

Ink Jet Media Structure in Correlation to Product Performance

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Abstract

Demands on modern ink jet media are increasing. A number of product features has to be optimized to achieve a high quality product. Therefore, it is imperative to control the ensuing potential interference of key product properties. This principle of controlling product properties for best overall fit is discussed using the following exemplary quality criteria:

- Impact of Pigmented Inks versus Dye-Based Inks on Image Quality
- Curl
- Drying time
- Banding and Bleeding

As a premise for looking at the quality criteria mentioned above, I want to point out at this point that it is impossible to separate these criteria from one another. There will always be some kind of an interrelationship between them whether one likes it or not. By the same token, for chemical and physical reasons, it is not possible either to produce an ink jet paper that is optimized in all respects, i.e. that complies equally well with the most important quality criteria. The following considerations can therefore not be regarded as complete, but rather are supposed to give an overview concerning the complexity of the subject and hopefully provide some insight by focussing on the most important items. The following results are based on investigations of the R & D Department of DuPont de Nemours (Deutschland) with support from DuPont Ink Jet Enterprise in the U.S. Besides competitive products, primarily the DuPont ink jet papers called "DuPont Jet LF" were investigated. These are especially suited for universal use in large format ink jet printers that are market leaders. The products "DuPont Jet LF" are also optimally suited for the use of dye-based inks as well as pigmented inks. Therefore, as an example, investigation of the quality criterion "pigmented and dye-based inks" was made possible by looking at only one identical material. In concluding these introductory comments, I'd like to add that most of the quality criteria that I will describe can be evaluated much better visually, so I will show some illustrative samples during this presentation. Illustrating the text of this presentation with printed images would not be adequate compared to the visualization using samples.

Quality Criterion:

Impact of Pigmented Inks versus Dye-Based Inks on Image Quality:

In order to compare inks with "dyes" to those with "pigments", these two designations need to be explained more closely. Pigments as used in inks are ultra-small solid particles with a diameter between 500 and 50 nanometers. Each pigment contains a multitude of color molecules. These pigments do not float dissolved in the carrier liquid, mainly water which makes up the biggest portion of the ink. Dyes by contrast are "liquid". This means they are dissolved in the carrier liquid and float in it in a molecular state. Many colors may be used as pigments or as dyes in inks. In comparing the color gamut of pigmented inks with the color gamut of corresponding dye-based inks, there is a slightly smaller range for pigmented inks, but they are very similar in all other aspects.

After printing, dye-based inks will diffuse into the ink jet layer with their solvents - a mixture of water and glycols. During the drying process, this dye mixture does not spread within the layer, this means the image impression cannot change during drying. The situation is different with pigmented inks. After the drops impinge upon the surface, there is a filtration effect there. The pigment particles essentially remain at the surface of the ink jet layer while the solvent mixture diffuses into the ink jet layer. With respect to this mechanism, basically two different effects can be observed with commercially available ink jet papers and the respective ink jet layers which have been formulated for use of pigmented inks:

1. If the solvent diffuses into the ink jet layer relatively rapidly, one sees a uniform distribution of the dispensed ink at the surface. However, during drying the appearance of cracks in the pigmented layer is frequently observed. As a result, the optical density (in reflection and transparency) is strongly reduced and the gloss of the printed surface is strongly diminished. The effect is caused by flocculation and coagulation of the pigment particles during the drying process. This phenomenon can be observed particularly well at high color loadings, this means for example "400 % black" built up from cyan, magenta, yellow, black.

2. Those media that absorb the solvent mixture of the pigmented inks more slowly, "puddling" may occur. At high color loadings, there is formation of coherent liquid films which then may spread into each other with different colors. As a first stage of this phenomenon, there may be some kind of drop formation in the full density areas of any color. After drying, non-uniform full density areas are observed which create a very mottled image impression.

To eliminate or optimize these negative aspects of ink jet layers, there is an option to use more than just one ink jet layer. In applying this technology, the topmost layer should be crosslinked and coated relatively thin. Also, a high amount of small size silica particles has been found to be beneficial. With this measure, the topmost layer is indeed optimized for pigmented inks, however, under certain circumstances, there may be interferences with other important properties. For standard binder concentrations, the crosslink-ing step mentioned above may excessively increase viscosity so that problems may arise in the coating process of the ink jet layer. In addition, drying times may change and may possibly become too long. Furthermore, the use of high amounts of silica in this layer may also influence gloss of the coating which in turn influences color density and color hue.

Quality Criterion:

Curl:

Curl is defined as the property of a coated material to curve from the flat state into a certain direction under certain outside influencing factors. For ink jet media, three influencing factors are important:

1. Humidity.
2. "Memory" (history) of the material.
3. Drying.

1. At low humidities of the ambient air, the binders of the ink jet layers will desorb their residual humidities resulting in high internal tension forces within the ink jet paper. If these forces are not compensated for, the ink jet paper will react by curling more or less strongly towards the side coated with the ink-receptive layer. In general, with commercially available materials, this problem will occur at relative humidities below 20%. Besides handling problems due to curl outside the actual printing process, the main potential problem is in the printing process itself because the printing heads are in conflict with the raised edges of the paper during printing.

2. When using large format ink jet printers, the paper media are mainly wound onto two-inch-cores with the coated layer outside. As the paper material may stay wound on such cores for up to two years between production and consumption, the substrate (paper, polyester) will exhibit a so-called memory curl. This type of curl is a tendency to curve towards the backside of the ink jet material. It does not adversely affect functionality during printing and is less pronounced with thicker paper media. Experience shows that after printing the material will not be optimally flat. However, since a large part of the ink jet materials is laminated over anyway after printing, this type of curl has no relevancy. Memory curl cannot interfere with the function of the printing heads either because it is oriented towards the direction of paper transport, with the curvature away from the path of the printing head movement.

3. In order to suppress drying curl, there is technically the option to coat the back side with an ink jet layer in addition to the front side. This method is not new and is successfully being applied in silver halide manufacture. The functional principle is that the gelatin of the back side compensates for the tension forces of the gelatin of the front side (silver halide layer). This way of preventing drying curl works by producing nearly the same reaction of the front side and the back side concerning different humidities by having very similar coatings on both sides thereby balancing curling towards any one side. This method, however, is not being applied in the manufacture of ink jet materials due to higher costs associated with the two coating passes, although this type of material could be printed on the front and on the back side. The most practical solution is afforded by the method of applying different layer thicknesses of polyethylene (PE) on the front side and the back side of the substrate paper. This type of formulation of an ink jet paper material also requires consideration of possible interaction with other quality parameters, for normally in manufacturing PE-coated papers, it is made sure that the PE coating thicknesses are the same on both sides in order to reduce paper curl. By applying different PE layer thicknesses, however, the curl tendency towards the thicker PE side is being utilized to balance the tension forces in the ink jet layer. It has to be kept in mind, though, that this is only a conditional problem solution because the combination of raw paper and PE will react differently against humidity differences versus the ink jet layer proper. The goal in selecting a binder combination for ink jet coatings is to possibly find one which builds up the least possible internal tension forces at low humidities and therefore has a low tendency for curl formation. To underline the complexity of the subject, I'd like to mention that an optimization for curl alone may cause adverse effects for gloss and for uniformity of full color density areas. As a satisfactory compromise with respect to the various influencing factors and optimization programs, ink jet materials consisting of a multi-layer complex have proven to be effective. These materials lend themselves to applying a very thin binder layer in the overcoat which is beneficial for gloss and reduces streakiness, even if curl properties are possibly negatively affected. The interaction and the resulting interdependence of various properties become especially clear in optimizing the total coating weight of the ink jet layer. On the one hand, reducing curl requires working with a minimal coating weight, at any rate, on the other hand, however, under these circumstances, this may cause problems with drying time, especially at high color loadings.

The description of the subject of curl is a good example to illustrate the complexity that R&D teams face with respect to the right calibration of measures that need to be taken for overall optimization of product performance.

Quality Criterion:

Drying Time:

When talking about drying time in this section, this is defined as surface drying, not the complete drying throughout the ink jet layer. Investigations have revealed that even after two hours an ink jet layer is not completely dry, even if it is only coated thinly. This effect is a direct consequence of the ink property. At this point, one must remember that ink jet inks - irrespective of dye-based or pigmented inks - are formulated to prevent plugging of the printing heads from rapid ink drying, and, therefore, contain solvents of low volatility. This situation is an important aspect in formulating functional inks, but it does adversely affect the formulation of ink jet layers regarding drying time.

In a normal production process, the time interval between printing on the ink jet material (partially with high color loadings) and the next process steps (winding etc.) is typically no more than ten minutes. But after this time, a maximum of only 20% of the solvent (predominantly water) of a dye-based ink has evaporated. Therefore, it is very important, on the one hand, for an ink jet coating to be able to take up large amounts of water and solvent, and still show the performance of a dry layer in subsequent application. Only many hours after printing is an ink jet layer really completely dried. Drying properties can be improved by using hygroscopic binders. These components absorb water and solvent very well, but also absorb humidity from the ambient air after printing. In such cases, the dried colors may "bleed out" by absorbing water. Another aspect of incompletely dried layers that needs to be addressed is anchorage on the polyethylene layer where under certain circumstances during lamination, the printed layer can shift on the PE layer by the applied pressure. The importance of drying time will strongly increase in future. The new generations of printers that are primarily aiming at ever faster printing time and throughput will make the drying properties of ink jet media a key selection criterion. Drying systems are available with these printers already today, it is true, but the real breakthrough for new markets with ink jet printers in the large format segment will only become possible with still more productive equipment. Since the measurement of drying is mostly subjectively assessed in the marketplace and is adjusted to the production conditions, the rule of thumb stands that the paper should feel dry to the touch at the latest before it comes in contact with the floor or is wound up. Different ink jet papers have matting agents in the surface so as to improve drying, but this may sometimes lead to problems in the lamination process (formation of bubbles, formation of spots).

Quality Criterion:

Banding and Bleeding

Banding:

Banding is defined as streak formation when printing full density areas. In order to explain this issue, it is important to mention that ink jet drops are distributed in a random pattern by the raster image processor (RIP). In spite of this random distribution, there may be repeats of printing patterns in uniformly printed areas. Also, streaks may form as a result of print lines overlapping at the end of a print line adjacent to the next line. There are materials which tend to aggravate these effects and thus lend themselves to "banding", and others which compensate this phenomenon better. This matter shows additional complexity by the fact that also the different types of printers and inks have an influence on banding. Therefore, it is not always certain that a successful optimization of the ink jet layer for one type of printer will simultaneously be successful for another one. Thus, only the most "universal" material has the best chances of market success.

Bleeding:

Bleeding is defined as the diffusion of a color ink into a directly adjacent color spot. The occurrence of "puddles" and the spreading of different colors into one another is strongly determined by the type of printer, the inks, and the type of ink jet media.

To prevent both effects (Banding and bleeding), it has been found to be beneficial, if the rate of absorption of the ink jet inks by the layer, directly after impingement of the ink drops, is very rapid. In this way, the formation of high liquid amounts on the coating is prevented which otherwise would detrimentally spread into bigger drops and puddles. The non-uniform absorption of inks in the layer causes the surface to become dull at areas with big drops so that the gloss which the material had before printing is diminished.

Conclusion

To summarize as a conclusion of the quality criteria discussed above: An ink jet paper cannot possibly satisfy all quality criteria to the same degree. There will always be quality areas where different materials have different strengths and weaknesses. In spite of this interdependence of quality criteria, research must continue to develop an optimum overall formulation in order to ideally provide the benefit to the end user to use just one high quality ink jet material for different types of printers and different types of ink. In addition, it would be desirable to improve the test methods for quality which in most cases tend to be rather subjective so as to standardize them by using technically and scientifically reproducible methods.