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Procedia CIRP 40 (2016) 557 – 561

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13th Global Conference on Sustainable Manufacturing - Decoupling Growth from Resource Use

Wood As A Technical Material For Structural Vehicle Components

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Abstract

The application of molded wood parts as an alternative, innovative and sustainable multi-material system (MMS) for structural, resource-efficient and sustainable components within the body shell is a new approach in light-weight constructions. In many of the cases where a structural application of FRP is being considered, they can principally be substituted by wood-based MMS. Although there are great challenges; wood has the potential to fulfill the demands of the present technical appliances and social requirements. Actual results offers the first systematic approach to use wood in structural applications. The main properties and demands, which correspond with those of the specific original structural components, could be met. So, as regarding performance and reproducibility, it is possible to apply a wood-based material in technical appliances. Furthermore, material models have been designed and concepts for the repair and recycling of the wood-based MMS were developed.

Peer-review under responsibility of the International Scientific Committee of the 13th Global Conference on Sustainable Manufacturing

Keywords: wood; technical material; automotive; multi-material-systems, lightweight construction

1. Introduction

Lightweight constructions that aim to reduce weight and be ressource-efficient are and will be of great importance for traffic-related technology. In most cases, the mere substitution of materials is not the best economic and technical solution. Instead, a more holistic approach should be taken to meet the increased demands on driving comfort and security within a vehicle, but also to meet the targets for the reduction of CO_2 emissions [1]. Especially for traffic-related technology, multi-material-systems (MMS) have great potential for the application within light-weight constructions. However, these MMS demand an appropriate combination of materials that serve the specific application and, for this, the specific joining technologies need to be refined.

Here, the research project which is funded by the Federal Ministry of Education and Research ‘Moulded Wood Parts as Multi-Materials Systems for the Applications in Car-Bodies’ could help to face these challenges by defining the potential for wood as a material for car-bodies. The main goal is to develop a structural application of moulded wood parts as an alternative, innovative and ressource-efficient MMS for structural and sustainable light-weight components of car-bodies.

This design could be used for conventional but also for electric vehicles, giving this research project a long-term perspective and good economic implementation possibilities. [2] In the following, we would like to present the tests that have been performed within this project so far, and, subsequently, we would like to introduce their results.

2. Potential and Challenges for Wood in Car-Body

There is no doubt that the application of wood in car-bodies poses great challenges; apart from the purely mechanical compatibility, further characteristics such as reliability, process compatibility and reproducibility are highly relevant. Wood is, on the other hand, one of the oldest materials, a material with attractive potential and possibilities for today’s technological appliances.

Peer-review under responsibility of the International Scientific Committee of the 13th Global Conference on Sustainable Manufacturing
doi:10.1016/j.procir.2016.01.133

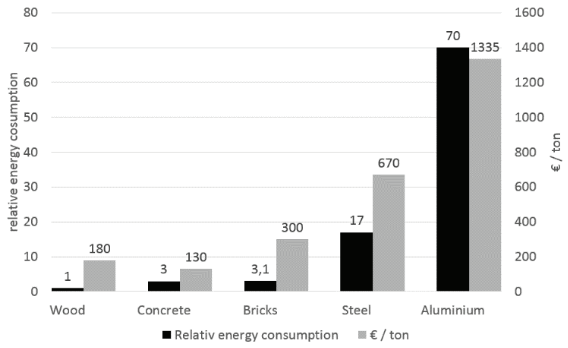

Figure 1: Average relative energy consumption of the production of a tonne of selected raw materials, with wood as reference (=1) [modified from 6] and prices.

2.1. Potential Weight, Emissions and Energy

Apart from the specific drive technology, the weight of a vehicle has a great influence on its CO_2 emissions [3]. The applied materials, the specific joining method and joining technology have a strong impact on this weight. As an example, a weight reduction of about 100 kg leads to a mean reduction of CO_2 emissions of about 13.9 % [4]. Current research shows that the substitution of steel with wood-based multi-material systems leads to a reduction of weight of about 15-20 % and still allows for the same performance. The comparision between usual materials and beech wood is shown in table 1.

Table 1: Comparision of relevant material properties with regard to the strength/density proportion. [3,13]

Material	**Density [g/cm³]**	**Tensile Strength [N/mm²]**	**Tensile Strength/Density**	**Properties**
Beech	0,54-0,91	135 (longitudial)	~187	anisotropic
Steel	7,85-7,87	340-1,250	~44-160	Isotropic
Aluminum	2,3-2,8	45-500	~20-217	isotropic

As Germany has large woods of high-quality beech trees, short transportation routes improve the value chain right at the beginning. As wood is available nationally and regionally, this material offers a first ressource-efficient advantage in comparison to materials that need to be imported [5]. Furthermore, in comparison to materials such as steel or aluminium, the relative energy input for the production and provision is clearly lower, as shown in Figure 1.

This advantage would be even clearer, if the comparison had included high-strength and super high-strength steels as are currently used in the automotive industry as they can only be produced using highly energy consumpting forming processes [7].

In addition to the energy-related CO_2-emissions, table 2 compares the environmental impact of 1 kg of beech veneer plywood with urea-formaldehyde binder to aluminium.

Table 2: Impact on the environment when producing a kilogram of beech veneer-plywood with urea-formaldehyde adhesive and aluminium [8]

Impact Categorie	Aluminium Mix	Veneer Plywood	Unit
Photochemical ozone creation potential (POCP)	0,0069	0,0005	kg Ethen-equiv.
eutrophication potential (EP)	0,004	0,0006	kg PO4-equiv.
Acidification Potential (AP)	0,054	0,0025	kg SO2-equiv.
Ozone-depleting potential (ODP)	3,056E-06	9,4E-08	kg R11
Global warming potential (GWP)	17,122	-1,21 (-1,84)	kg CO2-equiv.
Excavation	27,35		kg/kg

2.2. Potential Price and Availability

Apart from the aforementioned potentials, wood is an attractive material as regard feasability in comparison to conventional materials. The price range of wood per tonne is listed in Figure 1. For metal, Germany is dependant on imports of the raw materials which makes it vulnerable to price fluctuations and supply shortages [9]. In Germany, woods cover an area of approx. 111 billion m^2, about 31 % of the entire country. Thus, with approx. 3.4 billion m^3, Germany has one of the biggest timber ressources in Europe. In addition, this amount increases by about 107 million m^3 every year whilst the total annual cut is about 56.8 million m^3 (mean value of the years 2003 to 2012) [10, 11]. Sustainability is embedded safely in the German forest management values, thus, the cultivation and cut cannot be increased to an endangering limit, even if the demand on wood should increase.

As the demand for finite ressources, especially in developing countries, will increase in future, this will inevitably lead to rising prices for these raw materials. Furthermore, the prices for raw fossile materials have always been liable to price fluctuations. Wood, however, is a renewable and quite often a regional raw material, therefore it offers a certain reliability and price stability [12]. And, as already mentioned, much of the transport costs can be saved due to the regional supply.

2.3. Challenge Process Chain

As the automotive industry has focused mainly on the processing of metal materials for the last decades, established and refined processes and methods that have grown through continuous optimisation dominate the field as they are highly efficient and economical. Thus, the process chain for car-bodies is adapted to the processing of steel-dominated structures. This becomes aparent when looking at the design of the car-body, where steel sheets in different strengths are applied in accordance to the specific demands on the constructional element.

Furthermore, the trend to design integral constructions leads to the production of few separate constructional elements that