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DEVELOPMENT AND PERFORMANCE EVALUATION OF AN AUTOMATED LIQUID SOAP BLENDING MACHINE FOR ENTREPRENEURSHIP AND INDUSTRIAL UTILIZATION

Oghene A.M, Badejo A.O. Owolabi M. K. & Okoye. G.
Department of Mechanical Engineering, Yaba College of Technology, Yaba, Lagos State
Corresponding Author: adebola.oghenebola@yabatech.edu.ng +2348023393672

Abstract

A liquid Soap production Machine was developed and evaluated to facilitate local production of liquid soap in Nigeria for entrepreneurship and industrial use. A Preliminary study of the liquid soap production process was carried out within the local soap industry to collect necessary information and establish the appropriate production procedure. This was translated into the design concept of the machine. The detailed design of the machine's components was completed, followed by their fabrication. The developed machine, powered by a 1 HP (0.746 kW) variable-speed electric motor, comprises a main mixer, two pre-mixers, a machine frame, a V-belt drive, and geared drive systems. All materials used in the fabrication of the machine were sourced locally. The result of the machine evaluation revealed that the machine ran smoothly in operation. Also, it was established that drudgery and fatigue associated with the local production of liquid soap had been substantially reduced according to the responses from the users of the developed machine. The viscosity and turbidity of the liquid soap produced using the developed machine were found to be higher than those of the manually produced one, while its viscosity was found satisfactorily at par with that of the liquid soap produced using one of the commercially available mixing machines (MMs). However, the cost of production of the machine developed herein and its subsequent maintenance cost is cheaper than that of the MMs.

Keywords: Automated blending machine, liquid soap production, mixing efficiency, performance evaluation, industrial automation, soap industry.

Introduction

Soap is a cleaning agent produced in bars, granules, flakes, or liquid forms from sodium or potassium salts of fatty acids derived from natural oils and fats. Soap is widely used for washing clothes, dishes, vehicles, and for bathing. According to Ibryamova et al. (2010), soap was originally developed not only for hygiene but also for industrial purposes such as removing grease from wool in textile production. Finished products from chemical and biochemical processes, including emulsions and suspensions, require proper mixing to achieve stability during transportation and use. Several researchers later attempted to improve soap mixing technology. Saliu (2005) designed a portable mixer suitable for small-scale production, but preliminary mixing still had to be done manually. Ibryamova et al. (2010) developed an industrial mixer capable of handling liquid-liquid, solid-liquid, and liquid-gas mixtures; however, the system was large, expensive, and unsuitable for small-scale operators. Similarly, Ajao et al. (2011) designed a home-made laundry soap mixer, but the machine required continuous manual pedaling and was time-consuming. Traditional soap production methods involve prolonged manual stirring, which is laborious, energy-consuming, and inefficient. Consequently, there is a need for a semi-automatic soap mixing system capable of producing uniform mixtures with reduced human effort, shorter processing time, and improved efficiency. The introduction of soap mixing machines can improve production methods, reduce wastage and hazards, create employment opportunities, and increase profitability for small and medium-scale producers. Therefore, this study focuses on the design and development of a simple, cost-effective soap mixing machine powered by a 1.5 hp motor. The soap mixing machine is an essential component in soap manufacturing because it ensures uniform blending of raw materials such as oils, caustic soda, colorants, and fragrances. This study aims to design and fabricate a stainless-steel soap mixing machine that is durable, hygienic, and corrosion-resistant. The machine is expected to improve mixing efficiency, reduce processing time, and enhance production output.

Section 1 of the paper discusses the introduction of the paper, Section 2, literature review of selected related work to the research area, Section 3 gives discusses the research methodology where we present the research framework, as in data collection and analysis, the conceptual design and architecture, Section 4 presents the implementation of design and testing of the blended system; the result of the testing was present, while section 5 gives the recommendation and conclusion.

Literature Review

Overview of Soap Production

Soap production is a chemical process involving the reaction of fats or oils with an alkali, such as sodium hydroxide, through saponification. This process produces soap and glycerin, a valuable by-product used in cosmetics, pharmaceuticals, and food industries. Proper mixing of ingredients is essential to achieve the desired soap quality, including texture, colour, scent, and consistency. Soap has been used for centuries, evolving from traditional household preparation using animal fats and wood ash to modern automated industrial manufacturing. Its importance extends beyond cleaning, as soap plays a crucial role in hygiene, disease prevention, and public health, especially during outbreaks such as cholera and COVID-19.

Economically, the soap industry contributes significantly to local and global markets by creating employment opportunities in small, medium, and large-scale enterprises. It is particularly valuable in developing countries due to its reliance on simple technology and locally available raw materials. The industry serves diverse market segments, including laundry, medicated, liquid, and cosmetic soaps.

Beyond hygiene, soap production has industrial significance because its by-products and residues are utilised in pharmaceuticals, biodiesel, lubricants, animal feed, and other sectors. However, modern production faces environmental concerns related to sustainable raw materials, wastewater treatment, and consumer demand for biodegradable and organic products. Consequently, green chemistry approaches emphasising renewable materials and eco-friendly formulations are gaining importance.

Overall, soap production combines chemistry, industrial technology, economics, and environmental sustainability, making it an important and continually evolving field relevant to both small-scale entrepreneurship and large-scale industry.

Methodology

The semi-automatic liquid soap mixing machine is designed to produce 30 liters of liquid soap per batch. It integrates a gear-driven mixing system, stainless steel mixing chambers, a power drive unit, and a supporting frame. The machine is composed of four major components: the gear mechanism, the mixing chamber, which is the heart of the machine made with stainless steel designed to handle the required 30-litre batch size, the electric motor of 1.5hp, and the supporting frame fabricated from mild steel circular hollow bars, welded to form a rigid base that firmly supports the motor, gear assembly, and mixing chamber.

Working Principle

The liquid soap-making machine operates on the principle of planetary mixers. 1.0hp will be transmitted from the electric motor to the shaft, which will be connected to the gear system. As the central shaft rotates at 1800 rpm, the gears rotate in the opposite direction as the shaft, transmitting torque to the shafts in the minor chambers. Mixing takes place in the chambers as a result of the torque experienced by the shaft, and this continues until an even mixture is attained. The manual discharge valves are then opened depending on the chemicals mixed in each chamber, allowing the mixtures to flow with the aid of gravity to the central chamber, where further mixing continues. Once an even mixture is attained in the central chamber, the machine is turned off, and the discharge valve in the central chamber will be opened, allowing the finished product to be collected in a container and stored.

Figure 1: MANUAL MIXER

Figure 2: ELECTRIC MOTOR

Figure 3: DIGITAL TIMER MODULE

Figure 4: **REMOTE CONTROL**

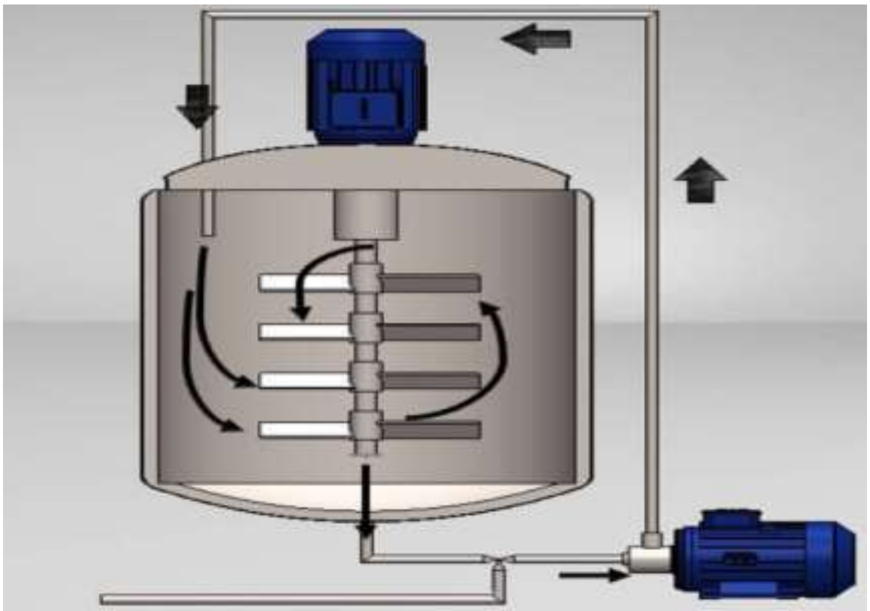

Figure 5: High shear mixer

Design Analysis

The main mixing chamber is cylindrical and must accommodate 30 litres (0.03 m³) of liquid soap mixture, with an allowance of 10–15% freeboard space to prevent overflow during agitation.

$V=\pi r^2 h$

Where:

-V=chamber volume(m³)

-r=internal radius(m)

-h=chamber height(m)

For design radius of r = 0.25m(250mm):

$h = V / (\pi r^2) = 0.03 / (\pi \times 0.25^2) \approx 0.153$ m (153 mm)

For freeboard, the height was increased to 0.20 m (200 mm).

Thus, chamber dimensions are: Diameter = 500 mm; Height = 200 mm

Thickness = 2.5 mm (stainless steel)

Gear Mechanism Design

A spur gear system was chosen to transfer motion from the motor to the mixing shaft because of its simplicity and efficiency.

Gear type: involute spur gears

Number of gears: 2 (driver and driven)

Gear ratio (G): 1:1

Number of teeth: 12 teeth each

Radius of driver & driven: 50 mm

Centre distance: 100 mm

Pressure angle: 14.5°

Power and Torque Transmission

Power Requirement

The power required for mixing was estimated using:

$$P = \frac{2\pi NT}{60}$$

Where:

P= Power (W)

N= Rotational speed (rpm)

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T = Torque (Nm)
Motor rating = 1.5 hp (≈ 1118 W). Assuming 70% efficiency:
P = 0.7457 kW
Motor speed: $N_p = 1800$ rpm
Torque transmitted:
$T = (P \times 60) / (2\pi N_p) = (745.7 \times 60) / (2\pi \times 1800) \approx 3.95$ Nm
This torque is adequate for uniform agitation of the 30-litre soap mixture.

Shaft Design
The shaft has to deal with the combined bending and torsional stresses.
$\tau_{max} = (16T) / (\pi d^3)$
Where:
T = 3950 N mm
Allowable shear stress (τ_{max}) = 42 N/mm²
$d = \sqrt[3]{(16T) / (\pi \ \tau_{max})} = \sqrt[3]{(16 \times 3950) / (\pi \times 42)} \approx 11.2$ mm
To provide a factor of safety (FOS), the shaft diameter was standardized to 20 mm.

Key Design
A rectangular sunk key is used to fix the shaft and gear.
Shaft diameter = 20 mm Key width: w = d/4 = 20/4 = 5 mm
Key thickness: t = d/6 = 20/6 ≈ 3.3 mm
Key length is determined from torque transmission, and a length of 40 mm was used.

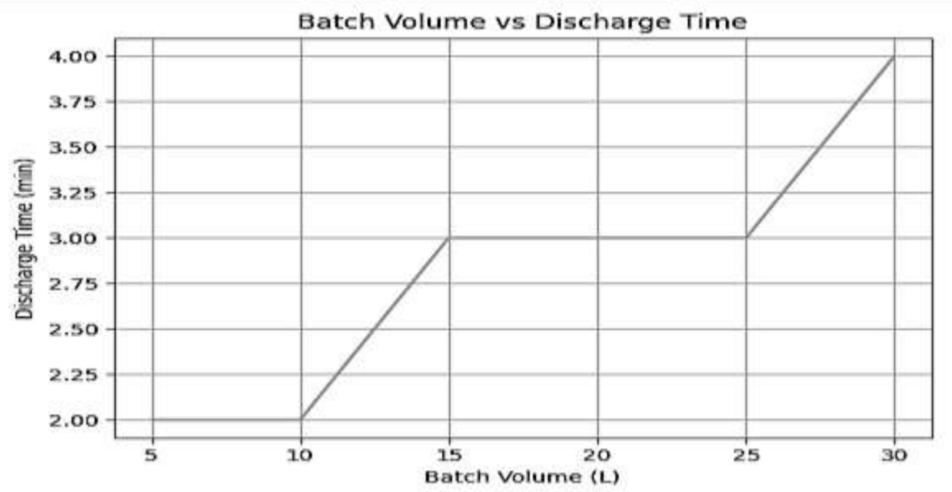
Bearing Loads
The radial load on bearings: $W_R = W_N \times \sin \varphi$
Where:
W_N = normal load on gear tooth
φ = pressure angle = 14.5°

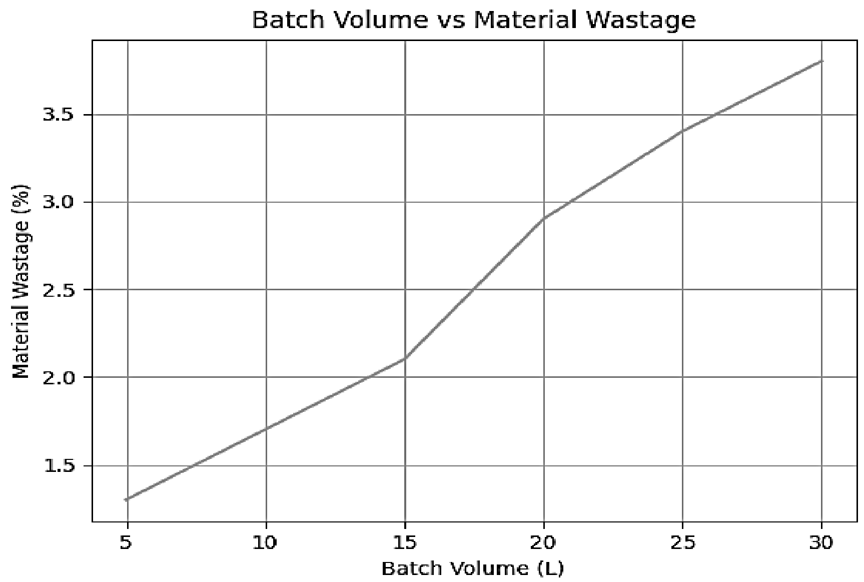
Results and Discussion
This report includes detailed results, discussion, performance tables, and generated charts for the 30-litre automated soap blending system.

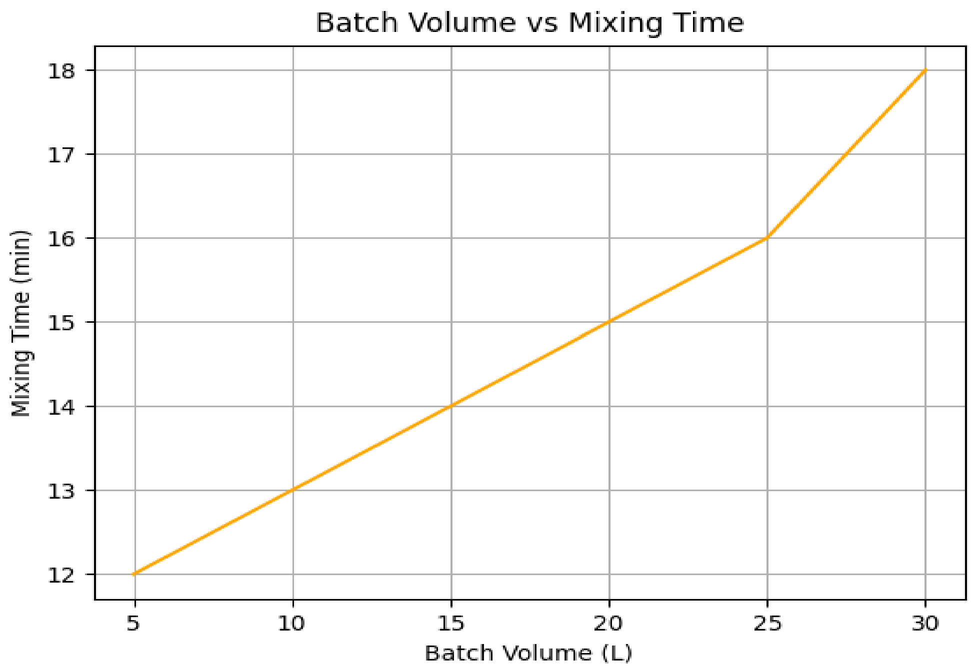
Table 1: Performance Evaluation Table

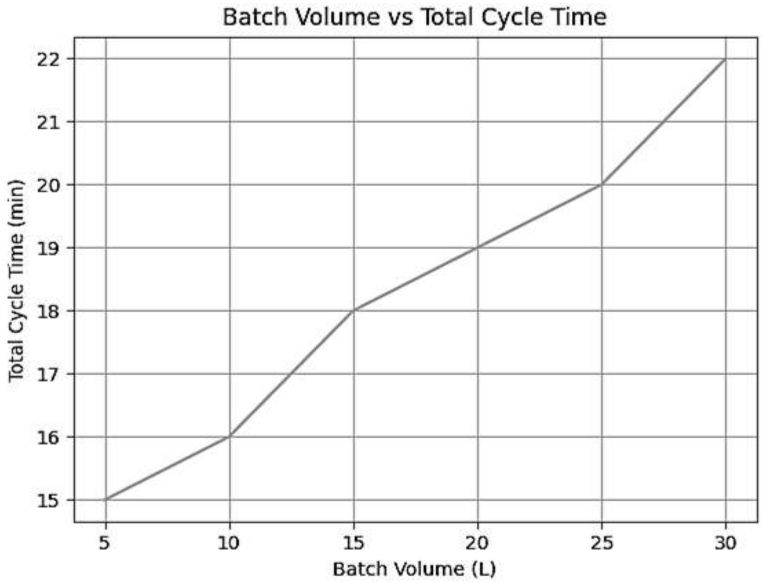
Batch Volume (Litre)	Mixing Time (min)	Discharge Time (min)	Total Cycle Time (min)	Material Wastage (%)	Energy Consumption (kWh)	Viscosity Variation (%)
5.0	12.0	2.0	15.0	1.3	0.18	2.0
10.0	13.0	2.0	16.0	1.7	0.19	2.5
15.0	14.0	3.0	18.0	2.1	0.2	3.0
20.0	15.0	3.0	19.0	2.9	0.22	3.5
25.0	16.0	3.0	20.0	3.4	0.24	4.0
30.0	18.0	4.0	22.0	3.8	0.26	5.0

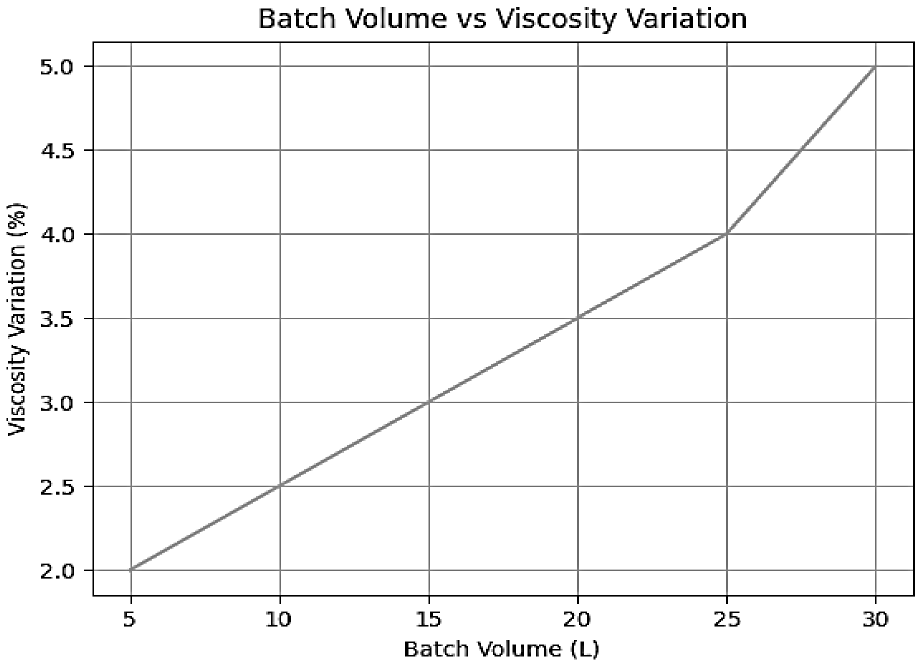
Charts


Batch Volume vs Discharge Time
Discharge Time (min)
4.00
3.75
3.50
3.25
3.00
2.75
2.50
2.25
2.00
5
10
15
20
25
30
Batch Volume (L)


Batch Volume vs Material Wastage
Material Wastage (%)
3.5
3.0
2.5
2.0
1.5
5
10
15
20
25
30
Batch Volume (L)


Batch Volume vs Mixing Time
Mixing Time (min)
18
17
16
15
14
13
12
5
10
15
20
25
30
Batch Volume (L)





Conclusion

The work successfully achieved its objectives. The developed machine:

Produced uniform and smooth liquid soap across all tested batch sizes.

Significantly reduced the physical effort and time required compared to manual mixing.

Demonstrated reliability and operational safety through the integration of dampers, a digital timer, and a remote-control system.

The development of an automated liquid soap blending machine offers an effective solution to the limitations associated with manual soap production methods. The machine improves efficiency, product quality, and productivity while reducing human effort and operational cost. This study, therefore. Contribute to the advancement of local industrial manufacturing technologies.

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