New Trends and Issues Proceedings on Humanities and Social Sciences

Volume 7, Issue 3, (2020) 53-60

www.prosoc.eu

Selected Paper of 9th Cyprus International Conference on Educational Research (CYICER-2020) 18-20 June 2020, Bahçeşehir Cyprus University Nicosia / TRNC (ONLINE CONFERENCE)

Solid Work simulation as a virtual laboratory concept for supporting student learning of mechanical engineering

Adivhaho Frene Netshimbupfe*, Department of Mechanical Engineering, Engineering Faculty, Near East University, 99138 Nicosia (via Mersin 10, Turkey), Cyprus

Mohame Almojtba Hamid Ali Abdalla, Department of Mechanical Engineering, Engineering Faculty, Near East University, 99138 Nicosia (via Mersin 10, Turkey), Cyprus

Binnur Demir Erdem, Department of Mechanical Engineering, Engineering Faculty, Near East University, 99138 Nicosia (via Mersin 10, Turkey), Cyprus

Youssef Kassem, Department of Mechanical Engineering, Engineering Faculty, Near East University, 99138 Nicosia (via Mersin 10, Turkey), Cyprus

Huseyin Camur, Department of Civil Engineering, Civil and Environment Engineering Faculty, Near East University, 99138 Nicosia (via Mersin 10, Turkey), Cyprus

Suggested Citation:
Netshimbupfe, A. F., Abdalla, M. A. H. A., Erdem, B. D., Kassem, Y. & Camur, H. (2020). Solid Work simulation as a virtual laboratory concept for supporting student learning of mechanical engineering. *New Trends and Issues Proceedings on Humanities and Social Sciences. 7*(3), pp 53–60. Available from: www.prosoc.eu

Received from June 28, 2020; revised from September 25, 2020; accepted from Noverber 10, 2020.
Selection and peer review under responsibility of Prof. Dr. Huseyin Uzunboylu, Higher Education Planning, Supervision, Accreditation and Coordination Board, Cyprus.

Abstract

Solid Works is a complete 3D CAD design solution, providing the product design team with all the mechanical designs, verifications, motion simulations, data management and communication tools that they need. This article presents an example of the design and analysis of the Savonius rotor blade to generate 10kW power output in the field of Mechanical Engineering (ME) using the Solid Work package (SW-P). The study was structured as an educational design experiment, which used the SW-P in teaching some ME courses in the ME degree programme at Near East University. An experiment of two equivalent groups was designed, one of the groups was the experimental group and the other was the control group; each of them consisted of five students. The same project was given to the first (the experimental group) and second (the control group) groups using SW-P and the traditional method: textbook-based numerical methods, respectively. The SW-P proved to be an efficient method for supporting the students' ability to improve and understand the concept of some selected courses. The results show that students used SW-P to demonstrate a deeper learning and understanding of the course compared to the traditional method.

Keywords: Educational design experiment, educational technology, mechanical engineering, Solid Work package.

* ADDRESS FOR CORRESPONDENCE: Huseyin Camur, Department of Civil Engineering, Civil and Environment Engineering Faculty, Near East University, 99138 Nicosia (via Mersin 10, Turkey), Cyprus.
E-mail address: huseyin.camur@neu.edu.tr

1. Introduction

At Near East University (NEU), as at many places, undergraduate mechanical engineering (ME) students must take a course related to machine design and fluid mechanics. The goal of these courses is to teach students the fundamentals of how to design an object, for example, to design a wind turbine and support its structures. Therefore, computer-aided design programmes aim to teach students the fundamentals of how to get a computer to perform calculations that are too difficult or too cumbersome to perform and check manually.

Major themes include discretisation, iteration, sources of numerical error and practical management of that error. These are the fundamentals that undergird most of the modern engineering and scientific computational tools that have become indispensable in contemporary practice.

Despite its importance, it is challenging to make the material engaging for students. Although the top-selling text books attempt to make connections to engineering, the homework problems are typically superficial, unconvincing and uninspiring (Coller & Scott, 2009). In recent years, several researchers have already found that computer-aided education eased the process of learning and understanding the concept of the courses (Ibrahim, 2011; Moussavi & Fazly, 2010; Naukkarinen & Sainio, 2018; Tejado, Torres, Perez & Vinagre, 2016).

1.1. Study problem

The study problem is focused on finding out the influence of the Solid Work package (SW-P) in teaching fluid mechanics and machine design courses on the students' academic achievement, especially students of the ME Department at NEU, in comparison with their department, who benefit from this curriculum through traditional education. This problem is made more specific in the following question: What is the impact of using SW-P in supporting and understanding the concept of the courses and its uses in education on the students' academic achievement?

1.2. Study objectives

This study aims to find out the impact of using SW-P on ME students' academic achievement in the main courses of the ME Department through knowing the difference of academic achievement between the students who solved their homework/projects by using SW-P (the experimental group) and those who solved their homework/projects by using textbooks and numerical methods (the control group).

1.3. Study significance

The importance of the study's subject is a result of the following issues:

1. It allows reaching a simplified strategy which leads to easily understanding the concept of the courses.
2. It raises the ME students' academic achievement in computer-aided design software.
3. It develops the ME teachers' and students' ability of using computer-aided design software in teaching other mechanical courses, like heat transfer, thermodynamics, static, dynamic and so on.

4. It encourages the use of computer-aided design software in other departments, such as Automotive Engineering, Civil Engineering and Petroleum Engineering Departments.

1.4. Study equations

The study's subject provides an answer for the following two main questions:

Q1. Can SW-P software help the ME students to understand the real world?

Q2. Is ME students' willingness to use SW-P related to their use of computer technology for understanding the courses very well?

2. Method

2.1. Course description

Computer-aided designing, such as SW-P, can help the teacher to achieve course goals. Computer-aided designing programmes can be used to design and create blueprints and 3D models of objects that engineers want to build. These programmes allow students to gain experience with software and create their own designs. The software will teach/help the student to see how to the environment factors, such as temperature, humidity and so on, effect the designing product. Also, they help the instructors to explain the course in an easy way compared to explaining the course theoretically. The instructors/students can use these programmes in most courses like the following:

a) Fluid mechanics

Fluid mechanics is a branch of science concerned with moving and stationary fluids. Given that the vast majority of the observable mass in the universe exists in fluid state, that life as we know it is not possible without fluids and that the atmosphere and oceans covering this planet are fluids, fluid mechanics has unquestioned scientific and practical importance. Its allure crosses disciplinary boundaries, in part because it is described by a nonlinear field theory and also because it is readily observed. Mathematicians, physicists, scientists, engineers of many types and even artistes have been drawn to study, harness and exploit fluid mechanics to develop and test formal and computational techniques, to better understand the natural world and to attempt to improve the human condition.

b) Machine design

Machine design is one of the important branches of engineering design. To understand what exactly machine design or mechanical design is, let us consider the example of the gear box of the car. Machine design or mechanical design can be defined as the process by which resources or energy is converted into useful mechanical forms, or the mechanisms, so as to obtain useful output from the machines in the desired form as per the needs of human beings.

2.2. Methodology of the study

The study empirically tested the effect of SW-P on the education of ME students. It also has a practical significance for learning support for students with different learning style profiles. In addition, an understanding of the relationships between theoretical and real world will inform students to promote the use of SW-P for learning. The researchers used the experimental method in studying the impact of an independent variable (SW-P) on dependent variable (academic achievement), and a comparison was made between the experimental group which studied both theoretically and numerically by using SW-P along with a teacher, and the other group is the control one which studied by using the traditional way of discussion (theoretically and textbooks), along with a teacher.

2.3. The study tools

The researchers designed the same project for both groups. The projects were (1) to design and model the Savonius rotor (see Figure 1) to generate 10kW output, (2) to estimate the physical parameters (velocity, pressure and so on) for the rotor and (3) to obtain the structural response of the blade due to the wind load applied in term of stresses and its displacements. In this project, the students worked in two groups (first group will use SW-P, while the second one will use traditional methods). It was conducted during a 6-week period to third-year bachelor-degree students of the courses, after the two group assignments had been handed in, graded and presented in the classroom.

The researchers conducted an academic achievement test, with the help of the teacher, which covered all aspects of the topic to measure the different levels of academic achievement. The test included 10 questions divided into two kinds of questions:

- Six equations related to fluid mechanics (drag force, torque and pressure distribution around the rotor).
- Four questions related to the machine design (stress and displacement/deformation).

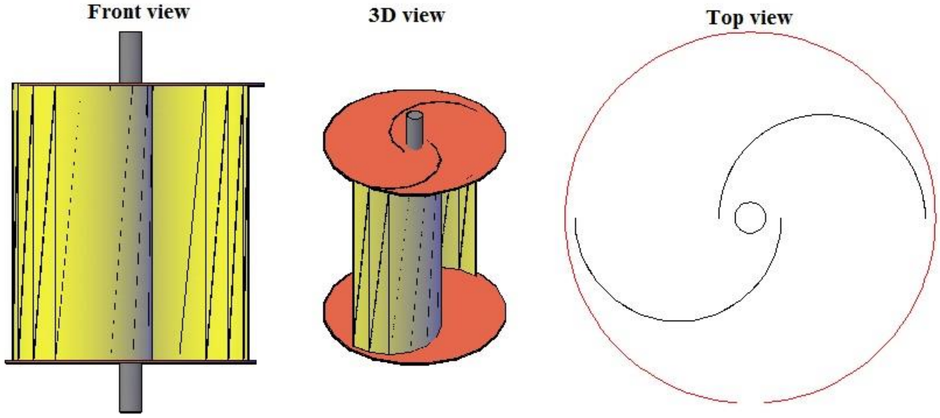

Figure 1. Design of Savonius rotor blade

2.4. Theory of calculating power of the Savonius rotor

The Savonius type rotor is a drag-based wind turbine because itis the drag component of the aerodynamic force that powers the Savonius turbine to rotate (Figure 1). Let us assume that the rotor has a mean radius R and it is rotating with an angular speed ω. The circumferential velocity of the rotor or rotor velocity, v_r, at the mean radius is equal to:

$$v_{rotor} = \omega R \tag{1}$$

During the rotation, the wind velocity is broken into two components: X and Y, as shown in Figure 2b. Vertical flows were not considered in this research, and it could be a topic for future exploration. Assuming that the axis of the C-section's vertical axis wind turbine rotor is the upward-pointing Y-axis, the flow experienced in the X-direction is the sum of the free-stream flow in the X-direction, and the Xaspect of rotational velocity (see Figure 2c).

Let us assume that the rotor is not rotating (see Figure 2a), then the average relative velocities of the wind $v_{rel,1}$ and $v_{rel,2}$ at the first and second rotating drums are given by following expressions, respectively (see Figure 2c):

$$v_{rel,1} = V - v_{rotor} \tag{2}$$

$$v_{rel,2} = V + v_{rotor} \tag{3}$$

The resulting drag forces $F_{D,1}$ and $F_{D,2}$ on the rotating drums is given as:

$$F_{D,1} = \frac{1}{2}\rho C_{D,1} v_{rel,1}^2 A = \frac{1}{2}\rho C_{D,1} A(V - v_{rotor})^2 = \frac{1}{2}\rho C_{D,1} A V^2 \left(1 - \frac{v_{rotor}}{V}\right)^2 \quad (4)$$

$$F_{D,2} = \frac{1}{2}\rho C_{D,2} v_{rel,2}^2 A = \frac{1}{2}\rho C_{D,2} A(V + v_{rotor})^2 = \frac{1}{2}\rho C_{D,2} A v_w^2 \left(1 + \frac{v_{rotor}}{V}\right)^2 \quad (5)$$

where$A$ denotes the projected area of the drums. The aerodynamic torque along the central axis is calculated as:

$$T = \left(F_{D,1} - F_{D,2}\right)(d) = \frac{1}{2}\rho C_{D,1} A V^2 \left[C_{D,1}\left(1 - \frac{v_{rotor}}{V}\right)^2 - C_{D,2}\left(1 + \frac{v_{rotor}}{V}\right)^2\right]\left(\frac{d}{2}\right) \quad (6)$$

The power by the turbine can be then determined using the following equation:

$$P = T\omega = \frac{1}{2}\rho C_{D,1} A V^2 \left[C_{D,1}\left(1 - \frac{v_{rotor}}{V}\right)^2 - C_{D,2}\left(1 + \frac{v_{rotor}}{V}\right)^2\right]\omega\left(\frac{d}{2}\right) = \frac{1}{2}\rho C_p v_{wind}^3 A \quad (7)$$

The average wind speed ($V_{average}$) is the major element that affects the power output. The three wind speed parameters involved in this design is the cut-in speed (V_{cut-in}), the rated wind speed (V_{Rated}) and the cut-out speed ($V_{cut-out}$). Jain (2011) stated that the three wind speed parameters related to the power performance are as follow:

$$V_{cut-in} = 0.5\, V_{average} \quad (8)$$

$$V_{Rated} = 1.5\, V_{average} \quad (9)$$

$$V_{cut-out} = 3\, V_{average} \quad (10)$$

According to Manwell, McGowan and Rogers (2009), solidity (σ) is related to the tip speed ratio. A high tip speed ratio will result in low solidity. Musgrove (2010) defines solidity as the ratio of the blade area to the turbine rotor swept area. For VAWT, the solidity is defined as follows:

$$\sigma = \frac{nd}{R} \quad (11)$$

where n is the number of blades, d is the chord length or can be defined as the diameter of each half cylinder and R is radius of the wind turbine.

2.5. SolidWork simulation

In this project, two kinds of simulation and analysis were done, i.e., Solid Work flow simulation (SWFS) and Solid Works structural simulation (SWSS).

The purpose of SWFS is to obtain the pressure difference between the concave and convex surfaces. The pressure difference between the concave and convex blade surfaces of the Savonius rotor induced drag force that turns the blade (see Figure 3a).

The structure of the Savonius rotor blade is analysed using the finite element analysis (FEA) for the static method by SWSS. Since the two Savonius rotor blades are symmetrical, the analysis was carried outon only one blade. The FEA result is interpreted in three criteria: stress, deformation and factor of safety. The first step of the FEA is assigning material to the blade model where PVC was the material chosen. Then, the fixed constraints/fixtures are applied on the top, bottom and centre of the shaft. The fixtures constrained all translational and all rotational degrees of freedom. Therefore, the blade is in a static and fixed position. The load for this analysis is the force (drag force) that is obtained from the aerodynamic analysis and is equally distributed on the concave blade surface. Von Mises stress and displacement for the Savonius rotor blade are shown in Figure 3b and c, respectively.

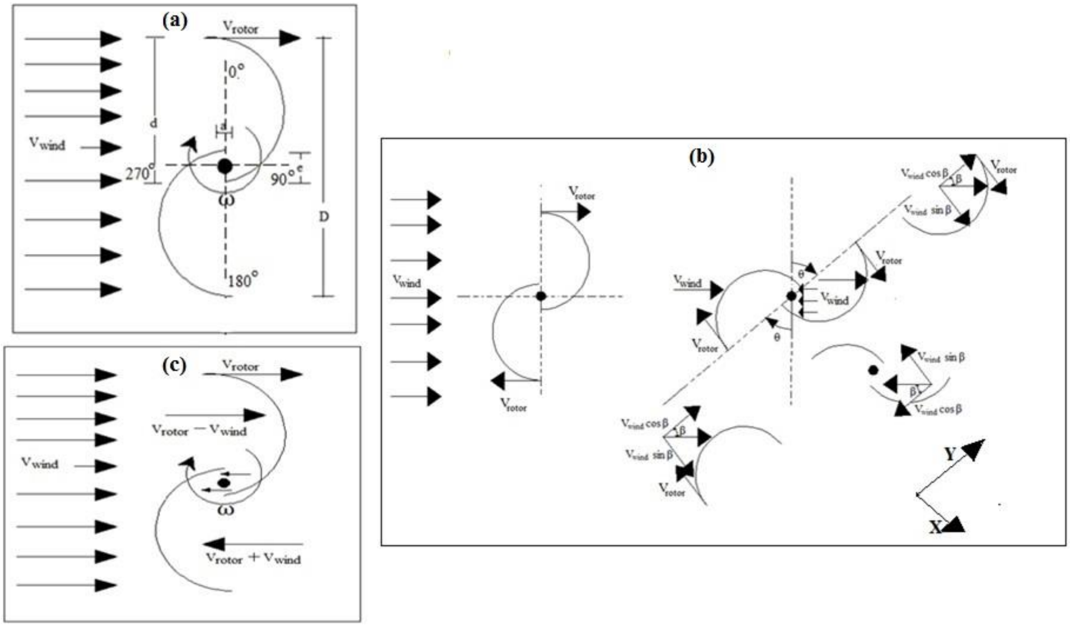

Figure 2. Schematic diagram of a two-bladed Savonius rotor and vector components of the wind speed at the rotor

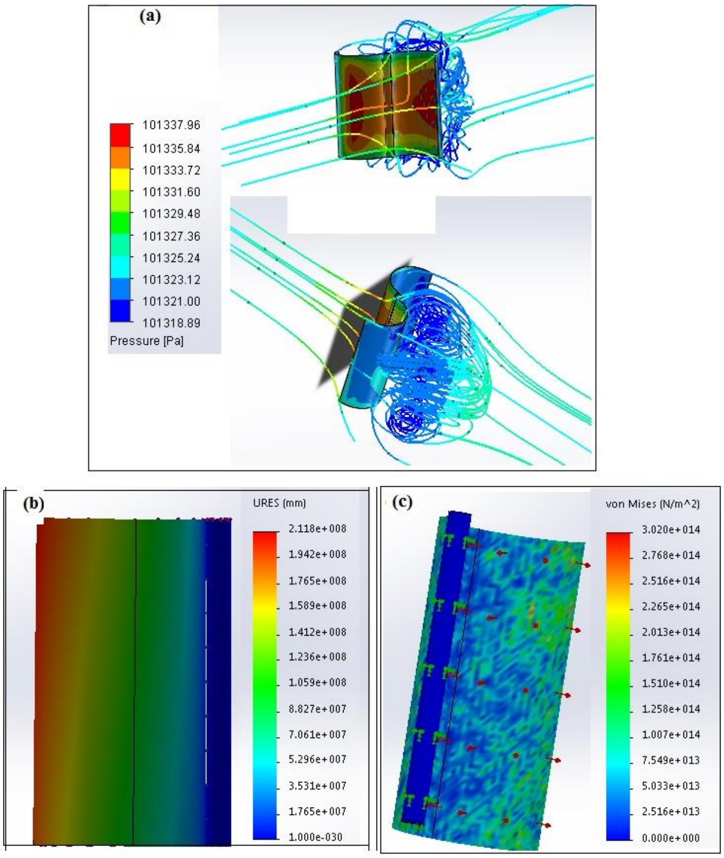

Figure 3. Simulation results for the Savonius rotor

2.6. Statistical processing

- The researchers in the following statistical processing used the Statistical Package for the Social Sciences for analysing all processes:
- Calculating the median.
- Calculating the standard deviation.
- *t*-Test to examine the difference between the performance of control and experimental groups.

3. Results and discussion

After applying the experiment, the researchers conducted a post-academic achievement test, and then they analysed the study outcomes to figure out the impact of using SW-P on ME students' academic achievement and the results are provided in the following sections.

3.1. Results related to the first and second questions

Q1. Can SW-P software help the ME students to understand the real world?

Q2. Is ME students' willingness to use SW-P related to their use of computer technology for understanding the courses very well?

After obtaining the statistical results of the test (*t*-test) of the control and experimental groups, the positive impact of using SW-P was clear on teaching and understanding the real world and on better scientific academic achievement of the experimental group compared to the results of the control group, which proves that using SW-P in education is an effective means of reaching a better learning.

3.2. Results related to the third question

Q3. Are there any statistically significant differences between the average marks of the experimental group and that of the control group in the t-test measurements?

To answer this question, the median and the standard deviation of the academic achievement test for the experimental and control groups were extracted, as shown in Table 1.

Table 1 shows the statistically significant differences between the control and experimental groups at the significance level of 0.05 in the test in favour of the experimental group.

Table 1. Results of the pre-academic achievement test for the control and experimental groups

Group	Number	Mean	Standard deviation	*t*-value	*F*	Significant differences
Control	10	5.60	1.897	3.242	2.356	0.005
Experimental	10	7.90	1.197			

4. Study recommendations

According to the study's results, which indicated the effective use of multimedia compared to the traditional methods of teaching, the study recommends the following:

- Using SW-P in other engineering departments.
- Giving training courses to the teachers regarding the use of SW-P in teaching educational subjects, provided these courses will be available over the academic year.
- Conducting more studies on using SW-P in the academic curriculum in the university.

Acknowledgements

The authors wish to thank the Faculty of Engineering, especially the Mechanical Engineering Department for their support during the work validation of this new technology. Also, the authors wish to express their sincere thanks to Miss Zeinab Halloumeh for her critical comments.

References

Coller, B. & Scott, M. (2009). Effectiveness of using a video game to teach a course in mechanical engineering. *Computers and Education, 53*(3), 900–912. doi:10.1016/j.compedu.2009.05.012

Ibrahim, D. (2011). Engineering simulation with MATLAB: improving teaching and learning effectiveness. *Procedia Computer Science, 3*, 853–858. doi:10.1016/j.procs.2010.12.140

Jain, P. (2011).Wind energy engineering. New York, NY: McGraw-Hill.

Manwell, F., McGowan, G. & Rogers, L. (2009).Wind energy explained. Chichester, UK: John Wiley and Son Ltd.

Moussavi, S. Z. & Fazly, M. (2010). Learning improvement by using Matlab simulator in advanced electrical machinery laboratory. *Procedia, Social and Behavioral Sciences, 9*, 92–104. doi:10.1016/ j.sbspro.2010.12.121

Musgrove, P. (2010). *Wind power*. Cambridge, UK: Cambridge University Press.

Naukkarinen, J. & Sainio, T. (2018). Supporting student learning of chemical reaction engineering using a socially scaffolded virtual laboratory concept. *Education for Chemical Engineers, 22*, 61–68. doi:10.1016/j.ece.2018.01.001

Tejado, I., Torres, D., Perez, E. & Vinagre, B. M. (2016). Physical modeling based simulators to support teaching in automatic control: the rotatory pendulum. *IFAC-Papers OnLine, 49*(6), 75–80. doi:10.1016/j.ifacol.2016.07.156