Ink properties and production

Ink and colour are probably the most discussed topics during set-up of a printing press and approval of print. Colour consistency of brand colours is what the print customer wants but how is this achieved? The result of all the discussions and arguments is often too long a set-up time and too great product waste at start-up. *Wilbert Streefland* asks whether this is all needed.

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 mostly measured by the printer and how they affect colour. Then introduce a different approach of checking ink properties and how it might influence production cost. For corrugated board producers there is a large advantage to gain. This approach also makes a positive contribution to improving the environment.

The theory

There are two ink properties which must be maintained by the printing press manager, viscosity and pH. Let us consider each in turn.

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 is the ink sample. Under these conditions of high shear the usual tangled polymer molecules are becoming untangled and the viscosity is more like that experienced under doctoring conditions on the engraved screen roll.

Luckily the press manager does not need to worry about any of this. All that is needed is for a correctly formulated ink to be brought to the press at the specified viscosity and that can be most easily defined in terms of a time to empty a flow cup. This flow cup time is determined in the ink formulation laboratory and the press manager 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 press 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 I have recorded for water based inks is that if the ink temperature increases then ink viscosity is not decreasing but increasing. 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 whilst in the bucket but bonds when printed as a thin film on the substrate. Thus 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 The ink pH is determined by its formulation. Ink contains amine and/or ammonia and ink pH is thus alkaline roughly between eight 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 but one ink dries faster if its pH lowers. However the pH differences are minimal and difficult to record.

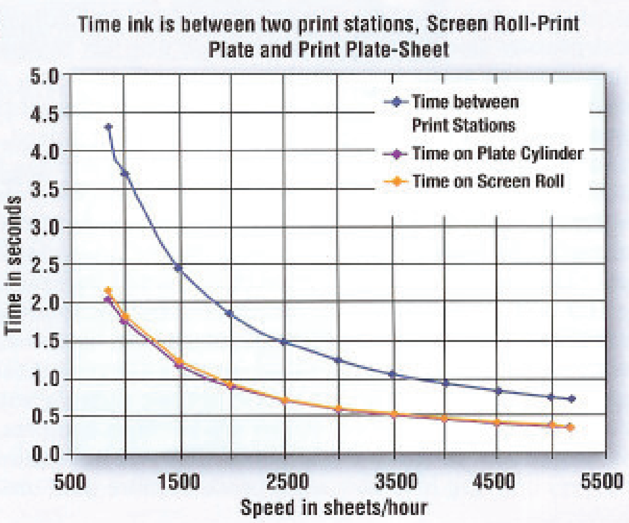
The problem

During set-up and printing the focus of the printer is on ink viscosity. I agree with how important the ink properties viscosity and pH are but question the usefulness of the data collected with the measuring systems used in production.

As mentioned in the theory section, viscosity at the press is commonly measured by flow cup. The cup used need only be equivalent to the one used by the ink supplier when it 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 throws it away and gets another! Those measuring viscosity at the press need training in the correct procedure and the correct procedure is that used in the ink formulation laboratory where the press 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 are very sensitive to being damaged and need to be calibrated frequently. In my period at Stork I did work on the construction of galvanic baths for plating cylinders with copper, nickel and chrome. These liquids were not sticky like ink and the liquids were not changed every hour like ink on a printing press. Yet the sensors used were calibrated daily. The best equipment available at Stork was used. I am not questioning the equipment sold for checking ink pH on the

Graph 1



press. I question the fact if 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. It will thus result in longer set-up time.

Measuring pH is fine but can the pH of an ink be changed? 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 do the correction. The ink has become unstable and the best thing to do is to change it.

So if the above is correct, then the drying speed of water based ink depends on the evaporation time for the amine. What evaporation time is being talked about during printing? Let us have a closer look at the relationship of production speed and the open time of the ink on screen roll, plate cylinder and substrate. In the case of substrate the time of printing and passing the next print station is looked at.

The graph shows the timing of a typical machine used for corrugated board printing. For me it is difficult to understand how one can adapt the drying time of ink by changing pH for time differences of at least a factor five changing speed from 650 to 4,750 sheets/hour. Thus at 650 sheets/hour it needs to be possible to re-wet the ink on the screen roll after two seconds and not to be dried in the cells. At the same time the 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 in the introduction it is colour consistency that the customer is interested in. So why not test the relationship between colour consistency over time and the effect of changing pH and viscosity? One also needs to record environmental properties. Let us include also temperature. This results in two trials.

Trial 1:

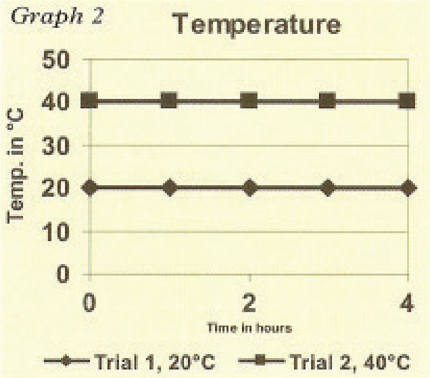
On a running printing machine over a period of about four hours in intervals of 15 minutes, the following is measured:

- 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).

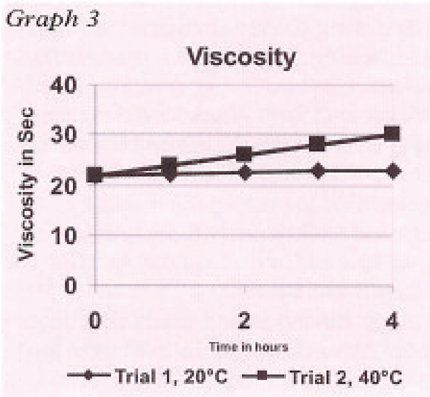
Trial 2:

The same as trial one but ink temperature is 40°C. This is common in hot countries or during summer time nearly everywhere. The corrugator produces a lot of heat so do pallets of cooling board and print units are often installed in the same environment.

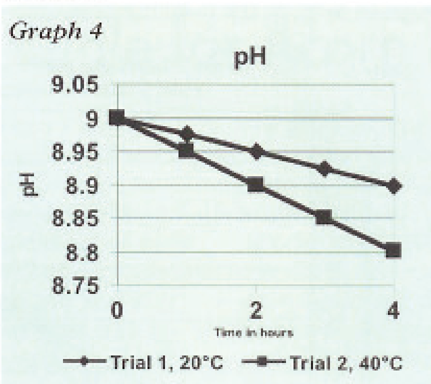
What can be expected from these trials? The graphs are simulated but the trend represented is what can be expected when doing these trials.



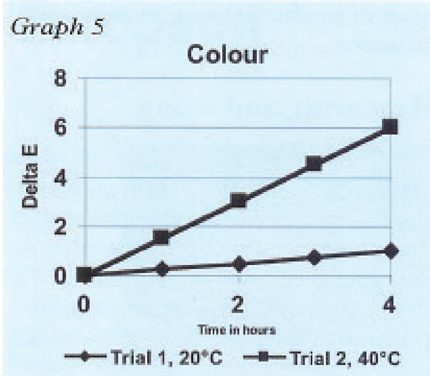
The temperature is higher in trial 2 than in trial 1. Temperature is the controlled variable in the two trials. Thus in principle no change was expected.



Viscosity increases faster than in trial 2.



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



The colour difference grows six times faster at 40°C ink temperature. It is the colour that matters to the customer.

A different approach

Until now only the possible pitfalls of measuring viscosity and pH during production have been highlighted. Also the problem of changing machine speed and the consequences for the ink properties has been highlighted.

The suggested different approach is based on three elements:

1. Ink temperature control;
2. Constant and the same machine speed for set-up and production;
3. Ink density control (specific weight!).

The usefulness of constant ambient ink temperature is clear by now. It just needs implementing in the press. I leave it to the discretion of the various suppliers of equipment to come up with solutions. Ink temperature control is common for gravure printing systems thus why not for water based flexo?

The constant machine speed is a matter of training operators and changing current practice. First of all constant raw materials is needed. Warped board does not travel smoothly through a machine. The operator compensates mostly by reducing speed of the conversion equipment but that is not a reason not to agree on a target speed for production. Set a target speed and use it during set-up and production. It also is not a reason to not improve a target speed but do not do this during a running order. This should be done after the 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 this should be communicated in a professional way to the operators responsible for board production. A blame culture does not help to improve! It is that simple to improve productivity and raw material utilisation.

Measuring and using ink density.

The property is easy to measure but equipment is not really available for doing it practically resulting in my having to develop my own tool kit. To do so I used HBM measuring equipment made to the highest standard. It is also used by automotive, aerospace and space industry. This quality level for the equipment is needed to get stable and accurate readings for the density measured.

The measuring principle 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 to make it practical and accurate. The device I developed allows measuring of ink density directly in the ink bucket with a precision better then 0.1%. This is a large improvement compared with the viscosity flow cup measurement yet the measuring of density itself is much simpler and less likely to be influenced by the operator in practice. However ink foaming restricts the use of the measurement but this is also the case for measuring viscosity. So how does it work?

1. First measure the density of water;
2. Then measure the density of the ink before putting it on the machine.
3. Then measure ink density when the ink is circulating on the machine or it is returned from the machine.

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

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

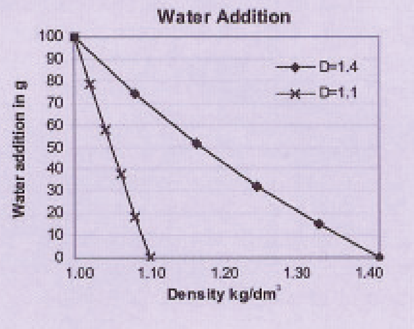
m = weight in kg   V = volume in dm³
ρ = density in kg/dm³

Graph 6 shows the relation between water addition and density for inks with a start density of 1.1 kg/dm³ and 1.4 kg/dm³.

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

Graph 7 shows the results of testing I did. It confirms the excellent correlation between actual water addition and the calculated water addition using the

Graph 6



Graph 6. Relation between ink density and water content

change in density with the special developed measuring device. Thus regular measuring of density allows controlling the ink water ratio which is what is done currently based on flow cup viscosity measurements. This process can be adopted easily for the addition of water/amine mixture if required.

The measuring of density allows also calculating 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 the printing machine when measuring ink loss during colour change.

Assuming that 10 kg ink is entered in 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% water. That means that the 9.5 kg ink + water returned contains only 8.55 kg ink. Thus 1.45 kg was lost and not 0.5 kg. This is nearly 3 times more.

After having tested many machines on ink loss during colour change and taking into account the number of colour changes per machine it was found mostly that the ink loss during colour change for a plant could be as high as 50% of the total ink consumption also it was found extremely easy to reduce it. It starts again with changing the current practice of the operators but machine suppliers can also do much by changing the design of the ink system. For example the use of short piping between the ink bucket and metering system. Bring the ink bucket close to the metering system. It is all about reducing the surface area in contact with ink. If it is necessary to know how much ink there is in the bucket then the bucket should be put on scales. If the scales are connected to a computer, ink consumption for the individual colours can be recorded correctly. It should not be forgotten to link the system to the machine speed! By applying this logic means that the ink bucket does not necessarily need to be accessible for the printer during production.

Conclusion

Control of temperature and ink density is probably the easiest way to keep ink consistent during the 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 water/amine mixture to maintain formulation and drying time.

Evaluating ink utilisation will give clear targets for cost saving and improving the environment. Ink belongs on the substrate nowhere else!

Recommendation

- Run and set up 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 ink utilization. ■

Graph 7