Introduction

Mercer International Inc. and Resolute Forest Products are leading the charge in biomaterial innovation in an era demanding sustainable solutions. Their collaborative enterprise, Performance BioFilaments, is a pivotal initiative in the development and market introduction of nanofibrillated cellulose (NFC).

Performance BioFilaments Inc., a partnership between Mercer International Inc. (NASDAQ: MERC) (Mercer) and Resolute Forest Products (Resolute), is committed to harnessing the commercial potential of nanofibrillated cellulose, one of the most promising biomaterials emerging on the global stage.

NFC: A Technological Breakthrough

NFC isn't merely another material; it represents a paradigm shift. Its unique nanostructure, derived from sustainably sourced wood pulp, undergoes a chemical-free, proprietary refining process that yields fibers with extraordinary characteristics. These include a high aspect ratio for unparalleled strength and a dense surface area rich in hydroxyl groups, which augments its rheological properties.

Cellulose filaments are a subset of nanofibrillated cellulose derived from conventional kraft pulp, consisting of 95% cellulose and 5% hemicellulose. In a wet state, the pulp resembles white polyester pillow filling. Yet, through the application of mechanical energy, the cellulose fibers undergo delamination, transforming into singular nano-sized filaments or fibrils. Delamination refers to the process in which layers of a material, typically in a composite structure, separate or split from each other due to various factors such as mechanical forces, heat, or chemical reactions. This separation leads to forming distinct layers or thin sheets within the material, often resulting in a loss of structural integrity and performance. In the context of cellulose fibers, delamination is the mechanism through which individual nano-sized filaments or fibrils are created by breaking down the original cellulose fibers under the influence of mechanical energy.

NFC: Properties, Production, and Environmental Advantages

The cellulose filaments that Performance BioFilaments develop differ slightly.

Nanocrystalline cellulose (NCC) particles are typically five to 10 nanometres wide and a few hundred nanometres long. Fibrils, on the other hand, can range up to several micrometres in length. This gives them different properties, especially from a rheological perspective. Rheology refers to studying the flow and deformation of materials, especially liquids and soft solids, under the influence of applied forces. In the context of cellulose filaments and materials, rheology examines how they respond to mechanical stress and how their flow properties change based on external forces.

Performance BioFilaments' reason for selecting a mechanical refining process over chemical treatment was improved economics. With mechanical refining, kraft pulp is put

between two spinning plates, breaking down the fiber and peeling filaments off, similar to unravelling rope licorice candy.

The material possesses remarkable thinness and significant length, enabling Performance BioFilaments to excel in specific applications, such as fortifying other materials. When substances like sulphuric acid are employed, some wood cellulose undergoes hydrolysis, transforming into sugar and decreasing the yield.

The term "hydrolyzed" refers to a chemical process where a substance, like wood cellulose in this case, is broken down into smaller molecules by adding chemicals and water. This implies that when wood cellulose interacts with certain chemicals, such as sulphuric acid, it triggers a hydrolysis reaction, breaking the cellulose into simpler components, including sugars.

Not only does the mechanical process allow for a higher yield, but the process is relatively low cost, making scale-up more economical. As an added bonus, the fact that mechanical refining doesn't require acids reduces the environmental impact.

Performance BioFilaments and Potential Applications

In addition to their ongoing efforts to improve the manufacturing process, Performance BioFilaments researches potential applications, including reinforcing plastics and concrete and rheology additives for industrial paints and coatings.

Performance BioFilaments focuses on injection-moulded plastics geared towards the automotive sector and driven by environmental regulations. For example, in the United States, cars will have to attain 54.5 miles to the gallon by 2025 to cut greenhouse gas emissions[1]. (Canada tends to harmonize national emission standards with the US Environmental Protection Agency federal standards.) European standards are based on how many grams of carbon dioxide are emitted per kilogram driven. From 2025 onwards, Regulation (EU) 2019/631 sets stricter EU-wide fleet targets: 93.6g/km from 2025 (15% reduction compared to the 2021 baseline), 49.5g/km from 2030 (55% reduction) and 0g/km from 2035 (100% reduction)[2].

The regulations have prompted automotive manufacturers in both North America and Europe to seek lighter plastic options. This initiative aims to decrease vehicle weight and meet fuel efficiency requirements. To ensure safety benchmarks are upheld, these plastics require reinforcement from lightweight materials. Cellulose biofilaments emerge as a potential solution perfectly suited for this purpose.

Regarding paints and coatings, the distinctive rheological characteristics take center stage. Cellulose fibrils showcase a unique trait called thixotropy, rendering them viscous and resistant to flow during regular circumstances. However, under agitation or stress, their viscosity experiences a notable decrease. By blending cellulose nanofibers with paints or

coatings, producers have the potential to precisely adjust the flow attributes of their goods, thereby enhancing overall performance.

The focus is on advancing three specific application domains, including (1) reinforcement of thermoset and thermoplastic materials, (2) enhancing concrete durability and strength, and (3) adjusting solution viscosity through rheology modification. Thermoset and thermoplastic refer to two polymer categories consisting of large molecules composed of repeating units. These polymers exhibit distinct traits and behaviours due to variations in their molecular structures and responses to heat and pressure.

Each of these domains presents unique challenges that are being addressed either by customizing the production process—often by adjusting refining energy levels—or by implementing supplementary procedures subsequent to cellulose filament production.

Performance BioFilaments will offer their products in various formats tailored to their specific applications. For instance, in the context of concrete, the cellulose filament can be incorporated directly to improve internal curing as the concrete dries., This virtually eliminates the micro and nano cracks that occur as the concrete dries. By eliminating this undesired phenomenon, cellulose filaments improve the durability of the concrete, resulting in potentially longer service life of structures such as bridge decks. r\Research by Performance BioFilaments continues to delve into this phenomenon.

A pivotal concern revolves around achieving optimal dispersion of filaments throughout the material. Ensuring uniform distribution of cellulose filaments within plastics, particularly thermoplastics, presents a greater challenge. The anticipated approach for achieving effective filament dispersion within plastics involves selling batches of plastic pellets containing a higher filament concentration than desired in the end product. When these specialized pellets are combined in the appropriate ratio with conventional plastic pellets, the resultant melted plastic will exhibit the intended cellulose fiber concentration.

Another significant hurdle involves ensuring the compatibility of the filaments with the matrix polymer. Performance BioFilaments has undertaken several approaches to address this challenge. These efforts encompass refining processes to improve dispersion within both thermoset and thermoplastic materials. Additionally, they are focused on altering the surface characteristics of the filaments to bolster the bonding between matrix polymers and the cellulose surface.

In the realm of plastics, the primary objective is to substitute the existing glass fibers used for reinforcement. The inherently lower density of cellulose compared to glass results in composite materials featuring cellulose fibers that are lighter than prevailing market options. This attribute holds particular appeal for applications in sectors such as automotive, aerospace, and sporting equipment. In these industries, component weight carries significant importance.

Plastics constitute just a single facet within cars or airplanes, and numerous gradual enhancements are necessary to lower the overall vehicle weight. These include advancements in metal alloys and more efficient motors, aligning with the fresh emission standards mandated by European and US governments. The significance of lighter vehicles extends to bolstering electric vehicle performance, as reduced car weight correlates with extended battery life. This emphasis on lightweighting remains pertinent for trains and buses, airplanes, rockets, and satellites.

The overarching aspiration is to create biodegradable vehicles. Notably, Performance BioFilaments is actively engaged in initiatives geared towards crafting completely renewable or bio-derived composites tailored for the automotive industry. Yet, the immediate reality dictates collaboration with non-biodegradable plastics, which presently dominate industrial usage. Consequently, while the exploration of cellulose filament reinforcement in biodegradable plastics stands as a "longer-term" endeavour, it unquestionably represents an area of profound interest for the company.

Future Potential: A Look into the Expanding Horizons of NFC

The recently inaugurated Resolute Forest Products facility in Quebec has a daily production capacity of 21 tonnes and an annual output of 7,000 tonnes of NFC. But capacity is just one part of the equation; the true value lies in the ever-widening applications for NFC, backed by robust research and economic feasibility.

Expert Insight

Gurminder Minhas, Managing Director at Performance BioFilaments, lends his perspective:

"*NFC technology is not just a sustainability play; it's a catalyst for transformation across industries. With the potential to revolutionize everything from construction materials to the transportation sector, NFC is a key driver for innovations from the lab to the marketplace. Our focus is not merely on scaling production but in creating a suite of applications that bring tangible economic and environmental benefits.*"

Economic Advantages and Risk Mitigation Through NFC Integration

In addition to sustainability, economic factors hold a pivotal sway over industrial adoption. NFC (nanofibrillated cellulose) has demonstrated the potential to curb operational expenses by elevating product longevity, thereby reducing replacement frequency. Furthermore, governmental encouragement of eco-conscious practices is poised to yield supplementary financial advantages for enterprises incorporating NFC into their endeavours.

In light of the fluctuating costs of petroleum-derived goods and the escalating stringency of environmental directives, NFC emerges as a robust risk mitigation approach. Embracing NFC empowers businesses to establish stability in raw material expenditures and

proactively navigate regulatory requisites. In effect, this ensures both business continuity and competitive standing.

Conclusion

It's not just about current capabilities; it's about the roadmap ahead. Mercer International Inc. and Resolute Forest Products, through Performance BioFilaments, are set to capitalize on NFC's burgeoning demand, owing to their advanced R&D and a strong economic rationale. They aren't merely contributing to the industry but setting the course for its future, backed by substantive data and a compelling business case."

For more information regarding Performance BioFilaments, please visit www.performancebiofilaments.com or telephone +1 (604) 806-0261.

Reference Materials:

a. https://www.cheminst.ca/magazine/article/cellulose-dreams/
b. https://www.performancebiofilaments.com/en/