УДК 621.914

DECOMMISSIONED WIND TURBINE BLADES: A PEDAGOGICAL PROJECT ON THE USES OF THE RAW MATERIAL

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Abstract: *The incorporation of new technical challenges created by the increase of the wind power industry in the world and how they were integrated into a MSc Course of Mechanical Engineering is addressed in this article.*

A Design Thinking Process [1] approach based on student-centered pedagogy of Project-Based Learning [2] was developed for the 12 ECTS course on Product Development and Industrial Processing at the Bragança Polytechnic Institute, Portugal, held in the second semester of the 2015/2016 school year [3]. In this pedagogic experience, the students where challenged to create new and innovative proposals for the use of a new material: the shredded straw derived from wind turbine blades.

Large wind turbines are designed for a life span of 20 to 25 years. As being decommissioned after that period, the steel tower is recycled, the cooper cables, generators, electric, electronic and hydraulics equipment and other different materials that are part of the whole machine are also sent to recycling centres where the raw material is recuperated and introduced back again into the economy [4].

The wind turbine blade presents a different problem because they are an inhomogeneous composite structure. The core material is made of PVC or different types of wood, reinforced with fibreglass and, in specific locations, carbon fibre embedded in resin. Gel coat protection is applied to the whole exterior surface to guarantee its smoothness. A lighting protection is inserted into the core of the blade to allow grounding atmospheric electricity discharges thus avoiding damage to the structure [4,5]. Once the wind turbine is decommissioned, the blades are one of the few parts that are not recycled and yield no economic value. The economic and environmental costs of disposing and neutralizing the negative effects of such material are not to be neglected in the near future assuming the evolution of the wind energy industry in the last 2 decades.

Since the last decade of the XX century that the wind energy, regarding multi-megawatt dimension wind farms, has constantly grown: first in Europe, followed by the US in the beginning of the XXIst century and then by China, that is currently the world leader of the installed capacity with 188,392 MW (34,9% of worlds wind capacity). EU-28 follows close with 168,729 MW (31,2%) and USA with 89,077 MW (16,5%), installed by the end of 2017 [6]. The evolution of the last 2 decades is large: the installed capacity for wind energy grew more than 88 times in the last 21 years, from 6,100 to 539,291MW, Table 1. However, not only the number of machines increased, but also their dimension. Larger machines yield larger power but require bigger blades: from the standard 21 m in 1990's, the blades dimension doubled after a decade to 42 m and just after 20 years it almost triple.

Table1

Estimate of wind turbine blades in the world-built accounting for the evolution of the technology and the increase on the dimension of the machines: 0,5 to 2 and then 3 MW turbines respectively for the 1990's, 2000 and 2010 decades

Year	Installed capacity (MW)	Blades (quantity)	Dimension (m)
1996	6 100	36 600	21
2006	73 938	138 357	42

2017	539 291	640 310	58

The same rate of growth is pressing the industry to find solutions to deal with the decommissioned blades. The early wind farms of 1990's are reaching the end of their working life and solutions must be find to address this issue. Moreover, because it will only increase throughout this century.

There are thermal methods of disposing the blades: pyrolysis or combustion. Mechanical methods are also quite crude: the blade is smashed and crushed to reduce volume and then placed in a landfill [4]. An alternative method is being addressed that consists in shredding the blade in small fillets creating a type of straw (Fig. 1).

Fig. 1. Complex and inhomogeneous material from the shredded wind turbine blade

This straw presented good thermal, but even better, acoustic insolation proprieties. On the negative side, the mechanical proprieties where weak and due to the shredded fibre-glass, it prunes to provoke skin irritation and should not be used indoors without proper coating.

To implement the referred pedagogical experience, the students were separated into groups and the final expected results was the proposal of a product with the respective quality analysis, specifications and technical drawings, accompanied by a prototype. The course was organized in 3 phases: inspiration, ideation and implementation. For the inspiration part, in front a design challenge, each group had to answer 2 questions: how to get started and how to stay human-centred.

The ideation part was related to the opportunity for design and address the issues of how the student will interpret what they've learned, how turn their insights into tangible ideas and how to make a prototype. The final part was the implementation of the innovative solution, answering questions such as how to make the concept real, how to access if it's working and how planning for sustainability.

The results of this process where proposed products depicted in Figure 2: acoustic barriers for subway and train stations (a); shipyard acoustic barriers (b); quick installed acoustic tiles for machine-shops or garages (c); cloistered study booth for schools' corridors (d); hybrid translucid brick for civil construction purposes (e). Products (a) to (d) focused mostly in the better acoustic properties of the material being thus used as a filling to absorb the sound wave of different environments.

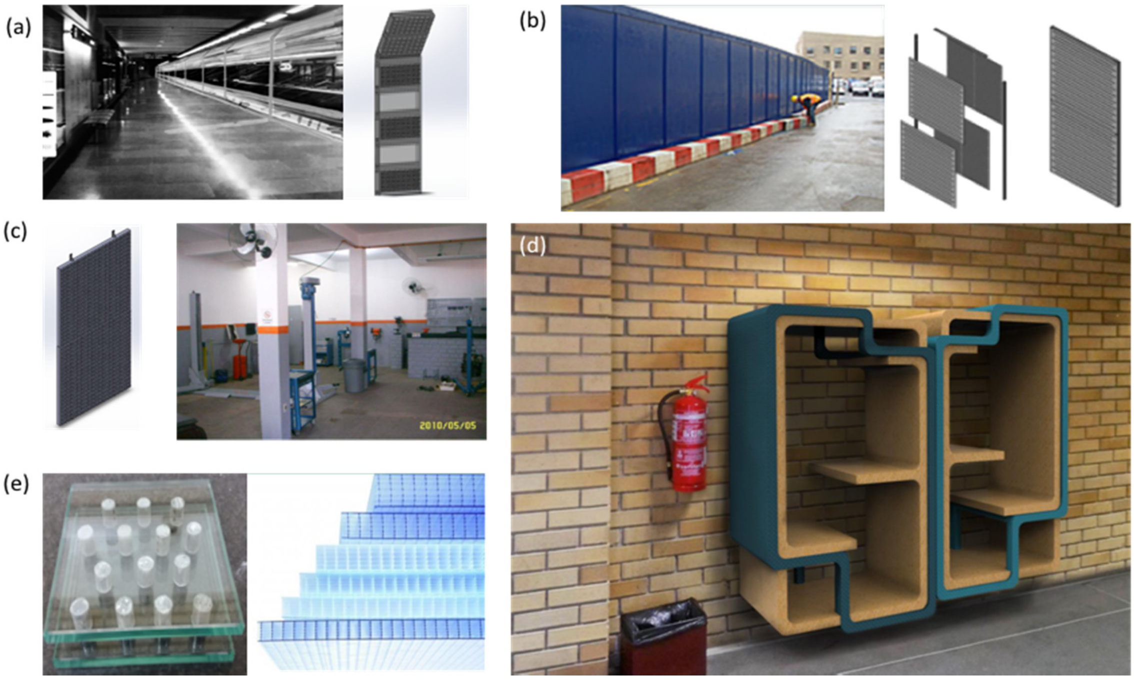

Fig. 2. Proposed products that included the straw from the wind turbine blades: acoustic barriers for subway and train stations (a); shipyard acoustic barriers (b); quick installed acoustic tiles for machine-shops or garages (c); cloistered study booth for schools' corridors (d); hybrid translucid brick for civil construction purposes (e)

The hybrid translucid brick in Figure 1 (e) was an attempt to investigate the benefits from the inclusion of the blades straw in a structural glass sandwich brick structure but the first compression values showed a disappointing threshold of 4.30 MPa, 11 times inferior against glass with 98% Si. The final evaluation of the proposed products was made with the presence of the company that provided the material and wanted to verify other alternative products than the one currently producing.

The same strategy of using a real problem was used for the elaboration of a comprehensive project related to the preparation and application of courses that relied in a Learning by Development pedagogical methodology in Ukraine by the members of the MRIA Consortium (mria.ipb.pt). This methodology intends to integrates knowledge from different areas in the analysis of a problem to be addressed by different specialities and contribute to the learning and teaching experience within the universities as well increasing the relationship and collaboration with local industries.

The consortium encompasses 2 EU and 5 Ukrainian Universities and the Ministry of Science and Education of Ukraine. It also involves other 28 Ukrainian entities, from factories to companies that already presented problems to be addressed in each Universities region. Although, that by the time this article is presented, the results of the funding application are not yet known, this proposal had a positive reception from the economic fabric all over Ukraine regarding sharing problems with the Universities and its inclusion in the learning process of the students.

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