Development of Mitsubishi Electronic Printing System

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The Mitsubishi Electronic Printing System MD 300 is a new generation system, providing what is called on-demand printing. Using on-demand printing, users can print as many copies as they want whenever they need to. Also, this system reduces the lead-time from make-up until print and finish. Additionally, this system reduces printing costs for short run printing. The Mitsubishi Electronic Printing System MD 300 prints at high speeds (72 sheets/min in A4 size), and simultaneously conveys high resolution (800 dpi).

1. Introduction

With the information society making rapid technological advances, electronization (the adoption of a digital system) is fast becoming the trend in the printing industry. Digital systems are being incorporated rapidly and steadily into upstream editing and preparing systems mainly because personal computers are low in price and give high performance.

On the other hand, the individualization and diversification being called for in the market for printing require fewer numbers of copies to be printed. Out of the environment of these digital technologies and market needs has come what is known as on-demand printing, a new concept in printing that calls for “printing the required number of copies of a given material when they need to be printed.” On-demand printing is attracting much attention as a technology that is key for the future growth of the printing industry.

However, conventional printing technology, which has been making progress since the days of Johannes Gutenberg and is based on the concept of “mass copy,” is not suitable for dealing with short printing runs of 10 or 100 copies. Its performance leaves something to be desired particularly in the areas of cost and delivery matters. Mitsubishi Heavy Industries, Ltd. (MHI) has, therefore, worked to develop a new generation “Mitsubishi Electronic Printing System” that satisfies the basic printing requirements, such as fast performance, high imaging quality, and low cost, and that provides the quick response and flexibility of on-demand printing as well.

The design for the Mitsubishi Electronic Printing System was completed successfully through the optimum integration of the electro-photography technology already used in OA machines, the liquid toner developed independently by MHI, image forming technology, and MHI’s printing technology which has been developed over a long period of time. This paper tells what class the Mitsubishi Electronic Printing System is in and describes its technical features, system configuration, and future prospect.

2. Features of on-demand printing

2.1 Measures for short run printing

On-demand printing does not use plates (there is no initial plate cost), so it makes no difference in unit cost whether printing is 1-copy or 1 000-copy printing. Thus the unit cost in short run printing is lower for on-demand printing than for conventional printing (offset printing, etc.) where plates are needed. Even for on-demand printing, however, it is necessary for the “printing machine” to have a structure that can handle mass production of about 500 000 to 1 000 000 copies per month. Color copying machines are thought to have a copying capacity of 5 000 to 50 000 copies per month. This is the basic structural difference between the two. [Fig. 1(a)]

2.2 Quick response

All upstream processes, including the work done in conventional preparation divisions, can be carried out with a personal computer performing on-demand printing. Also, since different images can be printed one by one, it is possible to connect a finishing machine directly to the system to produce copies of

Fig. 1 Object market and comparison of working flow for on-demand printing

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books one after another, which allows printing from the editing process to the finishing process to be completed within an extremely short time period at low cost. [Fig. 1(b)]

2.3 Variable data printing

It was not economically feasible to prepare prints with every page being different using the conventional printing system. However, variable data printing, which can be used for example for addresses for direct mailings, adds value to the printed matter. Variable data printing could therefore become a factor in the opening of new markets for on-demand printing.

2.4 Easy operation

An operator has to carry out maintenance in addition to operating a machine in the case of offset printing. The operator not only makes daily checks, but also repairs various problems with the machine to keep the operating ratio high.

In on-demand printing, however, distributed printing machines are used which need no skilled operators. Therefore, on-demand printing machines must have a structure that makes them easy to operate and maintenance-free in order to ensure that their productivity is equivalent to that of offset printing. They must also be compact.

3. Technical features of Mitsubishi Electronic Printing

3.1 Basic concept

3.1.1 Adoption of electro-photography

The recording methods used for on-demand printing, including ink jet, thermal transfer, and electro-photography, are compared in Table 1.

The ink jet method is inexpensive, but it generally has a low printing speed, large dot size and low gradation level per dot. The thermal transfer method can provide high imaging quality, but it has a limited printing speed. Compared to these two methods, the electro-photography can record faster with less energy, and can thus provide high speed printing. Further, the dot size in electro-photography is equivalent to that produced by thermal transfer, and the dot size can be further reduced when liquid toner is used, while the imaging quality can be as high as in offset printing. In light of the aforementioned points, MHI adopted the electro-photography method for its high speed and high imaging quality, and has developed a new liquid toner independently to ensure higher imaging quality. Further, MHI adopted an a-Si (amorphous silicon) photconductor (to be discussed later) with excellent printing durability.

3.1.2 Four (4) printing station

Color copying machines using electrophotography technology, an image is normally produced on one drum and it is transferred to the sheet, forming a 4-color toner image (cyan, magenta, yellow, black successively) at each turn of the drum.

Since the color copying machine is for office use, compactness is highly desirable. With the operating ratio of the machine being below 10%, there is hardly any need to improve the current printing speed of 5 sheets/min (A-4 size). Furthermore, sheets are used in order to reduce the number of wasted sheets. However, sheet feeding is vulnerable to external disturbances such as humidity and is likely to cause jams during high speed printing.

On-demand printing, both imaging quality and printing speed are important, and with the operating ratio assumed to be over 50%, continuous printing is assumed to be used. Therefore, 4 printing units are installed in tandem to ensure high speed printing, and webs providing steadiness during continuous printing are used for on-demand printing. On top of this, the size is compact and measures have been taken to reduce the number of wasted sheets.

Fortunately, MHI has already spent a great deal of time and effort developing roll paper (web) feeding technology, which is used in web offset presses and so on for commercial use. This technology has been applied in the development of the Mitsubishi Electronic Printing System.

3.2 Technology for high speed printing and high imaging quality

3.2.1 Principles of image forming

The electro-photographic printing process is shown in Fig. 2.

The corona charger first charges the photconductor surface uniformly, and then a laser beam is applied to the image area to eliminate the charge from the portion hit by the laser beam in order to form a latent image by leaving the charge where there is no image (area without image). The colored particles (toner) contained in the liquid toner fed from the developing roller have charges with the same polarity as the latent image and developing voltage. Setting the developing roller voltage level to higher than the potential for the image area and lower for the potential of the area without

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**Table 1: Comparison of recording method**

<table>
<thead>
<tr>
<th>Recording technology</th>
<th>Recording speed (ipm)</th>
<th>Recording energy (J/cm²)</th>
<th>Minimum dot size (µm)</th>
<th>Gradation level per dot (lev./dot)</th>
<th>Minimum size of color former (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ink jet method</td>
<td>10⁶ to 10⁷</td>
<td>0.1 to 0.2</td>
<td>50 to 150</td>
<td>1</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Thermal transfer method</td>
<td>10⁸ to 10⁹</td>
<td>1.5 to 2.0</td>
<td>30 to 150</td>
<td>1</td>
<td>0.2</td>
</tr>
<tr>
<td>Electro-photography (dry toner)</td>
<td>10⁸ to 10⁹</td>
<td>0.5 to 1×10⁻⁹</td>
<td>25 to 60</td>
<td>6²(phys)</td>
<td>6 to 12</td>
</tr>
<tr>
<td>Electro-photography (liquid toner)</td>
<td>10⁸ to 10⁹</td>
<td>0.5 to 1×10⁻⁹</td>
<td>1 to 4</td>
<td>6²(phys)</td>
<td>0.1 to 2</td>
</tr>
</tbody>
</table>

Note: No record exists as present, but producing one is theoretically possible.

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an image will make the toner cause electrophoresis before it adheres to the photoconductor where the laser beam is applied, and it will turn into a toner image. Next, the excess solvent is eliminated from the toner image formed on the photoconductor by using a squeeze roller. A recording paper is then placed on the toner image and a charge with a polarity opposite to that of the toner is applied from back of the paper with a corona transfer unit to transfer (copy) the toner image to the recording paper. The transferred toner image is then heated with a fixing unit to form the printing image on the recording paper through fusion. The toner that has been left on the photoconductor drum without being transferred is removed with a blade, while the remaining charge from the latent image is eliminated with the light from an erasing LED. Images are formed continuously by repeating the charging and erasing processes in series.

3.2.2 Technical problems for high-speed and high-quality printing

The technical problems that arise in the printing process and the ways to correct them are described below for high speed and high-quality printing using liquid toner.

(1) High-density and uniform developing

Achieving a high-density and uniform image from high speed printing calls for the appropriate developing processes as well as certain toner properties. Hence, verification experiments have been carried out that take into account the design of toners and developments obtained in the analytical model of developing process\(^{1(2)}\) in Fig. 3 to achieve these goals.

![Fig. 3 Analytical model of developing process](image)

The basic equation for electrophoresis used in the calculation is:

$$V = \frac{qE}{6\pi\eta a}$$

where,

- \(V\): toner mobility (cm/s)
- \(q\): toner charge (C)
- \(E\): electric field strength (V/cm)
- \(\eta\): viscosity of liquid toner (g/(cm·s))
- \(a\): toner radius (cm)

Fig. 4 is an evaluation of the density variation of the image (edge effect) attributed to the inconsistent field intensity at the periphery of the latent image, and it shows a high degree of coincidence between the actually measured value and the value obtained through calculations. It indicates that a uniform image can be obtained by setting the developing voltage to 300 V. In Fig. 5 the toner charge to mass ratio (the quantity of charge flowing into the electrode until the toner of unit weight adheres) and the quantity of the adhering charge are evaluated. The results indicate that the toner charge to mass ratio providing maximum adherence differs with the printing speed. It has been found that high speed, high-density printing (printing speed: 72 sheets/min; A-4 size) can be obtained by setting the charge to mass ratio to between 300 and 600 \(\mu\)c/g.

(2) Highly durable photoconductor

In order to achieve high speed printing using a liquid toner, the use of a photoconductor which not only satisfies conditions related to electrical properties such as chargeability and sensitivity, but which also resists solvents and is non-polluting and economical, is mandatory. Compara-
tive studies made on various photoconductors satisfying the aforesaid requirements, such as organic, selenic, and amorphous silicon type photoconductors, reveal that the amorphous silicon type is highly durable; it can print more than one million pages (A-4 size).

3.3 Variable data printing technology

3.3.1 Performance required for variable data printing

In order to carry out the high speed, high-resolution printing of an article containing several hundred pages, the processing speed of the RIP (Raster Image Processor, software that converts files fed with standardized formats into dot image data) is too slow in its present technological manifestation, and requires a great deal of memory. Further, the mechanism must read out the stored image data at a speed equivalent to the printing speed and resolution before the data is transmitted to the laser (photo writing device). A large capacity, high speed system with a memory capacity of 29 Gbyte and laser output speed of 35.4 Mbyte/s would be required to satisfy the Mitsubishi Electronic Printing specifications of “A-4 color: 1000 pages storage capacity,” “printing speed: 72 sheets/min” and “resolution: 800 dpi.”

The capacity requirement could be satisfied through the use of a hard disc, but the output speed would still fall short (5 Mbyte/s being the limit). On the other hand, the speed condition could be fulfilled through the use of semiconductor memory devices, etc., but these are too expensive to be adopted. MHI has, therefore, selected a disc array system that drives several hard discs in parallel together with data compression/decompression technology in order to achieve both a large capacity and high speed output in its printing system.

3.3.2 System configuration for variable data printing

The system configuration for the memory is shown in Fig. 6. The image data, developed into a dot image by the RIP, is compressed by the compression circuit before being stored in the 4 hard disc units. The hard disc, connected with an independent bus, enable simultaneous parallel operation. During printing, compressed image data is read from the hard disc and is returned to normal image data by the decompression circuit before being transmitted to the laser through the P-S (parallel → serial) conversion circuit. Further, since the hard disc involves mechanical operation, there arises an unavoidable time difference between the discs at the time of data readout. In order to absorb this time difference, a data cash is installed between the disc and the decompression circuit to correct the time difference and simultaneously transmit the data to the decompression circuit. There are two methods of compression and decompression, namely, “lossless compression” and “lossy compression.” The lossy compression method provides high compressibility and can make the memory capacity smaller, but it unfortunately causes a deterioration in quality such as blurring of letters and fine disturbances in the image. Therefore, the Mitsubishi Electronic Printing System makes use of the lossless compression method (Lempel-Ziv method), which is capable of thoroughly restoring data in order to ensure high image quality.

4. Configuration and specifications for the Mitsubishi Electronic Printing System

The configuration of Mitsubishi Electronic Printing System is shown in Fig. 7, and the specifications are given in Table 2. A personal computer (a Macintosh), common in the printing industry, is supposed to be used in the editing system upstream. The data file transmitted from the editing system is fed into the work station (SPARC station) through the network to get automatically rasterized in the RIP before being stored in the large capacity memory (printing memory). The digital printer adopts the electro-photography system using liquid toner. The 4-color printing units are arranged vertically (in tandem) to allow full 4-color printing or 2-color printing on each side (2 colors each on the front and back). The A-3 size rolled paper is used for printing, while paper cutout is in A-3 or A-4 size. Further, the finishing unit has made finishing possible.

5. Conclusion

The Mitsubishi Electronic Printing System MD 300 is a new generation system that provides on-demand printing. It has already been put into practice in the printing of such docu-
<table>
<thead>
<tr>
<th>General element</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Printing system</td>
<td>Electrophotographic system</td>
</tr>
<tr>
<td>Resolution</td>
<td>800 dpi</td>
</tr>
<tr>
<td>Printing form</td>
<td>4 colors on one side or 2 colors on each side</td>
</tr>
<tr>
<td>Printing speed</td>
<td>One-side printing: 72 sheets/min, 4 330 sheets/h</td>
</tr>
<tr>
<td></td>
<td>Both-sides printing: 144 pages/min, 8 640 pages/h</td>
</tr>
<tr>
<td></td>
<td>(for A4 horizontal printing)</td>
</tr>
<tr>
<td>Max. printing size</td>
<td>305×430 mm (A-3 with flyer)</td>
</tr>
<tr>
<td>Printing paper</td>
<td>Rolled paper (coated paper, lightweight coated paper, high quality paper: variable sheet cutting)</td>
</tr>
<tr>
<td>Printing memory</td>
<td>A-4 full color: approx. 1 000 pages (Mitsubishi standard image)</td>
</tr>
<tr>
<td></td>
<td>A-4 monochrome: 10 000 pages (Mitsubishi standard image)</td>
</tr>
<tr>
<td>RIP</td>
<td>Software RIP for SPARC station (Postscript Level 3 transposition)</td>
</tr>
<tr>
<td>Software</td>
<td>RIP + printing memory control software</td>
</tr>
<tr>
<td>Printer dimensions</td>
<td>2.0 × W14 × H1.9 m</td>
</tr>
<tr>
<td>Option</td>
<td>Connection to the finishing unit (stitcher)</td>
</tr>
<tr>
<td></td>
<td>Editing unit (Macintosh)</td>
</tr>
<tr>
<td></td>
<td>Building up the network with the editing system</td>
</tr>
</tbody>
</table>

Table 2 Specifications of Mitsubishi electronic printing system MD 300

ments as instruction manuals, company journals, and the like. Its fields of application are expected to expand to commercial uses such as the printing of leaflets, POPs (postures and advertisements displayed in stores), pamphlets and so on, and to the printing of publications such as paperbacks, name lists, and more.

Furthermore, research rooms have been opened in order to identify potential printing fields not currently exploited by conventional printing systems. We sincerely hope that a large number of people will recognize the tremendous advantages conferred by on-demand printing. We intend to open up new markets, and will continue to work to the utmost to further expand and improve the capabilities of the Mitsubishi Electronic Printing System.

References
(2) Kawanishi, T., A Studies on Mechanism of Liquid Development of Electrophotography, Electrophotography, Vol.12 No. 3 (1973)