

Application of the Working Model[®] Software in Mechanical Engineering Technology

**Dr. Thomas G. Boronkay, Laura Caldwell, Ronald D. Earley
University of Cincinnati / Miami University**

Abstract

The traditional method of presenting Engineering Science and Engineering Technology courses emphasizes theoretical derivations and applications of formulas to solve practical problems. While this method is effective, it does not provide adequate visual aids to reinforce the students' understanding of the subjects. The visual component of most lectures consists of manual sketches on the board or projected images. Very often, the quality of these visual aids is unsatisfactory. In addition, the static sketches are unable to represent motion. In order to improve student understanding and visualization of the course material the authors have modified their courses to include the Working Model[®] software. This paper describes how this software has been integrated into three Mechanical Engineering Technology courses at the University of Cincinnati and Miami University at the freshmen, sophomore, and junior levels. Representative laboratory projects and assignments are presented.

Introduction

In the past, the freshman level Statics course at Miami University was structured to include lecture and recitation sessions only. Textbook practice problems were assigned to help reinforce the theoretical concepts and solution methods discussed during the lectures. Beginning with the 1998-99 academic year the course was modified to include a computer laboratory. In this laboratory, students are taught to use an animation and simulation software package to enhance and reinforce their understanding of the lecture material.

Prior to 1997, the sophomore level Mechanisms course at the College of Applied Science, University of Cincinnati was structured to include lecture, recitation, and laboratory sessions. The laboratory sessions required the students to solve problems utilizing a combination of manual and non-graphical computerized techniques. Both of these methods were time consuming and lacked visual representation of full-cycle motion. Beginning with the 1997-98 academic year the course was modified to include the use of Working Model[®] to enhance visualization and provide a means of design iteration with full-cycle analysis. The laboratory portion of the junior level Mechanical Design course at the College of Applied Science was modified beginning with the 1997-98 academic year. An animation and simulation software package was introduced to reinforce

existing solution methods. In the laboratory portion of this course, students work in teams to design a subsystem of an industrial machine using Working Model[®] software by Knowledge Revolution.

This paper describes how the software was introduced in the three courses mentioned above. Samples of the laboratory manuals, assignments, and project are also presented. The implementation section describes how the introduction of this software package helps to enhance the concept of the interconnectivity and continuity of the Engineering Technology course sequence.

Implementation

At Miami University, the three-semester-hour Statics course consists of a two credit-hour lecture and a one credit-hour computer laboratory. In the laboratory, familiarization with the software is accomplished by having students follow a laboratory manual. Step-by-step directions guide them in setting up and solving the initial assignments. As students familiarize themselves with the software fewer and fewer details are provided. This forces them to fill-in the blanks and become more conversant with the software package while getting a better handle on the analytical aspects of the solution. By the end of the semester students are proficient enough to solve the final examination using both the computer and the standard analytical methods. The computer portion of the final examination was factored into the laboratory grade.

At the College of Applied Science, the four-quarter-hour Mechanisms course consists of a three credit-hour lecture and a one credit-hour laboratory. During the laboratory portion of the course, students use a combination of manual and non-graphical computerized solution methods supplemented by the Working Model[®] software. First the instructor demonstrates the use of the software through examples then the students are assigned problems to solve both by hand computation and using the computer. In addition to these problems, teams of students work on a 5-week industrial type project requiring them to use all concepts and solution techniques. As the students work through these laboratory assignments not only do they gain knowledge related to the specific course but are also prepared for the next level design courses.

In addition, the four credit-hour junior-level Mechanical Design course also consists of lecture and laboratory sessions. As in the previous course, teams of students are assigned a design project. During the past two years, projects furnished by local industry consisted of designing and analyzing a sub-systems of packaging machinery. The design calculations, which included analytical linkage synthesis and Polydyne cam design, were first carried out, using software furnished with their textbooks (Norton, Design of Machinery). Once the preliminary linkage and cam dimensions were obtained, Working Model[®] software was used to simulate the motion of the mechanisms and to calculate dynamic forces in the components. These forces were then used to size the parts, using standard design methods. A sample project assignment and a copy of the computer model are included in this paper. Building on their experience with the software in the Mechanisms course, students were well prepared to successfully complete all phases of the project.

Statics Course Laboratory Manual

ENT 271

LAB 1

- 1 Pull-down View→ Click Numbers and Units→ Click down arrow→ Click English Pounds→ Click OK
 - 2 Pull-down View→ Click View Size→ Click Window Width→ Type 240→Click OK
 - 3 Pull-down World→Click Gravity→Click None
 - 4 Pick the Rectangle Icon Button→Click anywhere within the Background→ Drag the Rectangle out Horizontally→Click
 - 5 Adjust the Rectangle Size→ Type and Enter 3 in the H-Field→ Type and Enter 100 in the W-Field
 - 6 Pull-down Edit→Click Duplicate
 - 7 Adjust Rectangle Rotation→ Type and Enter 60 in the Φ -Field
 - 8 Pick the Point Element→ Snap the Point Element to the mid-point of the lower end of the inclined rectangle by clicking
 - 9 Similarly, place a Point Element at the mid-point of the left end of the horizontal rectangle.
 - 10 Pick the Anchor Tool→ Place the Anchor Tool anywhere on the inclined rectangle by Clicking→Click again anywhere within a blank area of the background to deselect the Anchor
 - 11 Hold the Shift Key down and Pick Both Point Elements→ Pick the Join Icon button→ If the horizontal rectangle rotates during the Joining process, restore it to Horizontal by Picking it and Typing and Entering 0 in the Φ -Field
 - 12 Place two Pin Joints, one at the mid-point of the right end of the Horizontal Rectangle and the other at the mid-point of the top end of the Inclined Rectangle→ These Pin Joints pin each rectangle to the background
 - 13 Pick the Anchor Icon→ Pull-down Edit→ Pick Delete
 - 14 Pick the Force Icon Button→Click at the joined ends of the Rectangles→ Drag the Force Icon upwards→ Click
 - 15 Adjust the Force→ Type and Enter -600 in the F_y field→ Type and Enter 0 in the F_x field
 - 16 Pick the Force Icon Button→Click at the joined ends of the rectangles→ Drag the Force Icon down and to the right→Click
 - 17 Adjust the Force→ Type and Enter -693 in the F_x field→ Type and Enter 400 in the F_y field
 - 18 Pick the Pin Joint at the right end of the Horizontal Rectangle→ Pull-down Measure→ Pick Force
 - 19 Pick the Pin Joint at the top end of the Inclined Rectangle→ Pull-down Measure→ Pick Force
 - 20 Pick the Run Button→ Pick anywhere within a blank area of the background to Stop Run→ Observe the Meter Values→ Pick the Reset Button
- (see Figure 1 for the solution)

ENT 271

LAB 2

Model the two-dimensional frame structure using rectangle masses for the horizontal members ABCD and EFGH. Use Rod Constraints to model the rotated members CF and DG. You will have to set Gravity to NONE. Create Meters to measure the forces produced by the 700 Newton load in members CF and DG. Run the simulation and print out a hard copy of the solution. (see Figure 2 for the solution)

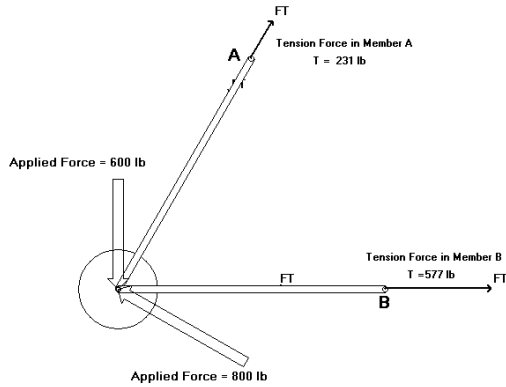


Figure 1

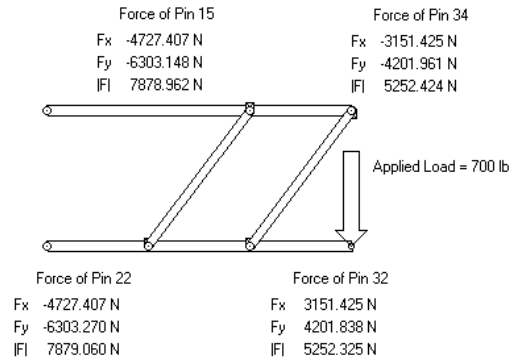


Figure 2

MECHANISMS LAB 2 - Inversions, Grashof, Working Model

1. Make a cardboard model of a 4 bar link (2", 6", 3", 6.5" in that order). Use the model and the computer program (Working Model[®]) to answer and verify the following questions. Hand in the answer for each question for each inversion:

- Inversion I = 6.5 inch link grounded
- Inversion II = 2 inch link grounded
- Inversion III = 6 inch link grounded
- Inversion IV = 3 inch link grounded

Definitions we will use for this lab only: Crank = attached to the left ground pin. Rocker = attached to the right ground pin. Coupler = floating link between crank and rocker.

- a) Sketch the inversion.
 - b) Is it Grashof? (Verify with computer)
 - c) Does the crank make a complete revolution? (verify)
 - d) Does the coupler make a complete revolution? (verify)
 - e) Does the rocker make a complete revolution? (verify)
 - f) Do links or pins interfere with each other when the mechanism is pinned to the world? Describe.
 - g) Sketch any toggle position(s), which occur. (verify)
2. Put it all together. Describe what can be determined about a linkage given the lengths (pgs 44-47, Norton, Design of Machinery).

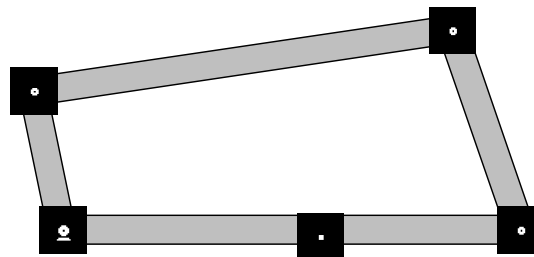
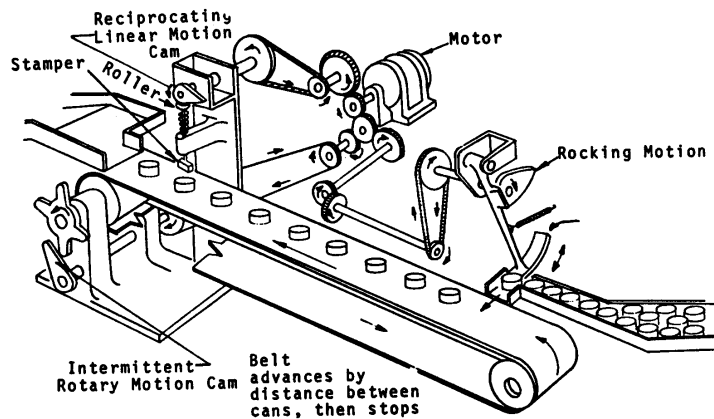


Fig. 3 Inversion I (not full scale)

Mechanisms Project (weeks 6 - 10 of quarter)



The stamping system must be designed using the given requirements:

- Maximum velocity of the can, 30 in/s
- Size of the can, 4-inch diameter
- Width of the conveyor, 6 inches
- Replace the rocking motion can pusher with a linkage.
- Drum diameter on the conveyor, 10 inches.
- It is required to minimize the cycle time.
- It is desirable for the accelerations of all parts to be less than 1 g and required that they be less than 1.5 g.

Fig. 4 Schematic for project. (Ref. Packaging/Converting Machinery Components)

Week 6-Construct the time charts and select an intermittent motion device.

Week 7-Synthesize the pusher and verify on Working Model that it will work.

Week 8-Specify the motor speed and verify that the velocities and accelerations are within limits. Calculate the sprocket ratios for the pusher, stamper, and conveyor.

Week 9-Draw the pusher and fixturing on CAD. Show front and top views.

Week 10-Present results as an oral report at the lab meeting. Turn in the final report.

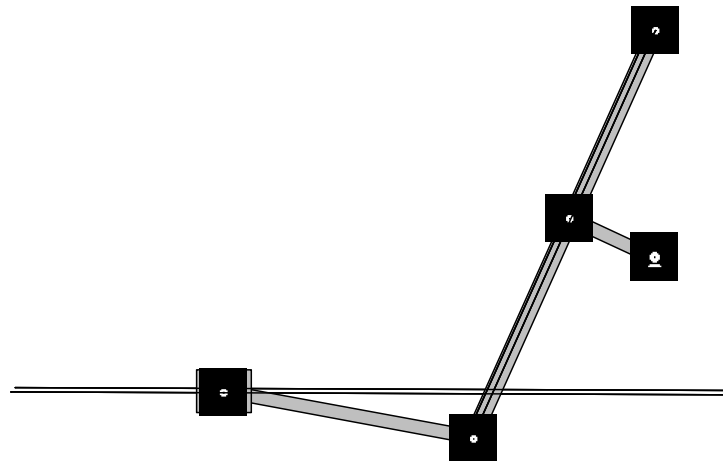


Fig. 5 Example of a quick-return pusher solution.

MECHANICAL DESIGN PROJECT

Partition Feeder

You are a member of a team, which is designing a machine to package your favorite beer bottles. Your group is assigned the development of a sub-system that inserts cardboard partitions between the bottles, in cartons coming down the line. (See Fig. 6.)

Partition Feeder

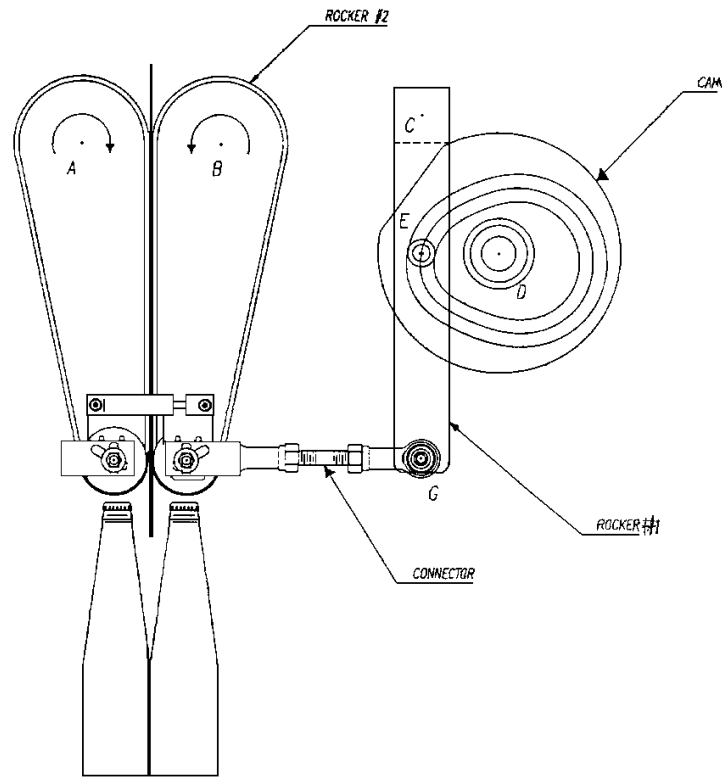


Fig. 6 Partition Feeder

The project will be divided into Four Parts:

Part 1:

Determine the Preliminary dimensions of the 4-Bar Linkage, using Analytical Synthesis methods that will generate the desired motion.

Part 2:

Design the Preliminary Cam profile. (The combination of parts 1 & 2 should generate the desired motion)

Part 3:

Perform the Dynamic Analyses of the Linkage and Cam, determine the Forces, torques etc., using both analytical methods and the Working Model© software package

Part 4:

Final Redesign of the Cam and Linkage. Design of the drive shaft. Selection of the drive motor, bearings, etc..

Known Parameters:

Bottle Conveyor Speed: 100 two Bottle grouping/minute

Bottle Dimensions: See attached Figure

Partition Dimension: See attached Figure

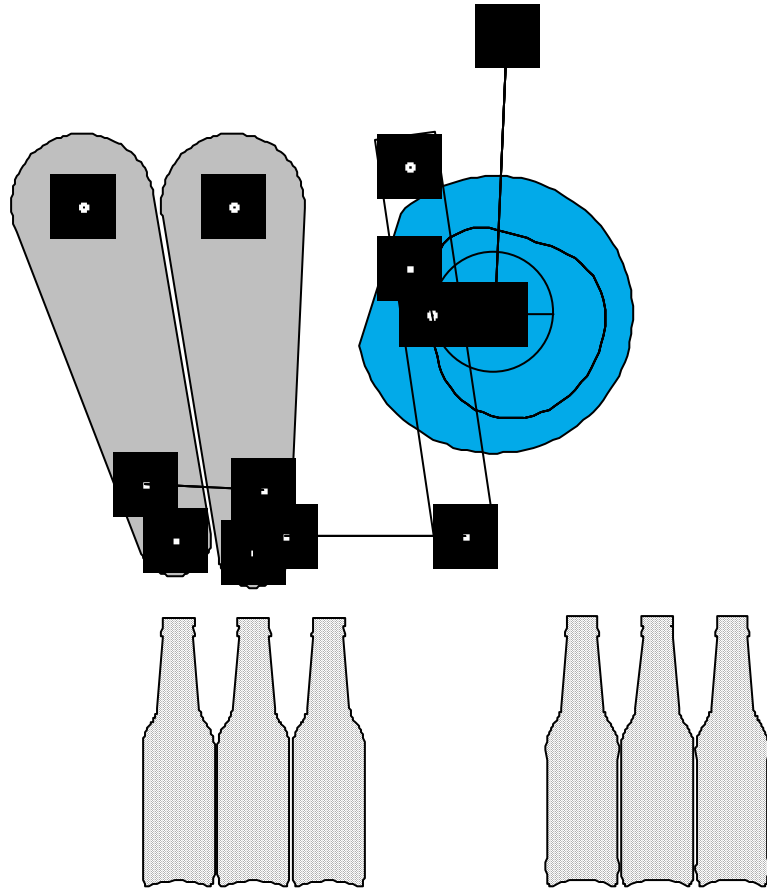


Fig. 7 Partition Feeder Solution on Working Model[®]

Conclusions

Since the introduction of the software package into the laboratory portion of the above courses, the authors have observed increased student interest and understanding of the subjects. To date formal assessment data have been collected only in the Statics course in the form of lecture/lab/instructor evaluations. Seventy one percent (71%) of a student population of fourteen (14) rated the laboratory portion of the course as excellent. Only two students rated it below average. The evaluation forms used in the Mechanisms and Mechanical Design courses showed overall improvement when compared to previous years, however the form had no separate questions specifically targeted to the laboratories.

The approach described in this paper demonstrates a way of reinforcing the common-thread that should be present in a well-designed Engineering Technology program. Using common software and reinforcing analytical computations with graphical simulation/animation in successive courses achieved this objective.

Bibliography

1. Cole J. Brooking, Daniel A. Smith, "Simulation and Animation of Kinematic and Dynamic Machinery Systems with MATLAB, 1998 ASEE Annual Conference,
2. George H. Staab, "An Interactive Computer Tutorial for Strength of Materials", 1998 ASEE Annual Conference.
3. William E. Cole, "Using CAD Analysis Tools to Teach Mechanical Engineering Technology", 1998 ASEE Annual Conference.
4. Thomas G. Boronkay, Ronald D. Earley, "Simulation Software in a Dynamics Laboratory", 1998 ASEE Annual Conference.
5. Working Model User Manual, Knowledge Revolution.
6. *Packaging/Converting Machinery Components*, 6th ed., Packaging Machinery Manufacturers Institute, Arlington, VA. 1996.
7. Robert L. Norton, Design of Machinery, McGraw-Hill, Inc. New York, 1992.

Thomas G. Boronkay is a Professor of Mechanical Engineering Technology at the College of Applied Science, University of Cincinnati. He has a Ph.D. in mechanical engineering from the University of Cincinnati, and is a licensed professional engineer in the state of Ohio. He joined the faculty after twenty years of industrial experience in the areas of mechanical design, stress analysis and simulation. He developed and taught courses in mechanical design, product development, design for manufacture and computer aided engineering.

Ronald D. Earley is an Associate Professor at the College of Applied Science, Miami University. He has an MSAE from the University of Cincinnati and is a registered professional engineer in the states of Ohio and Hawaii. He has over ten years industrial experience in the aircraft industry. He has over twenty-five years combined teaching experience at the University of Cincinnati and Miami University. His areas of interest are Mechanical and Computer Aided Design.

Laura Caldwell has 22 years of academic and industrial experience. Her area of interest is data collection and analysis. She has conducted projects on production data for reporting and measurement data for statistical analysis.