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# Design and Construction of a Turbine Pump as Laboratory Scale Micro Hydro Electricity Learning Media

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***ABSTRAK***

*Kurangnya pemahaman siswa mengenai energi terbarukan dapat dihasilkan dari pompa yaitu energi listrik. Energi yang dihasilkan pompa ini bermanfaat bagi daerah pedesaan yang belum memiliki listrik. Tujuan dari penelitian ini adalah untuk memodifikasi pompa sebagai turbin pembangkit listrik tenaga mikrohidro yang dapat digunakan oleh mahasiswa Jurusan Teknik Mesin Universitas Muhammadiyah Pontianak sebagai media pembelajaran pada bidang mesin fluida dan skala laboratorium. mesin konversi energi. Subjek penelitian adalah 15 orang mahasiswa teknik mesin dan pompa yang diubah menjadi turbin untuk menghasilkan listrik. Data yang dikumpulkan pertama kali berasal dari uji kinerja pompa yang telah diubah menjadi pompa sebagai turbin. Data selanjutnya diperoleh dari siswa melalui pretest dengan konsep jenis pompa yang digunakan sebagai pembangkit listrik. Kemudian setelah pretest siswa diberikan perlakuan dengan menggunakan dan mengoperasikan pompa sebagai turbin sebagai media pembelajaran. Dari media ini siswa juga harus menjelaskan konsep dan bagaimana pompa sebagai turbin dapat menghasilkan energi listrik secara tertulis. Hasil tertulis siswa yang diperoleh dianalisis untuk mengetahui pengaruh model pompa sebagai turbin terhadap pemahaman analisis konseptual siswa. Hasil dari penelitian ini berupa pompa yang diubah menjadi pompa sebagai turbin. Selain itu, sebagai alat praktis sederhana untuk menguji kinerja pompa sebagai turbin. Terjadi peningkatan pemahaman siswa dalam hal kemampuan mendeskripsikan konsep sumber pembangkit listrik dari pompa serta menganalisis proses dan cara kerja pompa sebagai turbin untuk menghasilkan energi listrik.*

**ABSTRACT**

Lack of understanding of students about renewable energy can be produced from pumps, namely electrical energy. The energy produced by this pump is beneficial for rural areas that do not have electricity. The purpose of this research is to modify the pump as a turbine for a micro-hydro power plant which can be used by students of the Mechanical Engineering Department, the University of Muhammadiyah Pontianak as learning media in the field of fluid machines and laboratory-scale energy conversion machines. The research subjects were 15 students of mechanical engineering and pumps that were converted into turbines to generate electricity. The data collected first comes from the performance test of a pump that has been converted into a pump as a turbine. Further data was obtained from students through a pretest with a conceptual type of pump used as a power plant. Then after the pretest, students were treated by using and operating a pump as a turbine as a learning media. From this media, students must also explain the concept and how the pump as a turbine can produce electrical energy in writing. The student's written results obtained were analyzed to determine the effect of the pump as turbine model on students' understanding of conceptual analysis. The result of this research is a pump that has been converted into a pump as the turbine. In addition, as a simple practical tool to test the performance of the pump as a turbine. There was an increase in students' understanding in terms of the ability to describe the concept of power generation sources from pumps and analyze the process and workings of the pump as a turbine to produce electrical energy.

## 1. INTRODUCTION

Indonesia has a lot of potential for hydropower which is quite large because it has an area that is drained by many rivers, although this is not the only source of hydropower. There are still many other potential sources of hydropower originating from waterfalls, lakes and so on. The hydropower potential is in all parts of Indonesia, but not all of this potential is utilized. This hydropower potential is a renewable energy that can help overcome the electrical energy crisis and reduce the impact of the use of fossil fuels that have started to run out (Adu, 2020; Lydon et al., 2017; M Stefanizzi, 2018). Therefore, it is necessary to buaild a power plant by exploring various equipment that is around us to take advantage of the available sources and potential of hydropower. With current technological advances, much-modified equipment is used innovative and effective. One example is the field of mechanical engineering, especially

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in the field of energy conversion and the use of nature as an energy source. Among them is the use of water that can be used to produce electricity. To develop learning, the theories taught must always follow the development of science and technology. The practice of engineering learning can not only be done through classroom theory**.** In educating students as state assets, it is necessary to develop facilities and infrastructure to support science in the academic environment (Chen, 2020; Poudel, 2021). Learning engineering sciences that have been running, especially learning in the field of fluid mechanics, energy conversion machines, namely pumps and water turbines, in the Mechanical Engineering Department, Faculty of Engineering, University of Muhammadiyah Pontianak, is still considered necessary to improve the learning process optimally. In addition to the lack of facilities and infrastructure to support practicum, especially in fluid mechanics, energy conversion machines, namely pumps, are also still lacking in student understanding (Rafli & Hazwi, 2014; Teuteberg, 2010).

The energy produced is environmentally friendly renewable energy which is very useful for rural areas that do not have electricity. Where the pump can be used as a turbine (Pump As Turbine), a pump as a Turbine is a form of micro-hydropower that produces less than 3 kW of electrical energy. The electrical energy generated from the pump as a Turbine can be used for agricultural facilities, local lighting, small business units and others (Carravetta et al., 2013; Rachmat & Hamdani, 2017). The price of a pump axle turbine is relatively lower than a water turbine. Besides that, it does not use fuel and has low maintenance costs. Pump as Turbine is suitable for use as an applied technology to meet electrical energy needs, especially for those who live in the interior. However, students' understanding of the machine that generates electrical energy from this pump is still lacking because they cannot see the finished tool directly. Students are less active in learning pump courses. Students rarely ask questions or express their ideas even though the lecturer repeatedly asks questions. In addition, the activeness of students to read reference books is also still low. Because of the complexity of this pumping course, it is not enough to only be taught theoretically in class. However, it is necessary to have media or other learning tools to increase understanding of the material (Garad et al., 2018; Singh et al., 2017). Therefore to deepen students understanding of pump lesson, it is necessary to develop educational equipment for building pumps, such as laboratory scale micro hydro generator turbines. This learning media was chosen because it can provide broad creative opportunities to design interactive learning media models, encouraging student activity and understanding in a field. Many types of research on pumps as turbines have been carried out, but none have been used as learning media for students. The design of a pump as a turbine can be used to manufacture pumps that replace the materials and production processes used. Several studies of engine-powered water pump modifications have been carried out using weak water flow (Aminuddin et al., 2019; Isnugroho, 2012)**.**

Various designs have also been carried out in the design of Pump As Turbines (PATs), which are made using water pressure generated from the centrifugal engine pump as a substitute for the water level to become pressure on the turbine. Research for Pumps as turbines for throttling energy restoration of the water distribution network has also been carried out. Research on various types of pumps for PAT has also been carried out, such as the use of the Shimizu Type PS-128 Bit water pump, which functions as a water turbine for a Micro Hydro Power Plant, which is an effort to find alternative energy that is simple and easy to assemble (Koehuan et al., 2021; Situmorang et al., 2020) Research has also been done to see the performance of the pump. One of them is a study to see the performance of two centrifugal pumps (one Chinese product and one non-Chinese equivalent product) operated as water turbines (Indonesia). Design analysis for a pump as a Turbine System for a 100kW power supply was carried out for the Sangama Community in the Niger Delta Region of Nigeria (Obriki et al., 2019; Michele Stefanizzi, 2019). Meanwhile, the design of a pump as a turbine for a micro-hydro system for the Abalone plantation in South Africa. Design and prediction of the use of pumps as turbines are also carried out using Computer Fluid Dynamic (CFD) (Frosina et al., 2017; Zariatin et al., 2017). In a one-dimensional theoretical analysis by optimizing the geometric parameters of the impeller through a theoretical model, it is found that the selected design variables have a significant impact on the efficiency of the PAT. Utility of a physics based version to expecting the overall performance curved of pumps as mills. The relatively deviation of the model prediction with admire to the BEP's constanly regarded suitable, as compared to traditional deviations of other techniques to be had within the literature (Manservigi et al., 2019; Wang et al., 2020) In testing the diffuser and volute pumps as water turbines, both types of pumps showed that maximum efficiency was achieved at the head of water flow through the pump as high as the maximum characteristic of the pump head (Mdee et al., 2019; Suarda, 2012). Performance characteristics of the pump as turbine (PAT) using one suction pump for power generation. This study emphasizes the experiment of a pump that functions as a turbine (PAT) by modifying the inlet and outlet angles on the PAT blade. Research on the procedure for selecting a pump that runs as a micro hydro turbine for plants has also been carried out (Florio, 2017). This study reviews the PAT selection criteria for various hydroelectric power plant sites

with different potentials because no general model has been developed which can be used to calculate the conversion factor for PAT (Agarwal, 2012). A numerical and economic study of the workings of using a centrifugal pump as a turbine. The results show that PAT has a lower payback time than turbines with the same output power (in lower capacity), although they have lower efficiency (Bahreini & Sattari, 2017; Penagos-Vásquez et al., 2021). From the various studies that have been carried out by previous researchers, most of the research that has been carried out has not made the pump a turbine as a learning media for mechanical engineering students. Therefore, this research needs to be carried out as enrichment material for learning materials about energy sources originating from fluid machines (Jemal & Haile, 2019; Rossi et al., 2019).

The purpose of this research is to modify the pump as a turbine for a micro-hydro power plant which can be used by students of the Mechanical Engineering Study Program, the University of Muhammadiyah Pontianak as learning media in the field of fluid machines and laboratory-scale energy conversion machines.The research subjects were 15 students of mechanical engineering and pumps that were converted into turbines to generate electricity. On the other hand, we want to take part in increasing production and capacity building by improving the quality of human resources in academia, especially students of the Mechanical Engineering Study Program at the University of Muhammadiyah Pontianak and mastery of technology must continue to be done so that independence in the development of renewable energy can be realized as a form of participation in the community. The government is establishing a plan to gradually increase the use of various energy sources in Indonesia.

## 2. METHOD

This study uses a descriptive research type with an approach quantitative. Descriptive research in this study is intended to obtain descriptions and information regarding the understanding of mechanical engineering students towards how to operate and work processes of a pump that has been converted into pump as turbine to produce electrical energy contains how data is collected, data sources and ways of data analysis.

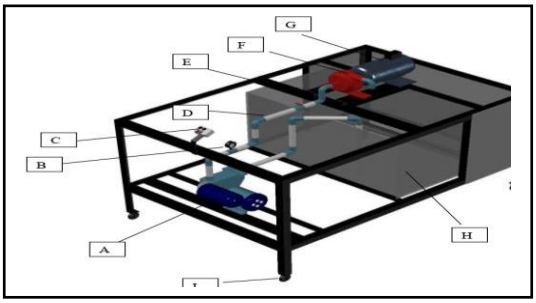


**Figure 1**. Pump as Turbine Design

The research subjects were 15 students of mechanical engineering and pumps that were converted into turbines to generate electricity. The data collected first comes from the performance test of a pump that has been converted into a pump as a turbine (PAT). Further data was obtained from students through a pretest with a conceptual type of pump used as a power plant. Then after the pretest, students were treated by using and operating PAT as a learning media From this media, students must also explain the concept and how the pump as turbine (PAT) can produce electrical energy in writing. The student's written results obtained were analyzed to determine the effect of the pump as turbine (PAT) model on students' understanding of conceptual analysis.

Data analysis was carried out by descriptive analysis and based on the performance testing of the pump as a turbine that has been carried out and the ability of students to understand the concept of power generation technology derived from pumps and describe how PAT works to produce electrical energy. The procedure used in this study went through four stages, where the first stage was the preparation of raw materials and supporting equipment. The second stage is to convert the pump into a laboratory-scale turbine. The third stage is testing the equipment produced from the second stage. And finally the use of a pump as a turbine as a learning media.

## 3. RESULT AND DISCUSSION

### Result

The engineering of the Pump As Turbine (PAT) learning media equipment has been done 100%, and the tools have been completed. By the research objectives, the pump as turbine learning media can already be used, although there are still many things that need to be added. The following are photos of the process of making the pump as a turbine learning media. Figure 2 is a pump as a turbine that has been installed in the system. Figure 3 is the shape of the finished pump as a turbine to be used as a learning medium, while Figure 4 is a display of the pump as turbine testing with a 30-watt lamp load.

**Figure 2**. Pump as Turbine That Has Been Installed

**Figure 3**. A laboratory Scale Pump as Turbine (PAT)

**Figure 4**. PAT Test with 30 Watt Load

A pump that is used as a turbine is a water pump type DAB-100 with a capacity of 400 litres/minute, which will then be studied for its performance such as how much power and efficiency the turbine axle pump has installed. How much power and efficiency of PAT can not be known, except by taking data of the tool. The purpose of data collection is to obtain the maximum power and efficiency of the pump as a turbine (PAT). Before being used as a learning media, pump as turbine performance is tested first, with the aim of whether this tool can produce electrical energy or not. Table **1**, it can be seen the results of the pump as turbine (PAT) performance test.

**Table 1.** Pump as Turbine Performance Test

| Q ($m^3/s$) | N (rpm) | V (volt) | I (ampere) | $P_{PAT}$ (Watt) | η (%) |
|---|---|---|---|---|---|
| 0,0006 | 2850 | 30 | 1,46 | 43,6 | 5,09 |

The data from the test results of the pump as a turbine in Table 1 are taken using a multi-tester measuring instrument to determine the current generated by the alternator rotation. The flow rate is

taken from the drive pump. For measuring PAT rotation, a tacho meter is used. Meanwhile, to measure the current strength, a clamp meter is used. This equipment model can already be used for media and simulation tools for learning fluid machines, one of which is a pump. This tool can also be used as a simple, practical tool for testing the performance of a pump as a turbine. After getting data from the pump performance, the next step is to use this PAT as a learning media for 15 students in the Mechanical Engineering Study Program, at the University of Muhammadiyah Pontianak. Before using and operating the pump as a turbine as a learning media, students were given a pretest with the first problem being an understanding of the technology of power generation from the pump and the second about the concept of the pump as a turbine. After understanding the pump as a turbine system, students learn how to operate the tool guided by the course lecturer. After the pretest, the students then learn about the operation of the pump as a turbine and describe in writing how the PAT process can generate electricity.

The next step is for students to analyze the concept of the pump as a turbine sourced from books, journals, and mass media. Based on the results of the initial analysis, students begin to understand the concept of a power plant derived from the modification of a pump that is turned into a turbine. Where after getting the theory about the pump as a turbine, students must also be able to operate and explain the process of how this PAT can generate electricity. In addition, in the future students are expected to understand starting from the basic concepts to the application of this PAT according to the needs of the community. The achievement of the final stage of the PAT learning media is the conclusion. At this stage, students must be able to explain and analyze the PAT performance process. Results of student's understanding of explaining the concept of generating electricity from the pump until the PAT process generates electricity is shown in Table 2.

**Table 2.** Percentage of Understanding Concepts for Pump as Turbine

| No | Aspect of Research | Result | |
|---|---|---|---|
| | | Before | After |
| 1 | Understanding of the technology of power generation from the pump | 60.5 | 93.6 |
| 2 | The concept of the pump as a turbine (PAT) | 61.3 | 90.8 |
| 3 | Describe in writing how the pump as turbine (PAT) process can generate electricity | 65 | 95,6 |

**Discussion**

With this simple pump as a turbine, the pump power as a turbine is 43.8 Watt, the rotation speed of the pump as a turbine is 2850 rpm, the water flow is 0.006 m3/s, the voltage generated is 30 Volt, the electric current is 1.46 Ampere, the PAT efficiency is 5,09 %. The maximum rotation of this turbine is 2850 rpm, but the high rotation produced by this turbine does not guarantee that the turbine can produce significant power. It explains that at a specific rotation, the turbine can produce maximum power and then the power can decrease (small power) at the maximum rotation of the turbine. It means that the greater the rotation (rpm) produced, the greater the power (Watts) it produces, but conversely, the smaller the rotation produced by the impeller, the smaller the power (Watts) produced. In general, the efficiency of the pump as turbine (PAT) test results is still quite low as shown in Table 1. These results with 100% valve opening have an efficiency of 5.09%. Based on the test data, the efficiency of the pump as turbine (PAT) results is still far below the ideal efficiency of a pump. This is because the flow of water entering the PAT is not optimal and limited. This limitation is because the pipe used in this test is small, namely 1.5 inches. It can still be developed for further research by using a larger diameter. With the use of variations in diameter will be able to get various data for the development of the pump as a turbine so as to produce maximum efficiency.

The test results show that the pump can be operated as a turbine to generate electricity. This is following previous research with the same statement (Garad et al., 2018; Satish et al., 2021). In addition, the pump which is converted into a pump as a turbine (PAT) is a type of pump with small specifications. In this study, the pump which was used as a turbine did not make any changes, such as the impeller. The pump used is the original factory default, by only changing the direction of the pump flow to work as a turbine, where the input flow is reversed, the discharge side of the pump is used as the fluid inlet side and the suction side is used as the output. PAT has a smaller power value when compared to other types of turbines. This PAT cannot rotate at relatively low flow rates or water discharges. The impeller used is the default pump which is used as a turbine. Based on other studies that modifying the impeller can increase the rotation (rpm), PAT can optimally produce power (Watts) even though the PAT is not explicitly designed as a turbine (Agarwal, 2012; Dai et al., 2020). The rotation value of an impeller as a turbine is

related to efficiency. The greater the rotation speed, the greater the turbine efficiency, with a maximum efficiency value of 5.09%. A pump as a turbine has a low impeller rotation, so the efficiency resulting from this pump as a turbine is also low. Modification of a pump that is used as a turbine as a power plant can provide advantages compared to having to make a turbine model. This is because pumps are mass produced so they are easy to obtain. Pumps that are operated as turbines can be directly used even without making changes to the design of the pump. Seeing Indonesia's topography, which has many sources of hydropower, the use of PAT needs to be developed. PAT is a solution to produce renewable energy that can be used for areas that have not been electrified.

The criteria for the success of this research are grouped into two aspects, namely the indicators of the success of the process and the indicators of the success of the results. These two groups are indicators of the success of achieving an increased understanding of mechanical engineering students at the University of Muhammadiyah Pontianak about the source of power generation from pumps. The indicator for the success of the results is based on the increasing understanding of students after participating in learning about the concept of a pump as a turbine and how the device produces electrical energy. Changes in students' understanding of positive learning can be seen individually or as a whole, as many as 15 students. Indicators of student understanding related to PAT learning media can be seen by comparing the results of the learning process before and after the action is taken.

The results of the initial test showed that the student's initial abilities before and after going through a test of understanding power generation energy from pumps and pump as turbines (PAT) and describing in writing the process of PAT producing electrical energy are very different. As can be seen in Table 2 that occurs increasing students' understanding of learning through this PAT learning media. The results shown in Table 2 also show that the PAT generated from the modification of the pump into a turbine is suitable if it is used for a power plant simulation tool. Students can understand the concept of PAT and analyze working principles about power generation systems. Maximum researchers trying to achieve the best results, but it must be admitted that this research is still has many limitations that must be stated as material consideration. The time used for this research is very limited because this research conducted at the end of the semester where students will take the final exam semester. In addition, the funds obtained from this research are also limited. It is hoped that this research can be used for further research to obtain research results better.

## 4. CONCLUSION

This research has produced a tool for learning media in the form of a modification of a pump that is used as a laboratory-scale power generator turbine. The pump can function as a water turbine and is more efficient if it is used for micro hydro power plants because the pump is cheaper, simpler, easy to obtain, and easy to repair.machines namely pumps and water turbines. This PAT learning media can be used for thesis for advanced students in looking for pump performance if it is used as a turbine and can be used as a teaching aid for lecturers to make it easier to explain courses about power plants originating from fluid machines.

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