# A BRIEF STUDY ON THE APPLICATIONS OF EXPERIMENTAL MODAL ANALYSIS

**Kanhaiya Prasad, Dr. Awari Mahesh Babu( Professor)**

Research Scholar, Department of Mechanical Engineering

Glocal University, UP

**ABSTRACT:-** The process of making adjustments or alterations to the mass, stiffness, and damping of the system is referred to as structural dynamic modification (often abbreviated as SDM). Whenever there is a change in the state of any of the entities, the dynamic behaviour of the system will adapt accordingly. With the use of a modal model, one may run a comprehensive simulation in order to make an accurate forecast of how the system would react to a change in any of its physical quantities. This "What if" analysis gives the analyst important information that can be used to change the dynamic of the system. The process of SDM may be repeated on the system while it is in a virtual environment, which saves the time and money that would otherwise be spent on the Design-Build-Test process.

**KEYWORDS:-** Experimental Study, Modal analysis

It is possible to anticipate the impact that modifications to the virtual physical environment will have on the dynamic behaviour. For instance, increasing the total mass at a particular area will result in a higher natural frequency, while reducing the total mass would result in a lower natural frequency; this enables the dynamic behaviour to be determined in advance. In a similar fashion, the stiffener may be introduced at select locations, which results in an effect that is opposite to that of adding or removing mass. The impact of damping is especially very essential since it does not "Shift" the natural frequency; rather, it affects the "peak" on the amplitude of vibration and resonance. This makes the effect of damping particularly very significant. This method is highly significant and helpful during the early stages of design, and it may contribute to the optimization of the design. If the modal model can be obtained either theoretically via modal analysis or empirically through the use of the EMA approach, having it on hand may be of great assistance in enhancing the dynamic behaviour of the structure. This model can be derived in any of these ways. The most significant problem of such a method is that the SDM does not permit significant alterations to the structure.

**Sensitivity Analysis:**

Because it quantifies the parameters that are more prominent for structural modifications, the sensitivity of modal parameters to changes in system physical parameters is very important. This is because some parameters may have a greater effect on system dynamics as compared to others, which either makes them a major contender for change or sometimes requires that they be restrained from change if the natural frequency is to be contained in a narrow band. Therefore, if the dynamics of the system are to be reined in, an analysis of this kind becomes very necessary and is the most effective criteria.

**Model Reduction:**

FE modelling for dynamic comparison and analysis needs the mesh process, and a fine mesh is more often permitted for greater accuracy of the findings. However, this increases the amount of freedom degrees of the system, and it is possible that this does not significantly improve the accuracy of the findings. If the dynamic behaviour at low frequency range is necessary, then this discretization could become impossible. This would need a much reduced mathematical model, which would cut down on the amount of time needed for computing while still producing accurate results. These models may be simply obtained from modal models or from FE models with decreased size. Both of these models are available online.

**Response prediction:**

It is sometimes necessary to provide an accurate prediction of the vibration response that a system will have to a particular force. If a modal model is well-defined, it may be used to clearly describe the behaviour to a given force. For instance, in the automotive or aerospace industries, if a modal model is understood, the reaction of a vehicle can be anticipated before the car is driven on a track or an aeroplane is flown. The superposition concept may be employed for cumulative response of forces operating o the system. It is possible to make an accurate prediction of how a building will react to a seismic event. The inaccuracy of measurement and estimation of forces acting on the system is the most significant disadvantage of such a system. However, if the response of the system is known and a well-established modal model is utilised, the forces that can be identified that may be responsible for severe vibration can be determined. In this procedure, a known force is utilised to produce the vibration response, while in the later approach, the response is studied in order to anticipate the force that is generating it. This process is the opposite of the response prediction process.

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A well-established modal model may serve the goal of forced response prediction or force identification in either scenario, and the overall prediction in a known dynamic environment can be seen. This is the case in both scenarios.

**Sub-structuring:**

This process is referred to as substructure coupling, and it occurs when the dynamic behaviour of the whole system can be anticipated based on the behaviour that is obtained from its components. In huge systems, when it is not possible, in practise, to examine the whole system owing to its complexity or size, the substructure methodology is an effective method that may be used instead. This method is most useful in situations requiring a finite element analysis, such as when the system in question is too complicated or exhibits variable qualities.

**Damage detection:**

In the manufacturing business, finding damage such as undetectable fractures has long been a top focus. This takes on a far greater level of importance in contexts where there is a potential threat to human life, such as in the aircraft sector. This method has recently found use in the field of civil engineering, namely in the construction of bridges. Damage detection based on modal analysis is predicated on the idea that the dynamics of a structure would shift in response to the existence of a fracture in the structure. This is the fundamental principle behind the method. When a structure is flawed, the dynamic reaction of the structure is significantly altered. Using this phenomena, it is possible to forecast the damage that will be sustained by a structure by comparing the structure's reaction both before and after the damage has occurred. It is possible to quantify the damage detection process by contrasting the findings (response) obtained from an undamaged specimen, also known as the structure's fingerprints, with those obtained from a damaged structure.

**Troubleshooting:**

This method, which makes use of modal analysis, provides an understanding of a structure that is the root of the issue. The analyst is provided with opportunities for subsequent application as well as an in-depth study of the structure, making this the most popular application.

**Model correlation:**

The process of merging the findings gained via experimental methods and through the use of the finite element analysis is what is meant by the term "model correlation" (Experimental modal analysis). Since it is clear that the findings acquired via the use of FE Analysis are often erroneous owing to the many different approximations and the discretization of the domain, "as it is plain that" Because of this, the FE model cannot be used as a trustworthy representative model of the dynamic behaviour of the system. On the other hand, the dynamic Model (Modal Model) obtained from experimentation gives realistic values and can be used to update the FE model, which in turn can be used for further analysis because it is now a representative updated model, and further dynamic analysis can be performed on it.

**Comparison of Experimental and Finite element results:**

One may forecast the source of a discrepancy between the experimental findings and the finite element results and, at times, the likely mistakes that are generating the same mismatch, by comparing the two sets of results. The most fundamental and widely used method of investigating the data is known as direct comparison of the various model features. The primary reason for doing the comparison is to examine the particular dynamic qualities, and then to determine how much of a mismatch there is between the data that was acquired experimentally and the data that was obtained analytically. The next step is a careful analysis to reduce the amount of difference between the two sets of data to an almost indiscernible level. This may be accomplished by altering or revising the values of either one or both of the sets of data.

**Response property Comparison:**

If we want to perform an extensive modal analysis process, the only option that is available is response parameters that can be measured directly. If the data obtained from the experiment model are not accurate, or if the process that is used to extract the model parameters is not suitable, this could lead to errors in the results of the analysis. The data obtained from the experiment model are available in the form of response properties of the structure that is being tested. As a result, the comparison of response properties is the approach that is most suitable for contrasting experimental data with theoretical data. The example shown in figure number illustrates a common kind of comparison between the direct measurements received from an experimental Modal Analysis of a beam and the results produced from a finite element analysis. The difference between the two measures is shown rather clearly by the image. It can be seen that there is a gradual change in the natural frequency between the two readings. Nevertheless, there is a strong positive correlation between the amplitudes. The other factors that have a significant role are the difference between the natural frequency at the resource and the anti-resonance frequency of the system. These are considered to be rather important. An in-depth investigation reveals that the discrepancies may be attributable to the localised stiffening of joints or to an inaccuracy in the values of the modulus of elasticity, density, or moment of inertia, among other factors. Another issue that might arise is when the points of measurement do not take into account the mesh grid or the nodes that are utilised in FE analysis. In this scenario, it is very difficult to carry out a direct comparison.

**Comparison of modal properties:**

owing to the fact that the response data may be obtained quickly and easily from the structure of the test. The problem arises on the analytical side, where the FRF plots are not easily available because they need to include a large number of modes to calculate the required response characteristics. On the other hand, the model properties can be easily driven by single modes selected from a narrow frequency band. This presents a problem. At this point, the results of an experimental test have a greater possibility of including a greater number of modes. In order to break it down into its component modes, one requires fundamental curve fitting and mathematical methods so that they may extract those modes. The comparison of modal properties is a typical approach that is used to highlight the similarity or difference between the findings obtained via experimentation and those obtained through the use of finite elements. Following this, a discussion will be held on the different modal property approaches.

**Comparison of Natural Frequency:**

The comparison of the natural frequency is the most fundamental comparison that can be performed between the values that are gained through experimentation and the values that are obtained through theory. The method of tabulating the values, which just offer the impression of a match or mismatch between the two, is the one that is used the most often. The two values that were obtained may also be shown on a graph, with the experimental data on one axis and the theoretical data on the other axis, as shown in figure 1.3. This method is somewhat more helpful than the first.

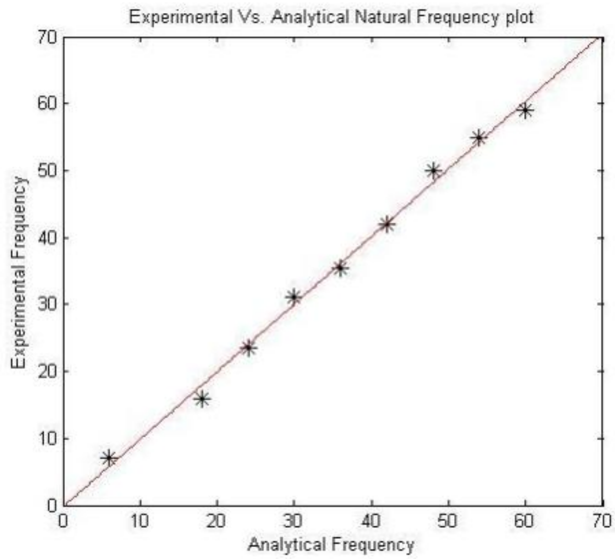


**Figure Natural frequency comparison**

A presentation of this kind may offer a greater perspective into the match or mismatch of the data, as well as the inconsistencies (if there are any). The plotted natural frequencies have to lay on a straight line at an angle of 45 degrees. If the trend follows a line that is tilted at a different angle, then it is obvious that the material qualities that were employed need to be adjusted. If there is a significant amount of point dispersion, this indicates that the Model that was used to depict the system need some kind of adjustment. However, a mistake in measurement or analytical solution that is within acceptable limits is shown as a dispersion that is less severe along the line.

**Mode shape comparison:**

The comparison of the mode shape is another method for determining the correlation between the experimental data and the FE findings. This method, however, is much more difficult to implement. The process of comparing natural frequencies can be helpful in straightforward situations that have vibration modes that are clearly separated from one another. However, when dealing with more complicated structures that have natural frequencies that are close to one another, it can be challenging to interpret the results. As a result, it is prudent to compare natural frequencies along with mode shapes at the same time. In situations like this, each natural frequency is analysed with the mode shape that is linked with it at the same time. Using the same method as the natural frequency comparison is all that is required to complete this process successfully. The alternative way involves comparing the results obtained by superimposing one mode shape plot on top of another. The overlay method is not simple to comprehend due to the fact that complicated modes often lead to misunderstanding.

**Finite element model updation**

The finite element method is a well-established technique for solving a variety of engineering field problems, including problems with heat conduction and dynamic analysis in structural dynamics. These problems range from static structural analysis to static structural analysis to problems with heat conduction. These numerical methods discretize the material into a number of elements, which are then linked to one another through nodes. It is highly important to get a meaningful answer with the least amount of mistake possible, therefore the kind of issue that has to be solved determines the kind of components that need to be examined, such as linear or higher order. In-depth discussions on the formulation and computational challenges in FE analysis have been presented by Zeinkeiwicz [1, Bathe [2, and Chehdruptla [3], respectively. In dynamic analysis, the mass, stiffness, and damping matrices are produced as their respective distributions of the structure's mass, stiffness, and damping characteristics. Ewins and lmreguen [4] have made the observation that the FE models that are generated independently by different people may not agree with one another at all. However, there may be similarities in the individuals' choices of components, software, and discretization. In order to get around this challenge and this inconsistency, modal testing is used rather often, as Ewins [5] and Maia and Silva [6] both point out.

The update of the finite element model may be categorised as

- Direct techniques
- Iterative techniques

In direct approaches, the updating procedure is carried out in a single step and does not need iteration. This results in a process that is computationally efficient and does not include divergence. These approaches also have the benefit of being able to reproduce the data perfectly, which is a distinct advantage; nevertheless, this benefit poses a difficulty since it also reproduces measurement noise and spurious modes. To prevent these mistakes from being reproduced, one must exercise extreme caution throughout the experimental procedure in order to get high-quality data with a minimum of variability. The close form solution of the structural system of equations of motion is necessary for the direct procedures. Due to the fact that this method calculates the solution of updated system matrices by solving equations, it has the disadvantage that such a procedure causes the updated matrices to lose their physical meaning as a result of the loss of symmetry and positive definiteness.

**CONCLUSION:-** The dynamic response of a FE model is contingent on a large number of characteristics, including modelling, boundary conditions, element type selection, and physical parameter values. Iterative methods get the answer in such a manner that the physical meaning of the updated parameters does not change; the only thing that shifts is the values of those parameters. Because of this, the iterative approach can only ever provide good and conclusive outcomes. The iterative procedures have the benefit of being able to minimise an error function via the use of an iterative process; however, the iterative process also makes them computationally more difficult to solve.

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