Applying animation in the teaching of mathematics for students of engineering

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Abstract

In this paper we give a short survey on the developing process which aims to increase the effectiveness of mathematics teaching in the training of engineers, using some mathematics computer software to support it. To advance the use of information technology in teaching we launched a project in which the curriculum was modified and animations were constructed in a mathematics course for mechanical engineers. One of the most important goals of our teaching method is to show the connection between theory and practice. Our examples are from the area of mechanical engineering.

Keywords: visualization, differential equation, mechanical engineering

MSC: 97C80

1. Introduction

Nowadays we have to face considerable changes in higher engineering education. A couple of manifestations of these changes are the following: 1. In the curriculums of engineering branches the ratio of lessons in mathematics is decreasing because of a large number of technical subjects. 2. The average knowledge of students is not enough to follow the traditional educational process. 3. The social feedback of the students differs from what we could see one or two decades ago. New tools are needed to motivate them, especially in such abstract subject as mathematics. 4. The ways of communication in our society is progressively shifting towards using more and more visual media and visual messages. 5. Because of the large amount of information during the training, it is often difficult for the students to find the connection between the different occurrences of the same notion or idea.

To answer these problems new ways have to be found to increase the effectiveness of the teaching process. Certain parts of the curriculum must be modified and suitable approach has to be found to the special possibilities provided by up-to-date IT. Using the methodology of communication theory (e.g. design of slides, planning presentations) and considering also the cognitive and pedagogical aspects

behind the subjects of the course higher number of examples have to be presented. Teachers in higher education have to learn to deal with new educational methods [4]: a learner's attention can be extended with attractive presentations. It is widely accepted that visualization is a powerful tool in the learning process of engineering subjects. [3] Combining the abstract notions with the practical technical problems applying graphical tools can be more effective.

2. Using visualization in lectures on mathematics

To show our activity in developing the teaching methodology of mathematics (analysis) in the training of mechanical engineers we present two simple examples from the area of differential equations. This part of the curriculum, in our experience, turns out to be one of the most difficult subjects from the point of view of understanding and application. The more complex and abstract a topic is, the more effective the usage of visualization, for example representing the meaning and role of parameters and initial values of a differential equation is difficult without visualization. Well-planned representations may have a strong impact on the lectures, showing the concrete content of the notions discussed in a course, and can be an important source of motivation for the students. Nowadays different pieces of mathematical software are available for lecturers providing excellent services for graphical applications. The author has experience first of all in the usage of MAPLE and MatLab. From the practical point of view MAPLE is an excellent tool for designing presentations containing pictures and animations, since one can find a lot of built-in tools planned for the educational applications. MatLab, in turn, is an effective tool for engineering students to carry out the calculation steps of particular methods in different mathematical models. In this paper we focus on lectures, in which one-way communication dominates. Students spend a high ratio of their contact lessons (about 40 %) listening generally passively to lecturers. Our experience shows that the effectiveness of the traditional lectures is often not very high, and the attention paid to this problem is not enough. So improvement in this area is a real adventure for us.

3. The first example: stressing of a spring

Studying the second order linear differential equations in the lecture we consider the equation

$$y''(x) + ay'(x) + by(x) = c\cos(dx) \tag{3.1}$$

as an example. To explain the effect of the parameters (a, b, c, and d) on the solution of the equation the lecturer has to draw a few curves on the blackboard or on the transparent. It is rather time-consuming to do it precisely by hand, so they generally put a sketch on the blackboard or refer to a textbook. Computer algebra systems (in this case MAPLE) provide comfortable tools for us: the demonstration of the dependence of the solutions on the parameters with the suitable combination
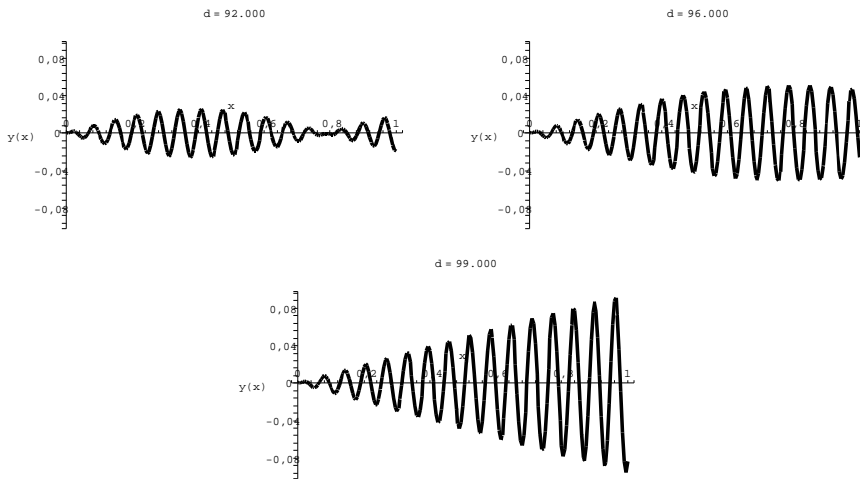
Figure 1: The solution functions (three steps of the animation)

of certain MAPLE commands ("animate" and "DEplot") is very attractive. Let $a = 0.5$, $b = 10000$, $c = 20$, and let us animate the solutions of (3.1) belonging with the values of $d = 70, 71, 72, \ldots, 100$ (let the domain be $[0, 1]$).

MAPLE command:

```
animate(DEplot,[DiffEqu,y(x),x=0..1,[[y(0)=0,D(y)(0)=0]],
stepsize=0.005],d=70..100,frames=31)
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The result is very attractive and provides lasting impression for students who have no experience in this topic. By the steps of the animation (Figure 1 shows three steps of it), we can follow the changes of the solution according to the changing value of the parameter, that is, the role of d can be checked. But there is a problem: is it motivating enough for a student of mechanical engineering? The answer, in our experience, is No. So we cannot stop here, but we have to continue the investigation with an example from the area of technical sciences they will have to study and understand later during their studies.

The following problem can be interesting to students of mechanical engineering [1]: Suppose that a component of a machine is connected with a spring, and the component is under the effect of an exciting force. The mass of the component is $1\ [kg]$, the stiffness of the spring is $10\ [kN/m]$, the exciting force is periodic with the maximum of $20\ [N]$, the air resistance coefficient is $0.5\ [Nm/s]$. Suppose that the spring is designed to work in order up to the elongation of $0.05\ [m]$.

Problem: considering the interval $[\,70[1/s], 100[1/s]\,]$ determine the range where the circuit frequency does not result in overstressing of the spring. Specially we can check whether the spring overstressed in the cases when the exciting frequency is $92\ [1/s]$, $96\ [1/s]$, and $99\ [1/s]$, respectively. The substance and the solution
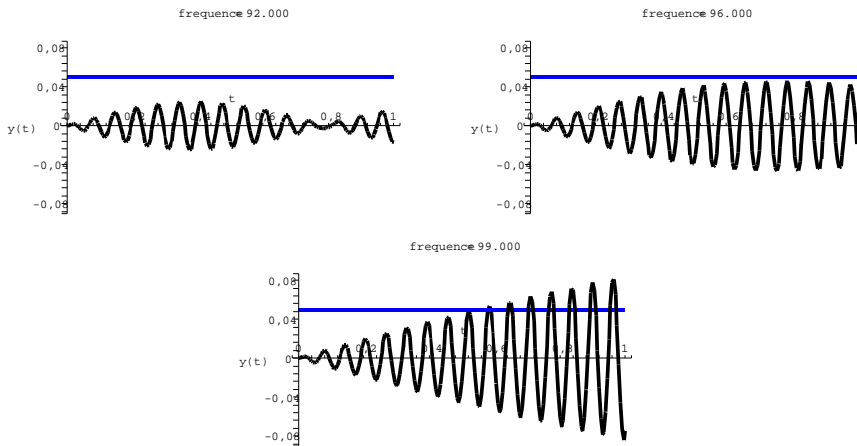
Figure 2: Investigation of the technical problem using animation

of this technical problem and the mathematical problem are the same, but the presentation of the technical problem is much more motivating, so it is much easier for the students to understand. To study the technical problem we use animation again, but instead of the parameters a, b, c, and d we have mass, spring stiffness, air resistance coefficient, exciting force, and frequency:

$$y''(t) + \frac{airresistance}{mass}y'(t) + \frac{stiffness}{mass}y(t) = force \cos(frequency\, t)$$

Following the steps of the animation (Figure 2) we can see that the values of frequency from the range $[\,70[1/s],\, 96[1/s]\,]$ result in normal working while a frequency from $[\,96[1/s],\, 100[1/s]\,]$ causes overstressing. It is clear that the accuracy depends on the length of the step-size used in the animation and $96\ [1/s]$ is only an approximate value for the limit frequency.
Figure 2 shows the answer to our particular questions clearly, too: the spring is not overstressed if $d = 92\ [1/s]$ or $d = 96\ [1/s]$, but it is overstressed if $d = 99\ [1/s]$. It also suggest that the system has characteristic frequency near $100\ [1/s]$).

There is no question about the fact that in order to give the correct answer to the problem the solution function has to be found a nd its properties suggested by the animation have to be checked. That is, the visual presentation must be followed by accurate theoretical investigation, for example with the symbolic tools of MAPLE. (It is an easy job for MAPLE users.)
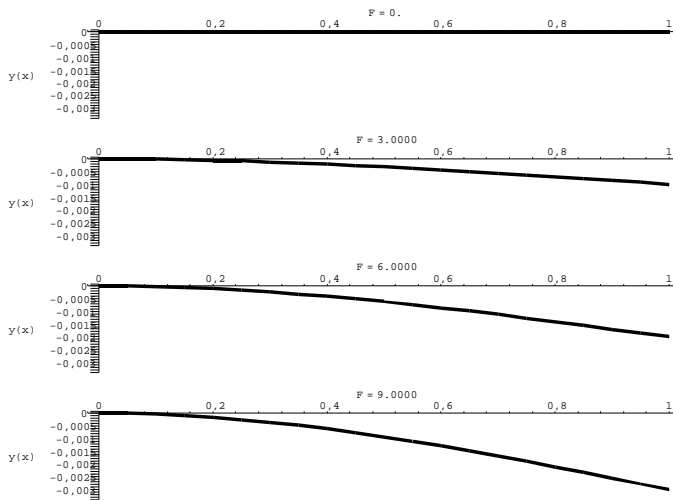
Figure 3: Investigation of the technical problem using animation

4. The second example: deflection of a clamped-free bar

As second example we consider the equation

$$y''(x) + 0.001F(1 - x) = 0,$$

where F is a parameter (constant). We can study the role of F using animation: Figure 3 shows four steps of the animation (F is changing from 0 to 10, the step-size is 1, the domain is $[0, 1]$). Making it more attractive consider the following problem: the deflection (y) of a clamped-free bar of length L is given by the second order differential equation $y''(x) + 0.001F(L - x) = 0$, where F is the loading force at the and of the bar. Let $L = 1[m]$ and suppose that the admissible (maximum) value of deflection is 2 [mm]. Let us determine the maximum loading force.

Using animation we can study the effect of force F on the deflection. (Figure 4) One can see that the (approximate) maximum value of the force is about 6 [N].

5. Conclusion

Presenting two simple examples from the area of differential equations connected with mechanical engineering problems, our aim was to prove that a possible way to increase the effectiveness of the teaching activity is to understand the special facilities provided by computers and to find new approaches to mathematical subjects.
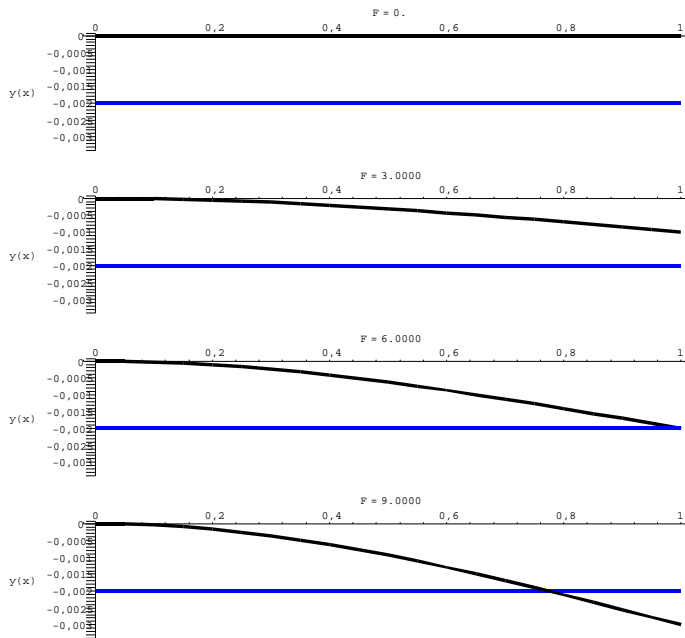
Figure 4: Investigation of the technical problem using animation

The application of new equipment in the teaching process requires new ideas and methods. These features allow the students to have a global view of the subject and also gives a visual clue of the insertion of this topic in the global context of study. It may also represent an important source of motivation because of a modern approach with visual and interactive features.

These presentations may have strong impacts on a lecture of mechanical engineering, showing real applications in the subjects discussed in a course, which normally are presented in theoretical or abstract forms. This material has to be used for introducing and explaining the subjects parallel with the usual mathematical development.

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