Drip Coffee Extraction Technology for Coffee Machines

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ABSTRACT

Fuji Electric has developed drip coffee extraction technology for coffee machines that rapidly prepare tastier coffee in large quantities. The coffee mill, which determines the quality of the coffee taste, is protected from static electricity and enhanced in the precision of the grinder blade gap adjustment to equalize grain size. For the brewer, which extracts coffee, a system that adds hot water during extraction and a tapered filter block are added to shorten serving time and continuously extract a large quantity of coffee. Furthermore, as paper filters are sometimes unavailable outside Japan, we have developed a mesh filter that is finer than paper filters.

1. Introduction

A coffee machine for convenience stores was offered in 2012, and in combination with a café latte machine added to the line-up in 2016, it has recorded a total shipment of over 60,000 units. This result is because our drip coffee extraction technology and delicious coffee with it have been appreciated. This technology has been developed and evolved over the past 30 years for cup vending machines.

In this paper, we will describe our important equipment for coffee extraction process, including a coffee mill (grinder) for grinding coffee beans into the grains, a coffee brewer for extracting coffee by mixing ground coffee grains with hot water, and a mesh filter for straining coffee.

2. Coffee Mill (Grinder)

A mill is a mechanism that grinds roasted coffee beans into grains with a predetermined size and dispenses them to the brewer. As shown in Fig. 1, Fuji Electric's mill consists of a lower blade rotated by a connected motor and an upper blade fixed to the housing. The gap between the two blades determines the grain size of the ground beans. This gap adjusts the coarseness of the beans with a minimum pitch of 0.05 mm. Our many years of experience developing coffee extraction mechanisms encourages us to adjust the gap with high accuracy so as to minimize the variation in the ground grain size of the beans to provide delicious coffee.

The fine grains of coffee created during grinding adhere to the passage of the grains and the brewer parts, increasing cleaning labor. Neglecting the cleaning can cause malfunction. Therefore, we have been required to take measures to the fine grain adherence.

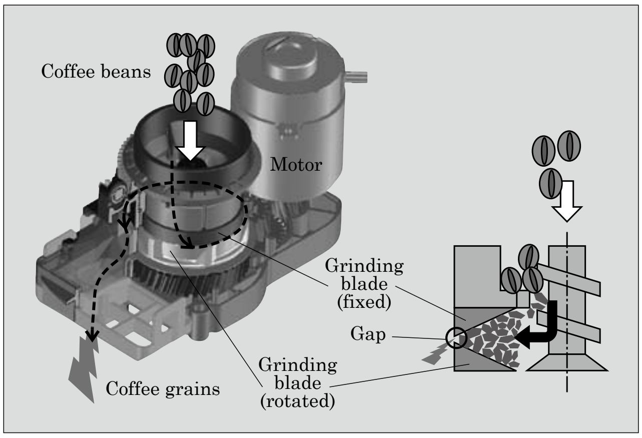

Fig.1 Coffee mill structure

2.1 Stabilizing grain size

In order to achieve a high-precision grain size, various measures have been applied to the shape and surface of the grinding blades. However, improving precision by simply enhancing individual parts has reached its limit. Therefore, we changed our viewpoint and focused our attention on improving the precision of the gap adjustment of the grinding blades, because we believed that doing so could lead to overall precision improvements.

Previously, the adjustment method determined the reference gap (default gap dimension determined by the product specification) based on the position obtained by simply returning the upper and lower blades to their specified dimensions after making contact with each other (gap = 0) (see Fig. 2). However, the gap dimension was not measured directly, and therefore

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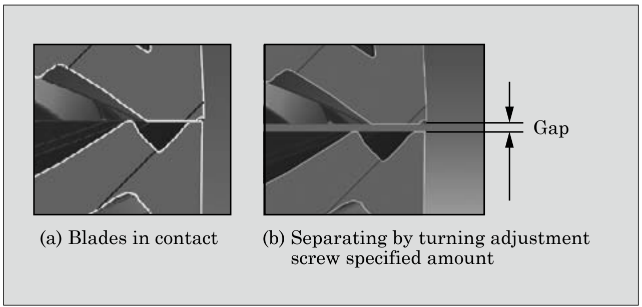

Fig.2 Gap adjustment of conventional mill grinding blades

variation occurred due to the difference in the force of the initial blade contact and the operation fluctuation of the return mechanism.

Therefore, by adding a high-precision sensor system, we have developed an automatic gap adjustment device that directly measures the gap dimension and adjusts it. This mechanism improves the adjustment error by approximately 30% from the conventional value of ±0.075 mm to ±0.050 mm.

2.2 Reduction of fine grain adherence using electrostatic suppression

It is well known that static electricity plays a factor in the adherence of fine coffee grains to mills, including those of other companies. Previous Fuji Electric mills also use structures for suppressing static electricity by selecting structural materials that were nearly the same in the triboelectric series*1 so that an identical charging tendency could be obtained for the beans and mill. However, the amount of static electricity (charging voltage) would increase depending on environmental conditions and the amount and type of beans used. Therefore, the adhesion of grains to the grain passage and brewer tended to increase, and this resulted in contamination and variation in the amount of discharge.

As a result of thoroughly examining the characteristics of conventional mills, we discovered that there were instances where a sufficient antistatic effect could not be achieved due to contact conditions between the ground grains and mill housing. Therefore, we developed a structure for creating effective contact between the ground beans and mill housing. Furthermore, we selected an aluminum alloy with good processability and durability as a structural material in close proximity to coffee beans in the triboelectric series (see Fig. 3). Adopting this new structure reduced the charging voltage to one third through one half that of previous structure, thereby allowing the mill to suppress fine grain adherence, stabilize the amount of discharge, and reduce brewer contamination (see Fig. 4).

*1: Triboelectric series: It arranges items in an ordered list based on their positive or negative charge for creating static electricity by rubbing objects with opposite charges together. In other words, when positive objects at the top of the list are rubbed with negative objects at the bottom of the list, they create a large static electricity.

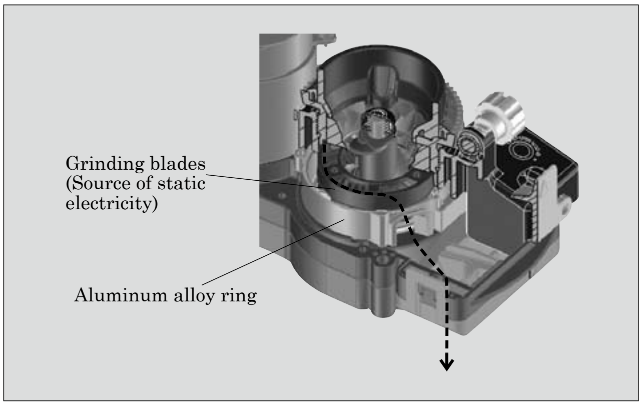

Fig.3 Antistatic structure for bean materials

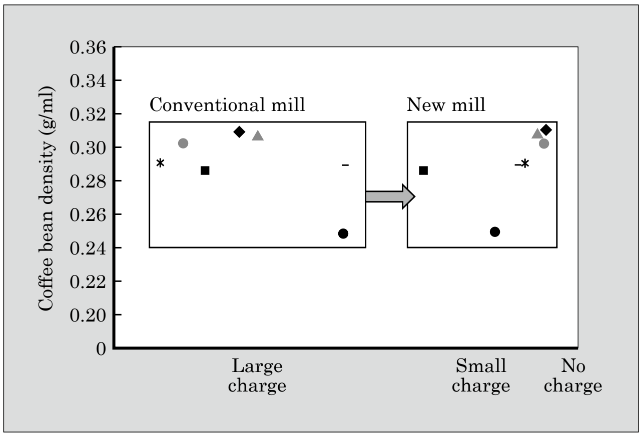

Fig.4 Antistatic effect

3. Coffee Brewer

3.1 System for adding hot water during extraction

Coffee extraction methods can be roughly classified into espresso and drip. The espresso brewing method extracts coffee to produce a rich and strong tasting coffee in a short period of time by passing finely ground coffee grains through a fine perforated metal filter by applying high pressure (approximately 0.9 MPa). On the other hand, the drip brewing method carefully extracts coffee by placing slightly coarse coffee grains in a paper filter or flannel cloth and then applies hot water. It is said that drip coffee has a smooth taste that suits the liking of Japanese people.

Coffee machines that use the drip method, which require a longer extraction time than those use the espresso method, adopt either suction (negative pressure) or pressurized (positive pressure) extraction to shorten the extraction time.

As shown in Fig. 5, a suction (negative pressure) brewer extracts coffee by sucking coffee liquid from the cylinder that mixes coffee grains and hot water. During extraction, hot water can be added while the cylinder is open to atmospheric pressure, thereby enabling

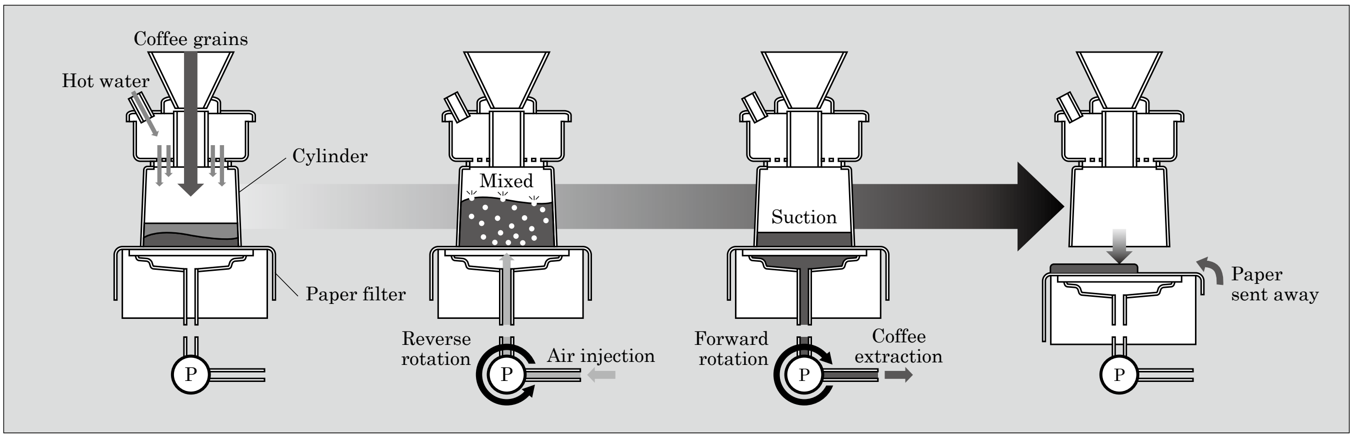

Fig.5 Suction (negative pressure) brewer

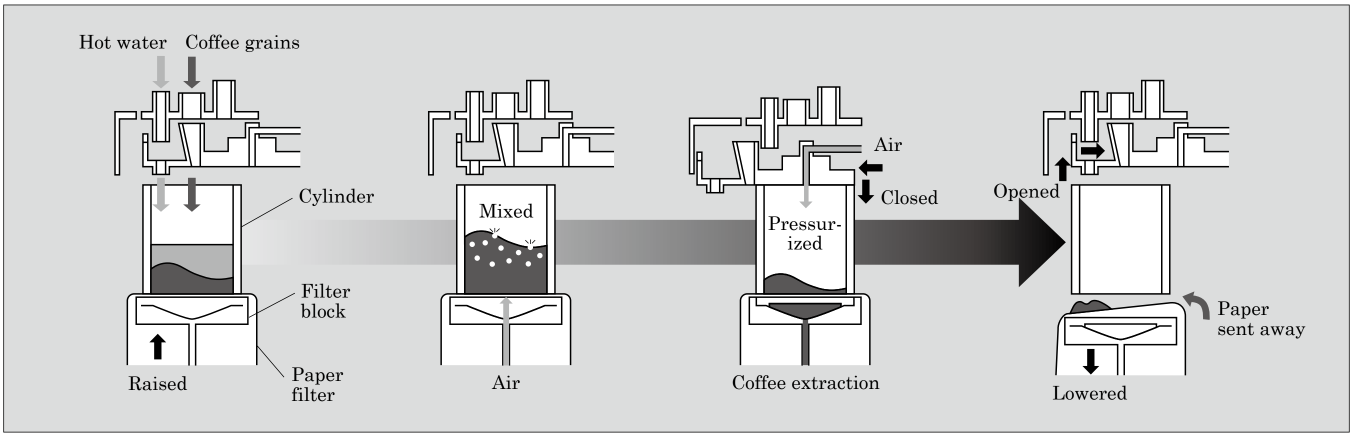

Fig.6 Pressurized (positive pressure) brewer

large-volume extraction using just a small cylinder.

On the other hand, as shown in Fig. 6, pressurized (positive pressure) brewer extracts coffee by sealing the cylinder after mixing the coffee grains and hot water in the cylinder, and then applying pressure (approximately 0.05 MPa) with an air pump (minutely pressurized extraction). Since the cylinder is sealed at time of extraction, delicious coffee can be extracted without losing its aroma. This method is used in many Fuji Electric products including our coffee machines for convenience stores. However, hot water cannot be added during brewing because pressurized brewers seal the cylinder during extraction. Therefore, when extracting large volumes of coffee, it has been necessary to divide the coffee into multiple batches. This is a problem because it lengthens the time for a sale and is not suitable for overseas markets where the portion size per cup of coffee is large.

To solve these problems, we developed a system capable of adding hot water to the cylinder during the extraction process of the pressurized brewer as shown in Fig. 7.

Figure 8 shows a comparison of systems for adding hot water. Conventional pressurized brewers employed a structure for opening and closing a solenoid valve that enabled hot water to be poured into the hot water tank through gravity. The passage of hot water along the cylinder walls enabled the hot water to be evenly distributed to the coffee grains inside the cylinder and prevented the coffee grains from adhering to the cylinder.

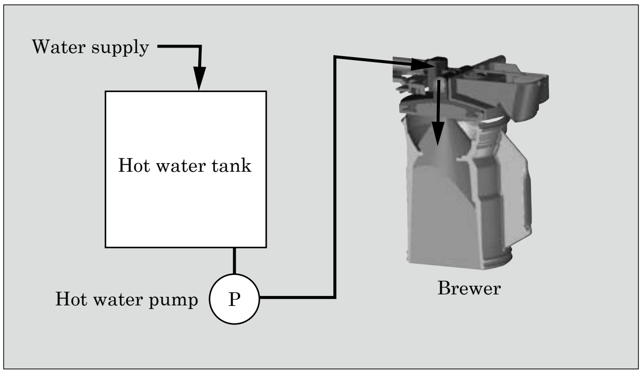

Fig.7 System for adding hot water during extraction

Our new machine employs a structure for supplying hot water to the cylinder by using a hot water pump to pour hot water from the supply outlet connected to the lid that seals the cylinder during extraction. The hot water pump can additionally provide hot water to the inside of the cylinder pressurized by the air pump for coffee extraction. As a result, it becomes

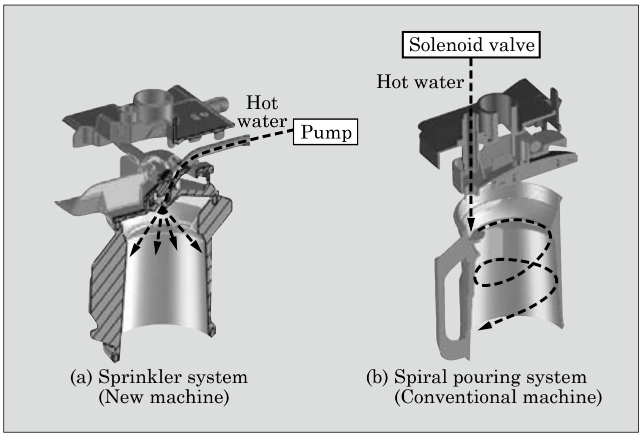

Fig.8 Comparison of systems for adding hot water

possible to continuously extract large volumes of coffee. Compared to conventional machines, it reduces the time needed to sell a large-sized coffee (240 ml) by 20% from 60 seconds to 48 seconds.

Furthermore, since the supply of hot water from the supply outlet to the cylinder employs a structure that can evenly sprinkle hot water on the coffee grains, we were able to improve the taste of the coffee while also making it more efficient to wash away coffee grains that adhere to the cylinder after extraction.

3.2 Tapered filter block

The amount of coffee grains needed increases according to the amount of coffee to extract. Therefore, the processing of residue after large-volume coffee extraction becomes a challenge. After coffee extraction, residue is removed by lowering the filter block and sending the paper filter away, as shown in Fig. 9. At such a time, the height of the residue must be lower than the gap between the cylinder and filter. However, the amount of usable coffee grains is limited to a certain amount, because the drop distance (stroke) of the filter block is restricted by the overall dimensions of the coffee machine. In order to develop a small coffee machine that is capable of extracting large volumes of coffee, it is necessary to increase the stroke without changing the size of the brewer.

In conventional machines, the filter block has a mechanism that simply moved up and down. In our new machine, we have added a mechanism for tilting the filter block lowered to its lowermost limit. The stroke is the same as before, but the gap between the cylinder and filter when discarding coffee residue is now larger. This enabled the new machine to increase the amount of usable coffee grains by 25%, while keeping the brewer size exactly the same as previous machines.

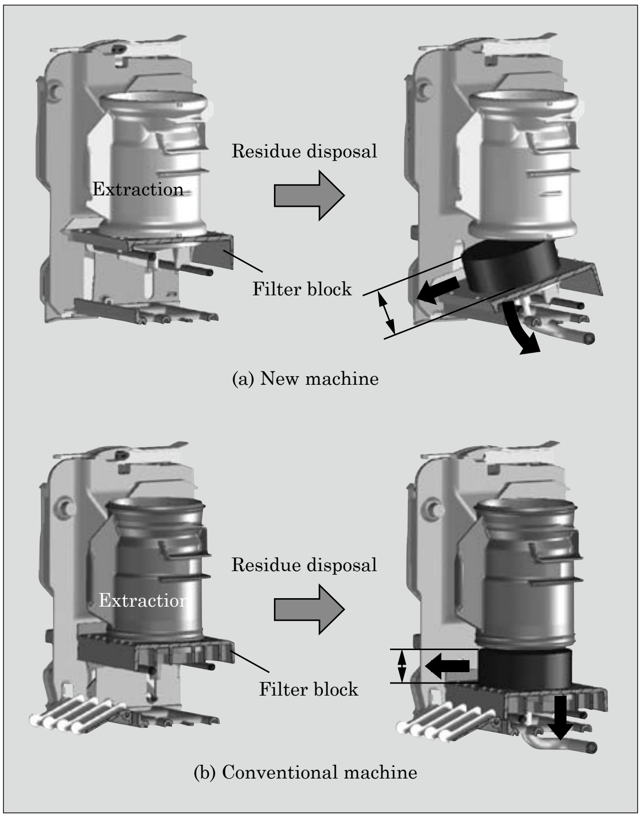

Fig.9 Residue disposal method

4. Mesh Filter

The role of the filter is to extract coffee liquid from the mixture of coffee grains and hot water. Drip coffee machines mostly employ a paper filter or mesh filter specially made for vending machines.

With a paper filter system, refreshing and clean tasting coffee can be extracted because the paper absorbs coffee oil and filters out the fine grains of coffee. This system is used for convenience store coffee machines and widely adopted in cup vending machines. However, since the dedicated paper filters used conform to a standard unique to Japan, they are hardly available overseas.

The mesh filter shown in Fig. 10 is formed by creating a countless number of holes in a mesh-like manner on a thin metal or resin plate. Since metal filters do not absorb any oil at all, they are used to extract coffee with a more explicit flavor that includes a high degree of coffee oil of the beans. However, the mesh is coarser than that of paper filters, and thus fine grains can mix in with the coffee liquid (see Fig. 11) and create a texture that is disliked by some consumers. This is a problem that must be solved before offering coffee machines overseas.

Simply creating a finer mesh to suppress the minute grains will not work because this will increase extraction time and require a higher extraction pressure, giving coffee an unpleasant taste.

We collected data on coffee extraction while experi-

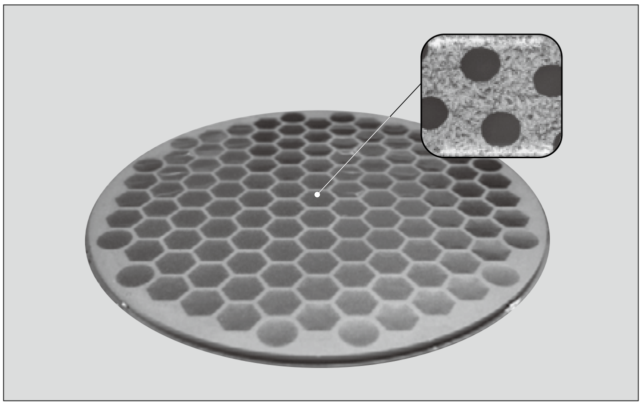

Fig.10 Mesh filter

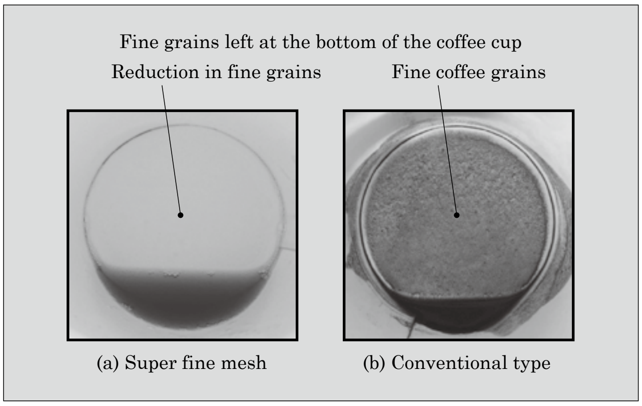

Fig.11 Comparison of remaining coffee grains

menting with various different filter meshes. By doing this we got closer to our target taste by clarifying the correlation between the pressure and time for extracting coffee and the values for bitterness, acidity and flavor of the extracted coffee measured by a flavor sensor. During the final stage of development, we made adjustments on the basis of the sensory evaluations of coffee appraisers and determined the optimal combination of mesh filter thickness, hole diameter, hole pitch, aperture area and number of layers. We thereby developed a "super fine mesh" consisting of about 130,000 holes on a total diameter of 50 mm. Using this mesh filter allows the coffee machine to deliver rich-tasting authentic coffee with a smooth aftertaste.

5. Postscript

In this paper, we described a drip coffee extraction technology for coffee machines. We have utilized our long and successful history of research and development into coffee machines to create products that have now become essential to convenience stores. In the future, we plan to pursue enhancements in taste, ease of use and size reductions so that we can contribute to the business development of our customers.

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