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A non-intrusive global/local method for fatigue computations on hot aeronautical structures

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ABSTRACT

For the new generation of engines being developed, in order to reduce weight and improve performance, parts have to be very precisely designed because they are loaded near their limits. Therefore, a high number of computations must be performed to check new design solutions and computational cost becomes a main barrier for engineers, especially for high temperatures structures (more than 1000 °C) such as the combustion chamber (*cf.* Fig.1) or high pressure turbine blades. Indeed for these problems full elasto-viscoplastic simulations have to be carried out in order to represent accurately phenomena like creep, stress relaxation and stress redistributions. Such computations need to be repeated over tens of complex cycles (*cf.* Fig.2) to reach the stabilized cycle, especially to find the range of stresses to evaluate the lifetime of structures.

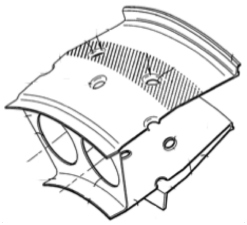

Figure 1: Slice of a combustion chamber

The cost of these studies, with complex behaviours as [3], is so huge that structural details (micro-perforations on Fig.1) are hardly taken into account in a monolithic approach. In order to simplify their introduction in the design chain of our industrial partner Safran Snecma, we propose an iterative global/local method as [5], but in a non-intrusive approach. With this original technique of coupling, we are able to reuse directly meshes of our partner especially for the global (without structural details) model. With a second mesh, we represent structural details or new geometric solutions like a fillet thanks to a local model, which may exist yet in other applications. Furthermore, this method works directly with commercial solver, in our case *Abaqus Standard*. Then the method consists in iteratives exchanges between these two models which conduct exactly to the monolithic solution.

More precisely, we go back over the method developed in [2] for our new applications. Indeed, we are confronted with generalized plasticity, so now all models are higly nonlinear and

we apply this strategy on large number of consecutive steps of loading (red circles on fig.2). Henceforth, as the plastic zone is not restrained to the local area, it can cross the interface between local and global models. We thus obtain a full nonlinear coarse model for the structure with local refinements where needed.

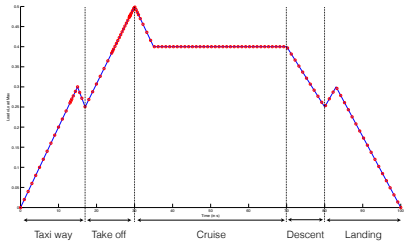

Figure 2: Definition of a plane load amplitude

On the contrary of previous methods apply on only one increment, we can not put up with accumulating any error at each time step. They must be controlled so they do not lead to an unwanted variation in the history of the solution in comparison to the computationally unrealistic monolithic approach. In addition, because of our highly nonlinear behaviour, the computation is very sensitive to the loading's history and automatical time discretization of *Abaqus* (named "cutbacks") lead to errors, which may deteriorate the solution also.

These difficulties can be mastered by a clever management of *Abaqus'* accuracy and of the convergence threshold of our iterations. Besides, cutbacks must be detected to eliminate them if they occur during the simulation. We are thus able to perform low cycle fatigue computations although the computational cost remains too high. That's why we add to the method several acceleration techniques, as SR1 [2], BFGS [4] and Aitken's Δ^2 [1], in order to reduce the number of iterations needed to obtain a sufficient accuracy of the solution and make our approach compatible with the needings of our industrial needings especially. In the presentation, we will detail our implementation, our solutions to control the method's accuracy and present first results obtained with acceleration techniques.

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