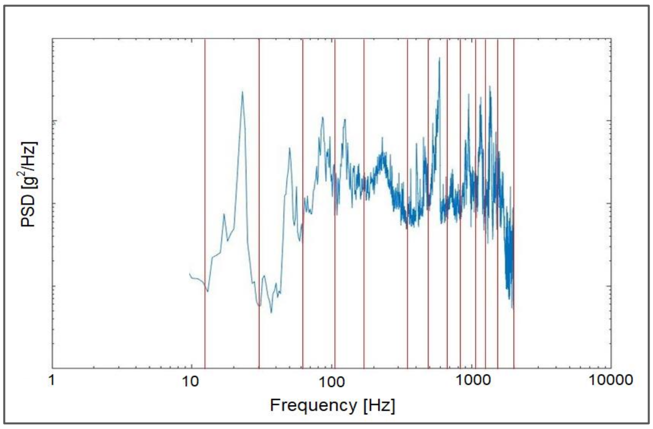

Figure 9 – Example of vibration spectrum frequency discretization

There are different ways to threat and manage the vibration data, depending on the kind of flight conditions they are related to.

The condition of “Ground”, both Landing and Take Off and Main Landing Gear Down, even if are related and driven by parameters as RPM or Dynamic Pressure (that is EAS), do not need a correlation analysis with those latter.

For the Manoeuvring phase, a simplified tool is used, in order to extract a proper Grms value for each frequency band and load factor sustained.

Finally, when the aircraft is flying with the AB extracted, or is flying “clean” (all surfaces retracted), the Grms trend, for each frequency band, must be correlated to the driven parameters.

In order to feed the calculus related to those phases, which represent the core of the following discussion, the data pre-processing phase ends with the extraction, from the totality of data, of only those parameters that belong to the considered flight phase. For level flight conditions, EAS, Mach and RPM are the main parameters normally selected but every other parameter could be taken into account to improve the analysis and obtain more precise results, depending on the qualification needs. Once the pre-processing phase is over, a matrix containing the aeromechanical parameters (as aforementioned, for level flight, generally, only EAS, Mach and RPM are considered but also other ones could be considered) is made available and the Grms matrix, both related to the level flight phase.

4. Statistical methods

The correlation analysis between the data is used to work out which of the parameters received as input shows a stronger link to the Grms values of each frequency bands. Thus, the correlation coefficient between Grms and the parameters is calculated. The parameter with the highest correlation coefficient will be called the “main variable” and will be used for deeper the vibration analysis.

Once the main parameter has been selected, the program applies the regression algorithm to the Grms data plotted against the main parameter identified in each band. Figure 10 shows an example of the graphs that are thus obtained.

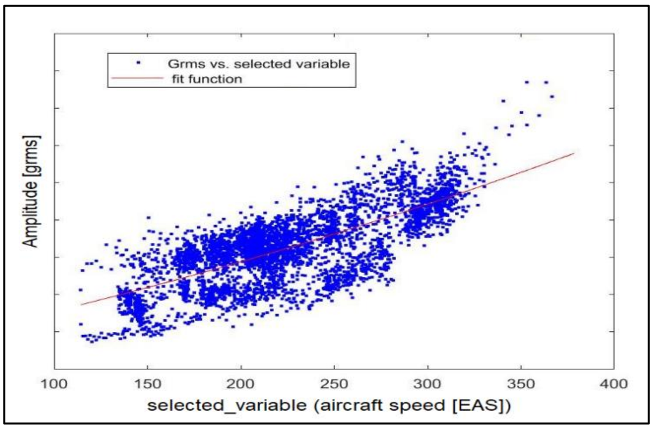

Figure 10 – Example of initial regression curves obtained with FastVibe

Once these graphs have been plotted attention must be paid to an aspect: the regression line obtained in this way, as can be seen, is able to capture the trend, but cannot keep the majority of points below itself.

In the vibration methodology currently in use, the function is shifted up by the environmental specialist based on his experience and engineering judgment. This procedure can lead to overestimate the final requirement. Now it would be desirable to create an analytical procedure. Therefore, a statistical tool has been introduced, so that the regression curve plotted is able to take into account more flight test points.

For this purpose, prediction intervals are what we need. In fact, by taking the upper limit into account, they make it possible to increase the threshold of conditioned points according to the confidence interval that has been selected (a 95 % confidence interval is normally applied).

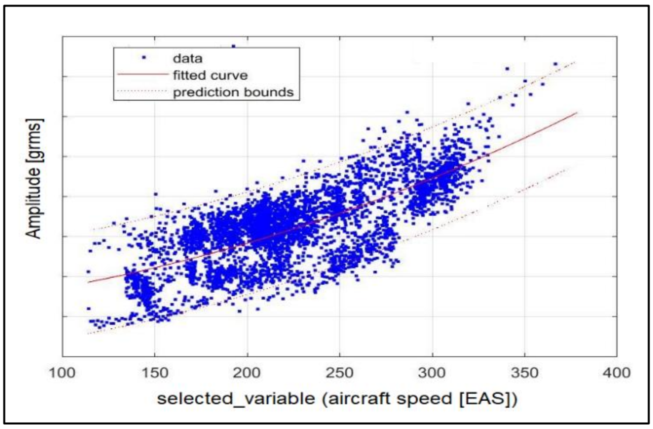

Figure 11 – Example of prediction ranges obtained with FastVibe

In addition, the use of prediction intervals allows extracting from the entire dataset of flight test points those that are out from the main trend and that are not consistent with the selected main parameter. In particular, we will consider “outlier” data those that prove to be outside the prediction interval [5].

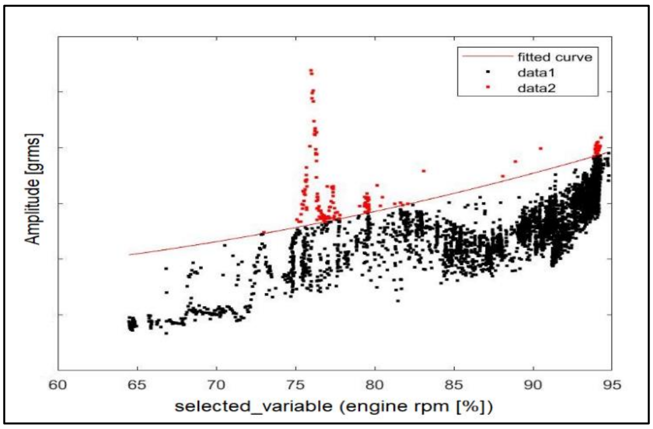

Figure 12 – Example of “outliers” identified above a 95% confidence interval

It is clear from looking at the graphs Figure 12, that the points showing anomalous trends, highlighted in red, are not a function of the main parameter that was derived earlier. It will then be necessary to conduct a second-level analysis in order to find a new parameter that explains this different trend. There are basically 3 alternatives to interpret off-trend data:

- they may be anomalous data resulting from a damage;
- they may be a function of another variable than the one used to plot the main trend;
- they may be spurious or completely out-of-trend data, which therefore do not depend on any of the variables taken into account.

Once anomalous data have been identified, it is appropriate to split them into clusters in order to analyse them one by one and find out which parameter (or variable) explains the anomalous trend [6].
In general, it may not be so straightforward to identify the number of clusters to be used.
However, it is possible to use a more objective method to decide this number: the so-called “elbow method”. In practice, you iterate the K-means for different values of K and each time calculate the sum of the squared distances between each centroid and the points in its cluster. By plotting the values of K (horizontal axis) and the values of the sum of the squared distances (vertical axis), a graph similar to the one in Figure 13 is obtained. This graph must be read from right to left. The point at which the curve tends to rise most consistently must be found.
In the example figure, it can be seen that from K=9 to K=3, the curve rises almost linearly. From K=3 to K=1 the curve rises more clearly. This means that the value K=3 is our elbow (thinking of the curve as an arm with the hand in K=9, the elbow in K=3 and the shoulder in K=1, hence the name of the method). The optimal number of clusters is the one in which the elbow is positioned.

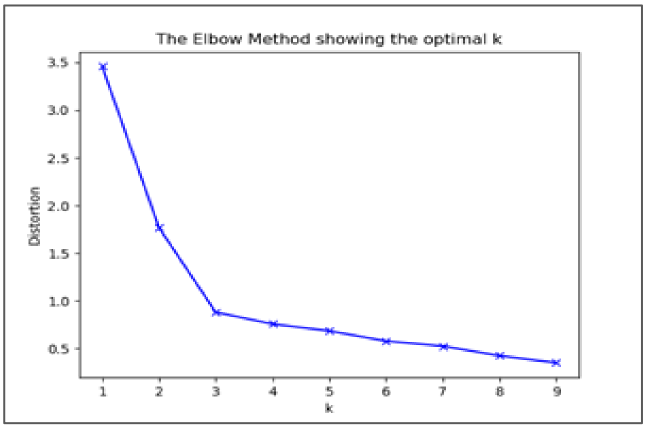

Figure 13 – Example of “elbow method” curve

Thus, once the optimal number of clusters to be used has been selected, it is possible to split the anomalous data previously obtained into the number of clusters just identified. Figure 14 presents the results of a clustering operation with a number of clusters equal to K=3.

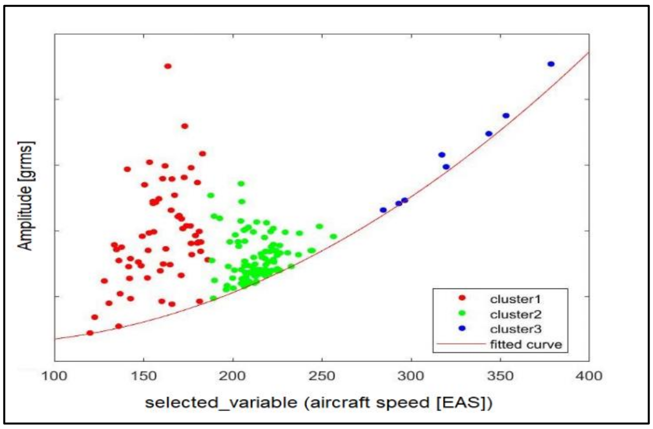

Figure 14 – Clustering results obtained with FastVibe (example, K=3)

Having therefore completed the previous steps, the next one is to understand which of the 'secondary' variables is the contribution of the 'anomalous' trends that seems not to follow the trend plotted according to the main parameter. This step is one of the most important because once it is understood which variable is contributing to a given trend, the correct trend can be assigned for the point cloud under consideration. In order to find a causal relationship between two variables, i.e. to understand in our case whether or not a variable is a *culprit* for abnormal Grms trends, it can be of great help to perform a statistical analysis using the ANOVA (ANalysis Of VAriance) [8] test to calculate the p-value.
In these types of test, the null hypothesis states that there is no relationship between the two variables under evaluation (that is, one variable does not influence the other).

In other words, the null hypothesis states that the test results are due to chance and therefore it is not meaningful to support it. Again, the null hypothesis assumes that whatever you are trying to test will fail. The alternative hypothesis instead is the one you would accept if the null hypothesis were false. It states the opposite of the null hypothesis, namely that the independent variable does not influence the dependent variable and that it is significant to support the question investigated.
Finally, having identified the anomalous cluster and the responsible parameter, all that remains is to plot the secondary trend with respect to the latter parameter. It may happen that within the cluster considered, the parameter that shows the highest significance is the same parameter that was previously identified as the main parameter. In this case, the cluster in question is added to the other data classified as 'non-anomalous' and a regression curve is drawn that also takes into account the new data in addition to the 'non-anomalous' data.

This results in 'definitive' curves which are referred to as primary trends. However, it may also happen that dependencies are found in some of the frequency bands with respect to parameters other than the one indicated above as primary; in this case, 'secondary trends' with its own specific validity limit must be provided instead.
When the influence of a new parameter is detected, Grms values are plotted and the point cloud showing abnormal behaviour highlighted by a different colour.

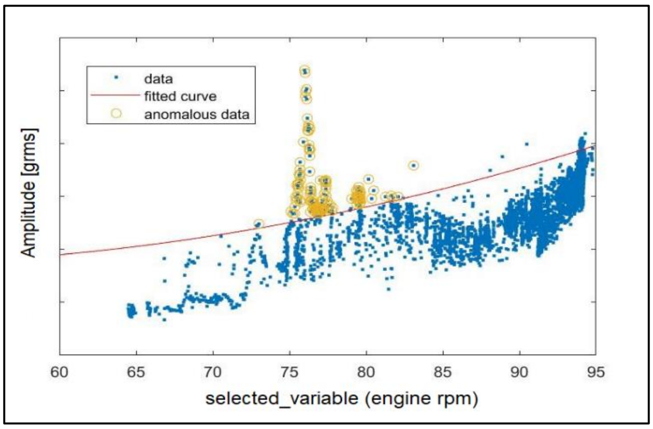

Figure 15 – Anomalous data highlighted within the whole set of flight test data

The secondary trend will have a validity limit defined by the cluster that has been identified. Of course, the validity of the new trend is referred to the new parameter identified, so what it will be obtained at the end will be a main trend, that is valid along with the entire flight envelope of the main parameter identified, and then a secondary trend, with a validity restricted to the interval found on the new parameter. Before obtaining the final result, however, the program allows for a check and possibly modifications that can be made interactively by the environmental specialist. So, there will be a final function defined as follows:

$$y_1 = f(x_1) \tag{1}$$

(1) is function of the main parameter x_1 and it is valid within the whole domain while the other function (2)

$$y_2 = g(x_2) \tag{2}$$

is function of the secondary parameter x_2 and valid only if $Lower_{limit} < x_2 < Upper_{limit}$

5. Check point definitions

Leaving the program completely automatic without any checkpoints could be risky. In fact, there could be exceptional cases that the statistical tools the program uses cannot handle adequately the data. This is why control points have been devised: to allow results that are not perfectly exact to be 'adjusted, if necessary.

The first control point is introduced when the validity interval of the secondary trend is evaluated. In fact, it may happen that the anomalous point cloud tracked automatically by the program is too large, thus making the secondary trend valid for a range too wide with respect to (w.r.t.) the one really needed. To resolve this situation, a second clustering was repeated on the clusters that showed a new dependency.

As can be seen in the figure of the examples below, the initial cluster, highlighted in yellow on the right, is subdivided, in this case, into three other sub-clusters. In this example it is clear that the one of interest is the cluster number 1. It is in fact the 'culprit' of the peak, as opposed to the other two clusters identified, which show much lower Grms values.

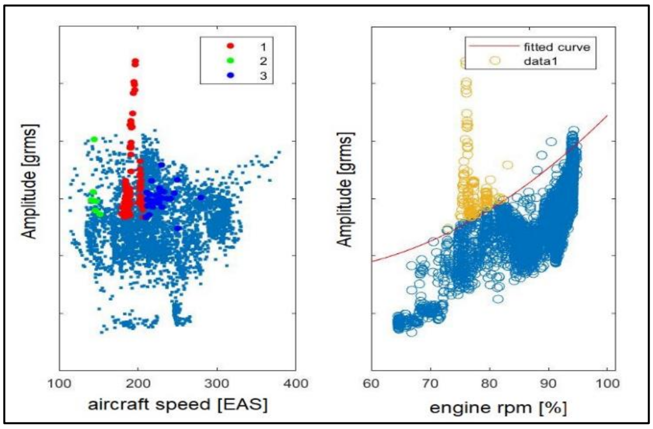

Figure 16 – Second clusterization of the anomalous data

Thus, the program offers an interactive screen where the environmental specialist can choose between the various clusters that have been identified the most relevant one. If, on the other hand, this is deemed not necessary , for example when the outliers point are significantly close to the main parameter curve, it is possible to select “None”.

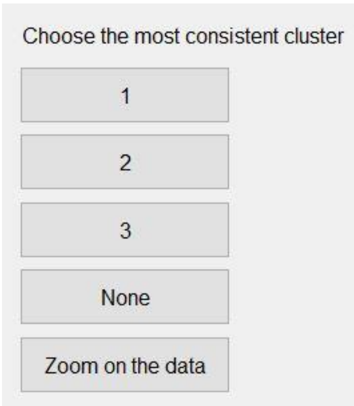

Figure 17 – First interactive check point

In addition, another possibility is provided: if the identified sub-clusters are not satisfactory but there is still the need to identify an area on which to draw the new curve, it is possible to manually select the points to be taken into consideration by drawing a box around the only ones the specialist wants to consider and then click on command ‘Zoom on the data’. In this way it is possible to better capture the validity limit for the secondary trend that has been tracked.

The second control point is introduced referring to the curves that will later be used to calculate the spectra. By showing the plotted curves, the specialist is asked if they are ready for the next step or if changes are required.

In particular, it is asked whether the primary tendency used has to be raised, lowered or can be left as calculated. The curve shifting is calculated as a percentage of the minimum value assumed by the function.

Figure 18 – Second interactive check point

Thus, just by looking at the graph the specialist can quickly decideto raise or lower slightly the plotted curve, on an opportunity basis. Then, another option is displayed for the secondary trend. This is necessary since the secondary cluster, chosen by the user at the first check point, can be poor in points or could have points widely spread whose interpolation could results sometime “not physical”. The specialist will interact through the following window:

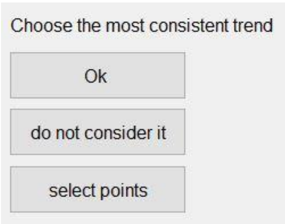

Figure 19 – Third interactive check point

The specialist can then select “OK” if the curve has not be changed. It is possible to select 'do not consider it' if the curve can be disregarded because it is already ‘covered’ by the main trend.. Finally, from the command string 'select points' the specialist can manually:

- Select 3 points: the program plots the parabola passing through the 3 points
- Select 2 points: the program draws the line through the 2 points
- Select 1 point: the program draws a constant at the level of the selected point

In all cases, the trends at the end have the previously defined area of validity.

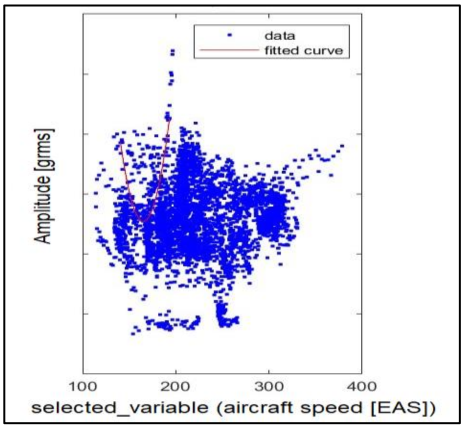

Figure 20 – Example of wrong secondary trend

For example in previous Figure 20, the curve that is automatically traced shows a not physical behaviour that can be easily corrected by the user as it has been said before.

Herein an example of primary and secondari trends is presented:

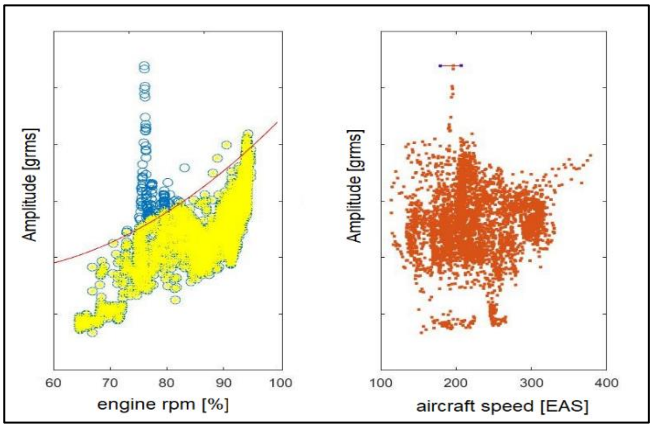

Figure 21 – Example of primary and secondary curves

Note that the primary curve is obtained with respect to the engine rpm (round per minute) parameter while the secondary one is respect to EAS (Equivalent Air Speed).

At the end of the process driven by the tool, the specialist has on the left the main trend plotted against the main parameter and on the right the secondary trend plotted against the secondary parameter. In this case, the main trend curve (on the left) was accepted as calculated, while the secondary trend (on the right) was re-defined by the user, through the definition of a single point to create a line with a constant-value covering the worst case, because it was not possible to determine a clear correlation between vibrations and the secondary parameter.

The first part of the FastVibe program uses the trends previously identified to calculate the maximum extrapolated values (useful if the flight envelope limits have not been yet reached during initial experimental flight phases).

Furthermore, using the three-dimensional tensor, it is possible to extract the maximum Grms values of the Ground (T/O and Landing) and Landing Gear Flight (after T/O and during approach to Landing) phases.

The Functional Grms pertaining to each frequency range selected at the beginning of the process (Figure 9) and covering all the flight test points (hence, all the flight envelope) is determined as the measured maximum Grms.

By then calculating the PSD values relative to the Grms values for each band the Functional spectrum is then found.

$$PSD = \frac{{G_{rms}}^2}{f_{max} - f_{min}} \tag{3}$$

In the following section the definition of the vibration qualification requirement for an airborne equipment, supported by FastVibe tool, is presented.

First of all Figure 22 and Figure 23 illustrate the definition of the functional vibration requirement starting from the results gathered from all the flight test points, then processed by the tool and finally synthetized in a simplified spectrum easy to be managed by the test house.

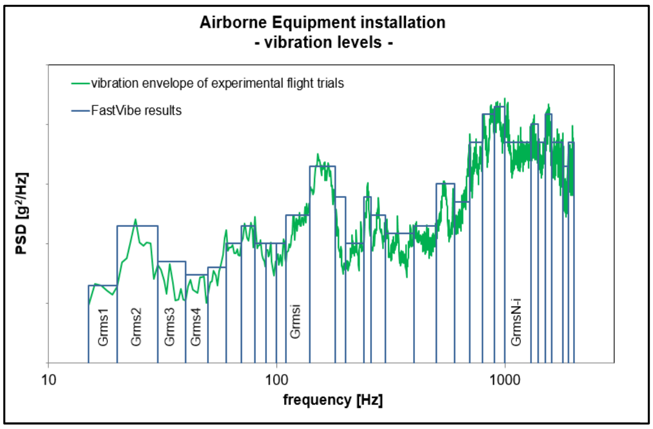

Figure 22 – Example of functional spectra (exp. -vs.- FastVibe results)

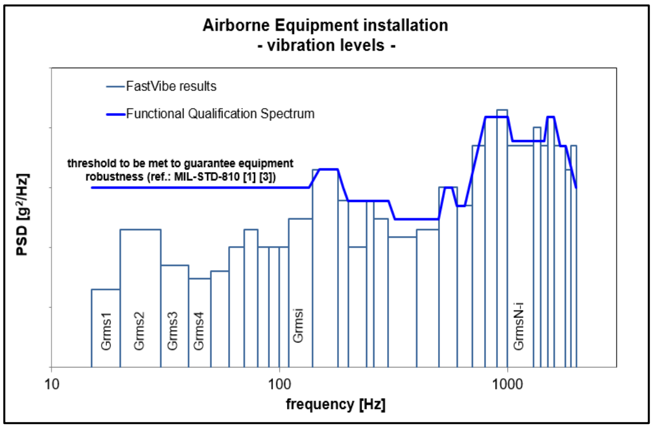

Figure 23 – Example of functional spectra (FastVibe results -vs.- qualification requirement)

As far as the Vibration Life section (that leads to the Endurance test spectrum calculation) is concerned, a kind of 'catalogue' was created which contains all possible missions for each aircraft, as described in their Technical Specifications. By regulations, mission sheets are defined in which the various phases that make up each mission with the relevant flight duration are listed in an analytical manner by means of a matrix.

Thus, thanks to a spreadsheet input file, it is possible to select the missions for the calculation. From the mission sheets, for each frequency band considered, the program adds together all the relevant flight durations for each of the design mission of the aircraft. Starting form this and taking into account the number of times each mission is repeated, the total equivalent flight time (generally called as “equivalent flight time in high dynamic environment”) for each of the selected frequency bands is provided.

At this point it is necessary to compress this “equivalent” time, which is often in the order of hours, so to let it acceptable for a qualification test to be carried out in a laboratory. This is done by using the Miner-Palmgren formula, which uses a power law based on fatigue to relate the exposure time and the level of Grms.

The mathematical expression is shown below:

$$\frac{t_2}{t_1} = (\frac{S_1}{S_2})^m \qquad (4)$$

where:

- t_1 is the laboratory test time
- t_2 is the time in service (the calculated equivalent time in high dynamic environment)
- S_1 is the laboratory test Grms
- S_2 is the Grms as estimated from the service conditions
- m is a material-specific value

In this way, starting from the single bands, the global Grms requirement (and, hence, the whole PDS endurance spectrum of Figure 24) is then determined to permit a reasonable test duration during laboratory qualification test aiming to cover the entire aircraft life.

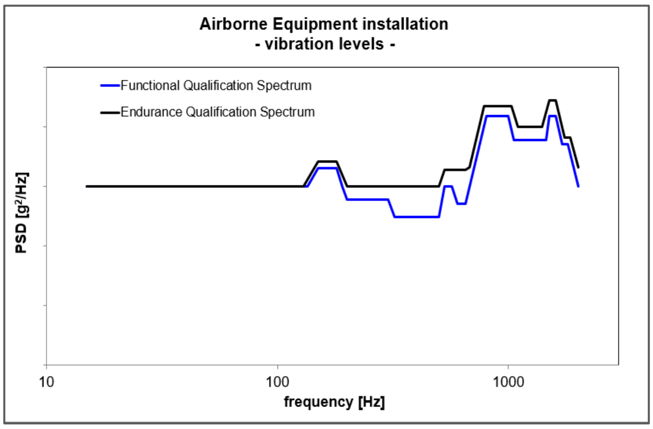

Figure 24 – Example of endurance spectrum plotted against the functional spectrum

These graphs showing the qualification spectra together with the vibration envelope of the experimental results are used to understand whether the PSD profiles are able to take into account the physics of the aircraft manoeuvres and relevant aeromechanic parameters and whether there is an overestimation in vibration determination. In that case, corrections should be implemented to make the final result optimal.

6. Conclusion

The present work purpose is to make the whole process of aircraft vibration analysis faster and more efficient. As this is a first attempt to automate the process, one of the goal was not to deviate too much from the methodology currently in use today, trying instead to substitute 'human' intervention as much as possible using statistical means and machine learning tool. Using an automatized program has several advantages, such as:

- it helps to rationalize the process and allow to be more analytical, enabling deeper calculation possibilities;
- it allows to ‘replace’ the technician's expertise in some way, so as to make the entire analysis as objective as possible and without the need for seniority expertise for most of the process;
- it gives anyway the possibility (when needed) to have a critical view of the results so that some adjustment can be made manually if required.

On the other hand, limiting the use of the standard procedure to assess specific flight conditions and/or to analyse exceedances still allows the great advantage to rely on seniority expertise, able to interpret exceptional trends that in the automated procedure might not be handled properly.

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8. Copyright Statement

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