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FULLY COUPLED TIME-VARYING LINKS USING LAGRANGE MULTPLIERS FOR FAST TRANSIENT DYNAMICS USING EUROPLEXUS

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ABSTRACT

Fast transient dynamics play a significant role in many safety analyses for the nuclear world, such as Loss Of primary Coolant Accident, Containment Accident or External Aggressions. In the particular case of non-linear structural dynamics, extensive use of kinematical links, mainly contact-impact conditions, is often required, for example for crashworthiness simulation of complex nuclear substances packages. A rigorous approach to systematically handle such conditions without introducing non-physical parameters is the Lagrange Multiplier Method.

The present paper proposes a review of the capabilities of the EUROPLEXUS [1] explicit code, jointly owned by the French Commissariat à l'Energie Atomique (CEA) and the Joint Research Center of the European Commission (JRC Ispra), in terms of efficient treatment of fully coupled and time varying links, by means of Lagrange Multipliers (LM) [2][3].

In the framework of explicit structural dynamics, dynamic equilibrium involving link conditions and LM can be schematically expressed as follows:

$$\begin{bmatrix} \mathbf{M} & \mathbf{C}^T \\ \mathbf{C} & 0 \end{bmatrix} \begin{bmatrix} \ddot{\mathbf{U}} \\ \mathbf{\Lambda} \end{bmatrix} = \begin{bmatrix} \mathbf{F} \\ \mathbf{B} \end{bmatrix} \qquad [1]$$

$\mathbf{M}$ is the diagonal mass matrix of the system, $\mathbf{C}$ is the matrix of link coefficients, $\mathbf{F}$ accounts for structural forces, both external and internal, and $\mathbf{B}$ accounts for the right-hand sides of the link conditions.

LM are then computed using the condensed equation [3] :

$$\mathbf{C}\mathbf{M}^{-1}\mathbf{C}^T\mathbf{\Lambda} = \mathbf{H}\mathbf{\Lambda} = \mathbf{C}\mathbf{M}^{-1}\mathbf{F} - \mathbf{B} \qquad [2]$$

The additional computational cost due to LM, in terms of both memory and execution time, lies in the construction and inversion of the **H** operator. Provided a suitable numbering of link conditions, this operator is block-diagonal. The key is then to identify coupled links in order to deal with blocks of **H** independently. To do so, EUROPLEXUS is equipped with a specific dynamic data structure that manages groups of coupled links, updated at each time step when non-permanent links, such as contact conditions, are used.

The next step is to make this treatment compatible with the domain decomposition approach which is necessary to perform parallel calculation on distributed memory systems. Groups of coupled links may be local to a subdomain, and LM are then computed locally, or involving several subdomains, which requires a global treatment. Detection of inter-subdomains coupled links in the case of non-permanent links implies a specific communication scheme between subdomains.

The purpose of this paper will be illustrated by some significant examples, demonstrating the various potentialities of EUROPLEXUS in terms of treatment of time-varying contact conditions by means of LM.

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