

Comments on the Paper Entitled “Splitting of Islands-in-the-Sea Fibers (PA6/COPET) During Hydroentangling of Nonwovens”

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The Journal of Engineered Fibers and Fabrics (JEFF) is gaining wide recognition in the global R&D community. However, this paper appears to fall short of your normal publishing standards. The data presented is unfortunately technically incomplete and inaccurate, plus the background literature omits some important publications and other ongoing research in this area.

Various sections are dealt with separately below:

Misleading title

To use the term “splitting” is inaccurate and incorrect for fibers such as islands in the sea. Split refers to “dividing” or “breaking-up”. A more appropriate term would be fibrillate or fracture. This is indeed why the title of several patents held by NC State filed over the last 5 years refers to fibrillating bicomponent fibers such as islands in the sea and other cross sections.

Splittable fibers are known in the art to refer to those bicomponent fibers that have one single common interface and where the two components are also exposed to air on the surface of the fibers. Classical examples are: segmented pie, segmented ribbon, side-by-side and tipped trilobal where the tips do not wrap the fiber to form a sheath.

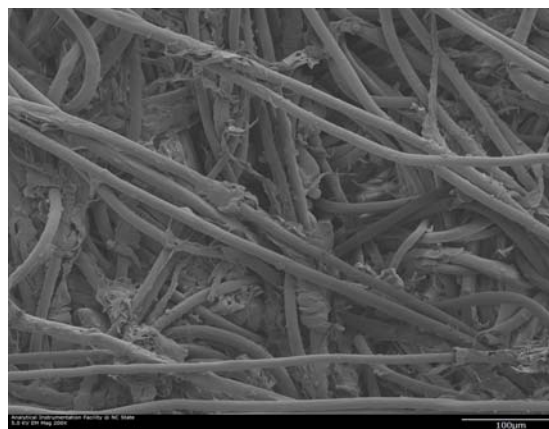
Literature Review

Even without the above distinction, there is a significant body of literature that deals with splittable fibers, and bicomponent where the sea or one component is removed. Most notably, the literature dealing with Evolon (Freudenberg) is totally ignored in the literature review. Evolon is the first splittable spunbond fabric commercially available for many years. The paper also cites only one of the published patents held by NC State and chooses to ignore two other key published patents that are relevant to the subject at hand. The paper states that:

“Finally, Behnam Pourdeyhimi, et. al. [23] utilized hydro-energy (hydroentanglement process) for fibrillating a set of bicomponent fibers. From their invention, they discovered that islands-in-sea fibers can be made to split by hydroentangling without dissolution if the sea polymer is sufficiently weak and particularly when the two components have little or no affinity for one another.”

The significance of the difference between splittables and fibrillatable fibers was not recognized. In splittables, it is the interface between the two components that controls splittability. In islands in the sea (I/S) structures, it is the interface together with the ability of the waterjet to break apart or fibrillate the sea from the island. Consequently, often higher levels of energy (hydroentangling) are required to break apart a fiber than to split one single interface depending on the polymers used in the two phases.

Below, we show a picture of a sheath-core structure where the sheath is fractured and fibrillated (not split). Clearly, it is the choice of the polymers that allows one to even fracture the sheath. This structure was not subjected to any thermal treatment and the break up of the sheath is primarily due to mechanical stress.

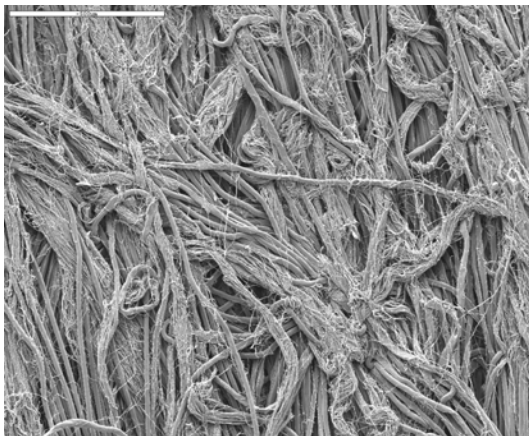


These are fully discussed in a number of worldwide patents filed by NC State. Several are published and several will publish soon. Some key published patents are:

1. B. Pourdeyhimi, N. Fedorova and S. Sharp, Lightweight high-tensile, high-tear strength bicomponent nonwoven fabrics, US Patent Application 20060223405, October 5, 2006.
2. B. Pourdeyhimi, N. Fedorova and S. Sharp, High strength, durable micro & nano-fiber fabrics produced by fibrillating bicomponent islands in the sea fibers, US Patent Application 20060292355, December 28, 2006.
3. B. Pourdeyhimi and S. Sharp, High Strength, Durable Fabrics Produced By Fibrillating Multilobal Fibers, US Patent Application 20080003912, January 3, 2008.

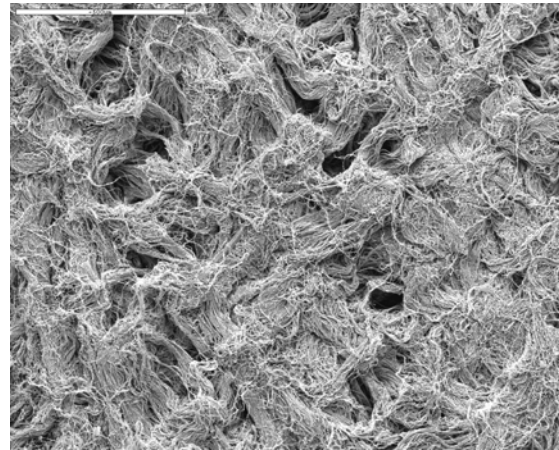
Additional patents will be published soon.

Below, we also show the onset of what we call fibrillation. At low levels of hydroentangling energy, the fibers on the surface only start to fibrillate. Therefore, to achieve bonding and fracturing in one step, requires sequential increases in waterjet pressure – another critical issue not addressed by the paper.



The following picture shows an example of a fully fibrillated I/S where there are 108 nylon islands in a sea of polyethylene. The same can be achieved by using other polymer systems

such as nylon and polyester or polyester and polyethylene.



Note that the small apertures seen in the fabric are due to the interaction with the surface used on the hydroentangling drum. The waterjet-fiber-surface interactions control to a great extent the degree of fracture or splitting. This topic will be discussed in a future paper.

The Methodology and the Analysis

The description of the hydroentangling set up is vague and unclear. It is stated that the fabric was passed through the Fleissner unit twice on one side and twice on the other side. It is not clear if the unit has only one manifold, or more and it is not clear whether the hydroentangling unit uses belt or drum for hydroentangling. The choice of the hydroentangling surface critically impacts the degree to which the fibers can be split or fibrillated.

The basis weight of the fabric was also not described. What is mentioned is that 2 grams of fibers were opened by hand and then hydroentangled. Therefore, it appears that no carded webs were produced and that the webs were produced by hand. If this was the case, then how would one determine mechanical properties of the final product given that we have no way of controlling the fiber orientation or the uniformity in the web? How was a web large enough produced to allow the tensile samples to be prepared? To open bundles of fibers by hand will lead to tremendous operator dependencies and non-uniformities that will determine the ultimate properties of the fabric. It is also not clear how sufficiently large samples were

developed for testing purposes? And what the final basis weight of the samples was.

The analysis of “splittability” leaves much to be desired. Fibers do not split evenly across the width. If one analyzes splittability, it will be seen that the fibers split differently on the top and in the ridges of jet streaks. Additionally, fibers split differently on the surface and in the bulk. Soon, there will appear a paper by Shim, *et. al.* that will discuss appropriate methodologies for determining splittability. To fully and reliably analyze splittability requires 3D sectioning and imaging of the structure over a relatively large area that encompasses several jet spacing. Shim’s paper will introduce the concept of using Digital Volumetric Imaging (DVI) for determining splittability.

The tensile data are plotted versus jet pressure. This graph is also technically incorrect and incomplete since we do not know the number of manifolds or the basis weight of the samples. The data should be plotted versus hydroentangling energy. This requires however, the basis weight and the number of manifolds to be specified.

The hydroentangling energy calculation is based on Bernoulli equation that ignores viscous losses throughout the system. Having the manifold’s pressure, P_1 , the jet velocity is:

$$V_1 = \sqrt{2P_1 / \rho}$$

Where $\rho = 998.2 \text{ kg/m}^3$ is the density of water at room temperature, P_1 is the pressure in Pa, and V_1 is in m/s. Note that 1 bar is equal to 10^5 Pa.

The rate of energy transferred by waterjet is calculated as follows:

$$\dot{E} = \frac{\pi}{8} \rho d^2 C_d V^3$$

where d is diameter of the orifice capillary section in meter (0.127 mm in the system used), C_d is the discharge coefficient, and \dot{E} is energy rate in J/s.

Specific energy is calculated based on the following formula:

$$SE\left[\frac{\text{J}}{\text{kg}_{\text{fabric}}}\right] = \frac{\dot{E}}{\dot{M}}$$

where \dot{M} is the mass flow rate of the fabric in Kg/s and is calculated as follows:

$$\dot{M} = \text{Samplewidth}[\text{m}] \times \text{Basisweight}[\text{kg/m}^2] \times \text{Beltspeed}[\text{m/s}]$$

Therefore, SE will be obtained in *Joules per kg of fabric*. This can also be expressed as *Watts per kg of fabric*.

Typically, as the energy increases, the tensile properties increase up to a point and then begin to decline somewhat. The tear properties are more sensitive to bonding and quickly decline after the structure has been consolidated. The data for tensile properties are impossible to interpret and given that the webs were made by hand, the data are not scalable to carded systems.

The authors make several remarks about the sea and the matrix and state that:

“For the case of these modified islands-in-the-sea fibers, the walls of the sea between the islands appear to be very thin and perhaps weak, while the islands solidifying and crystallizing within the matrix during processing become stronger. Therefore with implementation of high mechanical forces on these modified island-in-the-sea fibers, the sea components damaged easily and remain in contact with islands. Furthermore it can be seen in Figure 6 that the fibers split shows small dots or attachments which may be the presence of co-polyester particles on the surface of split fibers...”

This statement is pure conjecture and the authors are referred to the articles shown below:

1. N. Fedorova and B. Pourdeyhimi, High Strength nylon Micro- and Nanofiber Based Nonwovens Via Spunbonding, Journal of Applied Polymer Science, 104 (5): 3434-3442, (2007).
2. N. Fedorova, S. Verenich and B. Pourdeyhimi, Strength Optimization in Point-bonded Nonwovens, Journal of Engineered Fibers and Fabrics, Volume 2, Issue 1, (2007).

These papers clearly discuss and distinguish the role of solidification in controlling the properties of the island fibers. Similarly, the classical works of Kikutani in Japan need to be studied where he discusses the concept of “super-draw” in bicomponent fiber formation. The choice of the polymer systems together with processing conditions can indeed lead to highly oriented islands and highly amorphous sea to facilitate fibrillation.

What the NC State group has shown and is documented in the worldwide patent filings is that islands in the sea and other fiber configurations can be fibrillated at speeds much higher than 2 meters per minute (used in this paper). These include combinations of nylons and polyesters and polyesters (or co-polyesters) and polyolefins and similarly nylons and polyolefins. The polyester nylon combinations as a rule of thumb require higher levels of hydroentangling energy for fibrillation. Some of the most unique structures produced are polyester sea and nylon islands, nylon or polyester islands and polyethylene sea. In all cases however, the tensile and tear strength of these structures are superior to those of other splittables (segmented pie, for example) and much higher than the ones reported in this paper. Note that the titles of the patent filings often refer to “high strength” structures, a unique character of fibrillated bicomponents.

Based on our continuing project work, we will shortly prepare and submit a series of papers to address the issues and the pros and cons of fibrillation versus splitting of classical splittable fibers. Significant contributions are also being made in Europe and Asia. It is our hope that this Letter to the Editor will spark further rigorous discussion and more global interaction within the research community.

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Editor: We cordially invite you to share your technical insights on this and other areas of R&D. Please submit your comments, suggested additions and letters to the editor at <http://jeff.edmgr.com>. Please be sure to provide us with your name and contact information.