WEB DEFECT INSPECTION IN THE PRINTING PRESS—RESEARCH UNDER THE FINNISH TECHNOLOGY PROGRAM

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PROGRAM ACTIVITIES FOCUSED ON INTEGRATION OF PREPRESS PROCESSES, INFRASTRUCTURE FOR THE GRAPHIC ARTS BRANCH, AUTOMATION, AND ECOLOGY OF PRINTED COMMUNICATION.

PAPER RUNNABILITY ON THE PRINTING PRESS HAS been the object of repeated study by various research institutes over the past decades, quite often with the aim of finding a connection between the measurable strength properties of paper and the press breaks. Almost equally often the outcome has been that it is very difficult to predict the occurrence of breaks simply on the basis of tensile strength. In fact, breaks have been found to appear first in the weak areas of paper. But in earlier days, printing presses had no equipment to detect and identify the weak areas of paper.

Today, there are excellent optical facilities to establish the frequency of web holes and defects. These detectors are employed, for example, at paper mills to find holes in the base paper before it is coated. Also the resistance of a paper sample to breaks, which develop in a weak area, can be predicted by measuring—in laboratory conditions—the fracture toughness of the paper.

The purpose of this article is to report the results of VTT Information Technology's project on Comprehensive Web Management in the Printing Press. This project—a part of the Technology Development Centre's (TEKES) technology program for the graphic arts industry—consisted of an extensive study by means of optical web control on the press and using the latest state-of-the-art in laboratory measuring equipment.

RESEARCH UNDER THE FINNISH TECHNOLOGY PROGRAM

Implementation of the program

The special program for the graphic arts industry, known as GAT, was planned and designed by a working group with members representing the Federation of Finnish Printing Industries and the Association of Newspapers. The program consisted of several independent research and development projects which were implemented by companies and research institutes.

The principal aim of the development program for the graphic arts industry was to maintain and to strengthen the position of printed media in Finland. Another goal was to raise the level of technical competence and also to uphold the high standards of education and research in this country.

The program was carried out in the four-year period from 1992 to 1995, and comprised the four principal research areas:

- Integration of prepress processes
- Development of a branch network for the printing industry
- Automation
- Ecology of printed media.

Within the GAT program, 38 product development projects were carried out by Finnish companies and 9

Principal research area	Development	Research	Total
Prepress integration	12	2	14
Branch network for the industry	11	0	11
Automation	11	5	16
Ecobalance of printed products	1	2	3
Interrupted projects	3	0	3
Coordination and evaluation	2	0	2
Total number of projects	40	9	49

I. Number of the GAT projects and their distribution by principal area

Principal research area	Development	Research	Total
Prepress integration	12,882	5,869	18,751
Branch network for the industry	15,536	0	15,536
Automation	30,335	15,119	45,454
Ecobalance of printed products	800	560	1,360
Interrupted projects	2,726	0	2,726
Coordination and evaluation	1,317	0	1,317
Total budget of projects	63,596	21,548	85,144

II. Budget for the GAT projects and distribution between the principal areas (in FIM 1000)

research projects by research institutes. All the projects focused on the principal research areas as shown in Table I.

The total budget for the GAT projects was in excess of FIM 85 million (ECU 15 million) divided by the principal areas according to Table II.

The projects received financial support from the Technology Development Centre (TEKES) in three different forms, i.e., FIM 15 million in support of industrial development projects, FIM 11 million in risk credits for industrial development projects, and FIM 10 million to support research projects. Fifty companies took an active part in the program.

The program was coordinated by a steering committee, appointed by the Federation of Finnish Printing Industries and the Association of Newspapers. The steering committee decided the goals for the program and made recommendations for the financial support, while the Technical Development Centre decided about the support for each individual project. The industrial development projects were coordinated by Ulf Lindqvist and the research projects by Olavi Perila. Also made was an independent evaluation of the program *(1)*.

Results of the program with regard to printing

The principal research area relating to paper and printing was *automation*. The results of *prepress integration and branch network for the printing industry* are not discussed in this paper.

Projects with specific goals. Five research projects dealt with automation. Two of these projects involved the development of the production process, two projects focused on the continuing development of the automation of certain processes, and an integrated production process was developed in one project. Comprehensive web management in the printing press *(2)* was a part of this section, and is reported in more detail later in this paper.

One research project concentrated on the control of the drying conditions in heatset offset. According to the findings, the optimum drying conditions are used rarely in production. Drying cannot be improved significantly by adjusting the temperature profile of the oven. On the other hand, drying can be made more efficient by taking into account the specific requirement for drying energy in each combination of paper and ink. The drying process progresses non-linearly and material specifically as a function of the temperature. A procedure was developed to optimize the drying conditions.

The automation of materials handling and transport in a printing plant yielded a pilot-scale robot cell and a measuring method for the folding register and the folder disturbances. Also a simulation model was defined to optimize materials handling, required data files were collected and the feasibility of the model was tested on a real production line.

In the research project focusing on a global system for the control of the condition of printing presses, a prototype system was developed to steer the monitoring of the press condition by means of failure diagnostics. Vibration and acoustic signals were used to test defects in advance. The development of a commercial system still requires further research.

The project on book production in real time resulted in printing from data networks, an on-line system for educational materials, and an electronic book store. In addition, the electronic printing performance, the quality development of the final product and the user interfaces were analyzed. The prototypes are taken into use to produce educational material.

Product development projects. The participating companies also carried out 11 product development projects in automation. The projects may be divided into three categories according to the original plans: automation in prepress, automation for quality improvement, and automation for the improvement of productivity. (See Table III.)

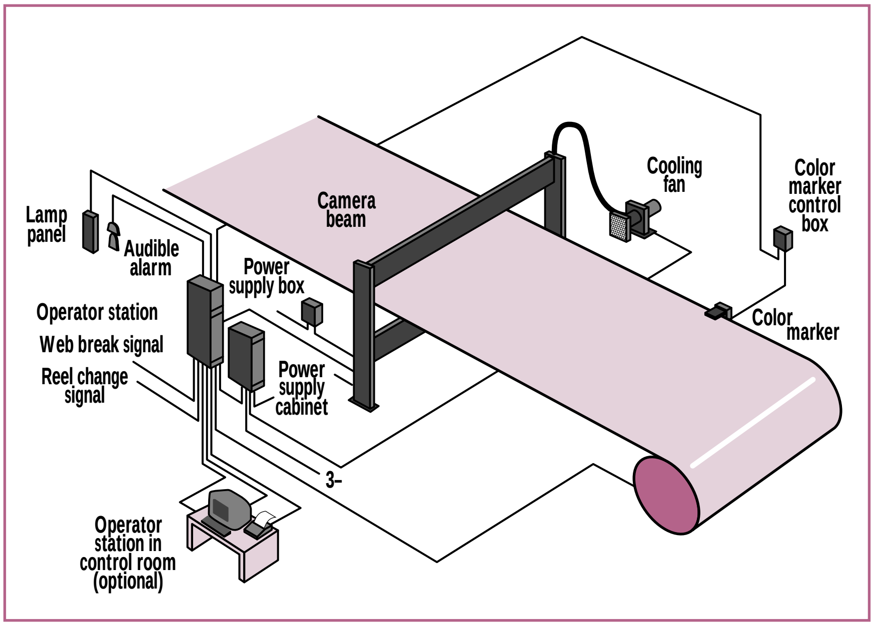
Two of the product development projects aimed at improving print quality. In one of them, a washing system was developed for the cylinder blankets of a newspaper press. The device was developed further, to include options for cleaning the blanket cylinders, inking rollers and turner bars. This system can be installed in any press control system. ARGUS D is a global press system for the quality control and measuring on-line in press production.

Productivity was improved by automation in five development projects. The Printa system for press control was developed further and given two new modules—i.e., generation and optimization of running sequences, and a global system for production control and management. The optimization of the running sequence is based on the data on the press structure and the costs. The production management system is modular, enabling simultaneous management of several processes for pagemaking, printing and postpress.

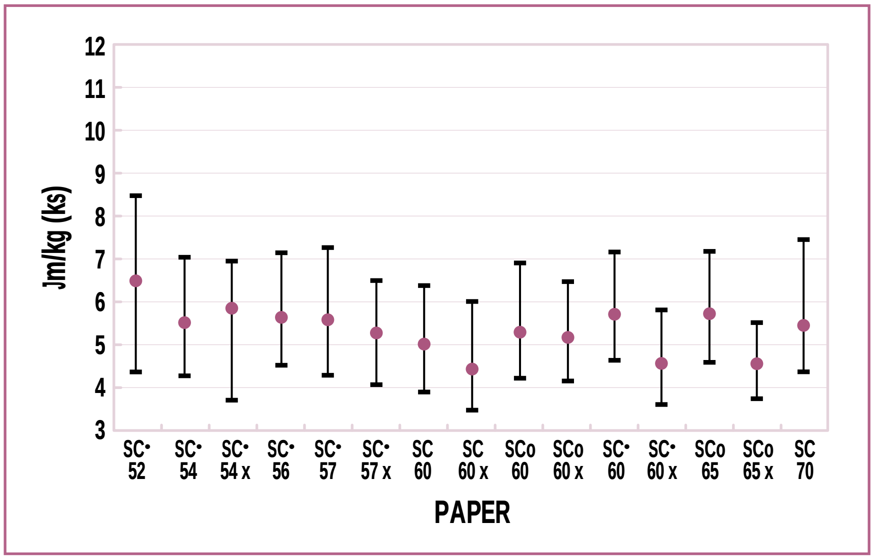
Another system—GD Prima—was designed for product and production control in book printing. The system meets a variety of needs within the company, such as sales, pricing, and production planning.

Prepress automation	Quality improvement	Productivity improvement
NEDIX Structuring system for newspapers	Automatic washing system for press blankets and rollers	Generation and optimization of press runs - PRINTA
Production management for prepress in newspapers	Global on-press quality control system - ARGUS D	Global production control and management system - PRINTA
Page vision - remote proofing		Product and production information system - GD Prima
		In-line trimmer for big presses
		Chilling device for lightweight papers

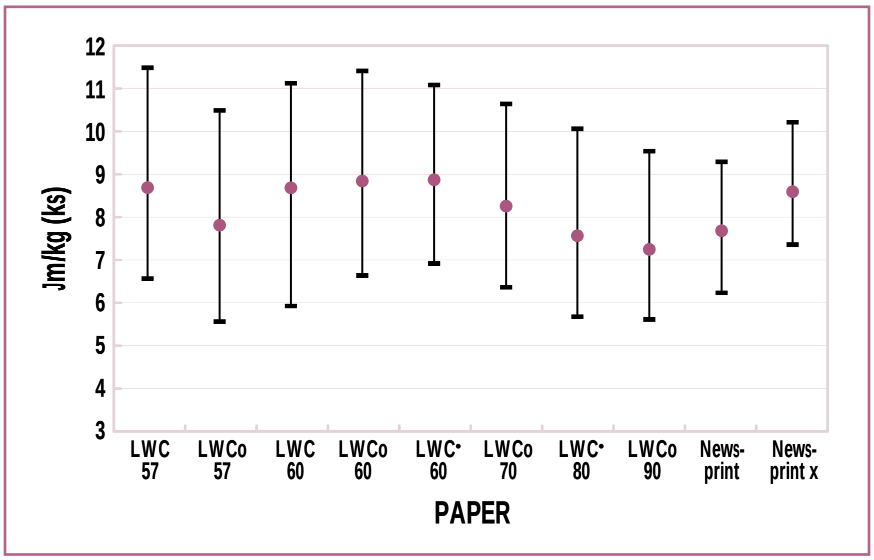
III. Product development projects for automation



1. The detector of web defects



2. The fracture toughness index of SC paper (broken rolls are marked with x)



3. The fracture toughness index of LWC paper and newsprint (broken roll is marked with x)

The production process was developed further in two projects. A new in-line trimmer, which stitches and trims at press speed, was designed for big printing presses. A special chilling device for lightweight paper was developed in one project. The device was designed to minimize paper waving, as well as the acceleration and deceleration forces.

INSPECTION OF WEB DEFECTS

A measuring system was mounted on a rotogravure press to detect pinholes and other defects in the paper web on-line, and field tests were made to find correlations between the paper defects and the runnability problems in the press. As a result, a measuring method was developed, to inspect the runnability of paper rolls, and web management was integrated into the press control system.

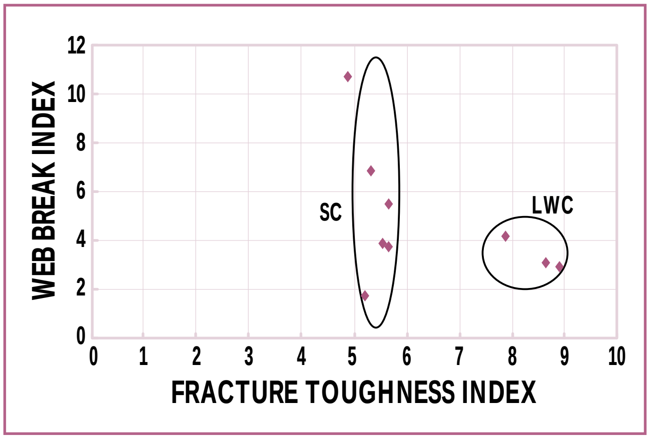
Web inspection equipment

Web fault analyzers are used mainly in paper mills to monitor the condition of paper machines, to inspect the produced quality and to generate reports. We employed an Ulma quality control unit, developed by ABB Industry, to detect different kinds of defects in a moving paper web—holes, spots and coating streaks—by means of powerful CCD cameras. Ulma-detected deviations from the normal web formation are viewable on a real-time color display and a fault map can be printed out by printer. This monitoring system allows to identify during the production run those paper rolls which may cause runnability problems at the printing plant, and they can be sorted out at the paper mill.

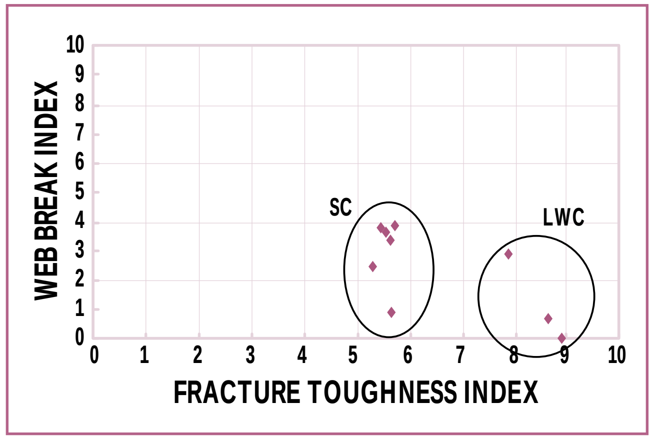
The Ulma quality control unit was used to check the web on the press especially for holes, cuts and spots. This project was the first time for the Ulma unit to be applied in a printing house. Because of the difference in the running conditions of the paper machine and the printing press, the Ulma software had to be adjusted to the printing press. The running properties of the printing press vary, depending on the work in preparation. The properties and width of the paper must be chosen according to the print job. Also the press speed and the web tension vary, depending on the number of pages and their makeup. To provide for the changed running conditions and to steer the printing press, external signals from the press control system were added to the electronic control unit, i.e.,

- Roll change
- Web speed
- Web break.

The roll change signal informed the unit of a roll change. The speed signal indicated the press starts and stops, to begin and stop feeding the defects into the memory of the operating station. Figure 1 shows a dia-



4. Web break index vs. fracture toughness index. Coefficient of determination: R^2 (all points) 0.21, R^2 (SC) 0.31, R^2 (LWC) 0.97



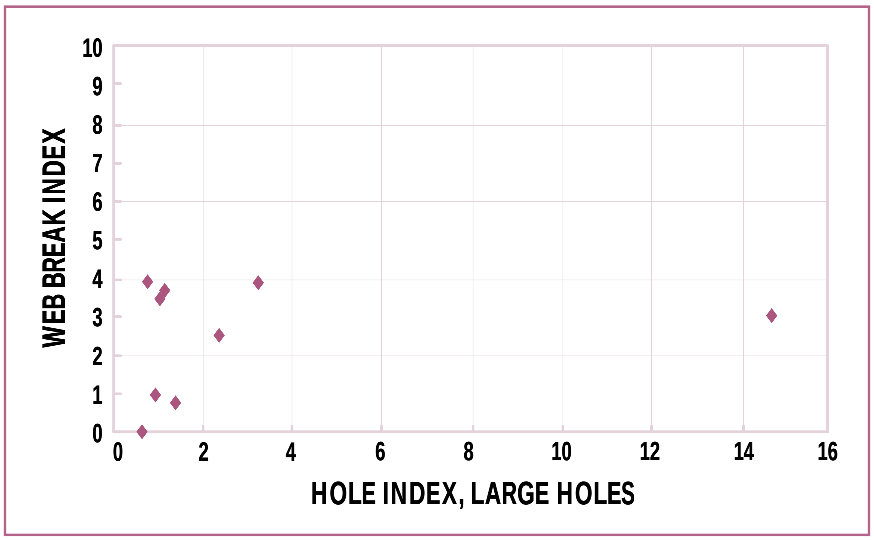
5. Web break index vs. fracture toughness index. Coefficient of determination: R^2 (all points) 0.47, R^2 (SC) 0.00, R^2 (LWC) 0.99

gram of this detection unit. The web runs between the source of light and the camera beam.

Methods

The Ulma detector was used for 5.5 months to collect information of paper defects in rolls supplied by various manufacturers. The holes and the optically detectable web defects were inspected with this unit. In the light of the literature, it was assumed that web holes would have a connection with the runnability problems and web breaks *(3)*. The optically detectable defects are generally thinner or weaker areas which, when subjected to the web tension and the load of the printing units, may develop into holes and cause runnability problems with the web.

The operator can decide which web defects are to be inspected, and these are included in the software. Two different fault definitions were used. In the long-term monitoring process the system was changed during the measurements. In the first two months, two categories of holes were used: 2 mm^2 and 8 mm^2 (the hole size). But this was found to be too rough for the project, and it was changed to include five different categories of holes: 0.5 mm^2, 1 mm^2, 3 mm^2, 6 mm^2, and 10 mm^2. The system with five hole sizes was used during the rest of the monitoring period, for 3.5 months.



6. Web break index vs. hole index. Coefficient of determination: R^2 (all points) 0.02, R^2 (SC) 0.05, R^2 (LWC) 0.93

Runnability data and reported information on the printed rolls were collected from the press control system. Also the printers were asked to record all paper-related runnability problems on the press, as well as their causes. The roll crew regularly collected paper samples from the printed rolls and from all broken rolls. These samples were measured in the laboratory.

Using the fracture toughness and tensile stiffness orientation (Lorentzen & Wettre) equipment, the laboratory measurements of the paper roll samples and the broken roll samples, collected from the rotogravure process, included the following properties:

- Tensile strength, stretch, tensile energy absorption
- Fracture toughness
- Tensile stiffness index (TSI)
- Tensile stiffness orientation (TSO).

Tensile strength, stretch and tensile energy absorption were measured by loading the paper sample to the breaking point and recording the situation at the time of the break. Fracture toughness was determined with two tensile strength tests. An initial cut was made in one sample sheet to indicate a hole in the paper. The TSO unit was used to determine the tensile stiffness index and the tensile stiffness orientation of cross-web samples every 50 mm. With a 1710-mm-wide roll, this gave a profile of 34 measuring points across the web.

Results

Web defects and web breaks. During the monitoring period (5.5 months), hole and fault information was collected of about 2372 rolls in the rotogravure press. The aim was to find a connection between web breaks, web defects, and measurable paper properties. There were a total of 76 breaks during the period, including 36 with no immediate and obvious reason. A closer analysis of these breaks revealed optical web deviations in 13 rolls. And an analysis of the web holes showed that in only three rolls the web break—with an unknown cause—was probably due to a hole. The holes of the rolls varied in size between 0.6 and 9.6 mm^2. On the other hand, for example, 10-mm^2 holes passed through the press without a web break. In other words, the compiled information did not allow to determine a critical hole or cut size that might cause a web break.

Pale spots were the most common of the other optically detected paper defects. Twelve of the broken rolls showed pale spots before the break. A recurrent defect, due to a pale spot, was discovered in the middle of the web in two of the broken rolls. Some of the unbroken rolls showed a variety of streaks over the whole length of the roll.

In addition to the monitoring period, the arrangements for the printing presses included measuring sequences, to inspect the hardness profile and unroundness of the rolls. Also the web tension was determined in the running direction and in the cross direction of the paper web.

The hardness profiles of the measured rolls were rather even. In the rotogravure press, the average hardness of the rolls varied from 610 to 690 Parotester hardness units. Some of the measured hardness profiles were oblique (the difference between the minimum and the maximum was over 100 Parotester units). The most oblique hardness profile was measured in a rotogravure roll where the difference between the minimum and the maximum was 290 units. But this obliqueness of the profile did not cause any runnability problems during the measurements. As far as roundness is concerned, the measured paper rolls were normal.

The web tension depended on the adjusted tension level of the press, and this varied according to the paper grade and the web width. In the rotogravure press, the web tension was measured after the roll stand, and it was found to be between 250 and 400 N/m. The tension variation during the measurements was normal and the tension peaks, measured at the roll change before the infeed, were below the set tension level of the infeed. Only a small number of the processed rolls were subjected to tension measurements in this study. The variations—over a long period of time—in the tension profile on the rotogravure press have been discussed, e.g., in *(4)*.

Fracture toughness of paper. In the laboratory measurements, the broken rolls were found to have the lowest tensile and fracture toughness indexes. In the gravure papers, the tensile toughness index of lightweight coated (LWC) papers was, on an average, three units higher than that of supercalendered (SC) papers. When the tensile and fracture toughness indexes of unbroken and broken SC rolls—with the same paper grammage—were compared, the indexes of broken rolls were found to be about 10% lower than those of unbroken rolls. Fracture toughness indexes are shown in Figs. 2 and 3.

The variation in the cross-web profile of the tensile stiffness index—in the running direction and in the cross direction—allows to anticipate poor web runnability, flutter or pleats. But the measurements did not show any large variation in the indexes.

Discussion. Based on the material during the monitoring period, a calculation was made of the connection between breaks and holes and fracture toughness. This was done separately in two different sequences. The information on the rolls was placed in nine mill/grammage groups. The connection shown in Figs. 4 through 6 between holes and fracture toughness was calculated as follows: the web break index is the percentage of breaks in a certain mill/grammage group, the hole index is the value computed on the basis of all rolls in the group, and the fracture toughness index is the average of the measured rolls in the group. Every group contained at least 20 or 50 rolls, depending on the number of hole categories during the period. There were six groups of SC paper and three of LWC. The paper grades were clearly placed in their special groups, especially with regard to fracture toughness.

The following conclusions can be drawn from the computed interdependencies:

- With regard to the whole material, the fracture toughness index is a more plausible predictor of breaks than is the hole index.
- As regards the whole material, plausibility was better in the second monitoring period (which is natural because of the larger number of rolls).
- As regards the fracture toughness index, SC papers (6) were a distinct group although plausi-

bility was low. Plausibility was better if the absolute fracture toughness value was applied instead of the fracture toughness index.

- LWC papers were very well in the same straight line, and plausibility was seemingly high because there were only three mill/grammage groups.
- The impact of large holes was clearly visible in a single mill/grammage combination.

On the basis of these results, only holes, especially large holes, and the fracture toughness index could be included in the characterization of roll runnability. Also the unevenness of the profile was inspected with the help of the coefficient of variation in the profile of the tensile stiffness index in the running direction, but its plausibility was rather low. Instead, based on the previous results, the hardness profile (difference in roll hardness) is useful.

In spite of the long duration of the monitoring process and the large number of measured paper samples, it was difficult to draw generally valid conclusions in regard to the runnability on the printing press. This was due to the large number of paper grades run in the press during the monitoring period, meaning that the number of samples from each paper grade was too small for a statistical analysis. But the results could be used to analyze the whole system of individual presses in this project.

CONCLUSIONS

Paper runnability (SC, LWC) in a rotogravure press was studied by determining related, measurable roll and web properties. After an analysis of the measuring methods for web management, optical web control with different methods and measuring equipment for the tension profile were chosen as objects of further development. VTT Information Technology's mobile runnability measuring system and the developed equipment were used to make a series of field measurements in the printing houses who took part in the project. The measurements of paper rolls included their hardness profile and unroundness. The variations in the tension level and profile of the web were inspected during the printing process. The strength properties of the paper samples, their fracture toughness, and tensile stiffness indexes were determined in the laboratory.

As regards the whole material, the fracture toughness index was a more plausible predictor of breaks than the hole index, and its level of plausibility was higher in the second monitoring period when more rolls were run through. As regards the fracture toughness index, the SC papers stood out as a group, but their level of plausibility was low. The level of plausibility was higher if the absolute fracture toughness value was used instead of the fracture toughness index. The LWC groups were very well in the same straight line, and their level of plausibility was seemingly high because there were only three mill/grammage groups. When breaks were explained by both the fracture toughness index and the hole index, the level of plausibility was 0.62 for the whole material. The level of plausibility did not rise significantly even if all holes were large. TJ

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