Development of An Automatic Cup Printing Machine Using a Screen Printing Method

Hendriko Hendriko[1], Prayoga Dimas Bagaskara[2], Dimas Maulana Permana[3]

{hendriko@pcr.ac.id[1], prayoga22trm@mahasiswa.pcr.ac.id[2], dimas18ms@mahasiswa.pcr.ac.id[3]}

Mechatronics Engineering Department, Politeknik Caltex Riau, Jl Umbansari, Rumbai, Pekanbaru, Indonesia, 28265[1, 2, 3]

Abstract. The urban lifestyle trend pushes the emergence of business on beverage businesses, especially cafes. Every cafe or beverage business must find its uniqueness compared to competitors. Except for the product's taste, innovation in attractive packaging is one of the business strategies. In this study, an automatic printing machine has been developed. The automatic process starts with the cup entering the machine until the printed cup is removed. The test has been performed to check the machine's performance in printing one batch of cups. Two designs have been tested, and every design was repeated three times. The result shows that the success rate, which is the number of cups that are completely printed, is about 91.7%. The average time for printing one batch (10 cups) is 55.8 seconds. The machine could operate automatically; hence, the operator's role in inserting the cup into the machine and pulling out the printed cup from the machine could be removed.

Keywords: cup, screen printing, automatic machine

1 Introduction

Indonesia has a tropical climate because it is located on the equator. The climate is influenced by human activities, both direct and indirect influences, which cause changes in the atmosphere's composition and increase climate diversity over a reasonably long period [1]. Considering that Indonesia is a tropical country where temperatures tend to be high, cold drinks are a daily necessity. Therefore, one of the MSME businesses that is currently popular is the beverage business, which is favored especially by youth. Youth prefer practical, creative, and innovative [2].

The current urban lifestyle prefers to make a meeting at cafes, whether it is a formal or informal meeting. This condition increases the demand for beverage products. The increasing demand led to the emergence of many new players in this business. It causes the competition to attract customers to become tighter. The competition in the beverage business is not only on the excellence in product taste [3] but also on aesthetics, such as attractive product packaging. Packaging can change customer perception, both rationally and emotionally [4]. A study [5] explains that the visual elements of packaging, such as graphics, shape, color, and size, influence

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consumer purchasing decisions. Packaging also gives uniqueness to a product [6] compared to other products. It helps the consumers to select a product among many other products [7]. Packaging can influence consumers to respond positively or negatively because the packaging intensely interacts with the consumers [8].

In this regard, the growth of the beverage business has also encouraged entrepreneurs to provide attractive drinking cups. The demand for attractive cups led to the need for machines to produce these cups. Cups with exciting pictures and words are produced using printing machines. Therefore, several cup printing machines have been developed.

Printing technology has been developed for a long time and mainly uses screen printing. The screen-printing method has been widely used in the textile and electronic industries. In the electronics industry, it has been used to print PCBs since 1940 [9]. Many studies have been developed to build printing machines, from fully manual machines to fully automatic systems [10-12].

Screen printing methods, which are applied to the textile and electronics industries, are also used to print the surface of drinking cups. Machines on a large scale with automatic systems have been widely marketed [11]. However, the machine's price should be more affordable for small-scale entrepreneurs. In addition, the large production capacity and high operational costs cause these machines to be inefficient for small-scale production. Therefore, the need to develop small-size machines that suit the needs of small businesses is essential.

In contrast to the flat shape of cloth and PCB board, the complex shape of the cup makes the printing process very difficult. The complexity of the process made the development of small-scale machines mostly manual-based [12]. The challenge in developing a cup printing machine is synchronizing the screen's movement and the cup's rotation. This synchronization is crucial to obtain good results. Handono et al. [13] developed a small-scale semi-automatic cup screen printing machine with around 300 cups/hour production capacity. This machine is functioning correctly, but because it is semi-automatic, it still requires the operator to insert the cup and remove the finished cup from the machine. Another research was carried out by Hidayatullah [14]. They developed a machine in which the movement of the cups was regulated using the perforated disc method. Holes in the disc were used to define the step length of the screen. Other research was developed by Maulana and Suhartini [15]. They implemented the Quality Function Deployment method and used a pneumatic circuit for the automation system. The test showed that the developed machine operates ineffectively. Another weakness of the proposed machine is that the pneumatic system needs a compressor to actuate the system.

Therefore, this research developed a cup printing machine that can operate automatically. The automatic process occurs from the cup entering the printing system until the printed cup is ejected from the machine. This machine is expected to reduce the operator's role to only putting the cup into the cup storage.

2 Research Methods

The design of a cup printing machine is presented in Figure 1. This machine was designed using a frame made of a 30x30 angle bar, with frame dimensions of 680mm x 564mm x 900mm. This machine has several parts: cup storage, insert platform, cup molding, and printing system. The cups to be printed are arranged by the operator in the cup storage horizontally and inserted one by one. The shape of cup storage is designed vertically to allow the cup to drop automatically by gravity. Several researchers inspired this idea by developing a machine that employs gravity to push the material to be processed from the hooper [16-18]. The cup storage was also designed thin, so the cups enter the insert platform individually. The cup storage capacity is 10 cups of 14 oz cup size. The design of cup storage is one of the advantages of this machine that makes this machine able to operate automatically and continuously.

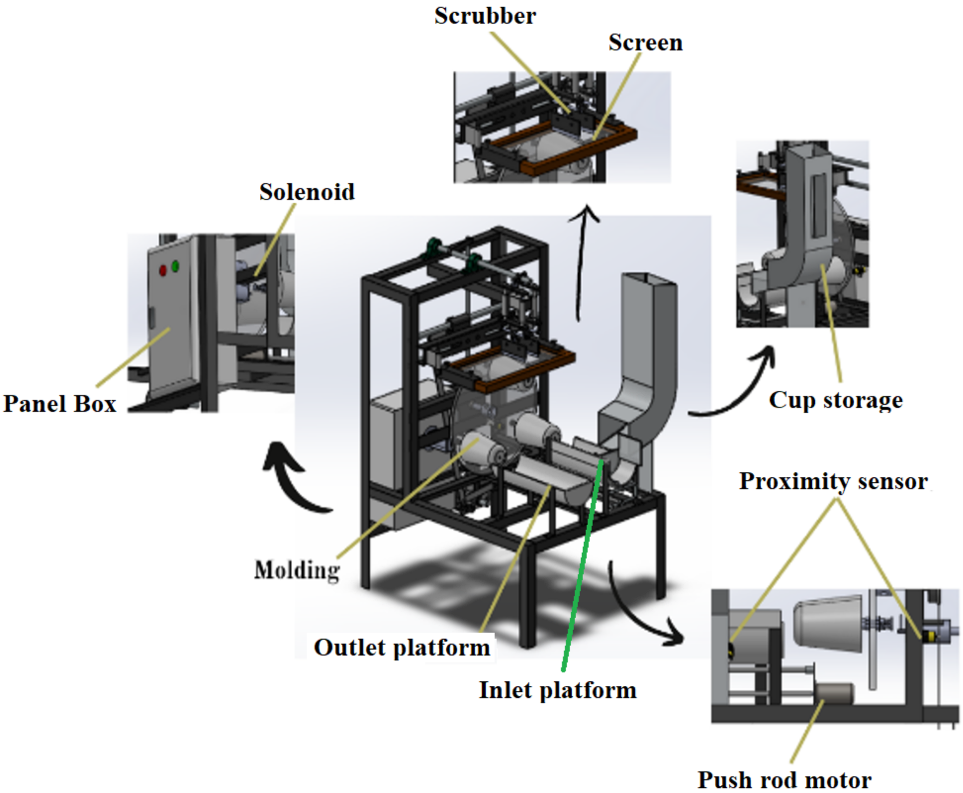

Fig. 1. Design of cup printing machine

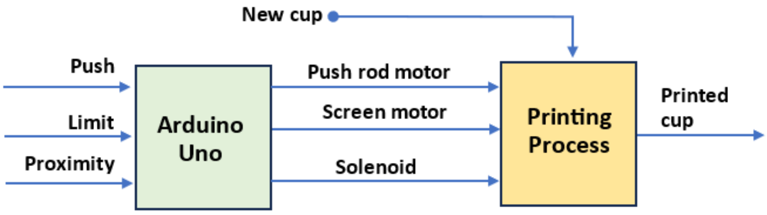

Fig. 2. Block diagram of the operating system

The insert platform is a place for a cup that comes out from the cup storage. The insert platform has a push rod that is actuated by a solenoid. The push rod makes the cup on the insert platform enter the molding in the first position. Another main component is one set of cup molding. Three pieces of cup molding are placed in three different positions, each with a different function. The molding cup in the first position is the place for a new cup, while the molding cup in the second position is for the cup in the printing process. The third cup molding is for removing the cup that has been printed. The cup molding is mounted on a rotating disc driven by a stepper motor. The last part of the cup printing machine is the printing system, which uses the screen-printing method.

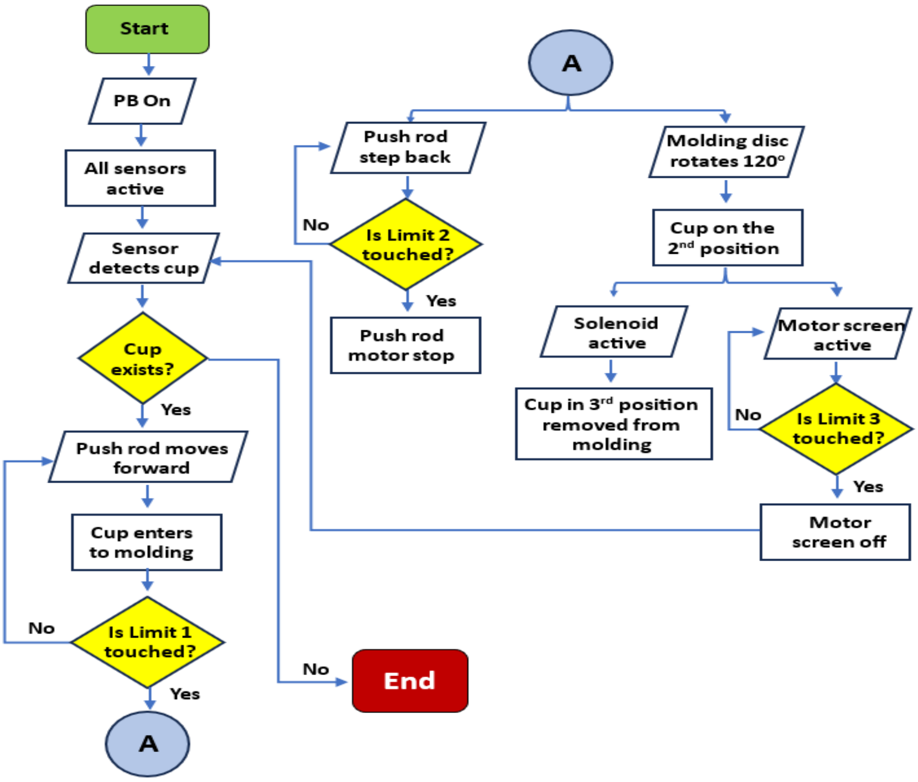

Fig. 3. Flow chart of the programming system

A block diagram to explain the machine's working system, in general, is presented in Figure 2. The printing process begins by inserting the glass into the cup storage. Then, the push button (PB) start is pressed to activate all sensors. Sensors activate all motors used in this machine. The work process of the machine is explained in detail using a flowchart, as shown in Figure 3.

Initially, the operator arranged the cups in the cup storage, and one cup fell onto the insert platform. Then, the operator presses PB start, which activates all the sensors. The proximity sensor, set on the insert platform, detects the cup's existence. If the cup exists, the push rod moves forward, pushing the cup into the molding in the first position. The push rod moves forward until it presses limit switch-1. After that, it moves backward until it presses the limit switch-2 and stops. When the push rod moves backward, the molding disc rotates 120^o to put the cup in the second position. Then, the screen motor is active to print the cup. Subsequently, the solenoid is active to remove the cup on the molding in the third position. The printing screen moves until it presses the limit switch-3, and the printing process finishes. The same process is repeated since the proximity sensor detects the cup on the insert platform.

3. Result and Discussion

The design of the cup printing machine, as shown in Figure 1, has been constructed as depicted in Figure 4. This machine uses 12 Volt DC for the push rod, a 12 Volt stepper motor for molding the disc, and a 5-8 Volt solenoid for removing the cup from molding. Two tests were conducted to examine the machine's performance in printing the cup. The test was also performed to define the speed of the screen.


(a)

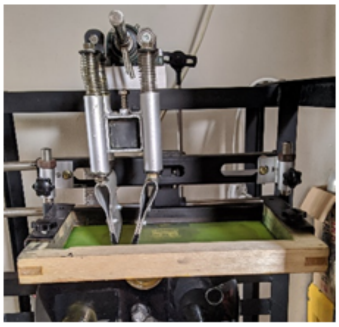
(b)

Fig. 4. The construction of the cup printing machine

3.1 Test for defining the speed of screen movement

The test was performed to define the optimum screen motor speed, producing high-quality printing results. Six speeds are tested, starting from higher to lower speeds. The speed and the test result are explained in Table 1. Meanwhile, the printing result for every test is presented in Figure 6. From this test, it can be concluded that the speed of the screen motion influenced the printing quality. Good quality printing is obtained when the motor speed is 40 rpm. The same result was obtained when the speed was 35 rpm and 30 rpm. Based on this result and for obtaining the optimum capacity of the machine, the speed of 40 rpm was chosen. It is the highest speed in producing good quality.

(a) (b) (c) (d) (e) (f)

Fig. 5 Printing result for various speeds of screen, a) 55 rpm, b) 50 rpm, c) 45 rpm, d) 40 rpm, e) 35 rpm, and f) 30 rpm

Table 1. Test result on the speed of the screen

No	Motor Speed (Rpm)	Result
1	55	Not completely printed (Figure 5a)
2	50	Not completely printed (Figure 5b)
3	45	Not completely printed (Figure 5c)
4	40	Completely printed (Figure 5d)
5	35	Completely printed (Figure 5e)
6	30	Completely printed (Figure 5f)

3.2 Test for defining the capacity of the machine

The system's ability to print the cup using all the processes was also tested. The test was performed to check the performance of all the machine parts and the controller system. Moreover, the test was also aimed to measure the time required to process a cup batch. The machine's capacity could be calculated by obtaining the printing time in one batch.

Table 2. Test results on the printing time and successful rate

Test No	Time (second)	Completely printed	Remark
First Design			
1	55.9	10	100% success
2	55.5	8	2 cups, about 90% printed
3	56.3	9	1 cup, about 80% printed
Second Design			
1	56.1	9	1 cup, about 80% printed
2	55,7	10	Completely printed (Figure 5)
3	55,2	9	1 cup, about 90% printed
Average	55.8	9.17 (91.7%)	

The test was performed using two screen designs, as shown in Figure 6. The test measured and analyzed the data for every batch, where each batch was set to print 10 cups continuously. Every design was tested thrice, and the result was presented in Table 2. The time for putting the cup into the cup storage is not measured. The measuring time starts after the cup set in the cup storage enters the insert platform and stops after the tenth cup is removed from molding in the third position.

The result shows that the average time for printing 10 cups non-stop is 55.8 seconds. The machine's capacity can be calculated using the test data. Considering that the machine operates continuously without a break, the machine's capacity is about 645 cups per hour. Compared to the previous study, the capacity of the developed machine is higher than that of Handono et al. [13]. The capacity of their machine is about 300 cups/hour. The printing time of the machine developed by Hidayatullah [12] is faster compared to this study, which is 4.31 seconds per cup. However, this time excludes the time for inserting the cup into the molding and removing the printed cup from the molding.

The test result in Table 2 also provides data on the successful rate of completely printed cups, which is about 91.7%. The sample of the cup result from the printing process is presented in Figure 7. A completely printed cup is shown in Figure 7a, while a sample of the incompletely printed cup is presented in Figure 7b and Figure 7c. Some mechanical and electrical issues make the incompletely printed cup, such as the accuracy of the stepper motor. The stepper motor's inaccuracy influences the molding's position in the third position. In this case, the molding is not precisely in the center position, affecting the screen's tightness. Less tightness between the cup and the screen causes slip.

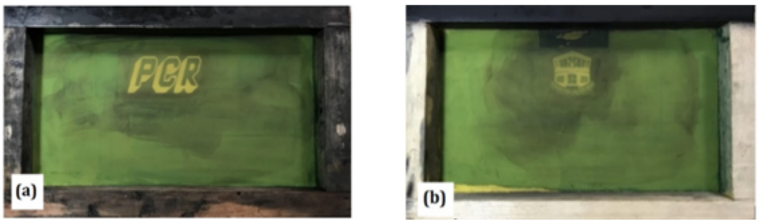

Fig. 6. Design on the screen, a) first design, and b) second design

From a series of tests, the machine could operate automatically from the cup entry to the molding in the first position until the cup is removed from the molding in the third position. Hence, the operator's role in inserting the cup into the molding can be removed. It is the main advantage of this machine compared to previous research [12-15], which is mostly still manual-based. Nevertheless, the cup storage capacity of the developed machine is tiny (only 10 cups). The test show that the average time to print 10 cups is only 55.8 second. Due to the printing time for 10 cups being relatively short, the operator should stand by to continuously input the cup into the storage. The research to improve the quality of this machine is ongoing. Several drawbacks of the machine in its current state have been identified, and it will be improved in future research.

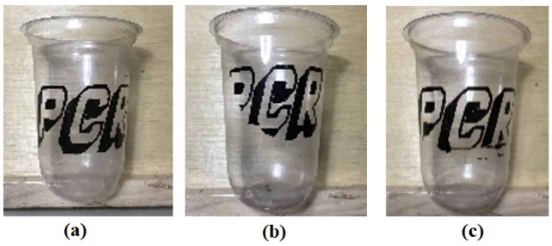

Fig 7. Printing result on the first design

4. Conclusion

The development of an automatic cup printing machine has been performed. The machine has been tested to print two designs in one batch (10 cups) without stopping. Every design was repeated three times. Several conclusions could be taken from the results of the test. The test proved that the machine could operate automatically and continuously. The printing process is continuously performed since the proximity sensor detects the cup's existence in the insert platform. The test showed that the average time for printing 10 cups without stopping is 55.8 seconds. The capacity of the machine is about 645 cups per hour. The speed of the machine is relatively higher as compared to other machines. The test result also demonstrates that the process's success rate is high, about 91.7%. The objective of the machine to remove the operator's role in inserting the cup into the machine could be achieved. However, due to the short printing time and the small capacity of the cup storage, the operator is still practically required to continuously input the cup into the cup storage.

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