Random response analysis of pre-stressed structures using MSC/NASTRAN

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Abstract

There are the static load, the thermal load and the dynamic load acting on a vehicle structure simultaneously. Hence, the research of design method based on accounting for the coupling effects of the static load, the thermal load and the dynamic load is necessary and important. The random response analysis of pre-stressed structures is one of key problems in this research.The random response analysis of pre-stressed structures using MSC/NASTRAN has been explored, the solution steps and key points are given in this paper. First the modal analysis of pre-stressed structures is done using the nonlinear static solution sequence SOL106,then the random response analysis of pre-stressed structures is completed by the RESTART method and using the frequency response analysis solution sequence SOL111.The verification of this method using some examples is also given in this paper.

Introduction

There are the static load, the thermal load and the dynamic load acting on a vehicle structure simultaneously. The stresses of the structure arising from the static load and the thermal load are the prestresses to the dynamic behaviors and the dynamic responses of the structure. The prestresses will change the modal parameters, and then dynamic responses of the structure. The coupling effects between the static load and the dynamic load have not been accounted for in the current vehicle design. First the basic structure of vehicle is determined by the structure analysis only accounting for the static load and the thermal load, then the modal analysis and the dynamic responses of this basic structure are done without accounting for the effects of the static load and the thermal load, finally the dynamic environment and load of the vehicle structure are determined from the dynamic responses without accounting for the prestresses. Hence, the design shortage resulting from no accounting for the coupling effects between the static load and the dynamic load has to be compensated by using a large safety coefficient. To decrease the weight and the size of the vehicle structure demands to decrease the safety coefficient, but to decrease the safety coefficient demands the refine design method accounting for the coupling effects between the static load, the thermal load and the dynamic load in order to guarantee the reliability of the vehicle structure. The new design method accounting for the coupling effects between the static load, the thermal load and the dynamic load has become an important research subject [1]. The random response analysis of pre-stressed structures is one of key problems in this research.

In MSC/NASTRAN, the modal analysis of pre-stressed structure can be done by the nonlinear static solution sequence SOL106 [2]; the random response analysis can be completed using the linear frequency response analysis solution sequence SOL111, and can not account for the effects of the prestresses.

In this paper, first the modal analysis of pre-stressed structures is done using the nonlinear static solution sequence SOL106, then the random response analysis of pre-stressed structure is completed by the RESTART method and using SOL111. The verification of this method using some examples has also given in this paper.

Modal analysis of pre-stressed structures

The solution steps and the key points for the modal analysis of pre-stressed structures using MSC/NASTRAN are as follows:

(1) Define the FEM model (including the static load and the thermal load causing the prestresses) using MSC/PATRAN.
(2) Select the nonlinear static solution sequence SOL106.
(3) Edit the bdf file created from the nonlinear static analysis and add the following lines:
   a. Add “METHOD= “ at the case control section, to select the real eigenvalue extraction method;
   b. Add “EIGL” or “EIGRL” at the bulk data section, to define data needed to perform the real eigenvalue analysis, including the method of eigenvalue

extraction, the mode frequency range interested and the number of eigenvectors desired (that is the number of modes);

c. Add “PARAM,NMLOOP,k” at the bulk data section, to define the number k of load steps. The modal analysis will be done at the k-th load step. If k is equal to the third datum value of “NLPARM” entry, the modal analysis will be done using the differential stiffness of pre-stressed structures at the final load step.

Random response analysis of pre-stressed structures

Basic method

First the nonlinear modal analysis is done using the bdf file modified (edited and added) as above, then the random response analysis is completed by the RESTART method and the frequency response analysis solution sequence SOL111.The main solution steps and key points are as follows:

(1) Establish the bdf file of the nonlinear modal analysis using MSC/PATRAN as above.

(2) Complete the nonlinear modal analysis using MSC/NASTRAN and the bdf file established. In order to translate the dynamic behavior data of pre-stresssed structures obtained from the nonlinear modal analysis (including mass matrix, stiffness matrix and corresponding modal parameters) to the frequency response analysis solution sequence SOL111, the selection item “SCR=NO” must be defined before running MSC/NASTRAN to complete the nonlinear modal analysis.

(3) Establish the bdf file of the random response analysis using MSC/PATRAN[3].

(4) Modify the bdf file of the random response analysis established:

a. Add ”RESTART VERSION=last KEEP” and “ASSIGN MASTER =*.MASTER” at the front of the bdf file, in which * is the name of data file for the nonlinear modal analysis;

b. The value of number N of “METHOD=N” in the case control section must be equal to the value of number K of “METHOD=K” in the bdf file of the nonlinear modal analysis;

c. Delete or comment on the data entries relative to the finite element modeling;

d. The number of load in the bdf file of the random response analysis must be different to the number of load in the bdf file of the nonlinear modal analysis.

Some examples

(1) Random response analysis of a pre-stressed beam

The beam of length 1.0m is simple supported on both ends, the cross section of which is 0.003m(width)$\times$ 0.004m(height). the material properties of the beam are 68.65 Gpa(modulus of elasticity), 0.3(Poisson ratio), 2700 Kg/m^3(density), 0.04(modal damping ratio). The beam is bearing the axial pull P and the random vertical force with equally distribution on the all length of the beam, its power spectral density is 9.617×10^{-2} Pa^2 /Hz (2-100Hz).

The modal frequencies of the beam obtained using the nonlinear static solution sequence SOL106 of MSC/NASTRAN are as the following table No.1. The results of analytical solution (AS) are also given in this table.

Table No.1 The results of the modal analysis of pre-stressed beam

Case of load	P=0 N		P=0.01 N		P=5 N	
	SOL111	AS	SOL106	AS	SOL106	AS
Modal frequency Hz	6.85932 9.14567 27.4332 36.5673	6.85944 9.14592 27.4378 36.5873	6.86494 9.14989 27.4388 36.5805	6.86507 9.15014 27.4434 36.5879	9.25361 11.0554 30.1136 38.6273	9.25377 11.0557 30.1190 38.6353

After the modal analysis using SOL106 is done, the random response analysis is completed by the RESTART method and using SOL111. The RMS of the vertical displacement on the middle point of the beam are given in the table No.2. The RMS with P=0 by analytical solution (AS) is also given in the table No.2. From the table No.2, it can be shown that the displacement response of the beam is affected by the prestresses of the beam; the axial pull will decrease the RMS of the vertical displacement (VD). The RMS of the vertical displacement converges to the computing result of P=0 by the analytical solution with the decrease of the axial pull.

Table No.2 The RMS of the vertical displacement on the middle point of pre-stressed beam

Case of load	P=0 N		P=0.01N	P=5N
	SOL111	AS	SOL106+SOL111	SOL106+SOL111
RMS of VD m	0.04877	0.04946	0.04874	0.03674

(2) Random response analysis of the pre-stressed structure composed of plates and shells

The dynamic computing model of the structure composed of plates and shells, and the random pressure load are taken from [4]. The static pressure loads causing the prestresses are taken as P=76 Pa, 76000 Pa, respectively. First the modal parameters are computed using SOL106, then the random response analysis is completed by the RESTART method and using SOL111. The RMS of the acceleration responses in Z direction on the middle point of the structure are obtained and shown in the table No.3. The computing result with the static pressure load P=0 Pa using SOL111 is also given in the table No.3. From the table No.3, it can be shown that the RMS of the acceleration responses are increased with the increase of the static pressure load.

Table No.3 The RMS of acceleration responses in Z direction on the middle point of the pre-stressed structure composed of plates and shells

Case of load	P=0 Pa	P=76 Pa	P=76000 Pa
RMS m/s^2	587.57	591.1	691.0

Conclusion

The work of this paper shows that the random response analysis of the pre-stressed structures can be well done using MSC/PATRAN and MSC/NASTRAN. They are the most efficient tools for complex structure response analysis accounting for the coupling effects between the static load, the thermal load and the dynamic load.

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References

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