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SIMULATION OF A MECHANICAL ASSEMBLY USING MODEL REDUCTION

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ABSTRACT

INTRODUCTION

The simulation in real time of a mechanical assembly composed of two parts (rigid/deformable) is very interesting during the design phase of a product. But the non linearities introduced by the contact combined with the geometric and material non linearities make the analysis by finite element method (FEM) not possible in real time.

We prefer to divide the simulation into a learning step and a real time step. During the learning step, a campaign of possible load cases, representative of the different possible handlings of the model, is calculated with FEM. This paper focuses on the first step with two aims: calculate the campaign as quickly as possible and obtain a reduced response surface [1] with 3 levels of reduction.

METHODS

1) In order to reduce the number of degrees of freedom (DOF) n, which can be very huge, an adaptive method [2] is used to solve the quasi-static equilibrium:

$$K(u).u - f(u) = r(u) \qquad (1)$$

Displacement u is projected onto a basis $\Phi=\{\varphi_1, \ldots, \varphi_m\}$, described by m modes ($m \ll n$), and coefficients a. By a Galerkin scheme, (1) is projected on the basis:

$$\Phi^T.K(u).(\Phi.a) - \Phi^T.f(u) = \Phi^T.r(u) \qquad (2)$$

Then a Newton-Raphson (NR) scheme proceeds on a and converges in coefficients a:

$$\Phi^T \cdot K_T \cdot \Phi \cdot da = -\Phi^T \cdot r \qquad (3)$$

But the residual r can be not negligible if the basis Φ is too poor to describe correctly the displacement u. So the basis needs to be enriched by one NR iteration:

$$du = (K_T)^{-1}.r \qquad (4)$$

This vector (4) is orthonormalized and added to the basis as a new mode.

2) When the problem is non-linear, the basis size increases during the campaign. This size could become prohibitive for the real time step. So the Karhunen-Loeve Expansion (KLE) is used to limit the basis size [1]. A KLE, done on the historical a matrix, is realized at the end of a load case if the number of modes exceeds a limit value.

3) An other way to achieve the aims is to use hyperreduction [3]. The Newton-Raphson scheme is solved only on few characteristic degrees of freedom (DOF). During the adaptive step (4), new DOF can be added.

ANOTHER FORMULATION

We propose an alternative to (3), which consists on the minimization of the residual. Then NR becomes by a Gauss-Newton approximated procedure:

$$\Phi^T \cdot K_T^T \cdot K_T \cdot \Phi \cdot da = -\Phi^T \cdot K_T^T \cdot r \quad (5)$$

The formulation (5) presents better results than (3), so the results exposed in next part provide from (5).

MODEL AND RESULTS

The model reduction is applied on the mechanical assembly of a flexible hose on a rigid tip. The 2D axisymmetric model presents 3200 DOF. The hose material is an elastic rubber modelled by an incompressible neohookean behaviour. An uniform displacement is imposed on the extremity of the hose.

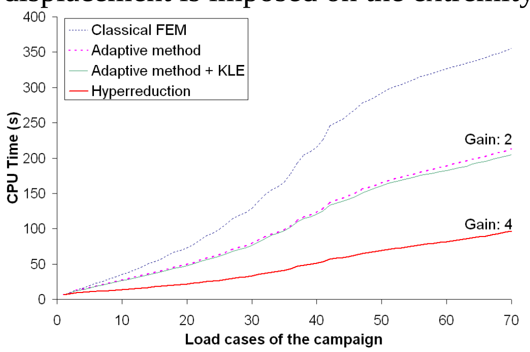

Figure 1: cumulated CPU time

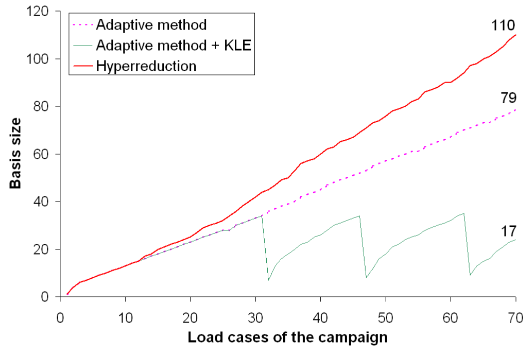

Figure 2: basis size during the campaign

Figure 1 shows that the gain on CPU time compared with a classical FEM is approximatively of 2 for adaptative method and adaptative method + KLE. With hypperreduction, the gain is about 4.

Figure 2 shows that finally model reduction present 79 and 110 modes for methods without KLE, and 17 with KLE compared with 3200 DOF of the problem.

CONCLUSION

These results show the efficiency of these methods to obtain quickly a reduced response surface. Next stage, real time step, will consist on the exploitation of this response surface, by interpolation, to realize the interactive simulation of an assembly.

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