



# Performance Study of Automated Bottle Filling and Capping Machine

Dr. G. SARAVANAN <sup>1</sup>, AJAYKUMAR M<sup>2</sup>, DHARUN S<sup>3</sup>, MANIKANDAN R<sup>4</sup>

<sup>1</sup> Department of Mechanical Engineering,  
Kongunadu College of Engineering and Technology,  
Trichy, India

<sup>2</sup> Department of Mechanical Engineering,  
Kongunadu College of Engineering and Technology,  
Trichy, India

<sup>3</sup> Department of Mechanical Engineering,  
Kongunadu College of Engineering and Technology, Trichy, India

<sup>4</sup> Department of Mechanical Engineering,  
Kongunadu College of Engineering and Technology,  
Trichy, India

[rj.saravanan@gmail.com](mailto:rj.saravanan@gmail.com), [ajaykumar2005aug15@gmail.com](mailto:ajaykumar2005aug15@gmail.com), [manikandanr142005@gmail.com](mailto:manikandanr142005@gmail.com),  
[धारुन7721@gmail.com](mailto:धारुन7721@gmail.com)

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## Abstract

This project presents a performance study of an automatic bottle filling and capping machine designed to improve efficiency in liquid packaging industries. In many industries, bottle filling is done manually, which requires more manpower and may lead to errors in filling quantity. The proposed system uses a flow sensor to measure and control the quantity of liquid during the filling process. It is capable of handling bottles of different capacities and ensures accurate filling according to the required level. After the filling process, the bottle is automatically moved to the capping section where the cap is properly closed. The performance of the system is evaluated based on parameters such as filling accuracy, time taken for filling, and overall efficiency. This automated system helps reduce human effort, minimize errors, and improve productivity in bottle packaging operations. The system is designed using pneumatic components such as double acting cylinders, solenoid valves, and an FRL unit to ensure smooth and reliable operation. The use of compressed air provides faster response and consistent movement during bottle positioning and capping. The integration of a conveyor system allows continuous movement of bottles between different stages, thereby reducing idle time and increasing production rate. The control system, either timer-based or PLC-based, coordinates all operations in a sequential manner to achieve proper synchronization. The inclusion of a liquid flow sensor further enhances the performance of the system by providing real-time measurement of the liquid being filled. This ensures uniform filling for all bottles and reduces variations in quantity. The system is tested under different operating conditions, and the results show that it maintains stable performance with satisfactory accuracy.



The machine is also capable of continuous operation for several hours without significant performance drop. Overall, the developed system offers a cost-effective and efficient solution for small and medium scale industries. It reduces dependency on manual labor, improves consistency in filling and capping, and ensures better quality control. With minor modifications and upgrades, the system can be further enhanced for large-scale industrial applications.

**Keywords** — Automatic bottle filling, Bottle capping system, Liquid flow sensor, Pneumatic system, Conveyor system, Solenoid valve, Industrial automation, Filling accuracy, Production efficiency, Packaging industry

## I. INTRODUCTION

The Packaging industries play an important role in the storage, protection, and distribution of liquid products such as drinking water, edible oil, juice, milk products, and chemical liquids. Proper packaging ensures that the product reaches the consumer safely without contamination or leakage. Bottle filling and capping are two major processes involved in liquid packaging. These processes ensure that the liquid is accurately filled into bottles and properly sealed before distribution.

In modern industries, automation has become an essential requirement to improve productivity and efficiency. Large-scale industries commonly use advanced automated filling machines that are controlled by programmable logic controllers (PLC), servo motors, and various sensors. These machines can operate at high speeds and can fill many bottles in a short period of time with high accuracy. However, these systems are usually expensive and require skilled operators and technicians for installation, operation, and maintenance.

Because of the high cost and complexity of such systems, many small-scale and medium-scale industries still rely on manual or semi-automatic methods for filling and selling bottles. In manual filling operations, workers fill bottles individually using simple filling devices or containers. This process consumes more time and requires significant manpower. It also increases the possibility of human errors, which may lead to variations in the quantity of liquid filled in each bottle.

Therefore, there is a need for a simple, cost effective, and reliable automation system that can improve the efficiency of bottle filling and capping operations while remaining affordable for small industries. The proposed system focuses on improving accuracy, reducing manual effort, and increasing production efficiency by using simple

automation techniques. In this project, components such as a liquid flow sensor, pneumatic cylinders, conveyor system, and control unit are used to perform the filling and capping operations effectively.

## II. MATERIALS AND METHODS

**Air Compressor:** Air compressor is one of the main components used in the pneumatic system. It is used to produce compressed air required for operating pneumatic devices such as cylinders and valves. In this project, the air compressor supplies compressed air at a pressure of about 6 bars. The compressed air is stored and then supplied to the pneumatic circuit

through air pipes. This compressed air provides the force required to operate the pneumatic cylinders used for bottle positioning and capping operations. The use of an air compressor makes the system simple, efficient, and suitable for industrial automation.

**FRL Unit** FRL stands for Filter, Regulator, and Lubricator. It is used to improve the quality of compressed air before it enters the pneumatic system. The filter removes dust, moisture, and other



impurities present in the compressed air. The regulator controls and maintains the required air pressure for proper operation of the pneumatic components. The lubricator adds a small amount of oil to the air to reduce friction and wear in the moving parts of the pneumatic system.



The FRL unit helps in increasing the life and efficiency of pneumatic components used in the machine.

**5/2 Solenoid Valve:** The 5/2 solenoid valve is an electrically operated valve used to control the direction of compressed air in the pneumatic system. Term 5/2 indicates that the valve has five ports and two positions. This valve controls the movement of double acting pneumatic cylinders by directing compressed air to different ports. It ensures precise control of air flow, which improves the accuracy of cylinder movement.

The valve responds quickly to electrical signals, enabling fast operation of the system. It also reduces manual intervention by automatically controlling the air direction. When electrical current is supplied to the solenoid coil, the valve changes its position and allows air to flow in the required direction.

**Double Acting Cylinder:** The double acting cylinders used in this project play an important role in both bottle positioning and capping operations. A double acting cylinder operates using compressed air supplied to both sides of the piston, allowing it to move forward and backward smoothly. The horizontal double acting cylinder is used to position the bottle under the filling nozzle by pushing it from the conveyor to the exact filling position. Proper positioning of the bottle is necessary to ensure accurate filling and to avoid liquid spillage.



The vertical double acting cylinder is used for the capping operation, where it moves in an up and down direction using compressed air. During the capping process, the cylinder moves downward to press the cap firmly onto the bottle, and after proper sealing, it moves back to its original position. The use of these pneumatic cylinders ensures quick, reliable, and efficient operation of the system while preventing leakage and maintaining product quality.

**Flow Control Valve:** The flow control valve is used to regulate the speed of compressed air flowing to the pneumatic cylinders. By adjusting the flow control valve, the speed of cylinder movement can be increased or decreased. This helps in achieving smooth and controlled motion of the pneumatic actuators. Proper speed control is important to avoid sudden movements which may cause damage to the bottles or machine components. Therefore, the flow control valve helps in maintaining safe and stable operation of the pneumatic system.



**Liquid Flow Sensor:** The liquid flow sensor is an important component used in the automatic bottle filling system to measure the quantity of liquid flowing into the bottle during the filling process. It is installed in the pipeline between the storage tank and the filling nozzle. The sensor continuously monitors the liquid flow rate and provides accurate information about the amount of liquid being filled.

**Tubes :** Tubes are used to connect different pneumatic components in the system and allow the flow of compressed air. The tubes carry compressed air from the air compressor to the FRL unit, solenoid valve, and pneumatic cylinders. These tubes are usually made of flexible materials such as polyurethane or nylon which can withstand air





pressure. Proper tubing connections are important to ensure smooth air flow and efficient operation of the pneumatic system.

**HMI Unit:** The Human Machine Interface (HMI) is used to monitor and control the operation of the automatic bottle filling and capping machine. It provides an interface between the operator and the machine. Through the HMI, the operator can start, stop, and reset the system, as well as monitor the status of the machine during operation. It also allows setting of parameters such as filling quantity for different bottle capacities.



**Filling Nozzle :** The filling nozzle is used to deliver liquid from the storage tank into the bottle during the filling process.

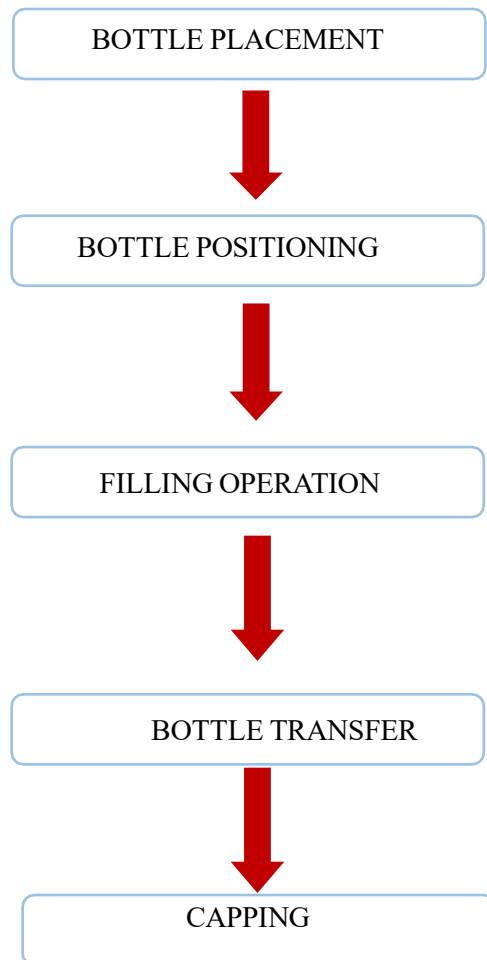


It is usually made of stainless steel to ensure durability and hygiene, especially in liquid packaging applications. The nozzle is connected to the pipeline through which liquid flows from the tank. In this project, multiple nozzles can be used to fill more than one bottle at a time, thereby increasing production efficiency. The nozzle ensures smooth and controlled flow of liquid into the bottle. Proper alignment of the nozzle with the bottle is important to avoid spillage and ensure accurate filling.

**Conveyor System:** The conveyor system is used to transport bottles from one stage to another in the machine. It plays a vital role in maintaining continuous operation of the system. Bottles are placed on the conveyor, and it moves them towards the filling and capping stations automatically. The conveyor ensures proper spacing and smooth movement of bottles during operation.



### III. EXPERIMENTAL METHOD USED





## BOTTLE PLACEMENT

In the first stage, empty bottles are manually placed on the conveyor system by the operator. The conveyor belt is used to transport the bottles from one station to another in a continuous manner. Proper placement of bottles on the conveyor ensures smooth movement and alignment for the next operation. This stage is important because it initiates the entire filling process. The operator ensures that bottles are placed correctly and evenly spaced on the conveyor to avoid collision during movement. Once the bottles are placed, the conveyor system moves them towards the bottle positioning station. This stage also helps in maintaining a steady flow of bottles in the system. Proper initial handling reduces chances of misalignment and improves overall process efficiency.

## BOTTLE POSITIONING

In this stage, the bottle is positioned accurately under the filling nozzle to perform the filling operation. A horizontal pneumatic cylinder is used to push the bottle from the conveyor towards the filling station. The pneumatic actuator ensures proper alignment of the bottle with the nozzle. Correct positioning is important to prevent spillage of liquid during the filling process. The cylinder operates using compressed air and moves the bottle smoothly into the filling position. Once the bottle is placed correctly under the nozzle, the system prepares for the filling operation. Accurate positioning also improves filling precision and reduces wastage. This stage ensures that every bottle is placed in the exact required location before filling begins.

## FILLING OPERATION

During this stage, the liquid filling process takes place. A solenoid valve controls the flow of liquid from the storage tank to the bottle through the nozzle. When the valve opens, liquid flows into the bottle. A timer or control mechanism regulates the duration of the filling process to ensure the required quantity of liquid is filled. The flow sensor monitors the amount of liquid entering the bottle and helps maintain accuracy in filling. This stage ensures that each bottle receives the correct amount of liquid without overflowing or underfilling. After the required quantity is filled, the solenoid valve closes automatically.

## BOTTLE TRANSFER

After the filling process is completed, the bottle is transferred to the capping station. The conveyor system moves the filled bottle from the filling station to the capping area. This stage ensures smooth transportation of bottles without disturbing the filled liquid. Proper transfer is necessary to maintain continuous operation of the machine. The automated movement of bottles between stations reduces manual handling and increases production efficiency. Once the bottle reaches the capping station, it is ready for the final sealing operation. Smooth transfer also prevents spillage and maintains cleanliness of the system. Continuous movement ensures higher productivity and reduces idle time between operations.

## CAPPING

In the final stage, the bottle is sealed with a cap to prevent leakage and contamination. A vertical pneumatic cylinder is used to press the cap firmly onto the bottle. The pneumatic actuator moves downward and applies pressure to secure the cap properly. Proper sealing is important to maintain the quality and safety of the liquid product. After the capping process is completed, the bottle is ready for packaging or further processing. This automated capping operation improves productivity and ensures consistent sealing quality. This stage completes the process and prepares the bottle for final distribution.

## IV. RESULTS AND DISCUSSION

This chapter presents the results obtained from the testing and evaluation of the automatic bottle filling and capping machine along with a detailed discussion of its performance. The system was developed to achieve accurate filling, efficient production, and reliable operation using a combination of pneumatic components and a liquid flow sensor. After fabrication and assembly, the machine was tested under different operating conditions to analyze its behaviour and effectiveness. During testing, the filling accuracy of the system was observed to be approximately  $\pm 5$  ml. This level of accuracy is achieved through the use of a liquid flow sensor, which continuously monitors the flow rate and total quantity of liquid entering the bottle.



Once the required quantity is reached, the system automatically stops the filling process. The results show that the system is capable of maintaining consistent filling levels for different bottle sizes such as 500 ml, 1 litre, and 2 litres. Minor variations in the filled quantity were noticed in some cases, which may be due to fluctuations in flow rate, air pressure, or slight delays in valve response. However, these variations are within acceptable limits and do not significantly affect the overall performance of the machine. The production output of the system was also evaluated to determine its efficiency. The machine was able to produce approximately 250 to 300 bottles per hour under normal working conditions.

This output rate is significantly higher compared to manual filling methods. The automation of bottle positioning, filling, and capping operations helps in reducing idle time and improving productivity. The use of multiple nozzles further contributes to increasing the production rate.

#### V. CONCLUSION

The automatic bottle filling and capping machine developed in this project successfully achieves the objective of automating the liquid filling and sealing process. The system integrates mechanical, pneumatic, and control components to perform bottle positioning, liquid filling, and capping operations efficiently. The use of a liquid flow sensor ensures accurate measurement and filling of different bottle capacities. The system provides satisfactory performance with a filling accuracy of approximately  $\pm 5$  ml and a production output of around 250 to 300 bottles per hour. The pneumatic system operating at 6 bar ensures smooth and reliable operation of the cylinders. The machine also shows stable performance during continuous operation, making it suitable for practical applications. The automation of the system reduces manual effort and human error, improves productivity, and ensures consistent output quality. It also minimizes liquid wastage and enhances overall efficiency. Although minor variations in accuracy may occur due to flow and pressure changes, the system performs effectively under normal conditions. In conclusion, the developed system is an efficient and reliable solution for automated bottle filling and capping, and it is suitable for use in small and medium scale industries.

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