The Use of Inkjet in Packaging Applications

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Abstract

There are several unique features in inkjet, which makes it almost the perfect printing method. For example, it is the only contactless printing method, so any substrate – flexible, rigid or fragile – can be printed. It is also an additive method, which means that multilayer structures or even 3D objects can be built, so many new applications for example in the areas of bio- and nanotechnology, decorative and fabrics printing, electronics, mechanical devices and combinatorial chemistry have been researched during last years.

In the area of conventional printing, inkjet is also gaining ground rapidly in the application areas like wide format graphics, direct mailing, textile printing and high quality publishing. One of the most potential areas for inkjet is the packaging applications.

In the packaging sector, inkjet has traditionally been used in the coding and marking applications. The lack of adequate print quality has prevented its use in the consumer packages, but now the situation is rapidly changing. This is due to the very fast development of inkjet printing head and ink technologies. VTT has actively been dealing with inkjet packaging projects for more than twelve years. In this article, findings of VTT's packaging research projects have been presented.

Introduction

The aim of this paper is to review the many aspects of using inkjet in package printing. There is multitude of reasons why inkjet is the ideal printing method of the future – even in very challenging packaging applications. The packaging area is special, because there are - keeping in mind that there are also a wide diversity of products in publication area – huge amount of applications, (product and logistical) demands, package forms and sizes, (packaging and printing) materials, (printing, converting and packaging) production lines, print quality requirements, food contact challenges, regulations, strict demands of legislation and so on. This makes the packaging area very difficult to handle, especially when we talk about on demand short run production enabled by a very flexible inkjet printing method. This is because the operations model of the area are still new and often under development. But due to the very fast development of inkjet printing head and ink technologies, all new solutions will also be seen in packaging industry in the very near future. VTT has actively been involved in inkjet technology more than fifteen years and packaging projects for more than twelve years. In this article, some key findings of VTT's packaging research projects are presented.

General Trends

Shorter delivery times, larger selections and smaller product quantities are general trends in packaging production. It is also important to develop packages to have better product information, a more visible trade mark and more selling appearance. /1/

One important function of packaging is to be an information source. Consumers need the information of the packed product, but information is also needed for identification and logistical needs. On one hand, good readability of information is crucial in consumer packages, but on the other hand there is a constant pressure to add more and more information on packages. This is because more product specifications and better product traceability are today required by consumers and authorities. But the area of information is very limited on packages. /2/

There are also needs to add functional properties to packages. These intelligent features can for example be special coding methods, which carry information in denser form, optical indicators, which monitor changing conditions inside or outside of package or printed electronics, which can be used as entertaining or anti-tampering devices.

Inkjet technology can be utilised to find solutions for all of these challenges. It can also bring extreme flexibility to package production chain and the whole production can be transformed from storage production into on demand production, in which the production of packaging or the whole product does not start until the order has been received. This model allows customised packages, means shorter delivery times, decreases material waste, minimises storage, shortens production chains and gives possibilities for new kinds of products and business opportunities. /3/

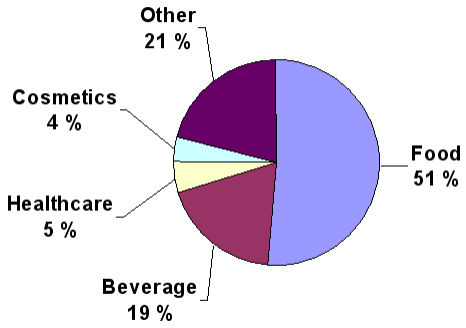

Figure 1. Global packaging end use market shares according to Rexam & Pira estimates /4/

Packaging Sectors

Consumer packaging is the packaging in which product is sold to consumers. Main consumer packaging sectors are food, beverage, healthcare and cosmetics. Estimates of the shares of different packaging sectors are shown in Figure 1. Each of the packaging sectors includes many different product groups. For example, dairy food is the biggest product group in food sector. Packaging sector is expected to become more fragmented and broader range of packaging will be needed. Packed products will also be more tailored and product life cycles will shorten. This requires faster response times and more flexibility from package production and printing. /2/

In addition, supply chains have complex demands e.g. widening range of products, shorter life cycles of products, shorter delivery times, extending distances and outsourcing. With all this in mind, packages, especially transport packages, have an important role for logistic improvements. Packages role in increasing the performance of logistics regarding e.g. lead times, ergonomics, information and environmental aspects is substantial. /2/

Packaging Materials

The main packaging materials are paper and board, plastic, metal and glass, as well as wood, which is mainly used in other types of packaging than in consumer packaging. Estimates of the shares of different packaging materials are shown in Figure 2. The packaging sector is mainly dominated by paper based and plastic materials and these packaging materials are competing of major material share in packaging. According to different estimates both account around 30 to 38 % of the total market value /2/.

The unique properties such as renewable resources, cost-effectiveness, excellent printability and versatility are the benefits of paper based packaging. Plastic, on the other hand, has advantages such as lightweight, flexibility and easiness to process. The combination of different packaging materials, such as paper with plastic or aluminium, allows manufacturers to combine the properties of different materials in one single piece of packaging. /2/

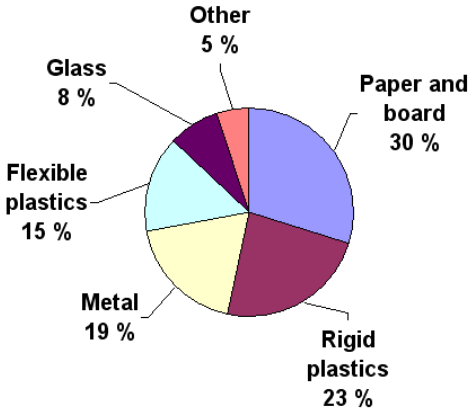

Figure 2. Global packaging material market shares according to Rexam & Pira estimates /4/

Inkjet Development

Inkjet has some special features, which makes it a unique printing method. First of all, inkjet is the only contactless printing method, so many kinds of rigid, flexible, smooth, rough and even 3D substrates can be printed. It is also an additive method, so it can be used for example in printing of multilayer electronic circuits. Inkjet has also very low material consumption. Due to the development of fixed array inkjet heads, it has potential for high speed and quality at the same time. Inkjet is also a very scalable technology from the desktop printing to the printing plant floor. It is also a very compact technology, because the main part of the technology is inside the printing heads. But inkjet is still at the very early stages of its technological and commercial development, so rapid progress will be seen also in the future. /5/

Inkjet is the only technology that has potential to challenge the conventional printing methods in terms of productivity and quality, while at the same time it offers the flexibility of digital printing. Until today inkjet has mainly been used in the applications, in which any other printing method can't technically and/or cost-effectively be used like in the areas of wide format printing, coding, decorative printing, direct mail printing and addressing. But today inkjet is gathering pace to penetrate into all new markets like high quality publishing. /6/

The overwhelmingly biggest business area of inkjet is wide format graphics printing, which means both flatbed and roll printers wider than 24 inches (Figure 3). Hundreds of inkjet printers are commercially available in the market today. Another important sector is direct mail and transaction printing, where personalised consumer documents are printed with very high speed from a database. Coding is the oldest industrial application area of inkjet. Addresses, expire dates and codes have been printed on publications products and packages for decades. The relatively new areas for inkjet are decorative, textile and package printing. The market volume of these applications is still small, but the area is expected to grow very rapidly. Because inkjet is a contactless printing method, it can also be used in many special applications like in deposition of materials in printed electronics, DNA research or medicine. /6/

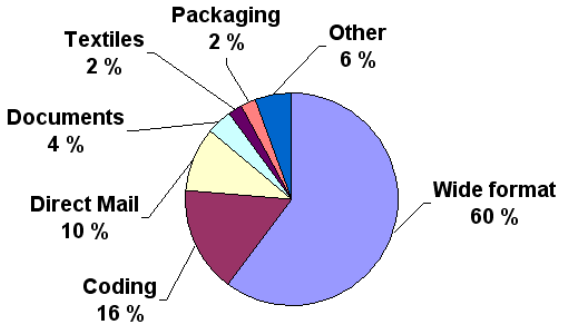

Figure 3. Global industrial inkjet integrators market shares according to I.T. Strategies /6/

Packaging Application Areas

There are several market segments, where inkjet printed packages are used today. The most important area has so far been labels and tags, but also point of purchase materials have been inkjet printed. This derives from companies will to get rid of high volumes of pre-printed labels that require stocking and inventory. Other quite new areas are corrugated board, folding carton, flexible packaging and 3D containers.

Labels

The label segment is a particular success story for inkjet printing. This was the first packaging application area, because the narrow web printing of labels was technologically the easiest area

to apply the first fixed array inkjet heads. Label printing does not even need sophisticated converting machines. Nowadays many label printing presses with compatible machines, inks and substrates are available. These are especially designed for short to medium run production and often to complement the conventional higher volume label printing presses. /6, 7/

Corrugated Packaging and Folding Box Board

The corrugated packaging and folding box board printing has traditionally been high volume production done with robust printing methods like rotogravure printing. These materials can be used both consumer and transportation packages. The area is challenging, because most folding carton operations employ several printing and converting processes. Nowadays there are inkjet machines for corrugated and folding box board, which can handle large and thick carton board sheets with high speed. These machines can compete with flexography and screen printing in short run lengths. /7/ The development of the area is still at a relatively early stage. There are certain, like pharmaceutical and cosmetic industries, which have adopted the inkjet technology very rapidly even into their production environment. This is due to the logistical challenges in printing of wide variety of short and medium run packages. Very impressive cost and time savings have been reported, when production strategy has been transformed from storage production into printing on demand. Many other applications are in operation or under development for a variety of applications but few are in the public domain.

Flexible Packaging

Usage of flexible packaging has increased during years, often at the expense of other packaging media. Flexible packaging has many similar features than labels, so it is also technically adaptable to a packing line incorporating variable data. Again, pharmaceutical industry has been the first one to utilise inkjet technology in their flexible packaging production. One potential application has been the printing of pharmaceutical blister backs. The food sector has also been interested in using inkjet printing for promotional printing as a valuable tool in capturing customer interest. /6, 7/

Container Printing

There is a tempting possibility for inkjet printing directly onto plastic, metal or glass containers. This would save money and help avoiding problems caused by labeling in production. There are systems available for printing directly onto containers of any shape /6, 7/, for example beverage cans, but some can manufacturers have also built their own solutions for their production plants. Also many other industries are interested in direct decoration of containers and even products, because of the logistical benefits of the approach.

Motivation, Challenges and New Possibilities

Reasons for early adopters of digital printing in the field of packaging are many. Information that VTT has gathered from real on demand package printing cases tells that among companies adopting digital printing, conventional methods were felt to be unable to accommodate changing requirements for more flexible and customised offerings. More flexible package production is nowadays needed, because of very rapidly changing consumer behavior. Flexibility is also wanted in order to print different language versions, barcodes, logos, images and marketing messages onto product packaging while reducing costs and lowering product lead times. In addition, with various carton sizes that can make hundreds of print variations per carton size. Allowing making changes in packaging design at short notice and without incurring additional printing costs is desired. Also ecological questions are getting more and more important all the time. /1/

Printing variable data

There are two main utilisation areas, dictated by the present level of digital printing technology, in which variable information printing on packages can be implemented. In the first case, the whole package is printed digitally, so that every printed package can be 100 % different. Another way to utilise digital printing in packaging production is to use inkjets to add variable information onto pre-printed packages. Several hybrid printing presses, which utilise both conventional and digital printing methods, are introduced. Inkjet heads can also be integrated in a packaging line before or after packaging. In any case, each interface and procedure must be carefully pre-organised so that the actual work flow will go smoothly. /3/

In digital package production, it is also important to understand that digital printing does not eliminate the need for graphic reproduction. In fact, variable data printing adds complexity to an already complex process. /3/

Converting

One bottleneck in the digital package process is still converting, although there has been rapid development also in this area during last years. Many converting stages are needed for packages after printing, such as scoring, die-cutting, varnishing, folding, gluing and filling. These stages should be integrated as an inseparable part of the digital work flow to avoid expensive manual work and to gain the greatest benefits from digital package production. Because the digital manufacture of packages is a new concept, there are only a limited number of suitable alternatives for most packaging applications. For this reason, converting machines must often be developed or at least tailored as a part of a digital manufacturing line development project. VTT has actively participated in projects to develop digital package production systems. /3/

Material Questions

Inkjet printing sets strict demands on the printing material, because the image is created directly onto the surface of package. The print quality will decrease dramatically, if ink flows on the surface of coated carton or spreads in the capillary network of uncoated carton. These phenomena are especially crucial in high-speed ink jet printing where there is no time for evaporation of solvent. A better knowledge of the basic mechanisms of the dynamic interaction between ink and paper is needed to produce more reliable and appropriate quality specifications for printing surfaces. A unique approach to this problem is the laboratory-scale testing environment developed by VTT for the high-speed imaging of inkjet drops. /3/

The rapid development of UV curable inks has given solutions for these challenges, because they offer rapid curing and

this way it is possible to print directly onto difficult substrates like uncoated media or non-absorbent surfaces. Some inkjet presses use primers, so that good printing quality can be achieved even with paper grades designed for conventional printing methods.

Product Safety

In general product safety issues are related to food contact materials. Actually these demands do not concern only food packages because for example pharmaceuticals, medical ware, toys and electronics must also be safe. Because food packaging is a part of the food production chain, the safety of food packaging is equally important as food safety. Many regulations are pointed to the food packaging materials intended to food contact.

In inkjet printing many different kinds of printing and ink systems are used and hundreds of ink formulations are commercially available. The relationships of ink components are complex and may vary from ink to ink. /8/ This makes it difficult to evaluate inkjet systems suitability for food production. As shown earlier in Figure 1 food packaging accounts for more than half of the global packaging end use market shares. To get into this huge business area, inkjet developers should take this question under special consideration.

The production of safe products begins with careful selection of materials, continues by ensuring uniform conditions during manufacturing and is finalised by testing the final product. The food-grade evaluating of digitally printed packages requires information of the specific materials used in printing. All the materials used in food package manufacturing have to be suitable for the final product. These include inks, primers, coatings, lacquers etc. When choosing an ink for food packaging the food-grade quality needs to be checked individually every time. In addition, it should be realized that the printing ink manufacturer cannot ensure the safety of printed package alone – the printing process affects the safety too.

Cost Factors

An essential part of VTT's research has been to evaluate economical viability of packaging manufacturing when using conventional and alternative methods. These case studies are usually selected in co-operation with VTT and a partnering company. This is because to assess the viability and impact of digital printing of packages a case-specific evaluation is necessary.

Fixed costs are lower in digital printing than in traditional printing methods, because, for example, of shorter make-ready time and lack of printing plates or cylinders, but traditional printing becomes more cost-effective as run lengths increase. In digital printing, printing itself often accounts 50% or more of all costs. So relatively slow printing speed, in comparison with conventional printing, combined with colour limitations and maintenance requirements in continuous production are some of the main constrains in the case of digital printing in packaging sector. /9/

One of the most significant factors affecting costs is the share of compact, solid print area, so this should be realized when designing packages for digital production. /9/ According to VTT's estimates over one hundred thousand four colour labels can be cost-effectively printed with inkjet when compared to conventional printing methods. Improvements in inkjet printing technology together with declining colour and equipment costs should still change the situation drastically. /1/

Codes, Indicators and Electronics

There are several ways to add new functionality to packaging utilising inkjet printing. These elements can be used for identification, anti-counterfeiting, logistics or information transfer and entertainment for consumers. VTT has for example developed systems, in which camera phones are used for reading 2D codes. Based on our research results, several applications for the mobile phone readable inkjet printed codes have been identified. /10/

Another application area for camera phones is inkjet printed optical indicators. Optical indicators are based on active compounds, which undergo a definite colour chance depending on changes in exposure conditions. VTT has for example developed a reversible heat indicator based on thermochromic inks. The action of the demonstrator can be shown by pushing it against a hot coffee mug. When heated, the indicator becomes transparent. When the indicator field starts to cool down, frames can be taken with a camera phone and special mobile phone software translates the colour values into a temperature, which can be seen on the display of the mobile phone. VTT has also developed several food quality and humidity indictors. /11/

Yet another possibility to use inkjet in packaging applications is to build printed electronics. VTT has for example developed and fabricated a game card demo that consists of six ink layers all inkjet printed on two different paper grades laminated together. By pushing alternative answers the player can see if the answer was right for the given question. The action is based on resistor that heats up thermochromic, which become transparent and displays the answer. By building this demo it was proved that this type of concept works even when printed on paper substrates, providing the quality potential of the paper is matched to the complexity of the elements to be printed. /12/

Conclusions

Numerous aspects have to be taken into account, when digital package printing applications are planned. On the other hand inkjet is a unique printing and manufacturing method, which gives possibilities to build solutions, which can not be done by any other means. Also it has to be remembered that the inkjet is only in the beginning of its evolution and revolution – the future possibilities of the technology are only limited by our imagination.

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Author Biography

Jali Heilmann (MSc.) is a Senior Research Scientist at VTT. In his Master of Science thesis, he developed new research methods for color electrophotography and he is also very well acquainted with other digital printing technologies, especially inkjet printing. His current research activities also incorporate technical solutions, uses and appliances for smart packages, printed electronics, electronic book technology and other new information carriers like flexible displays. He has also worked as a Visiting Scholar at the University of California, Berkeley.

Elina Rusko (MSc.) works as a Research Scientist at VTT where her current research work focuses on packaging development and digital printing applications. She graduated as Master of Science in Technology in 2006 from the Helsinki University of Technology's Forest Products Technology Department where she studied Packaging and Paper technology. Her Master's thesis focused on the development of value added consumer packages.