Investigations of Deinkability and Ink-Paper Interactions

Axel Fischer; International Association of the Deinking Industry (INGEDE); Munich, Germany

Abstract

With rising environmental awareness, paper recycling becomes a more and more important issue also in marketing of printers and – accordingly – in the development of a printer. But very little is known about coherences. During the recycling process, the ink is separated from the paper fibers dissolved in water, and then it has to be removed from the aqueous suspension. This is why current inkjet inks are almost impossible to deink. There are some ideas how they might be improved in terms of recyclability. One idea is to find a curing step that forms a macroscopic ink film that can break in to pieces big enough to be removed.

Dry toners easily fit into the deinking process that has been designed for offset and gravure inks. Still there are differences in fragmentation of the ink film, leading to different speck counts which are the critical parameter for toner based inks. The fragmentation is thought to depend on the homogeneity and the viscosity of the ink film. The morphology of the ink film might also be influenced by the surface properties of the paper used.

Introduction: Deinked Pulp for Graphic Paper

Today 50% of the European paper industry's raw material comes from recovered paper and board. Paper is the most recycled product in Europe, and Europe is the global champion in paper recycling with a rate of 55.4%, says CEPI, the Confederation of European Paper Industries. In 2007, the European paper industry used almost 50 million tons of recovered paper for the production of paper and board [1]. For newsprint and other graphic papers, 13.3 million tons were used.

In the US, total paper recovery was 54 million tons in 2007, with a total recycling rate of 56.1%, says AF&PA, the national trade association of the forest, paper, and wood products industry. But the use of recovered paper for printing-writing paper decreased from 2.4 million tons in 1997 to 1.7 million tons in 2007. The kinds of paper that have increased recycled content here are the low end of the paper quality selection: tissue and containerboard.

Recovered paper can be divided into different grades. Brown grades can be used for board production only. Standard deinking grades consist of mainly post-consumer magazines and newspapers. Deinked pulp has become an essential raw material for many paper mills. Recycling paper in Europe is understood as using recovered paper to produce graphic paper which involves a deinking step, the removal of the printing ink. In Europe, many newspapers are made of 100% recovered paper, on average the utilization rate for newsprint in the CEPI countries is 87.5%. This is why the European paper industry puts a lot of effort in keeping post-consumer graphic paper deinkable for the production of newsprint and other graphic paper. There is also a strong political demand to use recovered paper also for higher grades as in the production of newsprint paper, board and packaging paper the level is already high and cannot be raised significantly. Deinked pulp is already used as fiber source for SC magazine papers in some mills.

Assessment of Deinkability

To allow successful ink removal in the paper mill, each individual print product meant to be recycled should fulfill minimum deinkability requirements. For INGEDE, the International Association of the Deinking Industry, the assessment of the deinkability of printed products has been on the agenda for years, leading to ample research projects and discussions in the paper chain. INGEDE Method 11 has been developed as a scheme that allows to rate the deinkability of a specific printed product and to compare it to others. A small number of research institutes has proven to be able to perform this test methods in a reproducible way.

INGEDE Method 11 is also the basis for a new scheme to allow an easy assessment of the deinkability of a printed product. The "Deinkability Scores" [2] have been adopted by the European Recovered Paper Council as applicable to all kinds of printed products on white paper.

Deinkability Scores

The tests according to INGEDE Method 11 lead to five parameters: luminosity, color, cleanliness, ink elimination and filtrate darkening. To convert these results into a score, threshold and target values are defined. The maximum points achievable for each parameter are different thus indicating the importance of each individual parameter. A score below 0 in one or more parameters leads to the overall assessment "not suitable for deinking". The overall maximum that can be achieved is 100.

For a complete evaluation of the deinkability, the five individual scores are added. For dirt specks, there is also the limitation that the result of the deinkability test has to be "free of visible specks". If one or more individual scores are negative, the assessment of the print product is always "not suitable for deinking". However, the product may be well recyclable for a process without deinking.

The relevance of the Deinkability Scores is assessed according to the following table:

Rating of the Deinkability Scores

Score	Evaluation of deinkability
71 to 100 Points	Good
51 to 70 Points	Fair
0 to 50 Points	Poor
negative (failed to meet at least one threshold)	Not suitable for deinking

For toner based digital prints, the most relevant parameter is cleanliness, calculating as the area of dirt specks determined by optical image analysis. For inkjet prints, it is the luminosity and the filtrate darkening.

The detailed scheme is available from the European Recovered Paper Council's website [2].

European Deinkability Survey of Printed Products

At the PTS Deinking Symposium in 2008, the evaluation of 213 printed products all over Europe according to the scheme described above was presented [3].

The 90 newspapers (other tested print products were magazines, telephone directories, catalogues and flyers) were mainly printed by coldset offset. The samples were flexographic prints, in addition four inkjet and three dry toner printed newspapers were tested.

"Not suitable for deinking" were – for different reasons – 16 of the offset printed newspapers as well as all inkjet and flexographic printed papers, also one of the dry toner based prints due to a UV cured pre-print.

One outcome of the study was that none of the five offset printed flyers on uncoated paper was suitable for deinking. The study comes to the conclusion that the "most severe threat is however the use of water based inks as in flexographic newspapers and inkjet prints".

Testing Digital Prints

The poor deinkability of some digital prints has been identified early as a possible threat to today's paper recycling systems: Although some of these prints deink quite easily, others lead to severe problems, which may endanger the entire deinking process. A series of initial tests performed by scientists of the French Centre Technique du Papier (CTP) in Grenoble has also shown that all water based inks lead to severe deinking difficulties. Differences between processes currently on the market turned out to be surprisingly high.

Microscopic Investigations

Deviations in the deinkability of dry toner based prints lead to the hypothesis that the structure and properties of the paper surface might influence the detachment of the ink. Further information was expected from correlating differences in fragmentation of the ink film to different speck counts which is the critical parameter for toner based inks. The fragmentation is thought to depend on the homogeneity and the viscosity of the ink film. The morphology of the ink film might also be influenced by the surface properties of the paper used.

Method

An Alicona InfiniteFocus® microscope was used for images of the topography of the samples. This is an optical 3D measurement device for quality assurance in the micro- and nano range. A stepping motor moves the sample vertically through the focus. Both topographic and color information are registered to a 3D datafile. 3D measurements can be performed directly on the optical color image.

For best results, a transition of unprinted are to a fully black printed are was chosen. The device leads to images that are able to show the surface properties of the paper as well as of the toner. The thickness of the toner layer can also be estimated directly.

A principal picture of a scan is shown below *(Figure 1)*.

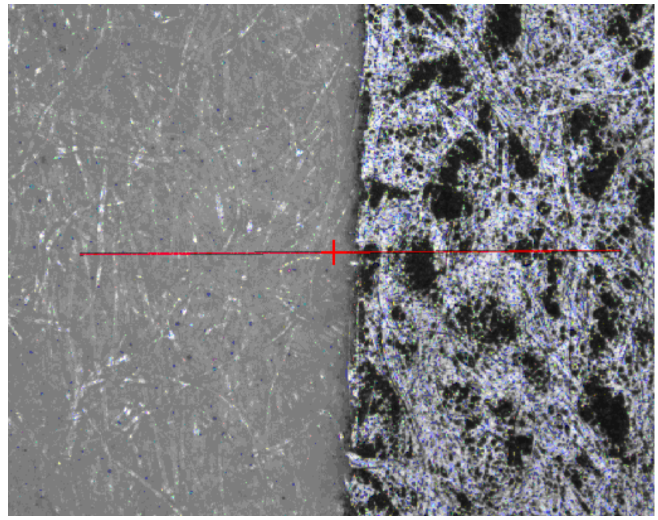

Figure 1*. Topographic scan showing the unprinted section (left) and a black printed section of a dry toner printed sample (right)*

Another sample *(Figure 2)* shows almost no structure of the paper and no topographical change by the applied ink.

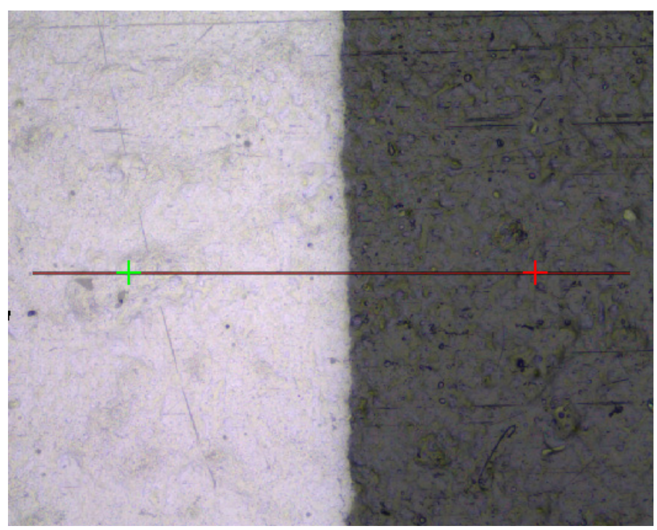

Figure 2*. Print sample (direct mail), width 1,000 µm*

These two samples show in principle the basic information that can be read from the pictures – whether an ink or toner layer covers and equalizes the paper structure or follows it. This view can also give a first estimate on whether the ink/toner builds up a layer or not.

For more information, a 3D picture can be calculated from the topological information (*Figure 3*). This picture corresponds to *Figure 1*.

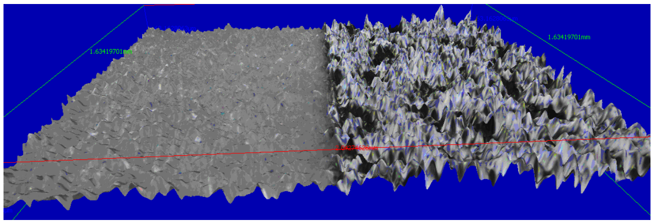

***Figure 3**. Calculated 3D image*

A profile along a chosen line allows estimating the height of the ink layer. *Figure 4* (corresponding to *Figure 2*) shows very little difference in the structure of the printed and unprinted surface.

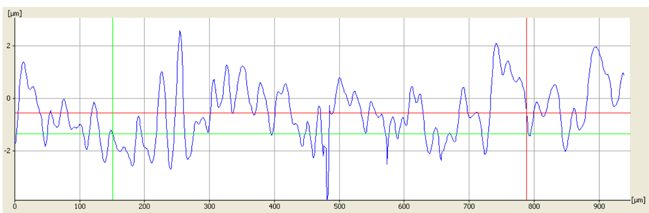

***Figure 4**. Height profile*

The next two pictures show – at the same magnification – two different dry toners that look completely different under the microscope and also differ in the number of specks seen in the deinkability test method.

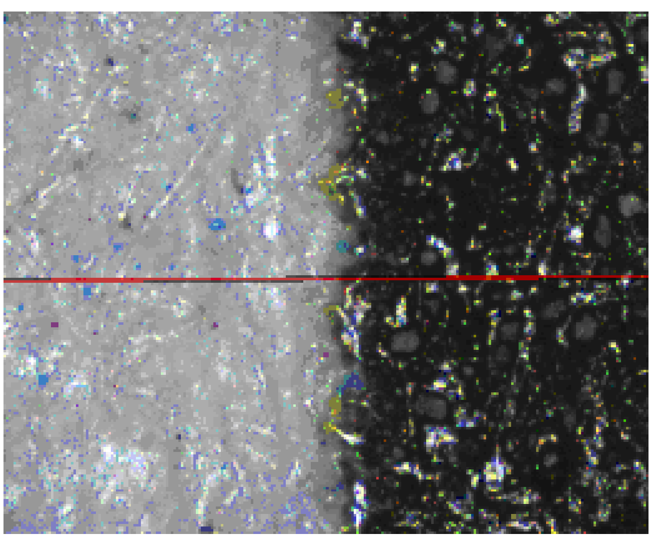

***Figure 5**. Dry toner print*

The corresponding height profiles also look completely different, though for technical reasons the axes in the profiles do not correspond in *Figures 7 and 8*.

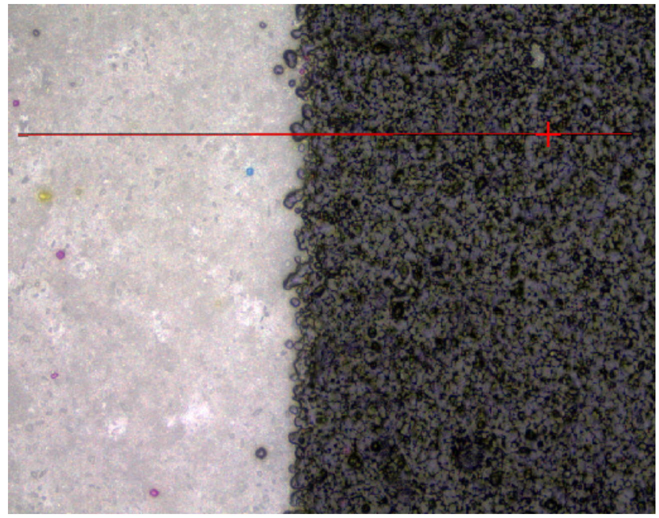

***Figure 6**. Dry toner print*

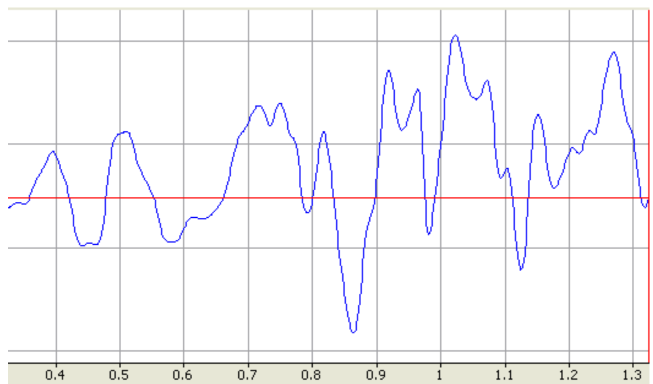

***Figure 7**. Height profile*

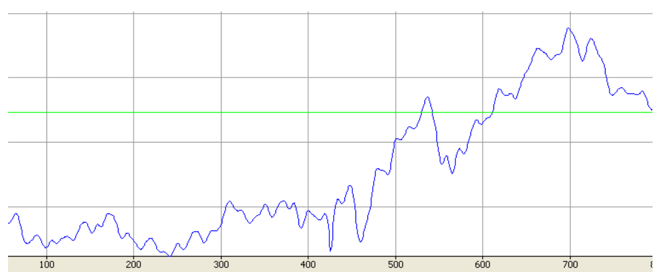

***Figure 8**. Height profile*

Conclusion

Further investigations have to be made to explain correlations with ink fragmentation. Currently it looks as if an inhomogeneous ink layer corresponds to higher fragmentation resulting in better removable dirt specks. It is possible that an increasing number of predetermined breaking points in an inhomogeneous layer ease the fragmentation and removal of ink. This might explain why – unlike observed in uncoated offset flyers – toner prints on rough paper surfaces seem to result in a better deinkability than on smooth surfaces. This might also explain the problems that liquid toners show in the deinking process – the very homogeneous and elastic film that is created before being transferred to the paper surface has less breaking point and is more difficult to disintegrate, resulting in a higher number of large visible dirt specks.

Outlook: New Inkjet Inks

At the drupa 2008 fair in Düsseldorf, Germany, a variety of production size inkjet printers were presented. Different print samples were taken and tested for their deinkability. The results will be discussed during the presentation.

Especially interesting are new approaches that influence the physico-chemical properties of the applied ink layer by a primer or special "bonding agent". Topographic investigations show that there is hardly a macroscopic difference to be detected in the samples available at drupa without *(Figure 9)* and with *(Figure 10)* this bonding agent. The deinkability results are to be confirmed in cooperation with the respective printer manufacturers.

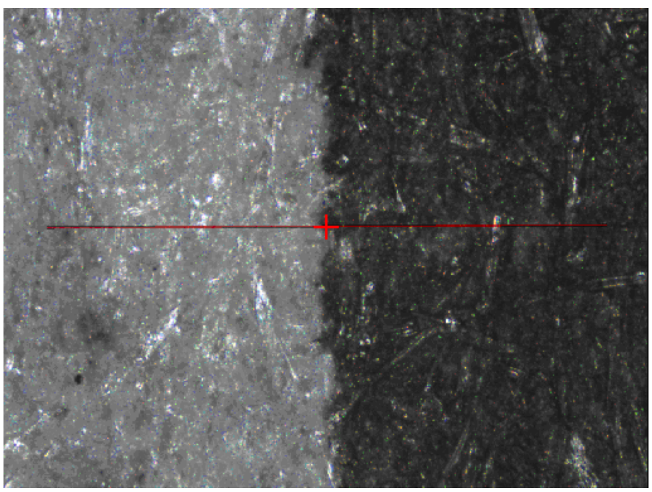

Figure 9*. Inkjet sample "without bonding agent" showing also some bleeding from the reverse side*

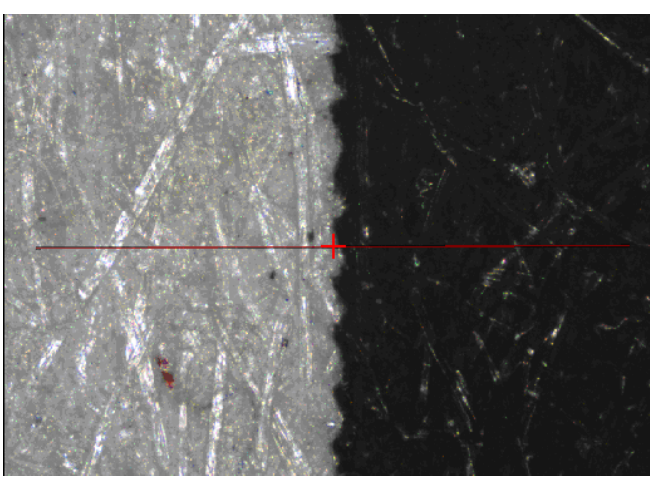

Figure 10*. Inkjet sample "with bonding agent"*

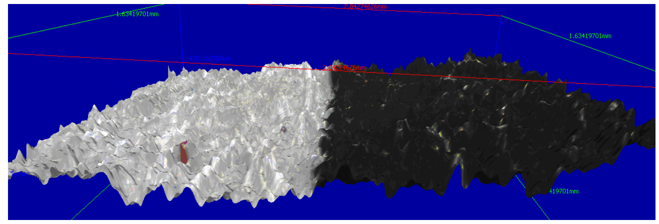

Figure 11*. The 3D model corresponding to Figure 10*

The 3D model corresponding of the inkjet sample (with bonding agent, cf. *Figure 10*) also shows no build-up of a layer at least in the dimensions of the paper roughness.

Acknowledgements

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References

[1] CEPI, Key Statistics 2007 (Brussels 2008)

[2] European Recovered Paper Council, Assessment of Print Product Recyclability – Deinkability Score, 2008 (www.paperrecovery.org)

[3] A. Faul, H.-J. Putz, European Deinkability Survey of Printed Products, presented at the PTS Deinking Symposium, Leipzig, 2008

Author Biography

Axel Fischer studied chemistry at Munich Technical University. He worked as a Science Writer for TV, print media and Germany's major news agency. Since 1994, he is responsible for the public relations of INGEDE, the International Association of the Deinking Industry. Besides dealing with international media, he also represents the association at international events and working groups dealing with recyclability, with flexo inks and digital printing technologies and the consequences of recycling printed materials. He chairs the European Round Table on the Deinkability of Digital Prints.