Unit V

Inkjet Printing

5.1 Principles of Inkjet Printing

Ink-jet technology creates printed documents with streams of ink drops that are deflected to the substrate based on information in digital files. It does not require an image carrier, or plate, and it does not require equipment like a Xerographic device or a printing press. The same information can be printed throughout a print job or variable information can be printed based on the requirements of the application. The main types of ink-jet technologies are continuous jet and drop-on-demand.

Continuous Jet

With continuous jet technology, drops of ink are continuously produced and applied to the substrate to produce the image. A pump sends ink drops through a nozzle at the rate of over a million per second which can produce an image of nearly the same quality as a continuous tone image such as a photograph. There are three types of continuous jet technologies: charged drops for printing, uncharged drops for printing, and electronic deflection.

- **Charged Drops for Printing:** Drops of ink are given a charge and are deflected to the substrate to produce the image. The ink drops that are uncharged are recycled through the system to be reused.
- **Uncharged Drops for Printing:** This type of technology also applies a charge to the ink drops except that the uncharged drops are used for the actual printing and the charged drops are recycled.
- **Electronic Deflection:** This type of technology applies a charge to all of the ink drops and the application of the drops is determined by deflection, which is controlled electronically.

Drop-on-Demand

Drop-on-demand is a type of ink-jet technology in which the ink drops are formed and then applied as a response to a digital signal. There are two types of drop-on-demand printer systems: piezoelectric and thermal ink-jet.

- **Piezoelectric:** A piezoelectric crystal is given an electric charge, which produces a pressure pulse in the imaging head. This produces the emission of an ink droplet onto the substrate.
- **Thermal Ink-Jet Systems:** There are two types of printer systems using thermal ink-jet technology: liquid thermal/bubble jet and solid ink-jet:
- **Liquid Thermal/Bubble Jet:** Heat produced from an electrical resistor vaporizes the moisture in the ink which causes an ink bubble to form. The expanding bubble creates pressure inside the ink nozzle which propels the ink to the paper. The ink bubble then contracts which lowers the pressure causing more ink to be drawn into the printing head. The entire process occurs very rapidly in the printing device. In fact, the process is repeated thousands of times per second, producing high quality results.

- **Solid Ink-Jet:** A solid ink-jet printer is also known as a "phase change ink-jet printer". The ink begins as a solid and is heated to convert it to a liquid state. The ink is propelled as drops onto the substrate from the impulses of a piezoelectric crystal. Once the ink droplets reach the substrate, another phase change occurs as the ink is cooled and returns to a solid form instantly. The print quality is excellent and the printers are capable of printing on almost any type of paper and transparency substrates.

5.1.2 Flow Chart for Inkjet Printing:

In additon to electrophotography, the most common non-impact technology used for digital printing systems is ink jet. The ink jet process is a computer to print technology in which ink is sprayed from nozzles, which means that no image carrier is needed .As shown in figure 5.1-1 imaging is done directly onto the substrate. The data of the digital print job is transferred directly to control the imaging unit. In this case the imaging unit is the ink jet system itself, which transfers the ink to the paper via nozzles, mostly directly or in same applications indirectly depending on the technology used.

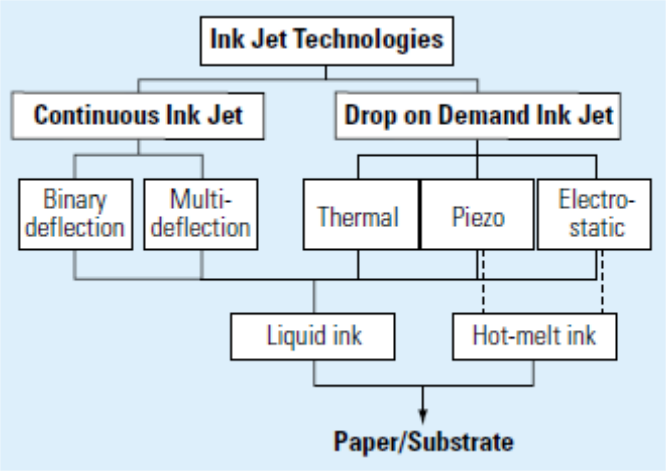

Fig. 5.5-1 Ink jet technologies: overview of processes

5.1.3 Functioning principles for ink jet technologies

The basic variants of the process are continuous ink jet and drop on demand ink jet. A schematic diagram of the processes is given in figure 5.5-2.

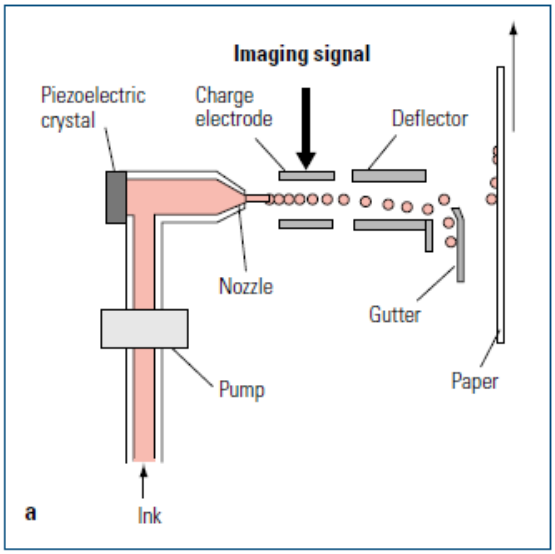

Fig 5.5.2 Continuous ink jet

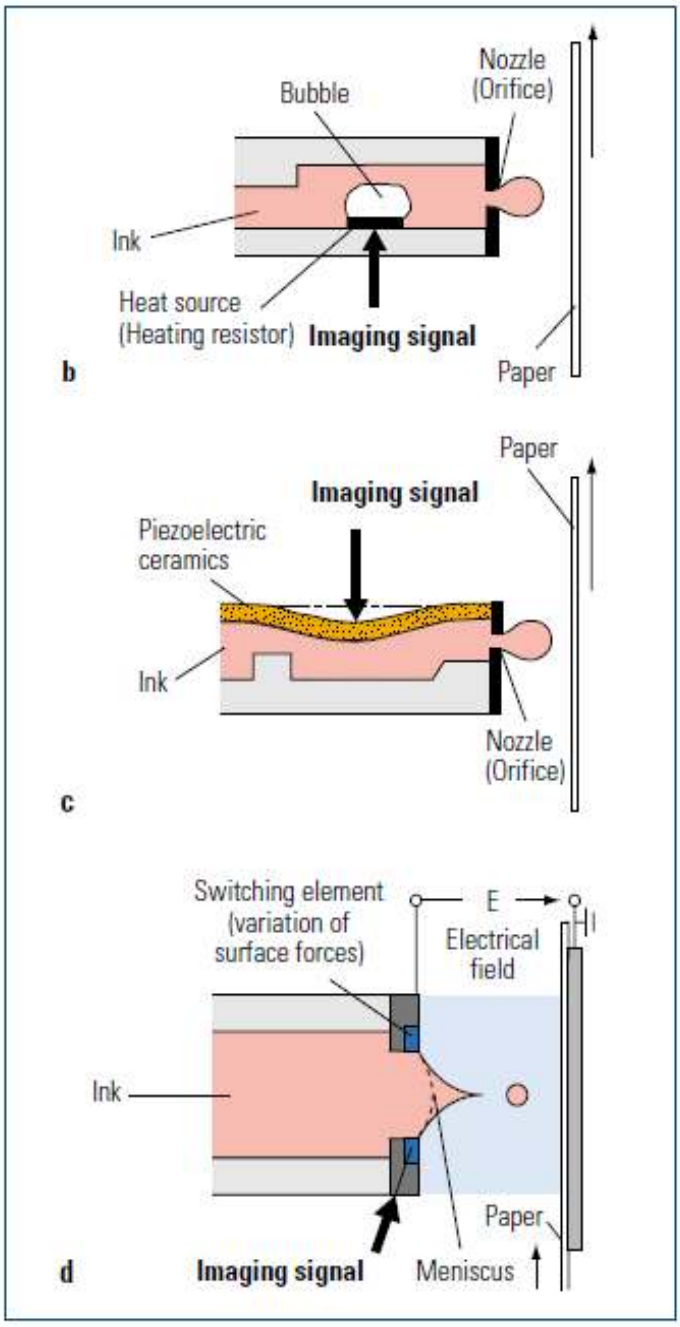

Fig 5.5.3 Functional principles of Inkjet Printing
B Drop on demand ink jet/thermal ink jet;
c Drop on demand ink jet/piezo ink jet;
d Electrostatic ink jet

Process Variants

Whereas in the continuous ink jet process, only part of the continuously generated flow of small ink drops is directed onto the paper during printing in accordance with the image, in drop on demand ink jet processes drops of ink are only generated if the information to be printed requires them.

Continuous ink jet can be subdivided into the process variants of binary deflection and multi-deflection. The binary deflection variant, in which the drop has one of two charge states (namely uncharged for conveyance to the paper and charged for deflection in an electrical field) has been described in preceding sections. In the multi-deflection process the drops receive different charges, so that as they pass through the electric field they are deflected in different directions and are transferred to different positions on the substrate.

Drop on demand ink jet processes can be classified according to the way that the individual ink drop is generated.

In the **thermal ink jet process** this is done by heating the liquid ink until it vaporizes, whereupon a certain quantity of ink is ejected from the nozzle as a result of the pressure exerted by the vapor bubble, hence the name “bubble jet”.

In piezo ink jet systems, the drop is generated as a result of a change of volume within the ink chamber due to piezoelectric effects, which leads to the drop of ink being ejected from the nozzle system.

Electrostatic ink jet is the third variant of the drop on demand ink jet process referred to in figures 5.5.3.

There are different process variants, but common to all of them is the fact that an electrical field exists between the ink jet system and the surface to be printed, and that by means of image-dependent alterations in the ink jet nozzle system, either the forces can be balanced or the surface tension ratios between ink and outlet nozzle can be changed, so that a drop of ink is released as a result of the field forces. Withdrawal of ink from the nozzles is prepared via the electrical field, and a control pulse (e.g., electric signal or the supply of heat) then enables the release of a drop.

5.2.1 Continuous Ink Jet

Binary Deflection Continuous Ink Jet

Figure 5.5-4 shows the underlying principle of a nozzle system based on Hertz technology, which enables a high frequency stream of drops (of 1 MHz or more) to be created. The pressurized liquid is pressed out of the nozzle. The high-frequency excitation via a piezo oscillator results in the constriction of the stream due to fluid dynamics-related effects and the separation of individual drops from the stream.

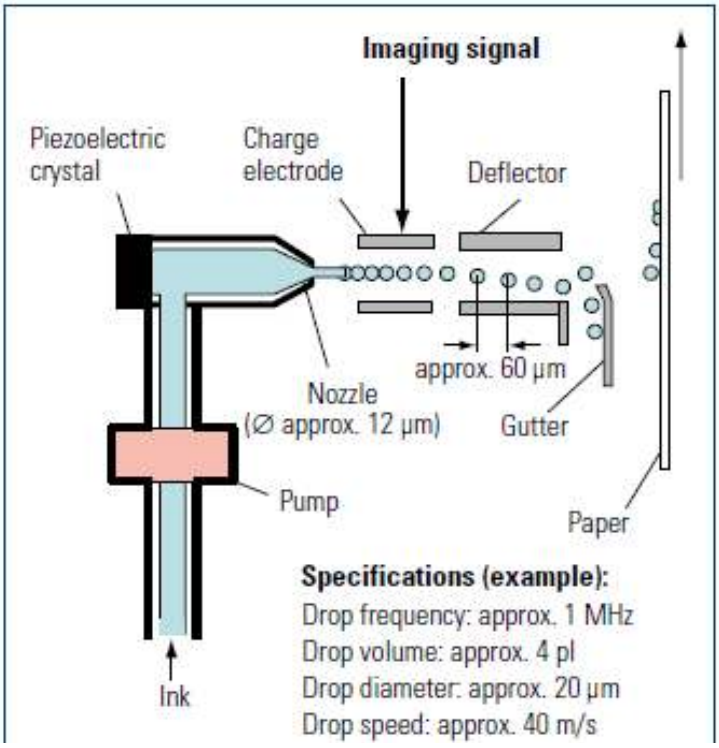

Fig 5.5.4 Continuous ink jet: process specifications

Drop size and interval basically depend on the nozzle diameter, and the viscosity and surface tension of the liquid, as well as the frequency of the excitation.

The individual drops are electrically charged by an electrode in accordance with the image just before separation from the jet. The charged drops are deflected in a subsequent electrical field (plate capacitor, deflector) and fed to a collecting device. The uncharged drops reach the paper.

so-called satellite drops are produced during the drop formation process, which should then merge with the main drop. The quality of the print depends on the quality and continuity of the drop stream generated.

Multi-Deflection Continuous Ink Jet

With the multi-deflection ink jet, the drops can be given different charges in the charging system and, as a result of this, they can be deflected more or less strongly between the deflector plates, depending on the intensity of the charge (fig. 5.5.5).

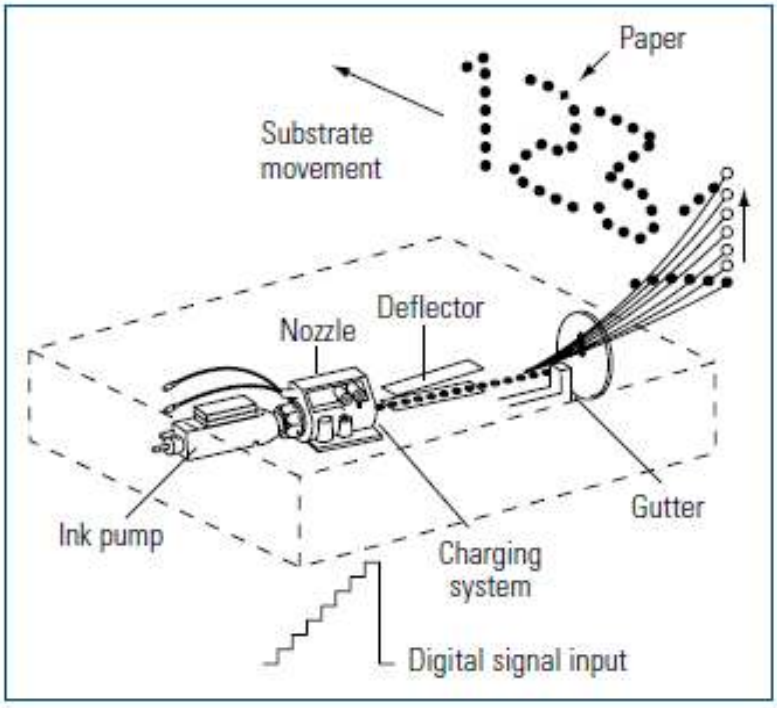

Fig 5.5.5 Multi-deflection continuous ink jet system

Consequently, one nozzle system can be used to image a short line (e.g., 10 mm in height). The jet can be deflected in approximately sixteen reproducible positions. The height of a line written in this way depends on the distance between the ink jet head and the paper surface. The writing height increases as the spacing increases, although the resolution will be reduced. The resolution in the direction of printing is determined by the speed of the substrate and the drop frequency.

The minimum resolution for the recognition of digitally represented characters (matrix structure) should be 7 ¥ 6 dots (height ¥ width). In principle, systems with two-dimensional jet deflection are also feasible. In this case the deflectors act in two directions so that two-dimensional characters can be printed even if the substrate is static.

5.3.1 Drop on Demand Ink Jet Technologies

With drop on demand technologies, a drop is only generated if the print image requires it.

The drop can be generated either by heat transfer (bubble jet) or by changing the chamber volume in a nozzle channel (piezo ink jet).

The two drop on demand technologies, thermal ink jet and piezo ink jet (including system specifications) are compared in figure 5.5.6.

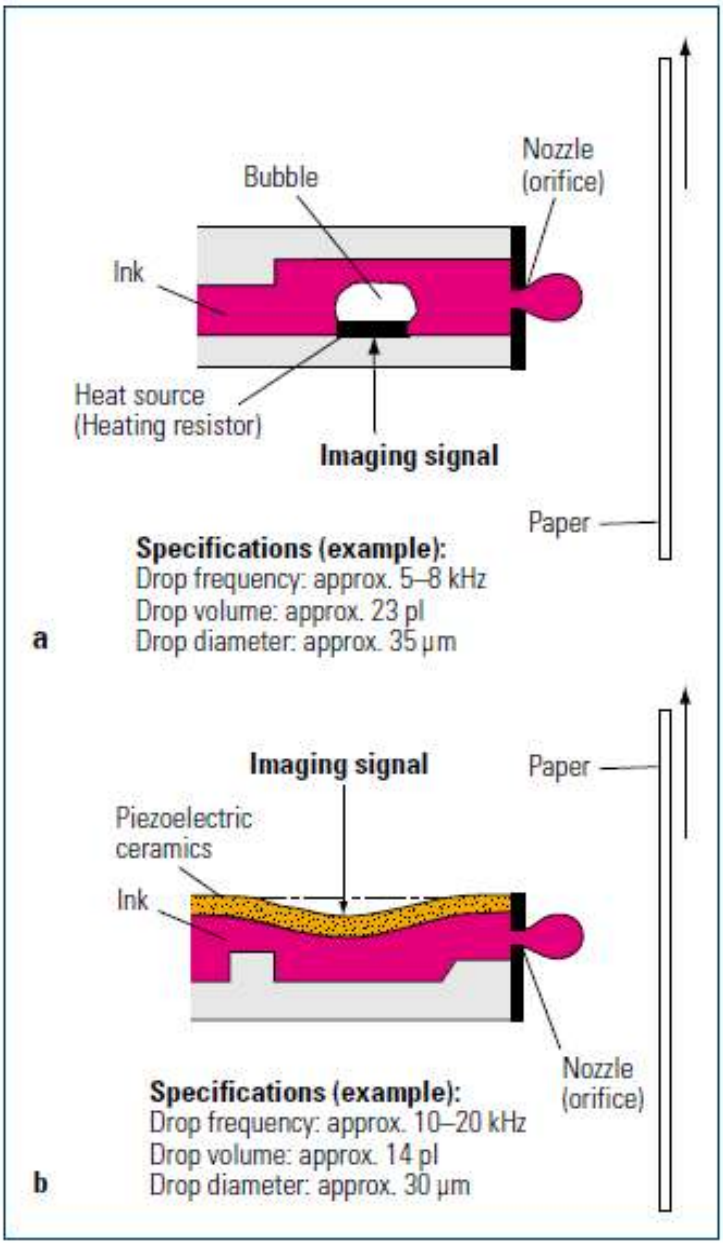

Fig. 5.5.6 Drop on demand ink jet: system specifications.
a Thermal ink jet (bubble jet);
b Piezo ink jet

Thermal Ink Jet:

The sequences in figure 5.5.6 show in simplified form how an ink drop can be ejected as a result of heating and bubble formation and how the channel is then refilled with ink. Drop volumes of about 23 pl (equivalent to a representative drop diameter of about 35 µm) are possible on the basis of current thermal ink jet technologies (Hewlett Packard and Canon are the leading manufacturers in this case).

Drop frequencies are in the range of 5 to 8 kHz. The resolution must correspond to the drop volume; 600 dpi is possible with 23 pl (dot diameter in the print around 60 µm, depending on the viscosity of the ink and the absorption characteristics of the paper, etc.). Depending on the design of the jet system with regard to the direction of the drop jet discharge and the position of the heating elements, a distinction is made between “roof shooters and “side shooters”.

The color printers used in desktop-publishing or in an office environment mostly use thermal ink jet systems.

In a typical application a separate ink jet head is used for each color, although a separate head is often used for the most commonly printed color, black, and a second head for the chromatic colors, cyan, magenta, and yellow. Powerful systems are available with resolutions of 600 dpi, operating at a drop frequency of 8 kHz, and with three hundred nozzles per printing head. The nozzles are arranged in several rows and staggered to ensure the desired resolution and the space required for installation of the individually addressable nozzles.

Piezo Ink Jet:

With piezo ink jet, unlike thermal ink jet, ejection of an ink drop is generated by mechanical displacement in the ink channel, and not by heating and vaporization within the ink jet system.

Piezo-ceramic materials are ideally suited for small, electrically addressable systems. As illustrated in figure 5.5.6 materials of this type change shape or volume in the electrical field. The so-called “shear mode,” with the appropriate electrical controller, is usually used in piezo ink jet systems. In shear mode operation the material’s volume remains unchanged and the geometry is deformed.

5.4.1 Drying Process:

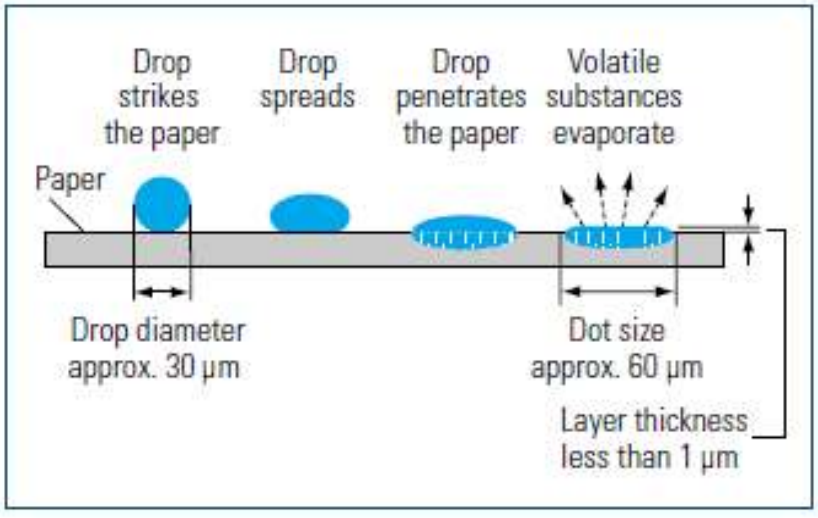

Fig. 5.4.1 Dot formation resulting from the reaction of ink drop with substrate in the ink jet process

Figure 5.5.7 shows examples of how ink drops may react with the paper in the ink jet printing process. The surface properties of the paper determine the spreading and penetration into the substrate. The illustration shown refers to water-based or solvent-based standard inks with which the colorants

(pigments or dyes) and binders produce a very thin layer of less than 1 µm ink application after vaporization and absorption of the base liquid.

5.5.1 Inks for Ink Jet Processes:

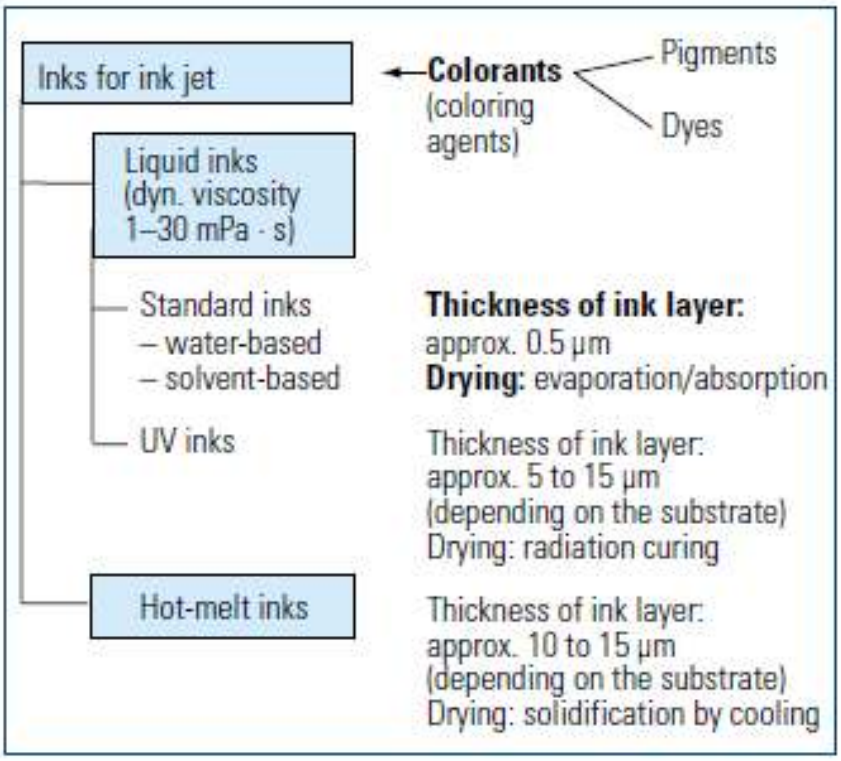

Fig. 5.5.1 Inks for ink jet processes

Figure 5.5.1 gives a systematic survey of the different inks that can be used in the NIP technology ink jet.

A distinction is made between liquid inks and hot-melt inks. Both types of ink can comprise dyes or pigments as colorants. Different types of ink jet processes –require different types of ink with respect to the ink carrier (e.g., water or solvents).

The type of ink to be used is also substantially determined by the properties of the substrate (absorbency, coating, foil, etc.), the surrounding conditions of use of the print media (light resistance, weather resistance, resistance to wear), and the drying process required during printing with different printing systems (productivity, multicolor printing, further processing, etc.).

If liquid inks are used, the drying process occurs through evaporation and absorption. The evaporation process can be accelerated by the application of heat. In the case of UV inks, the drying process involves UV light for radiation curing (cross-linking of organic molecules).

The use of hot-melt ink implies that the drying process is automatically included in the printing process: the ink that has been melted by heat prior to being processed cools down on the paper and becomes solid again.

The ink used and its interaction with the substrate determine the thickness of the ink layer on the paper and thereby the quality of the printed image, especially in multicolor printing. If liquid inks are used in

the ink jet process, the thickness of the ink layer may be approximately 0.5 µm (rendering a high quality product).

In the case of UV ink and hot-melt ink the ink layer thickness ranges between 10 and 15 µm, thus causing relief-like structures that can affect the visual impression.

Applications of Ink Jet Printing:

- The continuous ink jet process as a high-speed printing process
- Continuous ink jet systems for multicolor printing (digital proof system). In this system, printing is done with four ink jet heads, one head per color for black, cyan, magenta, and yellow, with a resolution of 300 dpi. The sheet is fastened onto a drum.
- A separate ink jet head is used for each color, although a separate head is often used for the most commonly printed color.
- Piezo ink jet technology with nozzle arrays came onto the market around 1990.piezo ink jet technology, an imprinting unit which can be used to imprint additional information on preprinted web material.
- Distinction can be made between highspeed printing systems, which print predominantly with one color or with an additional spot color, and systems for the high-quality printing that is required for proof purposes.