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MODELING MASS-SPRING-DAMPER SYSTEM USING SCILAB

Л. Бовнегра, В. Стрельбіцький. **Моделювання демпфера у Scilab**. Моделювання системи означає розробку математичного представлення для імітації певних властивостей, що спостерігаються в реальних системах. Ці системи можуть варіюватися від підвіски автомобіля до найскладнішої робототехніки. У сучасному машинобудуванні зазвичай фізичну динамічну систему моделюють у вигляді набору диференціальних рівнянь, які пізніше будуть змодельовані за допомогою комп’ютера. Ці системи можуть варіюватися від підвіски автомобіля до найскладнішої робототехніки. Використання програмного забезпечення для чисельного аналізу та якісного аналізу динамічних систем в інженерній та прикладній науковій освіті спрощує аналіз. У роботі динамічну досліджували поведінку системи маса-пружина-демпфер за допомогою математичних рівнянь у вільному програмному забезпеченні Scilab. Scilab – це безкоштовне програмне забезпечення для чисельних обчислень з відкритим кодом, що забезпечує потужне обчислювальне середовище для виконання інженерних та наукових досліджень. Отримані рівняння є узагальненням класичної моделі маса-пружина-демпфер; запропоноване подання може бути використано для опису широкого спектру систем, які раніше не розглядалися через обмеження класичного числення. Програмна реалізація моделі та розрахунки виконані у середовищі Scilab. Масове використання програмного забезпечення породило чудовий бізнес. Незважаючи на надійність та ефективність комерційного програмного забезпечення незаперечні, їх вартість недоступна для більшості дослідників, студентів та державних університетів. Ця стаття чітко показує, що SCILAB здатний впоратися з такими невизначеностями без особливих зусиль. Слід зазначити, що ця стаття написана з наміром поширити уявлення про те, як використовувати SCILAB для викладання теорії моделювання, динаміки машин або виконання пов’язаних з цим дослідницьких робіт.
Ключові слова: моделювання, маса, пружина, демпфер, коливання, Scilab

L. Bovnegra, V. Strelbitskyi. **Modeling Mass-Spring-Damper System using Scilab.** Modeling a system means developing a mathematical representation to simulate certain properties observed in real systems. These systems can range from a car suspension to the most complex robotics. In modern mechanical engineering, it is routine to model a physical dynamic system as a set of differential equations that will later be simulated using a computer. This systems can range from a car suspension to the most complex robotics. Use software for numerical analysis and qualitative analysis of dynamic systems in engineering and applied science education simplifies the analysis and analysis. In this paper, the dynamic behavior of mass-spring-damper system has been studied by mathematical equations in free software Scilab. Scilab is free and open source software for numerical computation providing a powerful computing environment for engineering and scientific applications. The resulting equations represent a generalization of the classical mass-spring-damper model; the proposed representation can be used to describe a wide variety of systems, which had not been addressed due to the limitations of the classical calculus. Software implementation of the model and calculations are performed in the Scilab environment. The massive use of software generated a great business. Although the reliability and effectiveness of commercial software is undeniable, their cost is not available to most researchers, students, and public universities. This paper clearly shows that Scilab is capable of handling such uncertainties with little effort. It should be noted that this paper is written with the intention of disseminate the ideas of how to use Scilab for teaching theory modelling, dynamic of machine or performing related research works.
Keywords: modelling, mass, spring, damper, vibration, Scilab

Introduction

Modeling a system means developing a mathematical representation to simulate certain properties observed in real systems. These systems can range from a car suspension to the most complex robotics.

Generally, linear approaches are sufficient for the analysis, but in many cases they are not satisfactory and non-linear models must be used (which increases the complexity of the algorithm).

In the field of Mechanical Engineering, it is routine to model a dynamic physical system as a set of differential equations that will then be simulated using a computer. The law of evolution of dynamic systems can take various forms: iterations, equations, partial differential equations, transformations or flows, stochastic equations. However, data computation in recent times are complicated and difficult without the application of modelling and simulation tools. Dynamic systems are often nonlinear when analyzed further.

Therefore, the computational methods and software for numerical resolution and qualitative analysis of dynamic systems in engineering education and applied sciences simplify the resolution and analysis of these systems.

Analysis of publications on the topic of research

A mass-spring system is the most common example of simple harmonic motion. It is common ehe experimental and mechanical behavior of the system is well-defined in basic physics textbooks.

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Much of the current work is theoretical. In addition, some generalizations are made about spring mass correction and in many cases analysis of vibrational phenomena such as spring mass ideally, an oscillating system is undamped [1, 2]. However, the vibrations are actually damped. mass spring damper models have many applications, including control parameter estimation, robotic control, and vibration control. There are many factors that contribute to damping force. Among them are Coulomb friction damping and dry friction damping. The force acting on the relative rate of change of displacement is called the damping force, which is the opposite of the spring [1 – 4].

The massive use of softwares generated a great business. There are several commercial software's, and among the most important are the Matlab, Maple and Mathematica [4]. For example, the most comprehensive bibliographic database, the Web of Science, presents the following number of articles which contains the aforementioned software's: 4,805 for Maple, 2,267 for Matlab and 1,062 for Mathematica.

Purpose and objectives of the study

Although the reliability and effectiveness of commercial software is undeniable, their cost is not available to most researchers, students, and public universities.

This paper aims at presenting the Scilab, as a friendly, free software and alternative tool for the analysis of a typical mass-spring-damper (MSD). Using the previously published ideas, this popular mechanical system is considered to provide another example of usefulness.

Materials and research methods

Fig.1 shows the mechanical system-damper. Under the action of the applied force *F*, the solid will shift by an amount x in the direction of the applied force. Under the action of the applied force *F*, the solid will shift by an amount x in the direction of the applied force.

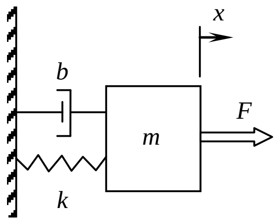

Fig. 1. Mechanical system for mass-spring-damper system

According to Newton's laws of motion, the force in the spring causes a displacement, the acceleration of the mass of the body against the force of friction [1, 2, 4].

The generalized equation for the mass-spring-damper system can be described by the following second order differential equation:

$$F = m\frac{d^2y}{dt^2} + b\frac{dx}{dt} + kx, \tag{1}$$

where: F – Force;

m – mass of system;

b – damping coefficient;

k – spring coefficient;

x – displacement.

By applying Newton's second law, the system can be transformed to the form:

$$\begin{aligned} x_1 &= x, \\ x_2 &= \dot{x}, \\ \dot{x}_1 &= x_2, \\ \dot{x}_2 &= \frac{F}{m} - \frac{b}{m}x_2 - \frac{k}{m}x_1. \end{aligned} \tag{2}$$

We have obtained the system of ODE's can be solved analytically or numerically. For solving will use a common numerical method:

1) which is called Runge-Kutta 4th Order Method:

$$\begin{gathered} \frac{dy(t)}{dt} = y'(t) = f(y(t), t), \text{ with } y(t_0) = y_0, \; h = \Delta t, k_1 = f(y(t_0), t_0), \\ k_1 = f\left(y(t_0) + \frac{k_1 h}{2}, t_0 + \frac{k_1 h}{2}\right), k_3 = f\left(y(t_0) + \frac{k_2 h}{2}, t_0 + \frac{k_1 h}{2}\right), \\ y(t_0 + h) = y_0 + \frac{k_1 + 2k_2 + 3k_3 + k_4}{6}h; \end{gathered} \tag{3}$$

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2) ordinary differential equation solver Scilab – y = ode(y_0, t_0, t, f).

Scilab is free and open source numerical computing software that provides a powerful computing environment for engineering and scientific applications and has been freely distributed on the internet since 1994 [7 – 12].

User interaction with Scilab can take two forms. In the first form, commands are entered directly into the command prompt (acting as a calculator). In the prompt, we also see error messages. In the second form, commands (routines) can be saved as .sci files with their editor. The file is brought to the command prompt and executed. When a command is invoked, the result is displayed on the screen as a prompt or as a graph.

Research results

The parameters used for simulation are as follows: F = 100 N; m = 1 kg; b = 0.15 N/(m/s); k = 100 N/m.

The calculation results are shown in Fig. 2.

Analysis of the results presented in Figure 2, *a* and 2, *b* shows that they differ slightly. The deviation of the ordinary differential equation from the Runge-Kutta 4th Order Method increases with the order of differentiation.

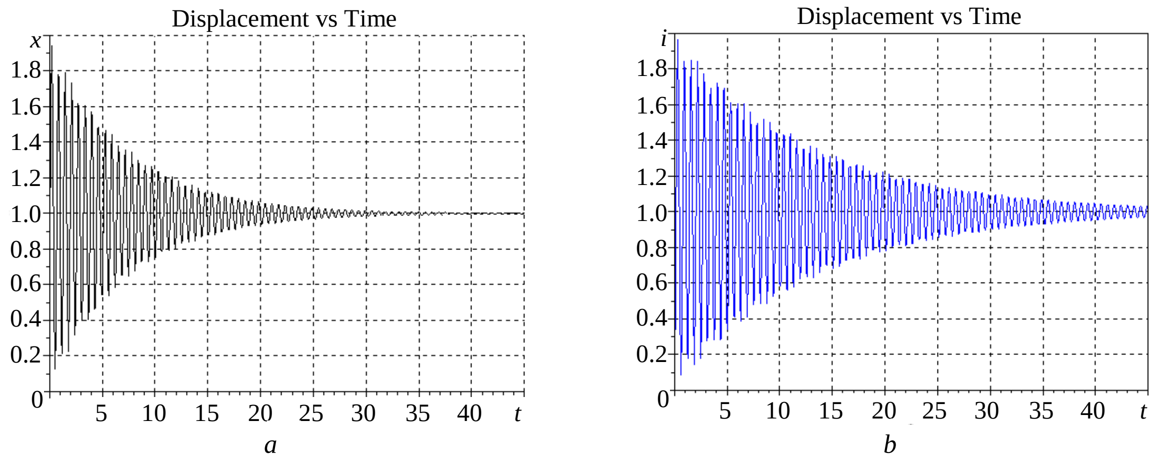

Fig. 2. The calculation results for Runge-Kutta 4th Order Method (*a*) and ordinary differential equation solver (*b*)

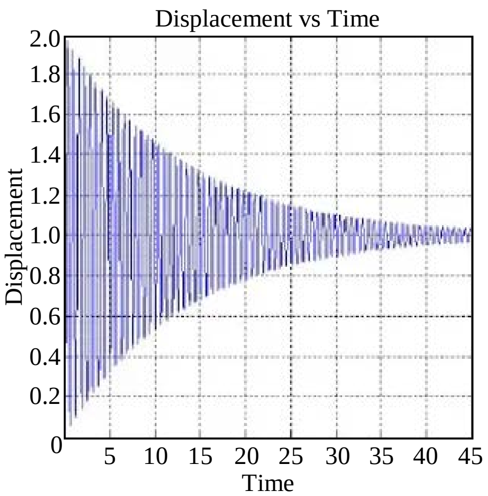

Fig. 3. The results for simulation in Matlab the parameters are as follows: F=100 N; m=1 kg; b=0.15 N/(m/s); k=100 N/m

Verification and validation are the primary processes for quantifying and building confidence (or credibility) in numerical models. Verification of the model was carried out by comparing the data obtained in the work [13] and presented in Fig. 3.

Analysis of the results presented in Figures 2 and 3 shows that they differ slightly. The results in Figures 2, *b* and 3 are almost identical, that suggests a good agreement between models.

Conclusions

This paper clearly shows that SCILAB is capable of handling such uncertainties with little effort. It should be noted that this paper is written with the intention of disseminate the ideas of how to use SCILAB for teaching theory modelling, dynamic of machine or performing related research works.

The help command is a simple tool that allows us to consult syntax features and this help allows new users to learn quickly, as the syntax provides a good overview of the functionality along with some examples. Scilab is good enough for simulations as an alternative to paid software like Matlab.

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