

DOUGLAS W. COFFIN
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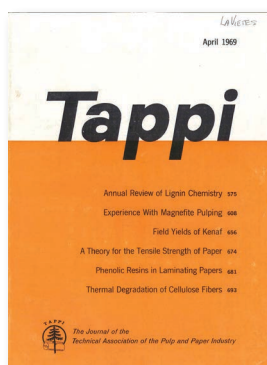
Looking back and looking forward: Paper physics and the paper industry

In 1937, E.W. Samson, a physicist for the Ham-mermill Paper Company, wrote an article titled “Physics in the paper industry” [1]. In his introduction, he wrote:

Without paper there would be few physicists and very little understood physics. Conversely, without physics there would be no paper, for paper making is fundamentally a physical process. And yet this great industry managed to wobble along for about two thousand years without the aid of the physicist, and without apparently missing him. It is a pointed question to ask, what can the physicist do for the paper industry?

It seems that this question is still relevant today, and maybe even more so than at any other point in the intervening 81 years. In the United States, Paper Physics started in 1935 when Johannes A. Van den Akker accepted the position of Chair of the Department of Physics for the fairly new Institute of Paper Chemistry in Appleton, WI, where he remained until 1970. During this time, the field of Paper Physics developed and grew. Samson stated that in 1937, he was only aware of 10 Ph.D. physicists in the entire U.S. paper industry. When I was a faculty member at the Institute of Paper Science and Technology (IPST) in Atlanta, GA, during the 1990s, we had 10 faculty in the Paper Physics group alone and a host of Ph.D. industrial advisors. In addition, all 14 paper programs in the United States at that time had staff involved in Paper Physics.

I was lucky to begin my career in the paper industry at such a place and time. Today, I think we can count the number of active paper physicists in the United States on one hand. I do not believe that this is because the physics of paper has become irrelevant, but rather the decline in activity was a



Derek Page's 1969 Tappi paper is perhaps the single most important work from the heyday of the Paper Physics field. TAPPI Journal is excited to reprint the original paper as a starting point for those interested in the topic (p. 581).

consequence of the major consolidation of the industry and the poor economic times at the start of this century.

Renewed Emphasis on Paper Physics

I am starting to feel an excitement in the U.S. industry today surrounding Paper Physics. There is renewed interest in understanding and improving the performance of paper materials. Much of that excitement is geared toward packaging and tissue, but the fundamental physics remain unchanged. There is a wealth of information published in the literature from the 1930s to present just waiting to be exploited. In addition, there is an active international community of paper physicists continuing to make progress and provide knowledge and tools that could help the industry stay competitive.

Just this fall (September 23-27), the Progress in Paper Physics Seminar was held in Lodz, Poland. This conference generated much discussion and some wonderful world-wide developments in the area of paper physics were reported. In Lodz, the 2018 Van den Akker Prize, the highest award within the Paper Physics community, was presented

to Amanda Matson and Tetsu Uesaka of Mid Sweden University for their work on the statistical mechanics of creep and failure for paper [2]. Theirs is interesting work that forces us to look at an old problem from a different point of view.

New Research and the Page Equation

At the Progress in Paper Physics Seminar, there were two presentations that both related to the Page equation [3]. Part of the presented work of Dr. Joel Pawlak [4] of North Carolina State University was a model for the tensile strength of tissue. Pawlak and his co-authors developed a model based on the physics of tensile failure of tissue being dominated by fiber pullout. To me, this shows that we still have people in the United States that are willing to think critically and develop new insights into the response of paper. Interestingly, Pawlak found that the Page equation was equally valid as a predictive model, once again showing the robustness of this Page equation. I presented a model [5,6] at the seminar for approaching tensile and tear strength development from the standpoint of a characteristic length that captures the ability of the paper to concentrate stored energy; in other words, using fracture mechanics to predict tensile strength. I think this is important because it links peak tear strength to fiber length, and that characteristic length is not just a geometric parameter. I emphasized that my approach is not unsympathetic to the Page equation, but we need to think beyond it.

That said, one could argue that the development of the Page equation [3] is the single most important work that came out of the Paper Physics community in the heyday of the field—1950 to 2000. Its originator, Derek Page, joined the paper industry in 1955 in Britain. In 1964, he emigrated to Canada to work for Paprican, where he was until 1993. After that he spent winters at IPST in Atlanta, GA. In 1969, Derek published a paper in *Tappi* titled “A theory for the tensile strength of paper” [3]. In this paper, he presented what later become known as the Page equation. A most important lesson one can take away from this article and the Page equation is the following: the strength of paper is a result of how well the fibers are bonded into the paper. For a poorly bonded sheet, it does not require much force to pull fibers out and strength is dominated by this low “bond strength.” As bonding is improved, the force to pull out a fiber exceeds the strength of the fibers until mostly fibers will break rather than pull out. The maximum possible strength is much closer to the fiber strength. This concept and the simple Page equation have withstood the test of time, and anyone interested in

understanding of the physics of paper should read this paper by Derek Page. Thus, this month, *TAPPI Journal* is excited to reprint the original 1969 paper as a starting point for anyone interested in Paper Physics.

We hope TAPPI can foster the new resurgence of Paper Physics in the United States by bringing new articles on the topic in future issues of *TAPPI Journal*. We are very excited that the International Paper Physics Conference will be held as part of PaperCon 2019 in Indianapolis, IN, next May. The last time this conference was held in the United States was in 1999. Hope to see you in Indy!

Douglas W. Coffin is a member of the TAPPI Journal Editorial Board and professor in the Department of Chemical, Paper, and Biomedical Engineering at Miami University in Oxford, OH, USA.

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