Design and Development of a Pedal-powered Soap Mixer

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Abstract

A bicycle pedal-powered soap mixer has been design and developed. The machine consists of a chain drive and gear amplification mechanisms that turns impeller blades in a large stainless steel container, where soap ingredients are stirred and blended. The machine is economically viable, can be used by unskilled workers, save time otherwise spent in traditional mixing and can be adopted for human-powered process units which could have intermittent operation without affecting the end-product. [New York Science Journal. 2009;2(7):6-9]. (ISSN: 1554-0200).

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1. Introduction

Soap is a mixture of sodium salts of various naturally occurring fatty acids. Air bubbles added to a molten soap will decrease the density of the soap and thus it will float on water. If the fatty acid salt has potassium rather than sodium, a softer lather is the result (Charles, 2003).

Pedal power is the transfer of energy from a human source through the use of a foot pedal and crank system. This technology is most commonly used for transportation and has been used to propel bicycles for over a hundred years. Less commonly pedal power is used to power agricultural and hand tools and even to generate electricity (AE Pedal Power: accessed at http://www.alternative-energy-news.info/, on 3rd May, 2009).

Traditional soap making demands hours of stirring by hand. The developed machine consist of a bicycle pedalled chain drive and gear amplification system that turns impeller blades in a large stainless steel container, where soap ingredients are stirred and once the ingredients start to thicken, the magic of soap making has begun, and the mixture is pour into a mold to set.

2. Soap Making

Soap is produced by a saponification or basic hydrolysis reaction of fat or oil. Currently, sodium carbonate or sodium hydroxide is used to neutralize the fatty acid and convert it to the salt (Charles, 2003). General overall hydrolysis reaction is given as:

$$\text{Fat} + \text{NaOH} \longrightarrow \text{glycerol} + \text{sodium salt of fatty acid} \qquad (1)$$

Although the reaction is shown as a one step reaction, it is in fact two steps. The net effect occurs as the ester bond is broken. The glycerol turns back into an alcohol and the fatty acid portion is turned into a salt because of the presence of a basic solution of Sodium Hydroxide.

The type of fatty acid and length of the carbon chain determines the unique properties of various soaps. Tallow or animal fats give primarily sodium stearate, a very hard and insoluble soap. Fatty acids with longer chains are even more insoluble. As a matter of fact, zinc stearate is used in talcum powders because it is water repellent. Coconut oil is a source of lauric acid which can be made into sodium laurate. This soap is very soluble and will lather easily even in sea water.

The method of production can also be used in classifying soaps. Industrial soap is a term describing the soap that has undergone processing and chemically treated or controlled to meet specific market demands and standards. Local soaps are those prepared locally through crude method of processing of the raw materials and are not chemically treated (Mustapha, 2004).

Mixing is to produce more uniform mixture of the constituents. In some cases an important part of the mixing operation is the transfer of materials to or from surfaces of particles or phases and temperature difference exists in the bulk fluid or between suspended particles and the continuous phase.

In the local soap industry, production involves strenuous human efforts. The mixing of ingredients is done manually with a stick or wooden ladle and this requires a lot of energy and time input by the soap producer. The final product is usually not uniformly mixed due to fatigue; this mixer is expected to overcome some of the problems associated with local soap production.

3. Methodology

3.1 Basic concept of the machine

The average power produced by a man is approximately 75W (0.1 hp), if he works continuously (Modak et al., 1998). Therefore human power may be used for a process if the power requirement is a maximum of 75W. If process power requirement is more than 75W and if the process can be of an intermittent nature without affecting the end product, a human-powered machine system can be employed.

Essentially, the machine consists of three sub-systems: (1) the energy unit (2) transmission mechanism (3) the process unit. The energy unit consists of a conventional bicycle mechanism, the transmission unit consists of a drive train; a chain drive mechanism running over a pair of speed-increasing gears and the process unit is a stainless tank/vessel where impeller blades stirs and blend the soap mixture.

The machine should principally have efficient velocity ratio obtained by maximizing gear ratios in order to minimize the energy requirement on the effort end and will have a low center of gravity for increased stability.

3.1.1 Drive Train

To propel most bicycles, the rider straddles the saddle and uses his legs and feet to rotate the pedal around the crank axle. The pedals, in turn, are fixed to a chain ring (sprocket) with teeth that engages the bicycle's continuous chain. The chain then transmits the pedaling action to a cog on the hub of the front wheel causing the front sprocket to rotate and then drive the shaft attached to the impeller blades in the mixing vessel via speed increasing bevel gears.

3.1.2 Impeller Blades

Impeller blades design has a strong impact on the agitation characteristics and the energy or power requirements. The choice of the turbine impeller was based on the viscosity of the soap, tank volume and other considerations such as circulation, shear stress and power requirement.

The mechanism of flow in an agitated tank is very complex, since laminar flow, turbulent flow and boundary layer separation may all occur in different regions of the fluid. Impeller power is a function of the geometry of the impeller, the volume of the tank/vessel, properties of the fluid (viscosity and density), rotational speed of the impeller and gravitational force.

The power required for the agitation of a single-phase liquid according to Mustapha (2004) can be written as:

$$P = f(\mu, \rho, g, N, D, T, W, Z, C, J, L, S, R, B, n, ...etc.) \quad (2)$$

Using the Buckingham-pi theorem, the following general dimensionless equation is obtained for the relationship of the variables:

$$\frac{P}{\rho, N^3 D^5} = f\left(\frac{D^2 NP}{\mu}, \frac{N^2 D}{g}, \frac{D}{T}, \frac{D}{W}, \frac{D}{Z}, \frac{D}{C}, ...etc\right) \quad (3)$$

The first term is the Reynolds number that determines whether the flow is laminar or turbulent and the second term, the Froude number account for the effect of surface behavior.

3.1.3 The Mixing Vessel

The mixing vessel is subjected to the soap weight, the circumferential pressure generated during mixing and corrosion from the composition of soap.

A vessel with sloping or dished bottom is often recommended, although tanks whose sides form a right angle are also commonly used. Square tanks or others having corners should be avoided because the corners hinders the fluid motion (Gray et al., 1987).

A cylindrical vessel having a flat bottom was used in this work. The vessel is provided with a discharge gate which penetrates into the main vessel. The gate is made in such a way to give effective and adequate discharge of the mixed ingredient that will be pouring into the soap mold.

The maximum pressure act on the base of the vessel and consequently, that is the region that must be well considered in designing. Since little or no pressure act on the top of the vessel, there is therefore no longitudinal stress exerted. The circumferential stress at any point in the in the vessel is given by:

$$c = \frac{p\,r}{t} \quad (4)$$

r is the radius of the vessel, t is the thickness and p is the pressure on the base plate of the vessel.

KEY
A – Sprocket
B – Chain
C – Mixing vessel
D – Handle bar
E – Bicycle frame
F – Pedal
G – Bevel gear
H – Bearing housing
I – Impeller shaft
J – Turbine blade
K – Mixer support
L – Saddle seat
M – Rollers

Figure 1. The Pedal-powered Soap Mixer

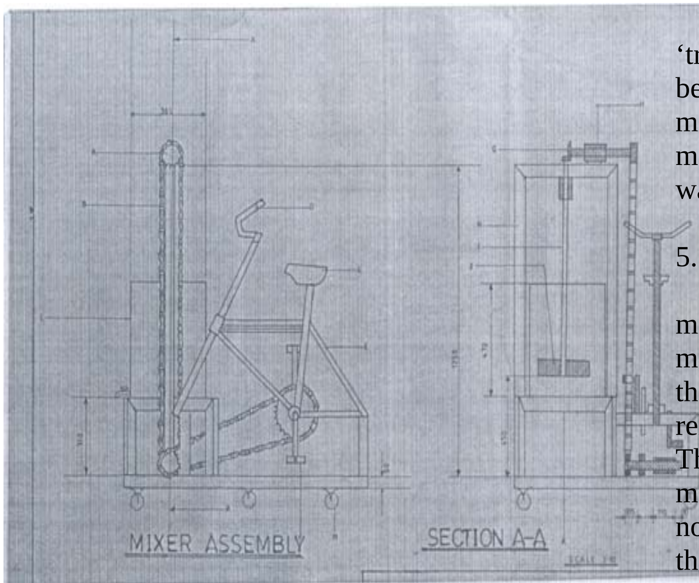

Figure 2. The Pedal-powered Soap Mixer Schematic Diagram

4. Result and Discussions

A simple, easy to maintain and shop floor size pedal-powered soap mixer was developed, constructed and tested and shown in Figure 1 above. The mixer is on rollers to ensure easy movement in and out of the shop floor.

To test the equipment, soap of the following composition was compounded: Coconut oil (580g), Vegetable oil (295g), Bees wax (30g), Avocado oil (58g), Lye (150g) and Distilled water (368ml). Oil temperature (55^0C), Lye/water temperature (55^0C), Trace time (15minutes) and Cure time (3 weeks).

The oil is heated in a stainless pot to a superheat of (10^0C) and care must be taken to avoid burning the oil. Distilled water at room temperature was poured into a clean measuring cup and while stirring, one bottle of lye is added slowly until the water becomes clean. When both oil phase and lye/water phase have reached their required temperatures, the lye/water mixture is poured slowly into the oil mixture while stirring rapidly.

The soap mixture is stirred until it 'traces' and desired herbs and essential oils can be added. The traced soap is discharged from the mixer through the discharge gate into the soap mold and allowed to cure and the final result was satisfactory.

5. Conclusion

In designing the pedal-powered soap mixer, the focus was on cheap, readily-available materials and we proposed a simplistic design that can deliver productive, efficient, and reliable mixer for use in local factory shop floor. This equipment can adequately replace electric motor-driven mixer in rural areas where there is no or limited supply of electricity, saves cost that would otherwise be spend to service utility bills and equipment is almost maintenance free.

6. References

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