PROPOSITION DE SUJET DE THESE

Intitulé : Super-élément fini perforé non-linéaire pour la modélisation des assemblages dans les calculs de structures

Non-linear super finite element for the modeling of assemblies in structural computations

Référence : SNA-DMAS-**2023-**05
(à rappeler dans toute correspondance)

Début de la thèse : Octobre 2023

Date limite de candidature : Mai 2023

Mots clés

Finite Element formulation, Reduced model, Transformation Field Analysis, Stress concentration factor

Profil et compétences recherchées

Master of Science (M. Sc.), Engineering School. Specialty: Computational mechanics and / or Mathematics.

Knowledge on the formulation of standard polynomial finite elements and on numerical analysis (numerical integration, interpolation, least squares, etc.), use of commercial FE softwares (such as Abaqus, LS-DYNA, Ansys, etc.) and of programming languages (Matlab, Fortran or C++).

Présentation du projet doctoral, contexte et objectif

The proposed subject concerns passive safety in transportation, and more particularly air transportation. Indeed, the response of aeronautic structures subjected to accidental situations of crash / impact nature (fast dynamics field) needs to be evaluated. These accidental situations can for example correspond to sea landing, bird or ice impact, etc.

The response of aeronautic structures to these loadings can be evaluated thanks to finite element (FE) numerical simulations. In fact, both the dynamic loading needs to be modeled accurately and the structure needs to be discretized with care. Indeed, the (riveted) assembly zones play an important role in structural failure initiation and propagation throughout the structure. It could thus seem quite natural to discretize finely the assembly zones so as to obtain an accurate estimate of the (strain, stress, etc.) mechanical fields, which are used to initiate and propagate failure in numerical simulations.

However, this fine local modeling of the assembly zones is incompatible with the scale of the full structure: the number of required finite element and the computing time would become too substantial (tens of millions finite elements, too low time step for explicit computation stability).

It is thus required to employ macroscopic approaches, i.e. special FE that are designed to predict the local mechanical fields experienced in the assembly (elastic, plastic, damage, failure) without needing to discretize finely the assembly, so as to enable a full scale structure computation. The so-called “Connector” elements are available in FE softwares in order to model the macroscopic behavior of assemblies in structural computations. However, it appeared that connector elements do not allow predicting accurately enough the local mechanical fields in the assembly to enable a realistic initiation of failure.

This is the context of the proposed research topic: it consists of proposing new and more realistic approaches to model the behavior and failure of riveted assemblies in full-scale structural computations.

Previous work has already permitted to develop a special FE containing an inner hole, which is both computationally efficient and accurate in the modeling of local mechanical fields (in particular in the vicinity of the hole of the riveted assembly). However, it appeared that this element is restricted to linear elastic problems (the super FE inner fields are somehow a superposition of elastic modes, based on an analytical solution). An extension from linear elastic problems to fast dynamics (crash/impact) problems is thus desired. A first substantial step is to enable geometrically and materially non-linear computations with this special FE. In particular, it consists of obtaining the non-linear modes to be included in the special FE formulation. To this end, several approaches - although of different nature – appear quite promising, and it is proposed to explore them:

- *Pragmatic correction of elastic modes*. A first approach would consist of building a correction of the existing elastic modes, based on the evolution of the stress concentration factor in elasticity and plasticity,
- *Building a reduced model of a geometrically and materially non-linear plate containing an inner hole.* A Reduced basis could be built, for example by means of Proper Orthogonal Decomposition (POD),
- *Generating the non-linear modes based on the structural embrittlement indicator based on Transformation Field Analysis (TFA).* The structural embrittlement indicator developed at ONERA could be applied to the case of a non-linear plate featuring a hole to generate the non-linear modes.

Finally, the modes originating from different sources may be combined, so that the modes exhibited by a perforated plate subjected to fast dynamic loadings are included in the special FE formulation, and without any redundancy. The selection and sorting of modes may be envisaged by means of Artificial Intelligence (AI) through a learning process based on perforated plate experimental and or reference numerical results.

Collaborations envisagées

La thèse sera réalisée en collaboration avec le Laboratoire d'Automatique Mécanique Informatique Industrielle et Humaine (LAMIH) de l'Université Polytechnique Hauts-de-France (UPHF).

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