Digital Multicolor Printing and Computer to ... - Technologies Evolution or Revolution in the Graphic Arts Industry?

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Abstract: The observation and analysis of the state of the art in the graphic arts industry regarding demands on high quality multicolor products - especially short run color, the automation and digitalisation in all sections of the production flow for producing printed products (prepress, printing, postpress), the influence of novel printing technologies (the Non-Impact Printing Technologies) in the traditional commercial printer market leads to the questions: "Is there a revolution in the graphic arts industry and is a survival battle running?" The answer will be concluded on a technical and economical basis.

Based on the description and comparison of conventional and NIP-technologies, the positioning of the several printing technologies regarding run length, print quality and total costs per sheet will be explained.

Potential for improvements of the conventional printing technologies and an estimation for new products basing on direct imaging and NIP-technologies will be worked out.

Computer to ... - technologies like computer to film, - to plate, - to press and - to print are defined and described in relation to the newest products. Especially an overview is presented with a description and comparison for the direct imaging computer to press/to print multicolor printing equipment which are launched and introduced in the market.

All in all it will be shown that there are magnificant chances and challenges in the printing industry, a wide range for innovations and synergies is available.

Remark:
The following report bases on the author's manuscript of his TAGA 95 Keynote Speech, originally not prepared as a proceedings paper. On request it will now, after some slight modifications, be included in the proceedings in a short form. Parts of the content are described more in detail in the reference Kipphan (1995), presented at an IS&T/SPIE Symposium on Electronic Imaging.

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1. Introduction

The goal of this presentation is to give an overview about the state of the art in the graphic arts industry regarding digital printing technologies and their relationship to the conventional printing technologies.

It will be shown that digital multicolor printing has it's focus not only on the printing process itself, digital printing means the digitalisation within the whole production flow for producing printed products.

As an introduction, an overview is given about the offset printing presses today used, state of the art presses, for example, as produced by Heidelberg. The Speedmaster SM 102 SP+L, is a 40 inch, 6 color sheet-fed offset press with perfecting, coating unit and dryer; the production speed is 13000 prints per hour (the speed will be improved with the new DRUPA-models).

There are also small size presses available, like the Quickmaster 46, a brand-new A3-size single color offset press, with the option for a second color head.

As an example for the press manufacturer's and their customer's confidence into the future of printing, last year a completely new product line called Speedmaster SM 74 - a medium size offset press - with a production speed of 15000 prints per hour was launched.

As an example for web offset presses the M-600 from Heidelberg Harris with a production speed of 50000 signatures per hour should be mentioned.

The demand for printed products is rising worldwide. The requirements on printing quality and the demand for multicolor printed products are increasing. The high quality level of printed products is an important part of the high quality of life. Nobody likes to miss printed products - especially high quality multicolor prints -, but nobody likes to pay too much for them. These are driving forces for innovations and improvements in the graphic arts industry.

2. Production Flow for Producing Printed Products

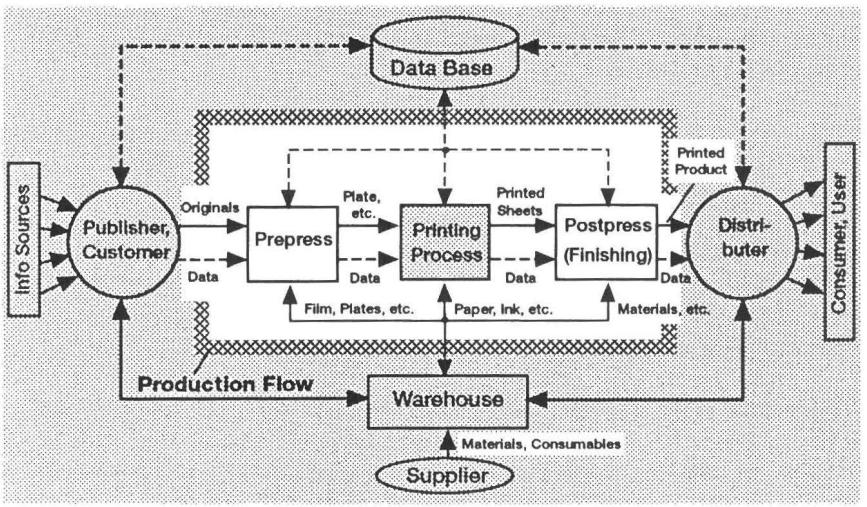

Figure 1: Production Flow and Streams of Material and Data for Printed Products

The product is created by a publisher using several sources with different kinds of information. Based on originals and digital data, the production process can be started.

The production flow can be subdivided into 3 steps: prepress, printing process and postpress (finishing).

The final product will then be distributed to the consumers.

Between the 3 sections prepress, printing process and postpress there are flows of material and data. In additon, a connection to warehouses and data bases must exist.

3. Automation, Digitalisation and Networking

In this chapter, some activities and trends for automation, digitalisation and networking are described more in detail.

For an economical and lean production process, special systems for material and data transmission must be used. Sheet-fed printing presses have to be prepared for non-stop production and automated pile transportation. AGVs, (Automatic Guided Vehicles) can be used for optimal transportation of paper piles on standardized pallets.

State of the art printing presses are designed with semi-automatic, i. e. toolless plate changing systems; sometimes also for fully-automatic plate changing, like the Speedmaster SM 102 with Multiplate (the multiplate cassette is prepared for the storage of 6 plates).

State of the art printing presses are connected and equiped with measurement, control and presetting systems like the CPC-System from Heidelberg.

The several departments inside the production flow for producing printed products can also be connected via networks and production management systems. For example, the CPData system from Heidelberg has been desiged for this purpose. The pressroom is connected with the prepress and also with the postpress/finishing department.

Especially in the prepress area digitalization has led to many useful changes.

For using digital printing presses or other computer to ... - technologies, the page to be printed must be completely prepared as a data file.

The content of the page is divided into image and line art. The image is digitized by a scanning process, image transformations are done by image processing, and color separation is made in order to prepare the printing process. The line art can be subdivided into type and graphics; designing and word processing must be done. After using special digital equipment and sortware packages at the end of the workflow the final digital page, to a large extent standardized in PostScript format, is created.

This file can now be used in several types of output equipment, for example in a digital printing press. Via a Raster Image Processor the PostScript file must be transformed to a bitmap, depending on the output device specifications and the required print quality and imaging/screening technology.

4. Print Quality

For the comparison of different printing technologies described later in this report, we need a short definition of print quality.

For multicolor printed products, the most important quality influences are the color with its positioning in the color gamut, the color register and the resolution for reproducing fine details.

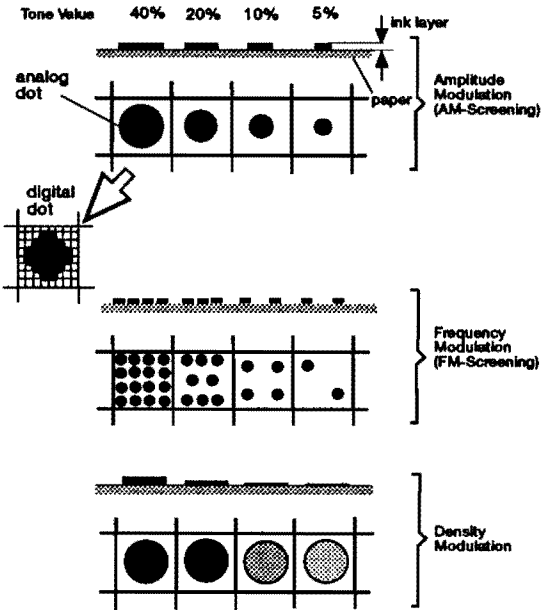

Figure 2. Technologies for Creating Tone Values

For creating halftone images, the conventional technique is the "amplitude modulation (AM) screening technique", where the dot size within a raster cell of consistent size is changed, as shown in Figure 2.

The "frequency modulation (FM) screening technique", also called "stochastic screening", is based on a small dot with a consistent diameter, but different distances of the dots to each other.

Printing technologies which provide the possibility to ink each dot with a different thickness of the ink layer enable "density modulation", that means printing more than two grey values per single dot.

The break-through of frequency modulated screening was especially supported by the digital imaging techniques. In the meantime a lot of different algorithms were developed and launched into the market.

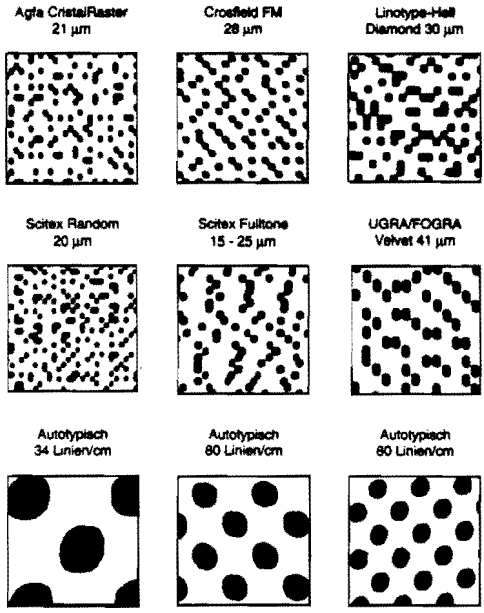

Figure 3. Various FM-Screening Methods in Comparison with AM-Sreening Tone Value 25 %
(Source: IFRA Special Report 2.13/Oct. 1994)

The major advantage of FM-screening is, that special structures of the original image can be reproduced without artefacts - like Moiré and rossetts - and that the multicolor print is less sensitive regarding misregistering. With FM-screening also a better reproduction of small details is possible.

High fidelity color is a further method for improving the print quality. In addition to the process colors cyan, magenta, yellow and black further colors are printed in order to expand the color gamut.

Mills Davis (Davis Inc.) and Donald Carli are powerful promoters of this technology. For example, in cooperation with DuPont, the HiFi Color System "HyperColor™" has been developed, using a special software/strategy for color separation.

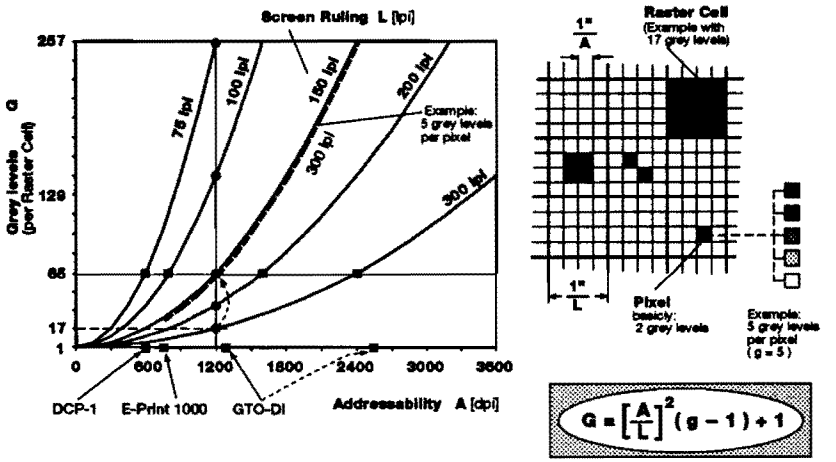

Figure 4. Resolution Specifications for Digital Imaging

In digital printing, the dot is created by several small pixels. The addressability is the measure of how close together the pixels can be positioned. The screen-ruling defines the resolution of the original image, but also the size of raster cells and in this way the number of possible, different tone values - grey levels.

Basically one pixel has only two grey values, that means the picture element is inked or not. Special techniques enable the creation of more than two grey values per pixel, explained before as density modulation.

5. Printing Technologies

Figure 5 shows the most important printing technologies, divided into two groups - conventional (traditional) printing technologies and non-impact printing (NIP) technologies.

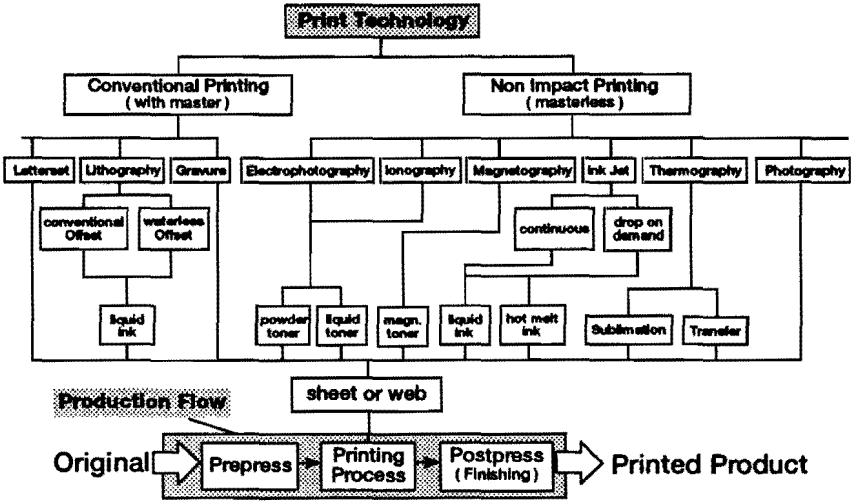

Figure 5. Print Technologies and Production Flow for Multicolor Printed Products

The conventional printing technologies like letterset, gravure and lithography/offset work with a printing forme.

The most successful conventional technology is offset/lithography. Conventional offset uses ink and water. The physical basis for this technology are the different surface energies of the materials which are in contact: water, ink and plate materials, rubber blanket and paper.

During the last years, waterless offset begins to spread through the market. Waterless offset only needs ink. It is possible with special printing plates and special inks. There is no doubt that waterless offset has potential for spreading more and more in the market. However, also in a long-term vision, waterless offset will not replace the conventional offset due to several reasons, i. e. when using lower quality paper there is a high risk to generate hickies.

Newer versions of offset presses are prepared for using waterless offset (for example the SM 74 from Heidelberg). They are equiped with a cooling loop for conditioning the inking unit with a stable temperature.

Non-impact printing technologies have the basic advantage that they do not need any job-specific permanent printing forme. However, the several technologies need special inks and normally it has to be printed on special paper.

Technologies which are realized in serial products are:

- electrophotography,
- ionography,
- magnetography,
- ink jet,
- thermography and
- photography.

The principle of electrophotography is that via optical imaging processes - for example with a laser beam - a latent image is created on a photoconductive surface. The charged surface takes over the ink - for example powder toner - from the inking unit. After printing is finished, a new image must be built up again, a cleaning process is done before. The toner must be fused on the paper with heat and pressure.

An example for a printer using this technology is the "Digital Color Copier" from Ricoh (400 dpi) with two different design concepts: satellite and tandem (unit) design.

With ink jet technology, the ink can be transferred directly onto the paper via nozzles. "Continuous" or "drop on demand"-techniques with liquid or hot melt inks are realized in serial products.

An example for continuous ink jet is the "IRIS 3024 Color Proofer" (300 dpi).

A special technology is used in the new "Phaser 340" from Tektronix (300 dpi); drop on demand ink jet technology in connection with solid inks. The ink is melted before jetted onto a drum as an intermediate surface - collected as 4 color separation before printed onto the paper.

There are further NIP-technologies: thermography with thermotransfer or thermosublimation.

For example, the "Laura" full color high speed printer (Datametrics Corp.) bases on thermotransfer. There are ribbons for the several colors and with a thermal imaging head the ink is transmitted from the donor ribbon to the paper surface (300 dpi).

As an example for thermosublimation, the well-known "Rainbow" desk top color proofing system, manufactured by 3M, using the imaging engine from Mitsubishi, can be mentioned (300 dpi).

An example for the non-impact technology photography is the "IntelliProof/Color Setter 4400" from Optronics, an Intergraph Division. With three lasers (blue, red and green) the color image is produced on special photosensitive paper (4000 dpi).

6. Computer to ... - Technologies

If the page to be printed is completely available as a digital data file, there are various ways for further processing: computer to film, computer to plate or computer to press.

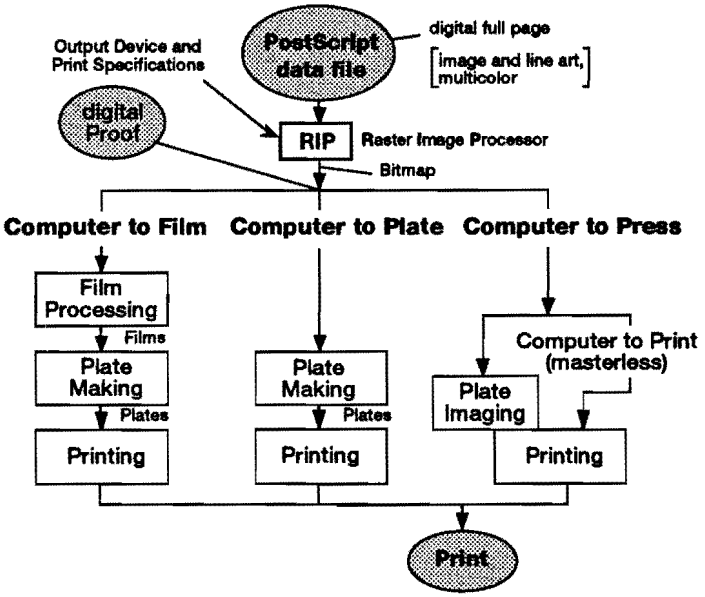

Figure 6. Computer to ... - Technologies

In the case of computer to film the digital data is transferred to a film image setter via a raster image processor. The film is made without manual stripping and assembly work. Computer to film is state of the art and used in many pre-press departments.

In the case of computer to plate the intermediate step of making and handling the film is eliminated. The digital data are directly used for imaging the printing plate.

In the case of computer to press the digital data are transmitted directly to the printing press. Here a difference is made between two possibilities.

In the case of computer to press the printing plate is created within the printing press; afterwards job printing can start immediately.

If a press is used which works on the basis of a non-impact printing technology - for example, electrophotography or ink jet -, no permanent, job specific printing form must exist, - computer to print is realized.

7. Computer to Plate

In the recent past, high performance computer to plate equipment, for small and large plate sizes, have been on offer. The break-through was accelerated with the development of many laser sensitive printing plates, aluminium based for high quality and high run lenght.

There are 3 basic design concepts for computer to plate equipment: external drum, internal drum and flat-bed design.

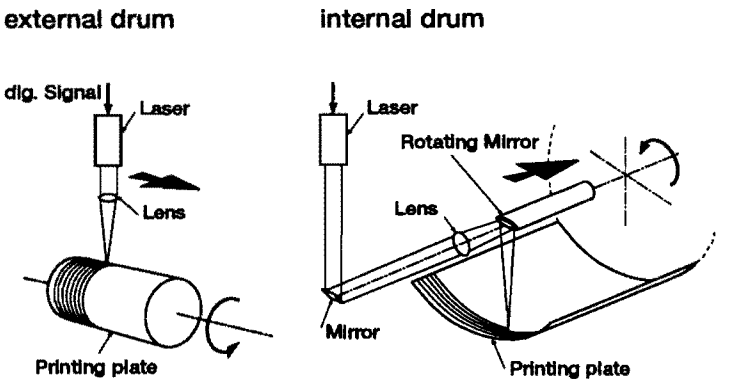

Figure 7. Design Concepts for Computer to Plate: external and internal drum

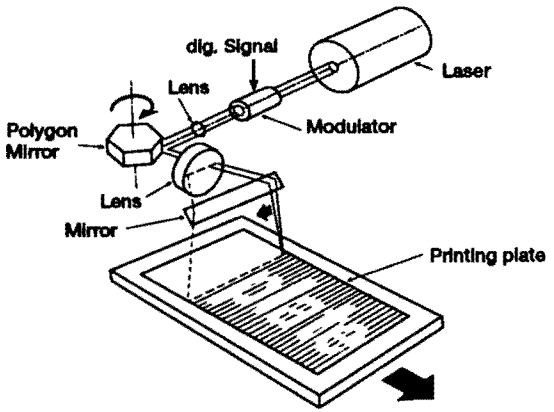

Figure 8. Design Concept for Computer to Plate: flat-bed

In an external drum system, the plate is clamped on a rotating cylinder. A moving single or multibeam laser imaging head writes the information onto the surface.

In internal drum systems, the plate is fixed in a shell, the imaging beam rotates with high speed and normally the imaging head additionally moves in lateral direction (also the movement of the plate holding equipment is realized).

In flat-bed systems, the plate is fixed on a flat table. The image is set by moving the imaging beam and the plate-holding table.

In the following only a selection of plate image setters is mentioned, designed for imaging aluminium based plates for high run lengths with high resolution.

Internal drum technique is realized, for example, by the equipment "Crescent/42" from Gerber and the brandnew "Plate Rite PI-R1080" sytem from Dainippon Screen.

External drum technique is realized, for example, with "Platesetter 3244" from Creo and "Color Setter XL 4000" from Optronics.

Flat-bed technique is realized, for example, within the equipment "Raystar" from Scitex.

Well-designed computer to plate systems can be connected with each state of the art conventional offset printing press.

The mechanical interface is the plate-register system for fixing the plate on the plate cylinder within the printing unit.

The digital data file of the complete page can be used in addition to plate imaging via an electronical prepress interface, for example, for ink key-presetting and further adjustment and presetting operations.

During the last IGAS exhibition in 1993 in Tokyo, Sony presented a digital press with the trade name "Gravuan". This is not a digital printing press as somtimes mentioned, it is a system consisting of a stand-alone computer to plate equipment for engraving polyester plates and a two color sheet-fed gravure press.

8. Computer to Press

In this chapter, digital multicolor presses are described which are available on the market, computer to press equipment producing with relatively high speed.

Let's start with the computer to press equipment GTO-DI, the digital direct imaging press from Heidelberg.

Heidelberg started with the delivery of this kind of presses in September 1991. This press was the first multicolor computer to press equipment and only after two years other manufacturers, Indigo and Xeikon, followed.

The GTO-DI bases on a conventional multicolor offset printing press in unit design. Using waterless offset, the space for the dampening unit could be used for the plate imaging unit.

Based on the digital data file, which describes the full page to be printed (PostScript-format) and is transformed via the Raster Image Processor into a bit map, inline in each printing unit the plates are imaged simultaneously; for example, with a resolution of 1270 dpi, full size A3, the imaging time is only 12 minutes.

The press produces at a speed of 8000 prints per hour. A wide range of paper stock and sizes can be used.

This first generation of the direct imaging press was equiped with an imaging head, based on spark erosion. For a lot of jobs, the plate imaging quality was good enough, but not good enough in comparison to "high quality offset"!

Two years later, since September 1993, the spark erosion imaging head was replaced by a new imaging system based on laser technology, developed again by the partner company Presstek in Hudson, New Hampshire. A big improvement in print quality has been achieved, now the quality is absolutely comparable with high offset quality.

The laser imaging head is equiped with an array of 16 laser diodes, each with a power of approx. 1 Watt. The dot size is 32 µm, the resolution can be changed from 1270 dpi to 2540 dpi. The plate is imaged by revolution of the plate cylinder and lateral movements of the diode array.

Now more than 100 GTO-DI presses are installed worldwide at customers and are in use.

The GTO-DI offset press is an example for a continuous evolution of printing technologies and equipment. New and traditional techniques are married for building up a new kind of printing system; no revolution in the press room, the basis is a well-known established technique.

If computer to press is designed without the need of a job specific plate, computer to print is realized. An example for such a multicolor press is the "DCP-1 Digital Color Printing Press" from Xeikon.

The used non-impact printing technology is electrophotography. Printing takes place on web on both sides.

The photoconductive surface on the drum is imaged with a high resolution LED-array. The addressability is 600 dots per inch and the number of grey levels per pixel is higher than 2 - presumably 16. A special fine-grained powder toner is used. After printing - directly onto the web - thermal fusing and cooling, the web is cut to get the final sheet.

The system is basically a 4-color press, with the option for a fifth unit. The productivity is 1050 A3-sheets per hour, 4 color printed on both sides.

When looking at a print sample with a magnifying optic, the characteristics can be recognized when using powder toner - sometimes small toner particles appear in the wrong position. The printed quality can be described as top copier quality.

The "E-Print 1000" multicolor press from Indigo is also based on electro-photography.

Imaging takes place through a laser diode array and a scanning optic onto a cylinder covered with an OPC-foil. The addressability is 813 dots per inch (exactly 320 dpcm). An especially developed liquid toner, called "ElectroInk", is used. Printing takes places on sheets. The transfer of ink to the paper is realized via a blanket cylinder, like offset printing (lithography).

The multicolor print originates through storage of the sheet on the impression cylinder and serial printing of the separations for the process colors cyan, magenta, yellow and black.

The production speed is 1000 A3-sheets per hour, 4-color, one side printed. The press is prepared for printing with 6 different colors or using - in addition to the process colors cyan, magenta, yellor and black - special liquids like magnetic ink or varnish.

The print quality is close to offset quality. However, there is still the restriction that the liquid toner needs special coated paper.

In February 1995, Indigo has announced its second type of a digital press called "Omnius", a digital web press with "one-shot" technology.

This press uses the same printing technology as the E-Print 1000. One-shot technology means that all 4 colors are collected on the blanket cylinder before the completed multicolor page is printed on the paper. The paper feed is designed for web material with a wide varity, especially for the packaging industry and label printing.

A comparison of the 3 digital presses - GTO-DI, DCP-1, E-Print 1000 - regarding total production time for jobs with different run lengths and total production costs per sheet (A3, both sides multicolor printed) leads to the result that the GTO-DI produces, for run lengths higher than approx. 450 sheets per job, with higher productivity, at lower costs and with higher quality than the other presses.

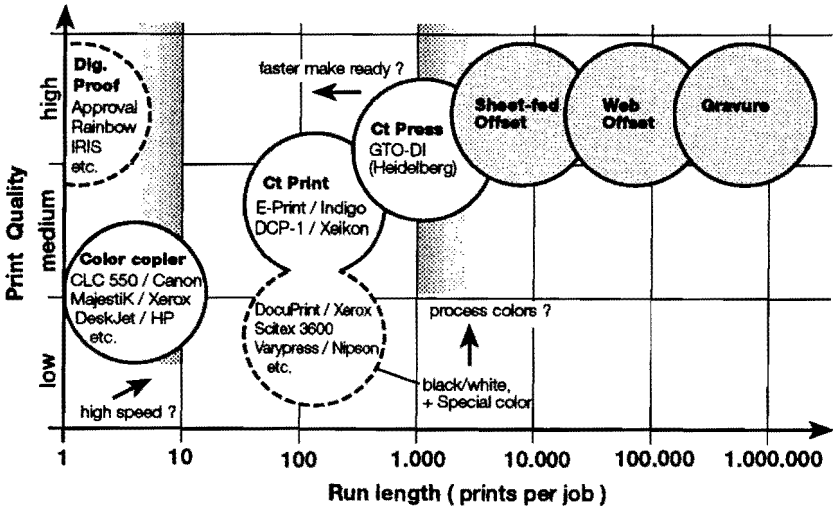

Figure 9. Positioning of Print Technologies for Multicolor Printing (including trends in development of digital printers)

When making a positioning regarding print quality and run lengths it can be recognized in Figure 9 that the conventional technologies, gravure, web offset and sheet-fed offset produce the highest quality and are very successfully used for high run lengths. Color copiers with low/medium print quality are used for producing only some prints per job.

We can recognize that there is a gap in the range from approx. 10 up to 3000 prints per job. In this niche, new printing equipment and technologies for short run color printing can be successfully positioned, especially computer to press equipment.

The GTO-DI with its high level of print quality is preferred for printing jobs with run lengths higher than approx. 500. The computer to print equipment from Indigo and Xeikon have their advantage at lower run lengths. The produced print quality is higher than the copier quality, but not on the level as the quality produced with conventional and computer to press equipment.

It can be clearly recognized that the several technologies have their own market and product segments. That means that the different print technologies complement each other rather than compete.

9. Further Digital Printing Equipment and Systems

For black and white printing or printing an additional color - for example, a special color in a company logo or in graphics - there are some high performance presses based on NIP-technologies for high speed production. For example:

- "DocuTech" (Xerox) using electrophotographic technology and powder toner,
- "DocuPrint" (Xerox), designed with two printing units, for printing a second color,
- "Scitex 3600 High Speed Printing System", based on ink jet,
- the new press "NIPSON 7000", based on magnetography,
- the system "ImageFast 180" (Delphax), based on ionography.

The systems mentioned before are at present not prepared for multicolor printing with process colors C, M, Y, K, but it can be presumed that there is potential for further developments.

There is another group of non-impact printing technology based equipment for producing high quality multicolor products. However, they are designed for low speed production, for producing digital proofs.

An example for this kind of digital printers is the Kodak "Approval" equipment (thermosublimation technique). Further digital printers are the "Digital Matchprint Color Proofing System" from 3M, the "Rainbow" (3M/Mitsubishi) and the "IRIS" ink jet proofing equipment, as technologically explained before.

10. Potential for Improvements and Future Trends in the Graphic Arts Industry

The three digital multicolor presses - GTO-DI, DCP-1 and E-Print 1000 - are examples for pioneer engineering. They prepared the market and encouraged other suppliers to build up further equipment for producing high quality multicolor printed products with high productivity.

There is a wide field for speculations and visions, especially regarding the use of NIP-technologies, and there are a lot of announcements for new products without detailed description.

For example, the "CLC-X", an announced high speed color printer from Canon; the first announcement was made in spring 94.

In fall 94, during a Non-Impact Printing Technologies Conference in New Orleans, a short view regarding a high speed engine from Fuji Xerox was given.

Scitex with their several ink jet technologies and general announcements expanded the area for speculations.

From Delphax several design concepts were explained with improved ionography and imaging techniques.

Interesting press concepts can be imagined in connection with rewritable printing formes/surfaces. With the realisation of such rewritable surfaces computer to press technology, as shown in Figure 6, could get a third possibility.

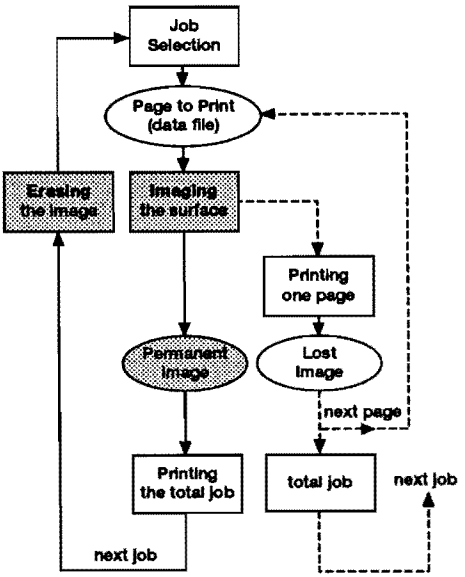

Figure 10. Computer to Press with Erasable/Rewritable Master

As explained with Figure 10, normally with computer to print, after imaging the surface and printing one page, the image on the carrier is lost and before printing the next page, a new image must be rebuilt.

Using rewritable surfaces with storing capability, the following production sequence is possible:
After imaging the surface, a permanent image is stored and the total job can be produced without repeated imaging print by print.
When the total job has been produced, the image on the surface can be erased and after job selection the new page can be imaged on the same surface without plate changing.

With this technology imaging can be done quite slowly - saving costs for high speed electronics, computing and imaging equipment; and after imaging high speed production can be started with the well-known advantages of using a master for continuous, equal quality page per page.

From the patent literature and conference presentations/publications, there are some ideas and concepts for doing this. One example is the possibility to use a special ferro-electric ceramic material which can permanently store a latent image, as described by MAN Roland in 1993 in Yokohama during a NIP-conference.

It will be interesting what will be announced or shown in the next time regarding digital printing systems, master based, but with erasable/rewritable surfaces.

Synergy effects from the NIP-technologies to the conventional printing technologies can be used for building up hybrid printing systems. For example, a NIP-technology like ink jet or a system with rewritable surfaces can be added to a conventional offset press as a separate additional printing unit for producing variable imprints, personalized products or segmented jobs. Digital hybrid systems are also possible if computer to press and computer to print technologies are combined.

11. Summary / Conclusions

Below some statements regarding trends in the graphic arts industry are listed:

- The future of printed media is not a question; the demand for high quality printed products is increasing. Electronical media and multimedia are not competing the print media, they are a further possibility for transmitting information besides the print media.
- The demand for higher print quality and more colors is still there.
- The run length is decreasing, a larger varity of printed products can be recognized.
- The conventional offset printing technologies have a lot of potential for future improvements, for example waterless offset and new screening technologies.
- Automation of production equipment is going forward in order to make the job for the operator much easier and improve the productivity and economy in print production.
- The digitalisation within the production flow is state of the art and more and more printers and publishers have their focus to invest in this digital technology and equipment.
- Networking for connecting equipment and departments within the production flow is going fast forward.
- Digital prepress production is state of the art.
- Computer to ... - technologies are spreading.
- Digital multicolor presses are not science fiction, they are already reality and in use. The foundation of more and more digital print shops can be recognized.

- Computer to plate and computer to press technologies are not in a competing situation. Computer to press is established for small size presses and computer to plate is preferred for printing based on digital data with large size presses, as a consequence of the investment costs for large size presses and the required flexibility for using conventionally or digitally produced plates, also regarding the offset printing technology - producing with conventional wet offset or with dry offset technique.
- The new technologies and equipment, as a consequence, need a change in education, training and qualification. In the future, the operator of the printing system will be more and more a data manager than a craftsman.
- The attention and requirements regarding our environment must lead to environmental-friendly products.

Figure 9 also contains information regarding potential for further developments in building up digital printers, as listed below.

- Digital color copiers can be improved in print quality and production speed.
- Black and white printers, special color printers could be improved for printing process colors.
- Computer to press equipment like the GTO-DI from Heidelberg can be improved for shorter make ready-times on their high quality level.
- The proofing equipment could maintain its position; but a shorter production time must be realized in connection with lower costs.
- Each of the several printing technologies can serve its own market segment.

To take part in the process of evolution and changes is a big chance and challenge for all the partners in the graphic arts industry. They need open cooperation and exchange of knowledge, experiences, ideas and complaints.

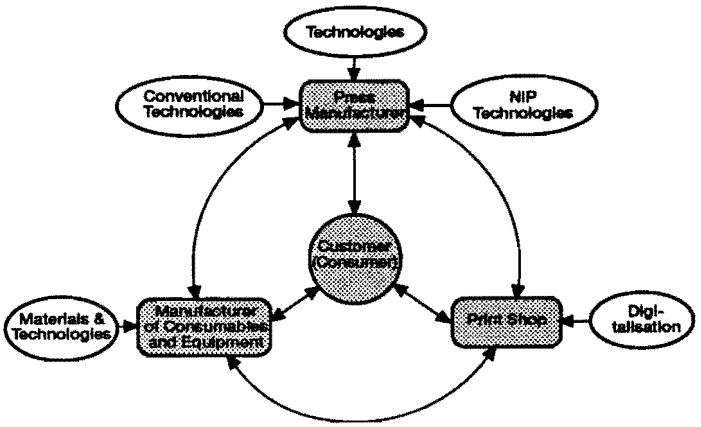

Figure 11. Innovation and Cooperation in the Graphic Arts Industry

The consumer of the printed product must be the common focus of press manufacturers, print shops and manufacturers of consumables and equipment.

In addition, there must also be a cooperation of technologies. Conventional and new technologies can and must be merged - well-balanced - to satisfy all the partners and mainly the users of equipment and consumables.

Communication and transformation are the guarantee for successful cooperation and a future with a high level of life quality, supported by high quality printed products.

The author has the hope that the given presentation has met the expectations of the auditorium and that the answer of the question in the title of his presentation "Evolution or Revolution in the Graphic Arts Industry?" was given step by step. Shortly summarized, the answer is:
There is not a revolution for all the partners in the graphic arts industry if they are prepared to recognize new possibilities and if they are in time to use new technologies and products in addition to the traditional technologies and to improve their activities; all producers, users and consumers can take part in a continuous evolution.

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