Development of an Application Oriented Interface for PHOENICS

Ricardo Serfaty[1], João Tornovsky[2], Bruno de Almeida Barbabela[2], Flávio Martins de Queiroz Guimarães[2] and Luiz Eduardo Ganem Rubião[2]

[1]Petrobras/CENPES, Cidade Universitária, Rio de Janeiro / RJ - Brasil

[2]Chemtech Engenharia, Av. Nilo Peçanha 50 G. 1509, Rio de Janeiro / RJ - Brasil
CEP 20044-900, Phone: +55-21-524-1916; Fax: +55-21-262-3121
e-mail: flavio.guimaraes@chemtech.com.br

Abstract

The present work describes the development of a dedicated interface operating over PHOENICS v.3.1 oriented for industrial furnaces applications. The system allows industrial furnaces designers who may wish not to invest in specific training in PHOENICS to take advantage of the benefits of computational fluid dynamics simulations. Data input consists of generic equipment and operational condition specification whereas the interface is responsible for all parameters management concerning the geometry, grid, properties, boundary conditions, initialization and numerical settings in PHOENICS. Running the simulation and viewing the results are performed from within the interface by accessing PHOENICS modules (VR Editor, EARTH and VR Viewer or PHOTON). Cases can be saved retaining the conceptual information of the application for future reloading. The system was developed in MS Visual Basic in a modular architecture. Three tools are available in the current version, all of them dedicated to the evaluation of the flow in different complex geometry ducts related to industrial furnaces design. The architecture of the system relies on intensive use of PIL commands in Q1 file, thus avoiding the risk and complexity of automating the construction of PHOENICS commands for Q1 externally. This work was developed by Chemtech for Petrobras – Petróleo Brasileiro S.A..

1. INTRODUCTION

PHOENICS has been improving on providing its users with a friendly interface which has been aiding them to take advantage of the benefits of computational fluid dynamics. On later versions, a virtual-reality environment has been included, enabling users to set up flow-simulation problems more quickly and easily. Another new feature which has been helping both novice and experienced users is PLANT, developed by CHAM-MEI. It permits users to augment the flow-simulating power of PHOENICS by supplying special formulae into GROUND. Although both of these features have made easier the task of implementing problems in general, this is still a time consuming and experience related activity. Adequate training is certainly required and some potential benefits of the results may therefore be lost.

For this purpose an special HMI (*Human-Machine Interface*) named Fornics had been developed by Chemtech. It consists of an application oriented interface over PHOENICS v.3.1 for the design, evaluation and optimization of complex geometry ducts in industrial furnaces. The current version of Fornics has three available tools, each of them dedicated for a specific geometry.

The definition of fluid dynamics simulations usually involves the geometry, grid, properties, boundary conditions, initialization and numerical settings, among other specifications. By using Fornics, data input consists only of specifications of equipment geometry and operational conditions. All other parameters concerning the simulation are automatically calculated and written in the Q1 file. The interface also searches for errors such as physically interfering positions, calls EARTH to run the simulation and then activates the desired graphical display package (VR Viewer or PHOTON).

The software was developed in a modular architecture which permits new tools to be easily added. The system requirements are 35 MB of free disk space and an operational copy of PHOENICS v.3.1 for Windows-95/98/NT.

2. DESCRIPTION OF THE SYSTEM

2.1. Architecture

The default modular structure of PHOENICS works (for the virtual-reality environment) as shown in Figure 2.1:

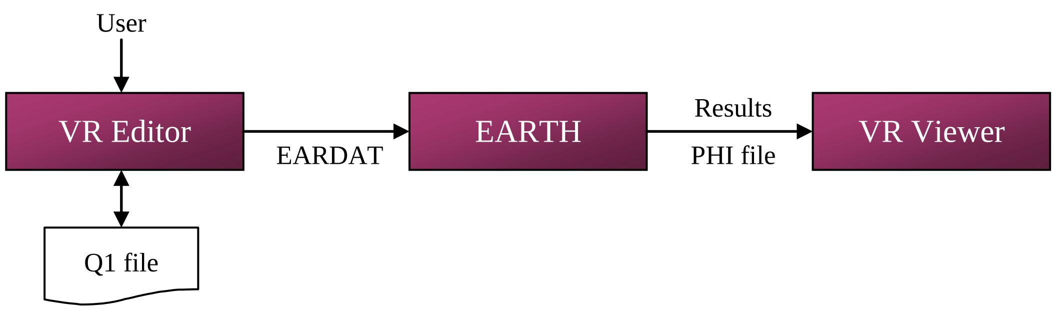

Figure 2.1 – PHOENICS' default structure

The data input is obtained from an eventually existing Q1 file and from the user's entries on the VR Editor menu and dialog boxes. The VR Editor then writes this data to an 'EARDAT' file which is called from EARTH to run the simulation. After converging to a solution, the 'PHI' file where the results of the simulation are stored can be visualized using VR Viewer or PHOTON.

Chemtech's solution for the integration of Fornics with PHOENICS is represented in figure 2.2 and will be described below.

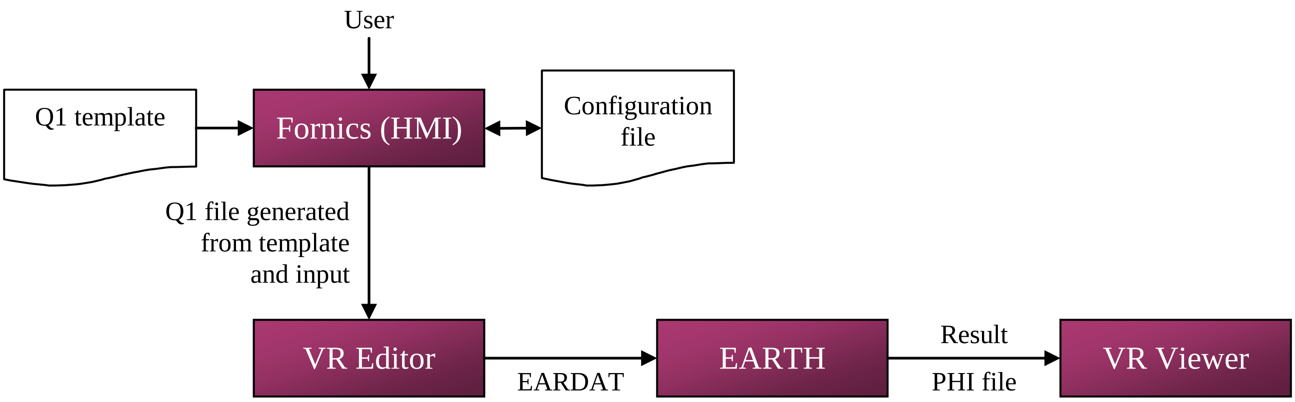

Figure 2.2 – Structure of the HMI system

The data input is obtained from an eventually existing 'configuration file' and from the user's entries on one of Fornics' input forms. Fornics then replaces the input values on a 'Q1 template' to generate a suitable Q1 file which can be processed and run by default PHOENICS modules.

2.2. Human-Machine Interface

When launching Fornics, the user is asked to select one of its tools. For each of them, Fornics opens an appropriate set of forms where geometry and operational conditions are set. Figure 2.3 shows the form for configuring the simulation of a circular feed ducts:

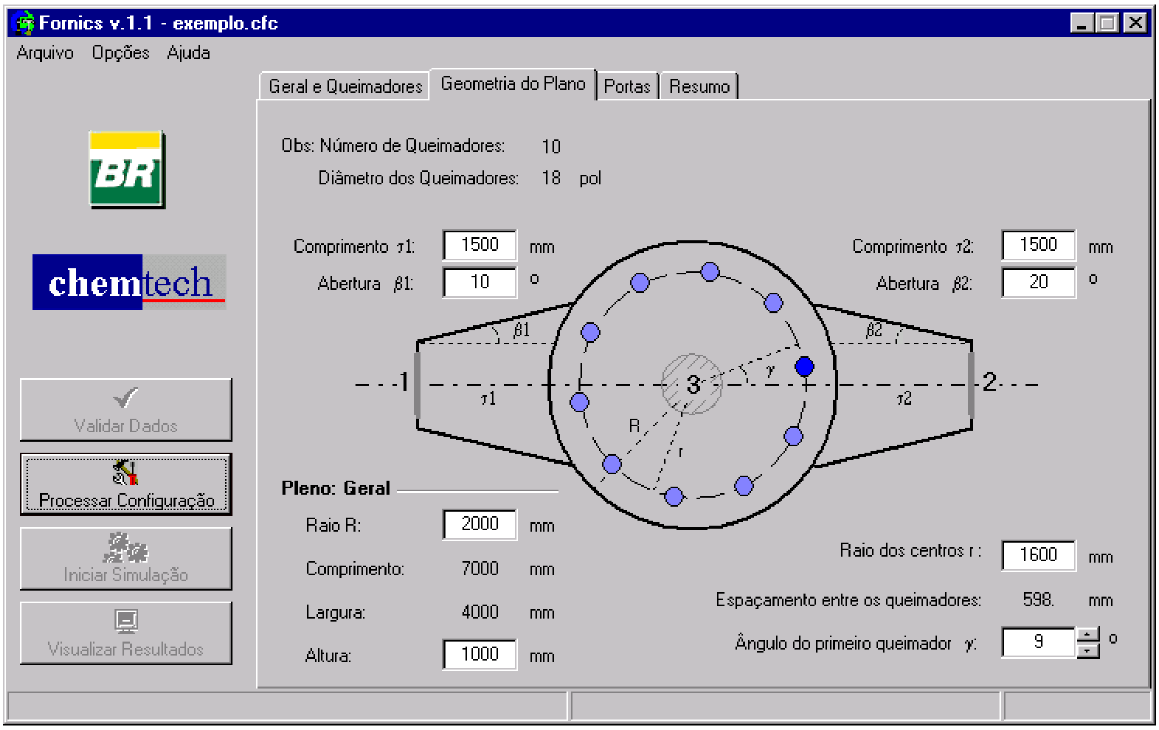

Figure 2.3 – Duct geometry specification form (Fornics)

At the form presented above, user specifies the dimension of the shell and the location of burners. Using these data, PHOENICS generates the desired geometry at the virtual-reality environment as shown in Figure 2.4.

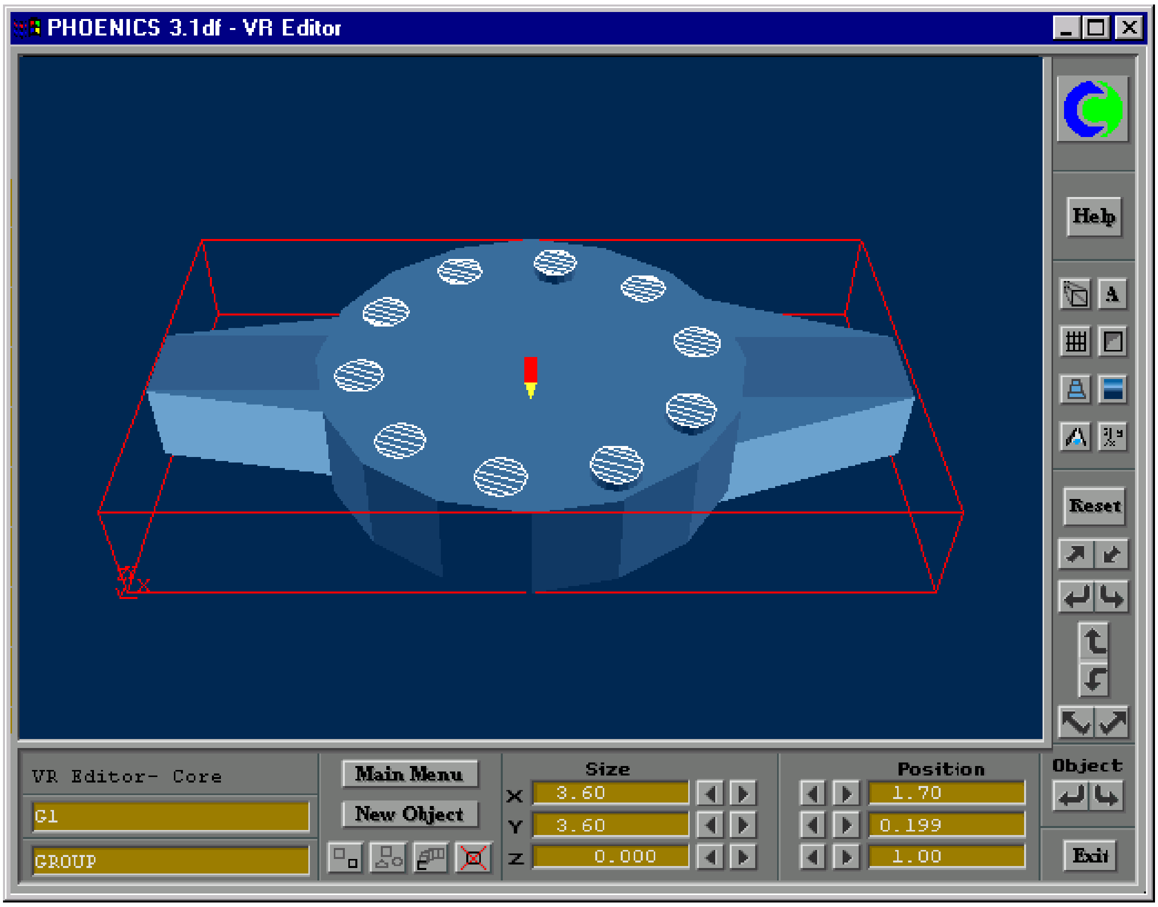

Figure 2.4 – Circular feed duct (VR Editor)

2.3. Configuration file

The ‘configuration file’ is a text file automatically generated by Fornics where all the variables of the problem are stored. This file works as a record of the flow simulation with all equipment dimensions and operational conditions and is written in such a way that it can be easily understood by any user.

The statements bellow show an example of the ‘configuration file’ structure (all comments have been translated from Portuguese to English):

```
BURNERS
======================================================
VazMass = 2000    *(kg/h) - mass flux, central burners
TemGas = 1300     *(oC) - combustion gases temperature
* NumQueim = 7    * number of burners per tunnel
```

In the above example, three parameters for burners’ set-up are being declared. The asterisk at the left of the third variable means that it has been automatically calculated from other data and not defined by the user at Fornics interface. Since some variables depend on others, modifying the ‘configuration file’ in a text editor instead of using Fornics interface is not recommended, even though it is possible.

2.4. Q1 template

The ‘Q1 template’ is the most important part of the program. It consists of an special Q1 file using advanced PIL programming. Each Fornics’ tool has it own private template from where appropriate settings are made. All statements of these templates are written as functions of a set of variables declared at the beginning of the Q1 file. What Fornics does is just to replace the value of these variables for the value of the associated parameters in the ‘configuration file’. Using this simple solution to write the ‘Q1 file’ (i.e. replacing only a few variables values in an already existing template) avoids the risk of writing wrong commands as if the Q1 file was entirely built externally.

For example, the following statements show how the default settings of the template look, with the name of the associated parameter written after the ‘`%`’ symbol:

```
    *** Burners
INTEGER(NQueim,TGas)
REAL(VazMs)
NQueim = %NumQueim
VazMs = %VazMass
TGas = %TemGas
```

Fornics reads the variable values from the ‘configuration file’ and writes them at the corresponding places of the Q1 file:

```
    *** Burners
INTEGER(NQueim,TGas)
REAL(VazMs)
NQueim = 7
VazMs = 0.556
TGas = 1300
```

All further definitions are made from arithmetic expressions involving those variables and other auxiliary ones, such as AuxR* (for real numbers), AuxI* (for integer numbers) and AuxC* (for character strings). There is an extensive use of DO loops and IF..THEN..ELSE statements in the ‘Q1 template’ files so as to make them suitable for several case specifications.

The next two statements show some examples of those calculations:

```
    *** Domain dimensions
AuxR1=4+4*:NQueim:+(2+:LCv:)/(0.23)+1
AuxR2=10+(:NTun:-2)*6
AuxR3=12+(:HRd:-(0.936))/(0.22)+1
AuxI1=:AuxR1:
AuxI2=:AuxR2:
AuxI3=:AuxR3:
RSET(M,:AuxI1:,:AuxI2:,:AuxI3:,5.000000E-02)

    *** Generation of VR objects statements for burners
do II=1,:NQueim:
+AuxR1=:AuxR1:+:AuxR2:
+if (II.LT.10) then
```

```
+ AuxC1=3QM0:II:
+ AuxI1=I3QM0:II:
+else
+ AuxC1=3QM:II:
+ AuxI1=I3QM:II:
+endif
> OBJ:AuxI1:,  NAME,       :AuxC1:
> OBJ:AuxI1:,  POSITION, :AuxR1:, :AuxR4:, :DomZ:
> OBJ:AuxI1:,  SIZE,     4.600000E-01, 2.300000E-01, 0.000000E+00
> OBJ:AuxI1:,  CLIPART,     cylinder
> OBJ:AuxI1:,  ROTATION,          1
> OBJ:AuxI1:,  TYPE,        USER_DEFINED
enddo
```

In the template are also selected the appropriate models and other numerical solution features for the current simulation such as the suitable grid dimensions for the user defined geometry. Each template has a private 'earexe.exe' file with special subroutines and from where special calls to GROUND can be eventually made. For example, the false time step relaxation was calculated in GROUND using the approximate in cell characteristic time.

2.5. Accessing PHOENICS modules

Fornics works like PHOENICS Commander from where all other PHOENICS modules can be called. It also manages at which stage of the simulation each module can be activated.

The procedure for creating and solving a new simulation through Fornics is as follows:

(a) First the user is supposed to entry the data for the selected tool or load an existing 'configuration file'.

(b) Then (and after any alteration on values) the interface checks the data for any non-acceptable value.

(c) If no errors or inconsistencies are found, it enables the user to call VR Editor where the problem geometry can be visualized and the Q1 file is processed to generate the EARDAT and the FACETDAT files.

(d) If those files are successfully created, Fornics will enable the execution of the 'earexe.exe' for the current tool.

(e) After execution is finished and the 'PHI' file is generated, the user is able to run PHOTON or VR Viewer and analyse the results.

2.6. Creating non-usual simulations

Experienced users can take advantage of Fornics features to create simulations that are not foreseen by the program. The interface can be used to generate a simulation as similar as possible to the desired model. From this point onwards the simulation can be modified using default PHOENICS tools. The advantage of this procedure is that Fornics generates the Q1 file faster and assuring it will be error-free. Anyone familiar to PIL programming can also create his own templates based on existing ones.

3. CONCLUSIONS

The strategy of using Q1 templates for the different tools showed to be a good practice. It minimizes the occurrence of errors on the creation of the Q1 files. Using this approach also facilitates the inclusion of new tools since the interface just does simple replacements and can be easily reprogrammed.

This tool turns typical sensibility analysis into an easy task, allowing series of tests to be performed with very few clicks of the mouse. This enables even novice users or equipment designers who may wish not to invest in training in PHOENICS to perform complex simulations and thus benefit from computational fluid dynamics simulations.

New trends

Some improvements have been made on Fornics since its first version. There is a continuous study on how the ‘Q1 template’ files could be optimized to enhance the simulation’s solving procedures and results. The interface is being changed to increase user capabilities such as the possibility of modify the grid if desired. Next advances also include the upgrade of Fornics to PHOENICS v.3.3.