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The Role of Virtual Laboratories in Improving Students Learning Performance

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It is known that experiments and hands-on learning are attractive for actual students. Furthermore, visualization permits an in-deep understanding of the learning content with beneficial consequence on the students' performances. Consequently, virtual laboratories can aid students in achieving higher performances when studying machine design. In our research, after the students have familiarized with the theoretical aspects, they dispose of Java applets that allow performing supplementary experiments. After performing numerous experiments, which imply modifying the simulation parameters, it is observed that the students thoroughly understand the studied phenomenon.

Keywords: *virtual instruments, Java applets, simulation*

1. Introduction.

Virtual instruments are increasingly used by students and especially by those who study engineering. The use of Virtual Instrumentation in various fields of science like biotechnology, biology, chemistry or physics is presented in [1-5].

Developing students' analytical or analysis and synthesis skills, i.e. the Bloom higher-order cognitive skills [5], are important in engineering education. Students must be able after graduating to apply what they have learned in theory to real-world problems. Therefore, the largest part of the studied disciplines in engineering faculties benefit from hands-on laboratories. The laboratories help students developing the mentioned abilities involving active learning, but they also have a number of disadvantages. The paper [6] presents the results obtained through the implementation of a virtual laboratory for fluid mechanics.

The use of Virtual Instruments was successful for developing some mathematical skills for engineering students, by using different dedicated software or by constructing the virtual instruments [6]. Java applets can be used to explain certain phenomena or as a tool for interactive learning both in the class and at home [7-8].

In this paper, after a brief theoretical introduction in the issue of vibration transmissibility and the need to achieve the appropriate isolation a Java applet was introduced. It allows students to deepen their knowledge and comprehensively understand the phenomena. In the end, a questionnaire was presented to the students to find out their impressions about the use of the virtual laboratory and its advantages.

2. The transmissibility

The operation of machines may cause vibrations that, depending on amplitude, speeds and accelerations, may suffer various effects. There are situations where machines can be vibration sources, or these can be subjected to vibrations from other sources. In both cases, isolation is needed. In Figure 1 we presented a lathe that while operating constitutes a source of vibration. In this case, it is necessary to achieve the protection of the foundation. It is equally possible to have external vibration sources which, transmitted through the foundation, affect the functioning of the machine [9].

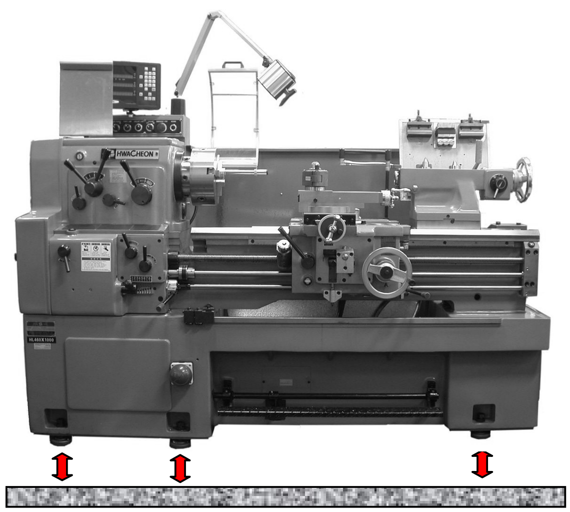

Figure 1. The vibrating lathe

In the first case, shown in Figure 2, the vibration source is an external sinusoidal load $F(t) = F_0 \sin \omega t$ and we need to protect the foundation. If the external force is given by a rotating mass *M* that has an eccentricity *e*, the force amplitude becomes: $F_0 = Me\omega^2$. In the second case, the vibration source is the periodic base displacement performed in respect to the function: $y(t) = Y_0 \sin \omega t$. In this situation, we need to protect the machine from these vibrations.

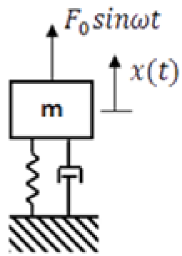

Figure 2. Vibratory system of the machine with external excitation

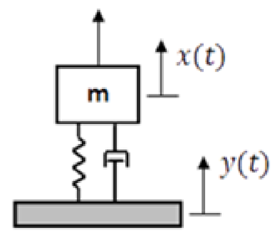

Figure 3. Vibratory system of the machine with base excitation

If the machine is the source of vibration, its isolation system can be described by the Voigt-Kelvin model shown in figure 4, see reference [10-11]. This system has the rigidity *k* and the damping coefficient *c*. The equation of the forced vibrations can be written [12]:

$$m\ddot{x} + c\dot{x} + kx = F_0 \sin \omega t \tag{1}$$

where *m* is the mass of the machine, *x* the displacement performed by the machine, F_0 the amplitude of the disturbing force produced by the vibration source with the angular frequency *ω* and *t* is the time.

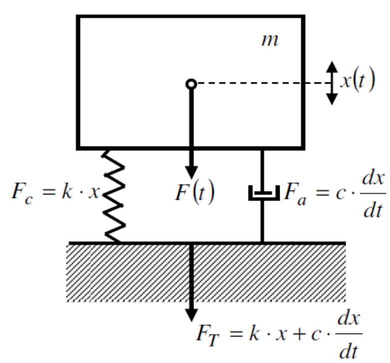

Figure 4. The Voigt-Kelvin model for a vibratory system of the machine

Considering the damping factor $2n = \frac{c}{m}$ and the angular frequency $\omega_0 = \sqrt{\frac{k}{m}}$ of the elastic system, equation (1) becomes

$$\ddot{x} + 2n\dot{x} + \omega_0^2 x = \frac{F_0}{m}\sin\omega t \quad (2)$$

The solution of this equation is in the form

$$x = A\sin(\omega t - \varphi) \quad (3)$$

where *A* is the amplitude of the vibration, φ the angle between the displacement *x* and the disturbing force *F*. The vibration amplitude is $A = \frac{F_0}{k}A_0$ where A_0 is the amplification factor given by the formula

$$A_0 = \left[(1-\delta^2)^2 + 4\zeta^2\delta^2\right]^{-1/2} \quad (4)$$

Where: $\delta = \frac{\omega}{\omega_0}$ and $\zeta = \frac{n}{\omega_0}$.

When $\omega \langle\langle \omega_0$, independent of the damping in the system, the amplification factor tends to $A_0 = 1$. The amplification factor will tend to zero when $\omega \rangle\rangle \omega_0$ and thus the amplitudes of the forced vibrations are not influenced by the damping in the system. The resonance phenomenon occurs when $\omega = \omega_0$ the vibration amplitudes increase, being influenced by the system damping.

The force transmitted from the machine (with the mass *m*) to the elastic spring and the shock absorber is given by

$$F_T = F_e + F_a = kx + c\ddot{x} \quad (5)$$

The transmissibility of vibrations is defined as the ratio between the force transmitted to the tool machine F_T and the amplitude of the disturbing force F_0 [9].

$$T = \frac{F_T}{F_0} = (1 + 4\zeta^2\delta^2)^{1/2}\left[(1-\delta^2)^2 + 4\zeta^2\delta^2\right]^{-1/2} \quad (6)$$

Analyzing the equation (6) and Figure 5 it is found that for $\delta = \sqrt{2}$, T = 1 irrespective of the value of ζ, ie independent of system damping, for $\delta > \sqrt{2}$ the lower the damping factor ζ, the better the isolation and in the resonance range $\delta \in [0.5;1.5]$ the higher the damping factor the vibration isolation is more efficient.

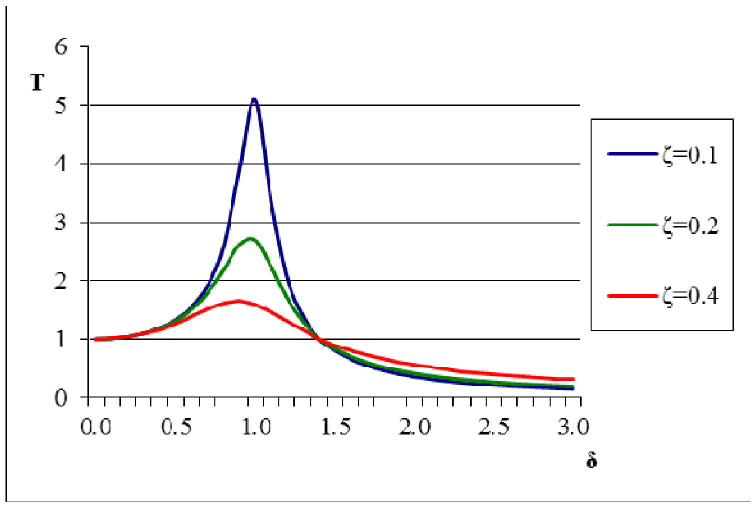

Figure 5. The variance of transmissibility for different values of ζ

3. Using the Java Applets as Virtual Instruments

At the course Machine Dynamics, students learn how to protect machines from the vibration effect. For this they have at their disposal an experimental stand on which they can make various measurements, but where they cannot change certain parameters. Thus, they also have a virtual instrument in which they can see how the variation of the different parameters influences other variables.

The Java Applets on Physics by Walter Fend has the following modules linked to the topic of the machine dynamics course: Mechanics, Oscillations and Waves. The second module will be described in this paper. After the students have become familiar with the spring pendulum, the application for Forced oscillation will be used. This applet demonstrates the variation of elongation, amplitude and phase difference for forced oscillations [13].

In the following figures the red circle on the spring pendulum performs forced oscillations. There are two buttons, one the "Reset" button that allows you to bring the pendulum to the initial position and a "Pause" button that allows stopping and then starting the movement. Students have the possibility to modify different parameters within certain limits. Thus, the spring constant can vary between 5N/m and 50N/m, the mass between 1kg and 10kg, the constant of attenuation between 0 and 100 1/s and the angular frequency can range between 0 and 10rad/s. A complete image on the applet window is presented in Figure 6.

As shown in Figure 6, which illustrates the interface of the applet, the students can choose which representation is displayed: the elongation, the amplitude or phase difference diagram. The radio buttons are in the left lower corner of the interface.

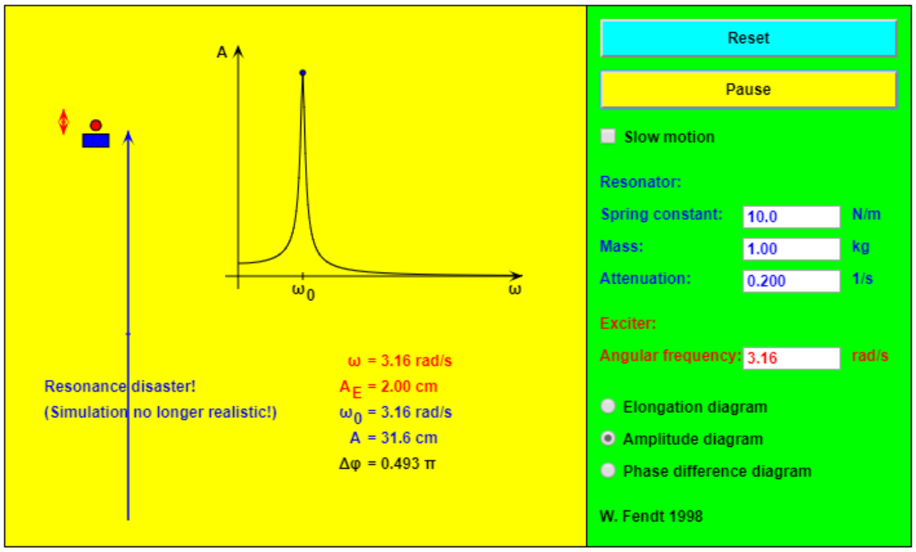

Figure 6. Java applet interface highlighting the resonance phenomena.

The students can select the values of following system parameters: the mass, the spring constant, the attenuation or the angular frequency. Several scenarios can be obtained:

- for equal frequencies, i.e. $\omega = \omega_0$, the resonance phenomenon occurs (see Figure 6);
- for an increased angular frequency ω, the amplitude of the oscillation becomes smaller (see Figure 7);
- the oscillation amplitude depends directly on the exciter's angular frequency ω_0;
- with spring constant growth k there is an increase in amplitude (Figure 8);
- as the damping factor increases the amplitude of the resulted displacement decreases (Figure 9).

The applicability of these aspects in real-world systems is highlighted in [14].

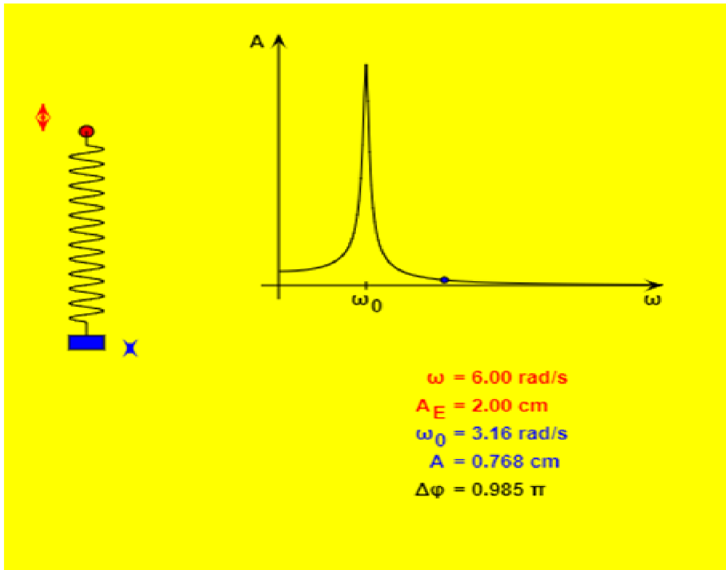

Figure 7. The amplitude diagram obtained from the angular frequency change

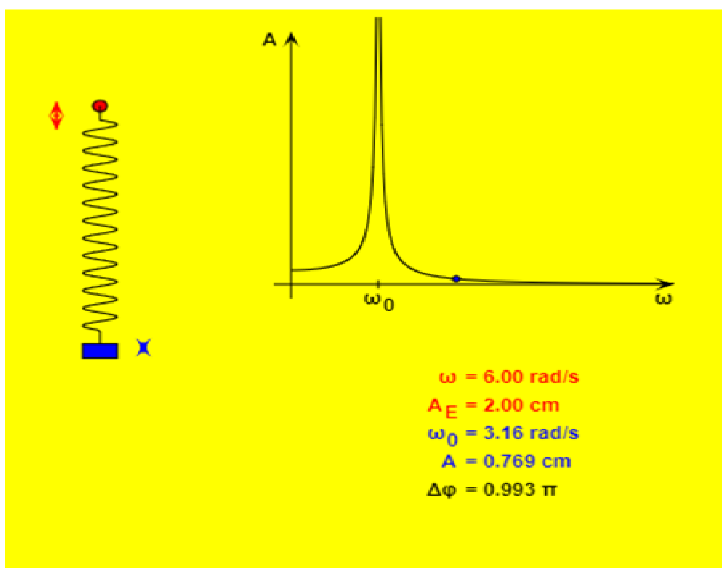

Figure 8. The amplitude diagram obtained by increasing the spring constant

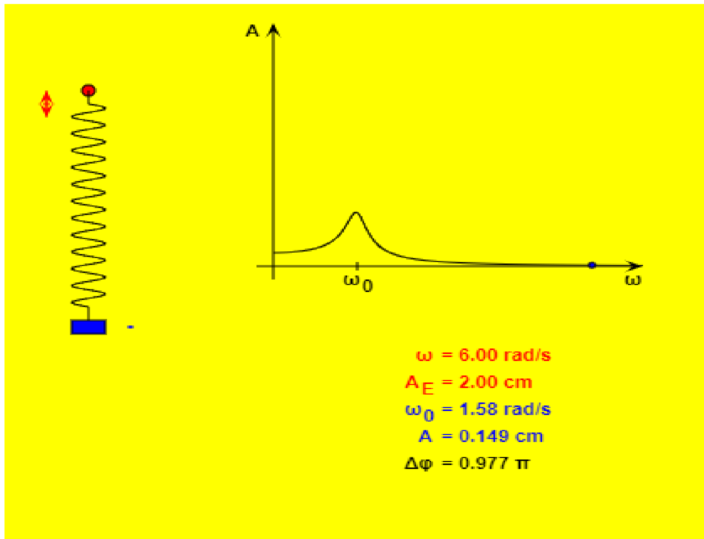

Figure 9. The amplitude diagram obtained by increasing the constant of attenuation

4. Conclusion

One of the drawbacks of using the classical lab is that practical experiments can be very complex and require complex equipment or longer time that exceeds the allocated time.

In the case of a lab, it is always necessary for someone to guide the students, while at virtual laboratory they can handle themselves. Experiments require well-equipped laboratories and some experiments must be done outdoors.

Using these Java applets to study the Machine Dynamics discipline, students have an easy-to-use virtual tool to help them better understand the phenomena, an instrument that they can integrate into classroom, seminar and lab work, and with which can perform virtual experiments independent of time and space.

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