INK PROPERTIES AND PRODUCTION

Ink and colour are probably the two topics discussed most during set-up of a printing machine. Colour consistency of brand colours is what the print customer wants - but how do we achieve it? The result of such discussion is often too long a set-up time and too much product waste at start-up.

It all starts with agreed colour correctly measured using a spectrophotometer but that is not what this article is about. I would like to take a closer look at the ink properties measured by the printer and how they affect colour, then introduce you to a different approach of checking ink properties and how it might influence your production costs while making a positive contribution to improving the environment.

The theory

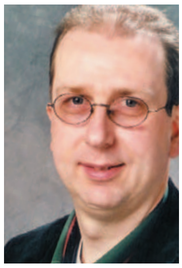
There are two ink properties which must be maintained by the machine operator. These are viscosity and pH.

Viscosity is the resistance of a fluid to flow. In the ink formulation laboratory, viscosity is measured, with minimum shear, by the retarding force exerted on a rotating dish immersed in the ink which is contained in a stationary vessel. It is also measured under high shear by the retarding force exerted on a fast-rotating cone almost in contact with a fixed flat plate between which the sample is placed. Under these conditions of high shear, the usual tangled polymer molecules become untangled and the viscosity is more like that experienced in doctoring conditions on the engraved screen roll.

Luckily, the machine operator does not need to worry about any of this! All that is needed is for a correctly formulated ink to be brought to the machine at the specified viscosity that can be most easily defined in terms of time to empty a flow cup. This flow cup time is determined in the ink formulation laboratory and the operator maintains the ink supplier's specified value. The temperature of the ink when determining the flow cup time is important, and must be adjusted to the specified value — usually 20°C.

If the viscosity at the machine is too great, then this is due to loss of volatile components (i.e. ammonia, amine and water) and must be adjusted by the addition of the appropriate mixture which the ink supplier must provide. If water alone is used, it will change the amine balance and hence the drying time.

What has been established for water based inks is that if the ink temperature increases, then ink viscosity also increases. This is common for water based inks and has been confirmed by independent sources. It has to do with the evaporation of amine and/or ammonia. Amine is responsible for the ink not bonding while in the bucket, but



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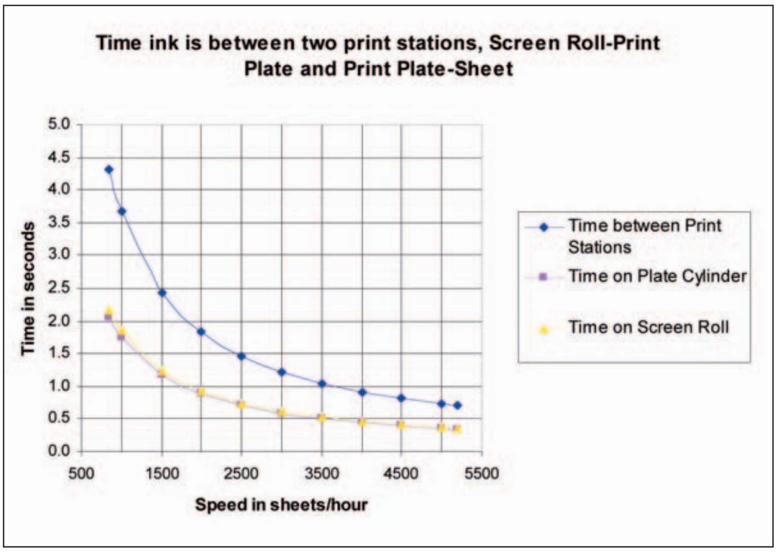
bonding when printed as a thin film on the substrate. The ink bonds when the amine evaporates. This process is not reversible, as ink suppliers will confirm, and it makes cleaning of dried ink difficult.

pH is determined by its formulation. Ink contains amine and/or ammonia and ink pH is alkaline — roughly between 8 and 10. The pH is probably an indicator of the drying speed of the ink. Rule of thumb is that, for an ink of otherwise similar formulation, the greater the pH the longer the drying time. This does not mean that a fast drying ink has a lower pH than a slow drying ink — that is the prerogative of the way the ink company formulates its ink.



Graph 1: Ink timing

The problem

During set-up and printing, the focus of the machine operator is on ink viscosity. I agree with how important the ink properties of viscosity and pH are, but question the usefulness of the data collected with the measuring systems used in production. As already mentioned, viscosity at the machine is commonly measured by flow cup. The cup used need only be equivalent to the one used by the ink supplier when he specified press viscosity. A plastic Ford 4 cup with metal insert is adequate until someone pokes a wire in the hole to clean it — then throw it away and get another! Those measuring viscosity at the machine need training in the correct procedure, that used in the ink formulation laboratory where the viscosity was specified. In this way, replication of the original formulation can be achieved and this is all that is required on the factory floor.

pH measuring is different. Sensors and equipment can be calibrated to an international standard. But these sensors can easily be damaged and need to be calibrated frequently. In my period at Stork, I worked on the construction of galvanic baths for plating cylinders with copper, nickel and chrome. These liquids where not sticky, like ink, and were not changed every hour like ink on a printing machine, yet the sensors used were calibrated daily. We used the best equipment available. I'm not questioning the equipment sold for checking ink pH on the printing machine, but I do question the fact that they are frequently calibrated and if the pH sensor is surviving the frequent ink changes. It is one item more that needs to be cleaned during a colour change — resulting in longer set-up time.

Measuring pH is fine but can you change the pH of an ink. Ink suppliers formulate ink so it is pH stable in chemical terms — this is called a "buffer". As far as I know, it is not easy to change the pH of a "buffer". Mostly when a "buffer" (ink) changes pH it is too late to make the correction. The ink has become unstable and the best thing to do is to change the ink. So, if this is correct, then the drying speed of water based ink is dependent on the evaporation time of the amine. What evaporation time are we talking about during printing?

Let us have a closer look at the relation of production speed and the open time of the ink on the screen roll, plate cylinder and substrate. In the case of substrate, we look at the time of printing and passing to the next print station.

The graph (top) shows the timing of a typical machine used for printing on corrugated. It is for me difficult to understand how one can adapt the drying time of ink by changing pH for time differences of at least a factor 5, changing speed from 650 to 4,750 sheets/hour. Thus at 650 sheets/hour it needs to be possible to rewet the ink on the screen roll after 2 seconds and not to be dried in the cells. The same ink needs to be dry after about 1.5 seconds when transferred through the machine at 4,750 sheets/hour. Is this possible?

Practical testing

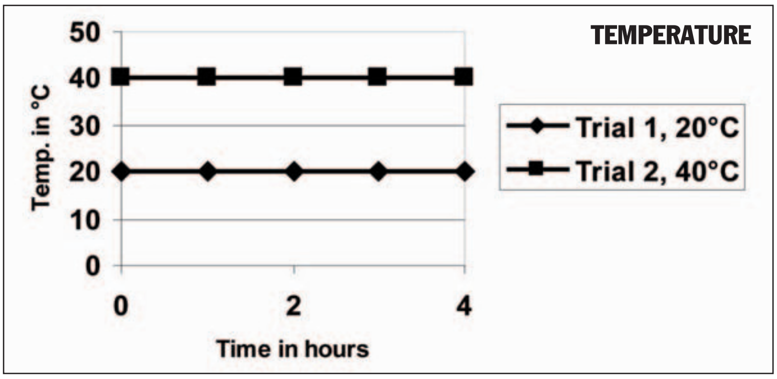
As indicated, it is colour consistency that the customer is interested in. So why not test the relation between colour consistency over time and the effect of changing pH and viscosity. You also need to record environmental properties. Let us include also temperature.

Trial 1: On a running machine we measure, over a period of about 4 hours — in intervals of 15 minutes — the following

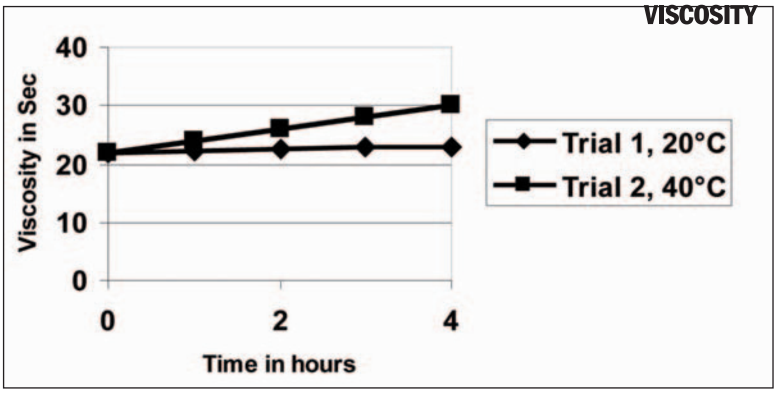
- Printed colour;
- Ink viscosity with an automated system to reduce the human influence;
- pH;
- Ink temperature (the target is to have the temperature at 21°C).

Trial 2: Same as trial one, but ink temperature is 40°C. This is common in hot countries or during summer elsewhere. Remember that the corrugator produces a lot of heat, as do pallets of cooling board, and print units are often installed in the same environment.

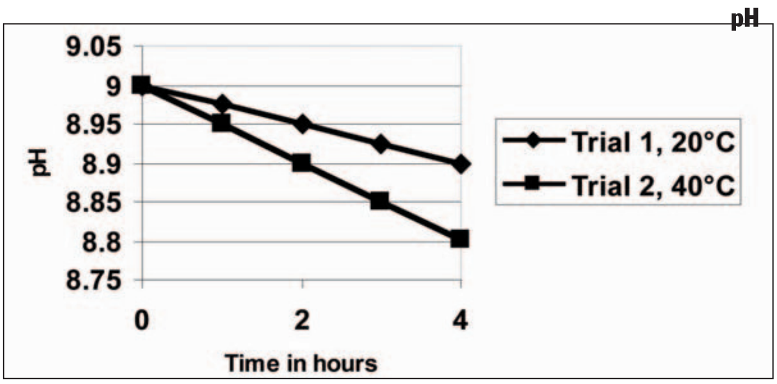
What can you expect from these trials. The graphs are simulated but the trend represented is what you can expect from such trials.



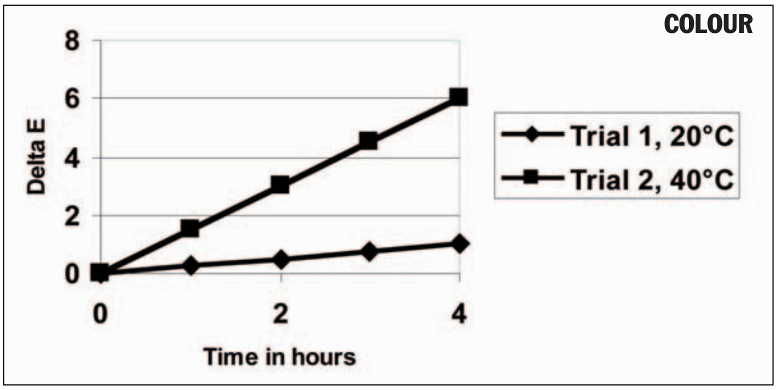
Graph 2: The temperature is higher in Trial 2 than in Trial 1. Temperature is the controlled variable in the two Trials. Thus in principle, no change was expected.



Graph 3: Viscosity increases faster in Trial 2.



Graph 4: The pH change is around 0.2. The measuring resolution for an average pH meter is mostly around 0.1. Is the change significant?



Graph 5: The colour difference grows 6 times faster at 40°c ink temperature. It is the colour that matters to the customer.

A different approach

So far, I have only highlighted the possible pitfalls of measuring viscosity and pH during production. I also highlighted the problem of changing machine speed and the consequences for the ink properties. A suggested different approach is based on three elements:

— Ink temperature control;
— Constant and the same machine speed for set-up and production;
— Ink density control (Specific weight!).

The usefulness of constant ambient ink temperature is clearly evident. It just needs implementing on the printing machine — I leave it to the discretion of the various suppliers of equipment to provide the solutions. Ink temperature control is common for gravure printing systems so why not for water based flexo?

The constant machine speed is a matter of training your operators and changing current practice. First of all you need constant raw materials. Warped board does not travel smoothly through your machine. The operator mostly compensates by reducing speed of the converting equipment. But that is not a reason to disagree on a target speed for production. Set a target speed and use it during set-up and production. Do this after your operators have agreed on it during an evaluation meeting — and then stick to the agreement. The only exception for reducing production speed is warped board. If this happens, then communicate this in a professional way with the operators responsible for board production.

Measuring and using ink density is easy, but equipment is not readily available for doing it practically. As a result, I had to develop my own tool kit. To do so, I used HBM measuring equipment made to the highest standard — it is also used by the automotive, aerospace and space industries. This quality level for the equipment is needed to get stable and accurate readings for the density measured.

The measuring principle I used is based on the well known Archimedes principle. The upwards force on an object in a liquid is equal to the weight of the liquid displaced by the object. The problem I had to resolve was how to make it practical and accurate. The device I developed allows you to measure ink density directly in the ink bucket with a precision better then 0.1 per cent. This is an improvement compared with the viscosity flow cup measurement — and the measuring of density itself is much simpler and less likely to be influenced by the operator in practice. However, ink foaming does restrict the use of the measurement — but this is also the case for measuring viscosity.

So how does it work?

— Measure the density of water;

— Measure the density of the ink before putting it on the machine.

— Measure ink density when the ink is circulating in the machine or when returned from the machine.

The following equation allows you to calculate the amount of water added to change the density:

$$m_{water} = m_{ink+water} * \frac{\left(1 - \frac{\rho_{ink+water}}{\rho_{ink}}\right)}{\left(\frac{\rho_{ink+water}}{\rho_{water}} - \frac{\rho_{ink+water}}{\rho_{ink}}\right)}$$

m := weight in kg

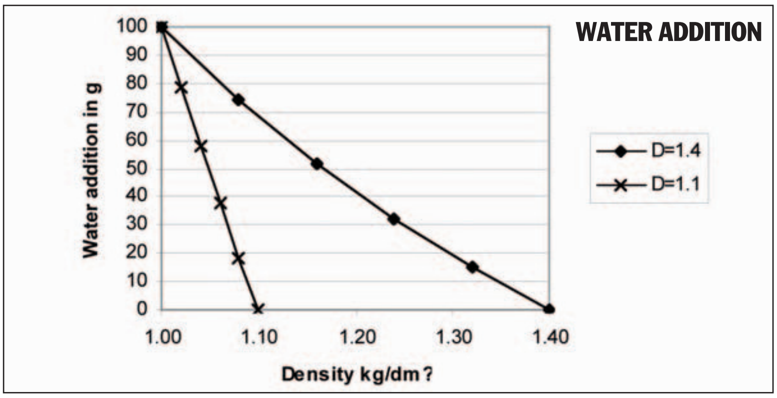
V := volume in dm^3

p := density in kg/dm^3

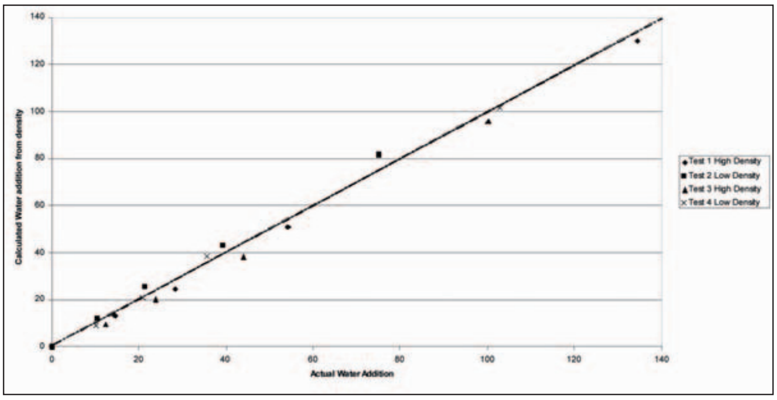
Graph 7 shows the results of testing. It confirms the excellent correlation between actual water addition and the calculated water addition using the change in density with the specially developed measuring device. Regular measuring of density allows controlling the ink water ratio, which is what we currently do based on flow cup viscosity measurements. This process can easily be adopted for the addition of water/amine mixture if required. The measuring of density also allows you to calculate the actual value for residual water left in the printing machine after a wash cycle.

The following example will explain why it is important not to forget the residual water after a wash cycle in your printing machine when measuring ink loss during colour change. Assuming that 10 kg ink enters the machine and 9.5 kg is returned, the ink loss is 0.5 kg. However, if there was 1 kg of water left in the system then the ink returned contains 10 per cent water. That means that the 9.5 kg ink + water returned contains only 8.55 kg of ink. Thus 1.45 kg was lost and not 0.5 kg. This is nearly 3 times more!

Having tested many machines on ink loss during colour change and taking into account the number of colour changes per machine, I found that the ink loss during colour change could be as high as 50 per cent of the total ink consumption. I also found it extremely easy to reduce it. It starts with changing the current practice of the operators. But machine suppliers can also do much, by changing the design of the ink system. It is all about reducing the surface area in contact with ink. If you want to know how much ink there is in the bucket, then put the bucket on a scale. If the scale is connected to a computer you can correctly record your ink consumption for the individual colours. Don't forget to link the system to the machine speed!



Graph 6: Shows the relation between water addition and density for inks with a start density of 1.1 kg/dm^3 and 1.4 kg/dm^3.



Graph 7: Test results measuring actual water addition and calculated water addition by measuring ink density and water content

Conclusion

Control of temperature and ink density is probably the easiest way to keep ink consistent during a production run. Measuring ink density will provide an indication of water additions to be made or made to the ink during production. Consider adjusting ink density with a water/amine mixture to maintain formulation and drying time. Evaluating your ink utilisation will give you clear targets for cost savings and improving the environment. Ink belongs on the substrate — nowhere else!

Recommendation

- Run and set-up your machine at one printing speed;
- Controlling ink temperature at ambient level will keep ink properties constant for most production runs;
- Ink density is an important property to determine water addition;
- Evaluate your ink utilisation.

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