

Introduction of Dynamics Laboratory in MET Program

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Abstract – Dynamics is scheduled as a sophomore level second semester class in the Mechanical Engineering Technology curriculum at Georgia Southern University. It is currently a four credit hour course out of which one credit is separately assigned for a two hour lab session. However, these lab hours were primarily used as interactive problem solving sessions. In the present work, the author introduced three separate physical laboratory experiments in the course while retaining most of the hours for problem solving sessions. The challenge was to introduce a “hands on” component in the course in compliance with the philosophy of a technology program without the requirement of a high level of report-writing skill. The first experiment was the motion analysis of a toy cart where the data was collected and analyzed using National Instruments’ hardware and LabView software. The second experiment was the determination of the mass moment of inertia of cylindrical object using the torsional pendulum principle. These two experiments were severed from the current lab-based Mechatronics course and a senior level elective Vibration course to free up their lab hours for more advanced topics. The last experiment was the determination of coefficient of restitution. This experiment is still in the developing stage. A Newton’s pendulum was modified to build the experimental set up. Students were asked for their suggestions to improve the accuracy and method of this experiment. The optimum method will be adopted for future use. A detailed survey was conducted which shows a positive opinion of the students about the introduction physical lab experiments in the Dynamics course. This work brings the undergraduate student research component into the course.

Keywords: Laboratory, Dynamics, Curriculum.

INTRODUCTION

Dynamics is a required course for Mechanical Engineering and Mechanical Engineering Technology curriculum throughout the United States. Often it is shared by the students from other programs, especially those who are looking for a Civil major. In Georgia Southern University, it is scheduled as a second year spring semester course. It is a four credit course with one credit assigned to a two hour lab session per week. These lab sessions were used for interactive problem solving sessions. Many of the Instructors, including the author, used to conduct quizzes and even some longer tests during those “lab” periods. However, the recent ABET visit prompted our instructors to reconsider the content of the course. It was observed that the course lagged in encouraging students of independent thinking and coming up with design solution of technical problems.

There are educators who introduced laboratories and design components as early as Dynamics in the curriculum. Some of them are simulations using software like Working Model, MatLab etc [1]. In Lake Superior State University McDonald et. al. introduced Instrumentation and Control at various level of curriculum [2]. Dynamics was one of the courses where the instrumentation was used. DeBella’s approach of introducing Lab into Dynamics course was unique [3]. In his lab, the experiments were selected from the textbook problems and students had to design their own experimental set up.

In the current work, a middle ground was chosen. Students were given two “canned” experiments where there was no room for flexibility. One of them was a standard toy cart experiment using National Instrument’s data acquisition system (NI DAQ). The other one was the measurement of mass moment of inertia based on the

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torsional pendulum principle. The third experiment, however, was open ended. It was barely a “working experiment” and the students’ opinion was asked to improve the experiment under a budgetary constraint. These three lab activities are illustrated in the following section.

EXPERIMENTS

The first experiment was based on the laws that students study in their first two sections of a Dynamics textbook, kinematics and kinetics of particles. It was a well known standard toy cart experiment, where a cart moves along a guide rail track due to a weight tied to the cart and hangs over a pulley. The Figure 1 shows the track that guides the cart. The set up for this experiment also had an electro-magnetic triggering system that set the motion of the cart. Transducers (housed inside the red box as shown in the figure) are used to convert the displacement, velocity and acceleration of the cart into electrical signals. National Instruments’ hardware was used to collect these electrical signals. LabView program was used for processing the data. For visual observation, displacement, velocity and accelerations were displayed on the computer screen almost at a “real time” (Fig.2). As expected, displacement showed quadratic relationship with time while the velocity was linear. Theoretically, the acceleration should be constant with time since the force on the cart remained constant. However, due to uneven friction, primarily at the wheels and at the pulley, the acceleration did not remain constant and had variations throughout the experimental run. Students were asked to conduct the experiment and collect all the data. It can be observed from the LabView diagram, the rides were extremely “bumpy” at the beginning and also at the end of the toy cart travel. Students were directed to ignore those portions and only consider the relatively smooth central portion for their analysis. In other words, in the analysis, time, t , was set to zero well after the toy cart has started its motion. So, it had non-zero initial displacement and velocity. Similarly, final time was set well before the cart actually came to stop after hitting a stopper. Students were asked to find out the average acceleration within the time period and compare that with the theoretical value. Students were also asked to verify the final displacement and velocity given their initial values by using the average acceleration. The author used to conduct this experiment in a sophomore level Mechatronics class. Since this lab is more appropriate for the Dynamics, the author decided to bring that lab to the Dynamics course to free up some of the Lab time for the newly developed Mechatronics course. Fast Fourier Transform (FFT) on the acceleration data can reveal that the variation in acceleration was random in nature. This FFT part of the analysis was used in Vibration and Preventive Maintenance, a senior level elective course [4].

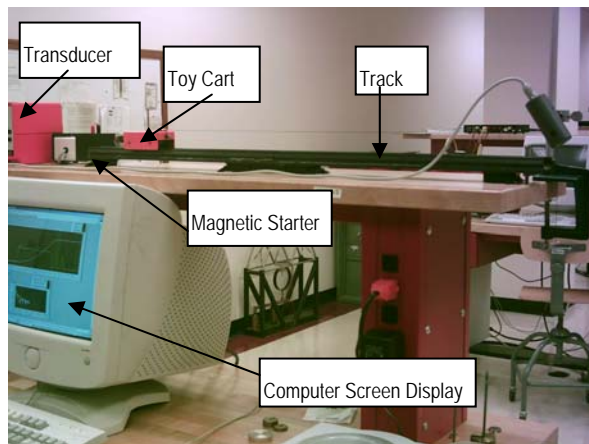


Fig 1. Set up for toy cart experiment.

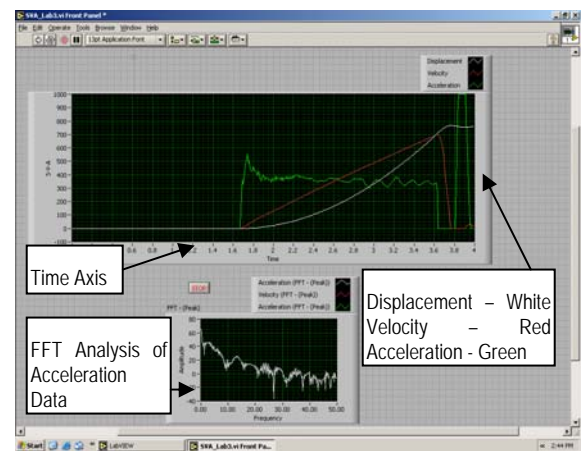


Fig.2. LabView display panel for toy cart

The second experiment was related to rotational mass (Fig. 3). This experimental set up was used to determine the mass moment of inertia of an object using the principle of torsional pendulum principle. Mass Moments of inertias of two circular objects, a hollow cylinder and a hollow cylinder with a cylindrical plug inside, were measured. At first the object was rotated by a small amount (within 10°) and was released. Students measured the time period of the freely oscillating object. Students measured some relevant dimensions and used a textbook formula to find out the radius of gyration of the object. Subsequently they were able to experimentally determine its mass moment of

inertia. The actual derivation of the radius of gyration formula relating the time period of oscillation was beyond the scope of the class and students had to accept that mathematical formula involving all the parameters as a “black box”. Since the shape of the object was uniform the students were able to calculate the mass moment of inertia theoretically. They compared the experimental results with the theoretical ones. They were also asked to address the source(s) of possible error(s) in a written report. This lab was originally developed for a senior level elective Vibration class. According to the author, however, considering the level of complexity involved, this lab is more suitable for a sophomore level Dynamics course.

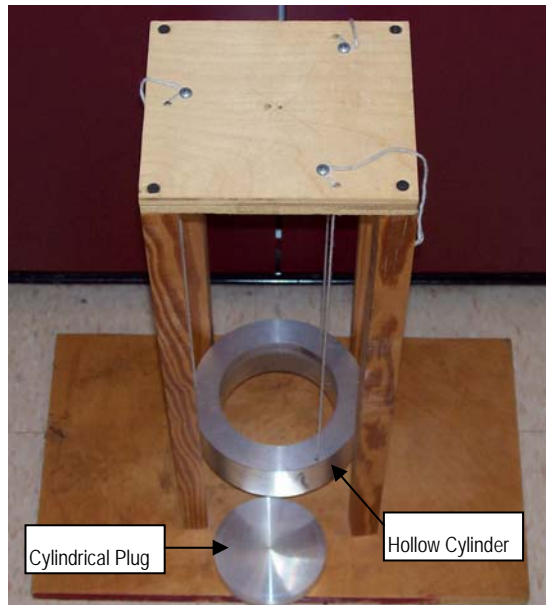


Fig 3. Mass Moment of Inertia Measurement.

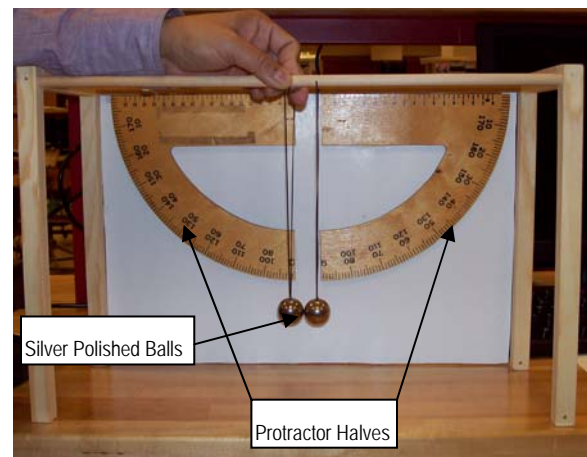


Fig 4. Coefficient of Restitution Measurement.

The third experiment was open ended. A conventional Newton’s pendulum experimental set up was modified and used to determine the coefficient of restitution in an impact between two silver polished balls (Fig.4). A protractor was cut in two halves and each half was used to track the motion of a ball. In this experiment, one of the balls was released from a certain height as measured by the angle in one half of the protractor. It impacted the other ball which moved up as measured by the other half of the protractor. From these two angle measurements, one can calculate the co-efficient of restitution of this impact. The experiment was repeated for several input release angles to show the consistency of the answer. This experiment was prone to some serious errors and students had to pay very close attention while conducting that experiment. The major problems that the students came across are listed below:

(1) It was extremely difficult to measure the maximum angle that the impacted ball traveled. It was an instantaneous phenomenon and with the naked eye, even with the careful observation, it was extremely hard to detect. (2) The impact between the balls was not a direct central impact. The co-efficient of restitution equation used, however, is based on direct central impact. There were two possible reasons why the alignment of the balls was hard to achieve; (a) Two balls were misaligned to start with, due to unequal length of the strings on both sides etc. (b) The release of the first ball was not properly directed in a concentric way and thus resulted in an oblique central impact instead of a direct central impact.

STUDENTS’ INPUT

The third experiment was used as a tool to initiate independent thinking from the students. That in turn forced the students to do some research which was new for this type of sophomore level undergraduate course. As described earlier the third experiments, in its current status, has lot of pit falls and needs to be modified. Students, while conducting the experiment, realized the probable sources of errors. At the end of the experiment the students were asked for their suggestions to improve the lab. Students were also asked to write down their ideas to modify the experiment in specific details within a budget of one hundred dollars. That gave the students independent thinking

and allowed them to explore the possible avenues to improve the set up. It also gave the students freedom to implement their project within a budget, at least in paper. It was announced in the class that the best feasible solution would be chosen for implementation for future lab classes.

The students came up with a wide range of solutions. Some of them are feasible and some of them are not. The use of digital camera and the use of laser for measuring the angles were the most common responses amongst the students. Most of them researched online and came up with the probable solutions. They also worked on their budgets. Some of them even approached the author to physically set up the experiment. While there were a lot of solutions for the accuracy of the angle measurement, none of the students addressed the other major source of error, the alignment issue. The next time around, the author plans to ask the students to come up with specific ideas to rectify that.

DISCUSSION

Dynamics is a typical text book oriented sophomore level course. Since the program currently does not have any typical first year design experience course, students are not exposed to design and implementation as required by the ABET criteria. So, an open ended topic like this, even in the middle of a standard Dynamics course, fits the assessment criteria and mission of the program.

Students are exposed to Lab environment for the first time beyond their first level of Physics lab. Data collection and analysis is a very important part of the program and it is introduced in the early stage. Students of MET program concurrently take Mechatronics class where they learn how to do data collection and analysis using National Instruments' hardware and LabView software system. In that class they are also taught on the subject matter of technical report writing. That way the Dynamics labs complement what they have learnt in Mechatronics class.

A student survey was conducted to get feedback from the students. Thirty eight students participated in that survey. Students were asked to fill out a questioner with answers in a scale of one to five, where five was excellent and one was poor. It was observed that the average for all the responses lied between 3.32 and 3.92. (Three stands for good and four stands for very good). It was also observed that the highest positive response came from a question about their opinion whether these labs complemented the lecture. The least positive response came from their opinion regarding the level of learning experience they went through while trying to find a better solution for Lab 3. Evaluating the student agreement of individual questions found no single question had more than 47% response to any particular rating on the scale. The variation of these responses ranged from 0-47%. 47% chose 4 out of 5 while expressing their opinion whether these lab complemented the lecture. In question number five, students were asked whether they were involved due to the interactive nature of the lab. Again, 47% students chose 4 in a scale of 5. Overall, the students' feedback was encouraging.

CONCLUSION

Physical "hands on" labs were introduced for the first time in a sophomore level Dynamics class in a Mechanical Engineering Technology Program at Georgia Southern University. There were three group laboratory activities. Two of those lab activities were well established. The third one required inputs from the students for the improvement of the experimental set up under a budgetary constrain. Students were surveyed and the responses were very positive. This lab also satisfied the ABET criteria of independent thinking and technical solution of a real problem and gave the students the opportunity to work as a team right from the sophomore level.

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