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Graphics Post-Processing for Thermal Analysis via CS-ASA/FA

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Abstract. Structural analysis aims to determine structural behavior, and whether it meets all the design's goals, such as adequate strength and stiffness for combinations of loading conditions within the serviceability limit and ultimate limit states. Stresses, deformations, and displacements are examples of response that act according to the boundary conditions imposed on the structure. The process of this analysis has three basic steps: create the model, the calculation, and analysis of the results. To facilitate this process, a a numerical method software was used for preprocessing, processing, and post-processing, providing a more realistic and efficient analysis. In this context, the aim of this article is to present the development of a post-processing for the module CS-ASA/FA. This module performs a thermal analysis in a transient regime of common cross-sections in civil construction, which are fundamental for the analysis in a fire situation. A graphics post-processing gives the analyst a major reduction in the required effort to visualize the results, facilitating the interpretation of the data generated by the analysis program. It developed the post-processing graphics using an interactive environment denominated GiD, and its implementation in CS-ASA/FA creates a new result file to attend the GiD's demands for input files and satisfactory graphic presentation.

Keywords: GiD-post-processing, CS-ASA/FA, thermal analysis, fire situation.

1. Introduction

The purpose of structural analysis is to determine the response of the structure to elements, such as stresses, strains, resulting stresses and displacements, under certain boundary and loading conditions. With the results of the analysis, whether at room temperature or in a fire situation, structural engineers must verify that a proposed design has adequate resistance and stiffness requirements for a combination of loading conditions and revise it until complying with all requirements. It divided the structural analysis process into three main stages, which are: the creation of the structural model; the calculus of that model; and the visualization of the results. First, the geometry and properties, the material used, the active loading, boundary conditions, and others are defined. Then, a numerical solution is produced, and in the last step, the analyst focuses on the verification and visualization of the results of the previous step [1].

The structural analysis process can be extensive and complex. Fortunately, with the creation of the computer creation, and its great capacity for data storage and manipulation, allied with new technologies, especially graphic computation, it is possible to create a software with environments that facilitate the application of structural analysis programs that use numerical methods, like finite element method (FEM) [2]. Thus, the designer or analyst can perform an analysis in a more efficient way, using preprocessing, processing, and post-processing programs.

There are two categories of computer programs for structural analysis. The first concerns non-commercial ("homemade") educational programs, which aim to introduce the user to numerical techniques for analyzing structures and most of these programs have limited graphics capabilities. The second involves commercial programs with educational versions, which despite having certain limitations and requiring experience and domination of concepts to be used, present advanced interactive graphic tools [3].

There are many programs for structural analysis developed by Brazilian universities, such as an integrated research project coordinated by Professor Marcelo Gattass of the Department of Informatics of PUC-Rio and director of PUC-Rio's Tecgraf Institute (Technical-Scientific Software Development Institute), with funds received from CNPq (National Council of Technological and Scientific Development). He developed the program Ftool (Two-dimensional Frame Analysis Tool [4]). The responsibility for Ftool is now in the hands of its author Professor Luiz Fernando Martha of the Department of Civil Engineering of PUC-Rio. Ftool presents an efficient interactive graphical system that, in the basic edition, enables the user to define models in an efficient and simple manner. It construes the structural model and gives many results, such as internal force diagrams and the structure's deformed configuration, as well as influence lines for any point on the structure and load-train result envelopes. This program is a single platform resource for creative manipulation of the model (preprocessor), the analysis (processor) and the visualization of the results (graphics post-processing). Cross-sections defined either parametrically according to multiple templates (rectangular, T-, L- and I-shapes, etc.), by selection from a diverse array of standard shapes (AISC, Gerdau, etc.), or generically by defining the sectional geometric properties, such as area and moment of inertia. Either the Euler-Bernoulli or Timoshenko theories may calculate the structural members. Supports may be rigid or elastic and inclined or suffer imposed displacements. This enables multiple types of structures, from the simplest to the more complex, to be modeled in Ftool in a matter of minutes; the INSANE (Interactive Structural Analysis Environment [5]) is a structural analysis program for beams, trusses, two-dimensional frames and grids. It was developed in the Department of Civil engineering of UFMG and its main proposition is to be an academic software, open coded, subject to alterations to adequate it to the educational demand; the AcadFrame [6] is a tool developed in the school of engineering of São Carlos of USP, which uses FEM for the analysis of two-dimensional frames and trusses, including geometric nonlinearity, temperature effect and a combination of external actions, together with CS-ASA (Computational System for Advanced Structural Analysis [7]) and its modules CS-ASA/FA (Fire Analysis [8]) and CS-ASA/FSA (Fire Structural Analysis [9]). CS-ASA is a homemade program, without pre- and post-processing which performs, together with the two modules, advanced numerical analysis of structural systems at room temperature and in fire situations. A research group from the Federal University of Ouro Preto developed it from the initial work of Silveira [10].

Considering the importance of a post-processing in a structural analysis program, this article presents the development of post-processing graphics for the CS-ASA program and its modules CS-ASA/FA and CS-ASA/FSA. More precisely, it developed the post-processing graphics for the CS-ASA/FA module that performs the transient thermal analysis of cross-sections common in civil construction. Unlike the works mentioned in the previous paragraph, it was used here for the elaboration of the post-processing tool, a graphic-interactive environment called GiD and was elaborated by CIMNE [12]. A graphics post-processing tool gives to the analyst a major reduction in the required effort and time to visualize the results, facilitating the interpretation of the data generated by the analysis program. To integrate the CS-ASA/FA module with GiD, implementations were made in this module for the creation of a new results file compatible with the reading and graphical presentation of GiD. The next section describes how the CS-ASA/FA–GiD interaction was made.

2. CS-ASA/FA–GiD interaction

The thermal analysis is an important step in the analysis of a structure on fire. The determination of the temperature across the cross-section of the elements affected by fire characterizes it. For each instant of postulated fire, there have been the thermal responses through the numerical calculus procedure for heat transference at different points in the cross-section. It is important to highlight that time is a control variable fundamental to the analysis. This way the computational module CS-ASA/FA [9], which uses FEM, aims to determine the temperature field in the structural elements in a fire situation thru a nonlinear equation solution procedure of a simple incremental type. Such a procedure allows the consideration of the variation of the thermal properties of the materials in function of the increase of the temperature, following recommended standards for advanced analysis models.

Thus, the most important result of the thermal analysis, provided by the CS-ASA/FA, is the temperature at the nodal point of the cross-section varying with the defined fire time. In other words, it is the temperature in any region of the cross-section as the fire progresses. Therefore, the graphical visualization of this result allows the most efficient interpretation by the user seeking to improve the understanding and interpretation of the thermal analysis results in the CS-ASA/FA module. The GiD presents the possibility to read the text files with a simple formatting which supplies the user with a graphical visualization of the results through an intuitive uncomplicated interface. The simplicity of use was what motivated the coupling of the computational module to the graphic-interactive environment GiD [12].

GiD used as a post processor of the CS-ASA/FA module was possible realizing implementations in the module, creating a new result file in the GiD reading format. As the CS-ASA/FA already has the preprocessing also performed by the GiD, it used the information about the finite element mesh in this step. In the Figure 1, it illustrated how the CS-ASA/FA–GiD interaction considers all stages of analysis processing. More details on this computational module are in Pires *et al.* [9] and Barros *et al.* [13].

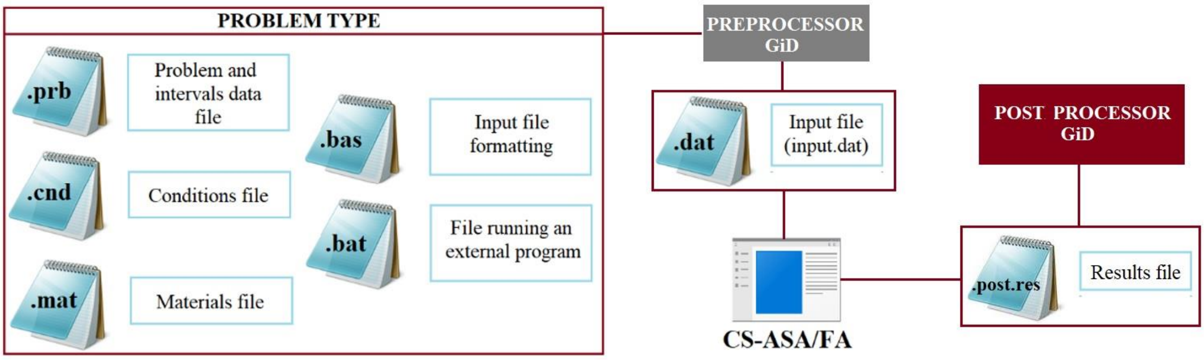

Figure 1 - CS-ASA/FA–GiD interaction flowchart

After the processing of the thermal analysis by the CS-ASA/FA computational module, a file .post.res is created. In this file, as shown in Figure 2, are the temperature value for each node in the cross-section, which are in text format according to post processor's compatibility. From the file's reading by GiD, it is possible to visualize the results with graphical means that will be detailed in the next section through the thermal analysis of a steel and composed steel-concrete cross-section.

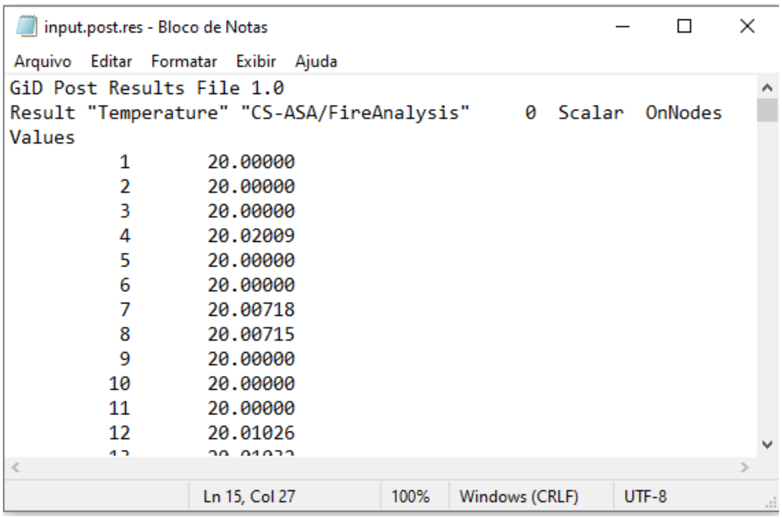

Figure 2 - Text file .post.res's format

3. Post processor application in thermal analysis via CS-AS/FA

In this section, the results of the thermal analysis of two cross-sections are shown to exemplify and validate the implementations carried out to make the post processor viable. Figures 3 and 4 illustrate how the results are visualized and presented considering a composed steel-concrete section and a steel section, respectively. It is possible to analyze directly the behavior of the temperature field in this section, at each instant of time, from the color contour (blue being lower temperatures up to the red color that represents higher temperatures), helping in the interpretation of the results. Furthermore, it is possible to visualize the temperature elevation as a function of time at specific nodes/points through the Temperature versus time curve provided by the post processor.

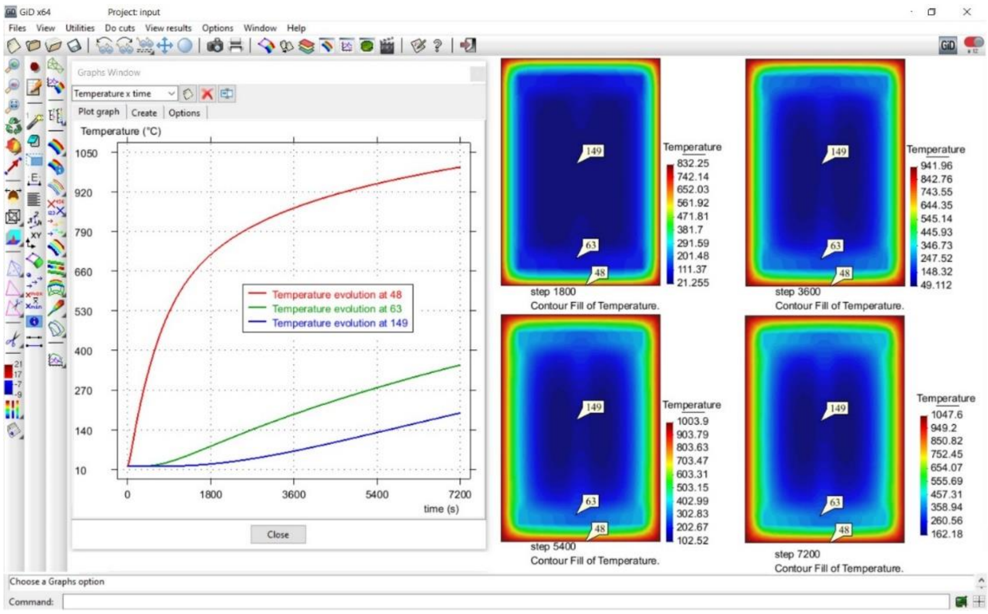

Figure 3 - Results visualization through the CS-ASA/FA's post processor – composed cross-section

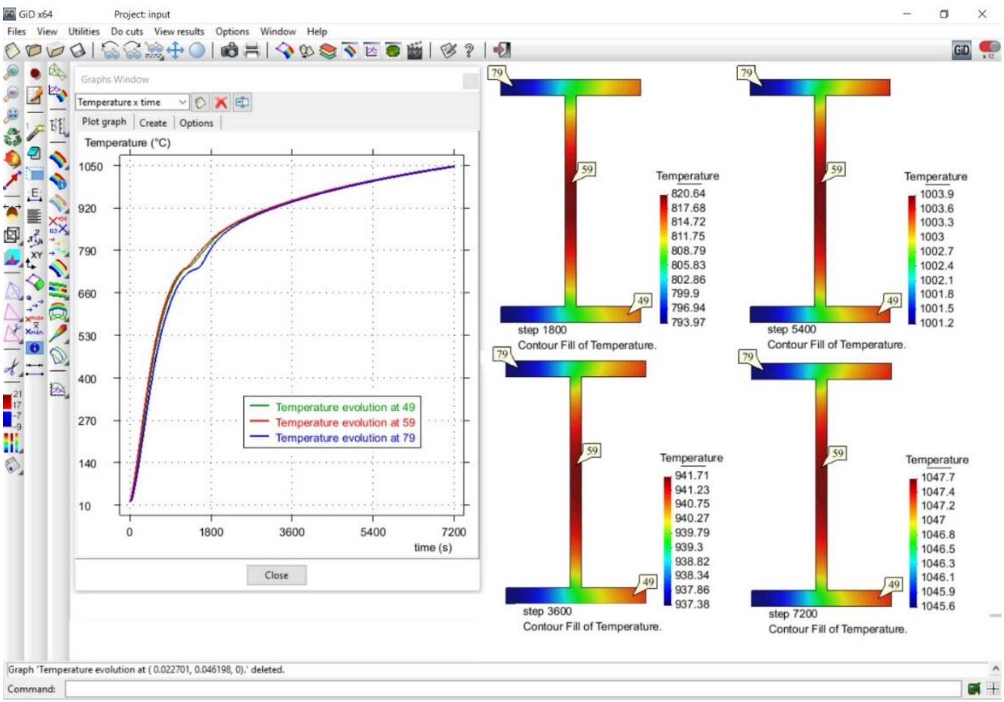

Figure 4 – Results visualization through CS-ASA/FA's post processor – steel cross-section

4. Final remarks

The purpose of the present research was to develop a graphical post processor to the CS-ASA/FA computational module, providing visualization of the results of the thermal analysis of cross-sections. According to the examples of use presented, it was possible to perceive the success in the implementations carried out in the computational module, which allowed the adequate interaction of the module with the graphical-interactive interface of GiD to visualize the results of the thermal analysis. Thus, it can be concluded that the use of GiD as a postprocessor brought a great reduction in the effort required to visualize the results, facilitating the interpretation of the data generated by the CS-ASA/FA. It is also worth noting that different ways of presenting the results are possible with the post processor, which contributes to the user's analysis. As future steps, the development of pre and post processors also stands out for the CS-ASA/FSA computational module that performs the thermostructural analysis, as well as the pre and post processors for the structural analysis at room temperature performed by CS-ASA.

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