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Prototype of Microcontroller-Based Oil Viscosity Measuring Instrument Using Flow Meter Sensor

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Abstract: *Viscosity is a fluid property that causes friction between fluid-forming molecules and the fluid cohesion force. Viscosity is also a measure of the thickness of a fluid which states the size of friction in the fluid, the size of the viscosity we can see from the ability of the fluid to flow, the greater the viscosity of a fluid it will be more difficult the fluid to flow. Oilis one of the fluids used as oil, where oil viscosity is very important to learn to find out if this oil can still work well. Measurements are made by measuring the speed of oil flow on a horizontal pipe using a flow meter sensor that has been placed on the pipe and the oil will flow using a pump. The oil flow velocity in the measurement will be converted into a form of oil viscosity to be measured. In this experiment the measurement results obtained for each oil such as SAE 10W-40 Oil by 0.170655208 Nm / s2 with an error of 6.4%, SAE 15W-40 Oil by 0.203941381 Nm / s2 with an error of 11.2%., and SAE 20W -50 Oil of 0.218243364 with an error of 14.8%.*

Keywords: *Flow Meter, Microcontroller, Oil, Viscosity.*

1. BACKGROUND

Ships are a more economical means of sea transportation than land or air transportation because they are capable of carrying larger loads. Optimal ship operation is highly dependent on engines that can work without obstacles. Good lubrication of ship engines is essential to prevent damage to parts that rub against each other. Oil is a common lubricant used as an absorber and heat transfer in engines, reducing friction between components, noise, and seals between pistons and cylinders. Oil viscosity affects engine performance, and oil standards are set by SAE based on its viscosity. The plan to build a "Prototype of Microcontroller-Based Oil Viscosity Measuring Instrument using a Flow Meter Sensor" is expected to provide benefits to the community.

2. THEORETICAL STUDY

Viscosity

Viscosity is an indicator of the thickness of a fluid, indicating the level of difficulty of the fluid to flow or undergo deformation. Influenced by the physical and chemical properties of the fluid such as temperature, pressure, chemical composition, and flow velocity. Viscosity measurements use SI units, pascal-seconds (Pa s) or millipascal-seconds (mPa s). The property caused by friction between molecules and cohesive forces

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is called viscosity. Cohesive forces cause similar particles to be attracted to each other, inhibiting flow. Friction between the fluid and the pipe walls also inhibits flow. The viscosity of a fluid is measured by the viscosity coefficient, according to Newton's Law, expressed by the equation. Viscosity in the SI system is Ns / m² or Kg / (m s), in CGS is dyne s / cm², in everyday life it is called poise (P) or centipoise (cps). One poise = one hundred centipoise.

Oil

Oil is used in vehicles to reduce engine wear and serves as an important lubricant. Oil must have a viscosity according to standards set by the Society of Automotive Engineers (SAE) to protect engine components from friction and wear during operation. Oil also acts as a coolant, cleaner, inter-engine space seal, and friction reducer for engine components during operation. There is a list of oil materials that are measured based on their viscosity according to applicable standards.

Poiseuile's Law

In viscous fluids, a pressure difference between the two ends of a pipe is required to maintain continuous flow. The amount of fluid flowing per unit time is determined by the pressure difference at the two ends of the pipe.

$$= \frac{\Delta P \pi D4}{128 \mu L} = \frac{\Delta P R2}{8 \mu L} = \pi R4$$

Source : Yunus (2006)

Information :

μ : Viscosity fluid (Ns/m ^{2})

: Rate flow (m^3 / s)

ΔP : Pressure difference on both pipe end (N/m ^{2})

D : Diameter pipe (m)

L : Long pipe (m)

Poiseuille's Law or Equation describes the flow of fluid in a pipe, known as Hagen-Poiseuille flow. The contribution of G. Hagen and J. Poiseuille is recognized in this field. This equation shows that the pressure drop and pumping power increase with the length of the tube and the viscosity of the fluid, but decrease with the fourth power of the pipe diameter. Increasing the pipe diameter can reduce the pumping power up to 16 times but it is necessary to consider the higher construction cost.

Viscosity Measuring Instrument

Hopper (falling ball viscometer) is a popular manual viscosity measuring instrument. It rolls a steel ball through a fluid in a glass tube. According to Stokes' law, the frictional force of the ball is equal to the gravitational force of Archimedes when it reaches maximum speed. The viscous force acting on the ball is directly proportional to its relative velocity in a given fluid. The pattern of flow lines around the ball will be symmetrical in a fluid at rest or a perfect fluid with zero viscosity. The pressure on the surface of the ball in one direction of the inlet is equal to the pressure at the opposite point. The ball experiences zero force if its surface faces the direction of flow.

Flowmeter Sensor

Flowmeter, Hall effect sensor, and plastic valve body form a flow measuring sensor. The rotor will rotate with the speed of the air flow as it passes through it. The ZJ-BT1 flow meter, developed by SEIDO and Pom Mini—two companies experienced in measuring instruments—utilizes the principle of an electric field increasing until the Lorentz force on the particle becomes zero. The Hall potential, which is directly proportional to the electric current and magnetic field passing through the device, is the potential difference measured between the two sides. Figure 1 shows the mechanical and physical dimensions of the ZJ-BT1 flow sensor.

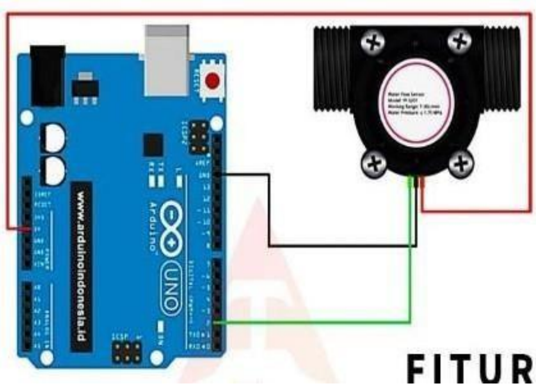

Figure 1. *YF-S201 Flowmeter Sensor*

Arduino Nano

The Arduino Nano microcontroller board is very small in size. There are 14 digital input/output pins on this board; six of which can be used as digital inputs and the other six as PWM outputs. A 16MHz crystal oscillator, USB port, power jack, ICSP header, and reset button are also included on the board. To utilize this microcontroller, users simply connect it to a computer via a USB cable, or can connect it to a battery or DC converter.

Jumper Cable

In Arduino projects, jumper wires are used as electrical conductors to connect components without soldering. There are male and female connectors on both ends of the wire, facilitating circuit assembly on a breadboard or other prototyping device. Jumper wires act as connectors in electrical circuits.

Figure 2. *Female To Male and Female To Female Jumper Cables*

3. RESEARCH METHODS

Literature Study

In the preparation of applied scientific work, an important step is to determine the research method before completing the work. This chapter explains the steps that need to be taken in the research, including Literature Study to understand the basics of tool development with references from various sources.

Place and Time of Implementation

The project of making a microcontroller-based oil viscosity monitoring tool was carried out in two places: on board the ship for analysis and at the North Sulawesi Maritime Polytechnic Laboratory. The research lasted for 12 months with a literature method to obtain basic knowledge about tool design. References were obtained from books, journals, and articles.

System Design

This device is designed using a panel or module that measures oil thickness using a microcontroller. The flow meter sensor is installed on the pipe to measure the flow of pumped oil. This sensor consists of an air rotor, a Hall effect sensor, and a plastic valve body. The rotor will rotate as the oil flows, and its rotation speed will regulate the oil flow rate. This sensor produces voltage only when the oil flows. The sensor output is a digital voltage that can be recorded by the Arduino microcontroller. Arduino will process the recorded data, convert the flow to viscosity, and transfer the conversion results to the computer. The functional diagram of the device can be seen in Figure 3.

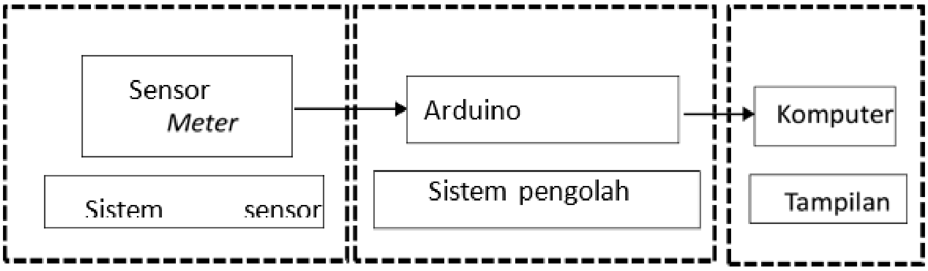

Figure 3. *Tool Block Diagram*

Tool Making

This research includes two main parts, namely hardware that includes a flowmeter sensor and Arduino microcontroller, and software that controls the oil viscosity measurement system. The organizational structure is shown in Figure 4.

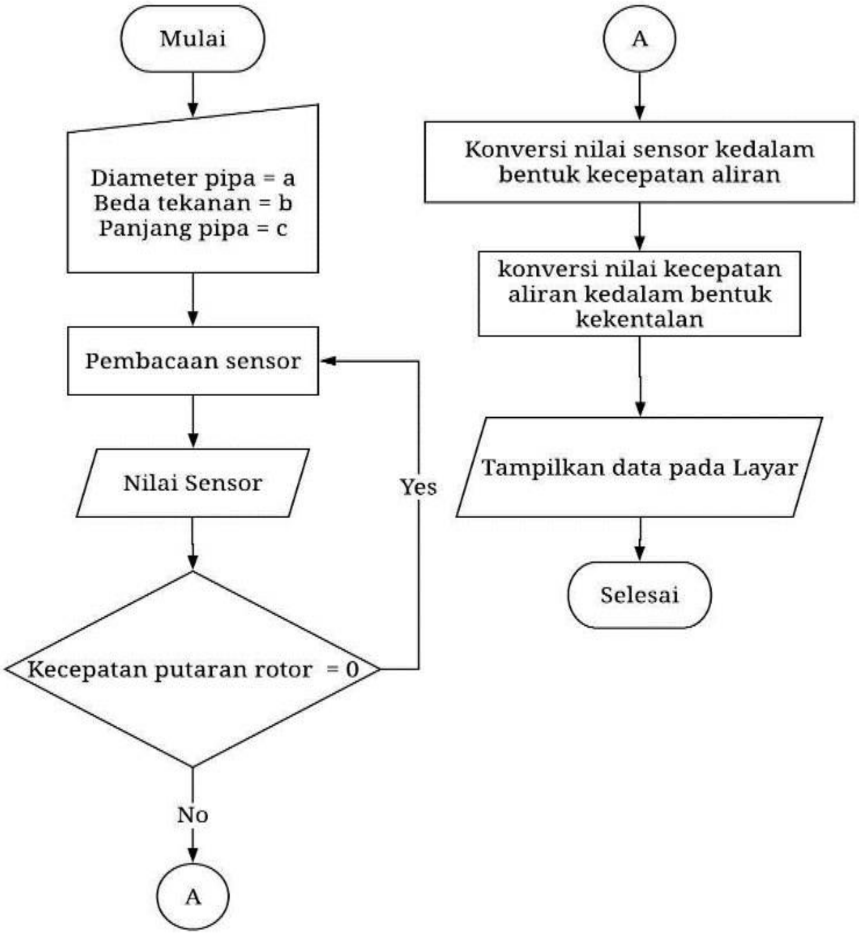

Figure 4. *Program Flowchart*

The microcontroller processes the flow sensor data to calculate the oil flow and oil viscosity values. The conversion results are displayed on the monitor.

Research Flow Diagram

Instrument testing is performed to ensure that each block functions as intended. The flow sensor experiment aims to verify sensor operation and data transmission accuracy. Instrument calibration involves measuring sensor data and comparing it to manual values. The research flow diagram shows the steps in planning a viscosity measuring instrument. These steps are illustrated in Figure 5.

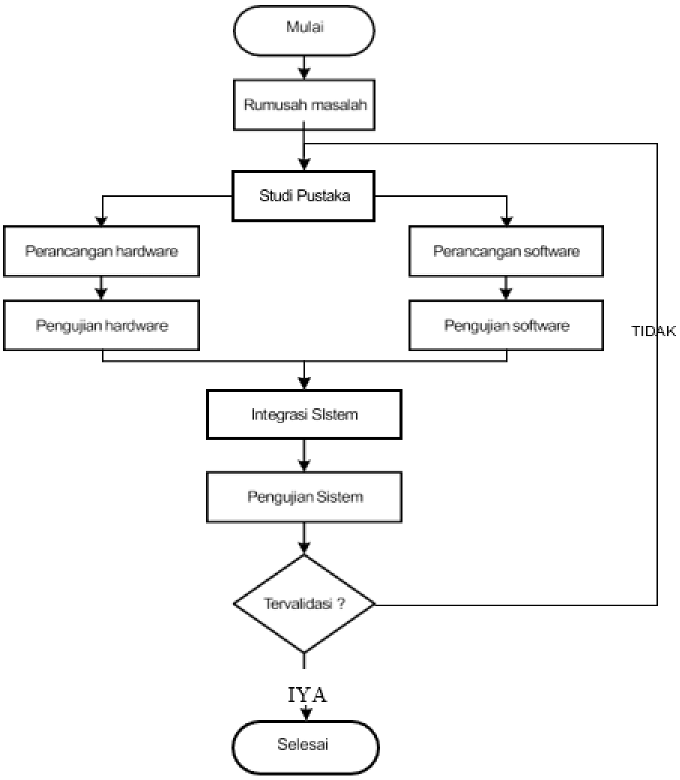

Figure 5. *Work Steps*

4. RESULTS AND DISCUSSION

Creating Schematic Diagrams

The design of this tool was previously made using a schematic diagram to show the electronic circuit that connects the microcontroller with sensors and other supporting devices. This electronic circuit is produced with figure 6.

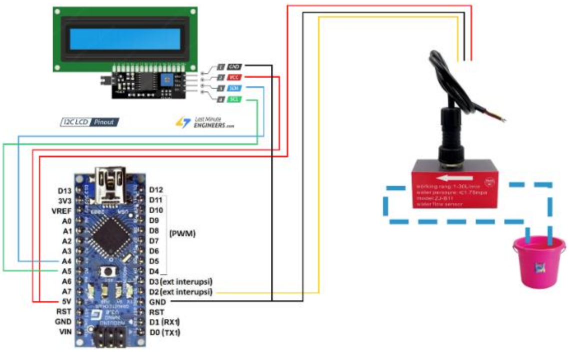

Figure 6. *Schematic Diagram*

From the diagram, the Flow Meter sensor is connected to the Arduino using the red cable to 5v, black to GND, and yellow to pin D2. The 12c LCD is connected to the Arduino Nano with vcc to 5v, GND to GND, SDA to pin A4, and SCL to pin A5.

Flowmeter Sensor Test Results

Flow sensor testing was conducted using a G1 type flow sensor for research. The experiment involved comparing the discharge and volume values of water measured by the sensor with measurements using a measuring cup and stopwatch. The main sensor test design is on the page. Experimental findings from the flowmeter sensor test used to calculate air volume and velocity are presented in the Test Results. The purpose of this test is to ensure that the sensor performance meets the research needs.

Table 1. Test Results

No	Acuan(L/min)	Kecepatanaliran*flowmeter* (L/min)	Volumeair *flowmeter*(ml)
1	16	15	0
2		15	266
3		15	572
4		15	765
5		15	990
6		15	1129
7		15	1395
8		15	1661
9		15	1936
10		15	2192

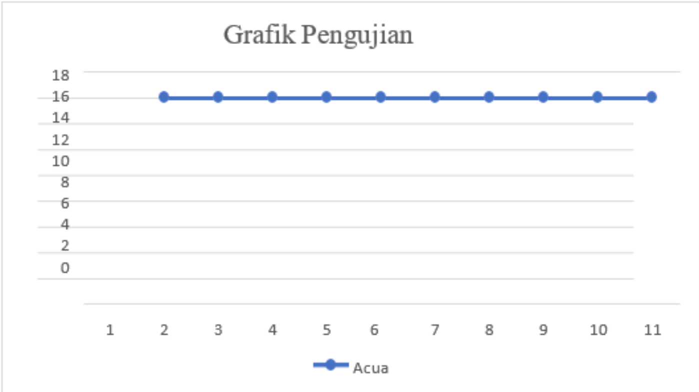

Figure 7. Graph of Flow Rate Test Results on *Flowmeter Sensor*

$$Error = \frac{\text{V acuan} - \text{V alat}}{\text{V acuan}} \times 100\%$$

$$= \frac{1000 - 990}{1000} \times 100\%$$

$$= 1\%$$

Table 1 shows the converted flow sensor data . become speed water flow . Water volume is calculated based on the data . Flow meter testing shows the result is 990 ml in 5 seconds , while manual measurement shows 1000 ml inside same time . There is a 1% error between second results The Flowmeter Sensor shows precision tall with consistent results .

Test Results Using SAE Oil 10w-40, 15w-40, 20w-50 And Falling Ball Method

From the experiments conducted , it was obtained results measurement Ball drop tools and methods for each type oil . Measurement results tool compared to with mark reference from ball drop method for determine level error tools . Graphics comparison between mark from ball drop method and results tool can seen in Table 2 and Figure 8.

Table 2 Graph Comparison of Falling Ball Method Values and Tool Values

Table 2. Graph Comparison Falling Ball Method and Tool Values

JENIS OLI	KEKENTALAN (Ns/m^2)		*ERROR (%)*
	BOLA JATUH	BUATAN	
SAE 10W-40	0.160320567	0.170655208	6.4
SAE 15W-40	0.183366195	0.203941381	11.2
SAE 20W-50	0.218243364	0.250550765	14.8

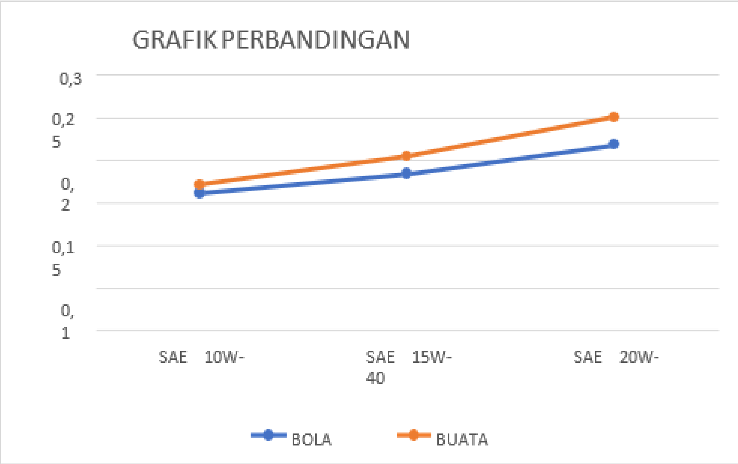

Figure 8. Graph Comparison of Tool Values and Reference Values

Numerical calculations produce higher accuracy compared to manual calculations, as shown in Table 4.5 and Figure 4.9, which are at higher risk of human error, such as in recording time using a stopwatch. SAE 20W-50 oil has the worst error of 14.8%, while SAE 10W-40 oil has the smallest error of 6.4%. These data show that the error value increases with increasing oil viscosity. This results in sensor rotor rotation errors due to slower fluid flow at high viscosity and increased circulation between the oil and sensor flow.

5. CONCLUSION AND SUGGESTIONS

Conclusion

Oil viscosity measurement is done by measuring the oil flow rate. The results of the experiment show that oil flow rate and oil viscosity are inversely related. The faster the oil flow, the smaller the oil viscosity, and vice versa. The data shows the viscosity and flow rate for Pertamina Prima XP SAE 10W-40 Oil, Pertamina Meditran SX SAE 15W-40 Oil, and Pertamina Mesran Super SAE 20W-50 Oil. This tool measures oil viscosity by measuring the oil flow rate through a pipe with a certain design. The measurement results for each oil also include an error rate to estimate the accuracy of the measurement.

Suggestion

Testing suggestions:

a. Use a voltage source from a battery/accumulator so that the tool is easy to use anywhere.
b. Use a digital viscometer for more accurate results.

c. Replace the flow meter sensor with an ultrasonic sensor to measure the flow rate.
d. without compromising the quality of the oil.

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