Automatic Dosing System

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Abstract: - Automatic dosing of raw materials is important to reach of accurate amount of dosed raw materials. The accurate amount is important to get right result of the production or laboratory tests. The dosing systems can work with a very small amount of materials in the laboratories or huge amount of raw materials in industry production. It can work slower and more accurate in the laboratory than in industry, where is important fast dosing. Combination of these parameters must be used in a pilot plant. Low price, fast and cheap reconfigurations of systems are important when tests are doing. These dosing systems can work independently or they can be controlled by main unit in production system. For these purposes an automatic dosing system was designed on the base of an ultrasonic amount measurement in liquids reservoirs. It has density temperature compensation for the higher accuracy of dosing. It saves time that is needed to manual dose of liquids, and it doses specified amount in each time when it is used.

Key-Words: - Automatic dosing, raw material, ARM microprocessor, ultrasonic measurement, pilot plant

1 Introduction
The purpose of the automatic dosing systems is accurate measurement of dosing raw materials on the base of user requirements or the supervisor control system requirements. These systems have to be easy to operation. They can include operation interface on the place where raw materials are dosed or it can be controlled by remote access depending on the type. Here can be used some kind of industry Ethernet protocol or wireless connection.

Due to deployment of these systems, it’s not necessary to use systems with huge amount of computing performance and they can be realized with use of microcontrollers which price is lower in comparison with industrial computers. Apart from this price, they have advantages in low power consumption, small dimensions, and easy hardware modification to the controlled system. The worse changing the firmware functions and lower computing performance (in some extra cases) can be as disadvantages, but it can be eliminated by the choice of an appropriate microcontroller, adequate development tools and a proper design of the dosing system.

A lot of attributes are required on these systems. These requirements are speed of dosing (in industry production) and accuracy with raw materials are dosed. Mostly these parameters are excluding each other, therefore it is necessary choice their compromises. The line of raw materials from reservoir to place of consumption is still important to be short and fast. The degradation of material or permanent change of some parameters should occur or temperature changes which increases the costs of the production.

These systems must measure and evaluate effects of environment for fulfillment of all parameters, especially accuracy. Most important is measurement of temperature and compensation of it. It’s necessary for dosing materials which volume is strongly depending on temperature and it is necessary dose it in weight units and simultaneously weighing is not available.

This paper is dealing with raw materials dosing in the pilot plant unit in the production of biodiesel. There are chemical aggressive liquids which are dosed in small amount due to the range of pilot plant unit. Small automatic dosing system was design for purpose of the acceleration of production and elimination of manual work with aggressive chemicals.

2 Production of biodiesel
The biodiesel as an alternative fuel for combustion engines has some advantages and disadvantages in compare [1] to normal diesel:
- Lower CO₂ emissions
- Production from waste materials or renewable resources
- Increases nitrogen oxide emissions

Some parts of biodiesel production are more expensive than a regular diesel. It’s given by the high price of the catalyst. On the other hand, it is compensated by a very low or zero price of the main raw material – oil or fat. Here can be used a vegetable oil (cooking oil) or an animal fat. Biodiesel parameters are very similar to a regular diesel, such as solidification temperature is almost equal and it’s not suitable for use in extreme cold.

The production from these fats and oils go through transesterification of free fatty acids to the biodiesel and glycerin [1-3].

2.1 Transesterification of unsaturated fatty acids

The transesterification of unsaturated fatty acids to biodiesel need a few basic raw materials:
- Free fatty acids – oil or fat
- Alcohol
- Acidic or alkaline catalyst, depending on the fat and its properties

Methylesters – biodiesel and glycerin are created in transesterification [1-3] which is written in equation (1). Glycerin is insoluble in biodiesel and it can be removed from a mixture by the centrifuge or a separating vessel.

\[
\begin{align*}
\text{O} & \quad \text{CH}_2-O-C-R_1 \\
\quad & \quad \text{CH} - O - C - R_2 + 3\text{CH}_3\text{OH} \rightarrow \\
\text{CH}_2-O-C-R_3
\end{align*}
\]

\text{Triglyceride} + \text{Methanol} \rightarrow \text{Methyl Sunflower Esters}

where \( R_1, R_2 \) and \( R_3 \) are long hydrocarbon chains.

During the oil crisis in the 70 – 80 years was used the vegetable oil instead of diesel as an alternative fuel in diesel engines. But it was appeared that the oil is not suitable due to its high viscosity, because engines weren’t prepared to this. However, the viscosity is reduced by the above mentioned transesterification.

During the development many publications show various results that were achieved in this area. It was founded that the production is strongly dependent on temperature: at 32°C transesterification takes 4 hours, but at 60°C approximately 1 hour. Further tests showed the influence of different catalysts and their molar ratios, as showed in Fig. 1 [1].

Also tests were conducted without catalyst, but it was necessary to reach a temperature 300°C – 350°C and molar ratio 42:1 of methanol to oil.

Potassium hydroxide or sulfuric acid in the presence of methanol is usually used on place of catalyst. If the oil includes free fatty acids, it is required next process to remove it. If the amount of
free fatty acid is higher than 5%, the sulfuric acid can be used to react with unsaturated free fatty acid to methylesters.

If we want to achieve maximum yield in the production, we must strictly observe ratios of individual substances, temperature and reaction time. [1-3]

3 Conception of the system

The proposed system is designed to dispense two ingredients - alcohol and a catalyst in a user-given rate and amount. The system will measure the dosed amount of raw materials indirectly by the change of liquid level in the tank. System can use capacitive level sensors for this measurement; possibly it can be used ultrasonic sensors which can have bigger differences between real level and measured level. It is given by spread speed of ultrasonic signal at different temperatures of air and surface liquid waves. It’s necessary to measure the temperature to compensation of thermal expansion of the fluid and convert volume, because the requirement was dosage in the weight units. Normal solenoid valves with higher resistance against aggressive chemicals are used in this system.

The concept of the system tries to approach to state, which is showed in figure 2, where significant

3.1 Measurement of level

As mentioned above, the measurement of dosed amount of dosed raw materials uses the indirect measurement of the liquid level in the reservoir and weight of materials is calculated by the change of the liquid level and temperature. There can be used
several ways how to measure continuous liquid level. Hydrostatic sensors can be used for measurement in high tanks, but there is disadvantage in the measurement range from 1m to 100m [8], which are unusable in the case of our pilot plant unit. The conductivity measurement can be better in our case, but liquids are highly flammable and an explosive environment may be in tanks – there is risk of explosion. Other suitable sensor is ultrasonic sensor. This is a non-contact measurement level method based on measuring the time between transmissions and receptions of ultrasonic signals. The advantages of modern sensors are very high precision and temperature compensation.

Calculation of the distance of the object can be described by equation (2)

\[ l = \frac{c \cdot T}{2} \]  
(2)

where:
\( c \) - sound speed in the environment [m/s];
\( T \) - time between transmissions and receptions of ultrasonic pulses [s].

Sound speed depends on several parameters and it can be describe by the following equation (3)

\[ c = \left(1 + \frac{1}{2} \gamma \cdot t \right) \sqrt{\frac{\kappa}{\rho_0}} p_0 \]  
(3)

where:
\( \gamma \) - thermal expansion of air [1/K];
\( t \) - air temperature [K];
\( p_0 \) - air pressure at 0°C [Pa];
\( \rho_0 \) - air density at 0°C [kg/m³];
\( \kappa \) - the Poisson constant [-].

Due to the high price of ultrasonic systems, capacitive measurement of level was selected. It uses capacitive changes between the measurement electrode and the conductive shield of tank or the second additive electrode of measuring system [10]. On the other hand this method is less accurately, it’s about 1% accuracy, as you can see in datasheet [11] of chosen capacitive sensor.

4 Conclusion

Presented text has given the several basic information about biodiesel and its methods of production.

For the purpose of the biodiesel production in pilot plant was designed the dosing system for raw materials to purpose save time by exclusion of manual dosing and it saves materials by more accurately dosing. This system provides dosing of chemical aggressive liquids in user defined weight ratio.

The dosing is based on indirect method which is the measurement of the liquid level in tanks. Amount of dosed material is calculated on the base of level change and it’s compensated by temperature measurement in each tank.

The core is based on 32-bit ARM microcontroller which gives a lot of performance, it’s controlled by touch screen LCD and it can be extended by other modules for communication.

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