Industrial Flat Bed Printer Design

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Abstract

This paper looks at the design requirements of flat bed ink jet printers for industrial use. Various possible configurations are described and compared, looking at the implications for speed, print quality, and size of machine. Some of the engineering problems are identified together with possible solutions.

What are Flat Bed Printers For?

Flat bed printers are for printing rigid materials that cannot be handled by reel fed devices. Digitally printed point of sale posters and signs are often mounted on foam cored board or corrugated materials; printing directly onto these substrates saves time and materials. There are also specialist applications for flat beds such as dispensing reagents into micro titre plates, applying light emitting polymers onto glass to make OLED displays, and using thermoplastic resins to build 3D prototype parts.

It is not surprising that these very different applications have resulted in a variety of machine architectures.

Flat Bed Architectures

Ink jet printing requires relative movement between printheads and substrate, this can be done by moving one or the other, or both. The different arrangements are classified below.

Stationary Table

The printheads scan in both axes across a stationary table. Typically a router table with printheads added, examples are the Perfecta Sheetmaster, and the Lüscher JetScreen.

Scanning Printheads

The printheads scan in the printing direction, the substrate is indexed between passes. Typically a modified reel fed plotter. Examples are VUTEk PressVu and Aprion.

Scanning Substrate

The substrate scans in the printing direction, with the printheads indexing between passes, e.g. Inca Eagle44.

Stationary Printheads

The substrate scans in both directions, with the printheads stationary, e.g. MicroDrop AutoDrop and MicroFab jetlab.

Single Pass

The substrate moves past stationary printheads in a single pass, e.g. Ferro Kerajet. This requires enough printheads to cover the width of printing, but gives very high throughput.

Printhead Reliability

The reliability of ink jet heads can be drastically reduced by pressure fluctuations in the ink supply, because this disturbs the meniscus in the nozzle. These fluctuations can arise from vibration of the head or the ink supply tubing leading to the head, or simply acceleration of the ink feed system. Keeping the printheads stationary makes this much easier for two reasons, firstly the printheads are less likely to get shaken, and secondly the ink feeds will not be. Indexing the heads (Scanning Substrate) is less arduous than scanning the heads, because the index move is usually a short distance. As printhead frequencies increase, the printing speed increases and so these problems become more severe. The culprit is rate of change of acceleration, rather than acceleration itself. Introducing some compliance in the ink feed helps to smooth out rapid fluctuations, and avoid depriming nozzles.

Print Accuracy

Print accuracy depends on the print height and machine positioning accuracy, as well as inherent print head accuracy. Mounting one axis on another moving axis makes it difficult to maintain stiffness, and can lead to larger height variations and positioning errors. Mounting each axis to the fixed frame is easier from this point of view, especially for larger sizes and higher speeds and accelerations.

Scanning printhead designs either use friction rollers to index the substrate, or “walking beam” systems, this makes it harder to accurately control the index distance than for designs where the substrate remains attached to a table.

Print Quality

Print quality depends not only on the size of the positioning errors, but particularly how these errors are distributed. Using large numbers of passes with a lot of interleaving does not reduce errors, but it does make them much less visible, and hence increases print quality. This requires higher print speeds to maintain the same printhead frequency, easier to achieve if it is the substrate that runs at print speed rather than the heads. Of course the single pass architecture does not allow these techniques, and so is much more sensitive to printhead faults.

Curing

Flatbeds are designed to cope with specific materials, this usually means it is not feasible to tune the substrate to the printing process. Most flatbeds use solvent inks or UV cure inks so that they can tolerate a wide range of materials. Solvent inks dry by evaporation, rigid materials are often good thermal insulators so that drying cannot be assisted by heating from underneath as is often done for reel fed plotters. Long drying times not only make handling difficult, but may produce puddling in dark image areas. If this is combated by using more volatile solvents, then nozzle clogging is more likely. UV curing requires an intense UV dose within a short time of printing to prevent bleeding of the image. This means the lamp must be fixed immediately after the printheads, and so needs to travel at print speed in a scanning printheads or stationary table system. UV lamps tend to be heavy, and require high voltage feeds, this significantly impacts the loading on systems that have the printheads travelling at print speed.

Physical Size

The physical size of a printer depends on the substrate size but also on the chosen architecture. Single pass designs can be very compact, especially if they are integrated into another process. Stationary tables have a footprint only slightly larger than the maximum print area, but scanning printhead and scanning substrate designs have a footprint of at least twice the maximum print area.

Bidirectional Printing

It is normal in reel fed plotters to print bidirectionally, so that printheads are working a greater proportion of the time. The registration of forwards and backwards passes depends on the flight time of the droplets, which in turn depends on the distance from the nozzles to the substrate surface. In a reel fed device, this distance can be carefully controlled, but in a flatbed device it is harder. Firstly the gap has to be maintained over two dimensions instead of a single dimension, and secondly rigid substrates tend to be more variable in thickness. This makes it harder to achieve good quality bidirectional printing with a flatbed device than in the more common reel fed plotters. With UV curing, bidirectional printing requires two lamps, since the curing must follow the printing.

Substrate Constraints

Designs where the substrate is held down on a table while printing (stationary printhead, stationary table and scanning substrate) make it easy to handle a wide range of materials, and also to print several separate pieces at once. The scanning printhead designs have to pull or push the substrate itself through the machine, which can be difficult with fragile materials or porous materials. It also means small pieces must be fed one at a time rather than being tiled together.

Throughput

Single pass systems allow very much higher throughput than any other design, and also give higher printhead utilisation, as long as the print width is close to the maximum width of the machine. The drawback is the large number of heads required, and the lower print quality.

Higher throughput requires multiple printheads per colour, this is more easily achieved with systems that move the heads least, e.g. stationary printhead and scanning substrate designs.

Distance between heads affects throughput, because print strokes must take the substrate past all heads, so that the time spent traversing the distance from the first to the last head is dead time. The impact of this dead time can be minimised by printing very large images with long print strokes.

Load and unload time can easily be a significant factor with the higher speed systems, so it is important to make it quick to fix the substrate to the table, for instance using vacuum. Scanning printhead designs can increase throughput by continuously feeding, so that the beginning of one print is being printed at the same time as the end of the previous one.

Printhead Services

Capping and wiping systems are fairly easy to integrate into designs that move the heads, simply by extending the range of movement beyond the substrate edge. On stationary table designs this will reduce the maximum print area, so it may be worth having more complicated designs where the capping and wiping is part of the head carriage in this case.

Single pass designs make it very difficult to integrate capping or wiping, especially when they use a large number of printheads. It is more important with these designs to use inks that have long decap times.

Larger machines will need long drag chains to route services to the heads, this can be a problem for data integrity and for ink and vacuum systems. These problems are worst where the printheads move in two axes.

Component Re-use

So far flat bed designs have been considered in isolation. In practice, manufacturers may have other printer designs in production, and will want to use parts of their existing designs. A manufacturer who has a good reel fed plotter will quite rightly look at adapting this design to rigid materials, possibly allowing the customer to use a single machine for reel fed and rigid materials.

Stationary printhead designs can take advantage of standard x-y stages, this is often done for specialist micro dispensing systems.

Conclusions

The best architecture depends on the particular needs of each application.

For micro dispensing applications on small substrates, a fixed printhead system is most appropriate, using existing precision x-y tables. The limited speed is not a problem for these applications.

For high throughput large format systems, a scanning substrate arrangement is best. This makes it easy to mount a large array of heads, and the substrate can handle large accelerations better than the printheads.

For hybrid reel fed/flat bed systems, scanning printheads are the best solution.

Single pass systems can be considered for high throughput narrow formats (e.g. credit cards) but good print quality is likely to be difficult to achieve.

Biography

Will Eve is Director of Technology for Inca Digital Printers Ltd. (www.incadigital.com), a manufacturer of industrial printers based on drop on demand ink jet technology. Inca was formed in May 2000 by engineers from Cambridge Consultants.

He was also a founder of Elmjet, a previous Cambridge Consultants spin off, where he developed printers based on continuous ink jet technology.