Featured Articles

Developing the High-power Cyclonic Cleaner

—Adding "Powerful 420 W Suction" to Environmentally Conscious Features—

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OVERVIEW: The demand structure of the vacuum cleaner market has been changing in significant ways and, as demand has shrunk in the high-volume cylinder-type segment of the market, cordless, handy, robotic, and other types have been increasing in popularity. Hitachi is developing a wide variety of different vacuum cleaners against this background of diversifying demand, however this article discusses the development of a cylinder-type that belongs to a market segment for which competition is growing increasingly intense. To satisfy consumer needs, the high-power cyclonic cleaner released in July 2014 uses a newly developed compact and lightweight high-power fan motor along with a new dust-collecting structure based on a compact design to achieve a light and compact body and powerful suction at the same time.

INTRODUCTION

SMALL and double-income households have been increasing in number recently. As a result, lifestyles are changing as well, with light cleaning being done on weekdays while thorough cleaning is left for weekends and holidays. A survey of consumer priorities when purchasing cyclonic cleaners has revealed that even though times have changed, many consumers still emphasize ease of carrying and a lightweight body in addition to the traditional basic performance of a vacuum cleaner, specifically easy dust removal and suction power [*1] (see Fig. 1).

This article discusses how we achieved both compactness and a light weight along with powerful

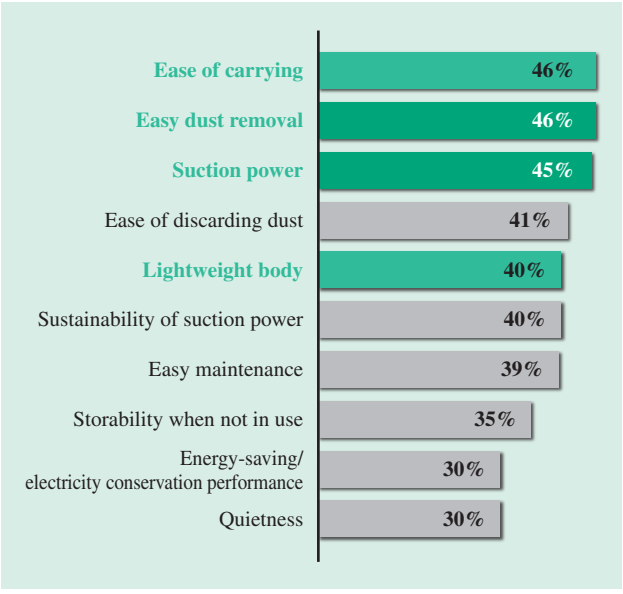

Fig. 1—Priorities when Purchasing Cyclonic Cleaner (Multiple Responses) (Hitachi Survey from October 2013: n=307). In addition to basic performance, ease of carrying and a lightweight body were both emphasized.

*1 Suction power guidelines established by JIS standard.

Fig. 2—High-power Cyclonic Cleaner (CV-SA700) (2014). Powerful 420 W suction in a compact and lightweight product is achieved with the adoption of a new dust collector structure.

suction in the cyclonic cleaner, which also offers improved ease of use and the ability to clean easily and efficiently (see Fig. 2).

ACHIEVING A COMPACT, LIGHTWEIGHT BODY AND HIGH POWER

To achieve both a compact and lightweight vacuum cleaner body as well as high power, Hitachi set two major development objectives: a high-performance fan motor as the heart of the product, and low loss in the dust collector.

Developing a High-power Fan Motor

The fan motor consists of a fan with both impeller and diffuser, and a motor with both rotators and stators, where the rotators drive the impeller to suck air (see Fig. 3). The impeller impart kinetic energy to the air, and the diffuser decelerate the air to convert this kinetic energy to static pressure.

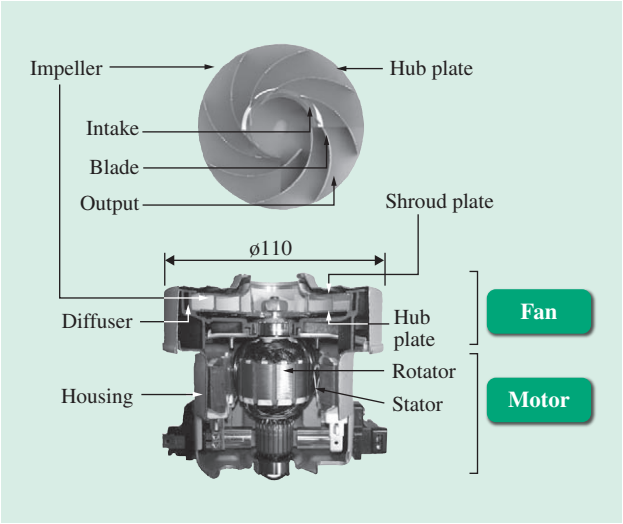

Fig. 3—Fan Motor Cross-section and Impeller. Light weight is achieved by changing the housing material from steel plate to aluminum.

As shown in Fig. 3 and Fig. 4, the blades of the previous impeller had a two-dimensional shape and were oriented vertically with respect to the hub plate. Since it became evident that the air flow was becoming separated near the center of the blades resulting in a low-velocity zone, the newly developed impeller features a three-dimensional blades with the intake-side shape of them twisted up in the rotational direction between the hub plate and the shroud plate. This smoothly expands the flow passage area between blades, and reduces the low-velocity zone, thereby improving efficiency of the impeller. Furthermore, by adjusting the number of blades, not only was the efficiency increased, but the harsh noise based on blade-passing frequency was successfully reduced. Magnetic field simulation technology was applied to the motor, the stator shape was optimized, and fan efficiency was improved to reduce loss and to increase output.

The housing material was switched from steel plate to aluminum, which has a low specific gravity, thereby resulting in a weight that is approximately 100 g lower than that of the fan motor in the previous product (CV-SY500).

Developing a New Dust Collector Structure

Reducing pressure loss in the body of the vacuum cleaner is important when it comes to effectively utilizing fan motor output. In the previous product (CV-SY500), pressure loss in the dust collector amounted to approximately 40% of the total, while

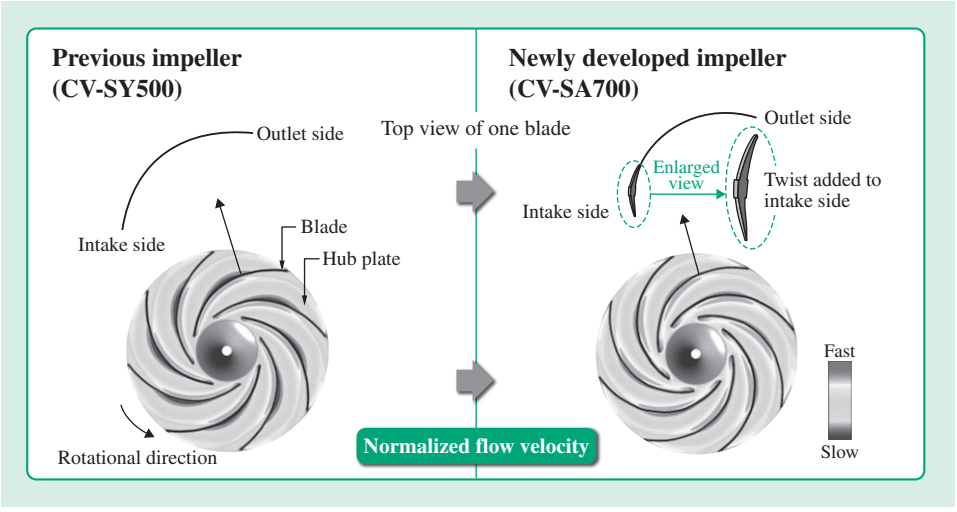

Fig. 4—Internal Flow Velocity Distribution of Impeller (Numerical Simulation Results). Although the previous impeller had a two-dimensional blades perpendicular to the hub plate, the newly developed impeller has a twisted three-dimensional blades.

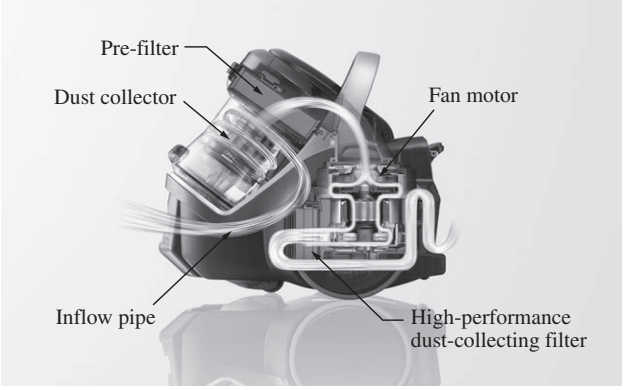

Fig. 5—Body Structure and Air Flow (CV-SA700).
Air from the fan motor is emitted through a high-performance dust-collecting filter.

loss in the filtering system amounted to approximately 30%. The achievement of clean exhaust is important in a filtering system (exhaust performance with a dust collection efficiency of 99.999%*2 is achieved using a high-performance dust-collecting filter), and it is difficult to reduce pressure loss in this area. Reducing pressure loss in the cyclone dust collector is the crucial factor in achieving both clean exhaust and powerful suction (see Fig. 5).

The cyclone dust collector is mainly comprised of external and internal cylinders, where the upper separates the dust from the air, and the lower collects the dust in a storage chamber. These mechanisms trap the dust using centrifugal separation (see Fig. 6).

As the arrows in Fig. 6 show, the flow inside the cyclone dust collector involves air entering the inlet opening of the external cylinder and then forming a swirling flow around the outside of the internal cylinder, where centrifugal force acts on the dust, which is heavier than air. The dust then passes into the storage chamber, while the air passes through the meshed opening of the internal cylinder before arriving at the fan motor. The main causes of increased pressure loss in the cyclone dust collector are the high flow velocity of the air at the inlet opening and the inside of the internal cylinder, and, disturbances in the swirling flow of air.

Although pressure loss can be reduced by increasing the aperture area of the inlet opening, this results in a trade-off with lower dust-separation performance. The shape of the inlet opening was optimized by applying methods such as computational fluid dynamics and robust design(1).

The shapes of the external and internal cylinders were also optimized, achieving both dust-collecting performance in combination with low pressure loss.

As described above, optimization of the shapes of the inlet opening as well as both external and internal cylinders allowed for the development of a cyclone dust collector with a new structure that reduces pressure loss compared to the previous product (CV-SY500). When combined with the increased output of the previously described fan motor, this enabled the achievement of a powerful 420 W suction power.

*2 Measured by third-party agency under conditions compliant with IEC 60312-1:2010 (Edition 1).

IMPROVING EASE OF USE

Dust Ejection Mechanism

In the cyclone dust collector with the new structure, the bottom cover opens to discharge dust. Because the adopted external and internal cylinder shapes increase

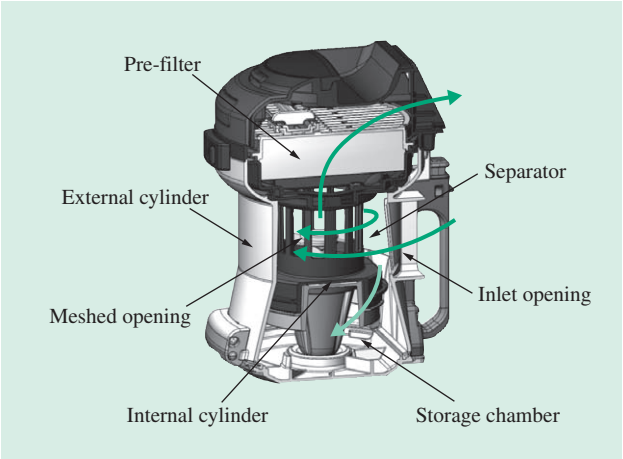

Fig. 6—New Dust Collector Structure.
The arrows show the flow of air after it enters the inlet opening.

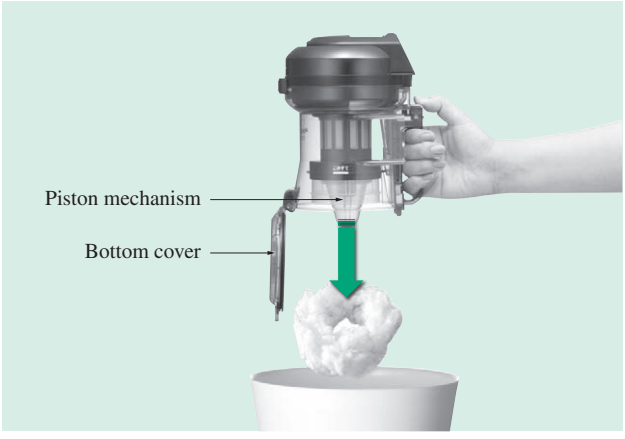

Fig. 7—Dust Ejection Mechanism.
The movement of the piston mechanism in the internal cylinder causes the compressed dust to be ejected.

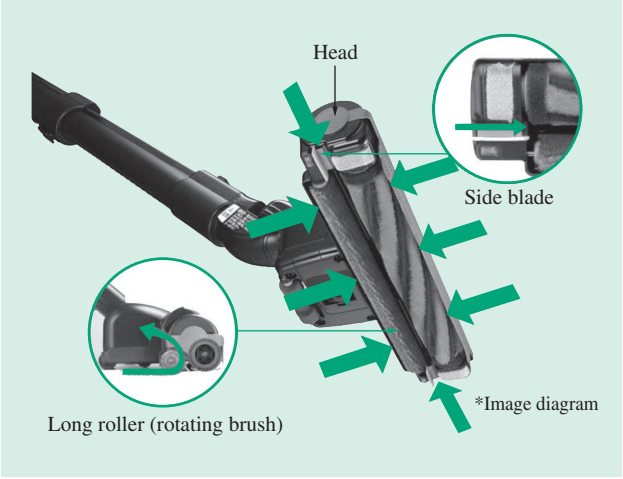

Fig. 8—Four-way Suction Mechanism (Front, Back, Left, and Right).
Four-way suction is achieved with a long roller (rotating brush) and a side blade.

in diameter towards the bottom, dust discharges readily. The piston mechanism built into the internal cylinder expels the dust. This unique dust ejection mechanism makes dust ejection easy (see Fig. 7).

"Smart Head with Four-Way Suction"

The "smart head with four-way suction" was developed to reliably suck dust from the front, back, left, and right directions (see Fig. 8).

A mechanism attached to the rotating brush halts rotation when the head moves forward, and restarts the rotation when the head moves backward. This allows for suction to hold the sucked dust inside the head to prevent it from slipping out the back of the head when the head moves forward, while sucking the dust behind the head and directing it into the head

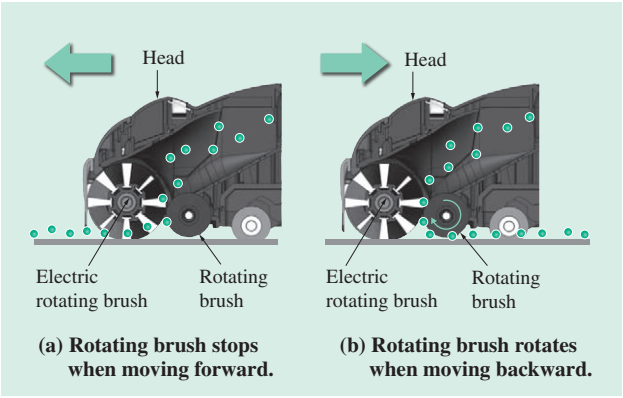

Fig. 9—Front/Back Dust Suction Mechanism with Rotating Brush.
A rotating brush that only rotates when moving backwards enables the backward collection of dust.

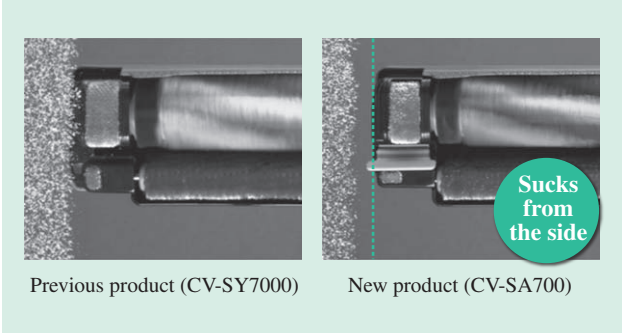

Fig. 10—Comparison of Suction Performance in Horizontal Directions.
The side blade greatly improves suction performance in horizontal directions.

with the rotation of the brush when the head moves backward (see Fig. 9).

The flow guide structure on the side of the head was formed with expanded aperture with "side blade" (see Fig. 8). Fig. 10 shows a comparison between the dust-collecting performance in lateral directions with respect to the head of the new product that uses this side blade, and the head of the previous product that did not. This induces the effective flow on the side of the head, and greatly improves dust-collecting performance in lateral directions.

The development of these functions has made it possible to suck dust in four directions (front, back, left, and right), which makes cleaning around walls, in the corners of rooms, on stairs where it is difficult to change head direction, and around the legs of furniture like tables and chairs quicker and easier. Furthermore, to achieve easy operation despite the strong suction, a powerful self-propelling function uses the driving force of the rotating brush so that dust can be reliably suctioned with a light touch.

"ONE BUTTON FOR ALL" FEATURE, WITH ENERGY-SAVING TECHNOLOGY

The "one button for all" feature uses a sensor to detect the type of floor during cleaning and automatically controls the power level of the fan motor in the vacuum cleaner body and the rotational speed of the electric rotating brush on the head. Since dust is reliably suctioned even in "one button for all" mode, power consumption is reduced by up to approximately 75% when compared to cleaning at full strength[*3]. In

*3 Comparison of power consumption between "one button for all" mode and full-strength operation after six minutes of cleaning on a wooden floor surface.

addition, power is automatically reduced when the head is not moved during cleaning, and if the head remains stationary for a certain amount of time, the power is switched off. Hitachi will continue including this idling and stopping functionality in order to help conserve electricity.

CONCLUSIONS

This article discussed the high-power cyclonic cleaner. Even as the structure of domestic demand changes, the needs for both compactness and light weight in vacuum cleaners is expected to increase even further.

Hitachi will continue creating unique technologies that lead the industry in both performance and functionality, while developing products that provide the value consumers demand.

REFERENCE

(1) K. Ueno, "Mechanical Design Based on Functionality Evaluation," Japanese Standards Association (May 1995) in Japanese.

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