New Breed of Hickeys in Offset Lithography Part II: Metal Contamination

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Keywords: Offset, hickeys, newspaper, microscope, metal

Abstract: In part I, we described the mechanism that led to print defects caused by plastic contaminants in both newsprint and value-added mechanical sheets. We found that these defects were created in the same way that conventional hickeys are, but that they showed very specific characteristics when viewed under a microscope. The source of contaminant was identified and the situation corrected.

In this study, we report outbreaks of print defects that have appeared in a large pressroom on newsprint and were first thought to be caused by plastic contamination; hence the paper was singled out as the source of the problem. The defects appeared as "white spots" on both solid images and high coverage screens and after a preliminary investigation in microscopy, it seemed again that the mechanism of formation was akin to classical hickeys.

The defects presented here constitute another breed of hickeys that is not random as they create stationary defects in the printed images. They showed to be resistant to the conventional methods of removing contaminants on an offset press. They have proven to be disastrous to print quality.

The hickeys were caused by iron particles adhering to the printing plates. Through various extensive microscopy analyses it was established that the ink was the source of contamination and not the paper.

Introduction

Hickeys are print defects resulting from contamination in the printing unit. In offset lithography, hickeys characterize defects that may come from numerous contaminants where the more common are dried ink and paper particles which are usually located on the plates or the blankets.

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In Part I of this study, the mechanism that led to print defects caused by plastic contaminants in both newsprint and value-added mechanical sheets was described [1]. It was found that these defects were created in the same way that conventional hickeys are, but that they showed very specific characteristics when viewed under a microscope. The source of contaminant was identified as particles of high-density polyethylene adhering strongly to the blankets that would resist any known simple method of removal.

In Part II, outbreaks of print defects that appeared in a newspaper pressroom and were considered to be the result of plastic contamination are reported; the paper was singled out as the source of the problem. The defects appeared as "white spots" on both solid images and high coverage screens and after a preliminary investigation in microscopy, it seemed again that the mechanism of formation was akin to classical hickeys.

The defects presented here appear to be yet another breed of hickeys that is not random as they create stationary defects in the printed areas. The printers have identified them as hickeys and they appear rather early into a run. They have shown to be resistant to conventional methods of removal and they have proven to be disastrous to print quality.

The contaminants responsible for these hickeys are identified through various extensive microscopy analyses and their effect on print quality clearly illustrated. Their origin is also identified.

PHENOMENOLOGY

Print defects can take one of several forms and an exhaustive list here would serve little or no purpose. However, in the case at hand, misprints in the shape of "white spots" were observed in a newspaper pressroom and the first characterization was that of hickeys principally in the black solids (Figure 1).

The more common sources of hickeys are listed as ink skin particles, greasy dirt from the press, particles of press rollers that are breaking down, chips of paint from ceilings and particles originating from the paper. When particles come from the paper, they are usually found on the blanket rather than on the plate; but if particles are found on the plate only, then it is unlikely that they originated from the paper [2].

In general, such particles will produce one of two types of hickey and this is mainly related to their ability to be water or ink receptive. With the former, the particle behaves like the non-image area and no ink is transferred to the blanket and the paper, hence a void. Conversely, the ink receptive particle will print its image and produce a doughnut (Figure 2).

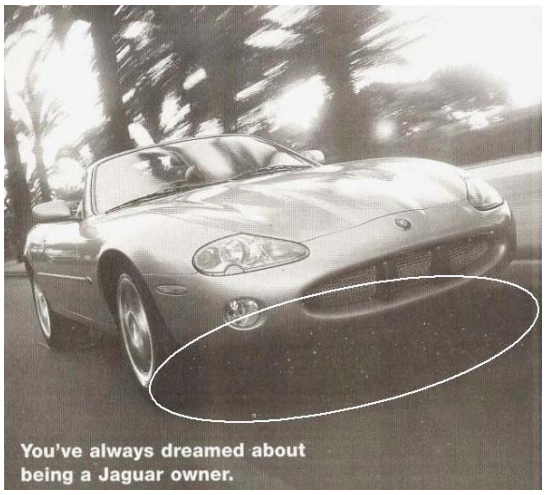

Figure 1: Print defects called "white spots" (after 43,000 copies).

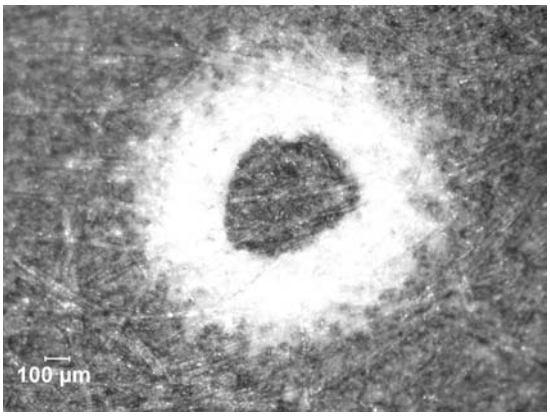

Figure 2: Classic doughnut hickey.

Contamination from paper normally produces void hickeys; but now in Part I of this study [1], we have identified a new type of hickey with a particular shape, generated by plastic particles adhering to the blanket. The resulting print defect is a "white spot" on a macroscopic scale, but we found that the print defect is formed in a manner similar to that of a conventional hickey with the exception that the contaminating particle transfers ink only partially, thus leading to the characteristic shape illustrated in Figure 3.

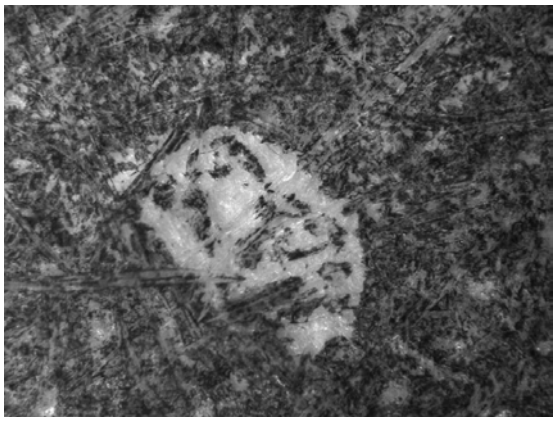

Figure 3: Print defect on solid black image caused by plastic particle stuck on blanket [1].

The particles coming from paper that may collect on a blanket include slitter dust, surface fibers, ray cells, shives (slivers), scale (surface sizing), coating lumps, hairs or synthetic fibers from paper machine fabrics and foreign particles within the paper (bark debris, plastic, recycled paper).

However, with mechanical grades, this list is reduced and for some of the remaining particles, there is little cause for concern because they would normally appear along with a situation of excessive linting and this would take precedence over a hickey issue.

BACKGROUND

The present problem with "white spots" remained for several editions until the pressroom elected to stop usage of the newsprint from this particular mill. Because the source of hickeys was attributed to the paper, an investigation was launched in order to assess the responsibility of the paper in this issue and what to do to correct the situation.

Print defects referred to as "white spots" were not new in this pressroom and particularly with the newsprint at hand. A few months earlier, the pressroom had been plagued with similar defects and the cause had been identified as plastic particles in the sheet [1]. This issue was eventually resolved and the mill now exercises careful control regarding the presence of plastic in the sheet at substantial cost and with methods of various degrees of sophistication. Nevertheless, the pressroom was quick to associate the new rash of print defects with plastic in the paper.

Samples of paper, tape pulls (from a plate and blanket), rags used by pressmen and printing plates were collected after a regular production run and sent for analysis to an independent laboratory. It was also known that the problem had not been observed in the color units although this had not been monitored very thoroughly given the severity on the black units. Debris analysis from tape pulls under light microscopy and Fourier Transform Infra-red Spectroscopy (FTIR) revealed that either cellulosic material (brown spots in the paper, ray cells, shives) and/or plastic contaminants (polyurethane) were the materials responsible for the accumulation of debris and presumably the cause of the print defects. The ink, fountain solution and physical degradation of rollers were also suggested as potential sources of contamination. An ink sample was also analyzed and showed a small amount of plastic and nylon fibers.

One of the preliminary conclusions from this investigation was that the brown spots mentioned in the independent study above could not be shives but could resemble stickies or sclereid cells (Figure 4). We also concluded that the plastic particles that had been reported were too small and too scarce to be associated with the problem of plastic contamination. Finally, the large number of "white spots" present on the printed samples, so soon after start-up (less than 5,000 copies), was of great concern.

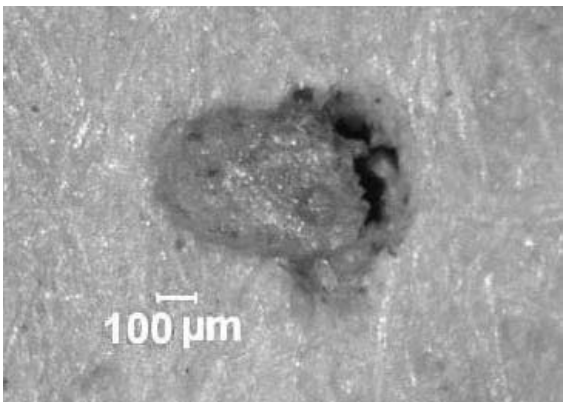

Figure 4: Sclereid cell picked out of the paper [1].

Concomitantly, we carried a preliminary microscopy study on the tape pulls as well as on various other samples available: printed and unprinted paper and a printing plate. No blankets had been supplied as they were being utilized on other jobs without problems and therefore had not been considered as a potential cause. In this study, we discovered the presence of metal-like particles clinging to the plates in the image areas where the defects had been most prevalent. Alongside or close to those particles, we could observe dark spots or stains as well (Figure 5).

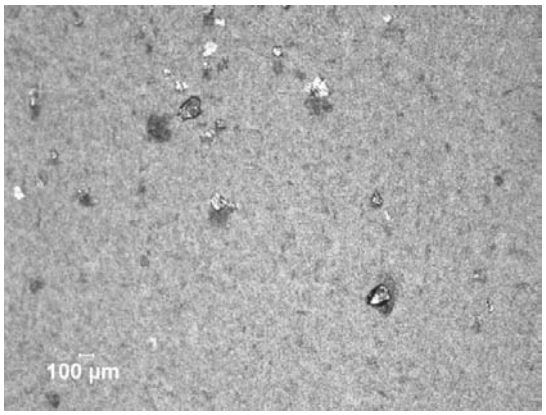

Figure 5: Metal particles and dark areas (stains) found on printing plate yielding "white spots".

EXPERIMENTAL INVESTIGATION: ANALYSES AND RESULTS

Through more microscopy analyses, it was possible to confirm the presence of the metal-like particles on the printing plates and the correlation between the position of these particles and the position of the defects within the printed images; hence, starting with new evidence of print defects, printing plates and blankets, we refocused the investigation on the metal-like particles.

Another clue came from the high concentration of print defects on the printed images while nothing through visual inspection could correlate with so many defects. However, following careful inspections of the plates under intense illumination at different angles of incidence, we found, for the optimum lighting angle, a myriad of shiny spots whose numbers corresponded to the high numbers of print defects encountered on solid images and heavy halftone coverage. Furthermore, this observation led us to discover that these particles were also present in the light coverage of halftones. Hence, the focus of the following investigations was set on trying to identify the nature of the shiny particles, verify the correspondence between their location on the printing plates and the defects on the prints, and support the findings with photomicrographs whenever possible.

It was through Energy Dispersive Spectroscopy (EDS) and Scanning Electron Microscopy (SEM) that we were able to identify the metal-like particles as elemental iron. The evidence is presented in Figures 6-8. Further analysis confirmed that the particles had no oxidation (rust) and this would narrow down the number of hypotheses when considering the source of these iron particles. Meanwhile, after isolating some of those iron particles (Figure 5) we decided

that in order to entertain any chance of finding their source, we needed to further characterize them in terms of their crystal structure or alloy composition, and perhaps relate them to some equipment, either in the paper mill or the pressroom. This would require metallurgical expertise. We tackled this problem on several fronts: paper, printing plates and blankets, ink, and metallurgy of the iron particles.

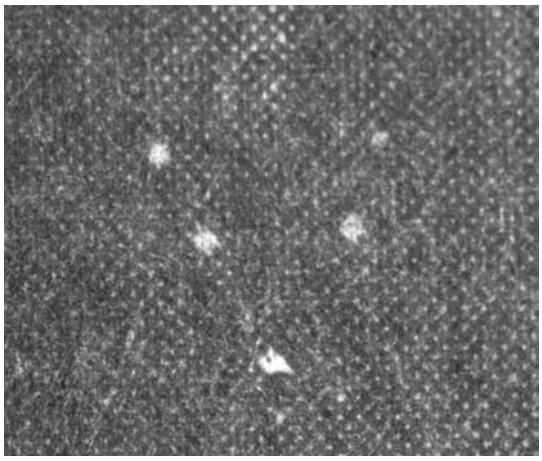

Figure 6: "White spots" on a heavy screened image.

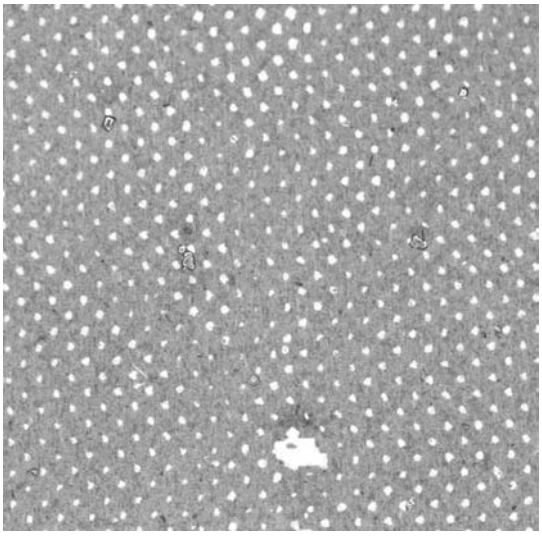

Figure 7: Metal particles stuck onto the plate that match the "white spots" in Figure 6.

The white defect in the lower section of Figure 7 is damage to the polymer of the plate.

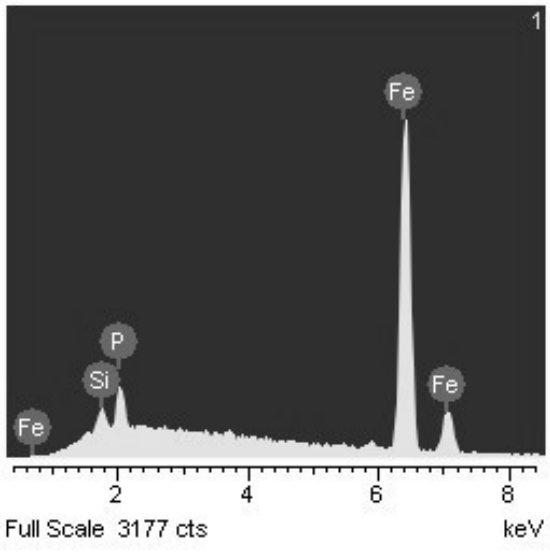

Figure 8: EDS spectrum of metal particles stuck onto the plate in Figure 7. The dominant element is iron.

Paper

Because the pressroom believed the paper to be the cause of the problem it was urgent to initiate an investigation to assess the responsibility of the sheet for those print defects. Visual and microscopy inspection of the unprinted paper did not reveal the presence of any contaminant that could be associated with iron particles. However, we quickly found the source of confusion regarding some of the erroneous conclusions arrived at in an earlier report.

This paper contained sclereid cells, a phenomenon more prevalent in winter (the print defects were first reported in January), and their shape and size could easily be mistaken for plastic particles as seen in Part I of the study [1]). Their sizes were also compatible with the size of the print defects. However, sclereid cells had never caused any significant amount of print defects before, probably because they are not removed from the paper surface during printing and if so, they will adhere only to the blanket, transfer ink while on the blanket but not stick permanently onto it. Another possible mechanism for sclereid cells to cause similar print defects would be to be picked out of the sheet after the ink had been laid down thus leaving an unprinted spot behind; however, we inspected numerous “white spots” under a microscope and never found a hole in

the sheet that could house the sclereids as seen in Figure 4, hence there was never any evidence to support this mechanism. Furthermore, the number of sclereids in a sheet of paper in no way matched the high concentration of "white spots" encountered on the prints. Finally, this pressroom was the only one to experience such defects with this particular paper and nowhere else had such a problem been reported.

While, investigating the printed images for other clues, we came across a peculiar pattern with several of the print defects with a dimension around 100 μm and above, that had escaped any previous observation. This would become paramount when studying other images that exhibited print defects in as much as the characteristic defects could be identified quickly and the problem evaluated with a high degree of certainty.

The peculiar pattern is shown in Figure 9 whereby a ring more or less regular is printed within the unprinted "void" of the hickey, in as much as the word "hickey" is used to describe a print defect rather than a contaminant. A significant fraction of all "white spots" on the contaminated images exhibited this "ring" characteristic. We singled out several such hickeys in both solid images and halftone screens, and this author believes that they too constituted a new breed of hickeys that will be referred to as "ring hickeys" in the rest of this report.

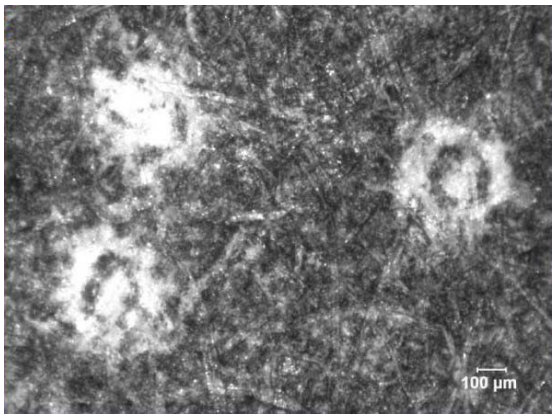

Figure 9: Cluster of ring hickeys on a solid black image.

It was possible to demonstrate the stability of ring hickeys as shown in Figure 10 where the pattern was distinct after 5,000 copies and then still evident after 70,000 copies. It was even possible to match the defect with the particle responsible (Figure 11).

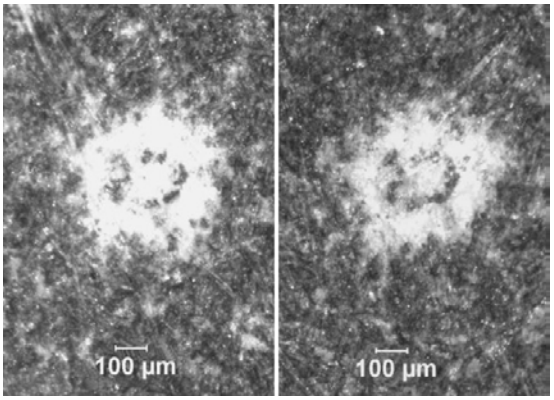

Figure 10: Ring hickey after 5,000 copies (left) – same hickey after 70,000 copies (right).

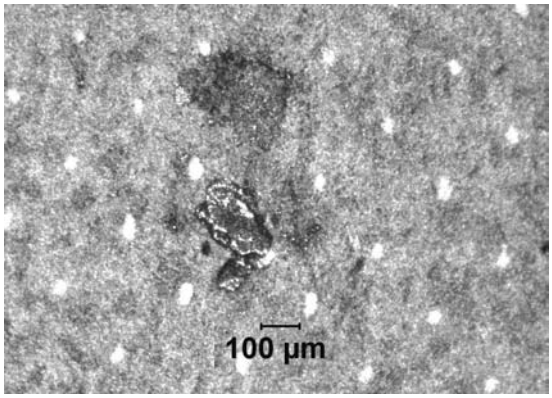

Figure 11: Displaced iron particle responsible for the ring hickey in Figure 10. Notice the dark stain left behind (top).

A potential explanation for the formation of such a ring pattern is illustrated in Figure 12. After inking of the plate, the ink will flow down the sides of the iron particle and through a mechanism akin to surface tension, the ink film will split: part will adhere at the bottom and the rest will flow outside of the stain area. The shape of the ring will be as irregular as the shape of the particles as seen in Figure 13 where the left image shows two rings from two particles close to one another and the right image shows a most irregular figure.

There were also some white dots without rings but generally their sizes were smaller than those of ring hickeys. These may have been produced by smaller

iron particles that behaved more like classic void hickeys and were too small to produce a pattern as proposed in Figure 12. Although the iron particles appeared to adhere strongly to the plates, we were able to dislodge them with relative ease with a sharp object and once displaced, they would leave a dark stain behind. The hypothesis here would be that these stains did not retain ink at first and hence produced "white spots" as well but not indefinitely. This would explain the observation that all the "white spots" did not correspond to shiny spots on the plate and that some likely appeared and disappeared at random throughout a press run.

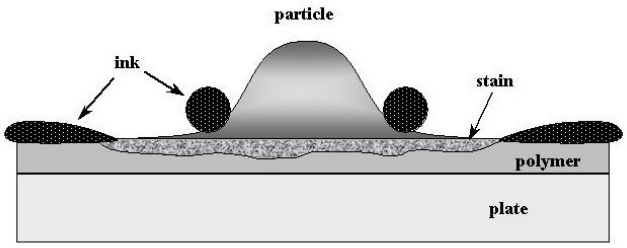

Figure 12: Model for "ring hickey" formation: ink flows down and surface tension keeps it around the contour at the bottom of the particle.

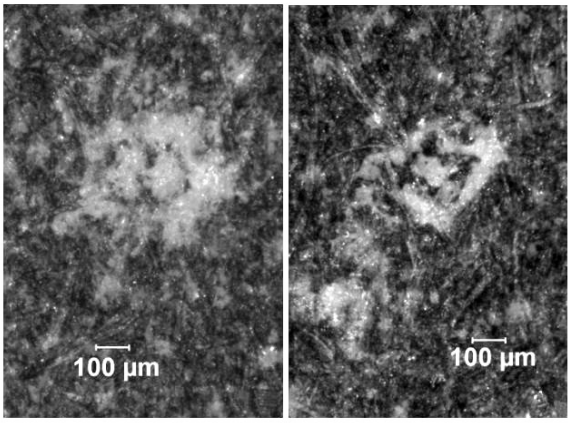

Figure 13: Ring hickeys with irregular shapes.

Going back to paper, another hypothesis as to the release of potential particles from the sheet was the web run in this particular pressroom whereby the web

traveled through a festoon with its small diameter rollers that would enhance the dislodging of incrusted particles within the sheet. To test this hypothesis or at least reproduce the conditions in the pressroom, the mill commissioned a local pressroom to run the presumed troubled paper through a similar path (Figure 14) prior to printing large solid black images on both sides of the sheet. It is here that the ring hickey concept proved most valuable: several rolls were printed and the technical staff at the mill who is highly skilled at identifying print defects could neither distinguish similarly high concentrations of "white spots" nor ascertain the presence of ring hickeys. This provided us with more evidence that the particles had not originated from the paper.

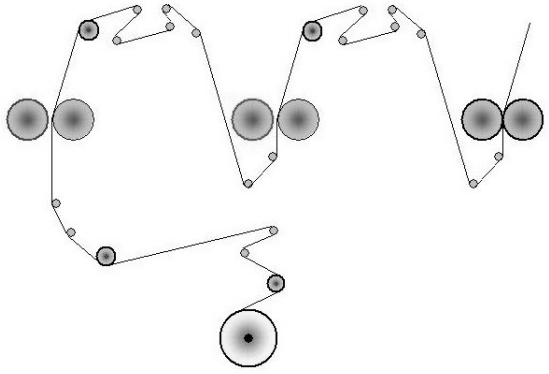

Figure 14: Web run at commercial printer to simulate the numerous small rollers prior to printing black.

Printing Plates - Blankets

Several sections of plates that had produced contaminated images were investigated and apart from the high concentration of iron particles and dark stains as shown in Figure 5, we found the odd scratch or defect in the polymer that we were able to identify on the images (Figures 6-7). It is however worth mentioning that some areas showed rather large "dirty" areas (Figure 11) but we could not determine if they contributed more, or different defects.

Particles were not found exclusively on the solid images but also on halftone areas in diminishing concentrations relative to the coverage. This was probably the strongest clue that prompted renewed interest to investigate the ink.

Blankets had not been recognized as part of the problem because the ones involved during the rash of "white spots" had been reused and delivered good prints. We inspected a section of a blanket containing a contaminated image and saw shiny spots under proper incident illumination. However, the concentration

of those spots was far less than that found on the plates. Furthermore, it seemed that those shiny spots were located mostly where there were debris of dried ink or inked paper or both. This would explain that after washing, the blankets were free of any contaminant and could be reused on other jobs. The blankets were therefore considered inconsequential to the problem at hand.

Ink

Early in the investigation, a grind test had been performed on a sample of bulk ink and on a sample taken from the ink fountain. The test revealed values of 3/0 for the former and 5/0 for the latter. The conclusions had been that the bulk ink was within specification for newsprint ink (4/1) while that in the fountain was out of specification. A description of the Grind Test is given in Appendix. The numbers obtained were more characteristic of pigment sizes and we realized that the test lacked the ability to detect the presence of the contaminating particles found here, because of their size (~25-200μm) and possibly their shape (plates). The differences reported between the bulk ink and that in the fountain were considered negligible and the results did not generate much interest.

As reported earlier, the concentration of shiny spots on the plate depending whether it was a solid print or a halftone sparked more interest about the potential contribution of the ink to this problem. We learned that many types of ink are prepared in a ball mill and we obtained, from a different ink manufacturer, samples of steel pellets used in the milling process of inks. The subsequent analyses carried on the ink are reported in the next section with regards to the metallurgy of the iron particles.

Metallurgy of Iron

Iron particles were collected from three different plates that had yielded significant amounts of defects and saved for metallurgical analysis. After a few failed attempts, we found a laboratory specializing in metallurgical analyses that accepted the challenge of characterizing these particles and comparing them with the composition of the steel pellets used in ball mills. The challenge was the small size of the particles collected (most were $\leq$100 μm) that did not lend themselves easily to standard analyses.

The iron particles were prepared for testing and after much manipulation, they were sent for characterization with an Electron Microprobe capable of determining quantitatively the chemistry of metallic particles of sizes above 10 μm. The pellets were also submitted to an identical characterization.

The results show that the chemical composition of the iron particles collected on the printing plates and that of the ball mill pellets were identical within the accuracy of the measurement particularly for microscopic particles. The values

obtained for four particles and four pellets were averaged to yield the data listed in Table I.

Table I: Chemical composition of particles collected on printing plates and of steel pellets used to prepare ink. Values are average of four samples.

Elements	Particles on plates (%)	Pellets (%)	Particles in ink (%)	Tool Steel O6 (%)
Carbon	**1.63**	**1.76**		**1.25 – 1.55**
Manganese	**0.91**	**0.94**		**0.30 – 1.10**
Silicon	**0.84**	**0.92**		**0.55 – 1.50**
Sulfur	**0.003**	**0.005**		**0.030 max.**
Phosphorus	**0.021**	**0.024**		**0.030 max.**
Chromium	**0.19**	**0.18**		**0.30 max.**
Nickel	**0.05**	**0.07**		
Copper	**0.09**	**0.09**		
Molybdenum	**0.04**	**0.04**		**0.20 – 0.30**
Iron	**96.23 max**	**95.97 max**	**Yes**	

The results were also compared against a worldwide database of over 100,000 alloy compositions and a tool steel (O6) was identified as the material used. The slightly higher concentration of carbon was characteristic of hardened steel.

During preparation of the pellets for microprobe analysis, it was shown that they were of poor metallurgical quality. Examination of cross-sections revealed numerous pores and cracks, and small pieces already partially broken as shown in the composite image of Figure 15. This would significantly reduce the resistance of such pellets to impact.

We also provided a small quantity of ink (~10 ml) that had been collected in the ink train of one of the printing units. After several dilutions and decanting, a final residue was filtered; then, using a strong magnet (it had been established that the particles were magnetic), micro-particles were collected and analyzed. It was not possible to complete a full chemical composition determination because of their small sizes, but they were confirmed as pure iron (Table I).

From the results of the various investigations conducted, it became clear that the role of the paper in this incidence of "white spots" could not be substantiated but rather, it was contamination of the printing plates with iron particles. Through sophisticated metallurgical analysis, we were able to match the alloy

composition of those particles to that of pellets that are used to grind ink in a ball mill.

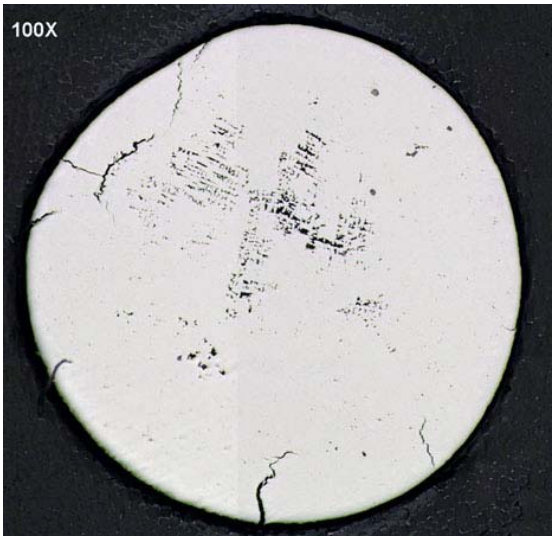

Figure 15: Cross-section of a steel pellet used to grind ink (diameter ~2mm).

COMPLEMENTARY TESTS - RESULTS

Printability on web press

Following completion of a technical report, we wanted to reconfirm the presence of "white spots" in a simulated run with some "troubled" paper. The next test took place in the pressroom on one of the presses where "white spots" had been experienced. Test plates were installed in a black unit and the press was started with the roll of paper that had been left on. This paper had been used for the normal production runs. The test was quite demanding since one image was 100% black over the full page while the other was an add that contained approximately 50-60% black coverage. The images were printed on both sides of the sheet.

This roll of paper already in place yielded 10,000 copies after which a roll from the troubled batch was spliced on and yielded 22,000 copies before the test was interrupted for production constraints. During the duration of the test, samples were collected and inspected. There were no signs of worse contamination for the second paper compared with the first, given the severity of the test.

Furthermore, it was not possible to detect any significant amount of "ring hickeys" although we did see one or two, which is to be considered negligible under the circumstances.

At the end of the run we collected the plates and found them covered with a fine dust. We made similar observations on plates set aside that had been used the night before but to a much lesser extent, as the coverage was only a fraction of that on the test plates. The dust had been observed by press crews before. The next day, a brief analysis in Scanning Electron Microscopy revealed that the dust particles were pure iron (Figures 16 and 17).

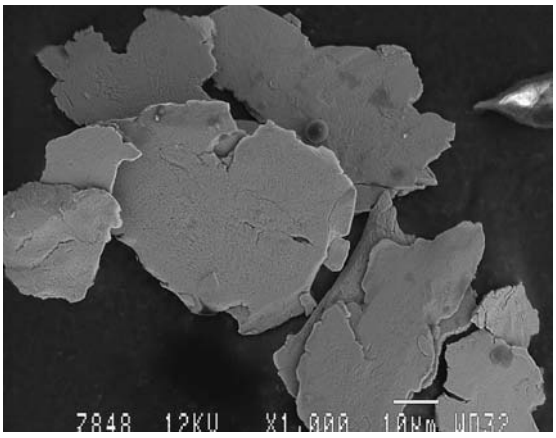

Figure 16: SEM micrograph of dust particles on plate.

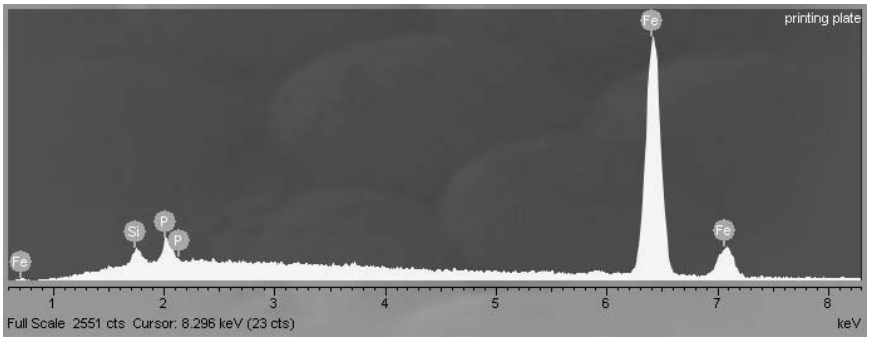

Figure 17: EDS spectrum of dust particles showing the strong iron peak.

A few weeks later, more plates from a regular run were collected, along with ink samples from the black fountain and the main reservoir. Small amounts of fine

dust were collected from the plates and again submitted to SEM analysis and once again they were identified as pure iron.

Isolation of metal particles in the laboratory

The plates taken after the regular run and the ink samples were prepared for chemical composition determination. First, one of the plates was cut up into small pieces and each piece was thoroughly cleaned in a beaker of petroleum ether immersed in an ultrasonic bath. A sizable amount of metal particles was thus collected and after washing with alcohol, it was stored in a vial in alcohol. It was easy to verify the ferromagnetic properties of the particles by bringing a magnet close to the vial.

The ink samples collected were taken to an independent laboratory and treated differently; samples of about 100 mL were diluted in petroleum ether and dispersed in alcohol with the help of a magnetic stirrer. They were then filtrated through millipore filters. Similarly to the plate, sizable amounts of metal particles were collected on the filters. The filtrate was easily recovered by thoroughly washing the filters in alcohol. We also found that we could wash the filters in acetone where they readily disintegrated and yielded only the metal particles.

For example, the concentration of particles with regards to the amount of ink collected from the reservoir amounted to 0.0173 gram iron particles for 113.31gram of ink. This information was not recorded for the ink from the fountain but the quantity of particles collected was very similar to that from the reservoir. Hence, we obtained two vials of particles immersed in alcohol from both the black fountain and the main reservoir. Finally, the amount of particles was very similar to that collected on the plate.

Metallurgical analysis

These iron particles were then sent to the metallurgical laboratory to be characterized for their chemical compositions with an Electron Microprobe. More pellets from the batch analyzed earlier were included in order to verify the repeatability of the method and compare with the new iron particles. Again the challenge was the small size of the particles collected and although now we had larger amounts of particles, we could not easily check their individual sizes (minimum size required is 10μm for complete identification).

The results, listed in Table II, were obtained from analyzing five samples from each batch of particles or pellets.

Considering the small variations between the chemical composition of the particles collected on a plate and those from the ink fountain, the experts in

metallurgy have confirmed the similitude between the two. Unfortunately, it was not possible to characterize the particles from the ink sample collected in the main reservoir due to particle sizes that were under the minimum threshold value of 10µm. We believe that sampling here could have been the cause whereby only small particles in suspension were collected with the ink. It is also interesting to note that the chemical composition of the pellets is identical to that obtained in the first stage of the study (Table I), thus confirming the repeatability of the analysis.

Table II: Chemical composition of particles collected on printing plates, in ink fountain and of steel pellets used to prepare ink. Values are average of five samples.

Elements	Particles on plates (%)	Particles in ink (%)	Pellets (%)	White Cast Iron (%)
Carbon	**2.71**	**2.59**	**1.76**	**2.40 – 3.00**
Manganese	**0.91**	**0.85**	**0.94**	**0.20 – 0.80**
Silicon	**0.91**	**0.81**	**0.92**	**0.50 – 1.50**
Sulfur	**0.008**	**0.004**	**0.005**	
Phosphorus	**0.020**	**0.021**	**0.024**	**0.15 max.**
Chromium	**0.21**	**0.18**	**0.18**	**0 – 2.00**
Nickel	**0.04**	**0.06**	**0.07**	
Copper	**0.12**	**0.14**	**0.09**	
Molybdenum	**0.06**	**0.05**	**0.04**	
Iron	**95.01 max**	**95.30 max**	**95.97**	

The chemical compositions of the particles from the plate were compared against a worldwide database of over 100,000 alloy compositions and the closest match was with a white cast iron whose composition is listed in the last column of Table II. This alloy is coded as either an IS 7925 or a BS 4844 white cast iron. This type of cast iron is described as an alloy specifically designed to resist abrasion from impacts. Furthermore, the composition of the pellets shows lower values in carbon content than that of the particles; this may reflect a switch from the ink supplier to more impact-resistant pellets since we had experienced the first rash of "white spots". Again, it is well known in metallurgy that a higher concentration of carbon is characteristic of hardened steel.

As mentioned earlier, the concentration of particles from one of the ink samples was estimated at approximately 150 ppm. In a 2-phase system like we have here: fluid-solid, this number could be meaningless. However, knowing that the individual sizes of the particles belong to the micrometric scale, we could

confirm that their numbers were quite large. Knowing also that most of these particles could cause a print defect, it was easy to conclude that this concentration level could be catastrophic to print quality. Finally, we were unaware of any norm regarding metal contamination in ink.

CONCLUSIONS

Print defects referred to as "white spots" in solid black images and heavy screens of a newspaper printed in coldset lithography on a 100% mechanical newsprint sheet were investigated by means of modern analytical techniques: optical microscopy, Scanning Electron microscopy, Energy Dispersive Spectroscopy and Electron Microprobe.

The "white spots" were associated with the discovery of metal particles stuck to the printing plates and it was established that their formation was attributed to a mechanism identical to that producing hickeys.

We have demonstrated that the contaminating particles were pure iron and from metallurgical analyses, that their composition was that of a carbon steel very similar to that of pellets used in a ball mill for grinding ink.

It was established that a significant number of "white spots" exhibited a peculiar geometry when viewed under a microscope and constituted a new breed of hickeys that we have called: *ring hickeys* because of the presence of a ring-shape pattern in the middle of a void.

It was not possible to detect the presence of any such iron particles in the paper even after printing several rolls in a commercial pressroom emulating the web run and the printing process (coldset offset).

A controlled test with a roll of litigious paper on one of the presses revealed no "white spots" after 22,000 impressions. However, a fine dust covering the printing plates was clearly visible and was later identified as pure iron through SEM analysis.

Printing plates and ink samples from the main reservoir and the ink fountain collected after a regular run also revealed the presence of iron particles. Metallurgical analysis confirmed the similitude between the particles on the plates and those in the ink fountain. The alloy was matched to that of a white cast iron specifically known for its high resistance to abrasion from impact, which could be easily linked to the type of iron used for the pellets to grind the ink.

Given the results from the print defect analysis and the subsequent confirmation that the iron particles found on the printing plates were identical to those found in the ink, we concluded that the contamination of the printing plates came from the ink and not the paper, and that this contamination created the print defects that were identified as “white spots”.

ACKNOWLEDGEMENT

The author wishes to thank R. Young and P. Cloutier for their devotion to find a solution to this problem and to E. Walker for the coaching in numerous microscopy sessions.

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APPENDIX

Ink Grind Test - Grindometer

The test consists of sliding a sharp edge over a steel plate that has calibrated beveled channels (Figure A1). The channels have a maximum depth of 25 µm at the beginning until they blend with the plate which is equivalent to 0 µm.

When the blade passes over a depth that is the size of the bigger granules in the ink then a streak (scratch) starts forming in the otherwise smooth trace of ink over the width of the channel. The numerator of the recorded value indicates the particle size where the scratch starts. To be accepted, a test must show at least three such streaks (Figure A2).

Over the length of the channel, the calibration runs from 0 to 10 µm. This means that a conversion factor of x2.5 is needed to convert to particle size.

Occasionally, the particles in the ink get crushed as they are dragged by the sharp edge and the streaks will disappear downstream from their initial point of

appearance. The denominator of the value gives the particle size at which the scratch disappears.

In the example here, the specification of 4/1 means that the size of the larger particles would be 10 µm (**4** x 2.5) and the streaks would disappear at 2.5 µm (**1** x 2.5).

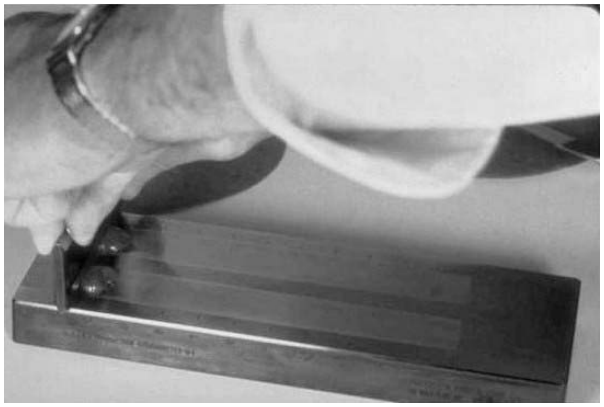

Figure A1: NPIRI grindometer to perform grind test for ink.

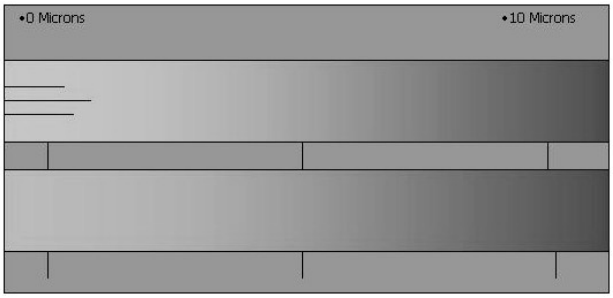

Figure A2: Details of the graduation on the NPIRI grindometer.