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FEA of automobile suspension system for vibration elimination

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ABSTRACT

In this article, the accurate and efficient calculation method for non-stationary random vibration analysis of large complex structures is one of the current research hotspots. According to the linear relationship between input and output of linear structure, the columnar problem of explicit expression of the structural dynamic response is first discussed. Based on the above explicit expressions of dynamic response, an FEA method for non-stationary random vibration analysis of large complex structures is proposed for deterministic structural models and stochastic structural models. For the deterministic structure, according to the explicit expression of the dynamic response, on the one hand, the mean and variance of the structural response can be directly calculated by the operation law of the first moment and the second moment; on the other hand, Monte Carlo simulation can be implemented to obtain the structural response. The peak statistic and the solution to the structural dynamic reliability. The random vibration analysis of the vehicle environment was carried out for the equipment mounting structure. Firstly, the characteristics of the vibration environment of the suspension platform are discussed. The random sinusoidal vibration spectrum is transformed into pure random vibration by the principle of equal energy. Then the 3D model constructed by Pro-E software is used to import ANSYS for geometric processing and meshing. Finally, the finite element solution is solved by ANSYS software to obtain the displacement stress response of the structure under the vibration environment of the suspension, and the dynamic strength of the structure is carried out.

Keywords— *Vibration response, FEA, ANSYS (CAE), Result Evaluation*

1. INTRODUCTION

In actual engineering, vibration often causes looseness of structural fasteners and structural seals. Vibration and noise mostly affect the physical condition of a person: they inhibit the central nervous system, the vestibular apparatus, cause changes in respiration and pulse rates, contribute to metabolic disorders, cardiovascular diseases, hypertension, and occupational diseases. Failure, component fatigue, cracks, and fractures. Vibration test is exposed to structural defects and identification structures are an effective way to withstand the environmental capabilities of applying the specified vibration excitation level to the test piece to assess the dynamic strength of the structure.

Human and its environmental adaptability. In the vibration test, it must be in accordance with the test specification. Requirements, using the vibration test system too accurately and real-time collect and record the DUT the vibration response signal to provide true and reliable data for vibration analysis. There are often many forms of interference in the vibration signals collected from the test site. Noise, such as random impulse interference noise, electromagnetic interference noise, by the amplifier or a spike or the like introduced by the sensor. Among them, some noise signals may drown the real Signals, so vibration signal analysis is very important. The processing of vibration and noise signals is often performed by analogue circuits or digital filtering law. Recently, the shortening of the development period of automobiles has progressed, and also, shortening of the development period is required. Of the means to respond. One example is prototype-less development, CAE without making a prototype before mass production (Computer-Aided Engineering) simulation. Higher reliability is required. Can reproduce the behaviour of the actual machine. It goes without saying that the construction of the CAE model.

2. ABOUT VIBRATION LOAD

Vibration called mechanical rhythmic oscillations of elastic bodies. Most often, vibration refers to unwanted vibrations. Arrhythmic oscillations are called jolts. Vibration propagates due to the transfer of vibrational energy from oscillating particles to neighbouring particles. This energy at any time is proportional to the square of the velocity of oscillatory motion, therefore, by the magnitude of the latter, one can judge the intensity of the vibration, i.e., the flow of vibrational energy. Since the velocities of the oscillatory motion vary in time from zero to a maximum, the load at the end of the spring oscillates, a tuning fork, a pendulum, and strings of a guitar. Inside any living organism, various repeating processes are continuously going on. Atoms in molecules and relative to the crystal lattice of a solid body oscillate.

Waves are a change in the state of a medium, or disturbances propagating in this medium and carrying energy with them. The most common types of waves - elastic, surface, electromagnetic. A special case of elastic waves is sound and seismic waves.

Radio waves, light, and X-rays serve as a variety of electromagnetic waves.

The simplest form of vibration is the oscillation or repetitive movement of an object near its equilibrium position. This type of vibration is called a general vibration because the body moves as a whole and all its parts have the same speed and magnitude.

2.1 Miles Equation

Modal analysis to find the natural frequency of the system.
Miles Equation in order to find 3 Sigma GRMS for the system.
Multiply 1.0 G by the 3 Sigma GRMS value and apply that product as an acceleration in the desired direction.
Perform static structural analysis to find deformations and stresses.
Miles Equation:

$$3\sigma_{GRMS} = 3 \times \sqrt{\frac{\pi}{2} \times Q \times f \times PSD}$$

$$Q = \frac{1}{2 \times \zeta}$$

2.2 Random Vibration analysis in Workbench

Perform modal analysis to find the natural frequency of the system.

Perform a random vibration analysis using the modal analysis as the initial condition environment, with the PSD Base Excitation applied in the desired direction. Evaluate desired stresses and deformations at 3 sigma values.

For free vibration analysis, the natural circular frequencies ω_i and mode shapes Φ_i are calculated from:

$$([K] - \omega_i^2[M])\{\Phi_i\} = 0$$

• Assumptions: [K] and [M] are constant:
• Linear elastic material behaviour is assumed
• Small deflection theory is used, and no nonlinearities included
• [C] is not present, so damping is not included
• {F} is not present, so no excitation of the structure is assumed
• The structure can be constrained or unconstrained: Mode shapes {f} are relative values, not absolute, ([ ]- 2[ ]){ }= 0

2.3 Evaluate the peak value of the response

When evaluating structural strength, it is necessary to design so that it does not break (or bend) in one shot separately from fatigue. This mainly concerns the peak value of the response. Using the statistical concept of random response analysis, it is possible to limit the probability of occurrence of excessive response exceeding the standard to 0 as much as possible. This makes it difficult to completely reduce the probability of corruption, but at least it gives you control over the probability of corruption.

This evaluation uses the concept of "the number of times exceeding the threshold α per unit time" explained in the previous section. I will explain in the next example because it is a little complicated.

The impact of vibration on a human operator is classified by the method of transmission of vibration on a person. In the direction of vibration; according to the time characteristic of vibration. As factors affecting the degree and nature of the adverse effects of vibration, the following should be taken into account: the risks (probabilities) of the manifestation of various pathologies, including occupational vibration disease; Indicators of physical activity and neuron-emotional stress; the influence of attendant factors that aggravate the effects of vibration (cooling, humidity, noise, chemicals, etc.); duration and intermittent effects of vibration; duration of the shift. Indicators of the vibration load on the operator should be formed from the following parameters: vibration acceleration (vibration velocity); frequency range; vibration exposure time.

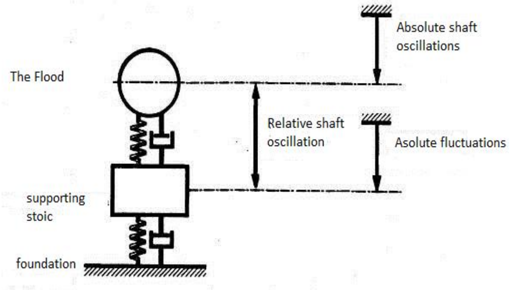


Fig. 1: Types of vibrations in cars

3. METHODOLOGY

Powerful ANSYS Workbench tools help calculate damage from vibrations that are missing distinct frequency Determining the fatigue life of parts with periodic sinusoidal oscillations is an understandable and clear procedure in which the degree of damage is calculated by multiplying the voltage amplitude obtained from harmonic analysis, on the number of cycles that the part undergoes during operation. The calculations are relatively simple because the exact value of the oscillating values is easily predictable at any time.

Vibrations can have a random nature in a wide range of applications, such as a car moving on a rough road, or industrial equipment operating under conditions of arbitrary loading. AT

In these cases, the instantaneous amplitude values will not be easily predictable, since the amplitude value at any time point is not related to its value at another time point. As shown in Figure 1, the absence of periodicity is characteristic of random vibrations.

The oscillatory motion of a solid can be completely described as a combination of six simplest types of motion: translational in three mutually perpendicular directions (x, y, z in Cartesian coordinates) and rotational with respect to three mutually perpendicular axes (0x, 0y, 0z). Any complex movement of the body can be decomposed into these six components. Therefore, such bodies are said to have six degrees of freedom.

The method of predicting the response of structures to a known external effect is solved using the finite element method (FEM) and modal analysis. Here we will not dwell on them in detail, since they are rather complicated, however, to understand the essence of vibration analysis of machines, it is useful to consider how the forces and the structures interact with each other.

3.1 Evaluation method

The evaluation method in the random response analysis can be roughly divided into the following three patterns (there may be other but will be introduced as a representative one).

3.1.1 Evaluate the level of response PSD

In random response analysis, instead of discussing vibration time series, vibration is handled using parameters such as power spectral density function (PSD) and standard deviation. We will explain the definitions needed to understand them.

For vibration tests, etc., there are also standards that require PSD level of response acceleration to be below the standard.

3.1.2 Vibration amplitude measurement

The following concepts are used to describe and measure mechanical vibrations Maximum Amplitude (Peak) is the maximum deviation from the zero points, or from the equilibrium position.

Swipe (Peak-Peak) is the difference between positive and negative peaks. For a sinusoidal oscillation, the span is exactly equal to twice the peak amplitude, since the temporal realization, in this case, is symmetrical. However, as we shall soon see, this is generally not the case.

3.1.3 Evaluate fatigue strength

The fatigue life is evaluated using minor rules from the standard deviation of stress (RMS stress) obtained by random response analysis. There are various methods in fatigue analysis, but it is easy to use stress values of 1σ, 2σ, and 3σ.

Data processing includes the collection of source data, filtering of unwanted noise and other signals that are not of interest for the subsequent analysis, and the presentation of signals in the form required for diagnostics. Therefore, data processing is an important step in the process of diagnosis. Collectors of data from vibration sensors should provide sufficient resolution in both amplitude and time. If the collected data is in digital form, then the bit depth of the device is must be high enough to provide the required amplitude resolution. High-resolution devices allow analysis with higher accuracy, but they are more expensive and have higher performance requirements.

4. RESULTS

For some vibrations, the law shows considerable randomness and uncertainty, and cannot be expressed by a deterministic function, so that it can only be described by probabilistic and statistical methods. This vibration is called random vibration. Random vibrations can be caused by the randomness of the system constituent parameters themselves, but in most cases are mainly caused by the randomness of the excitation source. The purpose of random vibration analysis is to obtain the statistical response of the structural response based on probability theory under a large number of uncertain excitations.

4.1 The analysis processes

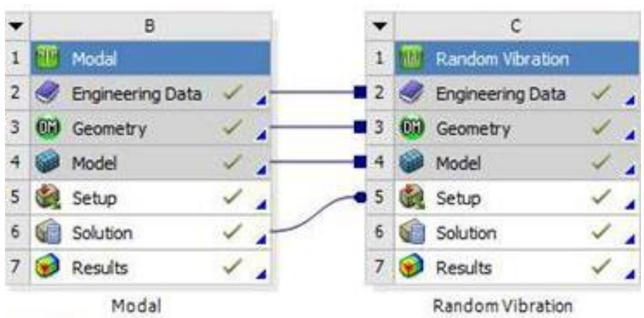


Fig. 2: Analysis process

4.1.1 Modal analysis with prestress

Model modeling, meshing, boundary conditions are applied first, followed by static analysis.

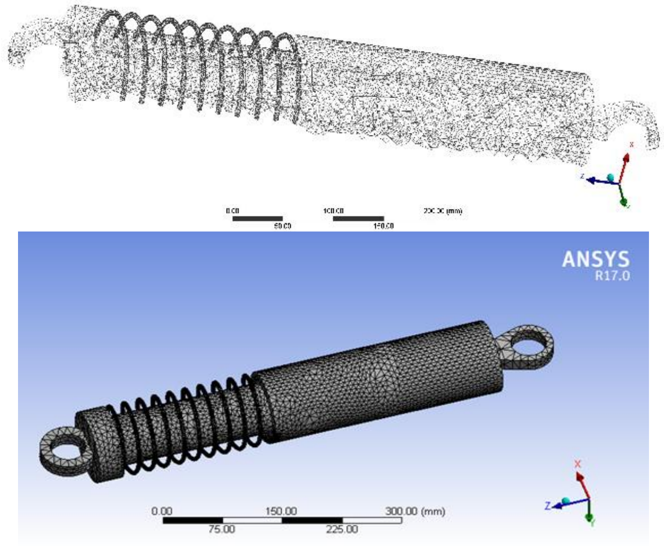
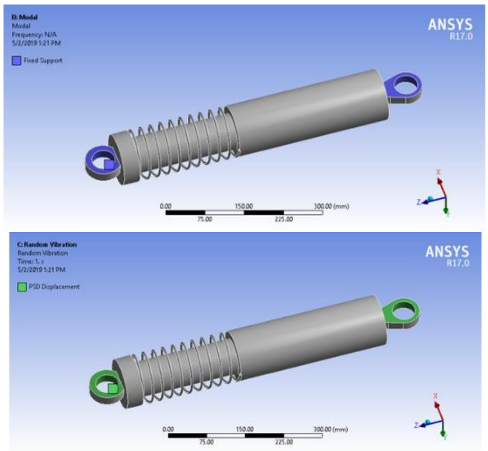


Fig. 3: Random vibration analysis

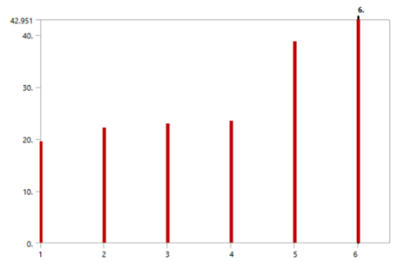
4.1.2 Boundary conditions

Add PSD acceleration spectrum curve: Select [Model] - > [Random Vibration] in the tree window on the left and right click and select [Insert] - > [PSD G acceleration].

In the detail [Boundary Condition], select the fixed constraint [Fixed Support] established in the static analysis, and [Direction] select the Z-axis.



[Load Data] Input according to the parameters in the figure below.



Mode	Frequency [Hz]
1.	19.519
2.	22.121
3.	22.896
4.	23.403
5.	38.749
6.	42.951

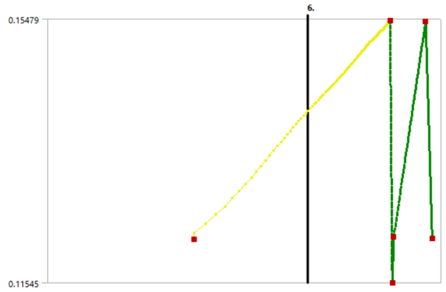


Fig. 4: Input curve

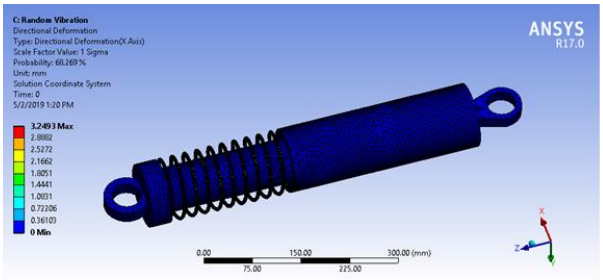
After the parameter input is completed, select the [Load Data]-> [Improved Fit] option, and the program will automatically evaluate the input data. The ANSYS Workbench will selectively add appropriate interpolation based on the data characteristics program to make the input curve more reasonable. After entering the parameters, each segment of the curve in the right graph shows the corresponding colour:
Green: The input parameter values are reliable and accurate; Yellow: Data input warning, the calculation result will be considered inaccurate;
Red: The resulting result is not recognized and is almost certainly incorrect. It is recommended to modify the PSD load value.

4.2 Calculation Solution

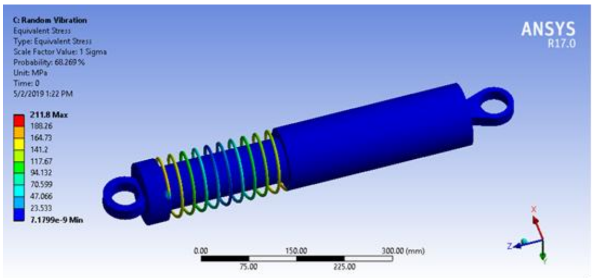
Select [Model]->[Random Vibration] and right click and select [Solve(F5)] to calculate.

4.3 Post-processing of results

View PSD response: Right-click [Solution] under the project tree, select [Insert]->[Respond PSD Tool], select [Respond PSD] in [Respond PSD Tool], the front point of the [Geometry] middle plate in the details [Result Type] Select [Displacement], [Result Selection] select [Z Axis], and obtain the response curve of the displacement under the PSD spectrum at different frequencies.



To view the equivalent stress: Right-click [Solution] under the project tree, select [Insert]->[Stress]->[Equivalent(Von-Mises)], select [1 Sigma] for the scale factor, and solve the result. Showing a probability of 68.269%, the maximum equivalent stress does not exceed 74.158 MPa.



The same method can solve the equivalent stress of 2 Sigma and 3 Sigma.

Alternating Stress MPa	Cycles	Mean Stress MPa
3999	10	0
2827	20	0
1896	50	0
1413	100	0
1069	200	0
441	2000	0
262	10000	0
214	20000	0
138	1.e+005	0
114	2.e+005	0
86.2	1.e+006	0

Fatigue due to cycles load

5. CONCLUSION

In every automobile and moving mechanical system have a vibration problem. The development of vibration mechanics has become a necessity, and advances in testing and computational techniques have provided possibilities for the development and application of vibration mechanics.

It has been formed based on physical concepts, using mathematical theory, computational methods and testing techniques as tools to solve vibration problems in automobile suspension system in engineering. The suspension is one of the most important parts of an automobile that controls random vibration. In this work, we are showing the RMS vibration calculation in the suspension system based on PSD technique by using FEM. The branch of mechanics of the target. The ways of doing things were generalized by using a graphic user connecting point way of interacting with something GUI. These values were validated using limited element modeling in ANSYS software. The workbench method is the more conservative method to use when solving random vibration problems. Special considerations regarding which solving method is appropriate to use should be made for any system where. The results from the workbench method more closely match the expected results based on the octave rule for the mass-spring system and the real model. Further testing could be performed to find the limitations to the random vibration analysis in ANSYS the effect of the magnetic holder can be easily extended by replacing them. With ANSYS Workbench, it is easy to establish a structural vibration characteristic analysis system, and analyze the vibration characteristics of the structure under the unified model and data through seamless transfer between data. ANSYS' complete dynamic analysis system ensures efficient, convenient and accurate structural dynamic analysis.

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