Research Project Bio - Blade

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Abstract

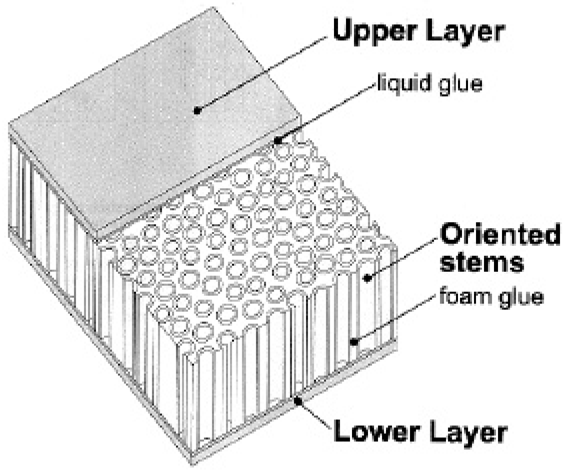
This paper introduces results of the research project "Development of a rotor blade using renewable materials: BIO-BLADE" (JOR3-CT96-0153), which is partially supported by the European Commission DG XII Non Nuclear Energy Programme aiming at the use of a light natural sandwich material as a substitute for PVC foams.

1. Introduction of the Project

Within the EU - project "Development of a Rotor Blade Using Renewable Materials, BIO-BLADE" a light natural sandwich material (LNS) is developed and optimised, with a core of orientated hollow plant stalks and glass fibre reinforced plastics (GRP) or wood-based top layers. The LNS is an extremely light and stiff composite material. The good characteristic results from the best possible use of wood and special plant stalks. Plywood with proper strength values and low density as top layers and orientated, undamaged stalks in an arrangement like a honeycomb core gives a high quality low cost lightweight sandwich material for many applications.

Fig. 1 shows the principal structure of the LNS and an example of a test specimen. Material testing has been carried out and the harvesting and production techniques were developed and optimised close to industrial standard. Data sheets characterising the LNS material properties have been determined in order to give the manufacturing industry information how to use the material for substituting conventional environmentally unfriendly core materials such as PVC. To underpin the environmental advantages a life cycle assessment (LCA) of the LNS compared against PVC foam has been performed within the project.

Preliminary results show a big advantage of the new material from the environmental point of view. Various rotor blade structure designs have been investigated in order to find the best combination of LNS, load carrying parts and load introduction. A test programme was defined to determine the actual material properties for the natural sandwich. Many different sandwich plates have been produced for demonstration of the production process for cutting out the specimens for material tests using different bonding quality. The failure mechanism of the LNS in bending tests was investigated and described. Construction details have been worked out in order to give guidance how to design structures using the new material. The main task was to identify the optimum design and the ecological best rotor blade. Another point is the introduction of LNS to the market. The today's large blades (40 m) are mostly manufactured in GRP and PVC foam. The aim of the project is to substitute the environment unfriendly materials. The future development is seen in combining the LNS-core with plywood for small rotor blades and glassfibre or natural fibres (e.g. flax, hemp) for large rotor blades.



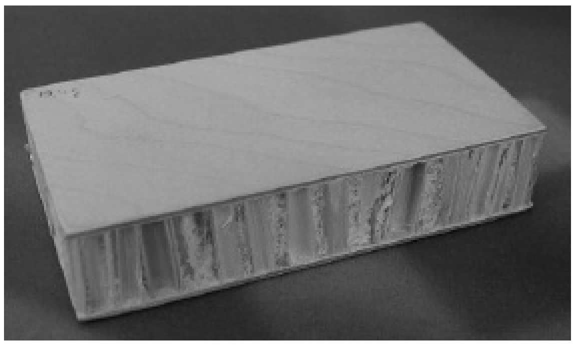


Fig. 1: The principal structure of LNS and manufactured test specimen.

2 Light Natural Sandwich Material (LNS)

2.1 Material Properties

The LNS sandwich material consists of upper and lower layers of wood and a core of orientated hollow plant stalks bonded with a foam glue. The natural light tubus core and the top layers are bonded with a liquid glue. The LNS material made from sustainably produced raw material is a cheap and environment friendly alternative to light sandwich constructions made from materials such as glass fibre, hard foams or aluminium. On the other hand wood materials can be replaced by a cheap and lighter plant stalk core. The weight of the LNS boards can be more than 50% lower than that of plywood or other wood materials with comparable mechanical properties.

For the light core (50-80 kg/m³) only hollow plant stems with low density and a high stability can be used. This can be rye straw, miscanthus or bamboo stems of special varieties. The structure of the plant stems should be not damaged during the harvesting and manufacturing process to guaranty the high stability of the stems within the LNS core. The principle of the LNS core production is shown at Fig. 1.

2.2 Production Process of LNS

The production steps are described below and shown in Fig. 2 and Fig. 3:

1. Filling a form box with a precise amount of stems
2. Filling the form box with a precise amount of foam glue
3. Compressing, heating and hardening the stem/foam glue compound
4. Hardening the stem / foam glue compound
5. Deforming the stem / foam glue compound
6. Preparing the form box for the next production cycle

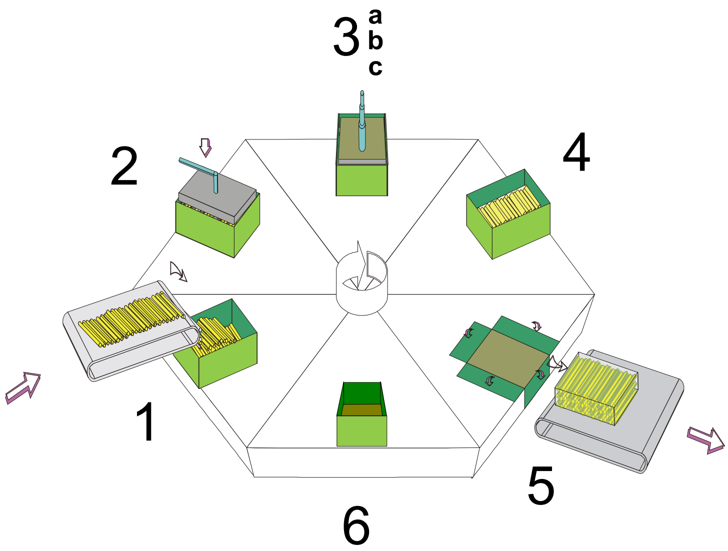


Fig. 2: Principle of the LNS core production

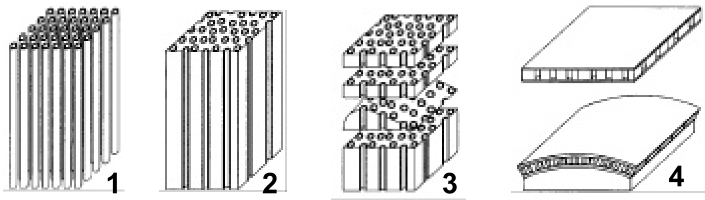


Fig. 3: Further production of LNS sheets.

3. Design Study of Rotor Blade Cross Section

A design study has been performed in order to assess the suitability of LNS for rotor blade structures. In this study a characteristic section of the 6.1 m rotor blade of the HSW30-12 has been used. The original design of this blade consists of a glass fibre reinforced plastics (GRP) skin, with Divinycell sandwich panels in the tail section and a massive foam web. The following five design alternatives have been assessed:

1. Original design as a reference (see Fig. 4 top),
2. Foam web replaced by LNS,
3. Web and tail section replaced by LNS,
4. Web tail and nose section replaced by LNS, only GRP girders,
5. Full LNS section (see Fig. 4 bottom).

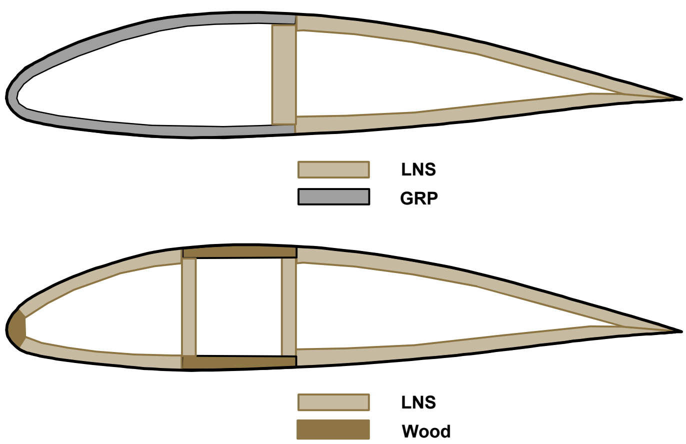


Fig. 4: Two examples of the rotor blade cross section which have been investigated in the design study.

In alternative 5, the full LNS section, massive wood has been used as a web girder where necessary. The loads on the section were taken from the original design load set used for certification of the turbine. The wall thickness and layout of each design alternative has been determined based on the ultimate load and the fatigue load for 20 years of operation.

Possible buckling of the thin walled sections has been assessed with the aid of the panel buckling tools developed in the Buckblade project [1]. The material properties for the GRP are taken from the original design calculations. For the wooden facings of the LNS and for the massive wood girders the allowable values for laminated birch wood have been used. It appeared that from the point of view of minimum mass per unit length, design alternative 4 was the most favourable.

4. Material Tests

In order to determine the mechanical properties of the LNS, coupon tests have been performed. The emphasis with these tests has been on those properties relevant for material to be used in sandwich cores. The main function of a core material in a sandwich is providing stability against buckling. In order to provide this stability, the core material has to have sufficient shear stiffness and strength, and to avoid core compression failure where the facings buckle inwards, the core also has to show sufficient compression strength.

The shear strength and stiffness of the LNS sandwich core have been determined with three point bending tests in accordance with EN310.

The bending deformation of a test coupon in the three-point bending test is a combination of pure bending were the facings show normal strain, and of pure shear where the core shows a shear deformation. In order to discern between those two effects, the bending tests have been done for two different lengths of the test piece.

In this way, two equations can be formulated in the two unknown deflections for different length. Solving this system gives both the shear stiffness of the core and the bending stiffness of the facings.

The compression strength and stiffness have been measured by compression tests on specimens of LNS bonded between aluminium plates. Aluminium has been used here to prevent errors due to local compression of the facing material at the location of the individual stems.

In order to acquire some knowledge about the sensitivity to moisture of the LNS material, a series of bending tests have been performed on material

LNS - Data Sheet								
Test	Value		Dry g Epoxy / m2				Wet g Epoxy / m2	
			200	250	300	350	200	250
	no of tests				24			
Compression in MPa	strength	avg			1.9			
		min			1.4			
	modulus	avg			249			
		min			130			
Shear in MPa	no of tests		2	2	9	6	2	2
	strength	avg	0.32	0.40	0.35	0.40	0.27	0.40
		min	0.26	0.36	0.29	0.30	0.13	0.38
	modulus	avg	13.0	15.5	15.1	15.9	19.3	15.9
		min	12.8	15.1	12.1	14.6	15.1	14.4

Tab. 1: LNS - data sheet

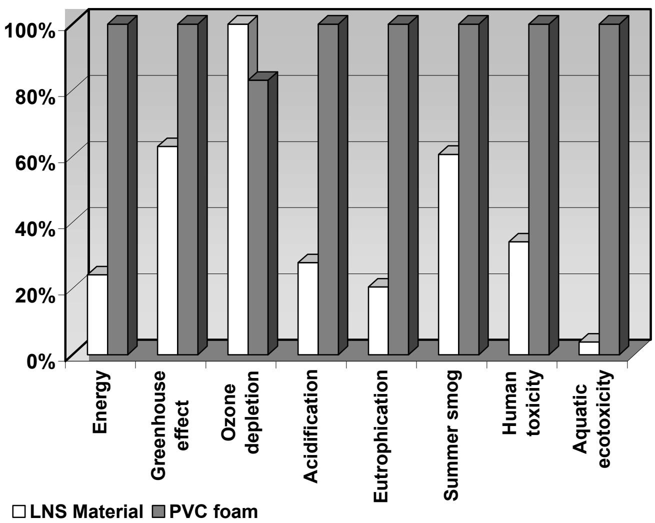


Fig. 5: Environmental profiles of LNS and PVC foam.

that was kept at 100% humidity for 24 hours.

The results of the tests are summarised it the data sheet shown in Table 1.

In general, the LNS tested in this project shows mechanical behaviour comparable to the low to medium density foams. As can be expected of a natural material the spread in measured mechanical properties is relatively high.

5. Life Cycle Analysis (LCA)

In order to have an objective measure on the impact on the environment of the use of LNS, a comparison has been made between LNS and PVC foam. This comparison encompasses the complete lifetime of the products, from production of raw materials to recycling or incineration. Because the sandwich core material can be used with different kinds of facing material, only the proper core material has been considered in this LCA. The foam used in the comparison is a 60 kg/m³ density foam.

The environmental profile of both materials is represented in Fig. 5.

It can be seen that the environmental load is lower for the majority of environmental themes. It should be noted in this Figure that it is based on the assumption that the same thickness of LNS core is required than in the case of PVC foam. Moreover, it can be noted that no attempt has been made to rank the individual environmental themes.

6. Conclusion

The LNS material has been tested and characterised. It is possible to substitute PVC foam by LNS. A free field test of a wind vane of a small wind turbine manufactured in LNS is running for more than three years.

Moreover the material can be used in other wind turbine components (nacelle cover, tower floors, etc.), in full natural material rotor blades for small wind turbines and in other non wind energy application such as furniture, doors, floors, walls, etc..

Parts of typical rotor blade components will be built and tested in the continuation of the project.

7. Acknowledgements

The research project "Development of a rotor blade using renewable materials: BIO-BLADE" (JOR3-CT96-0153), is partially supported by the European Commission DG XII Non Nuclear Energy Programme.

8. Literature

[1] C. Lindenburg: BUCKBLADE, Buckling Load Design Methods for Rotor Blades. Report ECN-C-99-015. Netherlands Energy Research Foundation ECN. Petten, May 1999.