New technologies of the inkjet textile printing system Nassenger-V

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Abstract
A new inkjet textile printing system, Nassenger-V, was developed. Reliability, productivity, and print quality were highly improved in order to meet the requirements as an actual production machine. A newly designed inkjet print head, an ink drop detection system, and a fabric belt feed system developed specifically for this printer are discussed.

1. Introduction
The inkjet textile printing technology has been rapidly getting accepted in the past few years.
The history of applying inkjet to textile printing is rather long, as an alternative convenient method to conventional printing technology. It was expected to be suitable for quick delivery, short-run production and photographic print with multi-level tone reproduction, which is difficult to achieve with existing analog technology. Some advanced users have already used inkjet for years to manufacture a wide variety of products, mainly for short-run production or sample-making. Recently, however, improved reliability of inkjet printers, along with the introduction of digital technology in design process has made this technology a realistic option to be utilized for mass-production. Market expectation for more productive inkjet textile printer has also contributed to this new trend.

With the aim of meeting performance requirements as a production machine, we have developed the inkjet textile printing system, Nassenger-V, reliability, productivity and quality of which are remarkably improved (Fig. 1).

Fig. 1 Nassenger-V

The basic performance parameters of Nassenger-V are summarized in Table 1. In order to achieve these specifications, technologies such as, (1) a newly designed print head customized for this printer, (2) a fabric belt feed system and (3) an ink drop detection system to detect miss-firing of droplet have been introduced. These newly applied technologies are explained in the following sections.

2. Newly developed inkjet head
Image quality requirements for inkjet textile printing systems include graininess, sharpness, tone reproduction, wide color gamut and high solid density. We have reported that a resolution of 540 dpi is sufficient for obtaining practically acceptable

Table 1 Characteristics of Nassenger-V

Ink	Disperse dye ink, Reactive dye ink			
Printing speed	**Mode**	**Resolution**	**Disperse dye ink**	**Reactive dye ink**
	High speed	540dpi x 360dpi	60 m^2/h	48 m^2/h
	Normal	540dpi x 540dpi	40 m^2/h	32 m^2/h
	High quality	540dpi x 720dpi	30 m^2/h	24 m^2/h
	Maximum density	900dpi x 540dpi	27 m^2/h	21 m^2/h
Maximum printing width	1650 mm			
Fabric size	width: 330 mm to 1650 mm, thickness: 15 mm			
Operating conditions	temperature: 15°C to 30°C, humidity: 40% to 70%			
Dimensions, weight	W4200 mm x D1600 mm x H1545 mm, 440kg			

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image qualities in inkjet textile printing systems.[*1]
In Nassenger-V, the standard mode was decided to be 540 dpi accordingly. In order for this mode to achieve printing speed of $40m^2/h$, two 256 nozzles heads were combined for each of 8 different color inks, totaling 16 heads. Table 2 shows a summary of characteristics of the print head used for this printer.

Table 2. Characteristics of the inkjet print head

Technology	shear mode piezo, drop on-demand
Number of nozzles	256 (128×2 lines)
Nozzle density	180 dpi (90 dpi×2lines)
Operating frequency	18.2 kHz (disperse dye ink) 14.9 kHz (reactive dye ink)
Drop weight	18 ng (disperse dye ink) 20 ng (reactive dye ink)
Dimensions	W59.5 x D18.3 x H67mm
Weight	50g

Though the ejection principle of this head is the same shear mode piezo drop on-demand as the previous model of Nassenger II, newly developed high-precision process technology and actuator lamination technology have made it possible to provide180 dpi, 256 nozzle print head comprising two 90 dpi, 128 nozzle actuators.
Ejection frequency was determined from print speed, print resolution, number of nozzles, and structurally caused non-printing time.
The volume of ejected ink droplet was experimentally determined to optimize image quality and performance. More specifically, the droplet volume has to be determined according to the print resolution. If the volume is larger than the optimum amount, not only are graininess and sharpness deteriorated but also is image quality degraded due to blur. On the other hand, if it is smaller, it becomes difficult to obtain required color gamut and/or solid density. In the worse case, white lines appear where sufficient ink amount was not delivered, resulting in considerable deterioration of image quality. In 540 dpi print mode, the optimum ink droplet volume of disperse ink for polyester was 18 ng, while that of reactive ink for cotton and silk was 20 ng.
The structure of a head that meets above performance specifications was designed by highly advanced computer simulation. Basic head performance can be calculated from dimensions of channel, actuator and nozzle shape, physical characteristics of piezo element, structure material, adhesive chemicals, and driving waveform to drive the actuator. All these parameters and ink characteristics determine the total inkjet head performance[*2.] The head dimension parameters such as channel length and nozzle shape were optimized to meet required printer specifications, taking into account easiness of exhausting air bubbles in the channel to ensure stable ink ejection. The driving waveform was also improved to achieve stable ejection at a higher operating frequency.
The head housing was re-designed to cope with increased heat generation associated with the increased number of nozzles and raised frequency so that quick heat release is assured. The head mount mechanism was also improved to ensure easy head replacement by the user, which leads to easy maintenance. Because of the compact design of the print head, the carriage size where heads are mounted was greatly reduced from the previous printer, despite the fact that the total number of nozzles used is four times that of the previous printer. Fig. 2 shows appearance of the newly developed inkjet print head.

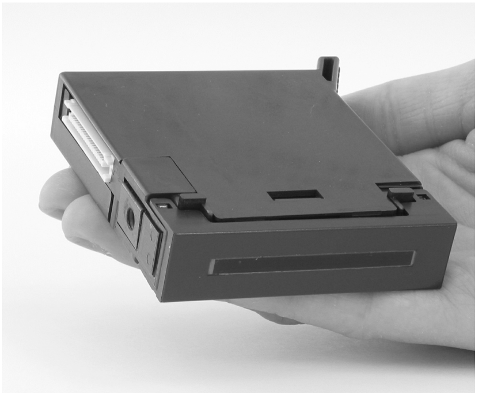

Fig. 2 Inkjet print head

3. Fabric belt feed system

Feed length of the previous printer, which adopted a feed roller system, varied by fabrics according to their thickness and friction behavior. It was necessary therefore to adjust the feed length for each fabric to be used, costing laborious work. This feed system also had difficulty in handling thin or elastic fabric accurately due to stretch or bent of the fabric. Moreover, in the case of thin fabric printing, ink having passed through the fabric on to the feed roll caused image stain of the successive print area.
In order to cope with these problems, a fabric belt feed system with electrostatic adsorption mechanism was introduced (Fig. 3). This system enabled feeding fabrics at a predetermined length regardless of the fabric characteristics such as thickness, since the feed length is determined only by combination of drive roller and feed belt.
In order to achieve higher image quality, print resolution of feed direction should be raised from 300 dpi to 540 or 720 dpi. Feed length accuracy of the previous printer, comprising worm gears and a timing belt, was found to be insufficient in preventing overlaps or jumps of each main-scan print swath.
To improve this accuracy, a new driving system

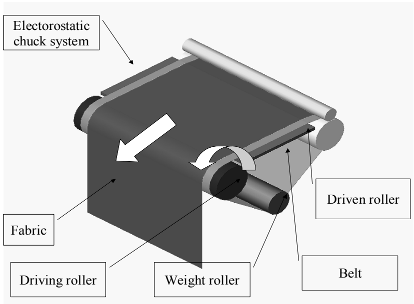

Fig.3 Schematic diagram of the belt feed

comprising a DC servomotor and a harmonic drive was introduced. PID control of it was also optimized. Results are shown in Fig. 4. Feed length for each scan is plotted on Y axis. The graph shows that fluctuation of feed length was reduced to approximately 25% of that of previous system.

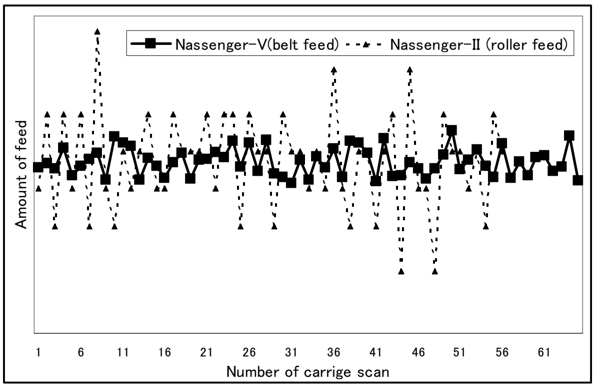

Fig.4 Fluctuation of belt motion

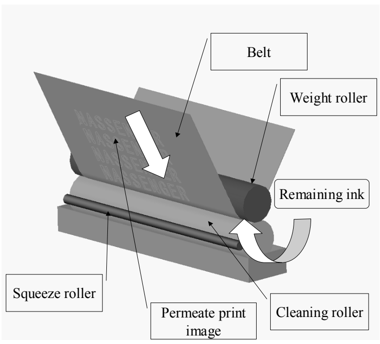

Fig.5 Schematic diagram of the belt cleaning system

With this belt feed system, when the fabric being printed is thin enough for the ink to get through to the backside and to reach the surface of the belt, or when the user intentionally deliver too much ink onto the fabric to let the ink reach the back side, the belt becomes wet with this ink. Therefore the belt should be cleaned to prevent it from staining successive print area at the next belt turn. A belt cleaning roller made of porous medium was therefore installed to touch the belt surface in the lower part of the machine to remove residual inks on the belt surface (Fig. 5).

Fig. 6 shows a relationship of the cleaning roller pressure to the belt and cleaning performance. When the pressure is high enough, the residual ink is completely removed from the feed belt.

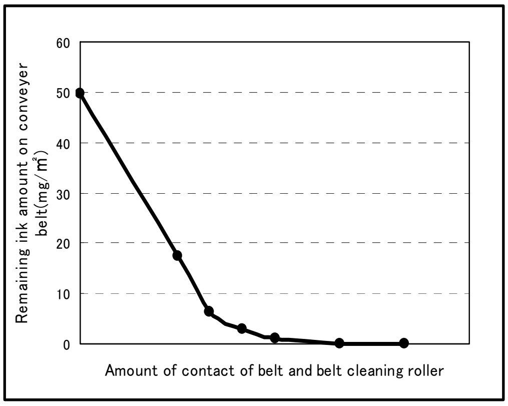

Fig.6 Relation between pressure of the cleaning roller and remaining ink amount on belt

To feed the fabric accurately with this belt system, it is necessary to assure the fabric adhered firmly to the belt. Without enough adhesive force, feed length of the fabric will be affected by its self weight and friction force. Hence ensuring stable feed performance regardless of the kind of fabrics becomes difficult. The electrostatic adhesion system was adopted to fix the fabric onto the belt.

The system is illustrated in Fig. 7. High DC voltage is applied to electrodes embedded in an insulation layer, alternately charged positive and negative, thus generating positive and negative charge between the belt and fabric. Table 3 shows the adhesion force of typical fabrics to the belt. Adhesion force here refers to tensile force necessary to start moving a 100 mm x 100 mm piece of fabric adhered on the feed belt. Fig. 8 shows fluctuation of feed length for polyester. The use of the electrostatic adhesion system clearly increased the adhesive force between them.

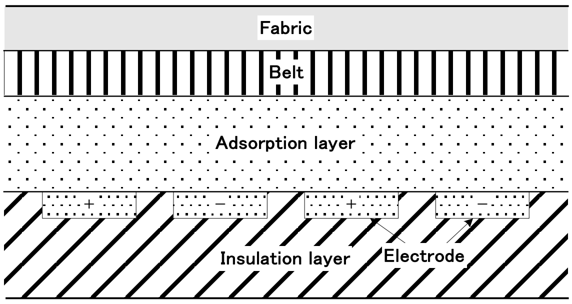

Fig.7 Cross section of adhesion system

Table.3 Adhesion force for fabric

Type of fabric	Adhesion system	Without adhesion system
Polyester	775	39
Cotton	470	29
Polyester knit	794	29
Satin	775	29

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(x 10^{-3}N)

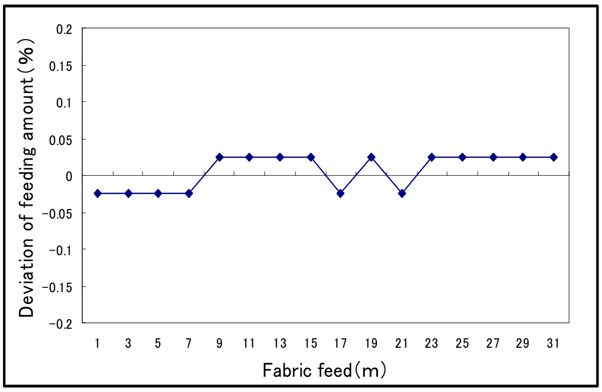

Fig.8 Deviation of fabric motion

4. Detection of ink drops

The number of nozzles in one print head has been gradually increased in line with market demands for higher image quality at higher print speed, resulting in development of printers having more than 4,000 nozzles with 16 colors. Ideally all these nozzles should be kept in good condition, but in reality, some of them may fail in ejecting ink. If printing is continued with these faulty nozzles, image quality deteriorates considerably with bandings. If ink drops can be detected, it becomes possible to clean the nozzles only when miss-firing occurred, instead of regularly cleaning all the nozzles even when they function properly. This leads to reduced ink consumption, shorter print loss time and remarkably improved reliability of the system by substituting faulty nozzles with other good nozzles.

Fig. 9 illustrates a schematic diagram of the layout for an ink droplet detector, inkjet heads and a spittoon. A light detector and a detection circuit are placed in a shielded case, placed opposite to a light source. Fig. 10 shows the mechanism of this system. A row of nozzles are arranged in parallel to an optical path consisting of the light source and the detector. Ink drops are ejected one by one from a nozzle at one end to the nozzle at the other end of the optical path. Shadow of ink drops thus ejected is checked by the light detector to identify the flying of the ink drops for every nozzle. Nozzles which do not eject ink drops are judged to be faulty.

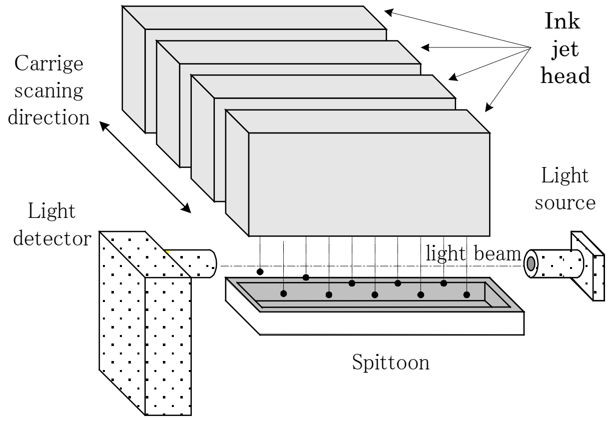

Fig.9 Schematic diagram of ink drop detection system

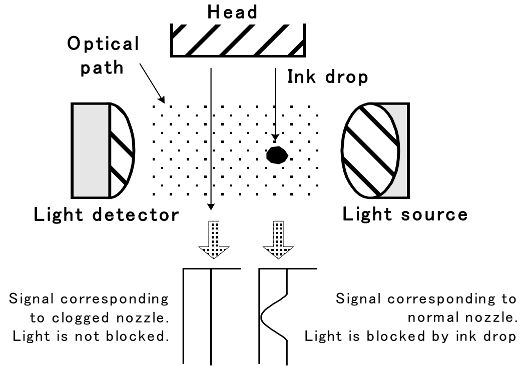

Fig.10 Mechanism of drop detection system

5. Conclusions

In the development of Nassenger-V, intensive improvement in the printer, including the newly designed head, belt feed system and ink drop detection system, has successfully contributed to greatly enhanced productivity, along with user friendly operation by sophisticated software and offering of post processing options. Nassenger-V is expected to be used as a very efficient inkjet textile printing system.

• References

1) MITSUHASHI, Taku, and KATO, Takayuki: Journal of Society of Photography Science and Technology of Japan, 41, 67 (2002).
2) TAKEUCHI, Yoshio: Konica Technical Report, 15, 31 (2020).