Thermal Balance of a Sheet Fed Offset Press And its Effect on Ink Transfer

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Abstract

The temperature of ink has a significant effect on its physical properties and hence the ink transfer in the printing process. In order to increase the thermal stability of a printing press it is necessary to obtain an understanding of how the various sources of heat interact in the process. This paper reports on a study of the temperature variations at various locations in and around a production four-colour sheet fed offset press. The press was fully instrumented to obtain frame and ink temperatures, with an infra red measurement system used to measure temperatures on the rolls. Large local time dependent temperature variations were found throughout the press. These changes were related to colour changes on the printed product. A thermal balance was made on the generation and dissipation of heat. This highlighted ways in which the press thermal stability could be improved.

Introduction

Earlier work into web offset printing has shown the importance of temperature change and its effect on the quality of the printed product [1]. The work highlighted that significant changes occur in the printed ink density for small variations in the thermal condition of the press, Figure 1. This shows the change in ink density for a 10 ^{0}C change in the ink duct temperature and how this varies dependent on the print coverage. For instance, in high coverage areas, temperature changes of as little as 1 ^{0}C were found to produce a visually detectable change in the ink density. The temperature fluctuations occur primarily during the start up and early part of the print run, prior to which the press will normally have been stationary for a period of time. During the start up, the rate of change is at its greatest, with the print crew having to compensate for the temperature effects by altering the ink flow in the units. However, after approximately two hours of production the rate of change of the temperature fluctuations is greatly reduced and the press reaches a stable condition.

In sheet fed offset printing the duration of individual print runs are much shorter than those encountered in web offset printing. The typical sheet fed print jobs vary between fifteen minutes and two hours. Due to the shorter duration of continuos printing, the sheet fed press will experience a significant change in its thermal behaviour throughout each of its print runs. The aim of the present work is to quantify the effects of temperature changes on the press and identify the key parameters in the generation and removal of the thermal energy in the press.

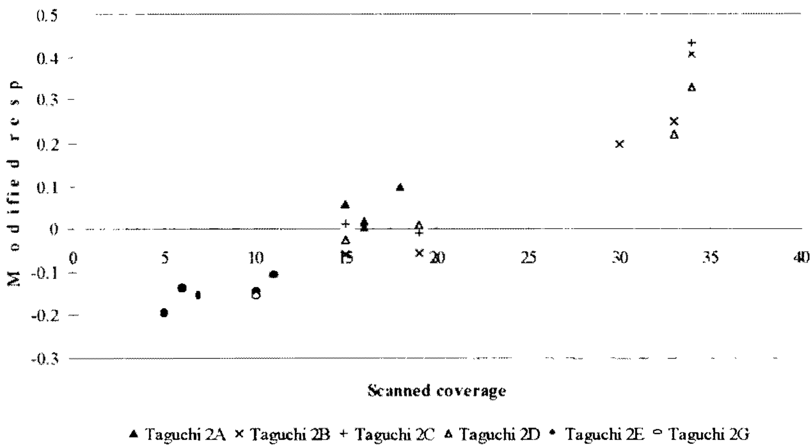

Figure 1 Relationship between scanned coverage and printed ink density for web offset printing [1]

Thermal Energy

Within a printing press, there are numerous sources of heat generation with the energy being dissipated by different mechanisms. These can be represented graphically, Figure 2, with the primary energy sources being electrical and mechanical and the removal of the generated energy by either conduction or convection. The direction of the arrows represents the heat flow either into or out of the printing press with the bi-directional arrows indicating cases where the energy transfer can occur in either direction.

Presses incorporate a number of electrically driven devices, all of which provide a heat source into the press. They include the press drives, compressors, vacuum pumps and any cooling units that are used. The majority of this energy is released by convection and will significantly affect the localised environmental temperature and the heat transfer co-efficients from the press in the local area.

The mechanical energy loss in the gearing systems is converted into thermal energy by friction and will cause an increase in the lubricant temperatures. This source of heat generation tends to be located to one side of the printing press. In addition, the compression of the rubber roller covering as they rotate will cause the bulk rubber temperature to increase. This effect is exacerbated with increases in the press speed. In the nip junction the mechanical working (shearing action) on the ink will cause an increase in its temperature.

The temperature variations within the pressroom will effect the heat transfer, giving rise to gross changes across the press as a whole.

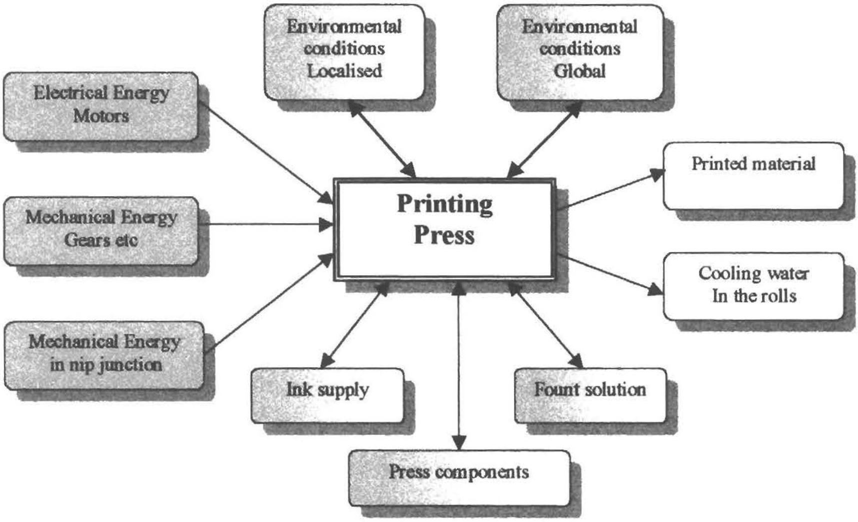

Figure 2 Overview of thermal parameters in sheet offset printing

When in operation, the use of cooling water to critical rollers in the inking train provides a major method of heat removal within the system. The cooling water supply needs to be controlled as it can introduce additional thermal imbalances in the press if implemented incorrectly [2]. The cooling rate has to be controlled with respect to the press speed and condition and the cooling across the width of the units has to be even. The damping system, which is essential for the correct operation of the plates also, has a secondary importance of acting as a means of removing heat from the roller system. It provides a buffer zone for small changes in the surrounding temperatures. The ink flowing into the ink train may also remove heat, as may the ink entering the duct.

The printed copy will increase in temperature as it passes through the press and will hence remove heat from the blanket cylinder. It also removes the thermal energy stored in the ink and fount solution which has passed through the press system.

Finally, parts of the press will be at different temperatures and there will be cooling by the local environmental temperature. There will also be heat flow through and exchange between various press components.

These summarise the primary parameters involved within the thermal balance of an offset press, but are by no means the exhaustive and definitive set.

Experimental Instrumentation

A four-colour sheet fed offset printing press was instrumented to allow the capture of strategic temperatures throughout a series of standard production print runs. The aims of the temperature measurements were to detect temperature variations both across each of the individual print units and along the length of the printing press. A total of nine thermocouples were used to monitor the temperatures in the four ink ducts and a further ten were used to measure those on the frames of two of the units. A schematic representation of the press layout is shown in Figure 3, with the location of the thermocouples indicated. Two thermocouples were placed in the ink ducts of units 1, 3 and 4 with three in unit 2. This allowed the temperature to be monitored along the length of the press and also across its width. The thermocouple placed in the middle of the ink duct on unit 2 was used to investigate the linearity of temperature changes across the units. The fame-mounted thermocouples were located on both sides of an end and intermediate unit, again investigate changes across the width of the units and along the length of the press. The inner frame thermocouples on unit 2 were installed to evaluate the changes through the width of the frame and as the roller temperatures would also be measured on this unit using the infra red pyrometer.

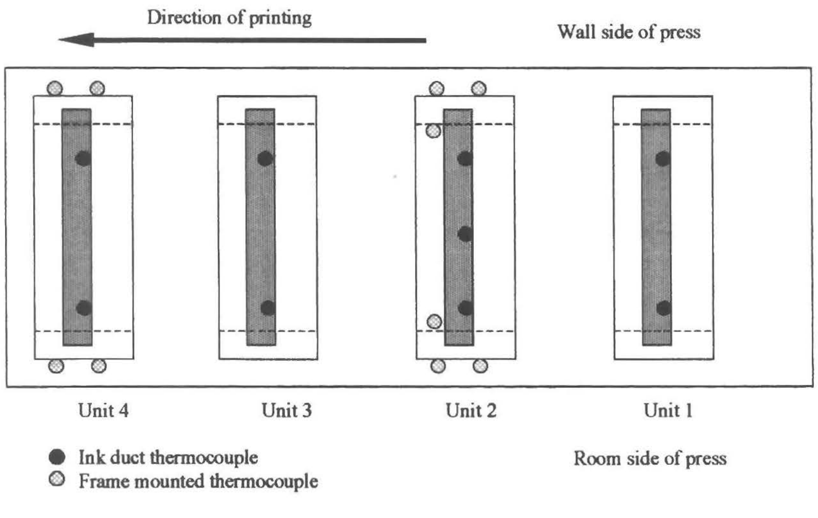

Figure 3 Schematic of press layout showing location of thermocouples

To allow ease of operation, the access to the press by the print crew was primarily from the room side where the individual unit controls were located. The gearing was on the wall side of the press, as were the majority of the ancillary motors, drives and cooling units.

The frame temperatures were obtained by surface mounting the thermocouples and fixed using a polymeric adhesive. To evaluate the temperature difference through the frame, thermocouples were mounted on both the inside and outside frame wall.

Sheathed thermocouples were used to measure the ink temperatures in the duct. These were clamped to the duct during production and having a degree of flexibility it was possible to ensure they were always located within the ink duct reservoir. T-type thermocouples were used throughout the investigation. The data capture was effected using a Solatron isolated measurement pod to S-Net adapter 35954A data logger, which allowed a total of twenty channels of data to be recorded on a personnel computer. The temperature data from each of the thermocouples was recorded at 10-second intervals.

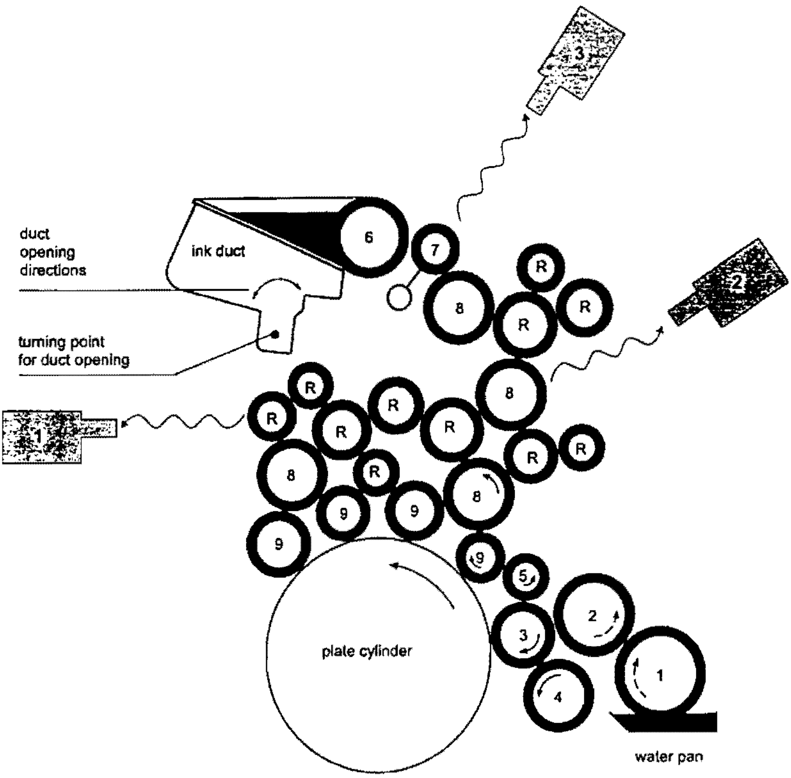

Figure 4 Schematic of roller layout showing position of infra red thermometry measurements

The impacts of external environmental parameters on the press were monitored using a hand held temperature and humidity meter to take measurements at several locations around the press, within the pressroom, and outside the print facility.

The temperature of the ink on several rollers within the ink train was also measured at the locations shown in Figure 4. These were used to identify the temperature changes that were occurring in the ink train and any difference with those in the ink duct. The location and number of points were limited by the guarding placed around the ink train. These temperatures were measured using an infra red pyrometer configured to allow a narrow band of the emitted radiation to be used for measurement purposes. This ensured the temperature measured was that of the ink on the roller surface and not the roller temperature itself.

Details relating to the press speed, ink duct roller speed, ink duct opening and key settings were obtained from the press instrumentation. The data acquisition system was designed and installed so that within minutes of arrival at the press all the data logging systems could be operational.

Experimental program

The aim of the experimental program was to obtain temperature information and to assess how this impacted on the print quality. This was achieved by continuously monitoring the press conditions over a number of days and collecting the appropriate number of samples to assess any changes in the product quality. The trials were carried out in a non-invasive manner and at no time did the program affect the quality of the print. The only cost to the company was the samples that were removed for analysis.

The data from two day long trials run on separate days are presented in this paper. Both of the trials investigated the thermal effects on solid ink density. For the first day, two print runs were carried out. These were both of very low coverage and all the measurements were carried out in the editorial matter. The duration of each print run was approximately two hours. During day two there were three print runs, two of which were the same (identical image on both sides of the sheet). However, the duration of each of the print runs was much shorter than those experienced on the first day being approximately fifteen minutes each. All operator changes on the press during production of copies were recorded, as was the speed of the press.

Samples were collected throughout each of the production runs at regular intervals. Previous work [3], [4] had indicated there was a cyclic variation in the colour printed from each of the units. One hundred and twenty four consecutive copies were collected from the press and Fourier analysis was used to examine the ink density fluctuations from solid ink patches. The results from the Fourier analysis were then used to determine the sample size. Thus the use of sequential multiple copies for the density measurements helped minimise any sampling error due to the natural fluctuations in the print.

Thermal Changes within the Press

The temperatures on the press frame for units 2 and 4 are shown in Figures 5a and 5b along with the production profile. These show an increase in the press temperature with each of the production runs. When the press is stationary these temperatures showed a slow reduction. The delays in the temperature response to changes in the production are due to the inertia within the system. An overall increase of 10 ^{0}C is detected on the wall side of the press, with a corresponding 4 ^{0}C change on the operator (room) side of the press.

The frame temperatures on the wall side of the press start at a slightly higher temperature (approximately 1 ^{0}C) than that of the room at the start of the days production. This is due to some of the ancillary units on the wall side of the press being in operation before the start of the data acquisition system. However, the difference increases throughout the day, with an average cross press variation of 5 ^{0}C after two hours of production. This increase in temperature can be attributed to the operation of the gears in the press and to the heat generated within all the ancillary drives, which were also located on the wall side.

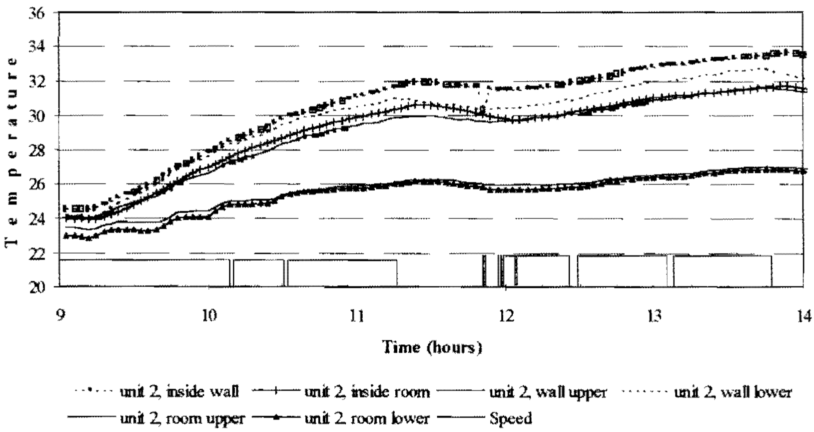

Figure 5a Temperatures on the press frame for unit 2 (day 1)

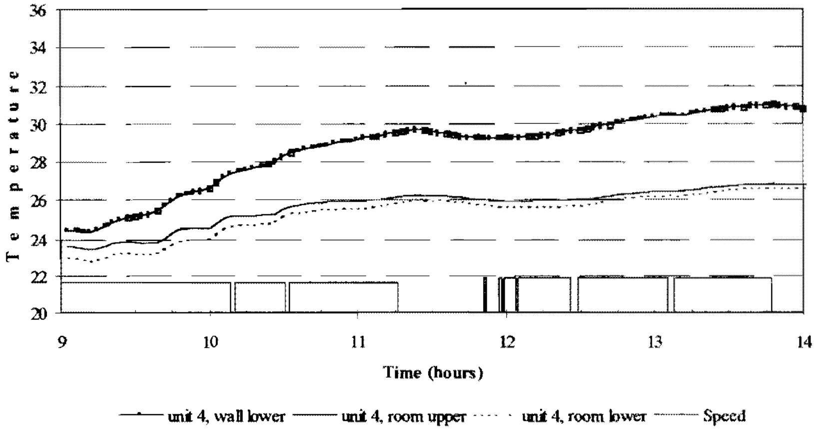

Figure 5b Temperatures on the press frame for unit 4 (day 1)

On unit 2 the temperatures measured inside the side frame showed a higher value than those did on the outside of the side frame. This resulted in thermal gradients being formed across the side frames. The temperature differences are shown in Figure 6 and these show a small increase across the side frame on the wall side, while a much larger change is detected on the room / operator side. The heat is generated within the unit and removed via conduction through the side frames and convection to the environment. However, the ambient temperature on the wall side was higher than that in the main press room and as a result the heat transfer rate is lower in this region compared to the room side of the press due to the lower temperature difference.

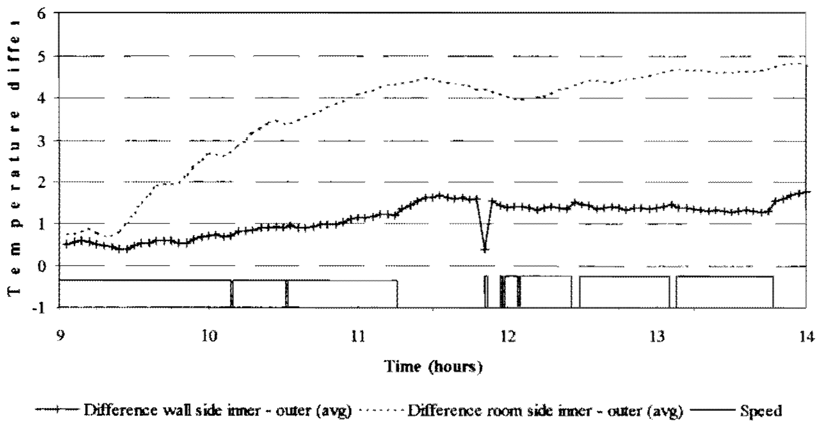

Figure 6 Temperatures difference through the frame on the press frame (day 1)

The inner frame temperature measurements indicate that the heat generated in each unit across its width is similar, with slightly more being produced on the gear side of the press. The inner frame temperature on the wall side is higher than the inner frame temperature on the room side. This is due to the lower heat transfer rate on the outside of the wall side frame, an effect of the higher ambient temperature in this location.

The series of step changes on the room side of the press seen in Figure 5 and Figure 6 can be attributed to the factory heating system being operational during this part of the day. The timing of the heater can also be seen in the ambient temperature as measured above unit 1, Figure 8.

The environmental conditions on both days analysed were similar. However, the variations in the frame temperature were much smaller on the second day, Figure 7. These showed a gradual increase throughout the monitoring period with changes of 2 ^{0}C to 3 ^{0}C being recorded. This gradual and smaller increase in temperature was a result of the much shorter production runs with less heat being generated within the press and by the ancillary units.

The shorter production runs resulted in a similar temperature difference across the width of the units with a 1 ^{0}C change between the wall and room side of the press through the day.

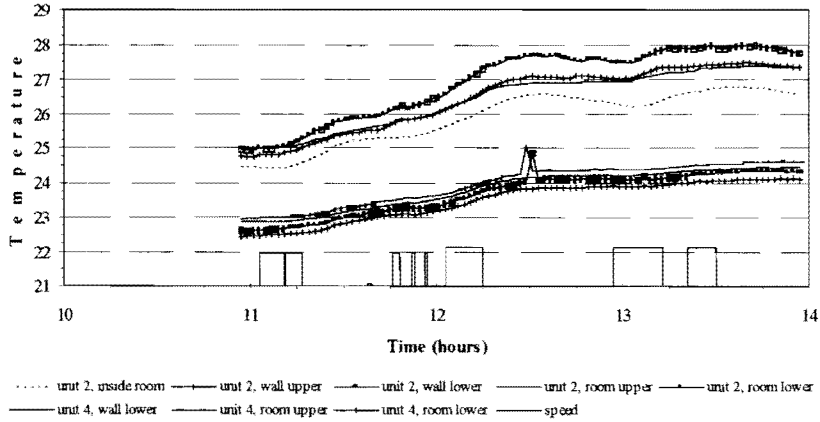

Figure 7 Temperatures on the press frame (day 2)

The temperature of the ink in the ducts for day one is shown for the and units 1 and 2 in Figure 8a, with units 3 and 4 in Figure 8b. During these trials unit 1 was not used for printing and the temperatures shown for unit 1 are those measured above the ink duct, giving an indication of the ambient temperature above the printing press unit. These clearly show the impact of the factory heating system, with a rapid 4 ^{0}C temperature fluctuations in the first hour and a half of production. These changes in the ambient temperature can also be seen to a lesser degree in the ink temperature measurements in the ink ducts with an increase in the rate of change of temperature, most notably while the heating was operational for a fourth time. The ambient temperature above the unit shows a slight increase of approximately 1 ^{0}C over the duration of the print run.

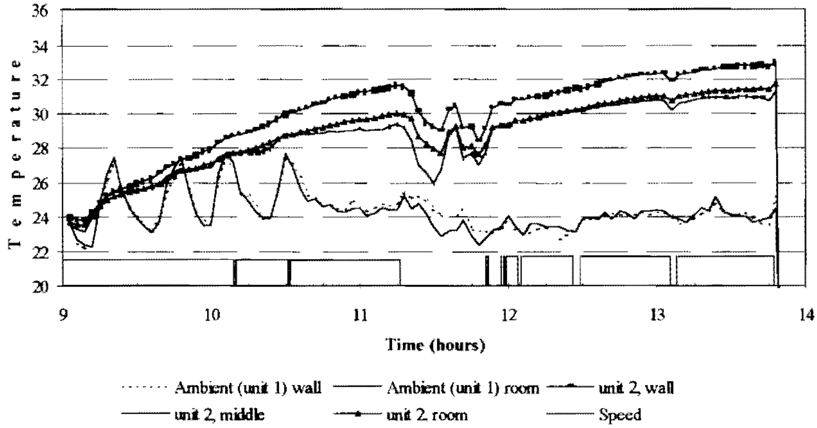

Figure 8a Ink duct temperatures for unit 2 and ambient (day 1)

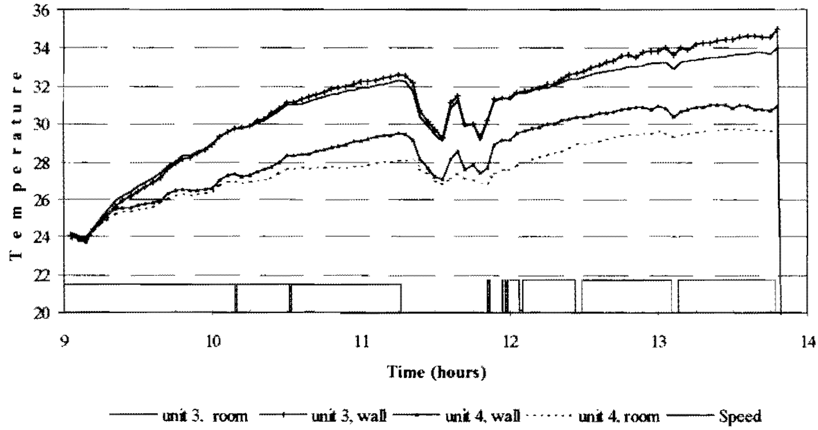

Figure 8b Ink duct temperatures for units 3 and 4 (day 1)

The ink temperatures increase throughout the press operation, the rate being dependent upon the production. The most rapid changes occur during the start of the print runs. The temperature of the ink was consistently higher on the wall side of the press for all the ink ducts measured. However, there is not a linear relationship across the width of the press with the temperature measurements taken in the middle of the ink duct being very similar showing little or no difference to those measured on the room side.

The effect of the shearing action on the ink in the duct on heating the ink is highlighted once the press becomes stationary. While the press is running the duct roll shears the ink through the key gap and moves it in the ink duct. Once the press stops the ink becomes stationary in the duct and there is a rapid reduction in temperature.

The temperature of the ink in the ducts for day two are shown units 1 and 2 in Figure 9a, and for units 3 and 4 in Figure 9b. The extent of temperature changes are much smaller than on day one, with similar start temperatures but lower maximum temperatures being observed. These are due entirely to the shorter duration of production. However, the rate of change is greater due to the residual thermal energy in the system with 2 ^{0}C temperature changes occurring in the first ten minutes of production. The differences in temperature across the width of each of the units are smaller than those measured for the longer production runs.

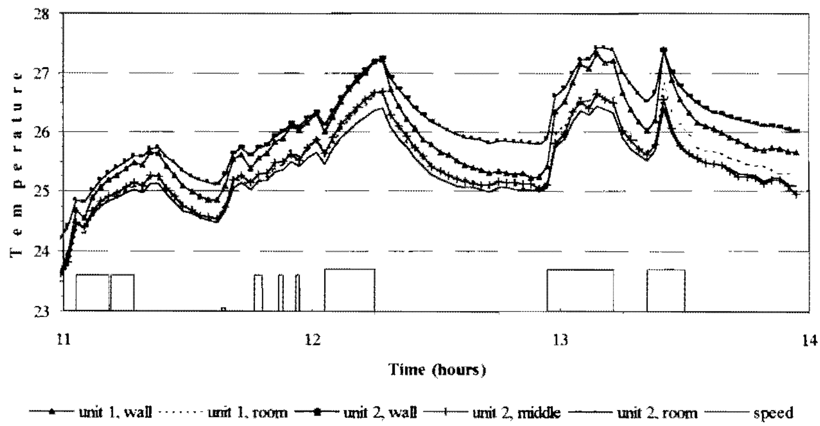

Figure 9a Ink duct temperatures for units 1 and 2 (day 2)

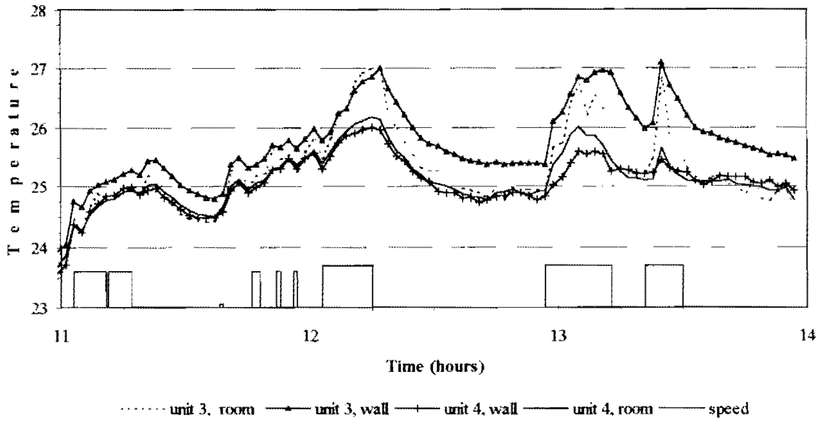

Figure 9b Ink duct temperatures for units 3 and 4 (day 2)

The temperatures measured using the infra red gun at position 2 show a higher ink temperature than was found on either of the other rollers measured, Figure 10, with the temperatures at positions one and three being similar. By referring to the roller configuration, Figure 4, it can be seen that roller 8 has three nip contacts whereas the there are only two nip contacts on the other rollers. This would result in a higher frequency of cyclic stressing of this roller and the ink being sheared to a much greater extent on the roller. The higher temperature measured on roller 8 (position 2) is a direct function of the number of nip contacts.

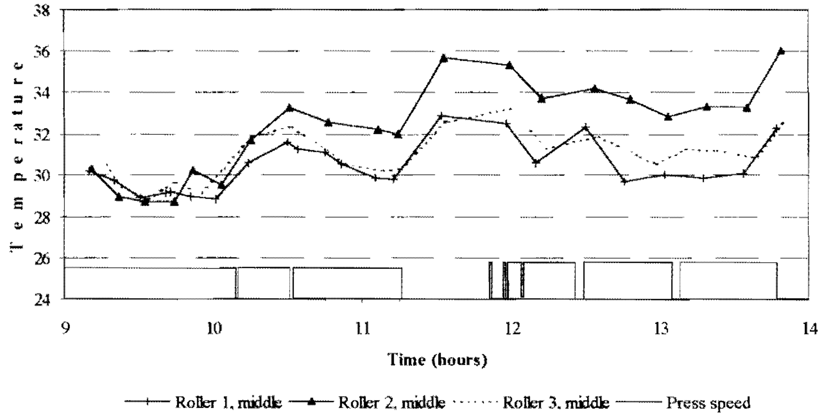

Figure 10 Ink roller temperatures measured with infra red gun (day 1)

Measurements were carried out at three positions across the width of the roll and these showed a change in temperature across the unit, with higher temperatures being found towards the wall side of the unit, where the gears and localised heat sources were located. This is in good agreement with the measurements on the frame and in the ink duct. This change was not linear across the press, with the temperatures in the middle being similar to those on the room side, again agreeing with the results from the ink duct measurements.

The ink temperatures measured on the rolls were generally higher than those in the ink duct, similar to the findings from experiments into web offset printing [3]. This indicates the heat generation in the roller train with the new ink from the duct acting as a coolant. At the end of each production run while the press is stationary the temperatures in the duct decrease while those on the roller surface increase. Once the press is re-started the temperatures in the duct increase while those on the rollers initially decrease. This is due to the ink acting as a coolant on the roller surface. When the press is operational the heat is removed from the rollers by the ink which is replaced by a cooler supply. However, the dwell time of the ink on the roller surface does not allow all the thermal energy to be transferred to the ink and therefore there is not a significant change in the ink temperature. When the press is stationary the ink temperature rises on the rollers indicating the ink is being heated by the roller. The ink acts as a coolant in the system and a means of removing the heat from the press.

Colour variations in the print

The colour variations for each of the print runs on day one are shown in Figure 11 in terms of ink density, with copies being collected at four to five minute intervals. The results shown are based on multiple samples being measured at each collection interval and the ink densities being averaged. This allowed the effect of the cyclical oscillation in the ink density which was measured to be averaged out. The adjustments made to the press of the sweep and key opening was also monitored.

The ink densities show significant colour variation through each of the print runs. The sudden changes in the density were a result of alterations made by the press crew to either the sweep or ink key setting. However throughout a specific run, minimal alterations were made and the gradual decrease in the density is a function of the temperature change in the press. Previous work [1] has shown, Figure 1, that changes in the ink duct temperature can either cause an increase, no change or a decrease in the printed ink density dependent on the coverage. The jobs printed were of very low coverage and as such are very sensitive to changes in the ink temperature in the duct and the gradual reductions in ink density are due to the very low coverage. All the alterations made by the press crew were in the direction to increase the flow of ink to the plate to maintain the image quality.

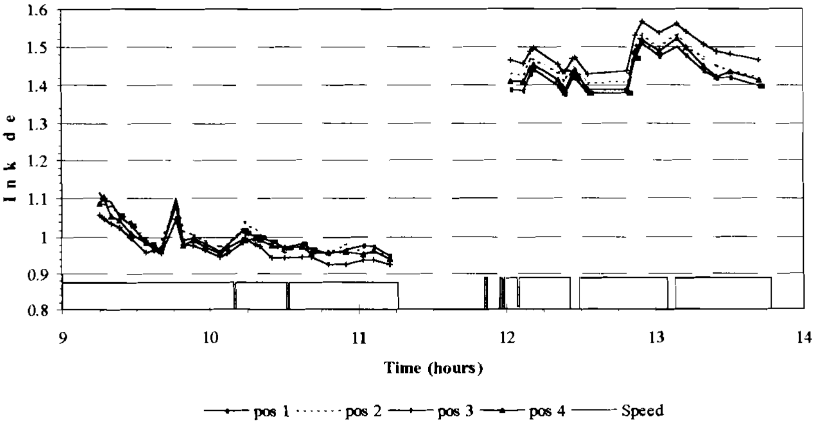

Figure 11 Ink density measurements for runs on day 1

Energy transfer in the printing press

On the basis of the results the primary heat flows within the system can be established and these are shown graphically in Figure 12. The direction of heat flow for each of the parameters is indicated using an arrow. The main parameters for heat generation in the press can be summarised as follows and are placed in order of importance

- The heat generated in the nip junction is a main effect and provides an even temperature change across the width of the printing unit. The heat is generated from the compression and expansion of the rubber layer through each of the nip junctions and the shearing of the ink. Changes in the speed of the press and the duration of the print run will have a significant effect on the temperature of the ink and the rate of change of temperature.

- The electrical energy from the motors, drives and pumps is converted into heat and this will increase the temperature of the local environment and as such the heat transfer from these areas will also be effected. Due to the location of these units, predominantly on the wall side away from the operator, the effect will tend to create a thermal imbalance across the width of the printing units. This will have consequences on colour control across the width of the press.

- The localised environmental temperatures will affect the heat transfer from the press and can introduce thermal gradients both along and across the press. One of the main causes of this imbalance is the electrical motors, but heating and ventilation systems can also impact the localised temperature distribution in the print room.

- The increase in temperature due to the mechanical interaction of the gears is small in comparison to the other heat sources in the printing system. However, the heat is generated primarily on one side of the press and as such will cause a thermal gradient across the units. This work in addition with the previous indicates this would be at most 1 ^{0}C.

The thermal energy is removed from the press by the several mechanisms, which are summarised below and placed in order of significance

- The cooling water in the rolls when used can remove large quantities of heat from the system. However, the designs of these tend to remove the heat in an uneven manner [2] creating thermal gradients across the press. In addition, the heat transfer rate needs to be controlled to ensure a constant press temperature.

- The printed material as it passes through the press will remove heat from the blanket but more importantly remove ink and fount solution from the press. The rate at which this removes energy from the system is relatively independent of the press speed.

- The fount solution and ink supply provide a steady supply of colder fluid into the roller train, at which point they remove the thermal energy from the rollers, most notably the rubber coated ones. There will be an increase in their temperature as they shear through each of the nip contacts reducing their effectiveness as they pass through the roller train.

- The global environmental conditions will affect the heat transfer rates from the press. This effect will primarily affect the repeatability of similar jobs under different operation conditions, e.g. summer to winter. This is a result of the different operating temperatures of the ink in the system, the rate of change of the ink and the point at which the ink flow starts to stabilise. Excessive deviations from the average will require large changes to the press set up and may require different consumable to be used to obtain product quality.

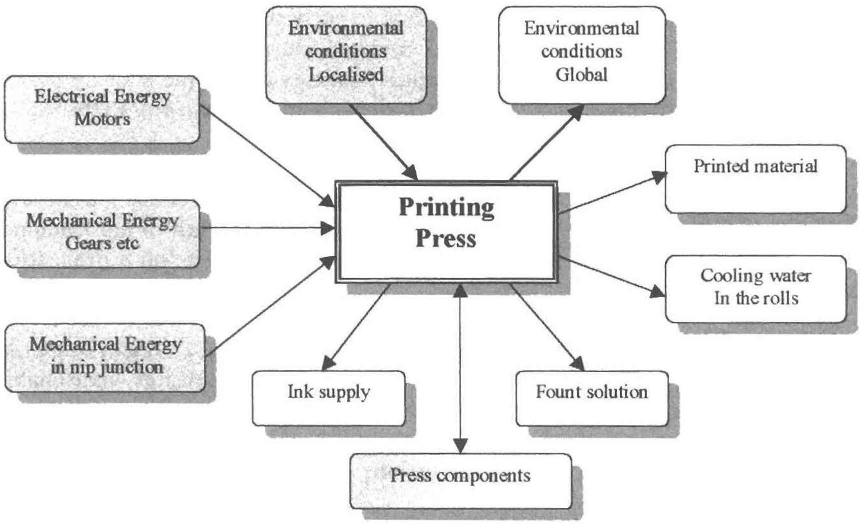

Figure 12 Thermal energy balance in sheet offset printing

Discussion

There are significant changes (of approximately 10 ^{0}C) in the ink temperature in the ink duct of a printing press unit throughout the day. Similar variations are also exhibited with the unit frame temperatures. These temperatures change through the day as the printing press is in production. The rate of change of temperature is dependent on many factors including the length of production, the press production history, the local and ambient environmental conditions. When the press is stationary the ink in the duct cools down rapidly towards the ambient room temperature, with a much slower reduction in the frame temperatures. Very fast transients are present when a series of very short production runs are undertaken. The ambient temperature in the print room is not affected significantly by production of copy with the thermal effects being much more localised.

A large part of the heat generated within the nip junction is removed by the ink and fount solution as they pass through the press roller train and onto the printed material. When the press is stationary this heat can not be removed and there is a large increase in the temperature of the ink on the rollers as it is heated by the rubber roller covering.

The physical properties of the ink are affected markedly by changes in temperature and as a result the ink flow in the press is altered. It has been shown that these changes are not consistent with respect to coverage. During the longer production runs large temperature fluctuations were observed over a two-hour period. This resulted in the press crew having to carry out significant alteration to the press settings to minimise the colour changes. During short production runs or on job change overs there are very rapid transients during the start up period and this increases the frequency of the alterations required to the press settings.

To minimise the impact of thermal changes on the product quality the local environmental conditions need to be controlled so as to reduce the thermal gradients both across the width of the units and along the length of the machine. This will help to minimise the non-linear changes in colour during a production run.

The control of the global temperature in the print run is critical primarily to allow repeatability of jobs and the repeatability of press settings. Reasonable daily control is required but it is critical the local conditions are maintained.

Conclusions

In order to establish better over print quality it is essential to consider the thermal environment and the thermodynamic control of the press. For example, providing a heat input to the press rolls before the start of production. This would imply the need to provide heating via the water circuitry utilising local thermostatic control and closing the loop on temperature. This would require good thermal design of the heat transfer circuits and may also imply the need for thermal control of the frames.

The results suggest that by ensuring that critical regions of the press remain at constant temperature the colour on the press is essentially stable. This would significantly reduce waste at start up and reduce or eliminate the need for closed loop colour control.

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