

Special Print Quality Problems of Ink Jet Printers

LUDWIK BUCZYNSKI
Warsaw University of Technology, Mechatronic Department, Warsaw, Poland

Abstract

Rapid development of Ink Jet print technologies has caused significant growth of interest in Image Quality (IQ) of Ink Jet copies. Quality of a hardcopy is determined by using of various Ink Jet technologies, different kinds of paper and ink..

The author performed a short analysis of Ink Jet printing technologies with special attention to improving Image Quality of high velocity printing. Image Quality of Ink Jet printing technologies has been evaluated according to DIS13660 ISO/IEC "Measurement of image quality attributes for hardcopy output. Binary monochrome text and graphic images." The author selected characteristic parameters of IQ specific for Ink Jet printing technologies, for example:

- great number of satellites originating near an edge of an image segment,
- significant vertical non-linearity existing with double-direction ink jet printing along stroke,
- great value of raggednes attribute of character's edge originating especially during curves and slanted line printing,
- lack of exactness in overlapping of primary colors pixels in color printing.

Measurements of values of IQ parameters have been done using scanning (scanner Agfa Scan, resolution 600 dpi) and computation of values of IQ parameters from a bit map of gray levels of pixels. Basing on results of these measurements, the author discussed an influence of printing technology, paper, and ink on Image Quality.

In his suggestions the author proposes that additional, new parameters, specific for Ink Jet printing, should be added to the general standard DIS 13660.ISO/IEC. The author also proposes to create an additional standard sheet, specific for Ink Jet printing, that would supplement a general standard DIS 13660.ISO/IEC.

Conclusions include:

- General errors of print quality characteristic for Ink Jet technologies.
- Image Quality parameters for Ink Jet technologies.
- Results of measurements of IQ parameters.
- Suggestions for supplementing general standard with parameters and additional sheet standard for evaluating Ink Jet IQ.

The author will present chosen parameters and additional sheet standard supplementing general standard DIS 13660.ISO/IEC during the meeting of Working Group "Image Quality" SC28 JTC1 ISO/IEC.

Introduction

Estimating Ink Jet image quality is an important economical and investigation problem [5,6].

Standardization of estimating process and measuring methods of image quality attributes can be applied by:

- manufacturers of printers and copy machines,
- producers of hard copies and trade organizations,
- government agencies (testing of copies, printers, papers, inks).[5]

The special print quality problems of Ink Jet printers are subject of this elaboration. Scope of this work are Ink Jet hardcopies on the paper, black-white and colour copies. The Ink Jet print technology has special properties which influence image quality of a hardcopy.

In this elaboration the author:

- selected parameters characteristic for Ink Jet and specific for Ink Jet printing technologies,
- defined these parameters and their measuring methods,
- presented results of measurements,
- suggested supplementing general standard of Image Quality (DIS 13660 ISO/IEC "Measurement of Image Quality Attributes" with an additional sheet standard for evaluating of Ink Jet image quality.

Specific properties of Ink Jet printing technology

Ink Jet print technology is characterized by specific properties:

- mosaic print by inking,
- various Ink Jet technology,
- rarefaction, dilution of ink,
- various properties of background (normal, coated paper, etc),
- reciprocal influence and adjustment of : print technology, ink , paper and print mechanism).

Ink Jet printing is a mosaic printing. Images are made by a mosaic of points. High resolution, characteristic for Ink Jet printing makes continuous outlines of characters and graphic images. Mosaic printing create possibility of high raggedness of image edge. There is even a possibility of a lack of continuity of image outline in poor quality printers.

Ink-Jet print technologies are various. There are two main groups of Ink-Jet printing methods: drop and

demand and continuous printing. Drop Ink-Jet printing make the most of bubble jet and piezo technologies.

Ink-Jet print mechanisms are very various, characteristic for individual manufacturers. There has been a rapid development of Ink-Jet technologies, their printing mechanisms, and investigation methods.

Obviously printing technologies influence Image Quality of Ink-Jet hardcopies. Influence of each technology is individual.

Dyes and inks used in Ink-Jet technologies are rarefied and diluted. This require a special paper and more time for drying of copies. Influence of rarefied ink on image quality is perceptible by dissolving of ink on the paper; blurriness of outline edge is high.

Ink-Jet printing technology uses various paper: normal, coated, with special properties.[7]. Costs of paper are important part of total cost of printer operations.

The print technology, print mechanism, properties of ink and paper influence reciprocal on Image Quality of Ink Jet copies and can be adjustment in printing process.

Typical Ink-Jet hardcopy imperfections

Image Quality investigations of Ink Jet hardcopies are concerned with both basic parameters (raggedness - fig.1, blurriness - fig.2, darkness, etc from Standard DIS 13660) and parameters specific for Ink Jet printing technology (satellites, linear resolution, linearity, stepping, circle uniformity, overlapping).

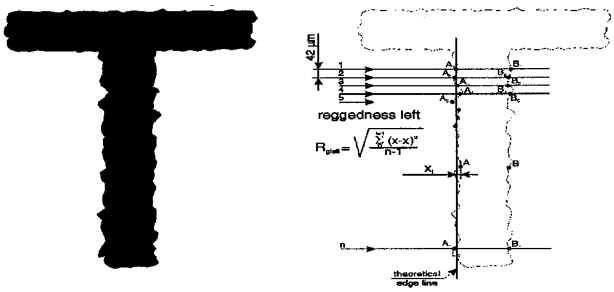

Figure 1. Raggedness

Satellites are most specific for continuous Ink Jet printing. Satellites are produced by the edge of an image as additional small dye drops in addition to basic , big drop of ink.

The size of the smallest dot is an important factor in evaluating Image Quality of Ink Jet as well as in other mosaic printing technologies. The size of the smallest drop is the most important in analysis of linear resolution. In Ink Jet technology ink is thin and has a tendency to splash over the surface of the paper with big size of fibers. Values of blurriness parameter may be significant in Ink Jet hardcopy.

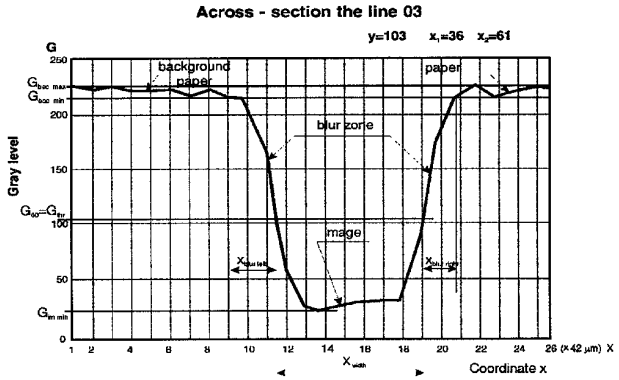

Figure 2. Blurriness - cross-section of line

The same situation may occur when electronic printing system control is set incorrectly. High precision in manufacturing of slide bars of Ink Jet head is necessary in order to avoid significant non uniformity of image edge - high value of raggedness parameter.

Imperfections specific for In Ink-Jet printing:
- non precise writing of sloped lines at small angle - (high value of parameter stepping)
- non uniformity of curved and circular elements of characters and graphic images (high value of parameter circular uniformity).

Quality of Ink Jet images depends very much on manufacturing precision of Ink Jet printing head and on following assigned technological parameters of printing process. Precise placement of ink drop on the paper is a fundamental requirement of obtaining high quality images. Established manufacturers of printers have solved this problem. Quality and precision in manufacturing of printing heads seems to be crucial.

Quality of used paper as well as ink features have sig-nificant impact on image quality in Ink Jet printing [3].

In regards to the above, it seems to be important to supplement general standard DIS 13660 with an additional sheet standard for evaluation of quality of Ink Jet hardcopy. The additional standard should include parameters specific for Ink Jet Image Quality as well as set precise conditions for measuring hardcopy quality.

Specific IQ attributes of the Ink-Jet output

Ink-Jet technology is characterized by specific Image Quality attributes:

- satellites,
- linear resolution,
- linearity,
- stepping,
- circular uniformity,
- overlapping.

Description of Image Quality attributes uses specific terminology.

Basic definitions are:

- **Region of interest** - (ROI, by DIS13660) - area that the user wants to analyze.
- **Reflectance factor** - (R, by CIELAB) Ratio of radiant flux reflected from the sample to the radiant flux incident on the sample.
- **Edge threshold** - (Eth, adequate to DIS 13660) Points in the gradients of an edge that defines the location of the edge1. This is commonly taken to be 60% of the transition from substrate reflectance factor to the image reflectance factor

$$R_{60} = R_{sub\ ave} - 60\%(R_{sub\ min} - R_{im\ min}) \quad (1)$$

where

- R_{ave} - average reflectance factor of substrate (paper),
- R_{min} - minimum reflectance factor of substrate (paper),
- Rim_{min} m - minimum reflectance factor of image .

Satellite (Sa)

Description

Ink-Jet technology, besides ground drops also produces additional, small drops of dye called satellites. They appear on paper, near characters or graphical images. Fig 3. If character stroke is made by moving of a printing head in two directions, satellites appear on the side of character's edge that is opposite to the direction of the headís movement.

Satellites depend on:

- parameters of technology of printing process (for example on drop velocity, pressure of ink, etc)
- parameters of printing mechanism (velocity and direction of moving of print head),
- ink properties,
- electronic control system.

Definition

Satellites - dyed elements, additional to image edge. They are made by ink splitting from the main drop of ink

Definition of calculating satellites

- Satellite - average value of the ratio of satellites area to area of region of interest (ROI)
- Minimum: 20 measurements and 20 calculations for the average
- ROI - is an area between ideal line of image edge and parallel line that is tangential to the furthest point of a satellite. (for example ROI on linear image contour is a rectangular with dimensions 5mm × 5 mm that is 25 square millimeters. It is adequate to the area of 50 × 50 points by resolution 600 dpi).

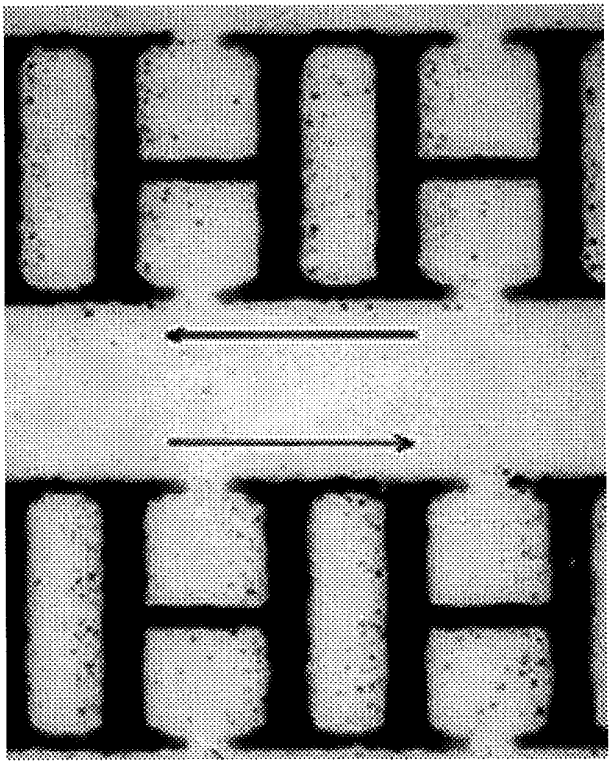

Fig .3 Satellites from printer printing in two directions along the stroke

Linear resolution (Rl)

Description

Ink Jet printers with poor linear resolution can not print separate lines in small distance from each other. Printers can be tested by printing parallel lines. The distance between first 2 lines should be n pixels (for example 20 pixels), between next pair - (n-1) pixels, next (n-2) pixels , etc. - Fig. 4

K (in millimeters) - the smallest distance between the last pair of separate lines that a printer can still print separately. Good printers would have small values of K, while poor quality printers- significantly bigger values of K

The measure of a linear resolution parameter would be the ratio of distance 25.4mm to distance K (in mm). This way the value of linear resolution parameter would be described by maximum number of parallel lines that a printer can still print separately on one inch. (lpi-line per inch).

Linear resolution depends on:

- dimension of minimal drops on the paper,
- properties of papers and ink,
- electronic control system of printer,
- properties of printing mechanism and print technology.

Definition

Linear resolution is the number of separated lines printed within the distance of 25,4 mm without connecting of lines (lpi).

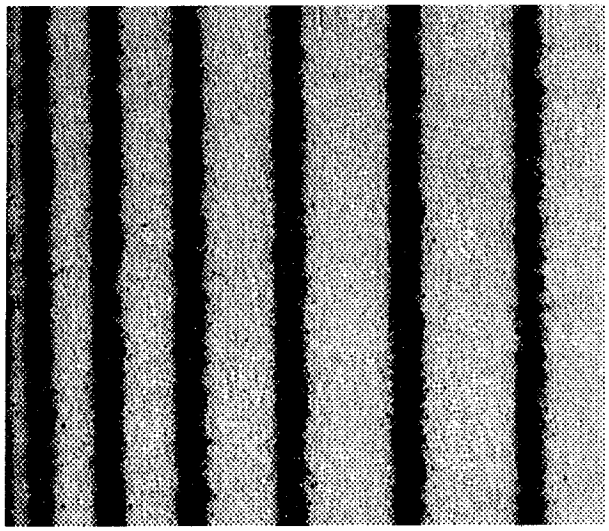

Fig.4 Sample for investigations of linear resolution

°

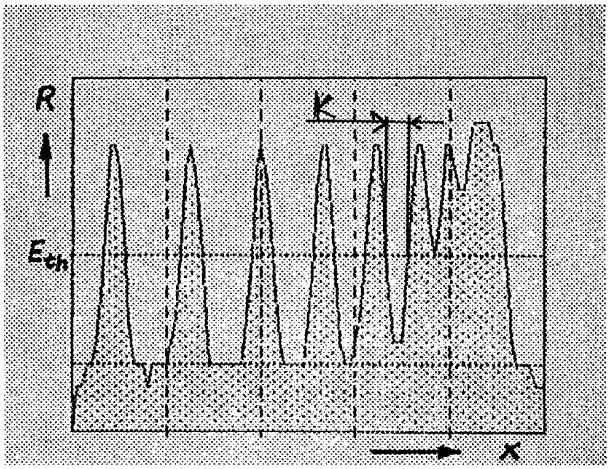

Fig.5 Scanning cross-section of parallel lines; illustration of value K

Definition of calculations linear resolution

Linear resolution is the ratio: 25,4 mm to value K mm. (where K -minimal distance between two separate parallel lines, written by printer.

Linear resolution calculation is done according to an equation:

$$R_l = 25{,}4 / K \qquad (2)$$

Measurement sample: by Fig 4 and description above.

Measurement method :

- preparing measurement sample,
- scanning perpendicular to lines on sample,
- computing K and R_l .

Linearity (by ISO 9241-3) [9] (L)

Description

During Ink-Jet printing process, printing head writes characters in strokes in two direction. In bad printers the beginning of stroke is not the same - Fig. 6

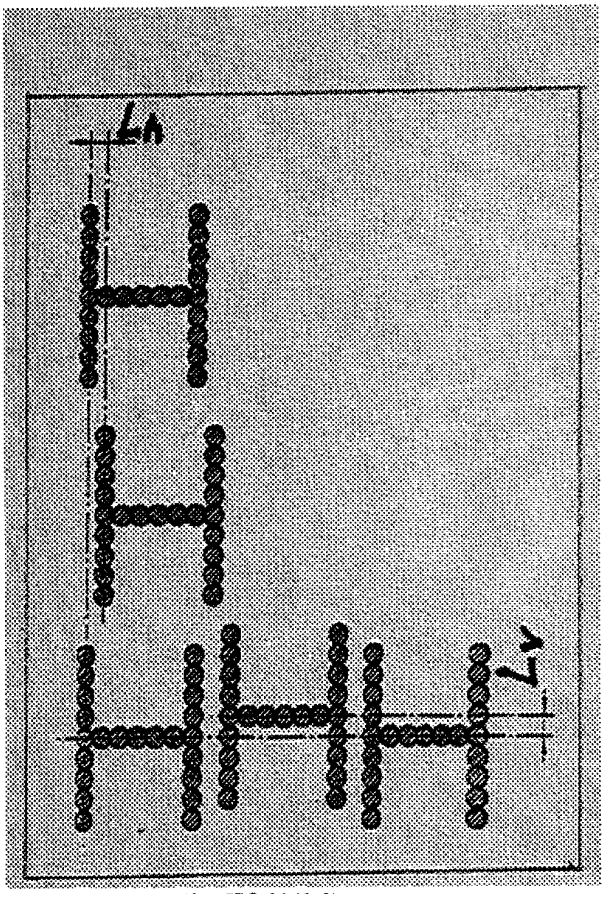

Fig 6 Linearity (by ISO 9241-3)

Linear difference of the beginning of stroke is the linearity and is defined by ISO 9241 -3 This attribute is characteristic for all mosaic printers, that print by moving printing head in two directions. My own investigations and measurements of Ink-Jet hardcopies with different printers show, that bad printers have this attribute high (for example more that 0,2 mm; with a contour of character - 0.3 mm). Just the same effect can be in vertical direction.

Linearity is measured in horizontal and vertical direction.

Linearity depends on:

- properties of print mechanism,
- electronic control system of printer,
- method of writing.

Definition

Linearity - the uniformity of the characters such that rows or columns appear straight and continuous.

Definition of calculations linearity

Linearity is the difference of placement of rows or columns, measured in linear units.

Stepping (St)

Description

Ink -Jet printers have difficulties in drawing long lines sloped at a very small angle. Often these lines are not smooth, but resemble small steps. This attribute is characteristic for mosaic printers.

a)

b)

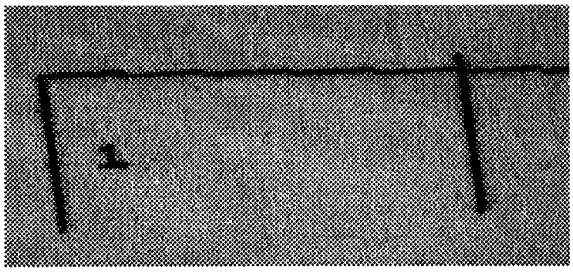

Fig.7 a) b) Examples of stepping of Ink-Jet image hardcopy.

Own investigations [3] show, that stepping is most visible in lines sloped at an angle about 7 degrees - Fig.8

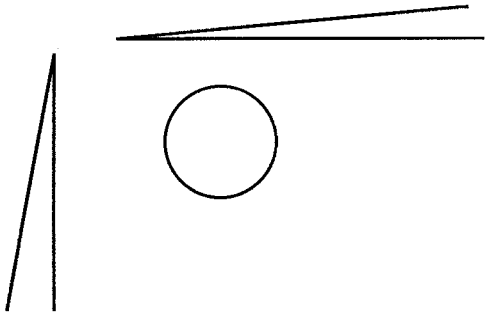

Fig 8. Sample of lines sloped at a small angle and circle

Measuring method:

Samples are scanned in vertical direction to base line. Bit map of scanned values of parameter R= f(x,y) of points of sample is computed and calculated: ideal line sloped on 7degrees, and length of stepps there create a sloped line.

Stepping depends on:

- electronic print control system,
- properties of print mechanism,
- dimension of minimal points on paper, [1],
- ink properties.

Definition

Stepping - the imperfection of drawing of long lines sloped at a very small angle.

Definition of calculating stepping

Stepping - length of steps there create sloped on 7o line (in mm).

Circular uniformity (Cu)

Description

Ink-Jet printers have difficulties in drawing an ideal circle and curved lines. Curved lines are not smooth but stepping occurs. -Fig 9.

a)

b)

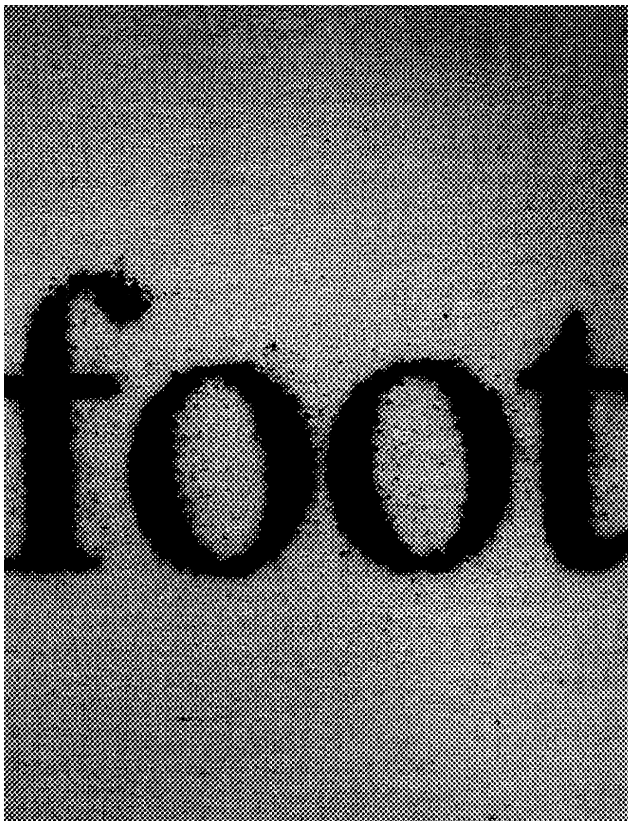

Fig 9. Examples of Ink-Jet hardcopies a) curved line of character b) characters with satellites and stepping

Sample of circular uniformity is a circle drawn by Ink-Jet printer (for example circle radius R=2 cm).

Sample is scanned in direction vertical to radius of a circle. Scanned value R=f(x,y) of points of a sample is computed and calculated: ideal circle, standard deviation of distance of points of circle from ideal circle.

Circular uniformity depends on:
- electronic print control system,
- properties of print mechanism,
- dimension of minimal points on paper,
- ink properties.

Definition

Circular uniformity is an imperfection of drawing of circle and curved lines.
Circular uniformity - ratio of standard deviation of the distance between points of an image of a circle from an ideal circle to radius of circle.

Circular uniformity calculation is done according to an equations:

$$\bullet S_{td} = \sqrt{\frac{\sum_{1}^{n} (b_i - b_{ave})^2}{n-1}} \qquad (3)$$

and

$$C_u = S_{td} / R \qquad (4)$$

where:
b_i - distance of point "i" of circle image to ideal circle,
b_{ave} - average value of distance of point from ideal circle
R - radius of circle

Overlapping (O)

Description

Colour images are created by mixing droplets of primary colours (RGB or CMYK systems). Colours are mixing above all on the paper. Separate droplets made of colours dots, should be placed in the some place. Often it is not realized in poor printers, dots are overlapped. It is visible on the copy, especially on the edge of an image. Inside of an image colour distortions are present. Displacement of dots of primary colours on the edge of an image is visible and measured as attribute “overlapping”.

IQ problems of colour copies are very complicated and require further investigations.

Definition

Overlapping is a displacement on the edge of an image of primary colours dots.

Definition of calculations overlapping

Overlapping on the edge of image is a linear displacement of primary colour dots, measured in perpendicular direction of edge of image. It is measured in linear units (mm).

Overlaping is measured by universal instruments, for example - by microscope with elementary unit 0,01 mm. Investigations of IQ problems of colour copies should be continued.

Measuring method

The author suggests the following measuring method:
- optical analysis of control sample of Ink Jet hardcopies by scanning,
- creating a bit map of values of reflectance factor of points of a scanned sample versus coordinates x, y of points on the control sample R=f(x,y)
- computing the value of each IQ attributes, based on previously created bit map and standard deviation.

A scanner or CCD camera with resolution not lower that 600 dpi is needed for scanning measurements. Measuring instrument will be calibrated before taking measurements (by DIS 13660). The author measured blurriness, raggedness, linear resolution by scanner Agfa Scan IIsi; others parameters was measured by universal instruments (microscope).

Computer programs for estimating other parameters should be elaborated. Measuring results of different manufacturers’ printers will be presented on the poster.

Discussion

Specific features of Ink Jet printing technology significantly influence Image Quality of a hardcopy. Both this paper and investigations of many others[1,2,3,4,6,7,8,10] indicate that Image Quality in Ink Jet printing technology significantly depends:
- properties of printing technology
- properties of printing mechanism especially electronic print control system
- characteristic of paper and ink used.

Parameters of Ink Jet Image Quality mentioned by the author are an important measure for evaluation of printer’s overall quality. Values of parameters of Image Quality en-able an objective evaluation of printer's quality. In order to be able to compare results, it is important to precisely define parameters, their measuring methods and conditions. All these should be included in an additional standard sheet for Image Quality of Ink jet printers.

Further investigations of Image Quality of Ink Jet printers may be conducted by scientific research teams from manufacturers of Ink Jet printers, standardization committees, and international bodies. The author is very

interested in cooperation in this matter and will welcome an interest in his research.

Conclusions

The following conclusions come from the analysis of Image Quality of Ink Jet printers:

Ink Jet printing technologies differ from other printing methods and create special problems in evaluation of Image Quality.

The most common problems in Ink Jet technologies are:

- satellites being created by the edge of an image
- high blurriness and raggedness caused by wrong parameters of a printing head, wrong paper and ink.
- stepping occurring during printing long lines at a small angle and circular elements
- geometrical imperfections of location of characters in a stroke, especially when printing head moves in two directions
- overlapping on colour printing.

In regards to Ink Jet Image Quality evaluation author suggests to investigate additional parameters, not included yet in general standard DIS 13660 ISO/IEC

- satellite,
- linear resolution,
- linearity,
- stepping,
- circular uniformity
- overlapping

Further investigations especially of colour Image Quality should be performed.

Author suggests to create an additional sheet standard, specific for Ink Jet printing, that would supplement a general standard DIS 13660 ISO/IEC. It should include definitions of new parameters, method of measurement, and control printing samples.

References

1. R.R. Allen, Int. Con. Adv. in Non-Impact Printing NIP11, 356, (1995)
2. B. Barbet, P. Atten, A. Saccemariandin, Int .Con. Adv. in Non-Impact Printing NIP11, 370, (1995).
3. L. Buczynski, Influence of dyes features on print quality.Analysis and research, Warsaw University of Technology (June 1997) (in Polish)
4. R.F. Burr, D.A.Tence, S.S.Berger, Int. Con. On Digital Printing Technologies, NIP12, 12, (1996).
5. B. Glover, Print Quality Standards from an ASTM Perspective, 2nd Annual Printing IQ Conf., (1997).
6. L. Palm, J. Nilsson, Int. Con. On Digital Printing Technologies, NIP12, 29, (1996).
7. Y.L. Pan, S. Yang, Int. Con. On Digital Printing Technologies, NIP12,399, (1996).
8. J. Shimoda, Int. Con. Adv. in Non-Impact Printing NIP11,353, (1995).
9. Standard ISO 9241-3, (1992).
10. T. Tanaka, R.S.Berns, M.D. Fairchild, Electronic Imaging, 6, 154, (1997)