INTERFACING OF THE OOFELIE MULTI-PHYSICS TOOLKIT WITH GID

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Abstract : *The aim of this paper is to present the interfacing of OOFELIE, a CAE code developed to address the need for multi-disciplinary, multi-physics analyses, and the pre/post-processor GiD. This interface provides an easy definition of the geometry and the meshing while the different conditions are assigned in a natural way for users familiar with OOFELIE. The paper will review, among others, the mechanism of selection of which physical fields (acoustical, electrical, fluid, mechanical, thermal) are to be considered in the problem, the procedure which allows to modify the parameters of the different solvers through the interface, or the use of additional sets of commands which can be placed before and after the solver call (prologue/epilogue). This will be illustrated through some multi-physics cases.*

1. INTRODUCTION

The advent of the OOFELIE toolkit development effort stemmed from the observation, in the early 90's, of two major changes of approach: the realisation that weak coupling is not accurate for multi-physics analyses (especially with respect to the time and frequency behaviours) and that more and more new developments started to use C++ rather than Fortran. The code OOFELIE was thus originally developed jointly by the Aerospace Laboratory (LTAS, now ASMA) of the University of Liège (Belgium) and INTEC, from the Universidad Nacional del Litorál (Argentina) since 1991. Its main objectives were (i) to allow the unification of the developments of several research units in numerical modelling with maximum reuse and ease of maintenance by proposing a unified, flexible and open analysis toolkit, and (ii) to open the way to solve multi-physics innovative problems of the future, allowing collaboration of experts of different disciplines around a unique platform. To achieve these goals, the choice was made to use object-oriented (OO) methods of programming in C++ ,a rather new method for engineering computing applications development at the time, and constantly look at optimisation of performances to match and sometimes exceed Fortran. This implementation allows for a great flexibility for multi-physics numerical modelling, adding new physics and their coupling, as well as the development of tailor-made products to address specific industrial problems.

To provide a more professional support and further development of the capabilities to address these new challenges in computer modelling and offer unique solutions to multidisciplinary analyses needs, Samtech and the University of Liège participated jointly in the creation of the Open Engineering spin-off in 2001. OOFELIE is now a highly modular and extensible library of numerical tools for multi-physics, multi-fields and multi-methods numerical analysis in a single unified platform, making maximal usage of Object-Oriented programming concepts in C++. This library has been adopted and is shared by a growing community of development centres to continue to enhance its capabilities while reducing significantly software development, maintenance and extension costs. A striking illustration of this flexibility was provided by the recent introduction in a very short time frame of fluids modelling capabilities and their coupling.

OOFELIE currently offers modelling capabilities for multi-physics problems with strong coupling in the areas of Structural mechanics (linear and non-linear), Acoustics, Piezo-electricity, Heat transfer, Electrostatics and Fluid mechanics, with Electromagnetism being in development. The couplings can be both strong and weak, realized internally or externally, for example through the coupling of other solvers with OOFELIE. The approaches selected enable the consideration of complete 3D models as well as reduced order models to allow faster multidisciplinary solutions. The method is open to a wide range of algorithms (direct, iterative, explicit, implicit, etc.) which can coexist in the modelling procedure. An interactive command interpreter allows for an even greater flexibility to address new or speculative solution ideas. Although the potential range of applications is much wider, OOFELIE currently is being used in coupled applications such as MEMS, piezoelectric sensors and actuators, vibroacoustics, thermoelasticity, fluid-structure interactions, etc…

However, it became clear very early that the very open and interrelated needs for pre- and post-processing of such multi-physics analyses to define problems and analyse solutions are not usually met by standard tools. In order to provide for such a flexible, interactive and graphically appealing user interaction, the interfacing with a suitable specific tool, such as GiD, was thus required and is presented here.

2. GENERAL PRESENTATION

The OOFELIE-GiD interface is designed to constitute a link between the OOFELIE toolkit and the pre/post-processor GiD. To make the definition of the problem as easy as possible in this interface, a general window was introduced, which appears on the screen when the user first specifies he wants to use the developed interface for his problem (Fig. 1). This window allows defining some general data concerning the studied problem:

- the choice of the solver and the customisation of its specific parameters,
- the selection of the considered physical fields,
- the definition of the prologue and the epilogue,
- the definition of the used partitions,
- the determination of some general data (like the system of units),
- the modification of the user’s preferences.

Note that, once this window has been closed, it is still possible to modify the introduced data by using some similar submenus, completely written in tcl/tk, introduced inside the interface.

In the following, it will be explained how the most relevant functionalities have been implemented and how the user can take benefit of them to define his own problem. In the next section, some multi-physics results obtained using the developed interface will be illustrated.

2.1. Solver parameters

In the general data window, the user is asked to determine the type of analysis he wants to perform (static, modal, transient, harmonic, buckling), linear or non-linear. Then, it is possible for him, by selecting the “Parameters” button, to open a second window in which he can modify the advanced parameters of the solver (number of calculated modes or maximum frequency for a modal solver, time integration method and its specific parameters for transient problems, etc.).

Another feature is the possibility for the user to define his own solver in a text editor (solver that still can be modified after its definition) or to specify the name of a .e file (OOFELIE entry file) which contains the definition of the solver he wants to use for his analysis.

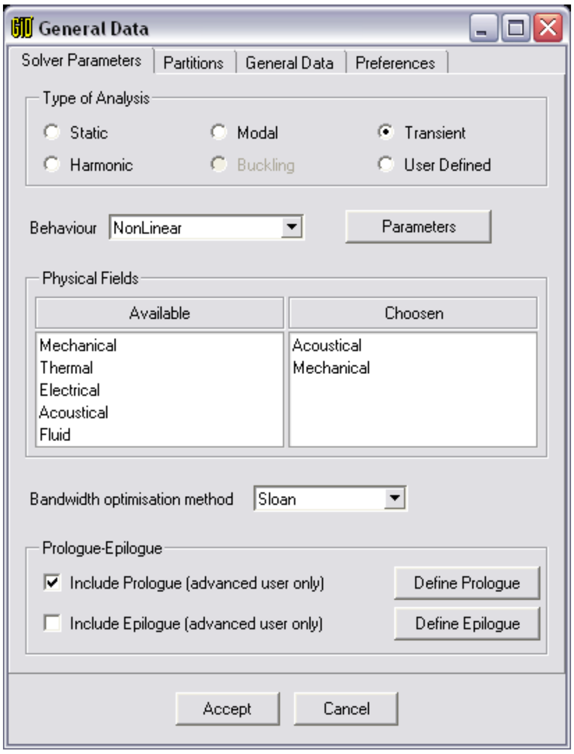

Fig. 1 – General data window

2.2. Selection of the physical fields

The user also has to select the physical fields that are to be considered in the studied problem (acoustical, electrical, fluid, mechanical, thermal). This choice conditions the kind of elements and materials available, as well as the boundary conditions or the loads. For example, if the chosen fields are "electrical" and "mechanical"

- the available elements will be the electrical, mechanical and piezoelectric elements,
- the available materials will be the dielectric, conductor, mechanical and piezoelectric materials,
- the boundary conditions and loads will be consistent with this kind of coupling problem.

2.3. Prologue – Epilogue

To make the interface more flexible, there exists the possibility for the user to introduce additional sets of commands that can be placed before (prologue) or after (epilogue) the solver call. It makes possible, for example, to use a preconditioner, define data that was not provided in the pre-processor, or to call some post-processing operations.

2.4. Automatic generation of the configuration files

An important remark about the interfacing of OOFELIE with GiD aims to draw the attention on the fact that the generation of the configuration files (.bas, .cnd, .mat, .tcl) is performed directly by OOFELIE. This way, it is possible to easily update the OOFELIE-GiD interface so that it remains consistent with the current version of the solver. The work of configuration is so done only once, and not for each release of OOFELIE.

3. MULTI-PHYSICS CASES

The figure on the next page (Fig. 2) illustrates some examples of multi-physics cases treated with the OOFELIE-GiD interface.

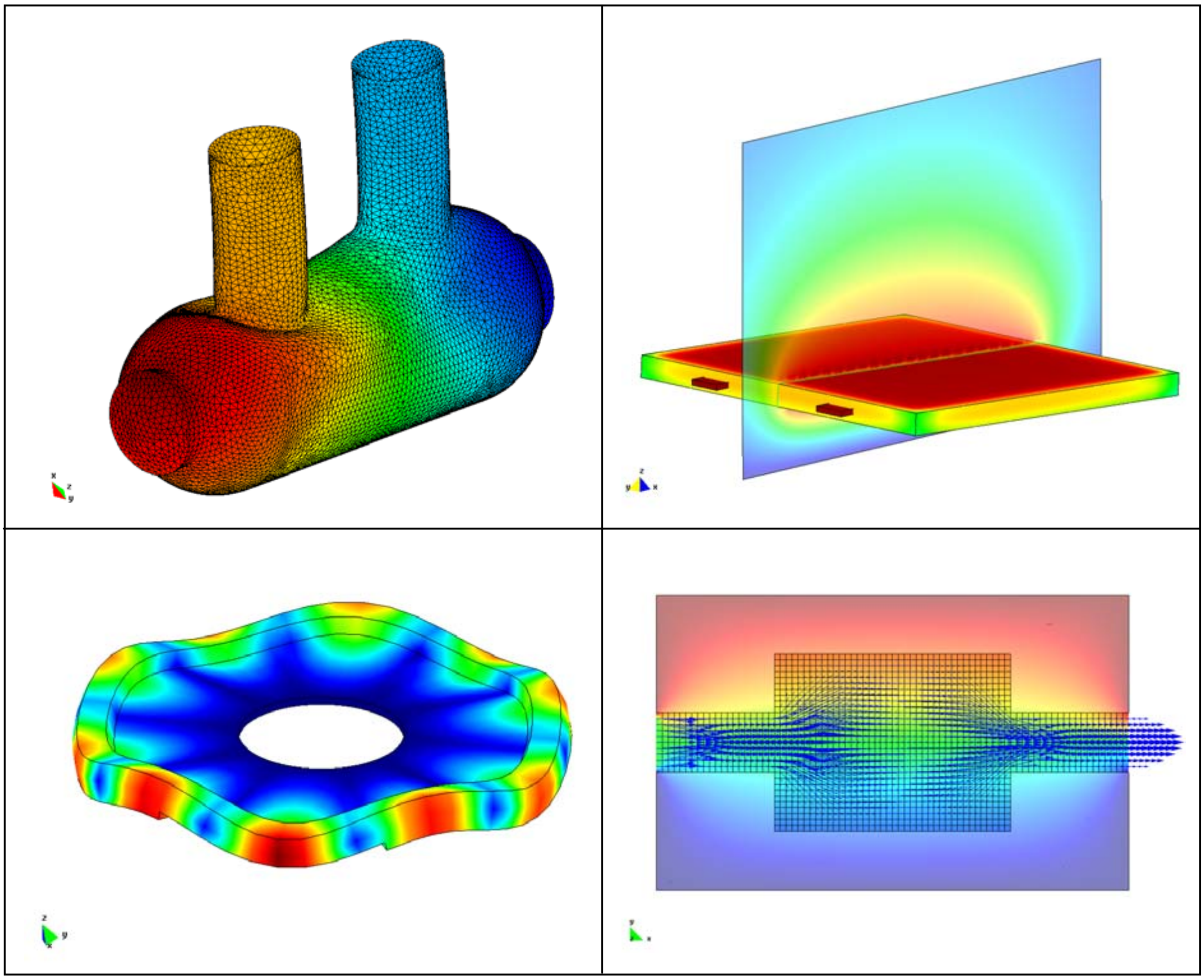

Fig. 2 – Multi-physics results

- The *upper left* figure shows the third vibroacoustic coupled mode of a tank filled with water. The pressure field in the tank and the structural displacements are represented. The eigenvalues extraction is performed by a powerful non-symmetric block Lanczos algorithm. Note that the strongly coupled harmonic analysis, with or without exterior acoustic scattering (using boundary elements), of such kind of systems is also possible.
- The *upper right* figure illustrates the deformation of a MEMS (Micro-Electro-Mechanical System), and the evolution of the electrical potential in its vicinity, calculated using the boundary element method. This problem consists in a charged structure (fixed electrical potential) placed over a plane which potential is equal to zero. It results in a non-uniform repartition of charge on the surface of the mechanical structure, and in electrical loads tending to deflect this one.
- The *lower left* figure is extracted from the transient analysis of the starting phase of an ultrasonic engine stator. It shows the stator displacements at a time step, when the harmonic regime of the travelling wave is established. In this problem, the structural movement is due to harmonic electrical potentials applied to piezoelectric strips glued on the stator.
- The *lower right* figure illustrates the temperature field (contour fill) and the fluid flow (vectors) in a non uniform pipe contained between two metallic structures. These structures are submitted to different thermal boundary conditions (300K on the top and 290K on the bottom), while the inlet temperature is equal to 295K. The calculation is performed assuming Stokes' hypotheses are fulfilled.