재귀 부분 합성법을 이용한 구조물 유체-고체 연성 해석

FSI Analysis of Structure Using Recursive Component Mode Synthesis

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요 약

본 논문에서는 재귀 부분 구조 합성법을 이용하여 유체와 고체가 연성된 구조물에 대한 거동을 해석하였다. 이 방법은 일반적으로 널리 사용하는 랜쵸스 방법과 비교하여 몇 배나 빠른 계산 결과 시간에 문제를 풀었음에도 거의 동일한 해를 얻을 수 있는 장점이 있다.

keywords : vibration analysis, absolute nodal coordinate formulation, large deformation, nonlinear analysis

1. Introduction

The recursive component mode synthesis method (RCMS) is implemented for the finite element analysis model as an efficient free vibration analysis tool. The RCMS method is intended to obtain a better performance than the Lanczos method. In this paper, the fluid-structure interaction problem is calculated with the RCMS method. The numerical example of finite element model demonstrates the outstanding performance of RCMS compared to the Lanczos method.

2. Basic Theory

In a free vibration, $([K]-\lambda[M])\{u\}=\{0\}$, the main issue is to calculate the eigenvalues and the corresponding eigenvectors accurately and efficiently. In structure problem, the Lanczos method, which is traditional method in industry for obtaining eigenvalues, has been widely used. In the component mode synthesis method (CMS) method, the free vibration problem is rewritten as

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$$\begin{pmatrix} K_{LL} & K_{LS} \\ K_{SL} & K_{SS} \end{pmatrix} \begin{Bmatrix} u_L \\ u_S \end{Bmatrix} = \lambda \begin{pmatrix} M_{LL} & M_{LS} \\ M_{SL} & M_{SS} \end{pmatrix} \begin{Bmatrix} u_L \\ u_S \end{Bmatrix} \qquad (2)$$

In a traditional CMS method, which is single level CMS methid, the stiffness matrix $[K]$ is decomposed into $[K] = U^T DU$ using the block Gauss elimination. The congruent transformation of $[K]$ and $[M]$ with U results in $[\widetilde{K}] = U^T [K]U$ $[\widetilde{M}] = U^T [M]U$.

Then, the CMS method is extended to multi-level recursively, which is called as the recursive component mode synthesis (RCMS) method, which is a generalization of the single level CMS method.

$$\overline{V}^T (U^T KU)\overline{V}\{\overline{u}\} = \overline{\lambda}\overline{V}^T (U^T MU)\overline{V}\{\overline{u}\}$$

3. Fluid-Structure Interaction Analysis

A fluid-structure interaction problem consists of structure domain, fluid domain and interaction domain. Then the modal frequency response problem can be represented as

$$\begin{bmatrix} -\omega^2 I + i\omega B + (1+i\gamma)\Lambda + iK_s & i\omega \bar{A} \\ i\omega \bar{A}^T & -(-\omega^2 I_F + i\omega \bar{C} + \Lambda_F)/\rho \end{bmatrix} \begin{Bmatrix} \mathbf{Z}_s(\omega) \\ \mathbf{Z}_f(\omega) \end{Bmatrix} = \begin{Bmatrix} \mathbf{F}_s(\omega) \\ \mathbf{F}_f(\omega) \end{Bmatrix}$$

In order to obtain above equation, modal equation, the eigenvectors and eigenvalues are obtained with RCMS approach that is introduced in section 2. The numerical example of finite element model demonstrates the outstanding performance of RCMS compared to the Lanczos method while obtaining the same accuracy.

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