Universal test-object for monitoring resolution of inkjet printers

I A Sysuev, M Yu Yudenko, S S Parshakova, O V Trapeznikova,
L B Šerkova, E G Bezzateeva

Omsk State Technical University, 11, Mira ave., Omsk, 644050, Russia
E-mail: sia1960@mail.ru, ol-trapeznikova@yandex.ru

Abstract. An inkjet printer is currently one of the most competitive types of a printer in a digital printing market. As in any printing technology, image quality is a key aspect. In this context, the development of evaluation tools, and in particular the tools of fine details reproduction along with color rendering, is relevant. The paper studies methods of assessing the resolution and inkjet printer resolution as well as the interpretation of the obtained parameters depending on the test-objects used to determine specified indicators. The expediency of using the developed test-object containing linear strokes positioned in different ways in the image space to assess the resolution and inkjet printer resolution is shown.

Keywords: Inkjet printer, resolution, test-object.

1. Introduction

Among the ways of digital printing, being widely used in the twenty-first century in various fields of human activities, from professional printing to a home "office", inkjet printing is one of the most common technologies. In this respect only electro-photography implemented in laser and led printers can be competitive.

In any image reproduction technology, in electronic device technology as well as in printing technology (from traditional printing to digital printing), the key issue is the quality of the image.

Evaluation of the quality rendering can be divided into two groups of equal importance: evaluation of colour rendering and evaluation of fine details reproduction of an image. This study belongs to the second group.

To assess fine details reproduction of the image, various technologies and test-objects necessary for their implementation are used [1–11]. Analysis of technologies and test-objects shows that they do not take into account the principle and specific nature of the formation of the reproduced image by inkjet printers by filling the space of the substrate with printed dots [12-19].

Thus, it is important to develop a universal test-object that takes into consideration the peculiarities of image formation in the technology of inkjet printing.

2. Task description

Taking into account image formation peculiarities of inkjet printing by spatial formation of the image, it is obvious that rendering and inkjet printer resolution depend on lengthwise, transverse and diagonal directions of the reproduced image formation. Studies conducted in this field are aimed at "smoothing" these effects [12-19], which still does not allow one to achieve the desired result. In the horizontal direction, inkjet printers provide a higher resolution and resolution definition than in the lengthwise printing direction. The aim of the study is to develop and test a universal test-object that allows improving the evaluation quality of fine details reproduction by an inkjet printer.
3. Theoretical basis

In order to properly assess the resolution and resolution characteristics of an inkjet printer, a test-object was developed, which in addition to standard techniques contains test samples accounting for the nature and specific features of substrate filling with printing dots. The test-object, developed to determine the above indicators, is shown in Figure 1.

The top row of test images (a set of vertical, horizontal and diagonal strokes) is an original development.

The second top row of test images (the concentric circles) is a standard technique [11].

The choice of these test images is due to the shape of the dot formed by inkjet and laser (led) printers when recording an image, as well as the nature of the image formation recorded using dots (dot elements).

The lower group of test images for determining the resolution is a variant of the standard Burmistrov test-object [11], developed to assess the resolution of halide-silver photographic materials.

Here and beyond, resolution is understood to be the width of the stroke, separately and continuously reproduced by the printer, and printer resolution is understood to be the number of separately and continuously reproduced strokes per unit of linear size of the reproduced image.

In these studies, two models of inkjet printers were used, and for comparison, it was decided to conduct similar studies for laser printers to clearly show the advantages of the developed test-object, namely in relation to inkjet printing. Traditional brands of paper for these printers were used.

It should be noted that these studies were conducted in accordance with the provision defining the printing system as a set of technical and technological means, including not only a printer itself, but also printing conditions (paper or other medium, software for preparing the source file, printing settings, etc.).

Figure 2 and 3 show that determination of resolution on concentric circles for inkjet printers is fairly cumbersome.

Figure 1. Test-objects to determine the print resolution (the top and the second top rows) and resolution of the digital printing system (the bottom group of test images).

Figure 2. Digital photography of test-objects to determine print resolution with different stroke widths oriented in the printing space at different angles.
Figure 3. Digital photography of test-objects of print resolution with different widths of the strokes on concentric circles.

4. Methods of research
Two inkjet printing systems were used for research. The first (printing system № 1): inkjet printer EPSON Stylus Photo t 50 (paper brand is Privision, application program in which the test-object was prepared is Corel Draw, file format is CDR). The second (printing № 2): inkjet printer EPSON Stylus Photo t 50 (paper brand is Privision, the application program in which the test-object was prepared is Corel Draw, file format is CDR).

Two electro-photographic printing systems were used for comparison. The first (printing system № 3): laser printer HP Laser Jet Pro 400 M401dw (paper brand is KYVLUX copy Laser & ink jet classic, application program in which the test object was prepared is Corel Draw, file format is CDR). The second (printing № 4): laser printer Samsung ML -1640 Mono LASER Printer (paper brand is KYVLUX copy Laser & ink jet classic, application program in which the test object was prepared is Corel Draw, file format is CDR).

The printing conditions were standard. During the tests, the values of environmental factors were within the following ranges: air temperature of 15-31 °C (namely 23 °C), relative air humidity of 20 - 70% (namely 45%), provided that during the test period temperature deviations were not more than ±2 °C and humidity was not more than ±5 %.

5. Experimental results
The indicators of resolution and inkjet printers resolution for the studied inkjet printing systems, as well as related indicators are presented in tables 1 and 2.

Table 1. Resolution indicators of inkjet printers (on minimum thickness of separately reproducible strokes of different shape, μm)

| Shape of strokes | Printing system № 1 | Printing system № 2 |
|------------------|---------------------|---------------------|
| On straight-line strokes |                   |                     |
| horizontal       | 50                  | 40                  |
| vertical         | 110                 | 70                  |
| sloped (45°)     | 120                 | 110                 |
| sloped (-45°)    | 110                 | 110                 |
| On concentric circles |               |                     |
|                   | 110                 | 90                  |

Table 2. Resolution of inkjet printers and related indicators

| Shape of strokes | Printing system № 1 | Printing system № 2 |
|------------------|---------------------|---------------------|
| Resolution, lin / mm; description of the nature of stroke reproduction; stroke size: reproduced / programmed, μm | on vertical strokes |                    |                    |
|                  | 5.55                | 7.24                |
|                  | blurred             | slightly intermittent|
|                  | 0.09/0.05           | 0.07/0.05           |
|                  | 9.71                | 9.71                |
|                  | very clearly        | very clearly        |
|                  | 0.053/0.0375        | 0.053/0.0375        |
| on horizontal strokes |                   |                     |
|                  | 5.55                | 7.14                |
|                  | intermittent        | intermittent        |
|                  | 0.09/0.025          | 0.075/0.0375        |
| on the sloped (45°) strokes |               |                     |
|                  | 5.55                | 7.14                |
|                  | intermittent        | intermittent        |
|                  | 0.09/0.025          | 0.073/0.0375        |
| on sloped (-45°) strokes |                  |                     |
Tables 3 and 4 represent similar indicators for laser printers.

Table 3. Resolution indicators of inkjet printers (on minimum thickness of separately reproducible strokes of different shape, μm)

| Shape of strokes      | Printing system № 3 | Printing system № 4 |
|-----------------------|---------------------|---------------------|
| On straight-line strokes |                     |                     |
| horizontal           | 70                  | 80                  |
| vertical             | 80                  | 90                  |
| sloped (45°)         | 80                  | 90                  |
| sloped (-45°)        | 80                  | 90                  |
| On concentric circles |                     |                     |
|                       | 100                 | 100                 |

Table 4. Resolution of laser printers and related indicators

| Shape of strokes      | Printing system № 3 | Printing system № 4 |
|-----------------------|---------------------|---------------------|
| Resolution, lin / mm; description of the nature of stroke reproduction; stroke size: reproduced / programmed, μm | 6.14 | <5.55 |
| on vertical strokes   | Blurred             | Blurred             |
| 0.085/0.05           | 0.09/0.075          |
| on horizontal strokes | Continuous          | Continuous          |
| 0.085/0.05           | 0.083/0.075         |
| on the sloped (45°) strokes | Blurred | Blurred |
| 0.085/0.075          | 0.09/0.07           |
| on sloped (-45°) strokes | Blurred | Blurred |
| 0.085/0.075          | 0.09/0.07           |

6. Results discussion

1. The nature and quality of fine details reproduction of the image by inkjet printers depend on the direction of strokes arrangement. This is explained by the way the image is recorded in inkjet printing: the round dots that form the image unfold in a row in the horizontal direction; and thus row by row.

   Therefore, the best strokes are those oriented in the horizontal direction. Separately reproducible strokes have a thickness of 40 - 50 μm for both printers (printing systems).

   For the same reason, vertically oriented strokes of 70 - 110 μm are worse reproduced, and the worst are the sloped strokes (45°, -45°) of 110 - 120 μm for both printers.

   Separately arranged concentric circles are reproduced with a mean value of 90 - 110 μm for both printers.

   The tests showed that printer № 2 has a higher resolution than printer No. 1. The highest resolution of 9.71 lin / mm for both printers (for the above reason) is provided in the horizontal direction, and the lowest resolution is in the vertical and diagonal directions with the mean values of 5.55 and 7.14 – 7.24 lin / mm, respectively. In this case, the horizontal strokes are reproduced continuously and separately, and vertical and diagonal ones are with distortion of a rectilinear shape and thickness. Also there is a distortion of the software-specified thickness of strokes with an increase by about 20 - 75 %.

2. The nature and quality of fine details reproduction of the image by inkjet printers do not depend on the direction of strokes arrangement. This is explained by the way the image is recorded in electro-photographic printing: the square dots forming the image unfold in a row in a horizontal direction; and thus row by row.

   Therefore, the best strokes are those oriented in the horizontal direction. Separately reproducible strokes have a thickness of 70 and 80 μm for the studied printing systems (№ 3 and 4), respectively.

   Differences in the reproduction of vertical and sloped strokes were not identified: oriented strokes are of 80 and 90 μm respectively.

   Separately located concentric circles are reproduced with the worst value of 100 μm in both cases.

   The resolution for both printers (for the above reason) also does not depend on the direction of the strokes and is of 5.55–6.27 lin / mm. In this case, the horizontal strokes are reproduced continuously and separately, and vertical and diagonal ones are with distortion of a rectilinear shape and thickness. Also there is a distortion of the software-specified thickness of strokes with an increase by about 20 - 50 %.
7. Conclusion

Peculiarities of image formation by inkjet printers require the use of test-objects that take into account fine details reproduction of the image in the transverse, lengthwise and diagonal directions. The assessment of resolution and resolution definition on the developed test-object and on the standard technique of concentric circles is significantly different. This is not the case for electro-photography implemented in laser and led printers.

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