

Monitoring Viscosity of Polymer Products on the Reactor Tank Using IoT-based NodeMCU

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Abstract: Viscosity is one of the critical parameters for polymer products; thus, monitoring the viscosity level is very important to know during the production process and production results. The Polymer Company recently suffered heavy losses due to an explosion in one of its reactor engines, the R306 engine. The investigation results show that the viscosity of the polymer is one of the causes of the heavy workload of the machine, when the viscosity is checked manually. This research was conducted based on these conditions, and a viscosity monitoring device was designed for the 306-tank product. The design used QFD visualization for product design and UML for information system design. In this study, polymer viscosity was measured using the falling ball method with an Infrared Sensor E18-D80NK to obtain the viscosity of polymer products. Viscosity data are configured directly with the Internet of Things using the NodeMCU microcontroller. The design results show that the tool can monitor the viscosity in the tank and provide polymer viscosity information in real-time, thus facilitating decision-making and increasing productivity.

Keywords: AHP, QFD, UML, NodeMCU, Sensor E18-D80NK, polymer.

Introduction

Aristec is a company that manufactures emulsion polymers, synthetic resins, and car care products. A total of 15% of the production at the Polymer Company is exported to Vietnam, the Philippines, and India; the remaining 85% are sold in the domestic market of Indonesia. As a chemical-based company, Aristec has vulnerabilities and risks to fire hazards. Recently, there was a fire in the company, causing an explosion in one of the reactor engines, the R306 engine. This explosion caused 85% damage to the entire engine, which included damage to the tank, combustion agitator, and agitator motor so the engine could no longer be used. Therefore, a study on prevention to the same occurrence should be done.

In the case of this polymer company, viscosity is one of the many factors that influence the explosions, in which the viscosity was not controlled and exceeded the engine workload, so the engine work became heavier. Viscosity is a measure of a fluid's resistance to change, either by pressure or tension [1], and viscosity is directly related to the resistance of fluid inflow [2]. The greater the viscosity value, the higher the fluid's viscosity level. The viscosity of the material produced has a significant influence. If the viscosity level exceeds the tolerance limit set by the company, the work of the agitator motor will slow down and have an excessive workload [3]. This can cause the engine to overheat, disrupting production. Table 1 shows the viscosity level product is not the same based on product specifications.

This study checked several variables by interviewing the operators working on the R306 machine and looking at the R306 engine specifications. The summarized data concluded that the viscosity level of the material in a few days passed the viscosity standard set by the company for the R306 engine, i.e., 5000-8000 cPs. The production volume can be okay with the tank capacity still accommodating the material. However, in practice, the tank cannot produce material equivalent to its capacity because the agitator motor will overheat. This can result in the work of the agitator motor exceeding the workload capability caused by the uncontrolled viscosity level of the material. Therefore, viscosity has a close relationship with the agitator motor, which are several factors that need to be controlled so that the overall R306 reactor engine system is in a safer state. The illustration of R306 can be seen in Figure 1.

Table 1. Observational data for the level of material viscosity, the average volume of material production, and Power motor agitator

Conditions/Date	04/08	05/08	06/08	09/08	10/08	11/08	12/08	13/08
Standard of viscosity level (cP)	5000-8000							
The highest viscosity level (cP)	8500	9450	8700	8000	8050	8000	8100	8000
Agitator (RPM)	20-30	20-30	20-30	20-30	20-30	20-30	20-30	20-30
Production volume / tank capacity (Kg)	1800/3500	1800/3500	1800/3500	1800/3500	1800/3500	1800/3500	1800/3500	1800/3500

**Figure 1.** Machine R306

There is a lot of research on controlling the viscosity of polymer products in the production process. Sahasrabudhe *et al.* [4] modeled density using the Rackett equation modified by the Eötvös and Andrade equations. The results showed that the type of oil affected the density and viscosity but did not affect the surface tension of the oil. Franco and Buiocchi [5] performed viscosity measurements using ultrasonic. Pham *et al.* [6] conducted a study to determine the correlation of mathematical equations to predict the relationship between kinematic viscosity and the density of biodiesel-diesel fuel mixtures. Some researchers use IoT to monitor humidity, temperature, and control systems in industrial settings [7][8][9][10][11][12][13]. The novelty of this research lies in the design process that uses Voice of Customer with QFD and the information system design that uses UML. Previous studies also showed no viscosity monitoring for polymer manufacture using the E18-D80NK Sensor. Therefore, this research produces a prototype viscosity control device for polymer products in reactor tanks using IoT-based NodeMCU.

This study proposed designing a viscosity-measuring instrument to determine the machine's workload related to the product's viscosity. In the proposed design, a tool can provide material viscosity information through displays and is integrated with the internet via Android with the concept of the Internet of Things (IoT) based on NodeMCU. The equipment is designed to make the viscosity of the material easy to measure and flexible to use. The product will be designed using QFD, and the information system will be developed using UML to get the appropriate tools and information systems in this research. State-of-the-art research uses NodeMCU and Infrared Sensor E18-D80NK to control the viscosity of polymer products in tanks with the permissible principle. The tool design process uses QFD to obtain tools to the user's wishes and field conditions and AHP to measure the level of interest [14]. The information system design process is carried out using UML so the information system can match the company's interests and needs and minimize problems that happen.

Methods

This study has the following research method steps. First, we observed the problems in the Polymer Company, namely the explosion of the R306 engine that had just occurred, and to get the actual data. Next, we conduct discussions and interviews with the Head of the Engineering Polymer Company to find the cause of the explosion of the R306 engine. The meeting found that various correlated factors caused the root cause of the R306 engine explosion. Among them are the temperature of the agitator motor, the pressure of the steam produced during production, and the viscosity of the material produced. They are interrelated and directly affect the explosion of the reactor, so extra handling needs to be done on this. Therefore, this study aims to design an information system for monitoring the workload of the R306 engine related to viscosity with the Internet of Things (IoT) concept and based on NodeMCU at the Polymer Company and how to design a workload

monitoring tool for the R306 engine related to viscosity with the Internet of Things (IoT) concept and based on NodeMCU at Polymer Company [14].

This study has two goals, i.e., planning and designing a working load measurement system related to the R306 engine viscosity and designing the tool. The planning for information system tools for monitoring workloads associated with the viscosity of the R301 engine uses the Analysis Hierarchy Process (AHP) method, along with a description of the steps for planning a viscosity measurement system tool using the AHP method [15]. First, we make a list of questions to get a VoC (Voice of Customer) from the internal Polymer Company to form essential criteria for the information system tool [16] [17] [18]. This list of questions is made in a language that can be understood and made as flexible as possible so that the results of the VoC can represent the wishes of the respondents. The questions are asked during brainstorming [18] [19] [20]. This list of questions is made in a language that can be understood and made as flexible as possible so that the results of the VoC can represent the wishes of the respondents. Then, the questions are enquired during brainstorming.

The obtained data are categorized into several groups for analyzing customer needs and outputs, the degree of importance (IR) of the Customer Request (CR). Then we performed the Normality, Validity, and Reliability (NVR) test and constructed a House of Quality (HOQ) matrix. [21].

The design of the measurement tool in this study uses the Unified Modeling Language (UML) method. This method serves to describe system boundaries and system functions in general. The first step is to design this research by illustrating objects related to the system. The relationship between objects must be explained to make it easier for the reader to interpret the system. The relationship between these objects is illustrated using a use-case diagram. After the objects are described, the next step is to create an activity diagram to describe the activities carried out by these objects. We use sequence diagrams to describe the flow of activities based on the time sequence or description of the activities of each entity in stages. In addition, they describe the relationship, activity, and sequence of activities based on time or stages of the process. Furthermore, UML describes the state of each object treated by another entity [22].

Finally, we develop and test the workload measurement tool related to the R306 engine viscosity using the Internet of Things (IoT) concept and based on NodeMCU. The development and test consist of the following steps. (1) Design a workload monitoring information system tool scheme related to the viscosity of the R306 engine using the Internet of Things (IoT) concept and based on Arduino. (2) Design a tool by combining an infrared sensor with a NodeMCU microcontroller to determine the viscosity of the material to be measured. The viscosity formula is entered into the microcontroller to calculate the viscosity automatically. (3) Adapt all components to the program module using the Arduino IDE (Integrated Development Environment) so the viscosity of the material can be read into the system language. Accessing material viscosity data online can be accessed via internet-connected devices. The viscosity calculation can be done automatically with input entered directly through an application connected to the internet. In this case, the input is the density of the fluid used. The appearance of viscosity information on the LCD and viscosity data that can be directly viewed online indicates that this research is complete.

The viscosity was measured using the falling ball method. Stokes' Law describes that if an object moves with velocity (v) in a fluid with a specific viscosity coefficient value, the object will experience a fluid frictional force called Stokes force (f_s). The value of k is a constant that depends on the geometric shape of the object. [23] The force that applies in calculating the falling ball method is according to the equation (1).

$$\sum F = 0$$

$$F_{floating} + F_{\eta} + (-mg) = 0 \quad (1)$$

By substituting the buoyancy force, the resistance force from Stokes' Law and the mass of the ball into the equation (1), the viscosity equation (η) is concluded as equation (2).

$$\eta = \frac{2r^2g}{9v}(\rho_0 - \rho_1) \quad (2)$$

where r represents the radius of a solid ball, g is the acceleration due to gravity, v is the travel speed of the ball, ρ_0 is the density of the solid ball, and ρ_1 is the density of the fluid.

Results and Discussions

Decision Priority with AHP

The discussion with the Head of the Engineering Polymer Company produced the criteria for viscosity-related workload measurement tools required by the company's management. The measurement tools should be lightweight, affordable, and easy to install. In addition, the results are accessible online, and the components are electrostatic. Next, we used Analytical Hierarchy Process (AHP) to obtain the attribute priorities. Figure 2 exhibits the AHP structure.

This study uses the assistance of three expert judgments, which provide several alternative criteria mentioned above. These three experts are the Head of Production, Head of Engineering, and Operator of the R306 engine. These criteria are then tested to get which priority is most needed. Finally, tests are conducted to determine which criteria are most needed based on the five alternatives proposed by expert judgment. The data is processed using Super Decision software. The analysis results show that technical aspects are prioritized over non-technical elements, i.e., 0.857. As for each alternative, products that can be accessed online are the most critical priority for the company. Table 2 summarizes the order of preference.

The next step is to process the data using the Quality Function Deployment (QFD) method. The instrument used in processing the data is a questionnaire. Questionnaires are needed to obtain processing data that reflect the company to obtain a workload measurement tool related to viscosity that follows the company's needs. In addition, the questionnaire makes data processing more systematic.

The research instrument is important to obtain research data. The instrument used is a questionnaire containing four questions that are easy to understand. The questions correlate with which alternative is most needed by the respondents towards the criteria for measuring workloads related to viscosity. Questionnaires were distributed to 10 people appointed by the Head of Engineering in the hope of representing the company's wishes. The proposed questionnaire uses a Likert scale with five criteria and different weights, namely:

1. Very unneeded (STD) = 1
2. Not needed (TD) = 2
3. Required (D) = 3
4. More needed (LD) = 4
5. Much needed (SD) = 5

With these five scales, respondents are asked to choose which criteria are most suitable for the company according to the respondents' perception (see Table 3).

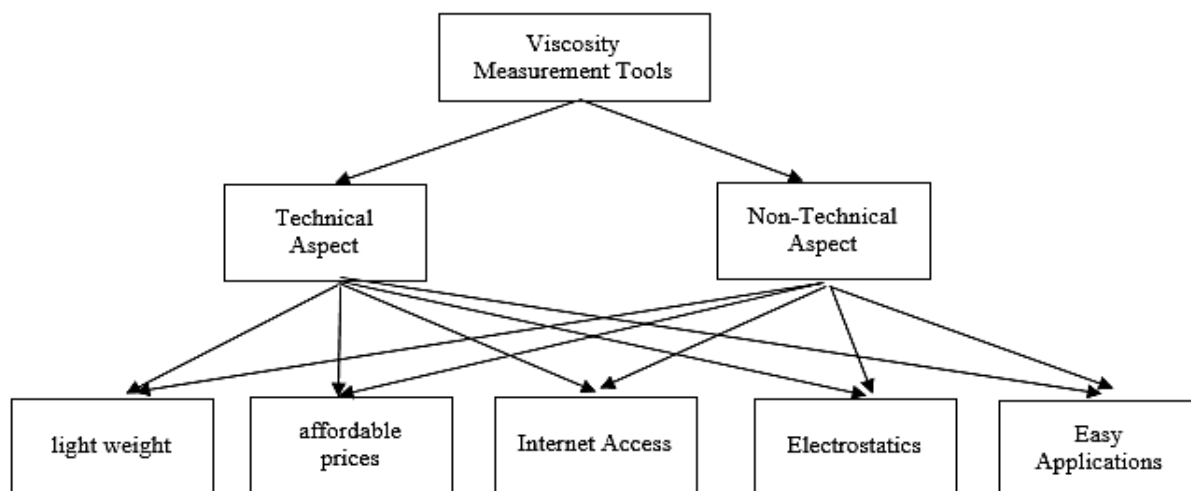


Figure 2. The AHP model

Table 2. Priority order of product criteria

Name	Normalized by Cluster	Rank
Internet-accessible	0.35123	1
Easy installation	0.18696	2
Electrostatic components	0.17754	3
Affordable prices	0.16178	4
Light weight	0.12249	5

Table 3. The Selected attribute

Attribute	Number of votes			
	TD	D	LD	SD
Internet-accessible		3	4	3
Easy installation	2	4	3	1
Electrostatic components	2	3	4	1
Affordable prices	2	4	3	1

Importance Rating

The level of importance determines how important the criteria for each attribute are based on the respondents' perception. By calculating the matter level, the researcher will easily determine the highest weight for each attribute. The importance rating (IR) can be calculated as follows:

$$IR = \text{number of respondents who chose} \times \text{weight of importance number of questionnaires} \quad (3)$$

Table 4. Value of importance rating

Attribute	IR Value
Internet-accessible	4
Easy installation	3.3
Electrostatic components	3.4
Affordable prices	3.3

Table 5. Tool technical specification

Company needs	Technical requirements
Internet-accessible	Using NodeMCU
Easy installation	Simple Tool Design
Electrostatic components	Electrostatic Component Design
Affordable prices	Cheap Tool Materials

Table 4 shows that the highest weight and priority of the respondents' needs is a measurement tool accessible online, followed by electrostatic components with an importance rating value of 4 and 3.4, respectively.

Technical Requirement

The company's need for a good workload measurement tool related to viscosity should match the tool's specifications. Technical specifications are supporting characteristics required so the product can genuinely meet the company's requirements. The proposed features are innovation and embodiment of what has been delivered by the company. The technical requirement table, which explains the product criteria specifications in general, should be constructed before creating a matrix (see Table 5).

Relationship Matrix

In this grouping, the level of relationship is a determinant of the product because it will be used as the basis for designing the product. A relationship matrix is likened to symbols (see Table 6) with different weights according to their level.

The matrix represents the relationship between Technical and customer needs is shown in Table 7. Additionally, Table 8. exhibits the weighted values matrix.

Table 6. Symbols of relationship matrix

Symbol	Value weight	Remarks
(Empty)	0	No connection
●	1	Weak relationship
○	3	Medium relationship
△	9	Strong relationship

Table 7. Relationship matrix calculation

Customer Needs	IR	Technical needs				Value weight
		1	2	3	4	
Internet-accessible	4	△		○	○	15
Easy installation	3.3		△	●	○	13
Electrostatic components	3.4	○		△	●	13
Affordable prices	3.3	○			△	12
value weight		15	9	13	16	53

Table 8. Relationship matrix calculation results

Customer Needs	IR	Technical needs				value weight
		1	2	3	4	
Internet-accessible	4	△		○	○	15
Easy installation	3.3		△	●	○	13
Electrostatic components	3.4	○		△	●	13
Affordable prices	3.3	○			△	12
value weight		15	9	13	16	53

The relationship matrix table shows four strong relationships, five moderate relationships, two weak relationships, and five categories that do not have any relationship. Based on the weighted value of customer needs, the attribute of accessible online has the highest weight with a value of 15; on the other hand, the affordable price attribute is the lowest with a value of 12. In comparison, the weighted value of technical needs is superior to the criteria for tool material, with a value of 16. Meanwhile, the requirements for simple tool design were the lowest, with a value of 9. These values cannot be used as a reference in research because they must be tested further to obtain absolute and relative importance values.

Value of Absolute and Relative Importance

As a further form of the relationship matrix, the next step is determining absolute and relative importance values. The value of fundamental importance relates to which technical specification items should be prioritized. When designing the tool, it is expected that the manufacture of the device can be carried out in a structured manner. Here is the formula for determining the absolute importance value:

$$Kt = \sum (Bti \times Hi) \tag{4}$$

Remarks:

Kt : Absolute importance value.

Bti : The weight of the value of the relative importance of the company’s needs that have a relationship with the attribute.

Hi : The value of the relationship of the company’s needs with attributes.

The following is a calculation of the absolute importance level for the attribute category attribute “Using NodeMCU.”

$$Kt = \sum (4 \times 9) + (3.3 \times 0) + (3.4 \times 3) + (3.3 \times 3) = 56.1$$

The results of the calculated technical requirements are listed in Table 9.

Table 9 shows the highest absolute importance value is the technical requirements of using NodeMCU, followed by tool material, electrostatic component design, and lastly, a simple tool design. The next step is to calculate the relative importance value. The following formula can describe the value of relative importance:

$$relative\ importance(i) = \frac{Kti}{\sum Kti} \tag{5}$$

where:

Kti : Value of the absolute importance of the technical necessity

$\sum Kti$: Total value of absolute importance of technical requirements

The following is a calculation of the relative importance of attributes using NodeMCU:

$$relative\ importance(i) = \frac{56.1}{56.1 + 29.7 + 45.9 + 55} = \frac{36}{159.1}$$

Data regarding the overall relative importance value can be seen in Table 10.

Table 9. Calculation of absolute interest value

Technical needs	Absolute value of interest
Internet-accessible	56.1
Easy installation	29.7
Electrostatic components	45.9
Affordable prices	55

Table 10. Results of relative interest value

Technical needs	Value of relative importance
Internet-accessible	0.3005
Easy installation	0.1591
Electrostatic components	0.2458
Affordable prices	0.2946

The relative importance value shows the percentage of each technical requirement attribute to the overall attribute. Therefore, it can be concluded that using NodeMCU is a priority with a relative importance value of 30%, and simple tool design is in the last order with a percentage of 15.9%.

Technical Requirement Correlation Matrix

The next step is to classify the correlation of technical requirements, whether the attributes of technical requirements are positively, negatively related, or have no relationship at all (see Figure 3). The design of electrostatic components and cheap tool materials have a negative correlation since electrostatic components can make measurements easier, but each material is costly.

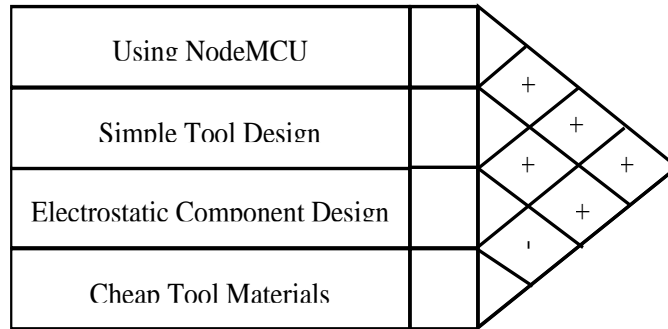


Figure 3. Requirement correlation matrix diagram

Metrics of House of Quality (HoQ)

After each component of the House of Quality has been found, the next step is to arrange the elements that make up the HoQ into a unified matrix, so the identification is structured systematically (See Figure 4).

(Goals)	% Priority (Relative)	Technical Priority (Absolute)	Customer Requirement				IR	Technical Requirement	
			Affordable Prices	Electrostatic Components	Easy Installation	Internet Accessible			
Easy internet configuration	0,3	56,1	○	○	△	○	1	Using NodeMCU	○
Easy to find the components	0,16	29,7			△		2	Simple Tool Design	△
Internet and electricity configured	0,24	45,9		△	●	○	3	Electrostatic Comp. Design	△
Summarize the components used	0,29	55	△	●	○	○	4	Cheap Tool Materials	△

Figure 4. The QFD for Viscosity Design

Figure 4 shows the highest priority is related to the purpose of the tool criteria, namely easy internet configuration by 30%, which is adjusted to technical requirements of using NodeMCU—followed by the aim of summarizing the components used by using a simple tool design. Then, it is configured with the internet and electricity with an electrostatic component design, and the last component is easy to find using a simple tool design.

System Design

The design of this viscosity-related workload measurement system uses the Unified Modeling Language (UML) method to make reading easier. Figure 5 shows a UML diagram consisting of use case, activity, and sequence diagrams.

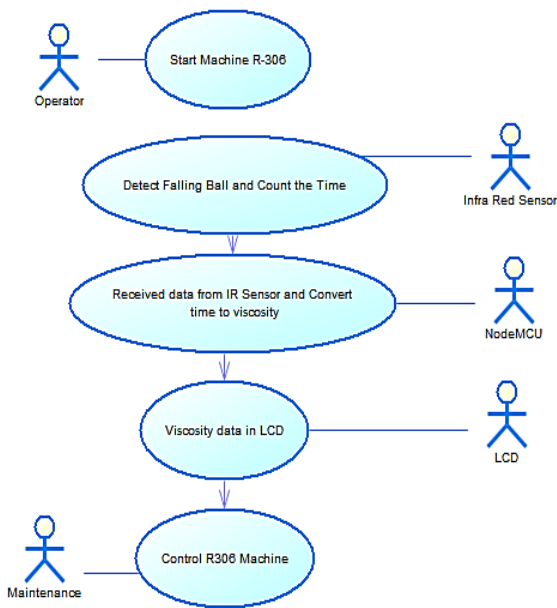


Figure 5. Use-case diagram of a measurement system

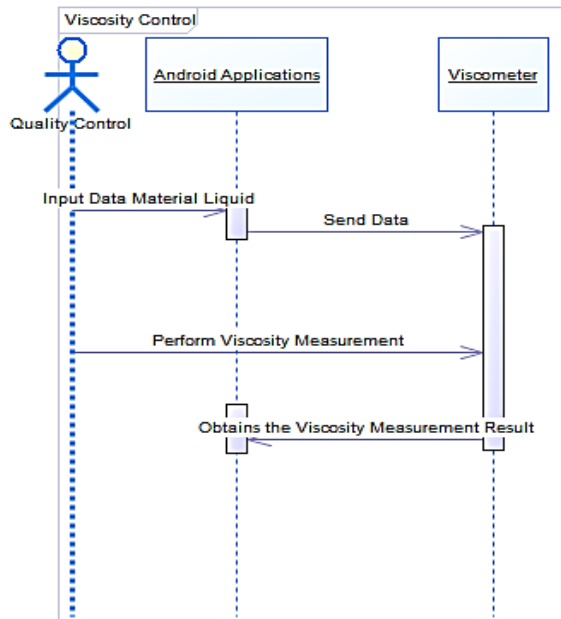


Figure 6. Sequence diagram of viscosity results

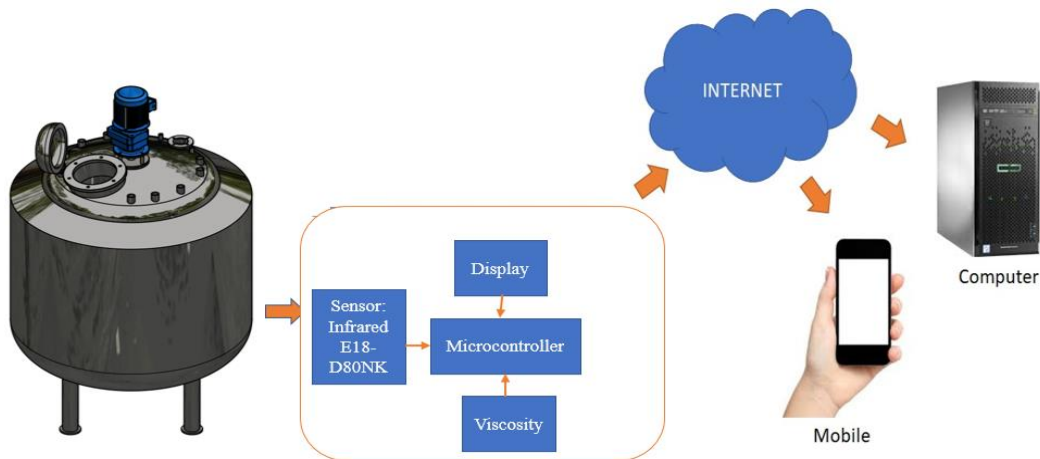


Figure 7. Design of viscosity monitoring for polymer products on mixing tank based on the Internet of Things

The delivery of viscosity results starts from QC, which enters liquid data in fluid density into the application. The following application will send information from the fluid density into the workload measuring device related to viscosity which is marked with a description on the LCD of the tool. After delivery, QC can measure viscosity using the falling ball method; insert a solid ball into an acrylic tube filled with a fluid whose viscosity value will be sought. The ball that enters the acrylic tube will automatically calculate the travel time by the infrared sensor. After the ball reaches the bottom of the tube surface, the viscosity result is printed on the LCD, and the measurement tool sends the data to the Android application (see Figure 6).

Figure 7 is the viscosity monitoring for the polymer products in the designed tank based on the Internet of Things. This system consists of Viscosity Control hardware and an IoT-based information system. The hardware consists of a E18-D80NK Infrared-Light-Barrier that measures the viscosity of the polymer in the tank, a microcontroller, an LCD, and a GSM module as a data bridge to the internet. The sensor used is Infrared E18-D80NK. The microcontroller will process the measurement result data to be displayed on the LCD and send the data to the internet using the GSM communication protocol. The working principle of this viscometer control device uses the falling ball method to obtain viscosity results. The infrared sensor can capture resistance when a solid ball is dropped into an acrylic container so the viscosity value can be displayed via the LCD and Android. This tool repeatedly works according to the specified time to measure the viscosity of the tank-producing polymer.

Tools Design

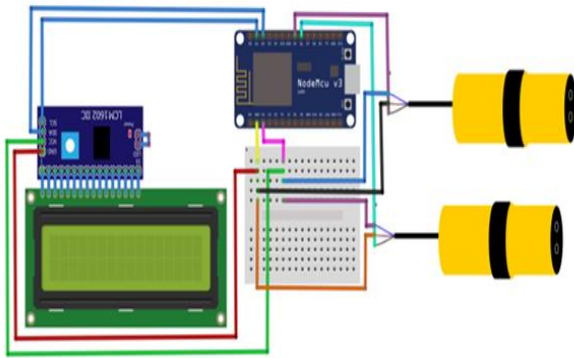


Figure 8. Workload measurement system circuit related to viscosity

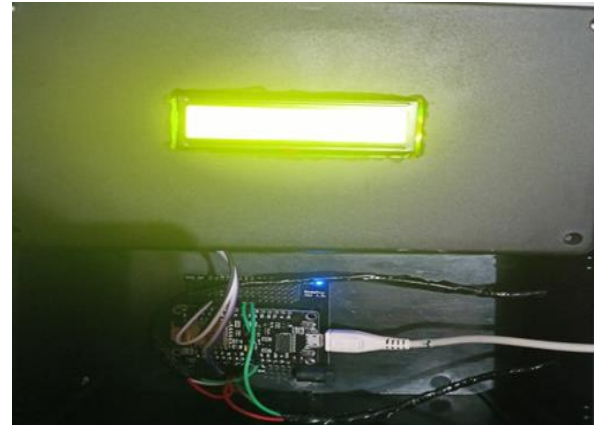


Figure 9. Actual circuit of wiring tool

Table 11. Connection of MCU node port and IR Sensor 1

Node MCU	Infrared Sensor 1
GND	GND
VU	VCC
D5	D-Out

Table 12. MCU node port Connections and 1 IR Sensors

Node MCU	Infrared Sensor 2
GND	GND
VU	VCC
D6	D-Out

Table 13. Connection of MCU node port and IR Sensor 1

Node MCU	Infrared Sensor 1
GND	GND
D1	SCL
D2	SDA
VU	VCC

The system established must be directly applied to the concept so that the viscosity-related workload measurement tool can be used as quickly as possible. The tool design uses several correlated components to form a workload measurement system related to viscosity. These components include NodeMCU ESP 8266 v. Lolin as a microcontroller, the infrared sensor as a timer for falling steel balls, LCD as a viewer of the measured viscosity data, Base NodeMCU as a circuit board for designing electronic circuits, Jumper cable as a liaison between components, Solid balls (marbles) as a tool for measuring viscosity using the falling ball method, Acrylic tube, meter, and wooden container as a container to accommodate the fluid to be tested.

Some components and equipment's used were correlated to form a workload measurement system related to viscosity. Figure 8 shows a series of viscosity measurement systems created using the Fritzing software. Based on Figure 8, Table **Error! Reference source not found.** - Table **Error! Reference source not found.** shows a connection to the NodeMCU port with other components:

Each port is connected using jumper cables; the connected components are placed in a black box to protect each component and make it look neater (see Figure 9).

Software Testing

Software testing is important to ensure that the program will run as intended. In designing this viscosity-related workload measurement tool, the device must detect the travel time of a solid ball dropped into an acrylic tube. After calculating time, the microcontroller processes the time data into a pre-programmed viscosity formula. Thus, applications connected to the internet and the LCD can display the previously measured viscosity value. Figure 10 depicted a program that has been designed to run tool components automatically into the NodeMCU microcontroller.

The program starts with installation of the thermocouple library, NodeMCU ESP 8266 v, dan LCD i2C library. Data used is viscosity value, with a condition if data is more than the value standard, the microcontroller sends a sign to switch off agitator button on/off. Afterwards, the program was uploaded to the NodeMCU microcontroller to operate properly.

```

Thermocouple Library
NodeMCU ESP 8266 v
LCD i2C Library

Var data

Begin () {
  Init thermocouple
  Init LCD

  Data = viscosity value ()

  If data > viscosity value, then turn on the
  agitator
  Else turn off the agitator

  Send data to Cloud
  Delay ()
}
    
```

Figure 10. Algorithm of the device

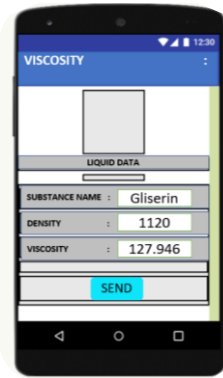


Figure 11. Android feature for viscosity monitoring

Tool Integration Testing with Android Apps

The next step is to test the tool's integration with the Android application to ensure that viscosity data can be sent via the internet. At first, the density data of the fluid is entered directly through the internet application, and the microcontroller will process the data along with the embedded formula. Providing the fluid density option will make this viscosity-related measurement tool more flexible because it can measure different fluids. The application created is a simple application made with the help of software called MIT App Inventor. This application allows the connection between the microcontroller and the application easily. The programmed NodeMCU is connected to the Android application via a WIFI connection, and the application can transfer the required data into the viscosity-related workload measurement system (see Figure 11).

Tool Test Results

To ensure that the measuring tool works properly and displays a viscosity number that matches the viscosity level of the fluid, this tool is tested by comparing the test results between measuring tools related to viscosity with the Oswald Viscometer. Table 14 and Figure 12 show the accuracy of the measurement.

Table 14. Viscometer test results with Oswald. viscometer

Fluid type	Density (kg/m ³)	Calculate viscometer (cPs)	Viscometer Oswald (cPs)
Glycerin (30%)	1120	127.946	130.746
Glycerin (30%)	1120	126.962	128.375
Glycerin (30%)	1120	125.978	129.67
Glycerin (30%)	1120	126.846	128.407
Oil	885	141.377	144.56
Oil	885	137.817	142.015
Oil	885	138.89	143.56
Water	1000	119.119	122.546
Water	1000	116.116	121.355
Water	1000	120.620	120.867

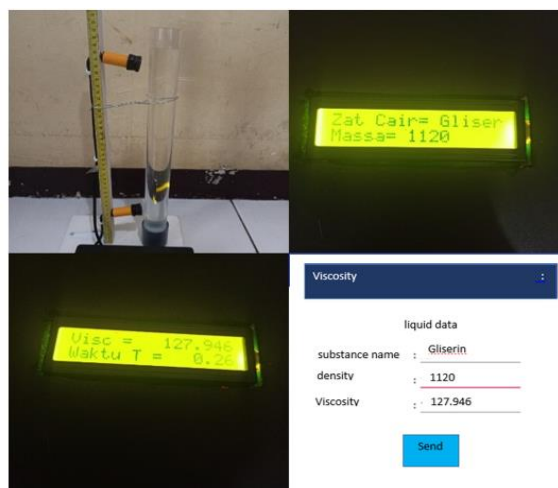


Figure 12. Actual glycerin viscosity test results through LCD and applications

Implementations

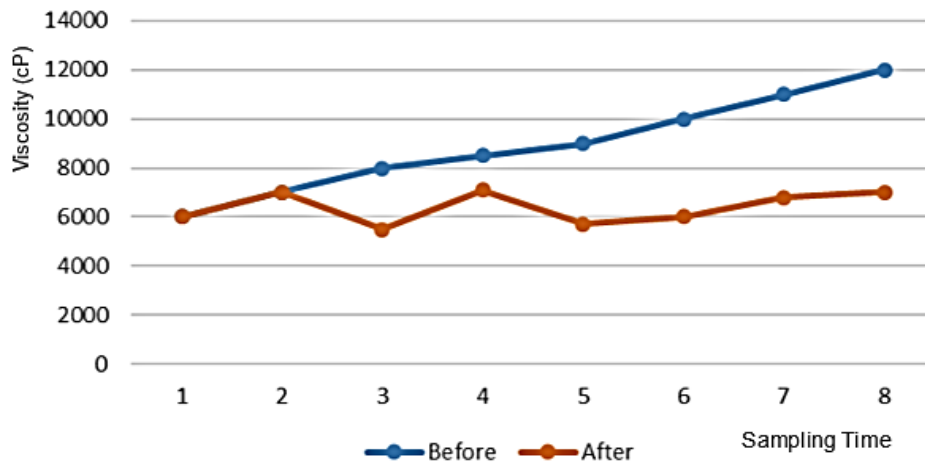


Figure 13. Conditions before using a monitoring system based on NodeMCU

The implementation showed standard viscosity of 5000 – 8000 cP, meaning the viscosity was well monitored. There is an indication of increased product viscosity, dilution, and immediate solvent addition, the workload of the machine will not become too heavy.

Figure 13 shows the polymer's viscosity is monitored more often after using a viscosity monitoring tool designed to produce polymer products. This condition increased the productivity, which is increasingly higher because the obstacles faced due to machine disturbances can be overcome.

Conclusion

The problem of monitoring viscosity manually and delaying information in the event of an abnormality can be solved by designing an R306 engine workload measurement system related to viscosity using the Internet of Things (IoT) concept based on NodeMCU. The results of the design using the AHP and QFD methods, visualization of the system using UML, the design of tools, and tools made with the concept of the Internet of Things (IoT) and based on NodeMCU using several components including Infrared sensors, NodeMCU ESP 8266 v microcontrollers, LCDs, jumper cables, balls solid, and tube containers, managed to show the viscosity in the tank during the production process. In addition, this research provides an opportunity to create an IoT-based monitoring system for measuring vapor pressure in the heat monitoring in the tank and agitator. This research deserves to be continued to implement Artificial Intelligence from the data generated.

References

- [1] R. Alcalde, G. García, M. Atilhan, and S. Aparicio, "Systematic study on the viscosity of ionic liquids: Measurement and prediction," *Industrial and Engineering Chemistry Research*, vol. 54, no. 43, pp. 10918–10924, 2015, doi: 10.1021/acs.iecr.5b02713.
- [2] L. S. Madsen *et al.*, "Ultrafast viscosity measurement with ballistic optical tweezers," *Nature Photonics*, vol. 15, no. 5, pp. 386–392, 2021, doi: 10.1038/s41566-021-00798-8.
- [3] M. T. Alam, B. Dai, X. Wu, A. Hoadley, and L. Zhang, "A critical review of ash slagging mechanisms and viscosity measurement for low-rank coal and bio-slugs," *Frontiers in Energy*, vol. 15, no. 1, pp. 46–67, 2021, doi: 10.1007/s11708-020-0807-8.
- [4] S. N. Sahasrabudhe, V. Rodriguez-Martinez, M. O'Meara, and B. E. Farkas, "Density, viscosity, and surface tension of five vegetable oils at elevated temperatures: Measurement and modeling," *International Journal of Food Properties*, vol. 20, no. 2, pp. 1965–1981, 2017, doi: 10.1080/10942912.2017.1360905.
- [5] E. E. Franco, and F. Buiochi, "Ultrasonic measurement of viscosity: Signal processing methodologies," *Ultrasonics*, vol. 91, no. August, pp. 213–219, 2019, doi: 10.1016/j.ultras.2018.08.006.
- [6] M. T. Pham, A. T. Hoang, A. T. Le, A. R. M. Said Al-Tawaha, V. H. Dong, and V. V. Le, "Measurement and prediction of the density and viscosity of biodiesel blends," *International Journal of Technology*, vol. 9, no. 5, pp. 1015–1026, 2018, doi: 10.14716/ijtech.v9i5.1950.

- [7] M. T. Seman, M. N. Abdullah, and M. K. Ishak, "Monitoring temperature, humidity and controlling system in industrial fixed room storage based on IOT," *J. Eng. Sci. Technol.*, vol. 15, no. 6, pp. 3588–3600, 2020, [Online]. Available: [https://jestec.taylors.edu.my/Vol 15 issue 6 December 2020/15_6_6.pdf](https://jestec.taylors.edu.my/Vol%2015%20issue%206%20December%202020/15_6_6.pdf)
- [8] G. M. Madhu and C. Vyjayanthi, "Implementation of cost effective smart home controller with Android application using Node MCU and Internet of Things (IOT)," *2nd Int. Conf. Energy, Power Environ. Towar. Smart Technol. ICEPE 2018*, no. April, pp. 1–5, 2019, doi: 10.1109/EPETSG.2018.8659128.
- [9] D. Abdulhad Aziz, "Webserver based smart monitoring system using ESP8266 Node MCU module," *Int. J. Sci. Eng. Res.*, vol. 9, no. 6, pp. 801–808, 2018.
- [10] K. M. Mohan, S. Abinaya, P. Kaviya, S. M. Sandhya, and P. Lavanya, "Engine oil condition monitoring using IoT and predictive analysis," *J. Crit. Rev.*, vol. 7, no. 04, pp. 1196–1204, 2020, [Online]. Available: <https://www.jcreview.com/admin/Uploads/Files/61b380f6afed00.39926551.pdf>
- [11] K. L. Raju, V. Chandrani, S. K. S. Begum, and M. P. Devi, "Home automation and security system with Node MCU using Internet of Things," *Proc. - Int. Conf. Vis. Towar. Emerg. Trends Commun. Networking, ViTECoN 2019*, no. March 2019, 2019, doi: 10.1109/ViTECoN.2019.8899540.
- [12] M. Kashyap, V. Sharma, and N. Gupta, "Taking MQTT and NodeMcu to IOT: Communication in Internet of Things," *Procedia Comput. Sci.*, vol. 132, no. Iccids, pp. 1611–1618, 2018, doi: 10.1016/j.procs.2018.05.126.
- [13] H. S. Hadi, P. Y. Aisyah, S. Arifin, and A. F. Adziimaa, "Fluid viscosity measuring instrument with Internet of Things (IoT) based rotary method," *J. Adv. Res. Fluid Mech. Therm. Sci.*, vol. 1, no. 1, pp. 65–89, 2022, [Online]. Available: <https://doi.org/10.37934/arfmts.92.1.6589>
- [14] R. S. Mor, S. Singh, and A. Bhardwaj, "Exploring the causes of low-productivity in dairy supply chain using AHP," *J. Tek. Ind.*, vol. 19, no. 2, p. 83, 2018, doi: 10.9744/jti.19.2.83-92.
- [15] C. N. Wang, Y. F. Huang, I. F. Cheng, and V. T. Nguyen, "A multi-criteria decision-making (MCDM) approach using hybrid SCOR metrics, AHP, and TOPSIS for supplier evaluation and selection in the gas and oil industry," *Processes*, vol. 6, no. 12, 2018, doi: 10.3390/pr6120252.
- [16] P. Paduloh and R. Muhendra, "Overheat protection for motor crane hoist using Internet of Thing," *Int. J. Comput. Appl. Technol.*, vol. 68, no. 4, pp. 332–344, 2022, doi: 10.1504/IJCAT.2022.125181
- [17] Y. H. Wang and C. C. Hsieh, "Explore technology innovation and intelligence for IoT (Internet of Things) based eyewear technology," *Technol. Forecast. Soc. Change*, vol. 127, no. July 2017, pp. 281–290, 2018, doi: 10.1016/j.techfore.2017.10.001.
- [18] P. Akkawuttiwanich and P. Yenradee, "Fuzzy QFD approach for managing SCOR performance indicators," *Comput. Ind. Eng.*, vol. 122, no. May 2018, pp. 189–201, 2018, doi: 10.1016/j.cie.2018.05.044.
- [19] K. E. Stansfield and F. Azmat, "Developing high value IoT solutions using AI enhanced ISO 16355 for QFD integrating market drivers into the design of IoT offerings," *Proc. 2017 Int. Conf. Commun. Comput. Digit. Syst. C-CODE 2017*, pp. 412–416, 2017, doi: 10.1109/C-CODE.2017.7918967.
- [20] F. Li, C. H. Chen, C. H. Lee, and L. P. Khoo, "A user requirement-driven approach incorporating TRIZ and QFD for designing a smart vessel alarm system to reduce alarm fatigue," *J. Navig.*, vol. 73, no. 1, pp. 212–232, 2020, doi: 10.1017/S0373463319000547.
- [21] S. KAYAPINAR and N. ERGİNEL, "Green design product connected by Internet of Things via Qfd," *23rd Int. QFD Symp. ISQFD 2017 - Tokyo*, no. October, 2017.
- [22] P. Paduloh, H. Fatahillah, M. A. Ramadhan, R. Muhendra, M. Widyantoro, and Sumanto, "Designing of temperature control for agitator machine using Internet of Thing," *IOP Conf. Ser. Earth Environ. Sci.*, 2022, doi: 10.1088/1755-1315/1063/1/012053.