## *Natural fiber reinforced (bio-based) composites.*

### *Introduction*

The use of natural fiber reinforcements has gained considerable attention in composite technology as a low cost, light weight and environmental friendly alternative to glass fibers. Natural fiber reinforced composites are mainly used for non-structural elements and products. The market is in need for natural fibers for structural composites, but these structural elements require more reliability, reproducibility and quality.

The manufacturing of natural fiber based composites is often troublesome due to the hydrophilic character of the fibers, which makes them incompatible with hydrophobic polymer matrixes. Therefore considerable research has evolved during the last decade on the modification of the fibers and/or matrix materials. This research is mostly based on a small number of tests of specific fibers. In general, the fundamental reason why a system works is not examined in detail. Due to this lack of scientific evidence, the modification methods can only be applied on a small number of specific materials and do not apply to the general usage.

### *Natural fibers vs. Glass fibers*

In the table, some mechanical properties of synthetic fibers as well as natural fibers are summarized.

| | Density $\rho$ [$10^3$ kg/m$^3$] | E- modulus E [$10^9$ N/m$^2$] | Yield stress $\sigma_y$ [$10^6$ N/m$^2$] | Specific stiffness E/$\rho$ [$10^6$ m$^2$/s$^2$] | Specific strength $\sigma_y$/$\rho$ [$10^3$ m$^2$/s$^2$] | Min. mass ratio $E^{1/3}/\rho$ [$N^{1/3}m^{2\ 1/3}$/kg] |
|---|---|---|---|---|---|---|
| **Synthetic fibers** (UD, wf=50%) | | | | | | |
| E-glass | 2.58 | 72-75 | 1400-3450 | 28-29 | 543-1337 | 1.61-1.63 |
| HT carbon | 1.76 | 230 | 3530 | 131 | 2010 | 3.50 |
| **Natural fibers** | | | | | | |
| Bamboo | 05-1.06 | 22.5 | 189 | 21-45 | 178-378 | 2.66-5.65 |
| Jute | 1.3-1.52 | 10-55 | 400-800 | 7-42 | 263-615 | 1.42-2.93 |
| Hemp | 1.48 | 26-30 | 550-900 | 18-20 | 371-608 | 2.00-2.10 |
| Sisal | 1.33 | 46 | 700 | 35 | 526 | 2.70 |

There are also many other favorable properties like:

- Natural fibers are a renewable raw material and their availability is more or less unlimited.
- When natural fiber reinforced plastics are subjected, at the end of their life cycle, to a combustion process or landfill, the released amount of $CO_2$ of the fibers is neutral with respect to the assimilated amount during their growth, since natural fibers are biodegradable.
- Natural fibers have also other advantages; for example the distortion of radar signals is less.
- Natural fibers are generally cheaper than glass fibers.
- The abrasive nature of natural fibers is much lower compared to glass-fibers, which leads to advantages with regard to technical and material recycling, or the process of composite materials in general.

There are, however also research challenges concerning the use of natural fibers:

- The quality and characteristics of natural fibers are never completely the same. There will be many defects in the fiber material, which causes safety factors to be higher, and thus the product heavier.
- Natural fibers are polar and hydrophilic and therefore have problems with the interfacial connection to non-polar and hydrophobic polymeric (matrix) resins.
- Natural fibers are sensitive to moisture, fungi and insects, but also to chemicals, UV-radiation etc.
- Natural fiber reinforced plastics can be made by using biodegradable polymers as a matrix. Biodegradable polymers are however still in a research phase in order to improve the properties for outdoor purposes.

### *Natural Fiber Reinforced Composites*

As mentioned before, the interfacial connection between natural fiber and matrix material is poor due to the difference in polarity and hydrophilicity. This fiber-matrix interfacial phenomenon controls the stress transfer between fiber and matrix. This stress redistribution as well as mechanisms of damage accumulation and propagation, in a negative way. In general, composite materials with weak interfaces have relatively low strength and stiffness but high resistance to fracture if the crack grows perpendicular to the fibers, whereas materials with strong interfaces have high strength and stiffness but are somewhat brittle.

In order to improve the interfacial connection as well as other properties like the sensitivity to moisture, fungi and insects, the homogeneity of the fiber material etc, modifications have to be made on the natural fiber and possibly in the matrix material. These modifications will lead to a more reliable material because several defects and impurities will be removed. Besides this, the weight of the final product can be reduced even further and sensitivity to moisture can be reduced significantly.
There are several modification methods to improve these characteristics. The most promising ones are the physical treatments (like electrical discharge: corona or cold plasma treatment or UV radiation), chemical modifications (like adding a coupling agent, graft copolymerization, adding a compatibilizer and mercerization), matrix modification (like polymerization initiation by adding an initiator to the fiber or sizing) adding other materials like Glass fibers or PET.
In literature many of these treatments have proven to be successful methods. Many tests have been performed with many different fibers and a variety of methods. Often the results look good. In Asia and South America, the use of natural fibers for small and simple objects but also for structural elements is already common for centuries. However, in order to use a material for a structural composite element in for example Europe, these specific tests do not provide enough evidence of the quality, reproducibility and reliability for the final product application. Therefore more research should be performed on the phenomena that take place on the natural fiber and in the matrix material when a modification treatment is applied.

***Project Objectives***

The overall goals of this research project are:

- Fundamental knowledge of the phenomena that take place at the interface.
- Improvement of the interfacial adhesion between the natural fiber and the matrix material in order to improve the strength and to reduce the sensitivity to environmental influences.
- Development of a new cost effective and improved surface modification process for natural fibers.

Overall objective 1: Improvement of the homogeneity of natural fibers–matrix combinations.
Overall objective 2: Weight reduction of final products by improved reproducibility and product quality.
Overall objective 3: Create the opportunity to use natural fiber for more (high-tech) applications.

***Project built-up***

During the first 2 years of this project, the following steps will be taken:

- Literature research: Which modification techniques are already available what are the (dis)advantages?
- Selection of the most promising fiber/matrix modification techniques.
- Start with both practical and fundamental research. In order to obtain more knowledge about the interfacial phenomena, many test samples have to be analyzed and subjected to both physical and chemical tests.

After those two years a large step forward will be made in order to improve the properties of natural fiber reinforced composite materials as a whole. However, to gain all relevant knowledge about the interfacial phenomena more research will be required.
This time will also be the right moment to start a follow up research project on the production process. Nowadays most production is done manually or by expensive tape laying robots. Therefore a better and more automated production process should be developed in which the new and improved modification techniques are integrated.

| ***Project steps*** | Year 1 | | | | Year 2 | | | |
|---|---|---|---|---|---|---|---|---|
| 1. Literature research | | | | | | | | |
| 2. Selection of modification techniques | | | | | | | | |
| 3. Practical research | | | | | | | | |
| 4. Fundamental research | | | | | | | | |

***Time schedule***

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| Kick-off meeting with partners: | June 29, 2010 |
| Submission of proposal to M2I: | July 15, 2010 |
| Start project: | October 1, 2010 |