Design of Monitoring and Control System of Water Turbidity as NOx Gas Binder at Spun Pile Manufacture Company

By

I Putu Eka Widya Pratama
Department of Instrumentation Engineering, Institute of Technology Sepuluh Nopember, Kampus ITS Keputih, Sukolilo, Surabaya 60111, Jawa Timur, Indonesia

Putri Yeni Aisyah
Department of Instrumentation Engineering, Institute of Technology Sepuluh Nopember, Kampus ITS Keputih, Sukolilo, Surabaya 60111, Jawa Timur, Indonesia

Moch Fajar Taufikkhurrahman
Department of Instrumentation Engineering, Institute of Technology Sepuluh Nopember, Kampus ITS Keputih, Sukolilo, Surabaya 60111, Jawa Timur, Indonesia

Nabiilah Aziizah Tjandra
Department of Instrumentation Engineering, Institute of Technology Sepuluh Nopember, Kampus ITS Keputih, Sukolilo, Surabaya 60111, Jawa Timur, Indonesia

Abstract

The continuous use of boilers in the manufacture spun pile concretes company causes increased exhaust gas emissions such as NOX gas from boiler combustion. In order to reduce NOX gas emission, clean water is used in the absorption process to tie the gases. The water resulting from the NOX gas binder will change color to become more concentrated which makes the water saturated in binding NOX gas. It is necessary to change the water in the tub shelter. Meanwhile the process of replacing cloudy water from tub shelter is still done manually. Therefore, in this research, a monitoring and control system for water turbidity is designed to improve the performance of the NOX gas binder. The monitoring system designed using a 16x2 LCD as a GUI will display the turbidity value on the NTU scale, while the control system designed uses Arduino Uno as a microcontroller and then uses a solenoid valve as an actuator to regulate the flow rate of water. Turbidity sensor type SEN-0189 is used as a water turbidity sensor and using a float switch to control the water level in the reservoir. The results show that the system is able to reduce the turbidity of the water from 250 NTU on the to 114 NTU.

Keywords: control of water turbidity; absorption; NOX gas; water tub

Introduction

In the precast industry, to support smooth production requires adequate machines, including a coal-fired boiler which functions as a steam generator to speed up the drying process of the molded piles and formed in the mold [1]. The continuous use of coal-fired boilers along with the increase in production needs causes the exhaust gas emissions produced by the boiler to increase [2]. The combustion process with this boiler will produce pollutants in the form of particulates (dust), and gases such as NO_2 and SO_2 [3], [4]. Referring to the East Java Governor Regulation Number 10 of 2009 concerning ambient air quality standards and emission from immovable sources in East Java, the quality standard for coal-fired boilers is 750 mg/NM3 for Sulfur Dioxide (SO_2) and 825 mg/NM^3 for Nitrogen Dioxide (NO_2) [5]. However, at spun pile manufacture company mostly still uses a manual water filter to filter dust in the exhaust chimney which causes blockages in the disposal of used water filters and a lack of effectiveness in filtering dust from coal combustion [6].

The lack of effectiveness of dust filtering can result in the concentration of Sulfur Dioxide (SO_2) and Nitrogen Dioxide (NO_2) exceeding the applicable standard [7]. With the high concentration of Sulfur Dioxide (SO_2) and Nitrogen Dioxide (NO_2) gas that exceeds the standard quality standards [8], [9], it can damage the surrounding iron which causes an increase in costs incurred by the company for maintenance costs, besides that it can also disrupt the health of workers and pollute the surrounding environment [10].

Hence, a prototype was initiated to optimize the boiler chimney filter system from manual to automatic [11]. This prototype measures the turbidity of water in a reservoir which is used as a filter in the exhaust chimney [12]. By monitoring and controlling the level of the water turbidity that will be used as a filter in the chimney [13], it will reduce toxic gas emissions produced by burning coal boilers [14], [15]. Using a turbidity sensor to measure the maximum turbidity level in the reservoir [16], if the turbidity of the water in the tub exceeds the specified one, it will open the solenoid valve which will drain the water and when the water has decreased to the specified level it will open the solenoid valve which will enter clean water to replace the turbid water exceeds the limit [17]. This system uses a microcontroller to regulate the output of the used water filter and the input of clean water [18]–[20]. The output of this research is expected after the system is installed in the NOX gas filter water reservoir at spun pile manufacture company is getting better and the air pollution produced from the chimney is decreasing.

Method

Design of Monitoring and Control System Turbidity Water

Preparation of design for monitoring and controlling water turbidity in the boiler disposal filter water reservoir includes making the design of the tool, determining the sensor, actuator, microcontroller and designing the system to be used. The following is the design of the tool that has been made.

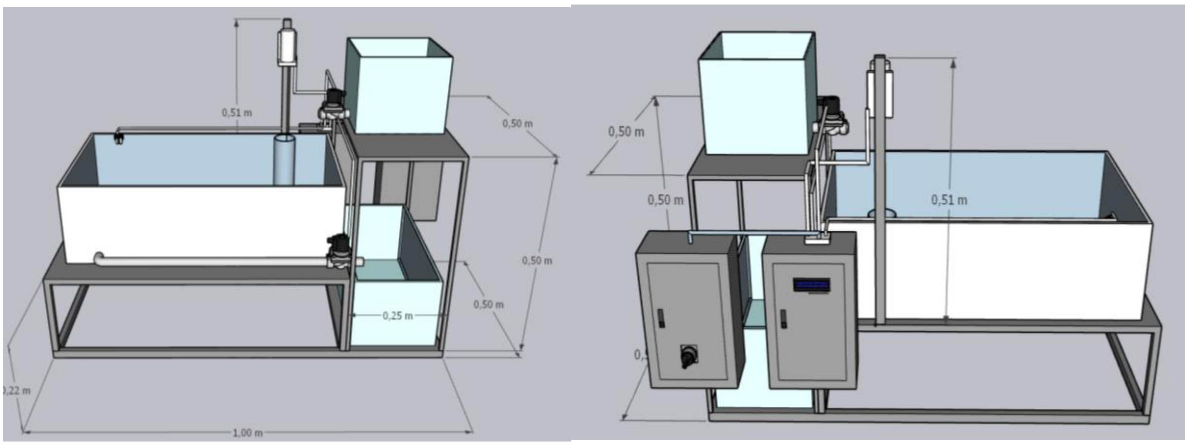

Figure 1 *Prototype Design*

The picture above is a tool design that has been made from the front and back views. From the front it is clear that there are several main components, namely there are 2 panel boxes, the first panel box is a panel box that contains the power supply component then the next panel box contains the controller component, there is a turbidity sensor and a water volume sensor in the reservoir after that there are 2 valves that will regulate the input of clean water as make up water and waste water as a drainage system. At the back there is a DC pump that will move the water in the 3rd tub to the 1st tub.

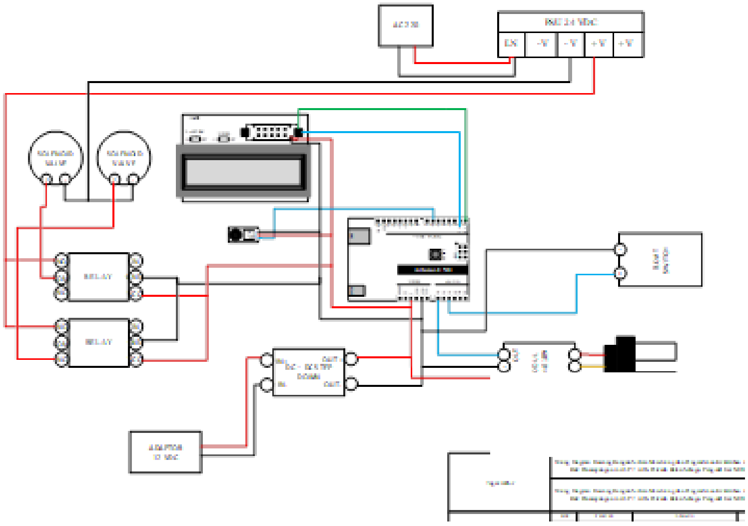

Figure 2 *Electrical Wiring*

Figure 2 is a wiring scheme in system design. The input is 24 VDC for the solenoid valve actuator. The power supply used for the controller uses an adapter that is connected to a DC-DC step down first before going to the Arduino Uno. The sensors used are directly connected to the controller legs which will later be used as setpoints to carry out commands. Using 2 actuators in the form of a solenoid valve which is connected to a relay first so that the use of the solenoid valve is more effective. Using I2C LCD so that wiring from Arduino to LCD is neater and easier.

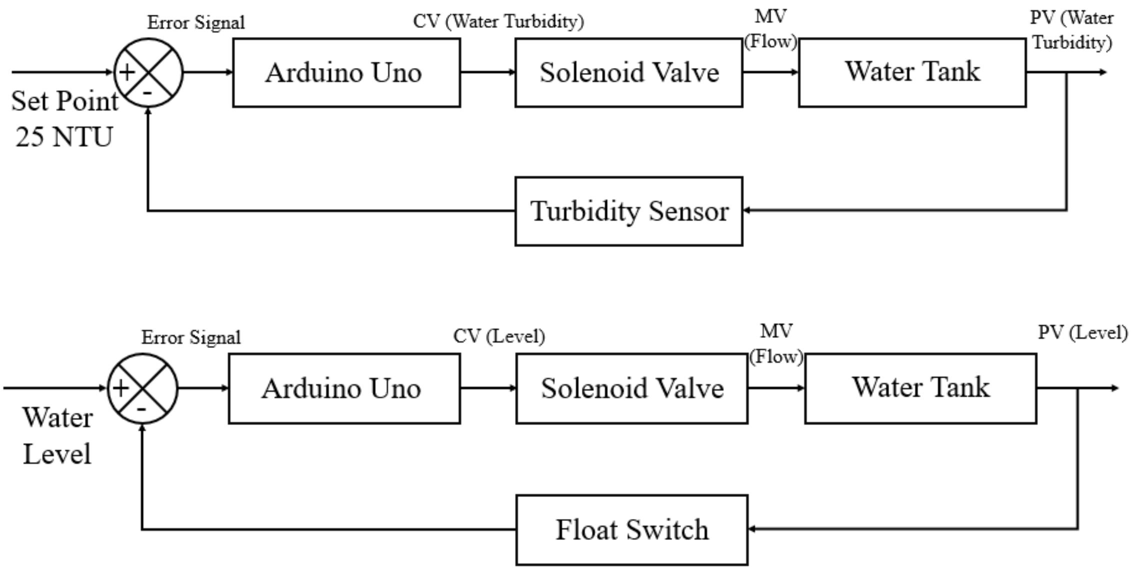

Figure 3 *Control Block Diagram*

The control block diagram above describes the work process for controlling water turbidity and water level where the turbidity and water level are set according to the Setpoint in the 3rd tub and then controlled by Arduino Uno. Arduino Uno will give a signal to reach the setpoint for electric solenoid valves 1 and 2. The signal serves as the action of controlling water turbidity [21]. Furthermore, the level and turbidity sensors send feedback where the results measured by the sensor are compared with the set point processed by the controller. Then the controller sends an output signal to control the electric solenoid valve. The measurement diagram of this system is shown in the image below.

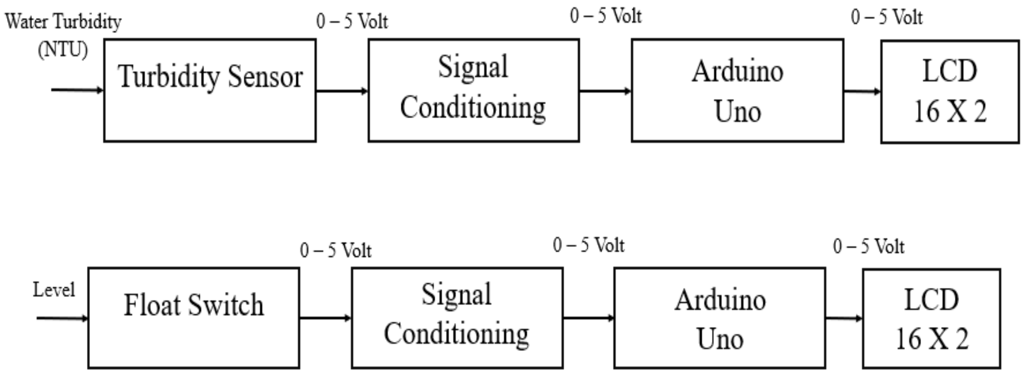

Figure 4 *Measurement Block Diagram*

The measurement block diagram above describes the working process of the sensor that will be displayed on the display. The measurement elements used are turbidity and water level which will send the measurement result signal after the signal is conditioned and adjusted according to the standard signal, namely 1-5 VDC or 4-20 mA. The output of the SEN 0189 turbidity sensor with an output of 0 - 4.5 V is then programmed so that the output of SEN-0189 can be read in NTU quantities on the LCD

Program Design

The control and monitoring system for the turbidity of the water used to filter the residual gas from burning coal as fuel for this boiler uses a solenoid electric valve as an actuator to remove water in a reservoir where the turbidity exceeds the limit and as an actuator for input of clean water that is inserted in the reservoir [22]. The water reservoir is divided into 3 compartments which are connected by small holes on each dividing wall, the first tub is the dirtiest tub because the water that has been used as a filter is fed into the first tub, the connecting holes for the first and second tubs are positioned higher than second hole. The second tub is water that flows from the first hole and the water in the second tub is still cloudy but not like the first [23]. In the third tub, the water is relatively clean and only light particles are in this tub.

Using the SEN0189 turbidity sensor and Float Switch to sensor the water level in the tub [24]. If the turbidity sensor in the third tub has detected a water turbidity exceeding 25 NTU, the exhaust valve will open and drain water in tubs 1, 2 and 3 simultaneously because one pipe flow until the turbidity is below 25 NTU [25]. Due to the process of removing cloudy water, the water level will decrease if the water level begins to decrease, the input of clean water entering is controlled by a valve in the third tub. The minimum height limit is set not less than the pipe that will draw water to the pump and higher than the connecting hole of the first tub so that the dirty and foamy surface in the first reservoir does not move into the second tank and does not affect the determination value for turbidity of the water in the reservoir. The display will show the level of water turbidity in the NTU scale. The following is a flow chart of the designed system.

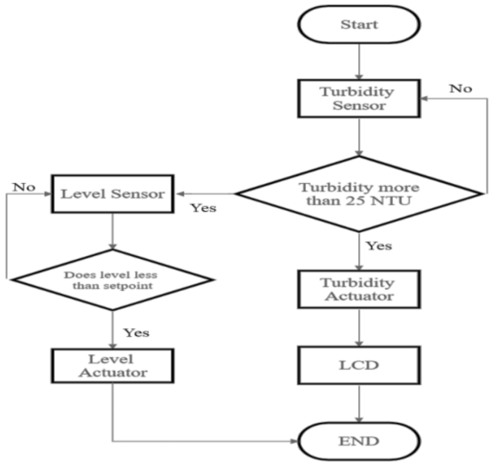

Figure 5 *Flowchart System*

Hardware Design.

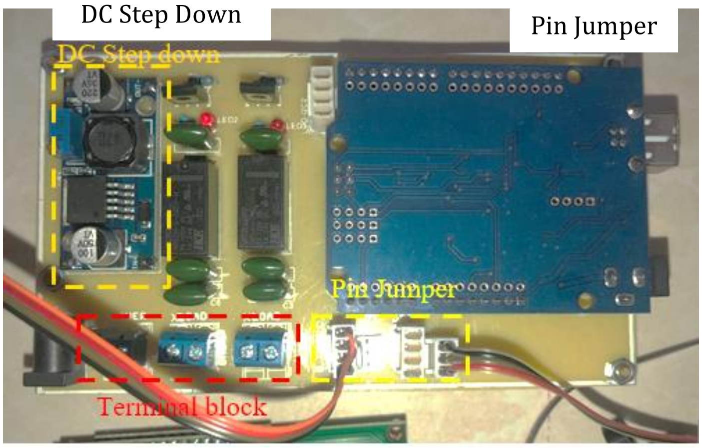

Figure 6 *PCB Board*

From Figure 6 there are 2 different power supply inputs. First, there is a DC step down of 12 VDC to 5 VDC as the Arduino Uno power supply input. Then there are 3 terminal blocks, the first terminal serves as an input with a voltage of 24VDC/4.5A which will be connected to the other 2 terminal blocks which will be connected to 2 electric solenoid valves. There are 2 relays that will regulate the opening and closing of the command valve from the microcontroller [26]. There are 3 jumper pins that have different functions, the first pin connects the Arduino and the LCD, the second pin connects the Arduino to the float switch sensor and the last one connects the Arduino with the SEN-0189 turbidity sensor [27].

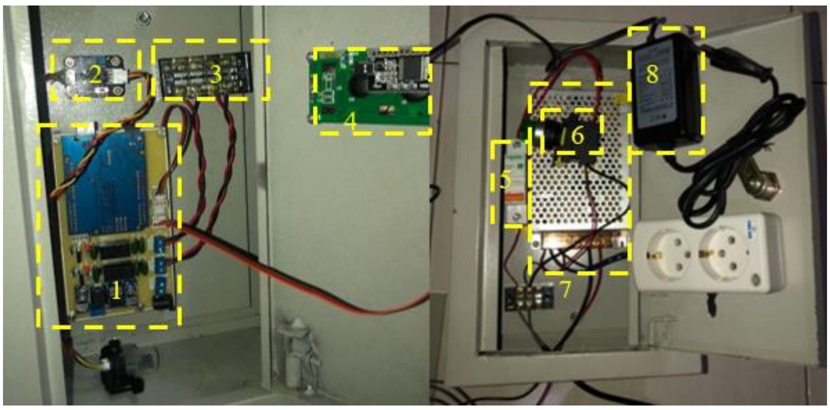

Figure 7 *Panel Box Result*

Table 1 *Panel Box Component.*

No	Component Name	Function.
1.	PCB.	As a system controller board designed.
2.	Modul Turbidity Sensor SEN-0189.	The turbidity sensor module used is SEN-0189.
3.	Terminal Block.	As a liaison between the valve and the relay on the controller board.
4.	LCD 16x2 I2C.	As a display that shows the value of turbidity (NTU) and water level.
5.	MCB.	As a safety circuit that can cut off the current in the event of a failure.
6.	Switch.	As a switch to turn the system on and off.
7.	PSU 24 VDC.	As a solenoid valve power supply is used.
8.	Adaptor 12 VDC.	As the Arduino uno power supply used.

Figure 7 is the result of a panel box that has been designed, there are 2 panel boxes made in Figure 6, the left is a microcontroller panel box that contains a PCB board that has been made, a 16x2 I2C LCD, a turbidity sensor module SEN-0189, and a terminal block that connects the valve with PCB. In Figure 7 the right is a power supply panel box that contains a 24 VDC PSU as 2 valve power supply, MCB, switch, and a 12 VDC adapter as an Arduino Uno power supply. A more complete explanation of the components in the panel box is described in table 1.

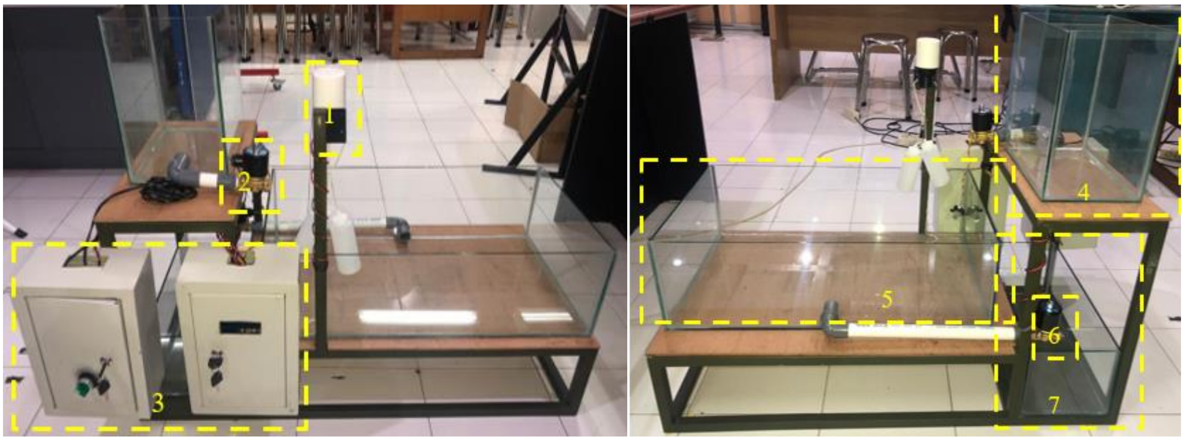

Figure 8 *Prototype Result.*

Table 2 *Prototype Component.*

No	Component Name	Function.
1.	Float Switch	As a water level sensor by setting the upper and lower limits of the water level using 2 buoys
2.	Clean water Solenoid Valve Input	As an actuator that works to add clean water if the water level decreases to a predetermined lower limit
3.	Panel Box	There are 2 panel boxes which have been described in table 1, figure 7, and the paragraph above
4.	Clean Water Tank	As a clean water reservoir
5.	Process Tank	As a process for measuring water turbidity and water level
6.	Dirty Water Disposal Solenoid Valve	As an actuator that works to dispose of the process tub if the turbidity of the water exceeds the set point
7.	Dirty Water Tank	As a reservoir for dirty water that has been thrown away

In the results of the prototype adapted to the water storage plant at spun pile manufacture company by changing the scale to a smaller one. The prototype measures 1 meter long, 0.5 meters wide and 0.75 meters high. In the prototype there are 3 tubs, namely a clean water tub, a process tub, and a drain tub. In the process tub measuring 70 cm long, 40 cm wide, and 20 cm high, the clean water reservoir is 30 cm long, 20 cm wide, and 30 cm high in the dirty water disposal tank measuring 45 cm long, 20 cm wide and 17 cm high. cm. In the prototype of the water to be measured the turbidity level is inserted into the process basin which later the turbidity level of the water will be measured using a turbidity meter SEN-0189 if the turbidity exceeds 25 NTU then the drain valve will open and remove the water in the process basin along with wasting water, the water level will be the process basin will decrease, there is a float switch sensor at the top that will control the water level by setting the upper and lower limits of the water level using the 2 buoys provided. If the water level has reached the lower limit of the regulated water level, the clean water input valve opens and adds water to the process basin until the water level is at the maximum limit. The process will continue until the turbidity is at the set point [28].

Results and Discussion

Validation Turbidity Sensor

SEN-0189 turbidity sensor validation is carried out by preparing a water sample to be tested with the SEN-0189 turbidity sensor and comparing its value with the existing validator in the form of a calibrated turbidity measuring instrument and also observing the voltage output generated by the SEN-0189 sensor. The difference between the value read by the SEN-0189 sensor and the standard measuring instrument will be assumed as an error value.

There are 3 water samples used at spun pile manufacture company, the first using the 3rd tub water, the second sample uses the 2nd tub of water, and the third sample used the 1st tub water. Each water sample is inserted into the measuring tube and glass that has been provided. Then repeated measurements of each sample were made using SEN-0189 and the turbidity meter TU-2016. The following is a graph of the relationship between stress and turbidity that has been tested.

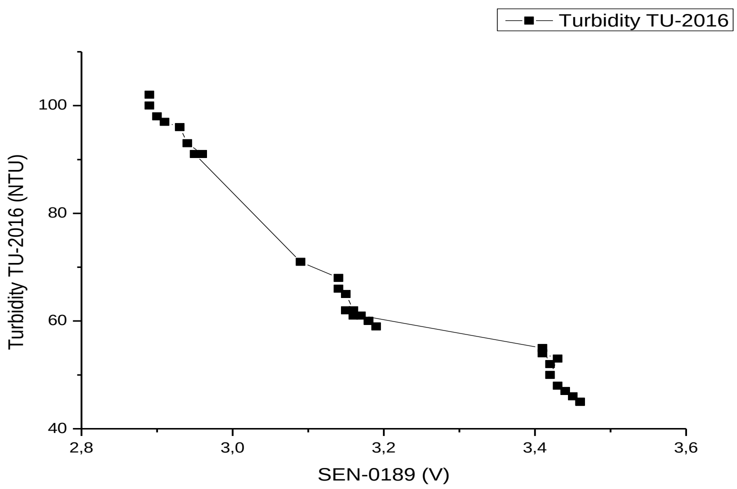

Figure 9 *Relationship Graph Between Voltage and Turbidity.*

Next is the turbidity test between SEN-0189 and the Turbidity Meter TU-2016 with 3 different samples. The result is indicated by figure 10-12.

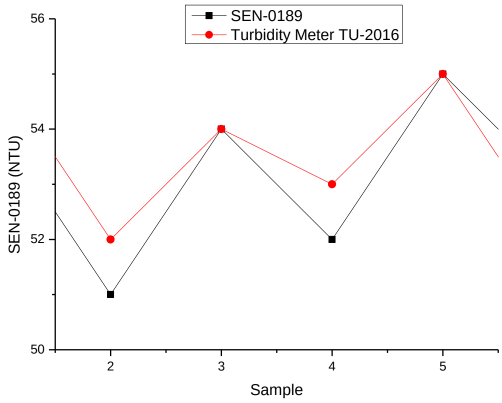

Figure 10 *Comparison of SEN-0189 and Turbidity Meter TU-2016 Sample 1*

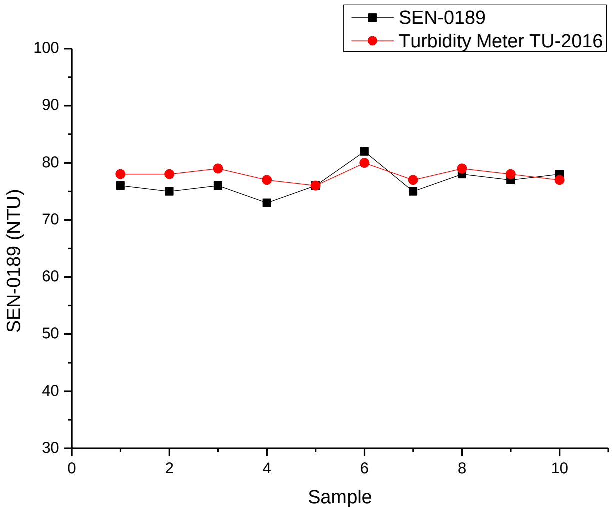

Figure 11 *Comparison of SEN-0189 and Turbidity Meter TU-2016 Sample 2*

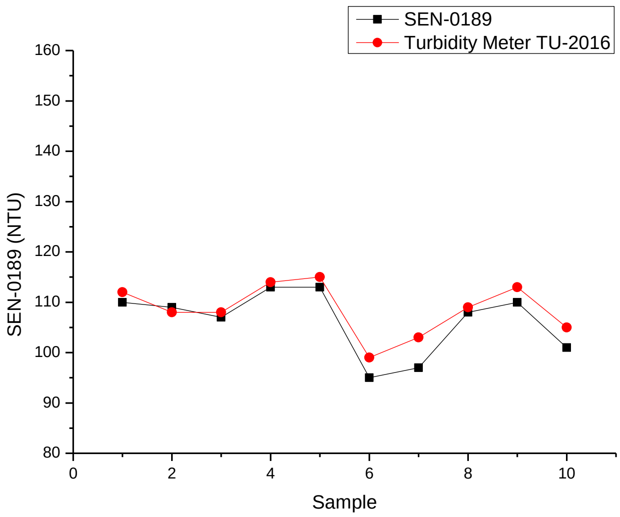

Figure 12 *Comparison of SEN-0189 and Turbidity Meter TU-2016 Sample 3*

From the experimental results above, it can be found that the static characteristics of the SEN-0189 sensor measurement can be found. The following is the calculation of the static characteristics of water turbidity control on the SEN-0189 sensor as follows:

- Input Range: 52 NTU – 114 NTU
- Output Range: 2.89 V – 3.46 V
- Input Span: 63 NTU
- Output Span: 0.57 V
- Accuracy: 2.751%
- Sensitivity: 0.009 V/NTU

Prototype Testing at Spun Pile Manufacture Company.

The test was carried out by connecting the prototype directly with the water tank and chimney at spun pile manufacture company. The test was carried out for 3 days on Friday, 17 June 2022 – Sunday, 19 June 2022, on Friday the data collection started at 14.00 – 17.00 while on Saturday and Sunday the data was collected at 08.00 – 17.00 with data collection carried out every 1 hour. The following data has been collected

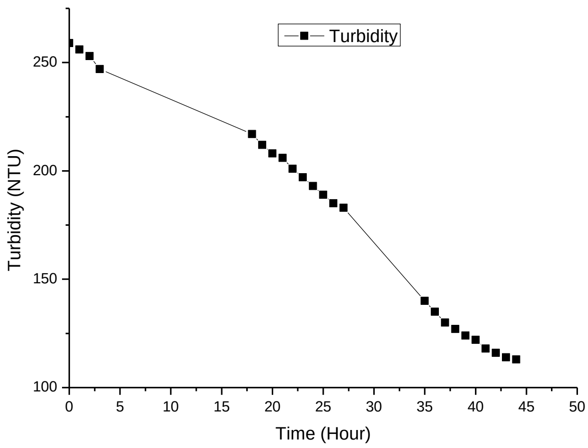

Figure 13 *Prototype Testing Result at Spun Pile Manufacture Company*

In figure 13 it can be seen that the system that has been designed can reduce the value of turbidity (NTU) and is able to adjust the upper and lower limits of the water level. In table 4.10 it can be seen that every 1 hour the value of turbidity decreases by about 3 NTU. The measured turbidity value tends to be high because the water reservoir at spun pile manufacture company the sedimentation process did not run optimally due to the different water levels in each tub and lower than the connecting holes between the compartments which resulted in the surface in the first compartment flowing into the second and third compartments which resulted in the same turbidity value in each compartment and the height due to the surface in the compartment first foamy and dirty.

Conclusions

The designed prototype is able to reduce turbidity by an average of 3 NTU per hour and is able to control the water level in the prototype tank. Seen from the graph, the relationship between voltage (V) and turbidity (NTU) has an inverse correlation, which means that the higher the turbidity value, the lower the voltage value and vice versa. The use of a float switch sensor is the right thing because it is made of non-metallic material that is not easy to rust due to contact with water in a corrosive reservoir and it is easy to adjust the upper and lower limits because it is enough to change the float height to adjust the bottom and bottom limits. below the water level in the water reservoir at spun pile manufacture company. The, the accuracy of

SEN-0189 sensor has a value of 2.751%, the input span is 63 NTU, the output span is 0.57 V, the sensitivity is 0.009 V/NTU output from SEN-0189 in the form of a voltage between 0 V - 4.5 V.

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