Applied Elasticity Computer Models in Automatic Design

Emil OANTA
Marine Engineering Department, Constanta Maritime University
Constanta, 900663, Romania

Abstract

Applied elasticity computer models and CAD are included in the computer aided engineering field which is a long run concern of the author, [1], [2], [3].
Engineering uses analytic, numeric and experimental models, as well as hybrid models, whose submodels belong to the previously mentioned classes, these components being integrated in an upper level of understanding model.
Computer based approaches are the best instruments employed to integrate the knowledge from different disciplines and from different fields of science.
Analytic models include the applied elasticity knowledge together with new algorithms and computer techniques.
Applied elasticity computer models are important because they can avoid the problems of the numerical models and the high costs of the experimental studies.
Actual CAD applications are flexible and may include either original software modules which are used to solve different problems in engineering, or the data resulted from computer aided engineering applications. On the other hand, the applied elasticity computer models use the CAD applications to automatically visualize the output data and to create libraries of drawings.
The aspects presented in the paper are based on the latest 25 years of experience of the author in mechanical engineering[1] and in information technology[2].

Keywords: applied elasticity, automatic design, interface

1. INTRODUCTION

One of the issues specific to this era when the information doubles every four years is that about the effective use of the information technology progress in the so-called classic disciplines.
The computer is used to solve problems in all the fields of the applied elasticity domain, such as experimental mechanics (data acquisition and analysis), numerical methods (FEM, FDM) and the particular analytic models.
It is important to identify the connections between the classic approaches and the actual facilities offered by the CAD applications, and their practical use.

2. THEORETICAL BACKGROUND REGARDING THE APPLIED ELASTICITY COMPUTER MODELS

Applied elasticity and the other classic disciplines are employed today either in educational problems to make the students acquire a common sense in technical matters, [15], or in research, where the theoretical background is useful to create advanced models.

Limits of the classic approaches

The classic approaches are limited because of the use of the old hypotheses which were useful in an age where the calculation mean was imprecise and slow. The solution was to create mathematical models which lead to acceptable rough approximations for that given problem. This was a progress for that era, with direct effects in industry, civil engineering and in the corresponding manufacturing technology.
When new technologies such as electronics, computer science, cybernetics occurred and developed, these solutions became obsolete.
In these new conditions, one could remark that the methods can be generalized not only from the mathematical point of view which solves a particular problem, but from a more general perspective which takes advantage of most of the technological progresses.

Disciplines employed in the creation of the computer based models in applied elasticity

The creation of computer based applied elasticity models require a new way of thinking, in comparison with the classic methods of solving the problems.
Being a profound analytic approach, a mathematical basic layer consisting of theory of elasticity, analytical geometry, numerical methods, computer programming is necessary.
The theory of elasticity uses a general mathematical approach to solve the problems, while the strength of materials discipline solves successively a set of simple problems and then puts them together in a more general solution. To conclude, the theory of elasticity uses deductive methods to create a solution, from general to particular, which is far more important in comparison with the inductive methods from other disciplines.

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[1] PhD in Mechanical Engineering, ‘Cum Laude’, 2001, [11]
[2] PhD in Cybernetics and Economic Statistics, 2007, [25]

The analytical geometry offers the mathematical instruments employed to parameterize the domains where the solutions are searched. Many approaches use geometrical information in order to make decisions and calculi and the analytical geometry offers an instrument to design algorithmic solutions.
Numerical methods are a natural component of the computer based models.
The general numerical methods are used in all the types of models: analytic, experimental (experimental data automatic processing) and dedicated numerical methods, such as FEM and FDM.
Computer programming is the most important component, because it connects all the other topics and it is synchronous with the information technology progress.

Advantages of the applied elasticity models

The applied elasticity computer models are very useful and they will be always employed because of their advantages, such as:

- they are simple;
- the questions regarding the numerical stability of the solution are not applicable;
- they can be easily generalized using algorithmic approaches;
- if a proper architecture is designed, the libraries employed in applied elasticity models can be used in upper level models;
- they are inexpensive.

Taking into account these features, several computer based models have been developed.

3. APPLIED ELASTICITY COMPUTER MODELS

There are several approaches when an applied elasticity computer model must be designed.

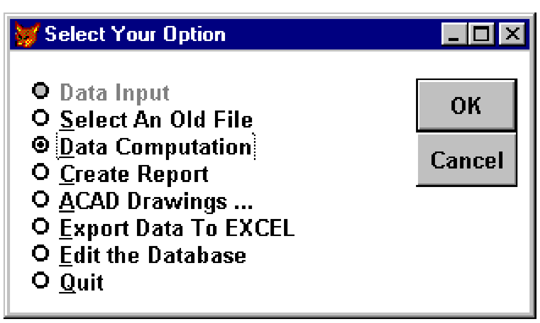

Figure 1 – Menu of the application employed to compute the geometrical characteristics of the cross-sections of a beam

A first standpoint is about the degree of generality of the problem which must be solved. From this point of view there can be general identified problems, like the calculus of the stresses, or particular problems dedicated to a given type of structure or for a given theoretical problem.

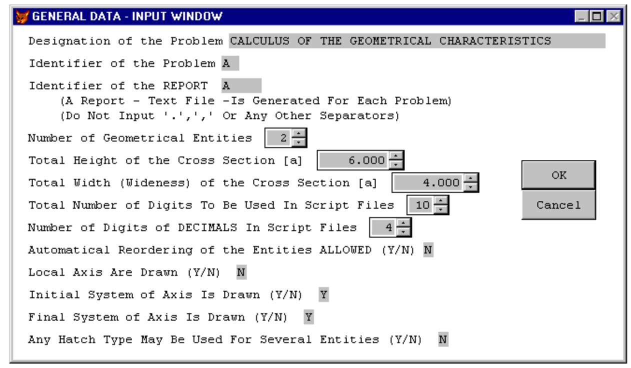

Figure 2 - General Data Input Window

Figure 1 and 2 present the first windows of the GUI of an original software application designed to compute the geometrical characteristics of the cross sections of the beams, [4].

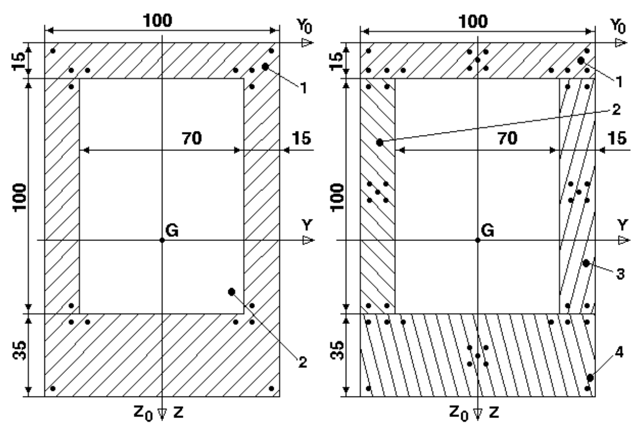

Figure 3 – Points where the stresses are computed

The application uses some libraries with information regarding the shapes and the materials to be used. The user is allowed to use a material as a prototype and to modify the properties in order to fit his demands. A Boolean algebra applied on geometrical shapes is used as a mathematical background. The application exports the data and the results can be used for the computation of the stresses.
Another application was developed in order to compute the normal stresses and the tangential stresses produced by the shear forces, [5], [10]. This application uses as input data the results of the previous application and the loads which result from a free-body diagram application.
In order to use only relevant information, an algorithm was designed presenting only the stresses in the areas where important aspects occur, such as: extreme values, sudden variations. This ‘filtration’ is important because the results can be easily identified and checked.

Other computer models are dedicated to the marine engineering field, [13], [16], [26]. The educational model of a hull is presented in the figure below, [14]. The model consists of only 4 intervals and is meant to present to the students the logic behind the method and the relevant aspects, such as

- the creation of the free-body diagrams;
- the relation between the diagrams;
- the shape of the deflected structure;
- the variation of the normal and tangential stresses along the hull, related to the free body diagrams;
- the method employed to compute the deflections;
- the most relevant boundary conditions for the calculus of the deflections.

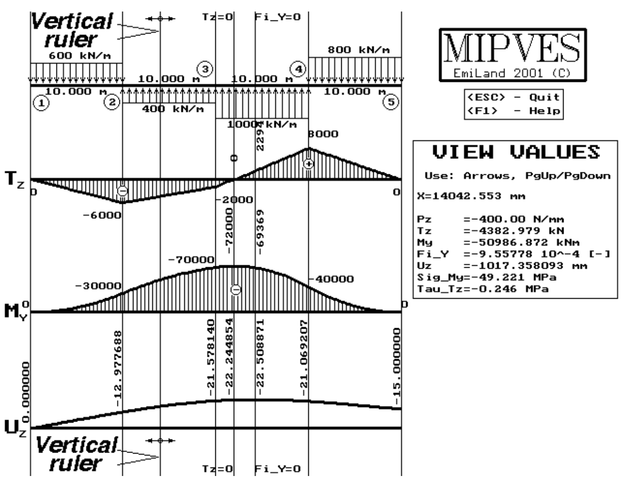

Figure 4 – Applied Elasticity Model of a Hull

The architecture of the original software application allows its use for real structures, such as the hull of a heavy lift vessel.

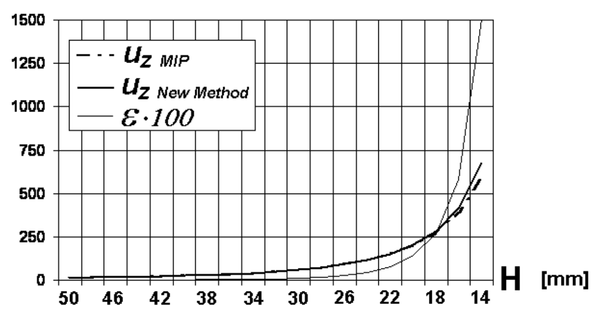

Figure 5 – Limits of the small deflections hypothesis

Another standpoint in the creation of the computer based models is to evaluate the limitations of the classic hypotheses, by the use of the modern algorithmic and programming techniques.

Figure 5 presents the differences between the results of the classic approach which employs the small deflections hypothesis and an algorithmic approach which uses the accuracy of the computer in order to solve the numerical issues of the model, [17]. The results in the diagram are the deflections of the free end of a cantilever computed for different heights of the rectangle cross section. As it can be noticed, the more slender the cantilever, the larger differences between the results.

It can be concluded that the applied elasticity computer based model is accurate for the classic problems and it is the unique instrument available for the special situations where the classic hypotheses cannot be applied, [9], [12].

4. INTERFACES WITH CAD APPLICATIONS

All the domains of science use matrix approaches in order to solve different problems: topology, numerical methods, business graphics, diagrams, etc.

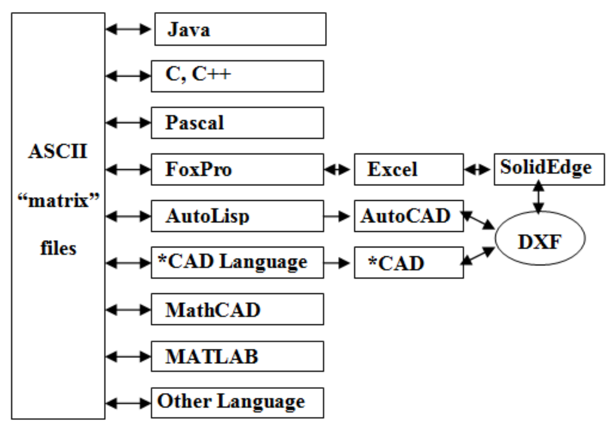

Figure 6 – Interface based on the matrix data type

Taking into account these aspects, an interface between the programming languages was developed, based on a so-called matrix data type. Applications offering facilities specific to the programming language employed for that branch of the application: scientific programming, databases, GUI, CAD, remote access, etc, could this way be created. As it can be noticed, several CAD applications were taken into account in the development of this software solution.

Several details regarding the methods to create the interface between the CAD applications and the matrix data type are presented in [6], [7], [8], [22].

5. CAD FACILITIES EMPLOYED IN APPLIED ELASTICITY MODELS

Beside the computation of the technical data, the application presented in the figures 1 and 2 is able to convert the information to external text files which contain AutoCAD commands. These script files (extension is SCR) are employed in AutoCAD to automatically draw a given cross section. The results are presented in figures 3 and 7.

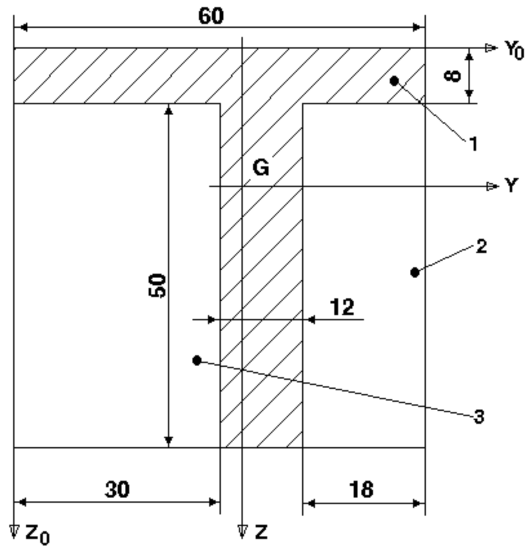

Figure 7 – Cross section of a beam

Figure 8 presents a plate with two simply supported opposite ends. The other two sides have a beam along them, being an ‘elastic built-in’ boundary condition.

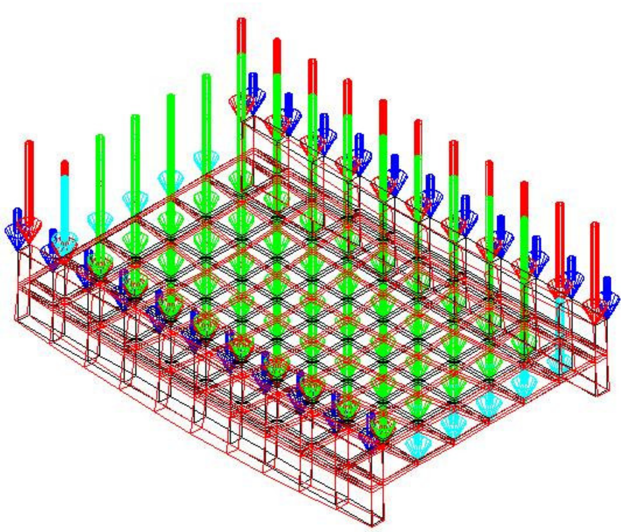

Figure 8 – Plate with special boundary conditions

The problem can be solved either analytic, or numeric, using a FEM model. The results of both studies are very close one to the other.
The visualization was done by the use of an original application which was designed to process the output file of the FEM program. The results were stored in a database and used to generate the appropriate SCR files. Each type of information (groups of elements, loads, etc) is stored in a dedicated layer of the drawing. After the automatic data processing, the user is allowed to select the visualization point (VPOINT), the layers which are visible and to ask the system to present only the visible edges (HIDE).

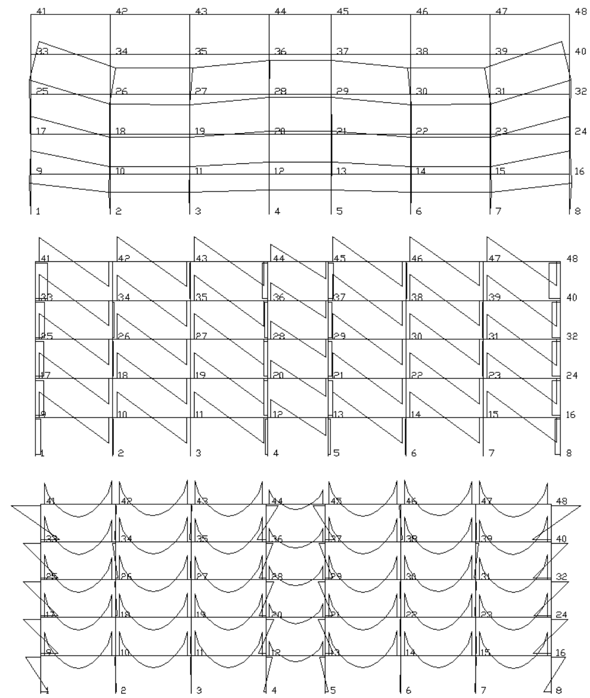

Figure 9 – CAD drawings in applied elasticity problems

Figure 9 presents other results of the previously mentioned technique consisting of the deflected structure and of the free-body diagrams of a civil engineering structure.
One of the problems of this computing method is to use a proper value for the scale of the deflections in order to have relevant graphical results. A proper value can be used if some loops are performed or if an educated guess based on experience is done.

6. CONCLUSION

The paper is the result of the experience acquired from the creation of several turn-key applications consisting of more than 120 000 computer code lines, in different fields of science and in different programming languages that belong to several generations of information technology.
The use of the applied elasticity computer models is an effective instrument in engineering, where creative solutions must be designed in order to solve complex problems, [18]. The flexibility and the reusability of the libraries of programs created for different models recommend this approach as a strategic direction to be used in interdisciplinary and in cross-domain modeling.
Once the libraries are created, this approach accelerates the computer aided design activities.
We should point that any computer based solution is influenced by the technological level of that given age. This is why a simple development of the software is not

an answer for a sustainable progress in a given area. Concepts relying on a strong mathematical background and on the capacity to understand the general problems and the strategic trends are more important and they must be used to integrate the knowledge acquired in engineering and in the adjacent domains, [19], [20], [21], [23], [24], [27].

7. ACKNOWLEDGEMENT

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