ANIMATION: A PROMLEM SOLVING TECHNIQUE IN ENGINEERING EDUCATION I

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ABSTRACT

In this paper we apply the methods presented in [1], [2] and [3] solving certain problems (connected with ordinary differential equations) arising in engineering education. Our tools are provided by Maple computer algebra system. In the first part we deal with a problem in connection with pendulum motion, in the second part we investigate cooling process and moving in liquid.

Keywords: animation, differential equation, engineering education

1. INTRODUCTION

Using visualization may have strong impact on the teaching process in engineering education. Showing applications over the subjects discussed in a course, which normally are presented in theoretical and abstract form, provides important source of motivation for engineering students.

Animation has essential role particularly in cases when there is no analytical solution method for the problem or when the available analytical method is too complicated for students.

The methodology of solutions presented in this paper are based on the combination of MAPLE commands **`animate`** and **`DEplot`**.

2. A PROBLEM IN CONNECTION WITH EXCITED PENDULUM MOTION

The background of the problem: let us consider a pendulum-rod of mass m [kg] and of length L [m] with exciting moment M(t) depending on time (t) at the axle, denote the deflection angle by φ and the value of gravity by g (9,81 [m/s^2]). (Fig.1)

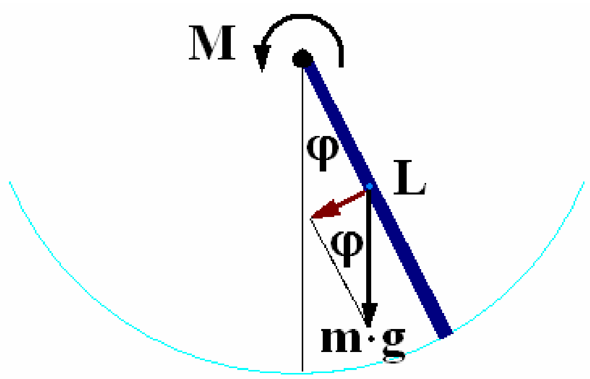

Fig.1 Pendulum-rod, notations

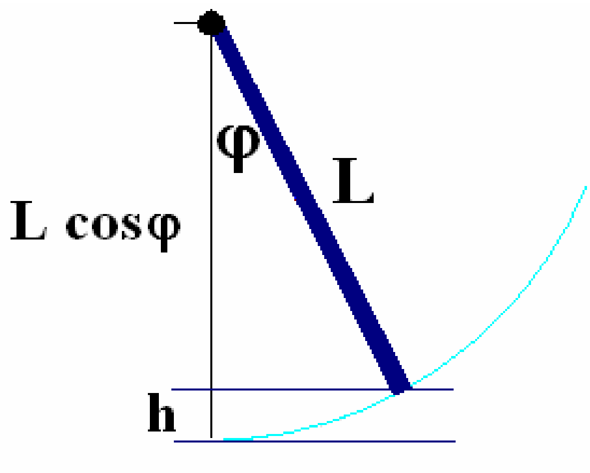

Fig.2 Lifting of the end of the rod

It is well known in physics that for the angle-time function φ we have the following second order (nonlinear) differential equation

$$\varphi''(t)+\frac{3g}{2L}\cdot\sin(\varphi(t))=\frac{3M(t)}{m\cdot L^2} \quad . \tag{1}$$

An example in teaching differential equations: we have a pendulum-rod with the parameters: m=3 [kg], L=5 [m] excited by periodic exciting moment given by

$$M(t) = M_0\sin(\omega t) \quad , \tag{2}$$

where M_0=2 [Nm] is the maximum moment and ω is the exciting circular frequency [1/s]. Suppose that the initial value of deflection angle and of the angular velocity are φ(0)=0 and $\frac{d\varphi}{dt}(0)=0$ [1/s], respectively and that the maximum admitted lifting of the end of the rod (h, see Fig.2) during the first 10 seconds is 2.8 [m]. Determine the exciting circular frequency ω*, such that for all $\omega\in[0,\omega^*]$ the lifting of the end of the rod (h) do not exceed the admitted 2.8 [m] during the first 10 second of motion.

3. SOLUTION TO THE PROBLEM WITH ANIMATION

To answer our question we have to investigate the following second order (nonlinear) initial value problem:

$$\varphi''(t)+\frac{9.81}{5}\cdot\sin(\varphi(t))=\frac{4}{75}\cdot\sin(\omega\cdot t) \quad , \tag{3}$$

$$\varphi(0)=0 \quad , \quad \frac{d\varphi}{dt}(0)=0 \quad . \tag{4}$$

We need the solution function φ (dependence of deflection angle on time) beside the different values of exciting frequency ω>0. To get the exact value of ω* we have to change the value of ω continuously from zero. Here we accept an approximate value for ω*, so it is enough to check the solution function beside specified values of ω: 0, ε, 2ε, 3ε, … It is clear, that the smaller the (positive) step size ε is, the more accurate the answer is.

Since the solution function gives the deflection angle, we have to transform the maximum lifting into maximum deflection angle. By Fig. 2 we have $1-\cos\varphi=\frac{h}{L}$, that is, $\varphi=\arccos\left(1-\frac{h}{L}\right)$, so maximum admitted deflection angle belonging to the maximum admitted lifting of the end of the rod is $\varphi_{max}=\arccos\left(1-\frac{2.8}{5}\right)=1.115$.

To construct the animation we use the combination of MAPLE commands **`animate`** and **`DEplot`** by the following

```
> restart:with(plots):with(DEtools):
> DE:=diff(y(x),x$2)+(2*g/3*L)*sin(y(x))=
3*M0/(m*L^2)*sin(w*x);
> g:=10: L:=5: M0:=2: m:=3:
> animate(DEplot,[diff(y(x),x$2)+(2*g/3*L)*sin(y(x))=
3*M0/(m*L^2)*sin(frequency*x),y(x),x=0..10,[[y(0)=0,D(y)(0)=0]],
linecolor=black,stepsize=0.1],frequency=0..2,frames=41,
background=plot(1.115,t=0..10,colour=blue,thickness=3));
```

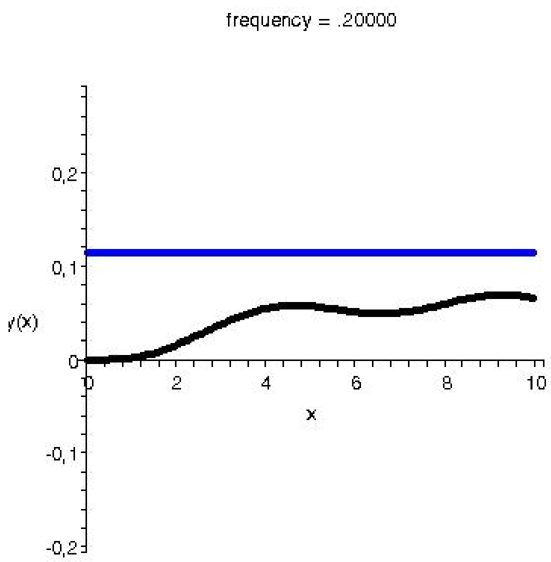

Fig.3 Solution function φ when the exciting frequency is ω=0.2 [1/s]

The value of exciting frequency is changing gradually from 0 [1/s] to 1 [1/s] the step size is 0.02 [1/s]. The following figures show the result of these commands. We can see six steps of the animation: ω_1=0.2 [1/s], ω_2=0.4 [1/s], ω_3=0.6 [1/s], ω_4=0.68 [1/s], ω_5=0.7 [1/s] ω_6=0.72 [1/s].

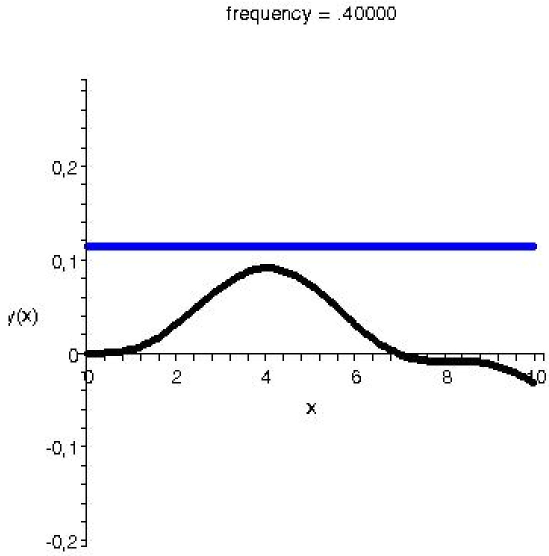

Fig.4 Solution function φ when the exciting frequency is ω=0.4 [1/s]

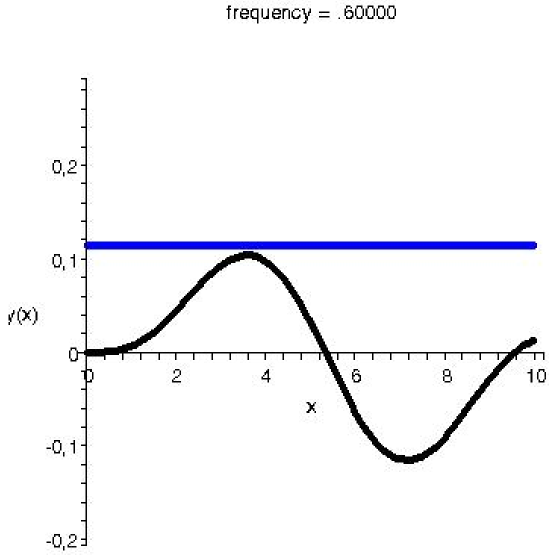

Fig.5 Solution function φ when the exciting frequency is ω=0.6 [1/s]

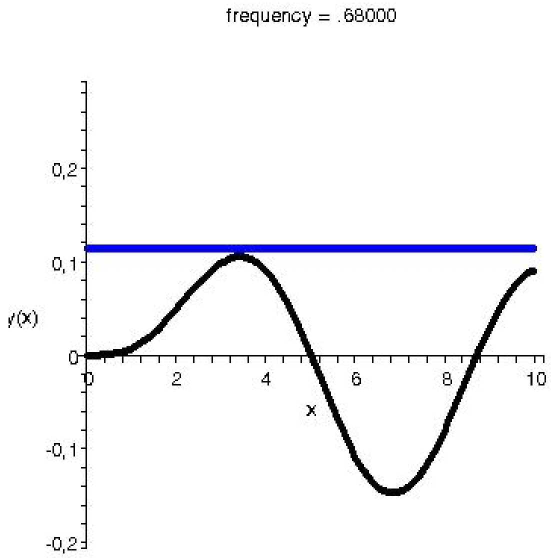

Fig.6 Solution function φ when the exciting frequency is ω=0.68 [1/s]

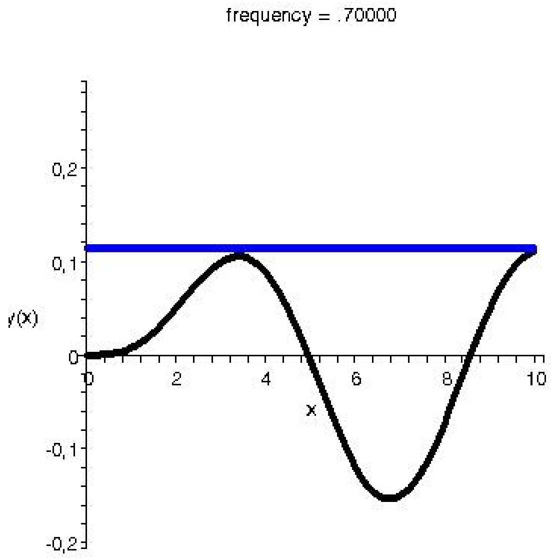

Fig.7 Solution function φ when the exciting frequency is ω=0.7 [1/s]

We can see that the approximate value of ω* is 0.7 [1/s].

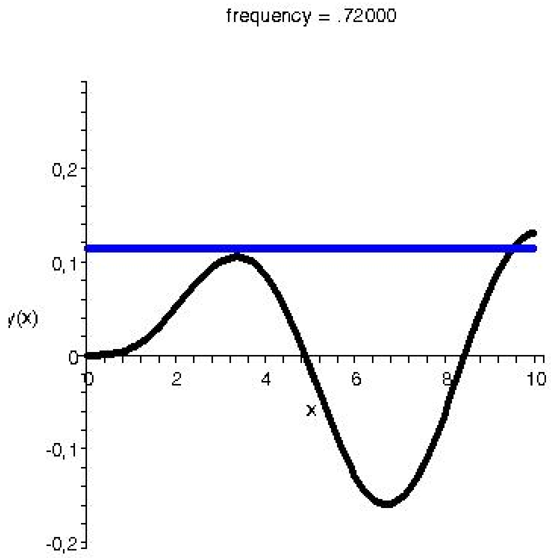

Fig.8 Solution function φ when the exciting frequency is ω=0.72 [1/s]

4. CONCLUSION

Animation supported by up-to-date IT devices is an effective way to investigate problems having differential equation in the background. In case of our problem studied above the analytical solution method and the formula of the solution function is rather complicated. Additionally to find the accurate answer to our question we have to solve a difficult equation related to the solution function. This is why animation can play important role in the investigation of similar problems.

5. REFERENCES

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ANIMÁCIÓ: EGY PROBLÉMAMEGOLDÁSI MÓDSZER A MŰSZAKI OKTATÁSBAN I

Ebben a kétrészes dolgozatban olyan – a közönséges differenciálegyenletekhez kapcsolódó – problémákat vizsgálunk, melyek a műszaki oktatásban felvethetők. A megoldásban használt eszközök a MAPLE computer algebrai rendszerben rendelkezésre álló utasítások. Az első részben egy feladatot elemzünk az ingamozgáshoz kapcsolódóan.