Digital image segmentation for foaminess measurement on foam stability of the lubricant products

R T Yunardi¹, A A Rizqi¹, R N Naufal¹ and F C S Arisgraha²

¹ Department of Engineering, Faculty of Vocational, Universitas Airlangga
² Department of Physics, Faculty of Science and Technology, Universitas Airlangga

E-mail: rikyтриунарди@вокаси.унай.ид

Abstract. Measuring the lubricating oil foam is used to measure the physical properties of the foam stability of lubricants. Lubricant tendency to produce a foam on its use in mechanical systems can be a problem because of the loss of lubrication properties and maintenance costs as a consequence. Foaminess measurement system is expected to have an advantage in terms of ease of foam high readings for the analysis of foam stability. In this paper, digital image segmentation method is used for the measurement of foaming at the foam stability of lubricating products. Segmentation techniques applied to extract the image to get the height of the foam in a glass tube using the camera. Foam stability related to the height of foam produced during a certain time period necessary to disappear at a certain temperature. In the experiment, a series of measurements on three types of lubricant products using comparative analysis in order to compare their foam stability objectively. The results showed that the instrument system based on the image segmentation that has been developed capable of measuring the foam stability of lubricants.

1. Introduction

The lubricant is a liquid chemical substances and applied between two moving objects to reduce the frictional forces. The lubricant is a substance derived from petroleum and additives used to lubricate machines and mechanical systems [1]. Lubricating function to support the performance of the machine, such as preventing scratches, cooling and preventing rust on engine parts [2]. A mechanical system that works like a motor, compressor and gearbox has a stirring motion. This movement will aerate lubricant that causes air bubbles and foam. Foaming is the fundamental physical properties of fluid lubricants. Foam can reduce the ability of lubrication because air bubbles can create a barrier between the liquid metal surfaces. Lubricant tendency to produce a foam can be a problem because of the loss of lubrication properties and over time the machine will be damaged.

Foaminess is the ability of a liquid to produce foam comprising gas bubbles dispersed in a liquid [3]. Additives contained in lubricants is causing the foam formed to be different. The surface area of the liquid will increase when the bubbles are formed therein increases. Foaminess measurement of lubricant offers several parameters, such as measures the foaming tendency and stability. The layer of foam can vary from a few centimeters at the surface of the liquid. In a conventional method, operators used manual methods of measuring the foam level with reading the numbers on a measuring cylinder glass, it can cause errors in measurements [4]. Several technologies including differential pressure (DP) transmitter, radar level transmitter, and ultrasonic level sensor have been used [5-7], but with unreliable results to
measure the height of foam in a glass tube. The segmentation is involved by color, shape, and size of the objects on the digital image. Color and shape are important elements of natural images and has an important information in visual perception.

Computer vision is a field of computer science that aims to obtain an understanding of the visual data on objects observed [8]. The acquisition of visual data is a digital image. The digital image is representative of the image captured by the camera in the form of rows and columns of pixels. Extraction of the image to get the height of the foam can be achieved by digital image segmentation. Segmentation is used to separate the object with the background image to describe the height of foam lubricant based on the area in the binary image.

The proposed system uses digital image segmentation to identify foams, measures the height of the foams, and calculates the volume and tests to find out of the foam stability in the different types of lubricant products. For the measurement, the foam is formed in a cylindrical glass from the sample after stirring, the stability of the foam is a foam time period shrunk to half the initial volume. This ensures that differences in the foam stability in the different types of lubricant products are only linked with the additives contained in the lubricants.

2. Methods

2.1. Foaminess Measurement

Foam is formed when air is blown through the gas distributor using the pump into the liquid foaming. The electric pump is used as a lubricant stirrer device with air pressure. Bubbles formed below the liquid surface, rising to the surface and produce foam. Foam tends to rise to the surface because the gas density is smaller than the liquid. Foaminess generally characterized by the volume of the foam, which can be made from a certain amount of fluid and depends on the additives contained [9-10]. The foaminess measurement parameter is affected by the volume of foam formed after stirring during a given period of time.

Parameters to consider the use of foaminess is the time setting and stability of the foam. The time setting is the time of foaming during stirring sample to produce a stable foam volume. While foam stability is the depreciation time of foam until the volume to half of its initial volume. These measurements were carried out using a liquid in a measuring cylinder were shown in Figure 1. The initial volume of the foam is present and the time it takes the foam to decrease is calculated as shown in Equation (1).

$$\varepsilon_f = \left| \frac{V_{foam} - V_{liquid}}{V_{foam}} \right|$$

Where $\varepsilon_f$ is the absolute value of foaminess. $V_{foam}$ is the volume of foam after stirring (mL) and $V_{liquid}$ is the volume of liquid placed in the measuring cylinder (mL).

2.2. Configuration of Hardware System

An overview of hardware of measurement system is shown in Figure 2. This designed system is applied to a foaminess measurement on foam stability. Electric pumps designed to provide bubbles and produce foam in the lubricant to be tested. The electric pump provides the driving force through the gas distributor to form a bubble under the surface of the liquid. Porous stone, which is effectively used as a lubricant stirrer in this system, attached to the gas distributor.
Figure 1. Illustration of the liquid foaming to measure foaminess.

The measuring cylinder is designed to collect the fluids and to simulate the stirring motion in lubricant. It has a marked line on the cylinder represents the amount of liquid that has been measured. Stirring motion is realized through the distributing the air pressure to form a bubbles in the liquid to produce a foam volume. From the glass cylinder, the level of the foam will be read by sensor and the signal of sensor is transmitted to the acquisition data system.

At the test of measure the volume of lubricant liquid and volume of foam collected in the measuring cylinder is used camera. The Logitech HD Webcam C270 1.2MP with optical resolution 1280 x 960. To read the volume accurately, observations should be in the range of the camera view. In part of acquisition data system, the interface between personal computer and camera, running under Windows OS and camera used an USB connection. The data sampling is processed by software based on Delphi 7 platform in the form of digital image.

Figure 2. Overview of hardware of experimental setup.
2.3. Segmentation
In this study method for foaminess measurement on foam stability by using digital image segmentation. Segmentation extracts the pattern of the height of foam in the measuring cylinder. While the height of foam has been detected, it is measured and used to determine the volume of foam.

To make the object more recognizable, HSV color space is chosen to describe the color of an object in natural [11]. The color space of HSV is obtained from the conversion process of the RGB color space. The success rate of object recognition in digital image affected by the saturation. Therefore, saturation also needs to be defined to obtain more precise to detect the height of the foam. Where saturation are scaled between 1-0 aims to normalize the values each component of the pixel $(x,y)$.

Yunardi [12] introduced the image threshold process that can be used to separate the pixels into the corresponding color intensity based on the HSV color saturation. The method used in this process defined as a set of the array pixel from the image. A set of the array is made to be the minimum and maximum saturation adjusted to represent the objects color. Generally, the threshold produced a binary image that that only consist of the elements that are in the suitable color intensity or not with threshold score that has been determined [13]. After that, it is changed to the 0 and 1 score that can represent in white and black color is calculated by Equation (2).

$$g(x,y) = \begin{cases} 1, & \text{if } s(x,y) < T \\ 0, & \text{if } s(x,y) \geq T \end{cases}$$

Where $g(x,y)$ is the pixel value of new image in white and black color from matching values. $s(x,y)$ is the saturation of the pixel $(x,y)$ respectively and $T$ is the adjusted threshold function. To minimize the noise around the object, the morphological operations is essential step [13]. In this study we used erosion and dilation operations. Both process eliminate unused object’s component in binary image. The flowchart of the proposed system is depicted in Figure 3.

![Flowchart](image-url)

**Figure 3.** Overall flowchart of the proposed system.

2.4. Volume Estimation
The next step is estimate the real volume of foam from each object in the digital image. The input image is taken from the height of foam in the measuring cylinder. The camera is placed in front of the measuring cylinder. The actual size is extracted from the image represented in a pixel using the bounding box. The bounding box provides a measurement of height and width, based on the size of the images displayed on the screen. By using the calibration process, the actual volume of foam compared with the
input image. Volume calculation is done by estimating the area and height of the object. In order to obtain actual volume of the foam is determined as Equation (3).

\[ v = \pi r^2 h \]  

(3)

The \( v \) is volume of a foam in ml. The \( r \) is the radius of the surface of the measuring cylinder by 3 cm. And the \( h \) is height of foam in cm.

3. Results and Discussion

In the experiment, the system performance can be obtained from the estimated volume based on proposed algorithm uses regression analysis. Eight samples of the estimated volume of captured using the camera is used to obtain regression. Regression analysis of the relation between the estimated volume and the actual volume is shown in Figure 4.

![Figure 4. Regression analysis of the relation between the estimated volume and the actual volume](image)

From the results in the Figure 4, the linear regression formula can be known the system performance including sensitivity is 9.7 ml, linearity is more than 90% and measurement range is 55 – 220 ml. Using 17 data testing the average error of measurements is 2.25 ml.

| Lubricant  | No. SAE Viscosity Grade | Viscosity Kinematic at 40 °C (cSt) | Viscosity Kinematic at 100 °C (cSt) | Viscosity Index | Density 15°C (Kg/l) |
|-----------|--------------------------|-----------------------------------|-------------------------------------|----------------|----------------------|
| Sample A  | 20W-50                   | 176.7                             | 19.85                               | 130            | 0.8881               |
| Sample B  | 10W-40                   | 100.7                             | 14.85                               | 154            | 0.8577               |
| Sample C  | 10W-30                   | 86.35                             | 10.99                               | 152            | 0.8541               |
Three types of lubricants with different specifications referred to as Sample A, Sample B, and Sample C was tested presented in Table 1. This experiment is ensures that differences in the foam stability in the different samples are due to with the specifications and additives of the lubricating liquid.

For preparation of the measurements, 10ml of each sample was introduced into the measuring cylinder. For the foaming process the respective sample was stirred for 20 seconds. The air pressured filled through the gas distributor which is equipped with porous stone as a lubricant stirrer to creating foam. The measurement were carried out at a temperature of 25 °C. Furthermore, the volume of foam was observed and recorded for 20 seconds after the electrical pump blowing an air pressured into the sample. Then, the sample is observed during the full dissipation without air pressure. Full dissipation is the amount of time decay of the foam to form a relatively stable foam. Next, the foam stability results are presented as a series of values of the samples associated with the foam volume remained constant over a period of time. Figure 5 shows the foam stability as result of the rate of decay in all samples.

![Figure 5. Measurement of foam volume as a function of time to determine the foam stability](image)

Measurement of foamability and foam stability is affected by the measurement of time with the volume of foam. For sample A, sample B and sample C were measured after stirring at 25 °C. In Figure 5 it can be seen foamability and foam stability have differences between samples in the maximum volume of foam. The increase in volume that occurs during stirring is an indication of the foamability of the sample. In this experiment, the sample C is the highest during the foaming. Sample A showed the lowest decay rate due to high foam decreases more slowly than the other samples, while two other samples have steep slopes. According to Figure 5, the foam stability results are presented as a relatively stable foam volume during a period of time, the results of all samples showed the same average rate of decay.

4. Conclusion
In this paper, digital image segmentation method using the camera for the measurement of foam stability has been presented. Operation segmentation is applied to extract the height of the foam image. By linear regression knowable system sensitivity was 9.7 ml, linearity is more than 90%, the measurement range 55-220 ml and the average error of 2.25 ml.
The foamability of the foam is calculated based on the current maximum high foaming and foam stability on the basis of foam height decay with time. Three lubricant products referred to as Sample A, Sample B, and Sample C were tested with the specification differences between the viscosities and densities. From the result, the foam stability for all samples showed the same average rate of decay. However, a high stability on the foam in the lubricant is to be avoided. As observed in our study indicates the concentration of the additives in the lubricant was not known, viscosity and density only not be an indicator of the potential performance of the lubricant [15-16]. To demonstrate the instability of the foam in the testing should be performed at different temperatures. Lubricant products made by industry, anti-foam is believed to have been added to enhance the decay process. Conclusions can only be drawn with regard to the instrument system based on the image segmentation that has been developed capable of measuring the foam stability of lubricants.

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