Type of contribution:
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Training on Viscosity Analysis to Optimize Positive Displacement Pump Performance in Milk Production

Pelatihan Analisis Viskositas untuk Mengoptimalkan Kinerja Pompa Positive Displacement dalam Produksi Susu

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This article contributes to:

Main Theme Figures

Highlights:
- Improved operator competency in viscosity analysis for optimizing positive displacement pump performance.
- Structured training and SOP implementation increased pump efficiency by 11.4% and reduced motor load by 12–25%.
- Operators can now identify optimal viscosity, adjust inverter settings, and independently analyze pump performance.

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Abstract

This community service program was implemented to enhance the competency of production operators in understanding and applying viscosity analysis to optimize the performance of positive displacement pumps in the sweetened condensed milk (SCM) production process. Based on pump performance data obtained from the production area, an increase in fluid viscosity from 1000 to 2000 cP significantly impacted flow reduction, increased motor load, decreased efficiency, and overall operational performance decline. This condition indicates the need for structured training for operators to understand the relationship between viscosity, temperature, and pump parameters. The activities conducted included theoretical training, field practice, implementation of new SOPs, and evaluation of pump performance before and after the SOP. The evaluation results showed an average pump efficiency increase of 11.4% and a motor load reduction of 12–25%, particularly under high viscosity conditions. The operator can identify the optimal viscosity, adjust the inverter frequency based on the recommendation table, and independently perform performance analysis. Thus, this program is effective in enhancing production process efficiency and strengthening human resource competencies in the sweetened condensed milk production line.

Keywords: *viscosity, positive pump, efficiency, sweetened condensed milk, flow capacity, SOP*

1. Introduction

The manufacturing industry plays a crucial role in Indonesia's economy, with a need for efficient and reliable production processes. High-performance machinery and equipment are essential to meet the continuously increasing market demands. One of the key machines in this industry is the pump, which is used to move fluids in various stages of production(Arijanto et al., 2015). Pumps are used in various sectors such as the chemical industry, oil and gas, waste treatment, and food and beverages(White, 2017). There are various types of pumps, one of which is the screw pump, known for its effectiveness in handling high-viscosity fluids due to its ability to

transfer liquids with stable flow and minimal vibration(Dolan & Goodrige, 1988). Pump performance is influenced by fluid viscosity, where higher viscosity results in lower pump performance(Nesbitt, 2006). This occurs because high-viscosity fluids increase internal friction and impede flow, which affects pump efficiency(Li, 1999).

The production of sweetened condensed milk uses a fluid with high viscosity and non-Newtonian characteristics that are highly sensitive to temperature changes. The high viscosity causes an increase in flow resistance, directly impacting the performance of positive displacement pumps(Borisova et al., 2017). This effect can be observed from changes in flow, slip, effective RPM, motor power, and the pump's hydraulic efficiency(Bakshi & Smith, 1984). Based on pump performance data recorded by the operator, an increase in viscosity from 1000 cP to 2000 cP resulted in a flow decrease from 60.54 g/m to 23.88 g/m, a drop in RPM from 591 to 315, a reduction in efficiency from 44.1% to 32.8%, and an increase in motor load under certain conditions due to higher torque requirements.

The main issue in the field is that operators do not yet understand the relationship between viscosity, temperature, and pump parameters. Operators adjust the inverter frequency based on experience without any standards, resulting in unstable production output, energy inefficiency, and an increased risk of pump damage. Additionally, the Standard Operating Procedures (SOPs) related to viscosity control and pump settings are not well-documented.

This community service program is designed to address these issues through theoretical training, direct mentoring, the development of new SOPs, and pump performance evaluation. The development of SOPs aims to ensure that operators carry out procedures and organizational regulations effectively and efficiently, guarantee the processing competence and reports required by the company, ensure the smooth and effective decision-making process of the company, and ensure the realization of control aspects in activities that can prevent deviations or fraud (Tambunan, 2013).

The objective of this activity is to enhance operators' understanding of the relationship between viscosity and pump performance. Implementing the Standard Operating Procedure (SOP) for viscosity measurement and pump frequency adjustment. Optimizing the performance of positive displacement pumps through viscosity control. Evaluating the impact of SOP implementation on motor efficiency and load.

2. Research Methods

1.1. Equipment and Material

- Pump: Positive screw pump Bornemann SLH4-GV -V-VC Twin Screw

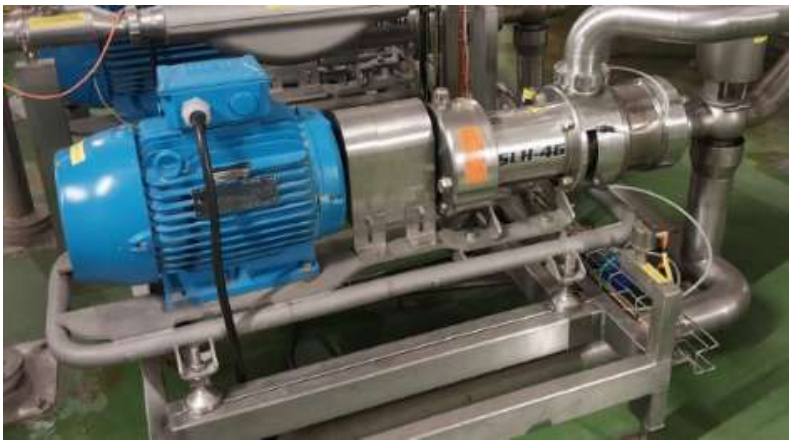


Figure 1. Positive Displacement Pump

- Fluid to be tested: SKM chocolate and plain variants with viscosity 1000-2000 cP

Figure 2.
Plain Milk

Figure 3.
Chocolate Milk

- Measurement Instruments: Flow meter, pressure transmitter, Brookfield RVT viscometer, inverter motor

Figure 4.
Pressure Transmitter

Figure 5.
Inverter Motor

1.2. Experimental Procedure

- Preparing the pumping system and ensuring all sensors are functioning properly.

Figure 6. Preparing pump and system

- Preparation of SOP (Standard Operating Procedure) and training materials for operators in working.

Figure 7. Preparing SOP

- Training on measuring the viscosity of sweetened condensed milk before pumping using a viscometer by operators in accordance with the SOP.

Figure 8. Training to Operator

- Operating the pump with varying viscosities and recording operational parameters such as flow capacity, pressure, electrical power, and pump efficiency by the operator.

Figure 9.
Training for Operating

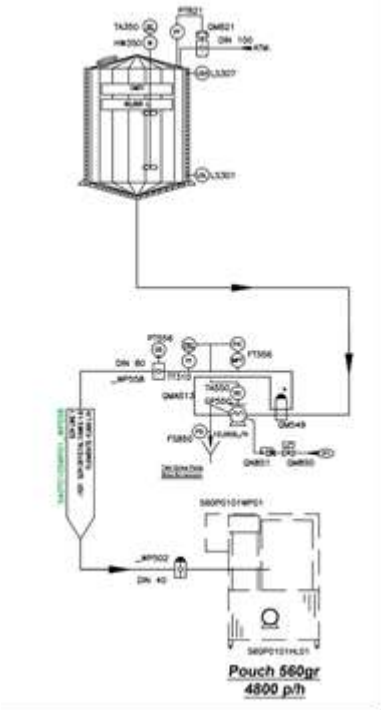
- Analyzing the relationship between viscosity and pump performance parameters using statistical and regression methods.

Figure 10.
Analyzing Data

- Evaluation by comparing pump performance data before and after implementing the SOP based on mathematical analysis.

Figure 11.
Evaluating by comparing data

Figure 12
Improving Operator Competence



In the testing process flow, sweetened condensed milk is pumped from the storage tank to the filler machine. Before pumping, the milk's viscosity is tested with a viscometer to determine its viscosity. After that, motor data can be obtained from the sensors and inverter on the panel.

3. Result and Discussion

3.1 Improvement of Operator Competence

After the training conducted, the operator is able to read viscosity changes through viscosity testing using a viscometer, can determine frequency settings according to the condition of sweetened condensed milk viscosity, and can analyze pump performance from the recorded data in accordance with the established SOP.

Figure 13.
System Flow

Table 1. Effect Viscosity on Pump Efficiency

Viskositas	Pressure (psi)	Flow (g/m)	Temp (C)	Speed (rpm)	Arus (A)	Frekuensi (Hz)	Daya (HP)	Efisiensi (%)
1000	98.625	60.54	52	591	20.4	28.1	7.88	44,1
1100	98.625	56.14	51.5	562	20.1	26.2	7.57	42,6
1200	98.625	45.64	51.2	542	18.9	27.9	6.87	38,1
1300	98.625	43.76	51	468	18.6	23.8	6.19	40,65
1400	98.625	43.25	50.3	454	18.3	23.1	6.12	40,62
1500	98.625	40.80	50	435	18.1	22.7	5.49	42,7
1600	98.625	37.53	49.2	418	18	21.3	5.42	39,7
1700	98.625	37.35	48.6	410	17.5	19.9	5.09	42,1
1800	98.625	28.90	48.2	402	17.3	20.4	4.75	34,9
1900	98.625	29.16	48	385	16.8	18.9	4.50	37,2
2000	98.625	23.88	47.8	315	16.5	16.6	4.18	32,8

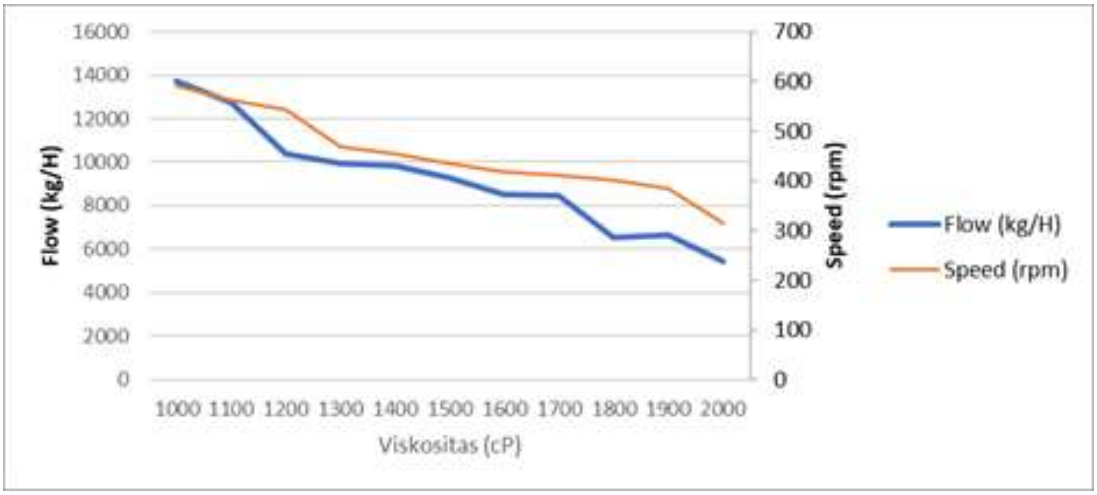
The Effect of Viscosity on Pump Efficiency

The table shows the relationship between fluid viscosity and various operational parameters, such as pressure, flow rate, temperature, speed, electric current, frequency, power, efficiency, and fluid temperature. Generally, as viscosity increases from 1000 to 2000, fluid flow decreases, rotational speed (rpm) decreases, and both power (HP) and efficiency decline. This indicates that more viscous fluids require more energy to pump, but beyond a certain point, this leads to a decrease in system performance(Wang & Zhang, 2023). Additionally, the fluid temperature also slightly decreases as viscosity increases(Susilo et al., 2021). From the test results, it was found that pump efficiency decreases with increasing fluid viscosity. The maximum efficiency achieved was 44.1% at 1000 cP viscosity and decreased to 32.8% at 2000 cP. This is due to the increased internal friction of the fluid, which amplifies flow resistance.

3.2 The Effect of Viscosity on Flow Capacity

The pump flow capacity decreased from 13,751 kg/hour at a viscosity of 1000 cP to 5,425

Figure 14. Effect Viscosity on Flow Capacity



kg/hour at a viscosity of 2000 cP. This decrease occurs because the increase in viscosity causes greater resistance in the fluid flow.

3.3 The Effect of Viscosity on Motor Efficiency

Figure 15. Effect Viscosity on Motor Efficiency

On Graph 2, at a thick viscosity of 2000 cP, the temperature is 28.5°C, while at a thinner viscosity of 1000 cP, it can reach 33°C. This is consistent with research conducted by (Bakshi 1984), which states that viscosity decreases as temperature increases, as viscosity is highly influenced by temperature(Sahdev, 2015). The efficiency of the pump produced by sweetened condensed milk is better used when the viscosity is thinner because the motor rotation is higher and the friction between pipes is smaller.

3.4 The Effect of Implementing SOP

- The operator has a better understanding of viscosity and its relationship to pump efficiency.
- The operator is able to set the most suitable parameters according to the viscosity of sweetened condensed milk.
- Production efficiency increased by 11.4% due to the operator's improved skills.
- The potential for motor overheating and seal damage decreased due to the use of appropriate parameters.

4. Conclusion and Recommendation

3.1 Conclusion

The implementation of viscosity analysis training has successfully enhanced operators' competence in operating positive displacement pumps in sweetened condensed milk production. The newly implemented SOP has been able to increase average efficiency and significantly reduce motor load, particularly under high viscosity conditions. Operators are now capable of determining operational parameters more accurately and consistently, making the production process more efficient, stable, and safer for the equipment.

3.2 Recomendation

- To enhance pumping efficiency, optimization of operational parameters such as pressure and pump speed needs to be carried out.
- Further studies can be conducted by testing the pump across a wider range of viscosities and other operational parameter variations.
- Consistent recording and thorough checking of parameters and viscosity by operator.

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