IMPACT OF THE USE OF AN EDUCATIONAL SOFTWARE FOR STRUCTURAL DYNAMIC ANALYSIS ON THE TEACHING IN THE UNDERGRADUATE ENGINEERING COURSES OF THE FEN/UERJ

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Abstract. *The significant development of constructive processes allied to the conception of daring architectural designs leaded to creation of very slender structures. These aspects induced civil and mechanical engineers to take extra care with the possible occurrence of vibration problems arising from various structures when subjected to dynamical load actions. These dynamical forces are frequently found in wind and wave loads acting on building structures and human rhythmic activities that can occur in sports pavilions and dance halls. On the other hand, it is clear that undergraduate engineering students present a great difficulty in understanding the physical phenomena associated with the dynamical behaviour of structures. This was the main motivation for the development of an educational software denominated "DINÂMICO". Based on this didactic experience it can be concluded that the developed educational program helps the undergraduate engineering students to visualize, understand and learn about the evaluation process associated with the dynamical behaviour of structures with the aid of simple practical examples.*

Keywords*: structural dynamics, educational software, engineering courses, engineering education.*

1. Introduction

Nowadays, based on the significant development of the new technologies associated with engineering (computing, constructive, managerial, etc), the engineers need to adapt to these technologies by reformulating concepts and attitudes. The Universities, as Educational/Research Institutions, have a fundamental role in this process. Considering all this aspects earlier mentioned, it makes necessary a constant updating of those Institutions concerning the actual academic needs of the undergraduate engineering courses in the most several areas.

On the other hand, the significant development of constructive processes allied to the conception of daring architectural designs leaded to creation of very slender structures. These aspects induced civil and mechanical engineers, responsible for structural design, to take extra care with the possible occurrence of vibration problems arising from various structures when subjected to dynamical load actions.

The dynamical forces are frequently found in: engine foundations, wind and wave loads acting on building structures. Some other examples are associated with earthquakes, explosions, impact of moving objects and human rhythmic activities that can occur in sports pavilions, gymnasiums and dance halls. In all those cases the equilibrium of the structural systems is only made considering the inertia forces. All the situations mentioned above confirmed the importance of a proper dynamical analysis in current day-to-day engineering practice.

This paper described the didactic experience obtained with the development of an engineering educational software denominated *"DINÂMICO"* that is able to consider the dynamical load actions over civil and/or mechanical structural systems. A simple analysis based on student's performance along the engineering courses indicated that the educational program was very useful to help undergraduate engineering students to clearly visualize and understand the structure dynamical response.

2. Dynamical load assessment in engineering designs

The increasing competitive trends of the world market have been making structural engineers to produce design focused to the minimum material and work consumption not disregarding the required construction speed. On the other hand, an increase of problems related to unwanted structural vibrations in structures subjected to dynamical loads is being clearly observed.

This growth is associated to the fact that the great majority of structural engineers do not know how to evaluate if these problems can compromise the structural performance only using the simple elastic static analysis procedures currently adopted in day-to-day practice. If this is the only used procedure, when the structure is subjected to dynamical loads excessive vibrations, compromising human comfort conditions and even jeopardising the structural system integrity could occur.

3. The educational software

The development of a graphical educational software to motivate undergraduate engineering students to understand the structure dynamical response led to adoption of the DELPHI programming language (Santos and Reis, 1998). The "*DINÂMICO*" (Structural Dynamics Applied to the Civil Engineering) program architecture was based on the use of several independent windows screens starting from the windows platform. The students use these windows screens to input data by filling block spaces or selecting buttons.

According to the sequential use of the program the undergraduate engineering students are able to perform free and forced vibration analysis of numerous simple didactic structural systems (Clough and Penzien, 1993; Craig Jr., 1981; Prodonoff, 1990 and Roehl, 1983). The educational software was conceived to be a useful complementary tool for the regular undergraduate courses of the Faculty of Engineering of the State University of Rio de Janeiro, FEN/UERJ (Structural Dynamics, Mechanical Vibrations, and Special Topics on Structural Problems).

Initially, this investigation will present examples associated with one degree of freedom (S1GL). The program is able to perform a free vibration analysis by evaluating the structure natural frequency (or frequencies) or a forced vibration analysis presenting the structural system dynamical response. This is performed considering rectangular and harmonic dynamic loads (Clough and Penzien, 1993; Craig Jr., 1981; Prodonoff, 1990 and Roehl, 1983).

The educational software enables the users to define new or adopt default values for the damping parameters. Another interesting feature is that the program allows the user to access and change the system physical properties like: mass, damping and stiffness. The first window of the "*DINÂMICO*" program introduces a menu with the *Begin* options. The *Begin* option enable the user to start a new analysis, recover data stored from a previous analysis, save the current analysis, to see the responsibility term and to exit the program, as presented in Fig. 1.

The analysis should be preceded by the required structural system dynamical characteristics, defined by the users from the "stiffness" and "damping" options. The user has at this point an option of accessing a "theoretical aspects" command that will briefly explain the physical concepts associated with structural stiffness and damping, as shown in Figs 2 and 3. The "theoretical aspects" option allows the student to access a series of information regarding the dynamical analysis as well as a detailed description of the software main features, see Figs 2 and 3.

Figure 1. Opening window of the program.

Figure 2. Definition of the stiffness and damping coefficients by the student.

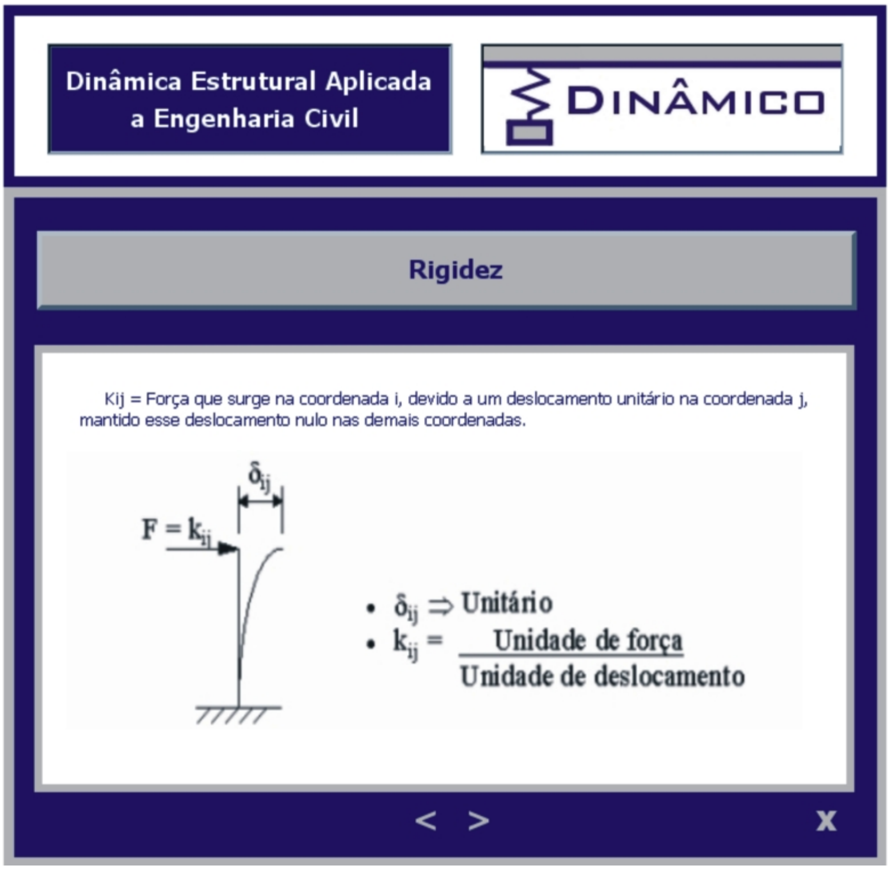

Figure 3. Theoretical definition of the stiffness coefficient.

With these results in hand the student should, based on the “vibration systems” option, see Fig. 2, choose the adopted structural model, for instance a one degree of freedom model S1GL, in which the dynamical analysis will be performed, as shown in Fig. 4. By selecting a new model (simple pendulum, rigid beam, mass-spring-damping and torsion pendulum) (Clough and Penzien, 1993; Craig Jr., 1981; Prodonoff, 1990 and Roehl, 1983), the user begins to use a distinct interactive data input window associated to each individual structural system.

Every data input window generated by the educational program based on the “vibration systems” option allows the program to obtain from the users the required information according to the used dynamical model. These numerical values should be positioned/selected in their respective boxes or buttons, as depicted in Figs. 5 to 8.

Figure 4. Dialog window for the selection of a structural model.

The *Help* option allows the undergraduate engineering student to access a series of information regarding the dynamical analysis and each structural model according to the user specific needs, see Figs 5 to 8.

When the option *Force Vibration* is selected the user can define the type of dynamical action that will be considered in the analysis. The *Calculating Displacements* button is used by the program to evaluate and displays in a separated window the maximum displacement values. When the student selects the *Generating Graphs* option the analysis results (accelerations, velocities and displacements) are shown in graphs.

A typical example of an engineering undergraduate course related to a flexible beam is presented in the Fig. 7. This figure illustrates the data inputted by the user as well as the system output result, in this case, the beam fundamental frequency in rad/s.

In sequence, Fig. 8 depicted another didactic example associated to a mass-spring-damping one degree of freedom structural system (S1GL) where the data inputted by the user as well as the system output results are also presented. In this situation it was evaluated the displacement $v(t)$ at t = 1.3*s*.

Finally, the option *Exit* is associated to the input and output data storage for the current analysis as well as to the return to the initial program window, in which the users define a new structure analysis, as depicted in Fig 2.

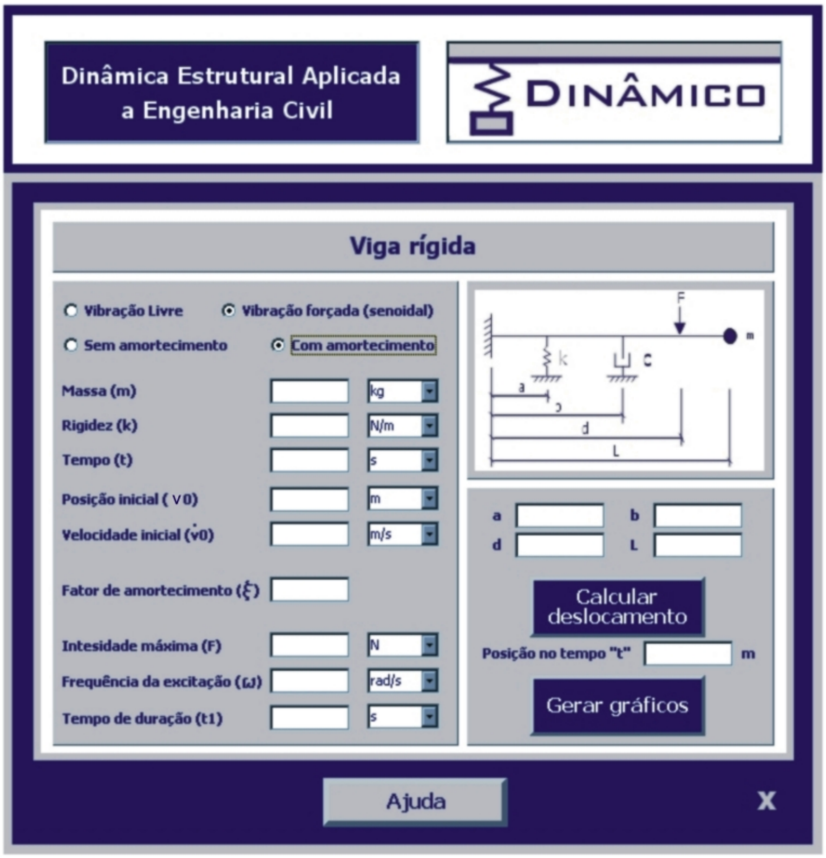

Figure 5. Rigid beam model.

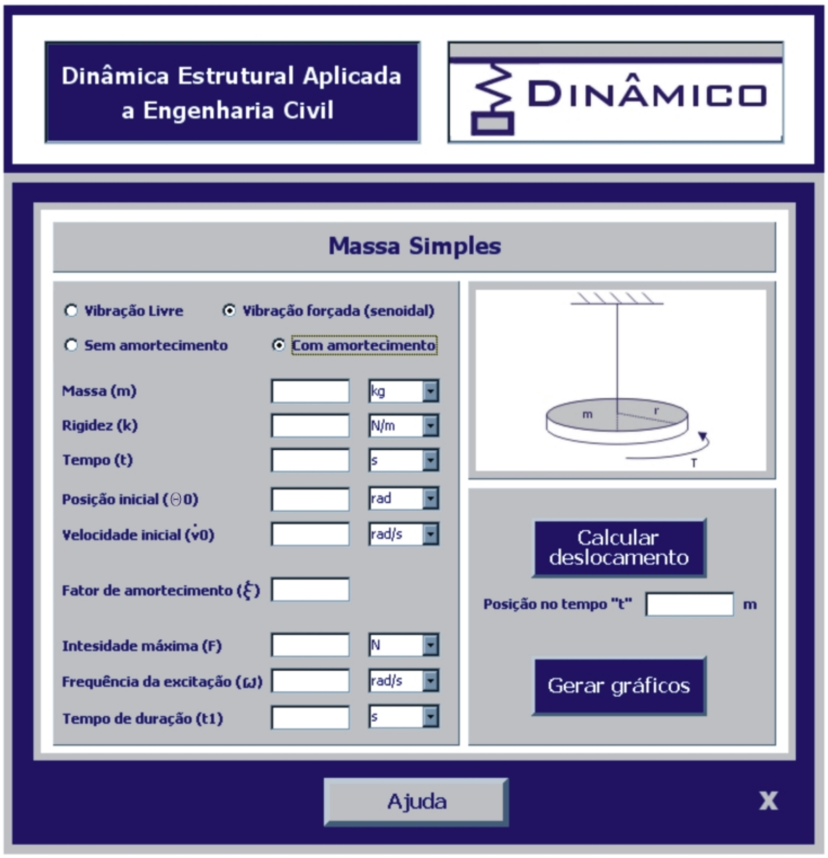

Figure 6. Torsion pendulum model.

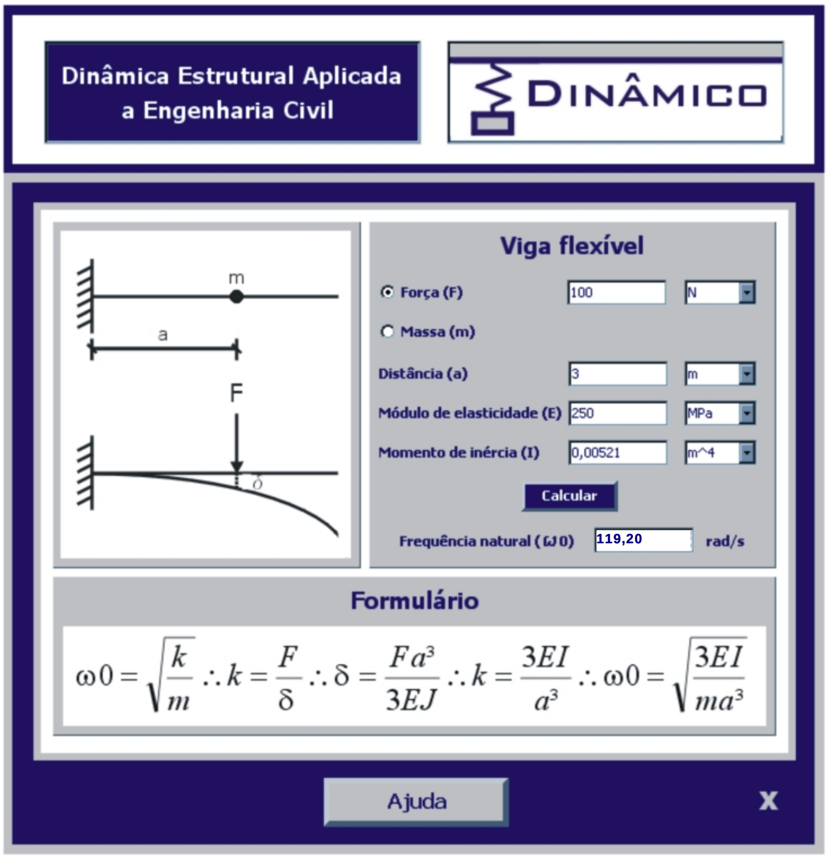

Figure 7. Dialog window with the results for a dynamical analysis: free vibration.

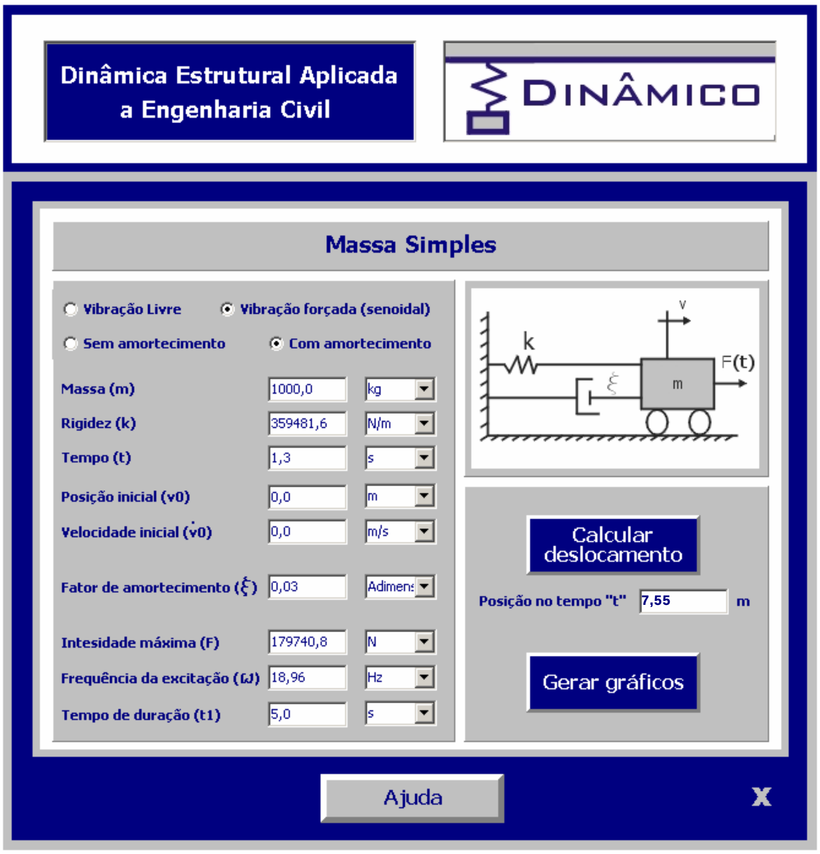

Figure 8. Dialog window with the results for a specific dynamical analysis: forced vibration.

4. Future developments

The first version of the "*DINÂMICO*" program still has some limitations. The first is related to the maximum number of degrees of freedom. At the present stage the program only evaluates one degree of freedom structural system (S1GL). Structural systems presenting more degrees of freedom (SVGL) are currently being implemented.

Another aim is to include: new structural systems like portal frames and new structure dynamical triangular and trapezoidal (load and/or pulse) to be used in a forced vibration analysis. Finally new dialog windows should be implemented presenting the users with the structure time response in terms of displacements, forces and moments as well as the response spectra for a determined dynamical analysis according to previously defined frequency bands.

5. Impact of the use of the developed educational program

The State University of Rio de Janeiro, UERJ, is a Public University funded by the State of Rio De Janeiro. Its students, after approved in the entry exam, can attend their chosen courses free from any fees and taxes. Its faculties and institutes are respected by their excellence, all over Brazil.

The Faculty of Engineering, FEN, part of the Technology Centre, CTC, of the State University of Rio de Janeiro offers a choice of five different engineering habilitations: civil, electrical, mechanical, process system and cartography. Nowadays 2800 students are registered in the Faculty of Engineering. The medium duration of the Engineering Course is ten semesters divided in two complementary phases: the Fundamental and the Professional Cycle. The first four semesters are dedicated to Fundamental Cycle that offers a range of basic disciplines common to all engineering courses. These disciplines cover the fields of mathematics, physics, chemistry and basic computer sciences. The other semesters are dedicated to the professional cycle in which the different engineering habilitations emphasis and skills are offered.

Since 1996, the Faculty of Engineering is engaged in an institutional project called "*The Modernisation of Engineering Courses and Curriculum's at UERJ*". This project, supported and sponsored by CNPq and FINEP, has its main goal related to the modernization of the engineering curriculum and courses, in order to adequate the future engineers to the new engineering professional concepts of the XXI century. This new strategies will prepare them to face and adapt themselves to the constant evolution of technology.

To fulfil this objective the Faculty of Engineering established a series of intermediate goals to create corrective actions to be incorporated in short, medium and long terms (Almeida *et al*, 1998). These investigations confirmed that these goals could only be achieved if a strict methodology of internal quality modernization of the courses/disciplines present in the engineering curricula was to be used (Almeida *et al*, 1998).

This was the main motivation for the creation and implementation of graphical educational programs. The educational software presented in this paper was developed on the Laboratory of Computation of the Basic Cycle, LCB, of the Faculty of Engineering of the State University of Rio de Janeiro, FEN/UERJ. The program denominated "*DINÂMICO*" has been used in the undergraduate engineering courses (Structural Dynamics, Mechanical Vibrations, and Special Topics on Structural Problems) as an interactive graphic application for the calculation of the structural models dynamical response.

The use of this type of teaching tool can cause an impact on the education of an undergraduate engineering student because is clearly noticed that these engineering students feel much more motivated to execute all the procedures related to structural dynamic analysis in each stage of the calculation comparing the results supplied by the program with those obtained manually. It has been verified that after an initial stage of learning of the software it is noticed that the students better understand the concepts regarding the structural analysis. This fact was demonstrated based on an opinion poll with engineering students before and after the use of the developed program. These observations can be extended to other situations related to different engineering habilitations.

The educational software has been applied on the teaching in the undergraduate engineering courses of the FEN/UERJ. The improvement related to the engineering student academic strength can be compared with their performance in specific courses, mainly those associated to design. Considering this didactic experience, it was verified clearly that the use of graphical tools together with specific disciplines as Structural Dynamics, Mechanical Vibrations and Special Topics on Structural Problems, have motivated and stimulated the undergraduate engineering students, as well as facilitated the visualization and understanding of very important theoretical aspects associated to the structural dynamic analysis. As a direct consequence the engineering students academic performance can increase based on this teaching methodology.

On the other hand, it is also important to emphasize that using the "theoretical aspects" option, see Fig. 2, the engineering student can access important information associated to structural dynamic analysis. This facility, allied to the fact that the classes are supplied in computation laboratories makes possible the learning to be more effective.

6. Final considerations

The development of this research project contributed to the implementation and use of a graphical educational tool, the "*DINÂMICO*" program that evaluates the structural systems response when subjected to dynamical loads. The software described in the present paper was implemented on the Computational Laboratories of the State University of Rio de Janeiro, FEN/UERJ.

Based on this didactic experience it can be concluded that the developed graphical educational program helps the undergraduate engineering students to visualize, understand and learn the evaluation process associated with the dynamical behaviour of structures with the aid of simple practical examples.

This initiative is currently motivating the development of new user-friendly engineering educational software on the Computational Laboratories of the State University of Rio de Janeiro, FEN/UERJ. These educational computer programs surely contribute to a more efficient engineering learning.

7. Acknowledgements

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9. Responsibility notice

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