

Development of Low-cost Filling System Indispensable to Beverage Industry



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There is a growing need for lower-cost production in the beverage market, where price competition is severe. As a response, in addition to energy-saving technology based on the cogeneration system, the beverage filling machines of Mitsubishi Heavy Industries Food & Packaging Machinery Co., Ltd. have introduced the following: technology for container and ambient sterilization with a smaller amount of disinfectant, and technology for the filling and conveyance of polyethylene terephthalate (PET) bottles that are thinner than the conventional ones and therefore are made using smaller amounts of raw materials. In this report, we describe an aseptic filling system, screw-less bottle entry mechanism and DLC coating equipment. Each of these is an individual machine developed using technologies to satisfy the same need, and the installation of these machines on production lines can realize the low-cost production of high-quality beverages in PET bottles.

1. Introduction

The low-cost production of beverage products requires not only minimized initial cost for production facilities, but also reduced running costs for operation and decreased costs for raw materials. As a solution, we have developed a sterilization technology in which a smaller amount of disinfectant and less energy is needed. We are also promoting coating and conveyance technology for containers (PET bottles) that can be made using smaller amounts of raw materials.

2. Sterilization technology for PET bottles

2.1 Aseptic filling system for PET bottles

PET bottles are widely used as beverage containers owing to their lightweight property, versatility and safety. The aseptic filling system, in which PET bottles are sterilized before being filled with beverages, enables bottle filling at ambient temperature. Therefore, the system can handle thin-walled, heat-sensitive PET bottles as well as various drinks such as juice and tea, the quality of which can easily be deteriorated by heat. It is obvious that many advantages of the system have contributed considerably to the increased use of PET bottles in the beverage industry. We installed the system in approximately 20 factories (mostly in Japan) and its high productivity and low running costs have been favorably received by our beverage manufacturer clients. The major features of our aseptic filling system are given below:

(1) Compact system designing

In the sterilization and rinsing process, several small transfer wheels instead of the conventional large transfer wheel are laid out and the adopted conveyance mechanism allows PET bottles to be carried in the inverted position. Both have enabled the machine to be compact.

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(2) Low running costs

Instead of the conventional jet method, disinfectant is nebulized during the sterilization process (**Figure 1**), which has decreased the sterilization time by 25% and reduced the amount of disinfectant used for sterilization inside PET bottles by 80%. The sustainability of the aseptic condition in the chamber has been improved, making it possible to operate continuously for 120 hours (2.5 times longer than before).

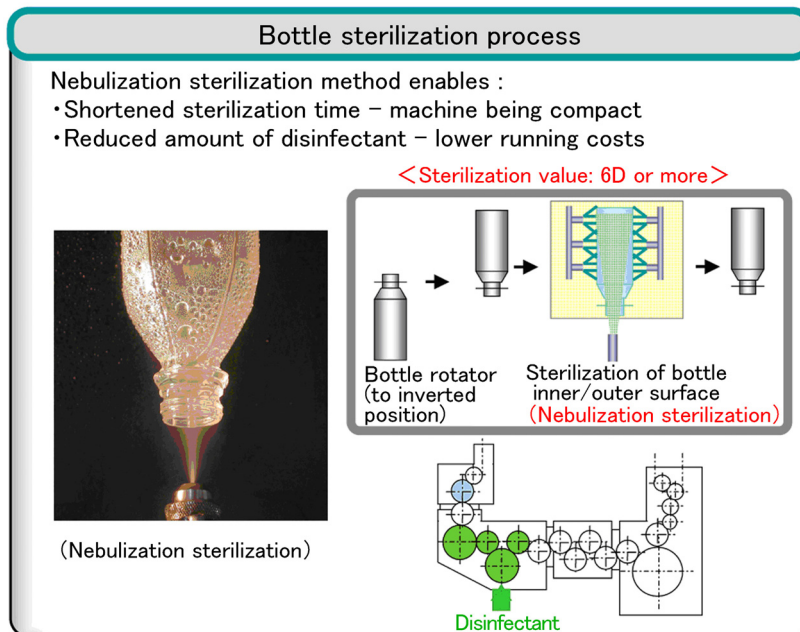


Figure 1 Jet sterilization method

(3) Handling capability regardless of bottle type

In the rinsing process of PET bottles, the insertion of the nozzle does not have to be adjusted according to the bottle size. We have adopted a new method (the juggling rinsing method; **Figure 2**) in which bottles can be sufficiently cleaned without inserting a nozzle into them, reducing the amount of aseptic water used for rinsing by 20%. Our results show that the residual concentration of disinfectant is 0.1 ppm, which is considerably below the regulatory level (0.5 ppm).

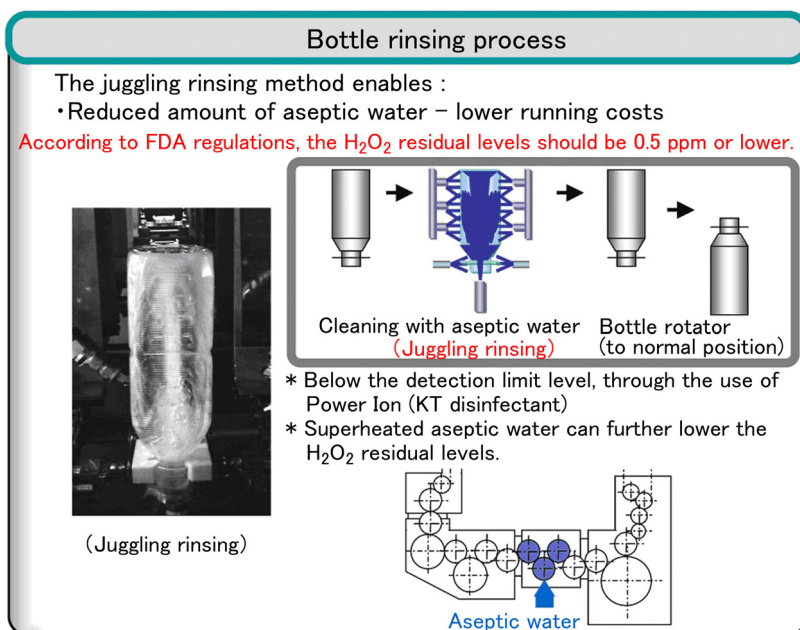


Figure 2 Juggling rinsing method

2.2 EB sterilization system for PET bottles

As a sterilization method for PET bottles, we have developed technology using an electron beam (EB) (Figure 3). With our unique method of EB source fixation, this technology does not necessitate the use of disinfectant or aseptic water and thus enables the sterilization of PET bottles under dry conditions, reducing the environmental impact and achieving lower running costs. We will be able to provide a choice between these two options (disinfectant or EB sterilization) depending on the needs of our clients.

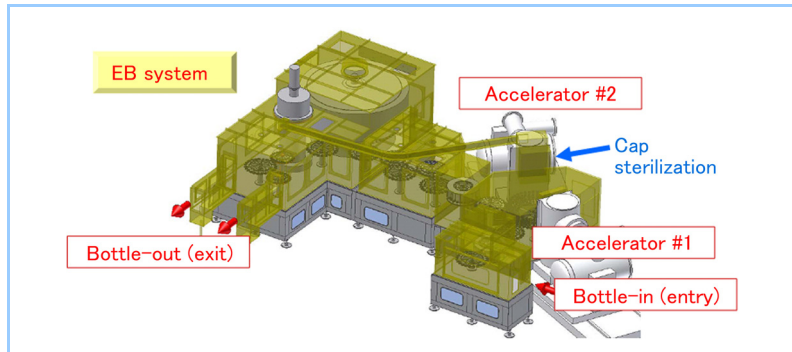


Figure 3 EB sterilization system for PET bottles

3. Conveyance technology for PET bottles (screw-less bottle entry mechanism)

In a conventional beverage filling system, a plastic screw is placed at the entrance to the system (bottle entry section) (Figure 4). The screw is used to correct the positions of PET bottles that have been carried by air conveyors and crammed haphazardly, so as to re-arrange them to maintain the desired distance in between. However, this system poses the following problems.

- (1) Screws have to be changed according to the design or size (ranging from 280 mL to 2 L) of PET bottles.
- (2) Whenever a screw is changed, some adjustment is needed to ensure that the performance of the high-speed conveyance system is not affected by the change. This is a hindrance to the improvement of productivity.
- (3) Clients have to keep as many screws as are necessary at their factories.



Figure 4 Conventional bottle entry section (plastic screw)

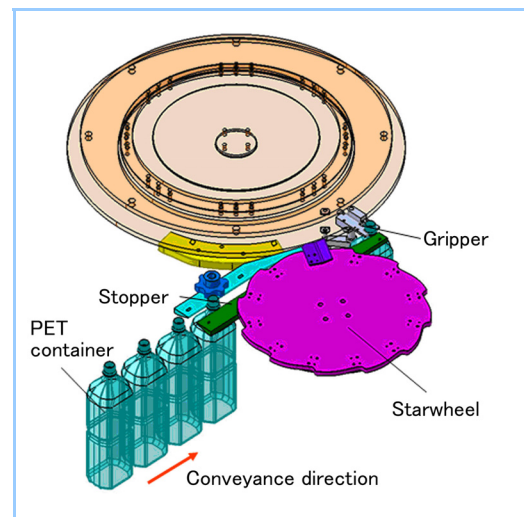


Figure 5 Container conveyance simulation by mechanism analysis

Our newly-developed bottle entry section features a lack of these plastic screws. For bottle conveyance, it uses the screw top of the PET bottles, which has the same shape regardless of the bottle type. Thus, changing bottle types has no influence on the production system. In developing the bottle entry section, we determined the basic structure and verified its feasibility by simulation. 3D-CAD models were drawn (Figure 5) and the behavior of the PET bottles during conveyance

was analyzed using mechanism analysis software. Based on the results, the conditions in which bottles can be conveyed without being dropped were specified. At the same time, we used the relevant component of the machine to examine the load on a PET bottle and the damage caused (**Figure 6**), thereby determining the maximum allowable contact load. Considering these results and conducting the mechanism analysis to verify the load on bottles during conveyance, the conditions in which PET bottles are neither dropped nor damaged were determined (**Figure 7**). Our new bottle-entry section has been made available for commercial use.

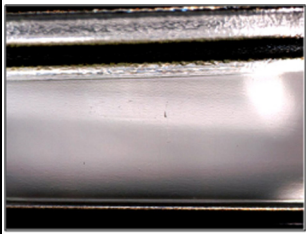
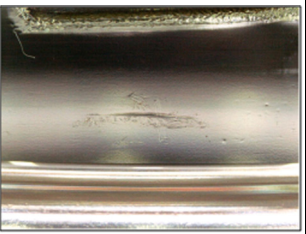
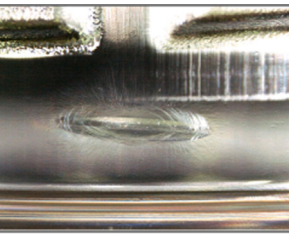
Load type (Contact time)	Impact load (Contact time: short)	Impact load (Contact time: long)	Static load
Damage to bottles			

Figure 6 Load type and damage to bottles

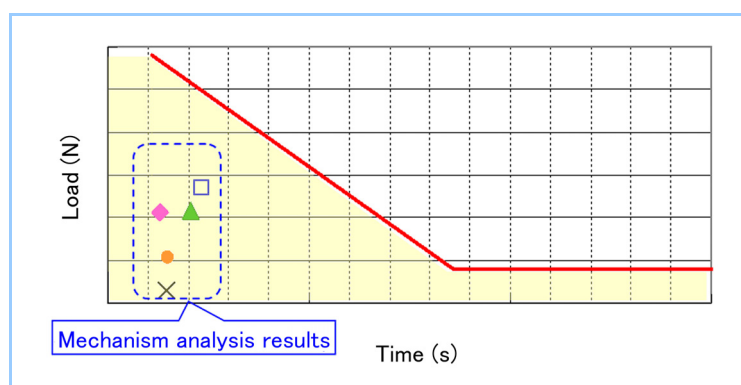


Figure 7 Maximum allowable load on bottles

4. Thin film coating technology for improved gas barrier performance

The use of PET for beverage and food containers has been accelerating owing to its versatility and economic advantages. However, its gas barrier performance is poorer than that of cans or glass bottles. The inflow of oxygen and outflow of carbon dioxide through PET containers result in the disadvantage of lower performance in the quality preservation of the contents. In co-operation with Kirin Brewery Co., Ltd., Mitsubishi Heavy Industries, Ltd. and Mitsubishi Heavy Industries Food & Packaging Machinery Co., Ltd. developed a technology in which the plasma treatment of organic gas allows the formation of diamond-like carbon (DLC) film on the inner surface of bottles. DLC film exhibits high gas barrier performance, thus enabling PET bottles to show better gas barrier performance as well. This technology has been commercialized as the DLC coating equipment and boasts high productivity of 300 bpm (number of bottles that can be handled per minute). It can be installed as an in-line facility on the beverage filling production line.

Thin DLC film is formed on the inner surface of bottles by plasma chemical vapor deposition (CVD), which improves the gas barrier performance of PET bottles by a factor of more than 10 (**Figures 8–10**). The features of this process include the formation of a dense film using high ion energy. Multilayer bottles (PET laminated with different types of plastics) and blend bottles (PET mixed with a component that can induce a greater gas barrier effect) are also used to achieve improved gas barrier performance, but DLC-coated PET bottles show a higher gas barrier performance than these.

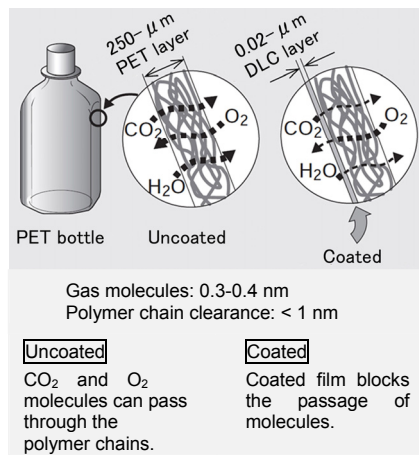


Figure 8 Gas barrier mechanism of DLC-coated PET bottles

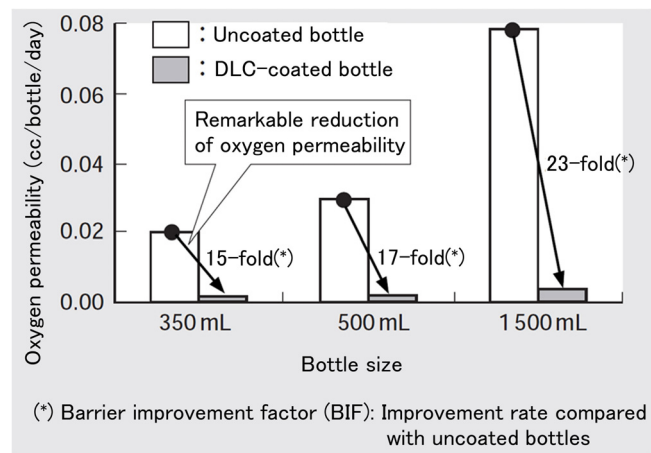


Figure 9 Oxygen barrier performance of DLC-coated PET bottles

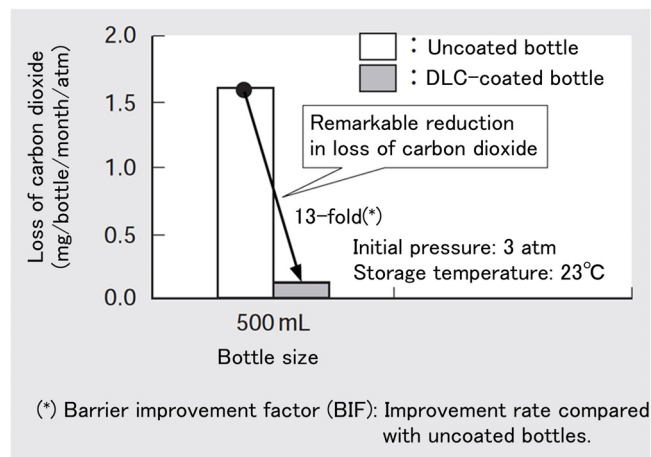


Figure 10 Carbon dioxide barrier performance of DLC-coated bottles

5. Conclusions

The use of PET bottles has reached approximately 65% of all containers used in the domestic beverage industry, and this predominance of PET bottles as beverage containers will unmistakably continue. On the other hand, in comparison with reusable glass bottles and completely recyclable cans, PET bottles have a high environmental impact and their use does not always serve the economic advantage of our beverage manufacturer clients. There is an increasing need for the availability of thin bottles that can be made using smaller amounts of raw materials. However, filling thin bottles with beverages has many technical challenges, for example, the need for technology to sterilize the PET bottles before filling, precise conveyance technology throughout the production line and PET bottle coating technology for improved gas barrier performance to preserve beverage quality over longer periods. Thus, the three technologies described in this report can be regarded as indispensable to the beverage industry. We will continue to work diligently for the advancement of technologies to meet the needs of our clients. Ensuring a high level of food safety, we will make a contribution to the realization of low-cost beverage production.

References

1. Mitsubishi Aseptic Filling System that Contributes to Cost Reduction, Mitsubishi Juko Giho Vol. 46 No. 3 (2009)
2. Ueda, A. et al., High Speed and High Gas Barrier Rotary DLC Plasma Coating System for PET Bottles, Mitsubishi Heavy Industries Technical Review Vol. 42 No. 1 (2005)
3. Development of the PET Bottle Transportation Mechanism that Improves Productivity in Beverage Filling System, Mitsubishi Juko Giho Vol. 48 No. 1 (2011) p.77-78