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DEVELOPMENT OF HIGH SPEED PAINT MIXER

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Abstract

This study focuses on designing and developing a paint mixer that is suitable for small and medium industries. The paint mixer is designed to mix and blend the paint ingredient in an efficient way to improve the production rate as well as paint quality. The paint mixer equipped with a high shear blade powered by an electric motor can mix the paint ingredient up to 200 liter for 4 hours. Therefore, the productivity increases from 30 liter a day up to 400 liters in 8 hours. The paint ingredient is fully dissolved in a shorter time as compared to the manually mixing process. The mixing process also reduces energy consumption by mixing a large quantity of paint ingredients needed by the current method in the same quantity. Thus, this machine is able to help small and medium industries boost their production and profit.

Keywords

Blade, Disperser, Paint Mixer, Mixing Process

1. Introduction

Paint mixer is widely used in paint making industries. Currently, most of the paint mixers available in Malaysia are suited for industrial used and imported from various countries such as China, Taiwan, and Europe. Therefore, for small and medium industries, the use of industrial paint mixer is limited and not cost-effective. Furthermore, the use of a complicated control board for its operation makes the industrial paint mixer unpopular among the small and medium industries. Most of them are still using the conventional (manual) method of mixing paint which is time-consuming, required many man powers, and lack of consistency in the quality of paint. Thus, this study focuses on designing and developing a paint mixer that is suitable for small and medium industries to mix and blend the paint ingredient in an efficient way to improve their production rate as well as the quality of paint.

2. Problem Statement

Small and medium industries need affordable and user-friendly paint disperser and paint mixing machine. The paint mixers available in the market are mostly imported from China. Most of the prices are not cost-effective for small and medium industries. In addition, some of the paint mixers have complicated control board which requires training and time for an inexperienced operator to understand the functions and operate the machinery.

3. Research Objectives

The research objectives of the study:

- To design, fabricate, and assemble a paint mixer that is suitable for small and medium industries.
- To mix and blend the paint ingredient in an efficient way in order to elevate the production rate significantly.

4. Scope and Limitations

The scope and limitations of the study:

- The focus is on the process of mixing paints in paint industries.
- The design is based on the simplest and easiest way to blend the paint ingredients in order to increase mixing capacity and blending quality.
- The machine is designed for the use of small and medium paint industries.

5. Review of Paint Mixing Process and Machine Design

This review elaborates on the main ingredients of the paint mixing process to enhance the design of the paint mixer. Furthermore, the mechanism used for the available paint mixers in the market is also discussed to highlight the advantages as well as disadvantages for the usage of small and medium industries.

5.1 Paint Mixing Process

There are four typical ingredients used in the paint mixing process: pigment, resin, solvent, and additives. Prime pigments bring the colour to the metaphorical party, accompanied by extender pigments that give the paint its substance and bulk. The resin binds all the pigments together and adds adhesives properties so that the paint will stick to the surface. Water is commonly used as a solvent in paint, and others use organic mineral derivatives that act as something of a carrier, enabling the painter to brush the paint from the can and onto the surface. Lastly, additives are added to provide durability such as to prevent the growth of mildew, to preserve the paint, and to prevent spoilage as well as to keep the pigments evenly mixed.

A good rule of thumb in judging the quality of paint mixing is the ratio of solids to liquids. High quality of paint tends to contain a higher amount of solids like the pigments and resins, and a lesser volume of solvent. Pigments are powder-like substances, which can quickly form bothersome clumps. So they have to be broken down into individual particles, and then resins and additives are applied to prevent the clumps from reforming. That entire phase is called dispersion. There are some types of heavy paints that require golf-ball sized spheres to be placed in the mixer to ensure the pigments are obliterated into individual particles. Those are called ball mills.

Meanwhile, the solvents, resins, and additives are mixed in a separate vessel; which is called the let-down. The mill-base and the let-down are then mixed with one another; and the end result is paint.

5.2 Types of Paint Mixer

This section discusses the mechanism, the design, advantages, and disadvantages of two types of paint mixer, DP1 Portable high-speed disperser and DP6 High-Speed Disperser (Loeschen, 2019).

5.2.1 DP1 Portable High-Speed Disperser

Figure 1: *Portable High-Speed Disperser*

The portable high-speed disperser is a mixing machine with a capacity of 5 gallon or 11 liters with a 2 horsepower anti-explosive motor without a lifting mechanism. The blade and shaft is made of 316 stainless steel. The advantages of this disperser are lightweight, easy to use and the motor can be used for a long period of time. The disadvantage is a small mixing capacity. Thus, small and medium industries may need more dispersers to meet their demand.

The design of the machine:

- The frame is made from hollow mild steel - Mild steel is used in this disperser due to its properties which is easy to be shaped. It is also strong enough to support the motor for the disperser.
- The shaft and the blade is made of stainless steel - Stainless steel is used for the shaft and the blade because of the anti-corrosive feature. It is also made the blend smoother.
- The explosion-proof motor - The motor is used to withstand the high-temperature material during mixing process.

5.2.2 DP6 High Speed Disperser

Figure 2: *DP6 High-Speed Disperser*

The DP6 high-speed disperser is the high volume disperser used in a larger scale operation which equipped with 200 horsepower motor driven with a belting system and with a 26-inch blade. It can mix a lot of wet and dry material. With a high capacity tank of 2000 gallon or around 7570 liters, it can contain a substantial amount of material at a time. A hydraulic lift with a pressure pack connected to the frame helps to lift the blade up to 60 inch or around 1.5 meter.

The advantage of this type of machine is the high capacity of mixing material. The hydraulic lift embedded in the frame makes the cleaning process of the blade easier. The disadvantages are high maintenance and the need for regular service as well as the tension of the belt from the motor to shaft may cause waste of power generated by the motor.

The design of this machine consists of:

- The frame is made of hollow mild steel - Mild steel is used in this disperser due to its properties which is easy to be shaped. It is also strong enough to support the motor for the disperser.
- The shaft and the blade are made of stainless steel - Stainless steel is used for the shaft and the blade because of the anti-corrosive feature. It also makes the blend smoother.
- The high-speed motor - The motor used for this machine can mix a large amount of liquid substances
- Connecting belt - Since the motor used cannot be directly exposed to the high-temperature substances, the belt is used to connect the shaft bearing and motor in order to start the movement of the blade.

6. Design Principles of Paint Mixer

The paint mixer applied the concept of disperser that breaks a part lumps of powdery material, uniformly distributing and wetting them in a liquid (Bakker, LaRoche, Wang, & Calabrese, 1997). The mechanism of the paint mixing process is guided by the principle of energy transfer. The blades are mounted at the bottom of the impeller shaft and rotated at high speed. The solids and liquids are mixed smoothly through the laminar flow created by the suction of the rotating blades (Ohko, Saitoh, Tatsuma, & Fujishima, 2001). The mixing materials built horizontal layers and contacted with the blade's teeth rapidly downward from the top and upward from the bottom created shear force.

Proper sizing and choice of the blades produce a perfect laminar flow moving outward over the teeth to ensure the mixing job becomes smoother and leaving no residue. To ensure good laminar flow, the dispersion blade diameter should equal 1/3 the tank diameter as shown in Figure 3 (Zhang, Xu, & Li, 2012).

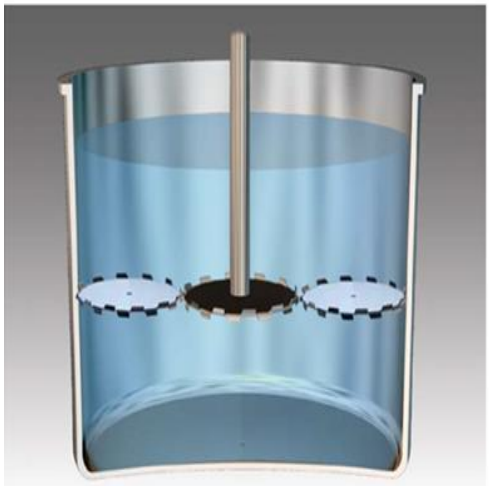

Figure 3: *Size of Blade Diameter Corresponding to the Tank Diameter*

The shaft height of the blade inside the tank is important to ensure the mixing job is properly done and no wastage occurred, as shown in Figure 4. The proper height of the blade from the bottom inside the tank is 1 to 1.5 diameter of the blade (Lu, Yao, Liu, & Zhao, 2015).

Figure 4: *Blade Positioning*

The performance of the paint mixer depends on the mixing tool, the rotating power, the design of the mixing container, and the frame structure.

7. Method and Material

This section presents the consideration factors of the design process and concept that led to the development and fabrication of high-speed paint mixer. The new design ensures the mixing capacity meets the requirement of small and medium paint manufacturing industries, at the same time; the cost of the mixer is affordable.

7.1 Design Process

The design process consists of several phases as shown in Figure 5. The problem is identified based on the needs and requirements of small and medium industries. Industrial paint mixer and the disperser principles were studied to determine the concept design of the paint mixer. The design of the paint mixer was drawn using the Computer-Aided Design inventor software version 2016. The design of the frame structure was analyzed using Fusion 360.

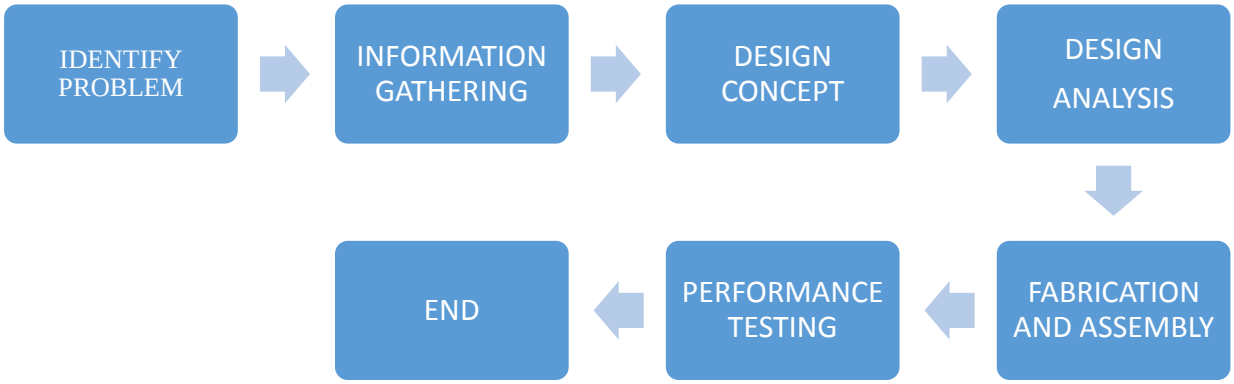

Figure 5: *Design Process Flowchart*

7.2 Design Concept

The design of the paint mixer machine consists of mixing tool, motor controller, mixer container and frame structure. The selection of components and materials emphasizes on low production cost, easy to maintain and operate, the quantity of mixing paint, and the availability of the replacement part.

This machine is designed for the paint production capacity up to 200 liter as compared to the current capacity of 15 liter. At the bottom of mixing container is furnished with an outlet valve for the ease of transferring the mixed paint without opening the top of the tank.

The detail design of paint mixer is shown in Figure 6.

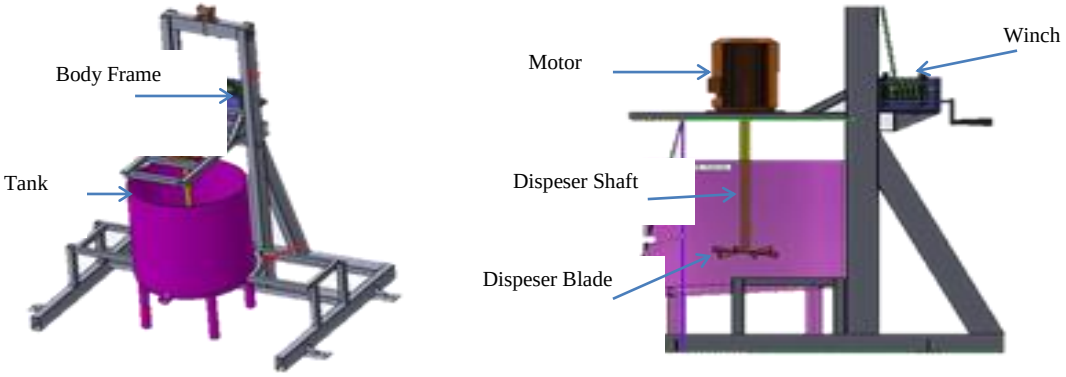

Figure 6: *Arm Condition Up and Down*

The mixing tool consists of disperser blades and shaft. Most of paint and ink industries use high shear blades as a mixing tool. Therefore, the designed paint mixer used the high shear blades which has the ability of self-cleaning and non-clogging for easy maintenance. The diameter size of high shear blades is equal 1/3 the tank diameter. High shear blades are also easy to remove from the shaft. Furthermore, it is able to rotate at high RPMs to facilitate the quick impartation of solids at a fine grind.

The height of blade's shaft inside the tank is important to ensure the mixing job is properly done and no wastage happened. Its design depends on product viscosity, tank size and shape, horsepower, baffles, and blade material. The proper height of the blade from the bottom inside the tank is 1 to 1.5 diameter of the blade.

Horsepower requirement for mixer can be estimated with the use of following equation:

$$SH_p = \frac{(D/15)^5 \, n^3 \times SG \times N_p}{6.12 \times 10^7}$$

(DisperseTech, n.d.)

SH_P = Shaft Horse Power

D = Impeller Diameter

n = Rotational Speed Specific

SG = Specific Gravity

Np = Power Number (Varies with Blade Type)

The dispersion shaft and the blades are made from stainless steel 304 SS, 316 SS, Chrome Plated and Tungsten Carbide Coated. Stainless steel is used for the shaft and the blade because of the anti-corrosive feature that is embedded in the steel itself (Foucault, Ascanio, & Tanguy, 2006). It also makes the blend smoother.

Motor functions to rotate the high shear blades to the desired rotation per minute (rpm) for the smooth blending of paint ingredients with perfect laminar flow.

The type of motor chosen depends on the required volume of mixing material and the speed to disperse the paint ingredient. Based on the standard rule of thumb, the horsepower of 10 HP is able to mix 379 liter (explosion-proof motor is used as the mixture of combustible material). Thus, for the design of 200 liter of paint, the motor of 5.5hp is adequate.

7.2.1 Mixing Container

Mixing Container used for the paint mixer is a cylindrical tank. The design requirements for the paint mixer tank are:

- The diameter has to be equal with product level
- The size has to be three times the size of the blade.
- The tank has to be flat bottom.

For 200 liters mixing paint, the suitable size of the tank is 640 mm (Diameter) and 740 mm (Height) 230 liters. From the straight side it will have 15-20% free bore. Stainless steel tank of 316 version is chosen as the mixing container due to its corrosive resistance ability.

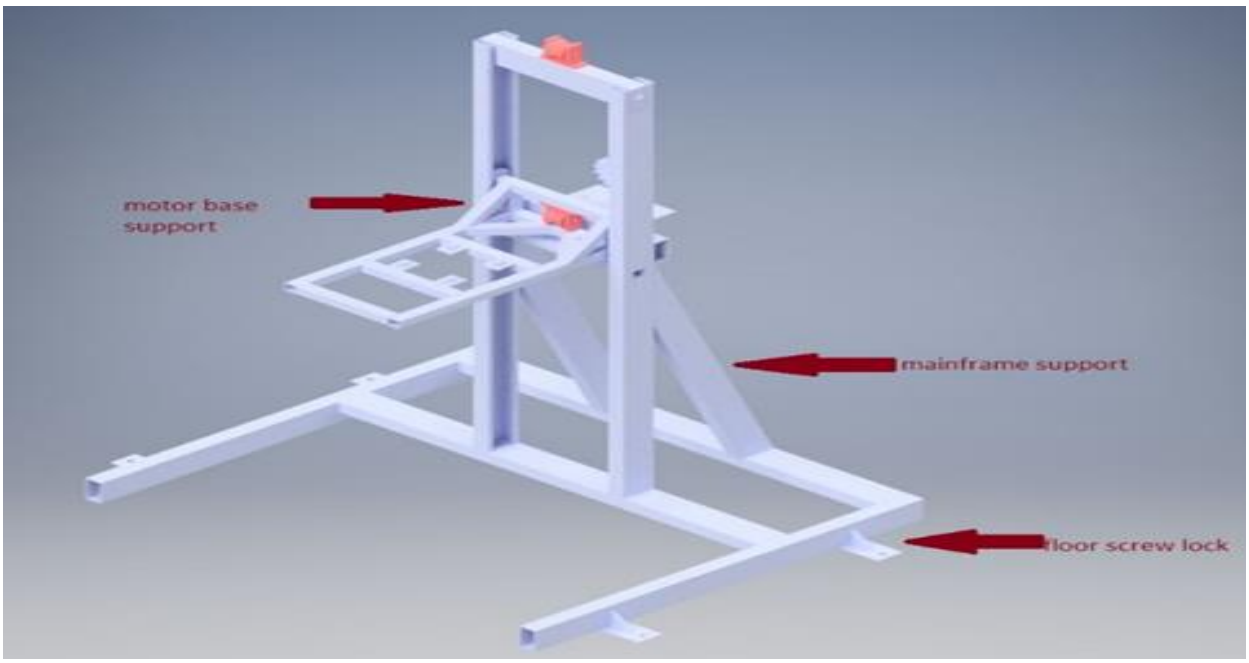

Figure 7: *Mainframe Design*

The frame structure is designed to hold the load, tank, and motor as well as to sustain stability during the operation process Figure 7. The hollow square and C channel mild steel are used for the frame structure to achieve stability. The use of mild steel is relatively due to cost-effectiveness compared to any other metal material.

The framework is supported by the base and truss design. The floor screw lock is used to ensure the position of the structure is stiff and preventing any distortion. The winch is placed in order to raise and lower the motor platform. The manual winch is used rather than the electrical motor due to less maintenance needed thus lower the cost of production.

7.2.2 Design Analysis

The design analysis was conducted on the frame structure using Fusion 360. The frame was analyzed to ensure the size and stability of the structure to support the weight of accessories that will be fitted.

7.2.3 Fabrication and Assembly

The fabrication process involved in welding, metal bending, metal cutting, drilling, part fitting, painting and finishing, and part installation. The construction of the paint mixer was divided into three main parts: the mixing cylinder, the mixing tool, and the frame.

The parts installation was conducted by installing the mixing tool - the drive shaft, high-speed shear blades, and motor. Then the mixing cylinder with the help of bolts and nuts was installed to the frame structure.

7.2.4 Performance Testing

The performance of the paint mixer was tested for the working flow of the motor, the consistency of the paint mixing, and the formation of a uniform vortex. The mixing time and the production capacity was also tested.

8. Result

The built paint mixer is shown in Figure 8. The parameters of the designed paint mixer are presented in Table 1 as follows:

Table 1: *Parameters of High-Speed Paint Mixer*

Cylinder Specification	Parameter
The actual diameter of cylinder	640 mm
Volume of the cylinder	230 litre
The overlapping volume	2 inches
Depth/Height of mixer	740 mm

Figure 8: *Side View of the Paint Mixer*

8.1 The Operation of the Paint Mixer Machine

The paint mixer is operated by filling mixing ingredients in the mixing tank. The winch is used to raise and lower the platform. When the filling is done, the platform can be lowered and the mixing can be started by pushing the green button on the control panel. The speed of the blade can be adjusted according to the consistency of the substances. When the substance is fully dissolved it can be transferred using the valve place on the bottom of the tank.

Figure 9: *Rotation of the Blade Creating a Good Laminar Flow*

The performance testing indicated that 5.5 horsepower motor is suitable for the mixing process with the capacity of 200 liters. The high shear blade fitted to the industrial paint mixer generated a good vortex and provide a good laminar flow as shown in Figure 9.

8.2 Performance of Paint Mixer

The advantage of the designed paint mixer as compared to others in the market is easy to use even with the less skilled worker. The lifting mechanism can also be adjusted to suit the height of the operator. Furthermore, the electrical panel is user friendly and equipped with the speed indicator to control the speed of the shaft. The moving part is also covered with the appropriate protection and safety signs.

9. Conclusion

The paint mixer is able to increase productivity from 30 liters a day up to 400 liters in 8 hours. The paint ingredient is fully dissolved in a shorter time as compared to the manual mixing process. The mixing process also reduces energy consumption by mixing a large quantity of paint ingredients in 4 hours, instead of 15 liters in the same time frame, thus reducing the power usage needed by the current method in the same quantity. In summation, this machine is able to help small and medium industries increase their production as well as profit.

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