SOCIETY. INTEGRATION. EDUCATION
Proceedings of the International Scientific Conference. Volume I, May 27th, 2022. 184-193

ENERGY GENERATOR PROTOTYPES DEVELOPMENT AND THESE RESEARCH INTEGRATION INTO THE EDUCATIONAL PROCESS

Vaidotas Matutis
Vilnius University of Applied Sciences, Lithuania

Loreta Savulioniene
Vilnius University of Applied Sciences, Lithuania

Paulius Sakalys
Vilnius University of Applied Sciences, Lithuania

Tomas Kasperavicius
Vilnius University of Applied Sciences, Lithuania

Abstract. *The paper presents the preconditions for improving the quality of technical training of engineers by integrating experimental research based on patented technology into the power supply circuits of autonomous robotic systems to improve power consumption and regeneration rate, ensuring longer autonomous robot operation. Not only the topics of arousal of curiosity in researching technical nuances are discussed, but also the promotion of motivation to delve into the study subjects envisaged in the curriculum and their integral understanding by examining the interrelationships. After-school activities are discussed: participation in the research, analysis of the research methodology, preparation of the layout for research and measurements; and the impact of these activities on the overall educational process. Suggestions for the integration of research results into the practical educational process of students are presented.*
Keywords: *electricity generator, integration, regeneration, robotic system.*

Introduction

The assumptions presented in this article to improve the educational process in the preparation of engineering students are based on two statements that can be described in this way. First, “Regard man as a mine rich in gems of inestimable value. Education can, alone, cause it to reveal its treasures, and enable mankind to benefit therefrom”. Second, children pay little attention to what adults tell them and learn from examples they see in their horizons. Of course, students are no longer children, so the second statement should be slightly transformed by combining the accents of the example shown with a verbal explanation of the motives. In this case, the emphasis is on communication and cooperation. John Berger draws on this principle in his book, "Ways of seeing" He writes:

- „Seeing comes before words. The child looks and recognizes before it can speak. But there is also another sense in which seeing comes before words.

https://doi.org/10.17770/sie2022vol1.6884

- It is seeing which establishes our place in the surrounding world; we explain that we are surrounded by it. The relation between what we see and what we know is never settled. Every night we see the sun setting. However, we know that the Earth is actually turning away from the Sun. But this knowledge, this explanation, never definitively coincides with the visible spectacle...“ (Berger, 2019)

Aspects of the practical application of these principles are widely discussed in the paper of the international project in the form of a book entitled “100 Ways to Improve Teaching: A Teacher’s Book for Student-Centered Teaching and Learning” (2018, Vilnius). Here it is presented as integrated project work or project based learning.

“Project Based Learning (PBL) is a backwards design process in which the teacher begins with the end in mind (Bayer & Hallerman, 2013). It is an instructional model that involves students in investigations of compelling problems that culminate in authentic products (Zafirov, 2013). The Buck Institute for Education (BIE) defines standards-focused PBL as a systematic teaching method that engages students in learning knowledge skills through an extended inquiry process structured around complex, authentic questions and carefully designed products and tasks. BIE, in their video “PBL Explained” that by focusing students on a project, teachers put them on a path that deepens their knowledge and builds skills they need for their future (BIE, 2010). They further break down the skills developed during Problem Based Learning as collaboration, question asking, giving feedback, research, presentation, and critical thinking (BIE, 2010)” (TechPLC, 2015)

In the presented case, the research activity is not directly integrated into the intended curriculum and is not even a direct education project or part of it, but is closely related to the subjects studied in terms of both acquired theoretical knowledge and practical skills. It is a project of more extracurricular activities that is based on the principles of volunteerism and interest on the part of students, although it is focused on students, the development of their competencies, the promotion of motivation, and the formation of professional skills.

The research project itself and its object are based on a patented technology, studying its applicability in the power supply circuits of autonomous robotic systems (Matutis et al., 2021). Thus, in the initial stage we are talking about the construction and research processes of the electric generator, where the practical possible application for electric cars is envisaged, because it is also a kind of autonomous robotic system.

General teaching part, research motives

The idea of the project was inspired and matured in the pre-pandemic period and is being developed in parallel through patenting processes where possible. In our article, “Research of power generator prototype development and integration into autonomous robotic systems" presented in 2021 (Matutis et al., 2021), we have just discussed the course of this project in the presence of pandemic constraints. The lack of contact work for such projects is holding back and slowing down all progress, but it is not destructive, so even during this difficult period, the work was moving.

The project is being developed as a research based on an invention that relates to the transformation of wind (air flow) energy into electricity. It is a natural, constantly renewable source of energy for the environment around us, environmentally sustainable and environmentally friendly. The process itself does not bring any harmful substances into the environment. However, to achieve practical benefits, an integrated approach is needed, as mechanics, electromechanics, electronics, and several other specific areas of practical physics are combined here. Examination of similar ideas has shown that many of them do not reach the efficiency required for practical application, as at some stage the loss increases more than expected and the potential efficiency becomes negative (which means loss).

The use of air flow energy is studied in the practical application studies of wind turbines, where the kinetic energy of air flow is used to the maximum. It was decided to develop a practical study of this aspect in the first stage. A key issue at this stage has been the need to determine the number of blades that would be most efficient for a selected wind turbine. The chosen turbine geometry (Fig. 1) is the simplest. The design of the wings is also simple but ensures a positive efficiency from a mechanical point of view due to the appropriate force ratio of the shoulders.

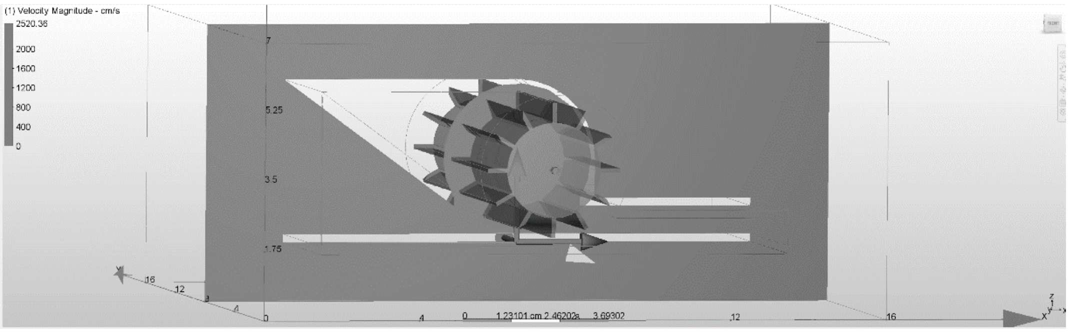

Figure 1 ***Selected turbine geometry in wind tunnel simulation*** *(created by authors)*

The simulations used Autodesk® CFD software to turn a 3D CAD workstation into a fully interactive liquid and gas test rig, thermal test rig, or wind tunnel. 3D layouts become interactive, at no cost to prototypes, revealing critical engineering information that is difficult to obtain during physical testing. Change the design of the model and we will see the same change in Autodesk® CFD right away. This software has been used in combination with Autodesk Fusion 360, which is 3D and 2D modeling software with a user-friendly environment that allows you to use it comfortably without much challenge. It is a powerful program that allows you to create complex and large-scale layouts.

The essence of the research chosen at this stage is the research of mechanics. It seems to have no direct connection with the future work of electronics engineers or engineers of computer systems. It should be mentioned here that research at this stage covers several areas, such as simulation or computer simulation; laboratory research including layout design (computer layout), printing of the layout and its details on 3D printers (practical use of applications); laboratory tests or specific measurements under laboratory conditions; as well as measurements with the same layout stand under external situation conditions. In this way, practical research and wider knowledge skills are developed for future engineers involved in project activities in one aspect or another.

Experimental part, description of research

Each stage begins with a discussion. The purpose of the discussion is to share the available information, to formulate tasks, to get an idea of the current situation, to plan further steps and upcoming works. At this stage, the visualization of the problem in question plays an important role. This stands out when we start discussing what an initial layout model is needed. The visualization here is very intuitive. During the project, this part of the visualization of the discussion phase remains intuitive, although it is already based on the initial information collected during the project.

This could be illustrated by the following examples from real situations during the project (Fig. 2).

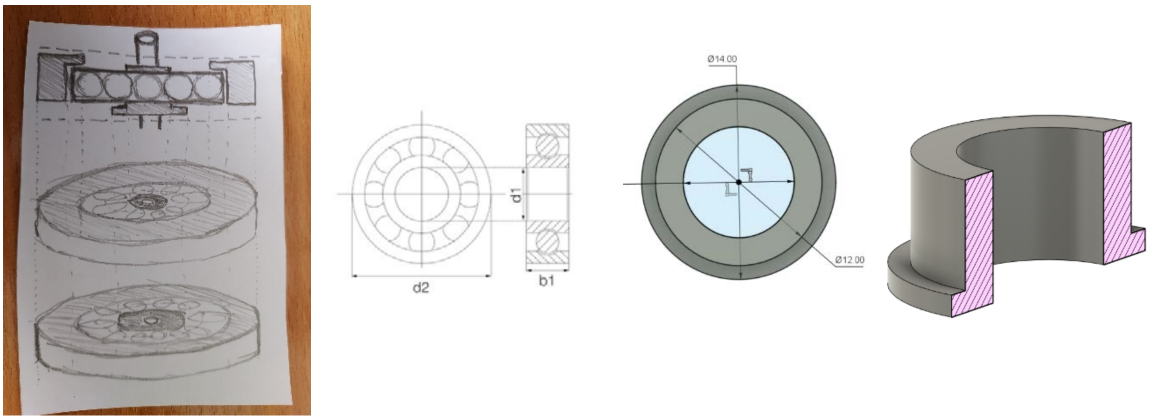

Figure 2 ***Stages in the process of visualization of the required part (bearing inner bush)*** *(created by authors)*

Any new detail acquires its shape and image first in our imagination. Only the initial conditions that limit the degrees of freedom of our imagination are changing. Those initial conditions are framed and strengthened depending on the information already accumulated during the project.

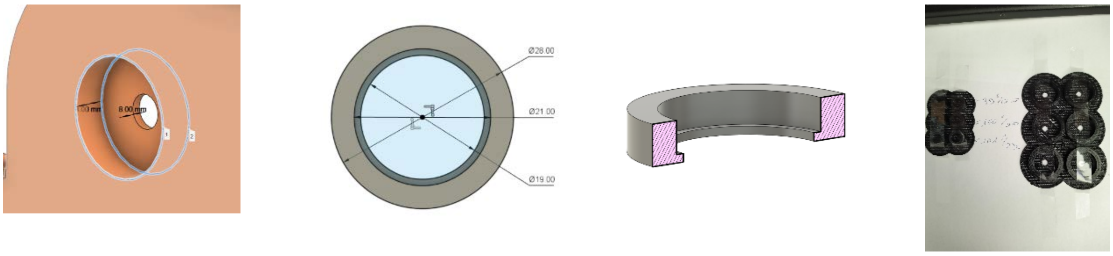

Figure 3 ***Visualization and realization of the part (bearing outer bush***) *(created by authors)*

So first the image, then the attempt to describe it in words, put it on paper and here are already used various tools from simple pencil to computer drawing and design. Then the image becomes a real detail with the helpof a 3D printer (Fig. 3). In this way, students acquire the skills needed for any engineering job. These skills can be called visualization-realization. This stage is repeated many times during the project.

The specifics of this project are its scope and longevity, so the change of students involved in it is natural. Graduates leave the project, and those who have just started their studies join the research team during the project. The formation of a replenishment is currently underway.

The next natural stage of this project is 3D printing, which provides students with theoretical knowledge and practical skills in mastering the application software for design and preparation for 3D printing. Acquisition of theoretical knowledge and skills in the operation of the 3D printer itself as a device. When a 3D printer works for several days (Table 1) to print the required detail, it is very important to optimally select its settings, and theoretical knowledge alone is not enough, practical skills are required. All this is very useful even when switching to other models.

Table 1 ***3D printer manufacturing runtime*** *(created by authors)*

Product completeness (%)	Printing time
32	1d 0h 46min
80	2d 1h 2min
100	2d 11h 4min

In close collaboration with students and faculty was developed an initial layout for critical measurements. The initial goal is to measure how the amount of energy absorbed from the air stream in a turbine of such a design depends on the number of impeller blades (Fig. 5).

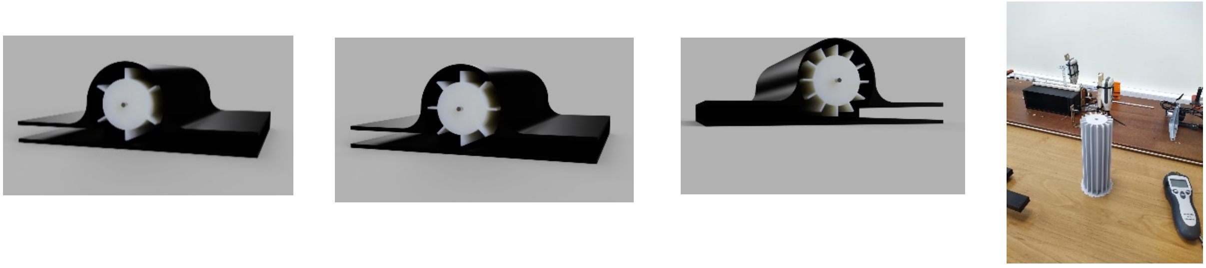

Figure 5 ***Layout with a different number of wings*** *(created by authors)*

Measurements were performed by changing the impellers in the same layout housing as shown in Fig. 5. The amount of energy itself was not measured directly, and it was chosen to measure the number of revolutions of the impeller per unit time.

The following layout geometry was chosen for the measurements of the critical values after computer simulation of the air flow (Fig. 6).

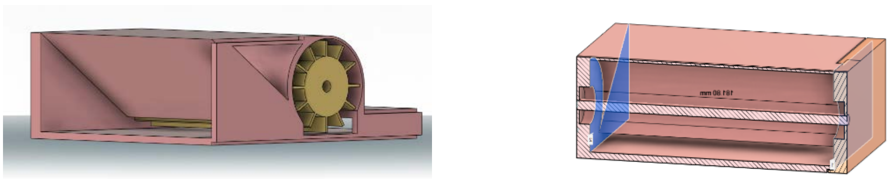

Figure 6 ***Geometry of the selected layout for critical value measurements*** *(created by authors)*

In the model, the height of the air flow inlet was chosen to be only half the length of the impeller wings. In this way, by measuring the air flow rate required to rotate the impeller, we will find critical values and will be able to improve the design of the turbine by increasing its efficiency.

This research process, in which students participate from the discussion of ideas, the submission of ideas and their own suggestions, to the production and assembly and coordination of an appropriate layout, allows them to become aware of and understand the interrelationships between practical skills and theory, also relations between theory and experimentation.

Measurement results, summary

We move on to the experimental measurements. Under the laboratory conditions, a stand with a constant air flow was installed in which the turbine model was also installed in the same place. This allows measurements to be made under the same environmental conditions and by varying the number of turbine impeller blades.

The layout for laboratory measurements is shown in Fig. 7. As we can see, two aerometers measuring the speed of the incoming air flow and the speed of the outgoing air flow are installed.

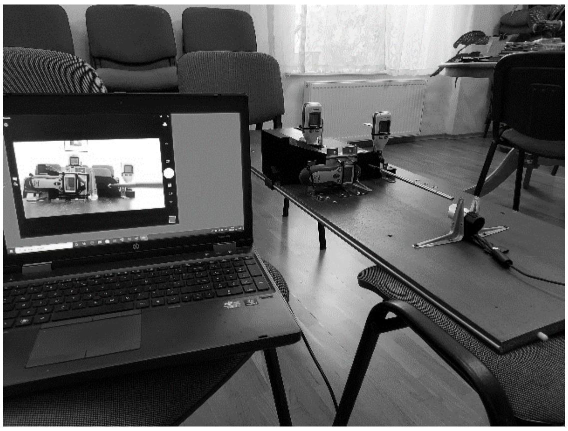

Figure 7 **Layout installation on a measuring bench** *(created by authors)*

The tachometer is mounted in such a way that it can measure the number of revolutions per minute of the rotating impeller. A video camera connected to a computer for monitoring the readings of the devices allows the recording of the measurement process. This is convenient for analyzing the obtained data and comparing the results.

An illustration of the course of measurements performed under laboratory conditions is shown in Fig. 8.

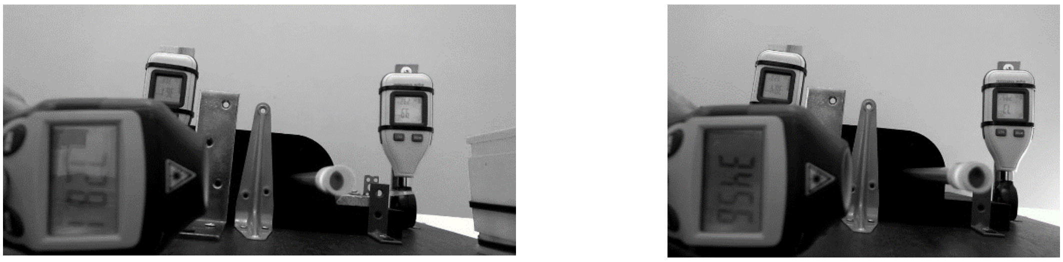

Figure 8 **Illustration of the course of laboratory measurements** *(created by authors)*

As we can see, in an effort to maintain the same environmental conditions: a constant flow of air, a fixed location of the layout, a fixed position of the measuring devices, etc.; we change only the number of wings of the impeller. The obtained results are shown in Fig. 9. a function of the number of revolutions of the impeller as a function of the number of wings.

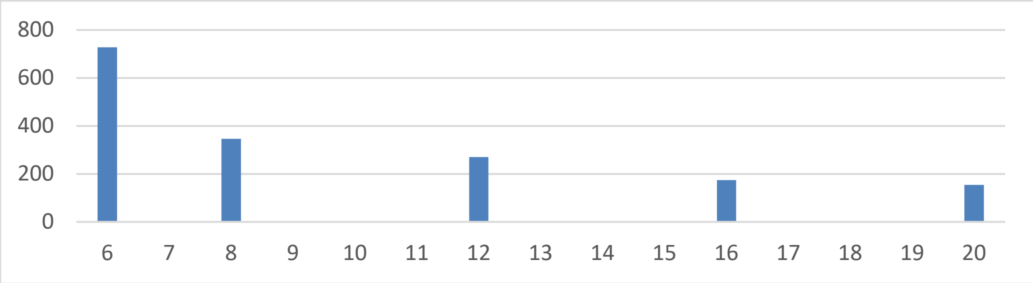

Figure 9 ***Graphical representation of laboratory measurements****(created by authors)*

From the graph of the measurement results we can see: as the number of wings increases, the number of revolutions of the impeller decreases during the same period of time. We can conclude that increasing the number of wings does not improve the energy absorption of airflow. Changes in airflow velocity were also observed during these measurements by measuring the airflow velocity before and behind the model. Although these were not our primary measurements, they are needed to analyze the potential for improving the efficiency of the turbine.

The maximum power factor of the ideal impeller is 0.593 and occurs under conditions where the air flow velocity behind the impeller is decelerated by a ratio of 2/3 to the air flow velocity in front of the impeller (layout). This law was adopted in 1919 formulated and proved by the German scientist Albert Betz. A. Betz published the results of his study in 1920 "Betas Maximum der theoretisch möglichen Ausnützung des Windes durch Windmotoren" ("Theoretical power limit of a wind farm using maximum wind energy"), and since then Betz's law has not been amended or proved otherwise. A. Betz's law defines the maximum of the energy transformation of a given operating point.

The results of our measurements, albeit indirectly, also confirmed this law.

Velocity v is a key characteristic for airflow (wind) energy analysis. Air masses, vol. y. the kinetic energy E of wind flow motion, based on the theory of classical mechanics (Augulis et al., 2012), is expressed as follows:

$$E = \frac{1}{2} m v^2; \tag{1}$$

where: v - wind speed, m / s; m - air mass, kg.

In the final result, taking into account the difference in airflow velocity before and behind the model, we obtain that the airflow power is directly proportional to its velocity cube (Mukund, 2006).

This means that once we find the critical points in the performance of this turbine, we still have a lot of room for improvement.

The measurements and experiments were then transferred to the real environment. The same model was mounted on the roof of the car (Fig. 10).

Figure 10 ***Experimental measurements in external situation*** *(created by authors)*

In this case, the critical air flow speed required for turbine spinning was about 100 km / h. It coincides with the speed of the car. The speed of the passing air flow drops tenfold. This shows that such a turbine is not efficient in case the 12-blade impeller it uses. However, it can be improved by raising its efficiency according to other laboratory measurements. More so as experiments with other count of wings in the outdoors have not yet been performed at this stage.

It should be mentioned that the organized practical measurements provoked a heated discussion in predicting the possible results, discussing theoretical assumptions, and using intuitive arguments. Participation in these processes provides students with the opportunity to develop perspective planning skills. Allows a clear understanding of the relationship between theory and experiment.

Conclusions, suggestions

A model of additional practical activities, integrated project work or project-oriented and project learning is presented. During this project, the impact of such activities on their (students) interest in learning and acquiring practical skills is clearly felt through the direct communication (as reflection of ideas and impressions in discussions with students on a wider scale). Therefore, this project is presented as creating preconditions for improving the quality of technical training of engineers in training. The technical platform of the project is also based on the pursuit of a public benefit that makes it socially relevant. As art teaches to see, this type of project activity helps future professionals to understand their own social role and the need for integration into society. The existence of such activities in addition to the basic curriculum helps to expand the educational process while acquiring the necessary professional skills and competencies.

References

Augulis, L., Jotautis, A., & Rutkūnienė, D. (2012). Fizika: mechanika, termodinamika, elektromagnetizmas. Mokomoji knyga. *Kaunas: Technologija*.

Autodesk® CFD. (2022). *Technical documentation.* Retrieved from https://academy.autodesk.com/getting-started-fusion-360#:~:text=Fusion%20360%20helps%20students%20and,turn%20your%20ideas%20into%20reality

Autodesk® Fusion 360. (2022). *Technical documentation.* Retrieved from https://academy.autodesk.com/getting-started-fusion-360#:~:text=Fusion%20360%20helps%20students%20and,turn%20your%20ideas%20into%20reality

Berger, J. (2019). *Ways of Seeing. Book.* Penguin Books Ltd.

Matutis, V., Savulionienė, L., Šakalys, P., & Kasperavičius, T. (2021). Research of Power Generator Prototype Development and Integration into Autonomous Robotic Systems. *Society. Integration. Education.* DOI: https://doi.org/10.17770/sie2021vol5.6453

Mukund, R.P. (2006). *Wind and Solar Power Systems: Desigm, Analysis and Operation.* Boca Raton: Taylor & Francis.

TechPLC. (2015). *A review of research on project-based learning.* Retrieved from https://tqptechplc.blogspot.com/2015/02/rsa-2-project-based-learning.html

100 būdų kaip pagerinti dėstymą: dėstytojo knyga į studenta orientuotas mokymas ir mokymasis. (2018). *Training material*. Retrieved from https://www.kaunokolegija.lt/kk_wp_content/uploads/2018/11/100-B%C5%AAD%C5%B2-KAIP-PAGERINTI-DESTYMA_-DESTYTOJO-KNYGA.pdf