Immediate Surface Characteristics of an Aqueous Pigment Coating Applied to a Porous Substrate

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Introduction

Film-press coating is a common and popular technique for applying an aqueous pigment coating to a (usually) porous substrate[1]. The coating is applied as a free-flowing aqueous suspension, and via consolidation processes during dewatering and drying; it develops into a solid layer situated largely on the surface of the substrate. The coating structure that develops as a result of this consolidation process is complex, and its uniformity is affected by many factors such as base substrate porosity and structure, rheology and composition of the coating, and processing conditions such as applied coat weight and drying conditions[2-5]. However, despite these well-known influencing factors, relatively few studies have focused on the consolidation process of an applied fluid film into a dried, solid film *under realistic paper coating conditions* (some exceptions being ref 6-7). In the current study, the surface characteristics of an aqueous-based pigment coating applied to a porous substrate was investigated by optically assessing the changes in surface structure of recently applied coatings, resulting from dewatering and natural drying in air.

Materials and Methods

The coating formulation consisted of calcium carbonate pigment, latex binder (15 wt% of pigment), Dispex N40 dispersant (0.5%) and CRX thickener (0.4%), to a total solids content of 55%. The substrate was linerboard, 110 gsm, kindly supplied by Visy Paper Coolaroo, Australia. A high-speed, film-press coater developed at Monash University was used to conduct the experiments, coating the above formulation onto the linerboard at speeds between 200 and 1000 m/min. Two different nip pressures and coat weights were used in the investigation. Changes in surface structure of the applied coating due to dewatering and drying (in air) was monitored on-line at two different distances from the nip using a high-resolution Pixelfly camera (Scitech), complete with a fibre-optic ring-light attached to an X-strobe (Perkin Elmer Optoelectronics). The time from coating application to image capture was defined as 'image capture time', which varied both with camera position as well as coating speed. ImagePro software (v. 4.5) was employed to quantify the changes in surface structure observed for each condition tested, by assessing the differences in intensity with respect to grey level (GL). Drier portions of the coating typically had higher intensities at low GL, while high GL dominated the wetter portions. The 255 grey levels were evenly split into four segments, assigned as follows: Segment A (GL 0-63) was the uncoated paper or 'dry' portion of the coating; segment D (GL 192-255) was the 'wet' portion of the coating; and segments B (GL 64-127) and C (GL 128-191) were the 'medium-dry' and 'medium-wet' portions, respectively.

Key Results and Discussion

Effects of nip pressure: For coating speeds up to 400 m/min, and constant coat weight, nip pressure had little effect on the coated surface structure, as judged by the segmentation analysis as well as visual observation of the resulting images. The analysis revealed a peak in segment B, indicating that the coating was partially dry. At higher speeds of 600 and 800 m/min, the segmentation curve for the lower nip pressure case showed a plateau at segments C and D, indicating that the coating was still quite wet. For the higher nip pressure case, a small peak at segment B had begun to form, indicating that the coating was somewhat drier than for the lower nip pressure. It may be that at shorter image capture times, a more rapid dewatering was observed due to a higher nip pressure being exerted on the coated substrate.

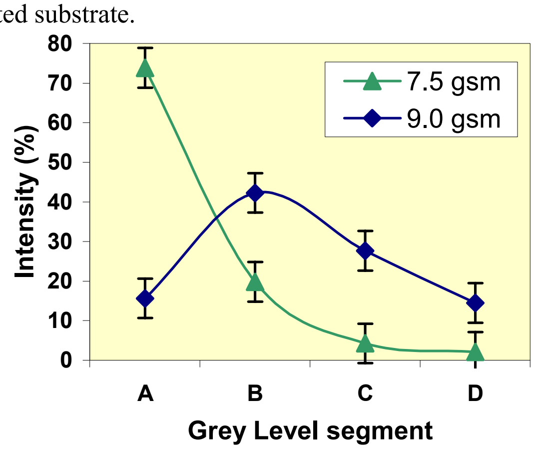

Figure 1: Effect of coat weight, 200m/min, 15 kN/m.

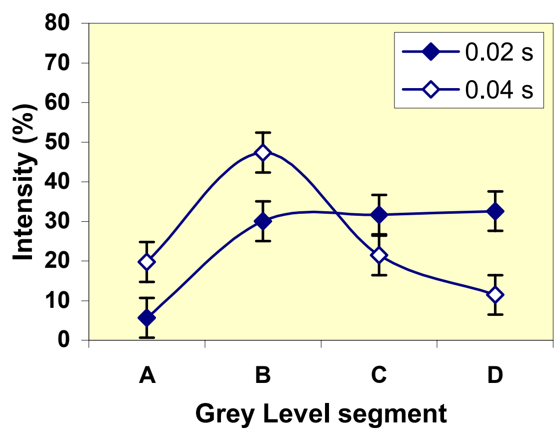

Figure 2: Effect of image capture time, 800m/min, 15 kN/m, 9.0 gsm.

Effects of coat weight: Figure 1 compares the variation in GL intensities with respect to coat weight at 200 m/min and a constant nip pressure of 15 kN/m. Given that less coating was applied for the lighter coat weight, it should dry more quickly than the heavier coating, as shown by the dominance of segment A (Figure 1). The heavier coat weight material showed a maximum at segment B, indicating a wetter material. A different behaviour was observed at higher speeds, corresponding to shorter image capture times. Both coatings were still quite wet due to the relatively high intensities at segments C and D. While within experimental error, the lighter coat weight material may have begun to dry as evidenced by a small maximum in the curve at segment B; the heavier coat weight by comparison showed a plateau at segments B, C and D.

Effects of coating speed: To assess the possible influence of coating speed on surface structure, it was necessary to perform some coating trials with the camera positioned at a different distance from the nip in order to maintain constant image capture times. Several trials were conducted at two different coat weights and image capture times, comparing speeds 200 and 400 m/min, and 400 and 800 m/min. In all cases, there was very little influence of speed observed, although the images at 800 m/min were at times more blurred than those at 400 m/min. However, the intensity levels with respect to GL segments were comparable.

Effects of image capture time: In a similar manner as described in the previous section, a series of trials were conducted at constant conditions and two different camera positions to assess the effects of time on surface structure. In all cases, the segmentation curves obtained at the longer image capture time showed a drier coating, with more dominance at segments A or B. By contrast, a plateau was observed at segments B, C and D for the segmentation curves representing the shorter image capture time. This is shown clearly in Figure 2 where the coat weight was 9.0 gsm, nip pressure 15 kN/m, and coating speed 800 m/min.

Determination of key features during consolidation: As the effects of coating speed on the resulting images were minimal (apart from blurring at the very high speeds), experiments were conducted at a variety of coating speeds and a constant camera position to determine some key consolidation features with respect to time more closely. The various coating speeds were therefore converted to different image capture times. Figure 3 shows the four-segment GL intensity variation plotted with respect to image capture time, together with the on-line images. These trials were conducted at 22 kN/m nip pressure and 9.0 gsm coat weight. The 'wet' segment D dominated at very short times after coating application, reduced shortly afterwards, and then rose a little before a further reduction. As expected, the 'dry' segment A experienced the reverse pattern. It is likely that the observed changes in GL intensity were representative of the first critical concentration (FCC) and second critical concentration (SCC), which are both observed by changes in the reflectance of light. It is important to note that the on-line image facility was *not* a gloss meter or similar device, but it did nevertheless pick up surface changes by capturing reflected light from the strobe source that was shone onto the coating. From Figure 3 it can be seen that the FCC occurred at 0.020 s (drop in 'glossiness'), while the SCC occurred at 0.039 s (increase in diffuse reflectance). These figures are approximately a factor of 10 lower than values recorded on real machine trials[6], but considerably more realistic than values reported in the vast majority of literature where idealistic systems were used for coating consolidation investigations[3,5,8-10].

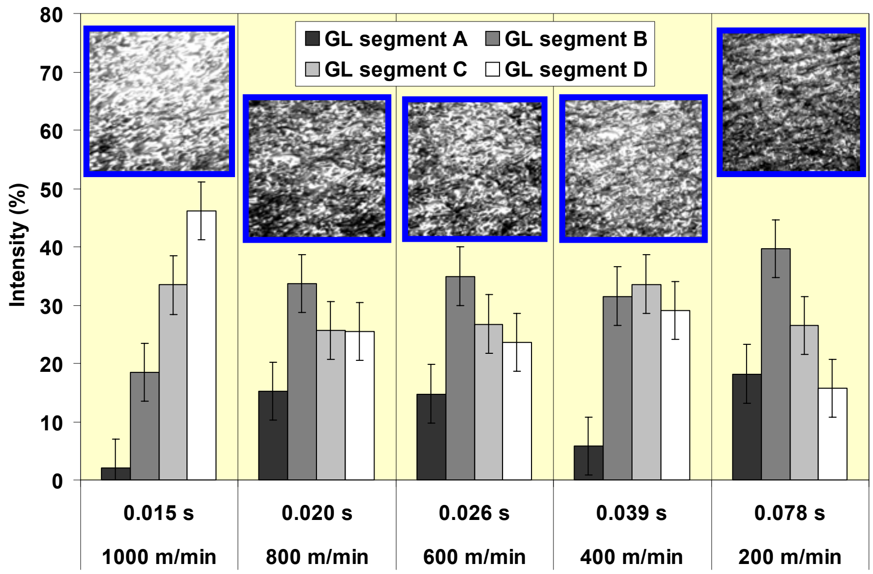

Figure 3: Consolidation behaviour with respect to image capture time. 9.0 gsm coat weight, 22 kN/m nip pressure and various coating speeds.

Conclusions

The surface characteristics of aqueous-based pigment coatings applied to a porous substrate using a film-press coater were investigated by assessing on-line images of the coating structure obtained shortly after application. The effects of nip pressure, coat weight and coating speed on surface structure were determined, as were the effects of time, which were found to be considerable. The FCC and SCC were observed, occurring at 0.020 s and 0.039 s from coating application, respectively. These times differed greatly from the vast majority of figures reported in the literature, where model systems had been developed to study these phenomena. The observations in this study stress the importance of investigating the effects of consolidation on a realistic system, where coating thickness, substrate porosity and dewatering kinetics greatly dominate.

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