

Evaluation of cut quality of woodfree coated papers

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ABSTRACT: Dusting and blanket pollution are of particular interest in offset printing. Papers must be free of dust and loose particles to drastically reduce the wash interval of the blankets. Those particles are mainly generated during converting operations, such as sheeting. Considering the end-customer point of view, the visual aspect of the cut appears to be very important. To study in detail the influence of the sheeting parameters and paper properties on cut quality, a new test method to quantify the cut quality of woodfree coated papers has been developed. In particular, this method takes into consideration the state of the coating layer near the cutting edges.

Application: This paper presents a new experimental method to analyze the cut quality of woodfree coated paper and emphasizes the influence of the state of the coating layer(s) located near the cutting edge on the printing quality.

For woodfree coated (WFC) papers, which are mainly printed in offset, the cut quality is of high importance. Papers must be free of dust and loose particles created during the cutting process (further called “cutting dust”), which can drastically reduce the wash interval of the blankets and lead to insufficient printing quality. Besides that, the visual aspect of the cutting edges can also be of high importance for the customers (e.g., for high-quality magazines).

Intensive research was carried out in the 1970s and 1980s regarding the cutting process in the paper industry. The main developments were aimed at the productivity of the cross-cutter with, for example, the development of the synchronous double rotary cross-cutter [1]. Modern and highly productive sheeters are designed to cut several paper webs simultaneously, and machine suppliers are already mentioning the possibility to cut up to 1000 g/m² knife load capacity [2]. Research work, experience, and advice on how to operate the sheeters to obtain and maintain the best cut quality have been discussed extensively by Reinhold Schable [3]. Several factors, such as the machinery (knife geometry, blades overlap, over speed, and knife quality) and the material to be cut (composition, architecture, and properties) can strongly impact cut quality.

To evaluate the influence and importance of those factors for WFC papers, a quantitative and reproducible test method is mandatory. Xerox has been a pioneer in setting up an official test method (ISO 22414:2004 “Paper-cut-size office paper—measurement of edge quality”). This method is based on the visual analysis of the cutting edge with a microscope. Based on the raggedness of the edges, a numerical value is given, with 1 being good to 6 being bad. Since then, offline automated measurement has been developed [4] for sheets up to 28 x 43 cm². It consists of a scanner and image analysis

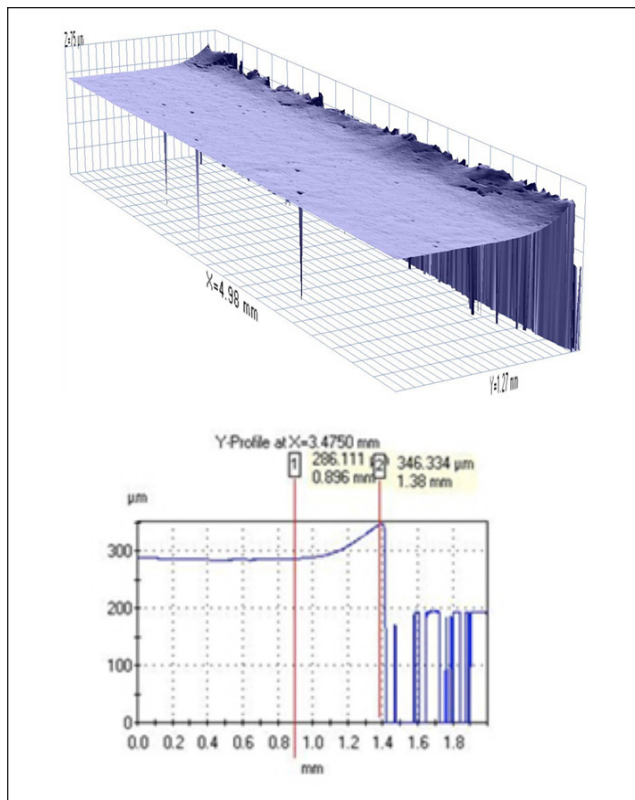
software and informs the operator on cut sharpness, hanging fiber count, sheet size, and the curvature of the cut. This system can be set up to measure in compliance with ISO 22414. Recently, an online measurement system has been developed [5] that collects and measures unbounded dust and debris from the paper web. The result consists of the time required to collect a certain amount of dust. All these test methods are essentially focusing either on the raggedness of the edges or on the amount of dust collected, and all have been mainly designed for uncoated papers or boards. Due to the brittleness of the coating layers, WFC papers are extremely sensitive to the cutting operations. Therefore, the raggedness information alone or the amount of dust developed appears to be insufficient to quantify their cut quality.

METHODS

Existing methods to evaluate cut quality

In addition to some tests used in paper mills, such as visual or “hand-feeling” evaluation, most of the methods mentioned earlier have been evaluated. Offline dust measurement methods turned out to be inefficient for WFC paper because they only measure dust located at the outer faces of the pallets, not between the paper sheets. During the cutting process, however, generated dust particles can be projected several centimeters inside the paper sheet surface. Online dust measurement systems work at correcting this weakness fairly reliably. With such systems it is possible to continuously monitor the sheeting process and to study the differences between paper grades. However, installation of such systems is cost-intensive because they have to be installed on every single sheet. A further disadvantage of both online and offline methods of dust measurement systems is that no information regarding the cut quality (e.g., raggedness and protruding fibers) is obtained.

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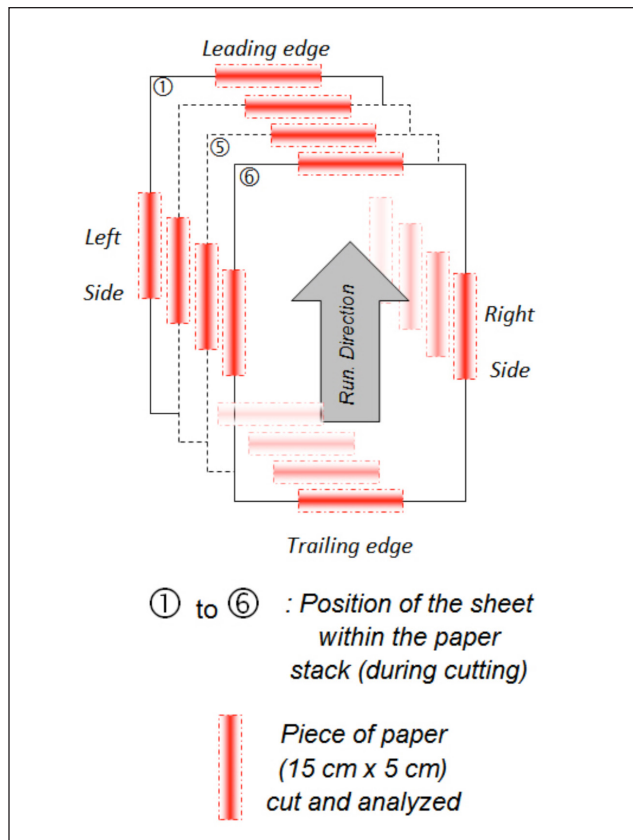


1. Representation of a cutting edge in 3D. Measurement performed with the COTE:M Nanoscope CNL-300 (COTE:M; Koblenz, Germany).

Noncontact optical metrology systems have the advantage of providing more information, such as the topography profile near the cutting edges shown in **Fig. 1** [6], but these measurements are highly time consuming and the data analysis requires extra time. Visual and hand-feeling methods are the fastest way to evaluate a sample, but as expected they are highly dependent on the person carrying out the test. Only an expert can quantify the cut quality obtained at the sheeter with the naked eye, and it is unrealistic to expect repeatable results with different testers. Using a stereomicroscope equipped with a digital camera (as used in the Xerox method) appeared to be the cheapest, easiest, and most reliable solution to observe the cut quality, even if it remains time-consuming. However, the measured parameters must be adapted for WFC papers.

Equipment

The equipment used to analyze the samples consists of a stereomicroscope (Leica MZ12, Leica Microsystems; Wetzlar, Germany) equipped with a digital camera (Leica DFC295, Leica Microsystems). The stereomicroscope is equipped with a lens of 10 mm x 21 mm. During the measurement, the surface of the paper sample is illuminated at an incident angle of 20° from two sides using a cold light source (Leica CLS 150XE, Leica Microsystems). The software used is Leica Application Suite (Leica Microsystems). Standard settings are a micro-



2. Paper samples collected at the sheeter, areas analyzed, and identification of the different edges.

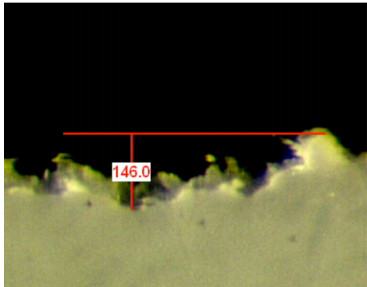
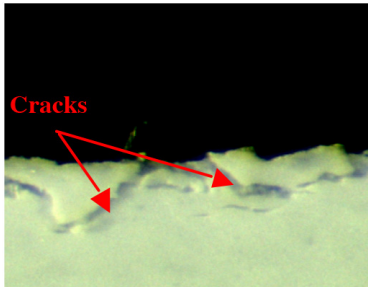
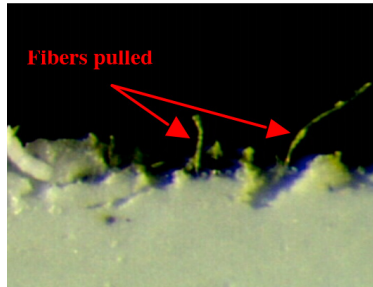
scope magnification of 8.0x, giving a total magnification of 80x. Illumination at a low angle of incidence is important to reveal the presence of coating cracks near the cutting edges due to the created shadow. Those cracks result from the high shear stress generated near the tip of the blade during the cutting process.

Sample preparation

The sample preparation is simple and takes only a few minutes (**Fig. 2**). It consists of cutting out an area of 15 cm x 5 cm at the four edges of the paper stack, defined here as a set of sheets cut simultaneously at the sheeter. Every sheet in the stack needs to be collected and marked (position within the stack, top and bottom side of sheet, respectively, and identification of edges). Identification of edges is important because, depending on the sheeter configuration, the cutting edge will either be supported by the bottom knife ring (“band edge”) or not (“blade edge”), resulting in different cutting qualities. A sample length of 15 cm is required to get a good representation or average of the cut quality.

Parameters describing the cut quality

Detailed analysis of more than 300 paper samples showed pronounced differences in the quality of the cutting edges between the sheets, depending on their position within the paper stack during the cutting process. The results vary with

"Raggedness"	"Coating cracks"	"Fiber pull"
The distance between the highest peak and the lowest valley	Number of cracks over a defined distance of 5 cm	Fibers pulled out at the cutting edges (visual evaluation; 1: very good, 5: very bad)
		

3. Three factors used to quantify the cut quality of woodfree coated papers (all images taken with the same camera settings; the width of the picture represents 700 μm). For raggedness, the distance between the highest peak and the lowest valley is as defined in ISO 22414:2004, but keeping the real distance as the measurement value.

blade characteristics (e.g., sharpness and geometry) and the paper grade to be cut. As mentioned previously by Frye [7] and Schable [3], the variations can be explained by the fact that the sheets in a paper stack will be subjected to different levels of stresses depending on their position in the stack and relative to the blades. Meehan and Burns [8] mentioned in their work that the applied stresses in a web and the material's response to these stresses dominate the quality of the cut surfaces. It is, therefore, necessary to separately analyze every single sheet in the stack and to record the sheeter's configuration (i.e., the position of the blade relative to the paper stack).

Three parameters were used to describe the cut quality (**Fig. 3**):

- **Raggedness:** Distance between the highest peak and the lowest valley at the edge
- **Coating cracks:** Average number of cracks longer than 60 μm per 5-cm cut edge length
- **Fiber pull:** Presence of fibers pulled out from the cutting edges

The parameter that has not been previously considered in the alternative test methods is the presence of coating cracks in the coating layer near the cutting edge. Those coating cracks will not necessarily result in loose particles and the formation of cutting dust during the converting operation; however, the resulting weakly bonded coating particles are likely to be pulled out during offset printing because of the tack of the ink.

The amount of cutting dust is not included in this test method because of the difficulty of quantifying its amount within a single paper stack. Indeed, extreme variations in the amount of cutting dust have been noticed because of the presence of trim removal systems, which also suck off cutting dust, and because of the influence of transporting the samples (e.g., from production to laboratory). Moreover, the presence of cutting dust is often controlled today by dust extractor sys-

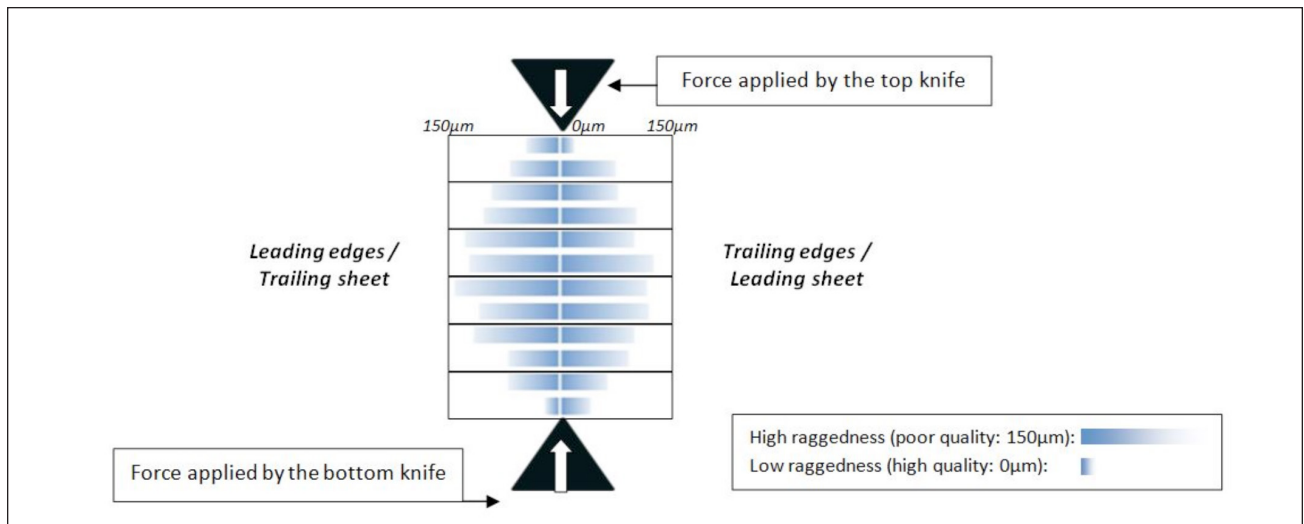
tems on the slitting devices. Therefore, evaluation of the amount of cutting dust on the paper surface will often more reflect the efficiency of the dust extractor system and the machine configuration than the actual cut quality itself.

The presence of fibers pulled out at the cutting edges might appear to be irrelevant in quantifying the cut quality specifically, due to the fact that the long fiber content is dependent on the paper grade produced. However, we believe that fiber pull might have some effect on printing runnability, as pulled out fibers at the cutting edges—depending on their number and size—could disturb the separation of the sheets at the feeding table of the printing press.

Visual representation of results

Application of the proposed analysis method results in a large number of data for every single paper stack. For example, when six sheets are cut simultaneously, we obtain 144 data points (six sheets x two paper sides [top and bottom] x four edges x three characteristics). To visualize these data, a system has been implemented to represent the three parameters describing cut quality on both sides of the knives over the whole paper stack for one type of cut (either longitudinal or cross-cut). In **Fig. 4**, the raggedness of the cross-cut through the paper stack is shown. A bar chart is used to represent the raggedness measured on both sides of the paper sheet over all sheets of a paper stack. The height of the bar relative to the center line is a measure for the raggedness with higher values indicating poor raggedness. In **Fig. 4**, it can be easily observed that sheets located in the middle of the paper stack are of poor cut quality in terms of raggedness, while the external sheets show quite a good cut quality (i.e., low values).

Visualization is easy to understand and very practical in the analysis of the effect of different machinery settings. The number of coating cracks and pulled out fibers may be similarly visualized.



4. Raggedness within a paper stack at the rotary cross-cutter (six sheets cut simultaneously).

Cutting and printing trials

As mentioned previously, the aim of this method is an in-depth analysis of the cut quality of WFC papers to ensure the best cut quality for the printer. To be able to validate the proposed method presented, a series of practical cutting and subsequent printing trials were carried out.

The same paper grade was cut and 12 pallets representing different cutting qualities from very poor to very good were produced by adjusting the sheeter's settings [3,9], varying the amount of sheets cut simultaneously, and using a dust extractor system (**Table I**). All the pallets were produced with the

same paper stock to exclude effects on the test related to paper variability.

In the printing trial, performed on a commercial printing machine, all pallets (5000 sheets/pallet) were printed under identical conditions. Between each test, automatic and manual washing of the blankets were performed on all printing units. Printing quality and paper runnability were precisely followed for each test. A special printing test form containing dust-sensitive raster fields near the cutting edges was designed. Any disturbance in a raster field is easy to detect with the naked eye because of the change in the points order.

Test N°	Type of Sheeter	Knife Geometry	Sheets per Paper Stack	Dust Extractor System	Comments
1	Twin slitter	Standard	6	Off	Referent
2	Twin slitter	Standard	6	Off	Same as referent but with different cutting edges (band edges)
3	Twin slitter	Standard	6	Off	Short grain pallet (all other pallets were cut long grain)
4	Guillotine	Standard	-	Off	Perfect cutting quality - Guillotine
5	Twin slitter	Standard	4	Off	Good cutting quality (4 sheets vs. 6 sheets)
6	Twin slitter	Standard	6	Off	Poor cutting quality (high overlapping + old knives)
7A	Twin slitter	Standard	6	On	Very poor cutting quality obtained with old blades & wrong sheeter settings
7B	Twin slitter	Standard	6	Off	Same as 7A but without dust extractor system
8	Twin slitter	A	6	On	Altered knife geometry
9	Single slitter	B	6	On	Altered knife geometry
10A	Twin slitter	C	6	On	Altered knife geometry
10B	Twin slitter	C	6	On	Same as 10A but pallet turned upside down at the printer

I. Specifics of sheeting conditions for the commercial print trial.

	Raggedness of the Edges	Amount of Cracks (5 cm)	Fiber Pull
Raggedness of the Edges	1	0.23	0.17
Amount of Cracks (5 cm)	0.23	1	0.34
Fiber Pull	0.17	0.34	1

II. R^2 values (linear regression) for evaluation of possible direct interdependence between the three parameters.

RESULTS AND DISCUSSION

Linear regression analysis of the three parameters describing cut quality of the pallets confirmed that the three parameters are independent from each other, as $R^2 < 0.35$ (Table II).

To evaluate the repeatability of the test method, the measurements were repeated three times for six different papers. The variation coefficients between the values were generally below 3%, which is an indication that the developed test method is repeatable and thus suitable for process control.

Influence of cut quality on printing results

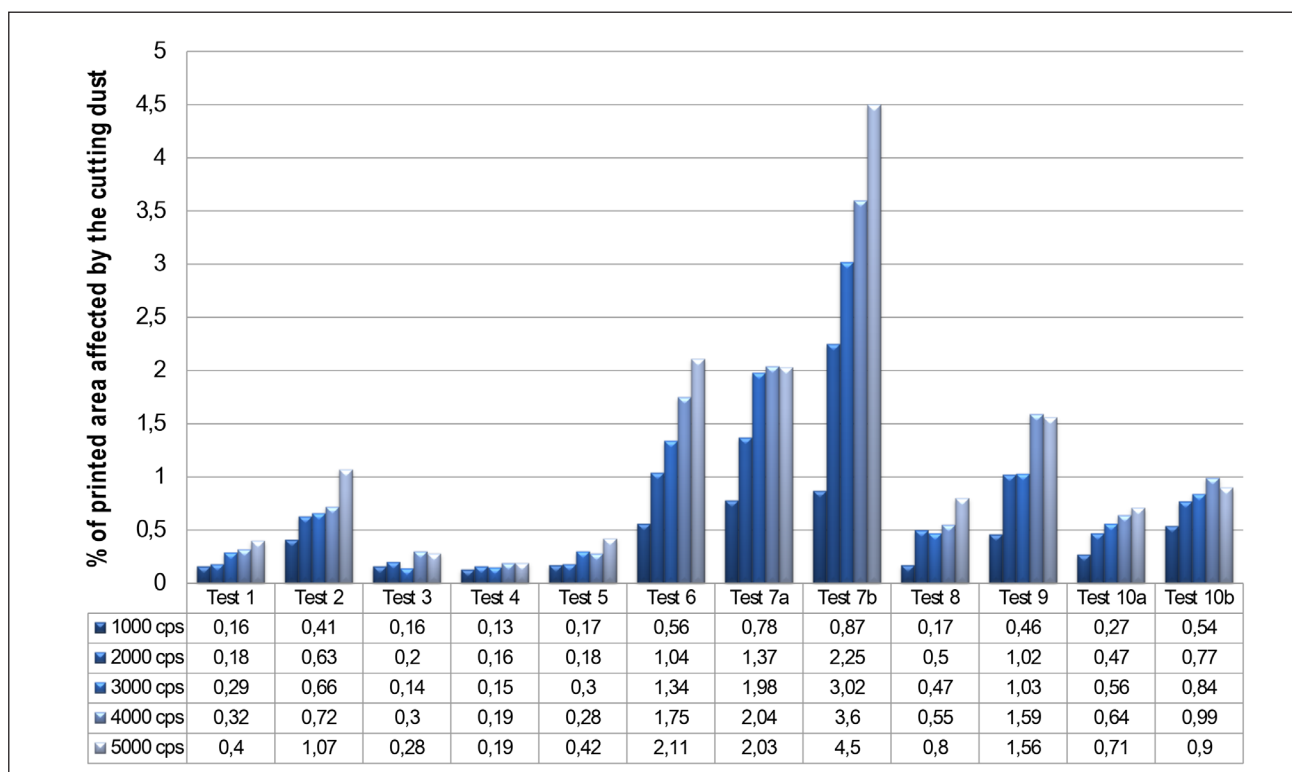
Five thousand copies were printed per pallet and printed samples were collected after each 1000 copies. The amount of dust disturbing the printing quality in a defined area near the cutting edges has been quantified with the help of a scan-

ner and image analysis software (internally developed). This program evaluates the surface (% of a defined area) covered with dust. The higher the surface, the worse the printing quality. Results have been plotted in Fig. 5.

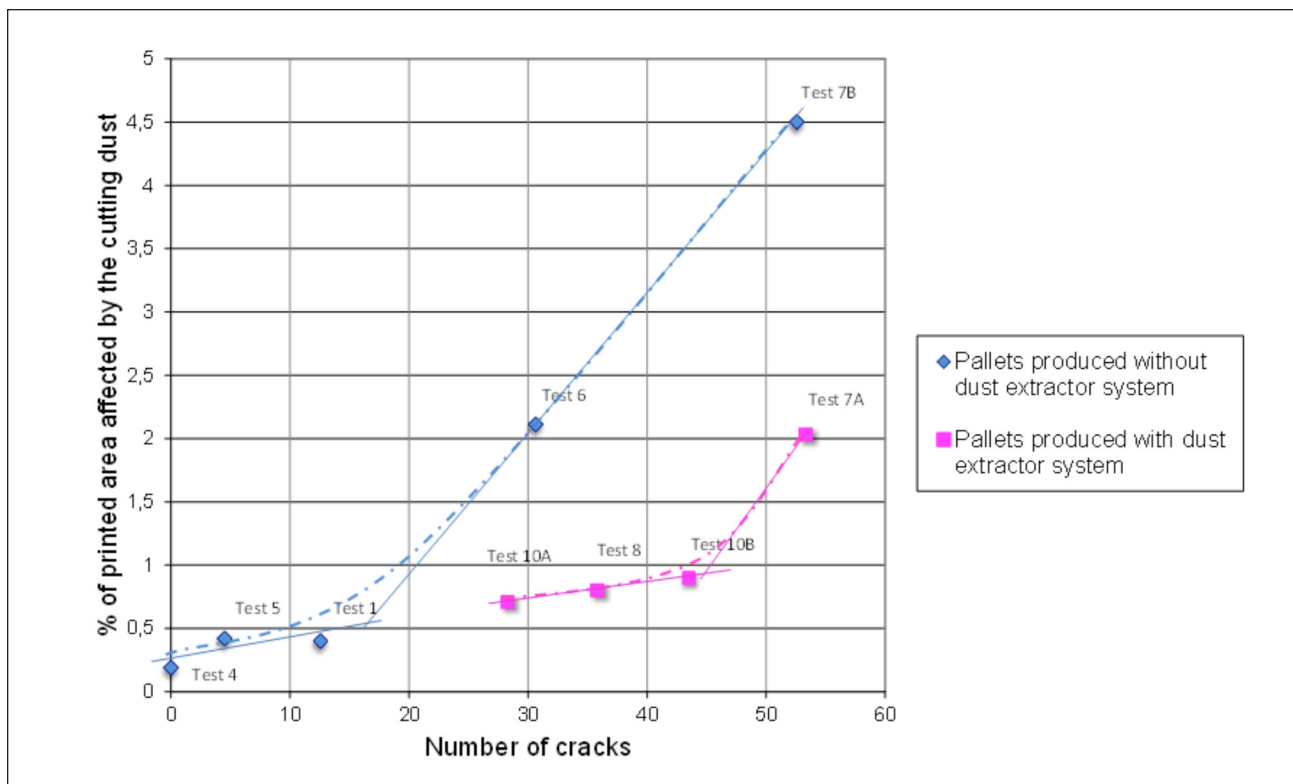
The amount of dust in the printed area increases with the amount of printed samples (i.e., coating particles accumulating on the blanket surface). No correlation was found between the parameters measured and the paper runnability, as all papers could be run at 14000–18000 copies/h. Also, no correlation was found between the raggedness of edges and print quality or printing runnability. However, we believe that these parameters are still important, affecting the visual appearance of a cut.

To study the correlation between the amount of cracks and the percentage of the printed area affected by cutting dust, the data were plotted as two separate series in Fig. 6. One series depicts the samples cut with the dust extractor system and the other depicts the samples cut without the dust extractor system. Only the pallets presenting the same type of cutting edges in contact with the blanket (blade edges) have been plotted (tests 2 and 9: band edges and test 3: cross-edges).

The number of cracks shows a clear correlation to the amount of dust on the printed samples after 5000 copies. For both series, it can be observed that the number of cracks is not creating a major problem until it reaches a certain level. Above this level, printing quality starts to deteriorate rapidly. Correlation between the coating cracks and the printed area affected by the cutting dust is not surprising because weakly



5. Percentage of printed surface affected by cutting dust.



6. Correlation between the amount of cracks per 5 cm and the percentage of printed surface affected by cutting dust.

bonded coating particles are easily released during the printing process because of the tack of the ink.

This test also illustrates the importance and efficiency of the dust extractor system. For example, pallets 7A and 7B are identical papers (same cut quality) and have been run at the printing press under the same conditions. Still, it can be clearly observed in Fig. 6 that, after 5000 copies, the printed area of sample 7B is significantly more affected by the presence of cutting dust.

Advantages and disadvantages of the approach

Because of the high degree of precision obtained, this new way of analyzing and representing the cut quality gives the opportunity to:

- Evaluate the influence of the machine parameters in detail (e.g., blade geometry, machine speed)
- Find out the influence of the material being cut (e.g., structure, composition)
- Predict and optimize the blade change intervals to ensure optimum cut quality for the printer

This test method is not taking into consideration the cutting dust produced during the cutting process. Our printing test had shown the importance of this parameter and the efficiency of the dust extractor system to limit impact. Also, the method is still quite time consuming today, but software

is currently being developed to speed up the measurements in the future.

CONCLUSIONS

A new test method for the evaluation of cut quality of WFC paper grades has been developed that takes into consideration three independent parameters: raggedness of the edges, number of cracks, and fibers pulled out at the cutting edges. The obtained results are encouraging and prove that the measurements are repeatable. This method is quite easy to put in place and allows for establishing a quantified criterion related to practical printing performance. Contrary to existing test methods, it also takes into account the state of the coating layer near the cutting edges. As observed during the printing test, it is foreseen to have an important impact on the printability of the papers. Looking at the evolution of the industry, with papermakers increasing their productivity by cutting more and more sheets simultaneously and the printers running their machines faster to reduce costs, we believe that this topic might become more and more important in the future. When implemented, the visual representation of the results helps to better understand the cutting mechanism by including the number of cracks.

The method is suitable to assist in understanding and quantifying the effects of the machine settings and paper properties on the cut quality of WFC papers. A practical printing test showed the importance of the new parameter

and the efficiency of the dust extractor system. Further research will focus on increasing the throughput of the test method by software adaptations and on developing a method to quantify the cutting dust at the sheeter in a simple and cost-effective manner. **TJ**

ACKNOWLEDGEMENTS

The authors thank Sappi Fine Paper Europe for supporting this work. Moreover, special thanks are given to Mario Penaso for his active participation in the elaboration of this test method.

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ABOUT THE AUTHORS

Recently the cut quality of WFC papers has become an important issue requiring special attention. This research complements previous research in that it focuses on WFC papers and takes into consideration their specificities (i.e., the fact that they are coated).

The most difficult aspect was identifying the specific parameters relevant to cut quality and finding a way to quantify them in a useful way. We addressed this by taking inspiration from previous work done on this topic, by analyzing several paper samples, by contacting printers and papermakers, and by being creative and persistent in our work.

Our findings revealed a strong correlation between the amount of cracks quantified by the test methods and the printed surface affected by the cutting dust. Mills can benefit from this information by using the described method to better understand the impact of their process and materials on cut quality, leading to a more consistent product and more efficient production.

The next steps will be to focus on the throughput



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of the test method by software adaptations and on developing a method to quantify the cutting dust at the sheeter in a simple and cost-effective manner.

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