

Automatic Drum Filling Machine Equipped with Liquid Level Control System

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In the interest of the smart factory, automatic production systems are always developing new technologies to increase productivity and safety. Numerous studies have been conducted on the automation of filling machines in the packaging sector. Specifically, in the dangerous chemical business, automatic liquid (drum) filling machines serve mostly for packaging goods into drums following the production process. With the majority of filling machines on the market today, the operator may simply adjust the injection capacity to the standard drum and open the drum lid to inject the product directly. But there's a challenge in accurately calculating the liquid's volume. If the liquid filling equipment is not calibrated correctly, problems might arise, such as overflowing the fluid or chemicals becoming exposed to the elements. In order to address the aforementioned problems, we present in this study a liquid level control injection nozzle device. The suggested automated injection nozzle has the ability to elevate the nozzle in accordance with the liquid level in order to eliminate bubble and inject the precise amount of fluid. We discovered through testing with the designed injection nozzle device that the goal value was surpassed for injecting capability, nozzle position, reaction time, and building data correctness. It is anticipated, therefore, that the invented filling machine would increase output and decrease human labor without endangering the chemical packaging sector.

Keywords: Drum Filling Machine, Liquid Level Control, Injection Nozzle, Packaging Industry.

1. INTRODUCTION

As smart factory gain attention, industry automation is continuous evolving to increase in productivity and safety. Automation had important role in a various industries field beyond manufacturing, for example, automatic irrigation or automated tracking of animals. (Porwal et al., 2022; AlZubi, 2023; Kim and AlZubi, 2024). In order to boost output, automated liquid filling devices are required. Liquid filling machines come in a wide variety of models and kinds for use in food, chemical, oil, and other packaging industries. More specifically, following product manufacture, chemical firms commonly utilize liquid filling machines to package their goods in drums. The liquid filling machine to automate in various size

packaging industries has been the subject of multiple studies (Abubakar et al., 2022; Solanki et al., 2015; Baoyun & Daniel, 2016; Saleh et al., 2017). In industrial automation, programmable logic controllers, or PLCs, are widely utilized. Researchers studied the design and implementation of a PLC-controlled water filling machine system for varying bottle sizes, as well as an automatic liquid filling unit (Suramwar et al., 2022; Saleh et al., 2017). The other study describes how PLC-Supervisory control and data acquisition (SCADA) systems were used in the design and implementation of an intelligent automated bottle-filling enterprise. According to Nadgauda et al. (2020), energy-efficient lighting systems, warehouse management, and bottle filling are among the automated procedures. Conversely, Sidik and Chani (2017) explored a water volume measurement system that used an ultrasonic sensor instead of a cylinder piston and two solenoid valves to regulate water flow. All proposed method can reduce the cost for small scale industries and help them in setting up and automated decision for filling water bottles (Muralidharen et al., 2021). The correlations between flow rate, exhaust pressure, and the average size of droplet with the shape factor of a water curtain nozzle were investigated (Park et al., 2020).

The aforementioned studies, however, concentrate on small-scale liquid filling machines for the food, soft drink, and water packaging sectors. Furthermore, there is an issue with accurately calculating the liquid's volume. If the liquid filling equipment is not calibrated correctly, problems might arise, such overflowing the fluid or chemicals becoming exposed to the elements. Chemical manufacturing workers may be exposed to contaminants at work, which might have negative health effects.

In order to eliminate bubbles, this study focuses on an injection nozzle with a traverse system and liquid level control which can raise or lower the nozzle and precisely inject a quantity of liquid inside the drums based on the liquid level.

2. DESCRIPTION OF AUTOMATIC DRUM FILLING MACHINE

This paper aims to introduce the developed automatic drum filling machine with liquid level controlled for the especially chemical packaging industry. Figure 1 shows the schematic of the automatic drum filling machine for this research. The machine mainly consists of an injection nozzle, a traverse system, a vision sensor, load cells, a roller conveyer system, and et al.

The description of the machine operation is as follows.

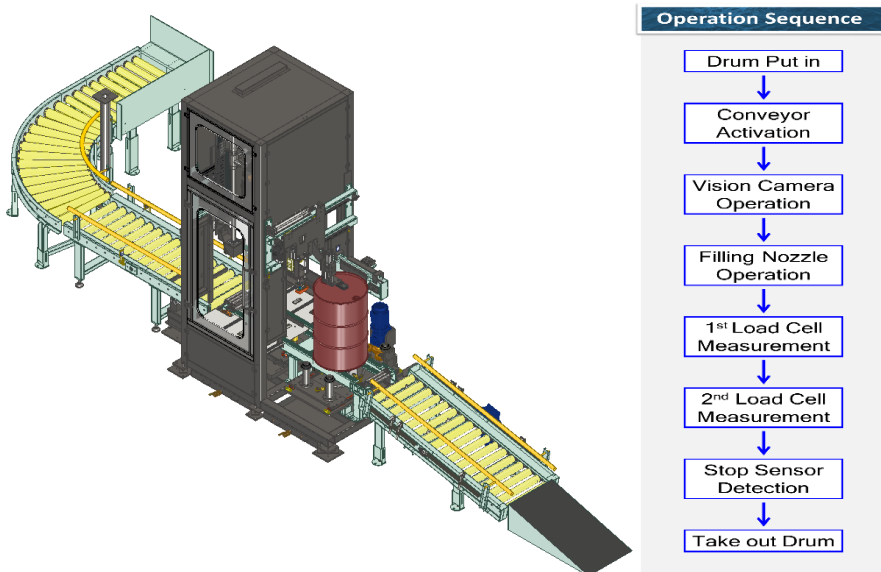


Fig. 1: Schematic of the Automatic Liquid Filling Machine and Operation Sequence

The main control system start, the conveyor motor will start to move a drum. The drum is rotated automatically in search of the bung opening by the vision sensor. Then the injection nozzle with liquid level controller operates to down and fill the product. The controller will automatically zero the tare weight before the filling starts. If filling a foaming product, the system starts in slow mode. At the same time, measure the weight of product by two times for cross-check. the sensor detects to move, take out drum. The conveyor transports the load to the next station.

2.1 Design of the Automatic Liquid Level Control System

Figure 2(a) illustrates the injection nozzle device equipped with liquid level control system in detail with photo of Fig. 2(b). The injection nozzle and traverse system (up/down unit) can raise and lower the nozzle and inject the accurate amount of liquid in the drums.

We have developed several parts device of the system. Injection nozzle device injects the liquid into drum, an up/down unit controlled by traverse can control the nozzle according to liquid level of the drum. Open/close unit can open and close the liquid. Load cell can detect the weight of the drum as well as connected with injection nozzle control to adjust the liquid level.

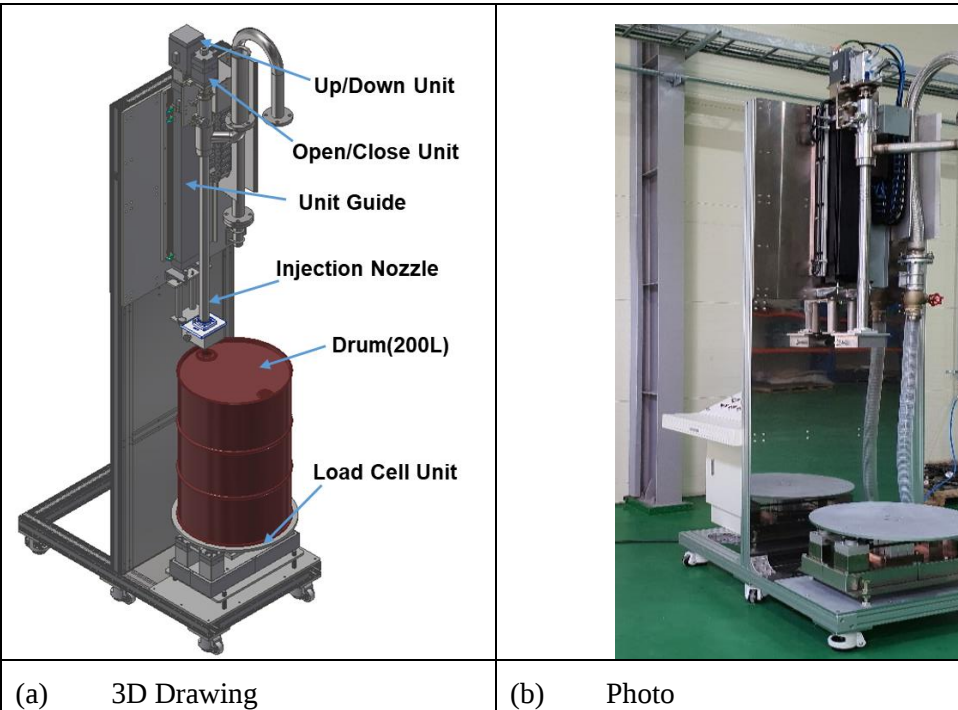


Fig. 2: Injection Nozzle Device with Liquid Level Control

2.2 Performance Test

There are four performance tests: Injection amount accuracy, Nozzle position accuracy, Nozzle response time, and Bubble generation test.

The injection amount accuracy test measures the accuracy of the injected capacity when injecting 50kg liquid based on the 60L drum. The water used in this test. The weight is measured through the load cell system. And repeat 5 times to determine whether or not under 100 g or less standard is satisfied. The nozzle position accuracy test divides the vertical traverse position of the injection nozzle into 5 sections (20, 25, 30, 35, and 40 kg of water, respectively) and measures the position accuracy in each section using a Vernier caliper, then measures the average value after 5-time tests.

The nozzle response time test is the time the injection nozzle responds to the change in the level of the injected liquid. The response speed was measured by checking the algorithm of the PLC program. And check the average value after 5-time tests. The bubble generation test is compared before and after the development of the liquid level control system over time when injecting the liquid.

Table 1: Performance Test Results

Test item	Unit	Test results (error)
Injection amount accuracy	kg	-0.05 ~ 0
Nozzle position accuracy	mm	0.15 ~1.25
Nozzle response time	sec	0.5
Bubble generation	-	No bubble

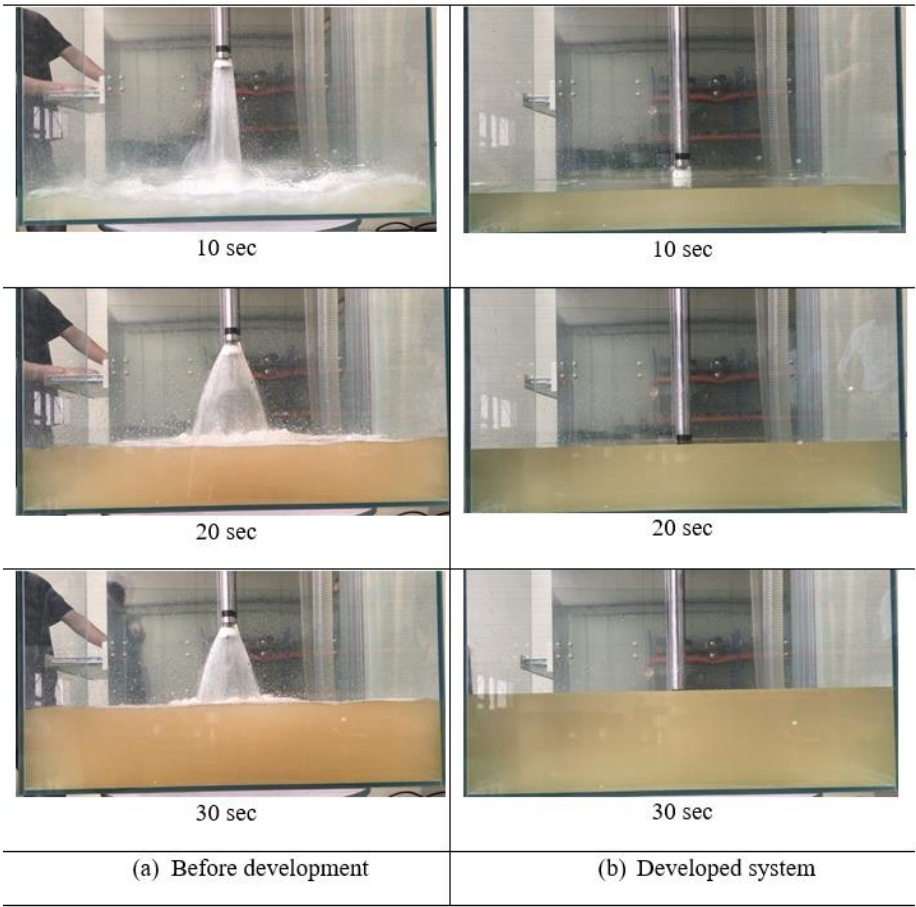


Fig. 3: Photos of Comparison Test Results Depending on Time

3. EXPERIMENTAL RESULT AND DISCUSSION

Table 1 shows the performance results for each 4 different test. As a result, all performances we expected were satisfied. In case of the injection amount accuracy, the maximum error of the target injection amount of 50 kg was – 0.05 kg. The maximum error range of the nozzle position accuracy is from 0.15 ~ 1.25 mm. It indicates that the nozzle response time was only 0.5 second.

Figure 3 show the comparison test photos before and after development of the machine over time of 10, 20 and 30 seconds. As shown in Fig. 3, in the existing device, since the injection nozzle is at a constant height with the packaging container, a lot of bubbles are generated due to a drop during the filling process, making it difficult to dose. However, the developed machine can control the liquid level without bubbles and splash during all injection processes as shown in Fig. 3(b).

Moreover, additional performance tests were conducted on liquids with different specific gravity(S), and as a result of performing the same experiment on water(S=1), diesel(S=0.85), *Nanotechnology Perceptions* Vol. 20 No.S1 (2024)

and gasoline($S=0.7$) rates. All of them satisfied the standard without bubble generation and no liquid droplets splashed.

4. CONCLUSION AND FUTURE WORK

For the production of hazardous chemicals, an automated drum filling system has been designed and put into use. This machine uses a liquid level control technology to increase production in less time and provide flexibility in the task. Each and every performance test is completed without any bubbles forming or liquid droplets being thrown. As a result, the chemical packaging business may minimize human labor without running any danger thanks to this equipment. We are creating a fully automated drum-filling machine in the future that will have a safe roller conveyor and a production management algorithm for increased worker productivity and safety.

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References

- Abubakar, A. N., Dhar, S. L., Tijjani, A. A., & Abdullahi, A. M. (2022). Automated Liquid Filling System with a Robotic Arm Conveyor for Small Scale Industries. *Material Today: Proceedings*, 49(8) 3270-3273. <https://doi.org/10.1016/j.matpr.2020.12.923>
- AlZubi, A. A. (2023). Application of Machine Learning in Drone Technology for Tracking Cattle Movement. *Indian Journal of Animal Research*. 57(12): 1717-1724. <https://doi.org/10.18805/IJAR.BF-1697>.
- Baoyun, G., & Daniel, C. L. (2016). Dielectric Liquids for Enhanced Field Force in Macro Scale Direct Drive Electrostatic Actuators and Rotating Machinery. *IEEE Transactions on Dielectrics and Electrical Insulation*, 23(4), 1924-1934. <https://doi.org/10.1109/TDEI.2016.7556463>
- Kim, T.H. and AlZubi, A.A. (2024). AI Enhanced Precision Irrigation in Legume Farming: Optimizing Water Use Efficiency. *Legume Research*. <https://doi.org/10.18805/LRF-791>
- Lee, J. S., Lee, J. H., Roh, Y. H., & Park, J. K (2020). Development of Automatic Water Level Controlled Smart Filling Machine. *Journal of the Korean Society of Industry Convergence*, 23(3), 507-513.
- Muralidharan, J., Saran S., Tamikavi G., Thivakar S., & Vivin M. (2021). An Automatic Fluid Filling Mechanism using Delta PLC. *Journal of Physics: Conference Series*. 1937. <https://doi.org/10.1088/1742-6596/1937/1/012004>
- Nadgauda, N., Muthukumaraswamy, S. A., & Prabha, S. U. (2020). Smart Automated Processes for Bottle-Filling Industry using PLC-SCADA System. *Intelligent Manufacturing and Energy Sustainability*. 189, (pp. 693-702). Springer Nature Singapore.
- Park, J. W., Shin Y. J., & You, W. J. (2020). Analysis of Correlations between Flow Rate, Pressure and Average Size of Droplet with Hydraulic Diameter of Water Curtain Nozzle. *Journal of the Korea Academia-Industrial Cooperation Society*, 21(4), 317-323.
- Porwal, S., Majid, M. Desai, S. C., Vaishnav, J. & Alam, S. (2024). Recent Advances, Challenges in Applying Artificial Intelligence and Deep Learning in the Manufacturing Industry. 16(7). 143-152.
- Saleh, A. L., Naeem, L. F., & Mohammed, M. J. (2017). PLC Based Automatic Liquid Filling System for Different Sized Bottles. *International Research Journal of Engineering and Technology*, 4(12), 57-61.

- Sidik, M. M. H., & Ghani C. S. A. (2017). Volume Measuring System using Arduino for Automatic Liquid Filling Machine. *International Journal of Applied Engineering Research*, 12(24), 14505-14509.
- Solanki, N. A., Raj, P. G., Patel, S. P., & Rajput, C. D. (2015). Automatic Liquid Filling Machine. *International Journal of Engineering Research & Technology*, 4(5), 108-110.
- Suramwar, P. V., Meshram, A., Bhadke, P., Pathode, P., & Thakre, T. (2022). Automatic Liquid Filling Unit using PLC. *International Journal for Research in Applied Science & Engineering Technology*, 10(6), 39–44. <https://doi.org/10.22214/ijraset.2022.41165>
- Zhang, D., & Li, S. (2015). Design and Realization of Liquid Filling Machine Intelligent Control System. *Proceedings of 2015 IEEE International Conference on Mechatronics and Automation*. <https://doi.org/10.1109/ICMA.2015.7237670>.