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Title: Low-Pulsation Liquid Pumps and Their Applications

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Abstract

Pump pulsation has long been a major issue affecting print quality in inkjet printers. Diaphragm pumps inherently generate pulsation, so users have traditionally installed external suppression mechanisms as a countermeasure. Recently, demand for recirculating printheads has increased, making pulsation suppression an even more critical challenge. KNF explored whether the pump itself could reduce pulsation without relying on the user. This led to the development of the FP series we are introducing.

Introduction

First, allow me to introduce our company, KNF.
KNF is a company headquartered in Germany. Founded in 1946, it develops, manufactures, and sells diaphragm pumps. It operates globally, primarily in Europe, with 3 development sites, 4 manufacturing sites, and 12 sales offices. Our primary markets are medical devices and inkjet printers. We also have a proven track record in various other applications, including analytical instruments, environmental equipment, semiconductors, and energy. Our product range includes gas pumps, liquid pumps, process pumps, and lab pumps. Gas pumps and liquid pumps are designed for equipment integration, process pumps for factory installations, and lab pumps for research and development in fields like drug discovery and chemistry. KNF has developed a modular system to facilitate customization. This modular system involves preparing components in advance, allowing specifications to be altered by changing the component configuration. It requires no initial investment and enables us to easily provide custom pumps starting from a single unit. KNF excels at consultative sales, offering proposals to help customers realize their desired systems. Over 90% of the pumps we provide are custom pumps. The specifications in Table1 represent the range KNF can accommodate.

Pumps	Flow rate L/min	Suction hieght/ Ultimate vacuum	Pressure head
Liquid	Max. 12	1.5 – 6 mWg	10 – 60, 160 mWg
Gas ※	Max. 240	0.5 – 800 mbar abs.	Max. 12 barg

Table1: Specification range

FP series

Next, KNF introduces the newly developed FP Series of low-pulsation liquid pumps for inkjet applications. As mentioned earlier, pump pulsation is a major issue in inkjet printers. Our company also sells the FPD pulsation damper as a product for conventional methods. However, it has not gained widespread adoption. The reason is that it has a narrow range of conditions it can suppress and cannot be customized, making it insufficient to fully meet the diverse requirements user's demand. The FP series pump was developed to solve this problem. It achieves low pulsation within the pump itself and employs a modular system, enabling customization.

Structurally, they can be divided into two types: multi-diaphragm type (Figure1) and damper-integrated type. The multi-diaphragm type (Fifure2) incorporates five diaphragms. Each diaphragm moves with staggered timing at equal intervals, counteracting the pulsation generated during suction and discharge to reduce pulsation. Theoretically, two or more diaphragms can cancel pulsation. However, in practice, achieving zero pulsation under ideal conditions is impossible due to factors like component interference and assembly tolerances. KNF selected five diaphragms based on the balance between pulsation reduction effectiveness and cost. The damper-integrated type reduces pulsation using dampers installed on both the suction and discharge sides. While the damper-integrated type may appear similar to conventional pump-and-damper combinations, its design is entirely different. Details are confidential, but the flow path, valve system, damper structure, and all other elements are designed to minimize pulsation generation. Consequently, it achieves not only low pulsation but also low vibration, low noise, reduced shear force on the liquid, improved linearity during flow rate changes, and reduced susceptibility to cavitation.

Figure1: Multi-diaphragm type

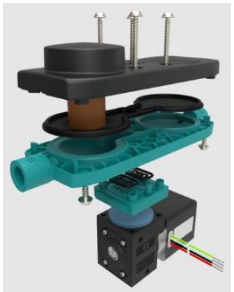

Figure2: Damper-integrated type

Five product types are available, each with standard discharge pressure-resistant and high discharge pressure-resistant variants.

Key specifications are shown in Table 2. Flow rate can be adjusted by changing the motor rotation speed, enabling adaptation to desired flow rates up to a maximum of 4.6 L/min. The high discharge pressure-resistant type is used when equipment enlargement necessitates transporting fluid over greater distances, or when the load from components (filters, valves, degassing filters, etc.) becomes excessive.

Characteristics

First, the primary pulsation characteristic has been significantly reduced compared to conventional pumps. Please refer to Graph 1. Particularly at low flow rates, such as FP7/1.7 and FP25/1.25, the peak-to-peak pulsation is less than 2 kPa. At this level, fluid can be delivered directly to a recirculating head. Pulsation is measured 20 cm downstream from the pump outlet, using rigid tubing to prevent attenuation. In practice, the distance to the head is longer, so further attenuation is expected, resulting in virtually pulsation-free operation. The pulsation of the three higher-flow pumps is not as low as the low-flow types. This is likely due to variations in components, including the diaphragm, and assembly tolerances, preventing assembly to an ideal state where pulsation is fully canceled. At this level, we consider it more suitable for ink supply rather than feeding a recirculating head. This is because pulsation during ink supply can adversely affect the ink circulation path.

Specifications		FP 7/1.7	FP 25/1.25	FP 70/1.70	FP 150/1.150	FP 400/1.400
Flow rate	ml/min	7 - 70	25 - 250	70 - 700	150 - 1500	460 - 4600
Pressure head	mWg	10 / 60	10 / 60	20 / 60	20 / 60	10 / 60
Pulsation	kPa	< 2	< 3	< 15	< 20	< 15

Table2: Specifications of FP series

The second characteristic is low vibration and low noise. Particularly, the multi-diaphragm type produces noise below 50 dB and vibration so slight it is barely perceptible unless touched. Since the risk of resonance with the equipment housing is low, this offers a significant advantage from the perspective of equipment integration. The multi-diaphragm type has a structure completely different from existing diaphragm pumps. Existing pumps convert motor rotation into linear motion perpendicular to the motor shaft via an eccentric rod, and this motion generates vibration and noise. However, the multi-diaphragm type moves the diaphragm horizontally relative to the motor shaft, eliminating lateral forces on the pump. This achieves noise levels below 50 dB. Vibration is barely perceptible unless touched by hand. The low risk of resonance with the equipment enclosure offers a significant advantage from the perspective of equipment integration.

The damper-integrated type also exhibits lower vibration and noise levels than existing pumps. While its basic structure is identical to existing types, the fluid inside the pump is rectified, ensuring fluid pressure is transmitted almost entirely in the direction of travel and eliminating vertical forces. This also contributes to improved linearity during flow rate changes. With minimal flow fluctuations caused by turbulence, the flow rate can be adjusted linearly from low to maximum flow.

Finally, pump lifetime. Based on our internal comparison, test results indicate it lasts approximately twice as long as conventional pumps with the same flow rate. KNF believes this is due to the design reducing pulsation, which in turn alleviates various mechanical loads.

The pump introduced was developed for inkjet applications, but it is now being considered for various uses. KNF cannot disclose details, so KNF will limit itself to listing the applications.

Various medical devices, robots, fuel cells, semiconductor manufacturing equipment, 3D printers, hydrogen power generation, food, beverages, drug discovery and new material development, space environment equipment, iPS cell culture, cultured meat production, printed circuit boards, solar panels, etc.

Summary

The FP7/1.7 and FP 25/1.25 are considered optimal for fluid delivery to recirculating heads, while other FP pumps are best suited for ink supply. Furthermore, the low vibration and low noise characteristics of multi-diaphragm types are useful in various applications, and demand for them is expected to increase in the future.

Biography

Nobuhiko Hosobata received her BS in applied physics Tokyo University of Agriculture & Technology (1983). Since, he worked on developing optical sensors at Copal, then served as a sales engineer for aircraft wiring at Tyco Electronics, then now holds the position of sales engineer at KNF Japan.