

## **Vibration with Simulink and ADAMS**

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# Vibration with Simulink and ADAMS

## Abstract

This work in progress paper presents an active learning approach to teach vibrations effectively to students without any labs/hands-on experiments. Computer simulation is a vital part of any course involving moving systems. Vibrations is a very mathematically intensive course, and often students find it very difficult and challenging. To make this class interesting and engaging, the instructor integrated Simulink and MSC ADAMS in the course to help students understand the dynamics of moving parts and vibrating systems. This paper also presents results from a survey regarding how the software affected students' learning and understanding of vibrating systems.

## Introduction:

Vibration is a complicated and challenging subject. It brings together many concepts from differential equations, linear algebra, and physics that students have previously seen often only in isolation. Also, many of the results and concepts of Vibration are non-intuitive which further complicates the subject. The author believes that one of the reasons that the students find this course difficult could be that the course is taught in a traditional whiteboard/power point slides based theory without the benefits of observing a physical model. When class consists of an instructor merely talking to the students, the students are not focused, and their attention is more likely to drift, especially if the class period is long [5]. Researchers believe that students learn and retain more when they can apply the concepts and not just read or hear about them [4].

For over a decade, the Vibration course at Grand Valley State University has been offered as a 4 credit lecture only. This course is offered as an elective to senior-level mechanical engineering students. Since this course is mathematically very intensive, it is challenging to engage students throughout the class time and make the lectures interesting. The instructor has tried to engage the students in class by doing some simulations of vibrating systems in Matlab and Simulink. Many papers discuss how Simulink can be used effectively in areas such as dynamic systems, [1],[3],[6] and mechanical systems,[2],[9] and [7]. The students seemed to enjoy doing these simulations, but they do not see the system moving. The instructor decided to use MSC ADAMS, which is a well-known Multibody Dynamics (MBD) software, in teaching Vibration for the first time in Spring/Summer 2019 semester. As mentioned above, Vibration is an elective course, which is taken by seniors in their last semester, and therefore it is not a prerequisite course for any other course. No other courses are affected by the changes made in Vibrations. ADAMS was introduced to the students in one lecture, and some tutorials were made available online for their use. Some HW problems and a semester project were assigned to the students in which the students were asked to simulate the systems using Simulink and ADAMS and compare their results. It should be noted that the students had prior knowledge of MATLAB and Simulink but were exposed to ADAMS for the first time. A brief introduction to the software is outlined below:

## Software Description:

**Simulink:** Simulink is a graphical editor for modeling, simulating, and analyzing dynamic systems. It consists of a library of blocks (Figure 1) representing the models. It is commonly used in control systems and digital signal processing for simulation.

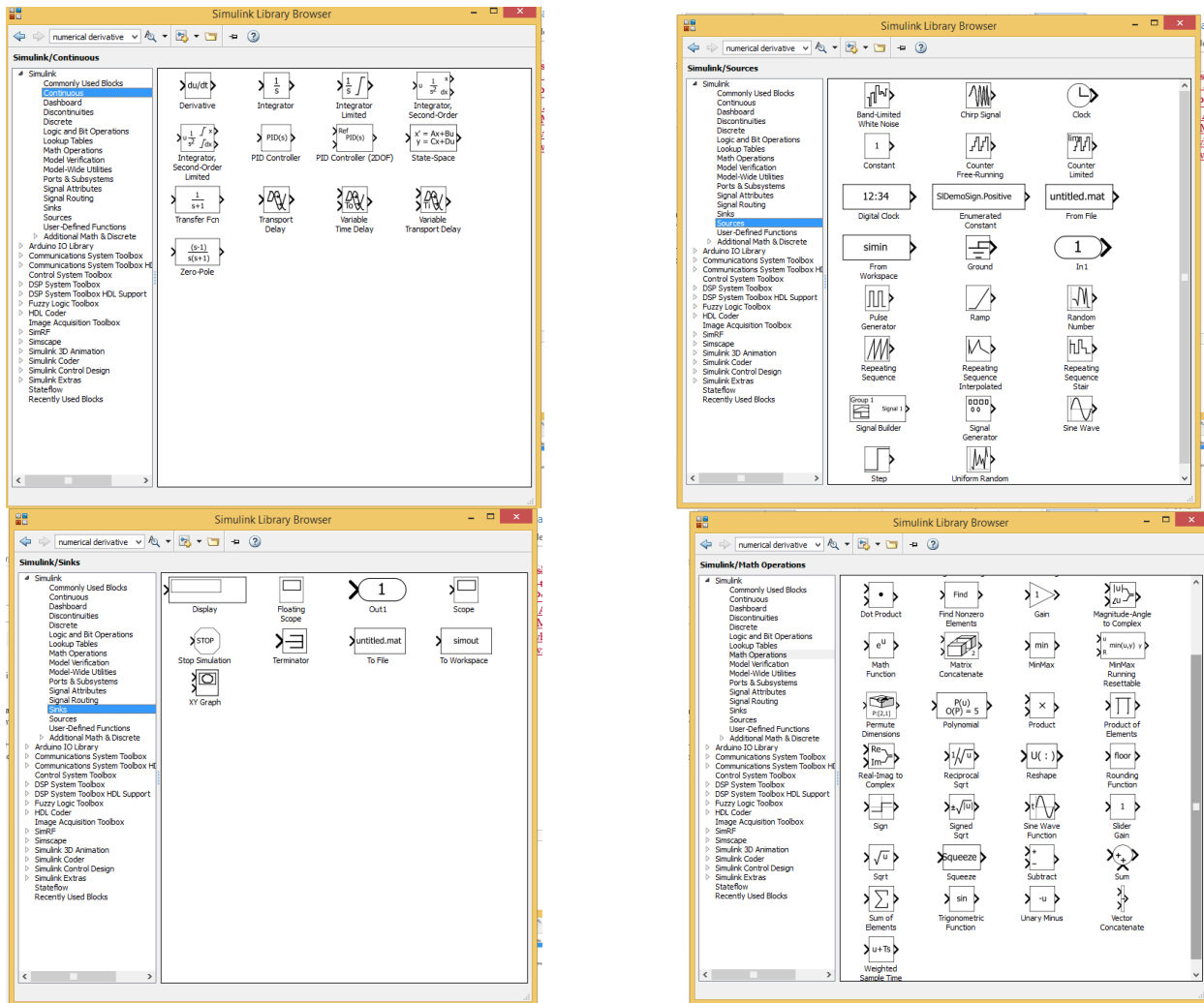


Figure 1- Simulink Library of Blocks

## ADAMS:

ADAMS (Automated Dynamic Analysis of Mechanical Systems) is a multibody dynamics simulation software that can be utilized to study moving parts in complex machinery. An engineer can use ADAMS to analyze the forces and loads that are distributed among different components of a machine.

**Simulations:** One of the assigned problems in homework is given below:

Problem Statement [8]: Figure 2 shows a simple model of a motor vehicle that can vibrate in a vertical direction while traveling over a rough road. The vehicle has a mass of 1200 kg. The suspension system has a spring constant of 400 kN/m and a damping ratio of 0.5. If the vehicle speed is 20 km/hr, determine the displacement amplitude of the vehicle. The road surface varies sinusoidally with an amplitude of  $Y = 0.05\text{m}$  and a wavelength of 6m. Simulate the response of the system in ADAMS and compare it with the response from Simulink.

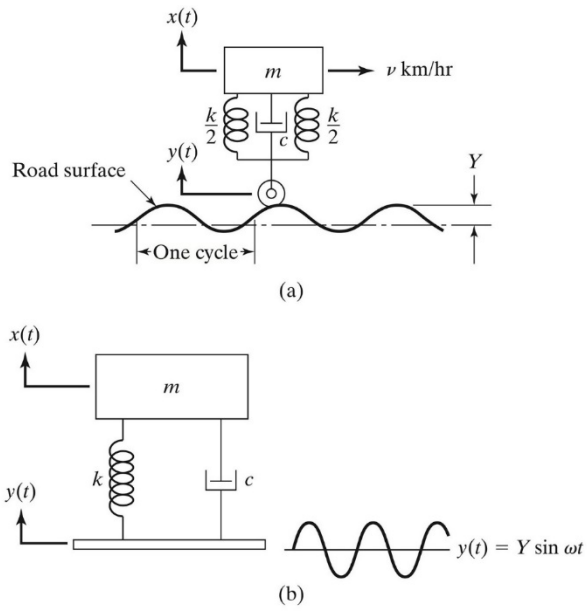


Figure 2- Model of a motor vehicle [8]

**Simulink Model:**

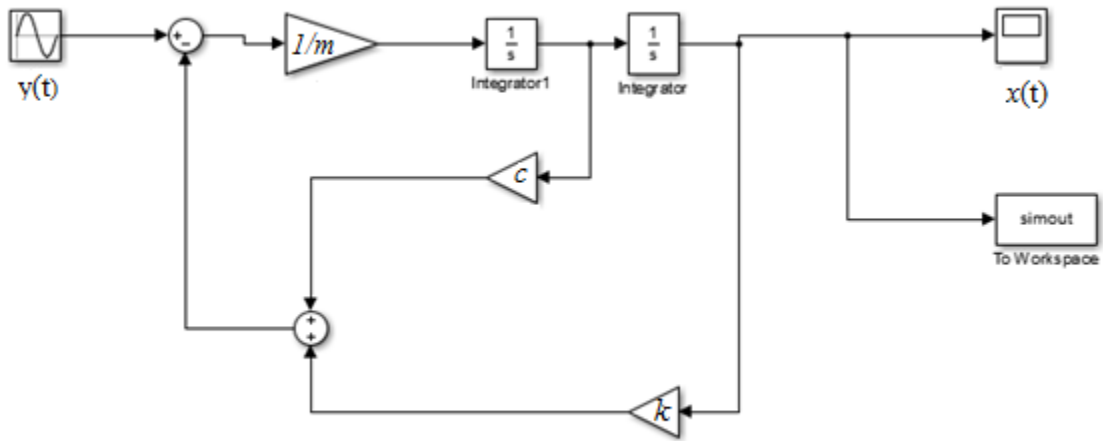


Figure 3- Simulink Model of the system

## Simulink Response:

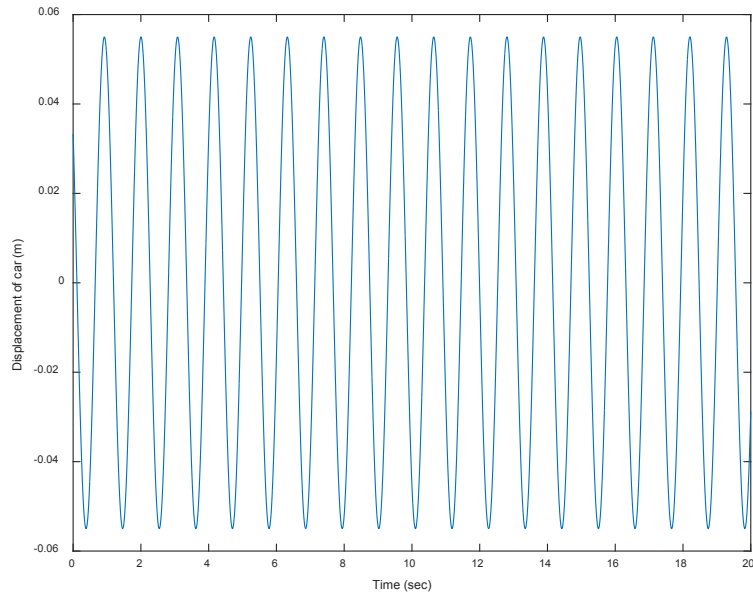


Figure 4- Displacement of car

## ADAMS Model:

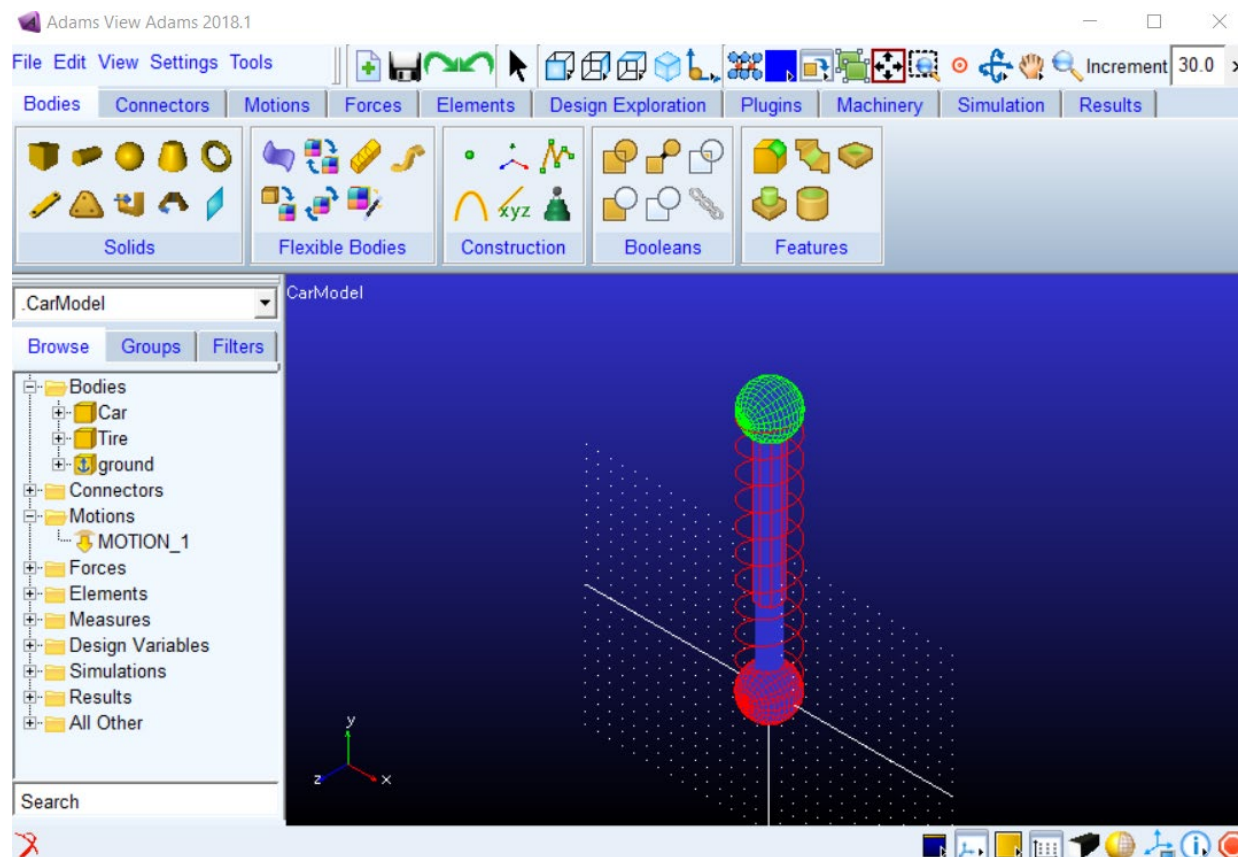


Figure 5- Adams Model of the system

## ADAMS Response:

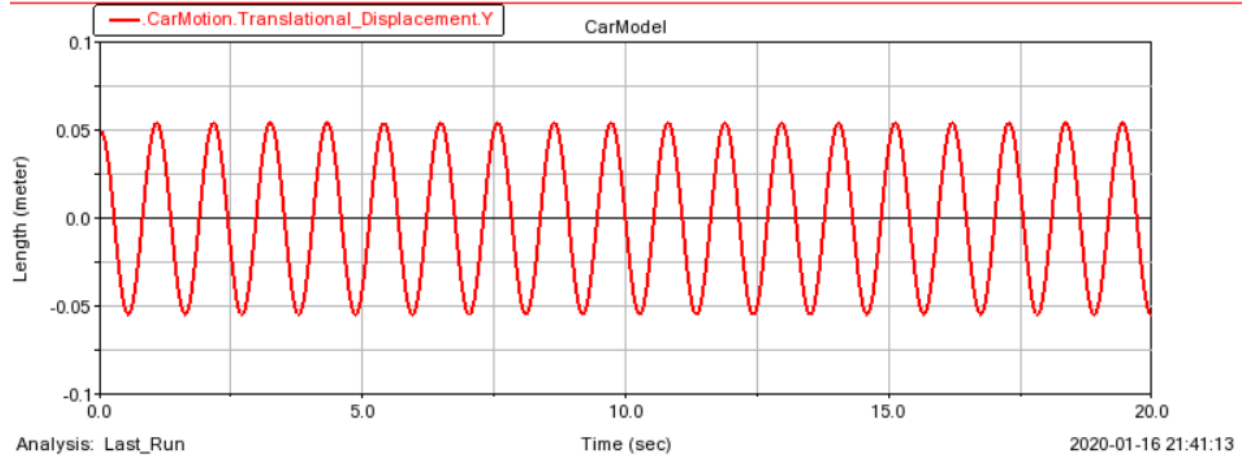


Figure 6- Displacement of car from ADAMS

As seen in figure 3, the Simulink model only represents the mathematical model of the system (differential equation integrated), whereas the ADAMS model (figure 5) shows the actual system whose animation can be viewed as well.

### Assigned Project: Vibration Control for a Milling Machine



Figure 7- Milling Machine [10]

The students were tasked to design a vibration isolator for a milling machine whose operation is disturbed by the vibrations coming from a crane, forging press, and an air compressor in operation nearby. These vibrations are detrimental to achieve specified accuracies during precision milling operations. The milling machine is subjected to harmonic excitations in the form

$y_1(t) = Y_1 e^{-0.1\omega_1 t} \sin\omega_1 t$  due to ground vibrations from a crane,  $y_2(t) = Y_2 \sin\omega_2 t$  due to ground vibrations from forging press and  $y_3(t) = Y_3 \sin\omega_3 t$  due to ground vibrations from the air compressor. The excitation frequencies in the three cases are given as  $20\pi$ ,  $30\pi$  and  $40\pi$  rad/sec respectively. Also, the amplitudes of the ground motion are given as  $14.82 \mu\text{m}$ ,  $20.10 \mu\text{m}$ , and  $20.47 \mu\text{m}$  respectively. The equivalent mass, stiffness, and damping ratio of the machine tool head in vertical vibration (at the location of the cutter) are experimentally determined to be 500 kg, 480 kN/m and 0.15, respectively. The equivalent mass of the machine tool base is 1000 kg. Design an isolator to improve cutting accuracies and attach it in between the machine tool base and the ground (by specifying its mass, damping and stiffness) such that the maximum vertical displacement of the milling cutter due to ground vibrations from all three sources does not exceed  $5 \mu\text{m}$  peak-to-peak.

The students were asked to use any two methods to compare their results. It can be Simulink vs hand calculations or Simulink vs. ADAMS Simulations. Most of the students use the two software as the system analysis is very hard to do by hand. Their results were comparable.

#### **Student Survey:** Sample size: 5

The following questions were asked in the survey to assess the interest of students in using ADAMS in future offerings.

Question 1. ADAMS simulations provide an effective source of learning response analysis. The options were Strongly agree, Agree, No Opinion, Disagree and Strongly Disagree  
100% of the students agree

Question 2. What do you think about the relativeness of ADAMS with course content?  
40% of students think it is easier to use than MATLAB and should be incorporated more in home works and lectures.

40% thinks more in-depth instruction should be provided.

20% liked it but were more comfortable with MATLAB/Simulink.

Question 3. Would you prefer to use ADAMS or MATLAB/Simulink for simulation purpose  
80% (4 students) of the students prefer Simulink and 20 % (1 student) prefers ADAMS.

This could be because the 4 students who took this course had prior knowledge of MATLAB and they are more comfortable with it and the student who would like to use ADAMS did not have prior knowledge of MATLAB and feels that ADAMS is more user-friendly than Simulink.

#### **Conclusion:**

The paper presents an active learning approach to teach vibrations effectively by engaging students in lectures by doing some simulations of vibrating systems in Simulink and ADAMS. The students had prior knowledge of Simulink and ADAMS was introduced to them for the first time. A survey was conducted to see the interest of the students in ADAMS as it was better software in terms of visual representation of the system. Based on the survey results, the students did not show much interest in ADAMS but no conclusion can be drawn at this point since the class size was very small (5 students) and also the students were more comfortable with using Simulink than ADAMS

because of their prior knowledge of the software. It would be more fair to compare the software if the students do not have any prior knowledge of both the software. The only student who learned both the software for the first time in this course preferred to use ADAMS because it is more user-friendly. The popularity and interest in ADAMS will be assessed again in the next offering when there will be more students in the class to get a better understanding of their interests.

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