*LANDING RESPONSE ANALYSIS OF AIRCRAFT WITH STORES USING MSC/NASTRAN

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ABSTRACT

In order to ensure safety flight of aircraft, it is very important to study the landing response analysis of aircraft with stores. Earlier aircraft was considered as a stiff body by reason of its lightweight and large structural stiffness. However, the structure of modern aircraft changes into more and more flexible with increasing of size and use of high strength materials. It would make for more accidents if the elastic effects were neglected for the aircraft. In this paper, the problem was solved successfully by means of generalized dynamic reduction and the large mass method of MSC/NASTRAN. The results in the paper show that the solution technique using MSC/NASTRAN is effective and feasible, which is especially suitable for the solution of the dynamic problem of large-scale structure subjected to base enforce motion.

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INTRODUCTION

With the rapid progress of modern aeronautic technology and social productivity, the performance of aircraft has been increased greatly. At the same time, the working environment of the aircraft is becoming more and more complicated and rather hard, resulting in the fact that the vibration problems of aircraft structures are becoming more and more prominent. Therefore, it is a very important means for ensuring the aircraft's safety to perform landing response analysis of aircraft with stores.

In the past, due to limitation of calculation means, such large-scale dynamic response problems as the aircraft landing with stores was always a tough problem in engineering. Nowadays, the development and widespread application of computer technology have provided unprecedented hardware condition, while the finite-element method has provided reliable and powerful calculation means for structural dynamics. Therefore, the solution of dynamic problems for large-scale complicated structures is no longer a vision now. This paper presents the successful analysis of a certain aircraft landing with stores. The analysis work was carried out using MSC/NASTRAN in the model of which generalized dynamic reduction technique and large mass method were employed.

BRIEF DESCRIPTION OF THE MODEL

MSC/NASTRAN provides a variety of elements that can be used to meet the needs of modeling. The dynamics model of the aircraft landing with stores is a multi-degrees of freedom elastic system involving the external stores. If only the symmetric landing cases are considered, the analysis model will be greatly simplified, reducing the size of the problem by a large amount. In other words, only half the structure of the aircraft is modeled. The simplified model consists of three main parts, the fuselage model and the wing model , as well as the external stores.

In the model, CROD and CBAR or CBEAM elements are used to define the stringer and beam of the aircraft structure, respectively. The CQUAD4 and CTRIA3 elements are used to define the skin and web plate of the aircraft structure. The connection between the fuselage and the wing is defined by RBEi cards, since its stiffness is much larger than that of other structure. The external store is defined as a rigid body using RBEi cards. Its mass is defined by the CONM2 card and assigned to its center of gravity. The CELAS cards are used to define the connection stiffness between the store and the wing, such as pitch stiffness, yaw stiffness and roll stiffness. These stiffness are determined directly from the ground vibration test (GVT).

Since the landing aircraft is a free-free body, it is very effective to suppress all rigid body motions using the SUPORT card in the dynamic analysis. In addition, the aircraft landing motion can be defined as a motion of the aircraft with base enforced acceleration, while the enforced acceleration is just the excitation condition, which is obtained by another specific program.

SOLUTION APPROACH

The finite-element analysis of structural dynamic problem consists of three stages: 1) the assembly of dynamic equations; 2) the solution of the dynamic equations; 3) the recovery of dynamic responses. With the increasing of problem size, the computation costs of the first and the third stages increase linearly with the problem size, while the cost of the second stage increases as the square or the cube of the problem size. Obviously the total cost of the problem is dominated by the cost due to the second stage. The problem of computation cost is also an important factor that restricts the analysis of large-scale structures. So, it is an urgent need to find an analysis method which can reduce the cost while ensuring sufficient accuracy. Besides this, since the landing aircraft is a free-free body, it is also a key technique determining how to model the base excitation. The use of MSC/NASTRAN has proved to be an effective solution in solving this problem, including the use of the generalized dynamic reduction and large mass methods.

Generalized dynamic reduction technique

The so-called “generalized dynamic reduction” method is the practice of condensing or removing from the analysis those degrees of freedom whose contribution to the overall response are insignificant, thus forming a smaller analysis set[1]. Moreover this technique may increase the solution efficiency greatly thus meeting the goal of reducing cost.

Unlike the Guyan reduction method, the generalized dynamic reduction takes not only the static effects but also the dynamic effect into account during the condensation process. First, the degrees of freedom set of the structure $\{u_f\}$ is condensed to the analysis set , $\{u_e\}$ that is:

$$\{u_f\} = [\Psi]\{u_a\} = \begin{bmatrix} G_{ot} & \Phi_{oq} \\ I & O \\ 0 & I \end{bmatrix} \begin{Bmatrix} u_t \\ u_q \end{Bmatrix} \qquad (1)$$

Where, $\{u_f\}$ means the set of the retained degrees of freedom of the structure, $\{u_q\}$ means the set of the generalized coordinates; $[G_{ot}]$ means the static transforming matrix derived through Guyan reduction; $\lfloor \Phi_{oq} \rfloor$ means the dynamic transforming matrix derived through the generalized dynamic reduction. Thus derived the dynamic equations for the analysis set:

$$[M_{aa}]\{\ddot{u}_a\} + [B_{aa}]\{\dot{u}_a\} + [K_{aa}]\{u_a\} = \{P_a\} \qquad (2)$$

Then applying real modal transformation to Eq. (2). Writing the following equation:

$$\{u_a\} = [\Phi_a]\{\xi\} \qquad (3)$$

Where, $[\Phi_a]$ is the modal matrix for the a-set; $\{\xi\}$ is the modal coordinate vector. Eventually, in order to recover the dynamic response of the structure, we perform the transformation twice, that is, merging Eq. (3) into Eq. (1), we can get:

$$\{u_f\} = [\Psi][\Phi_a]\{\xi\}$$

Large mass method

When a structure is subjected to base excitation, this method[2] can be used to apply the enforced motion onto the structure effectively. First of all, attaching a large mass M_L to the degree of freedom subjected to enforced motion with a known acceleration u_b, then applying on it a load which is:

$$P = M_L \ddot{u}_b \qquad (4)$$

Then, we can get an enforced acceleration at this degree of freedom $\ddot{u}_b$ which approximately equals $\ddot{u}_b$:

$$\ddot{u}_b \approx \frac{1}{M_L} P = \ddot{u}_b \qquad (5)$$

It should be noted that the value of the large mass may influence the accuracy of the solution. If the total mass of the structure is m, then taking the value of 10^6 m for the large mass may meet the accuracy requirement of ordinary engineering problems.

ANALYSIS RESULTS

There are two configuration cases[3] in the analysis of aircraft landing. Case 1 represents the aircraft landing with the only outboard stores. And case 2 represents the aircraft landing with not only the outboard stores but also with the inboard stores. The analysis work was carried out using modal transient response analysis of MSC/NASTRAN. In order to study the effect of the structural damping on the landing response, the structural damping value ¦Â was respectively taken 0.0, 0.01 and 0.025, and only the symmetric landing cases were considered.

The analysis results include the displacement responses and the acceleration responses at the attachment point and the c.g. of the outboard store. Table 1 shows the maximum value of displacement response with different structural damping, while Table 2 shows the maximum value of acceleration response with different structural damping. For each of the two configuration cases, when ¦Â = 0.01, the displacement and the acceleration time histories at the attachment point and the c.g. of the outboard store are given in Figures 1 through 4.

From these analysis results, it is clear that there is a rapid decrease in the acceleration response with the increase of the structural damping and the value of acceleration response for the case 1 is much larger than that for the case 2 at the same location. Therefore, it is suitable for the design to take the structural damping to be ¦Â = 0.01.

CONCLUSIONS

This analysis provides satisfactory results for the dynamic response of aircraft landing with stores. These calculation results show that the methods presented in the paper are feasible and effective, while the calculation accuracy meets the requirement of engineering problems. Moreover the solution technique using MSC/NASTRAN is especially suitable for the solution of the dynamic problem of large-scale structures subjected to base enforced motion. Therefore, MSC/NASTRAN is the most effective way to solve the problems.

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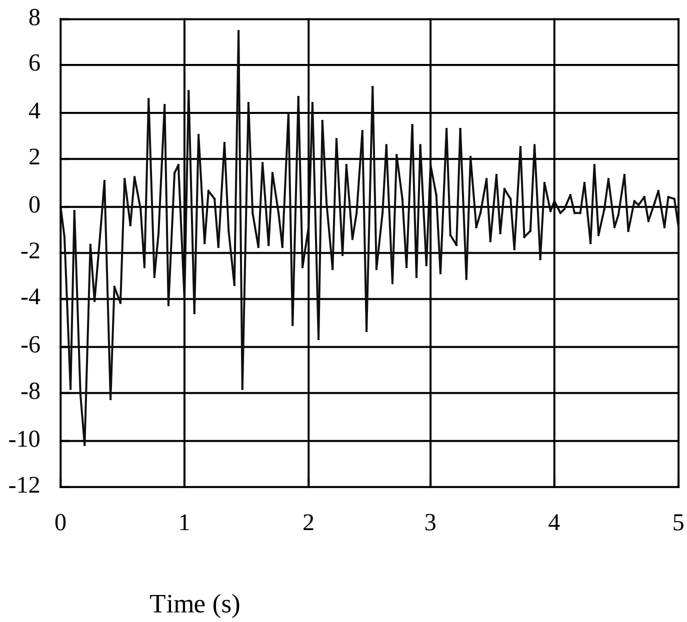
Table 1 The maximum value of displacement response (mm)

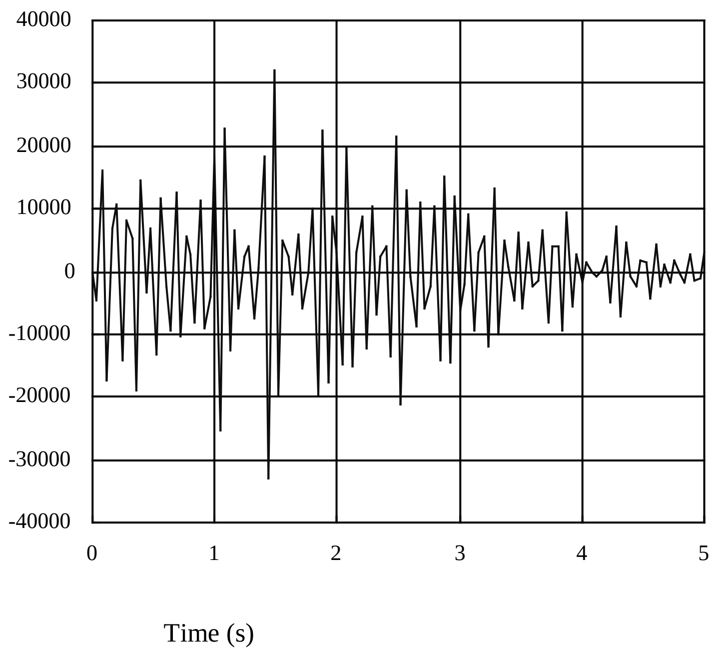
Case No.	Response Location	¦Â= 0.0	¦Â= 0.01	¦Â= 0.025
1	The Attachment Point	11.47	10.21	9.81
	The c.g. of Store	22.68	21.25	19.31
2	The Attachment Point	19.73	17.77	15.75
	The c.g. of Store	29.82	26.38	24.17

Table 2 The maximum value of acceleration response (g)

Case No.	Response Location	¦Â= 0.0	¦Â= 0.01	¦Â= 0.025
1	The Attachment Point	6.31	3.41	2.29
	The c.g. of Store	5.21	4.08	3.41
2	The Attachment Point	3.26	2.54	1.85
	The c.g. of Store	4.17	3.18	2.82

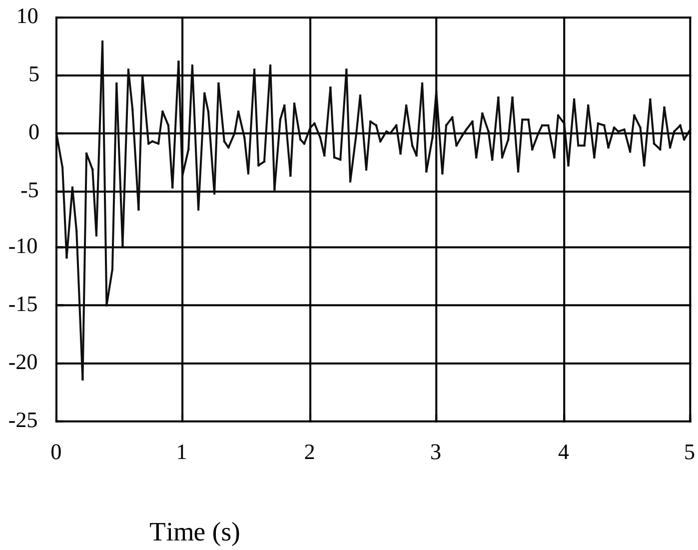


(a) Displacement (mm)

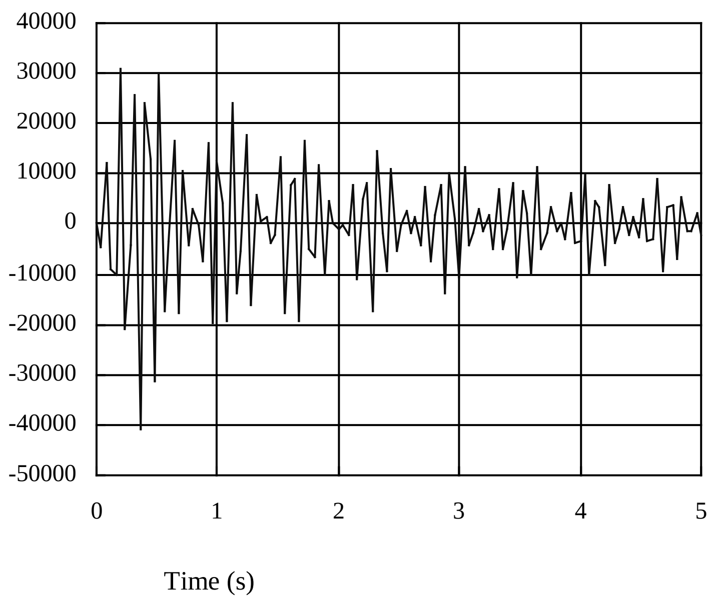


(b) Acceleration (mm/s ^{2})

Fig. 1 The response time histories at the attachment point of the outboard store for case 1

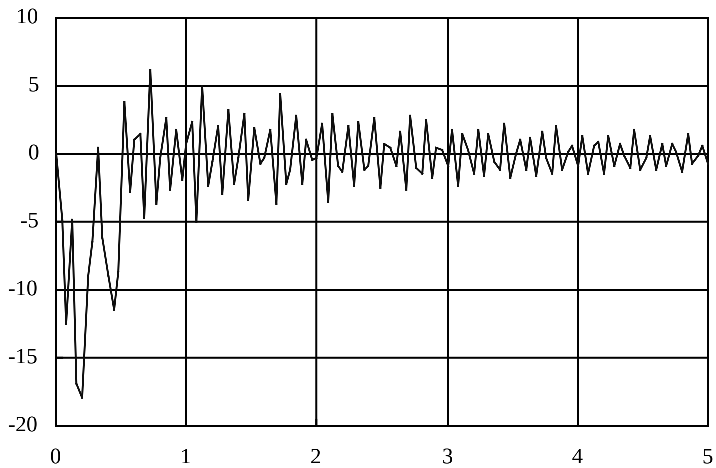


(a) Displacement (mm)



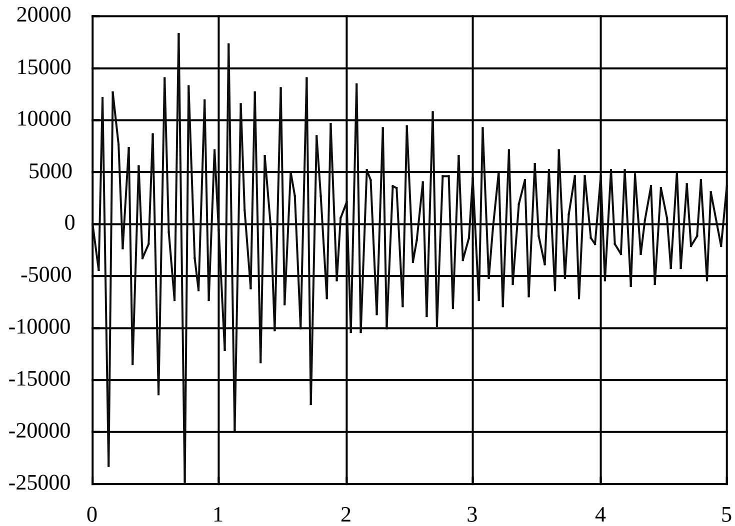
(b) Acceleration (mm/s^2)

Fig. 2 The response time histories at the c.g. of the outboard store for case 1



Time (s)

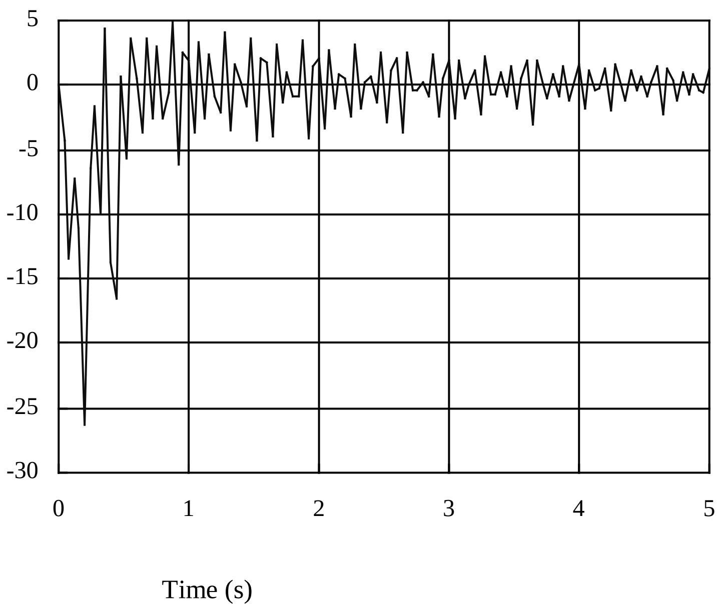
(a) Displacement (mm)



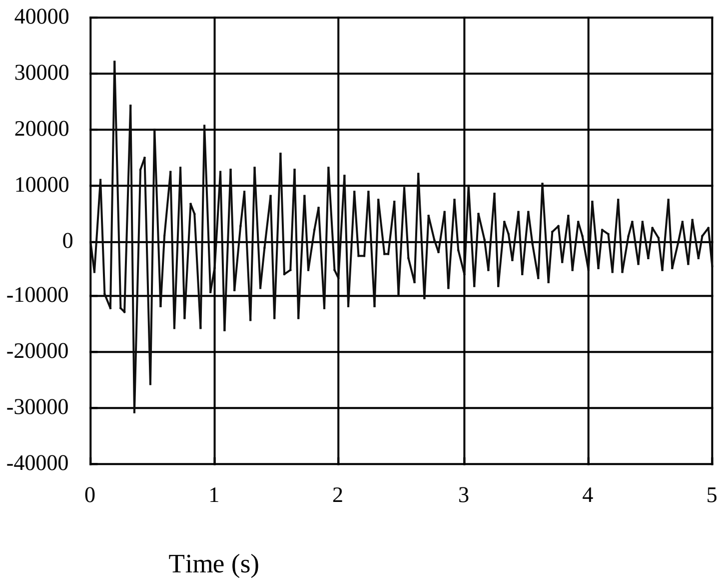
Time (s)

(b) Acceleration (mm/s^2)

Fig. 3 The response time histories at the attachment point of the outboard store for case 2



(a) Displacement (mm)



(b) Acceleration (mm/s^2)

Fig. 4 The response time histories at the c.g. of the outboard store for case 2