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An ecological design study of using hybrid biocomposite materials inside a motor-vehicle's cabin

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Abstract. The paper presents the analysis of the driver and the occupants' perception in the case of using composite materials to some cabin components. There were analyzed four biocomposite materials with reinforcements of wool, wool & cotton, bamboo and bamboo & cotton. They were analyzed for the dashboard, door panels and A&B pillar using a part of an ecological design – CAVE (Cave Automatic Virtual Environment). Having the four types of biocomposite materials it was necessary to determine their properties like color, texture, grain, bump, material flakes and emissivity, all of them with a special scanner. The data was uploaded into the Deltagen software to analyze every component at a real-life scale. The CAVE made possible analyzes of different light environment conditions, the grain, colors, shines, and the reflections to windshield, windows or mirrors. Thus, with the CAVE was done a digital testing by changing materials of the components in a short amount of time and with low costs. In the Beginning of Life of a vehicle, by using the CAVE and biocomposite materials for motor vehicles' components it is possible to obtain clean and sustainable product development.
Keywords: CAVE, virtual reality, digital testing, sustainable materials, biocomposites

INTRODUCTION

Every product has a life cycle that must be optimized to have a low impact over the environment maintaining its performances or even rise them. This optimization starts with a good standardization mainly at the Beginning of Life (BOL) and End of Life (EOL) parts. The main link between them is the use of recycled materials, not only from the same industry but from related ones. It is mandatory for the automotive manufacturers to use at least 25% of plastics that comes from recycling (of which 25% from recycled EOL Vehicles) [1]. The plastics are very resistant to degradation, fact that made the manufacturers to look forward for new materials especially composites ones. They have a low impact over the environment, because they can be produced in an environment friendly way at the Beginning of Life (BOL) and they are easily recyclable and biodegradable at the End Of Life (EOL) of a motor vehicle.

The composite materials were first used in Japan, in 1947, to reduce the weight and the fuel consumption [2] and will be used more in electric vehicles where it is vital to balance the additional weight of the batteries [3].

They can have the same mechanical properties as the classical ones, but with a lower weight. Moreover, an auto-body can be lighter using addition of natural fibers in the compound, because these fibers are less dense than the synthetic ones [4]. Natural fibers start to become more accessible to the automotive industry, replacing the thermoplastic glass fiber reinforcements.

A new path to environment friendly materials comes from the use of natural resin with natural fibers. While those materials are under development, the natural resin can be combined with a synthetic one, in different proportions, obtaining hybrid biocomposites. A good natural resin is dammar, that has good stability and mechanical properties [5].

CHALLENGES BROUGHT BY BIOCOMPOSITE MATERIALS IN THE AUTOMOTIVE INDUSTRY

The biocomposites are materials formed of at least of two constituents – a matrix and a composite reinforcement. The mechanical and chemical bonds between them rises the material properties higher than the constituents taken separately.

They are manufactured by traditional techniques for conventional fiber-reinforced polymer and thermoplastic composites – resin transfer molding, injection molding, compression molding, vacuum infusion, direct extrusion, blending etc. [6]

The use of thermoplastics for automotive components has encountered severe problems with high temperature changes [7]. The main problem is the decreased mechanical performance due to the low thermal conductivity. The biocomposite materials become more sensitive at high temperatures than the currently applied ones.

For epoxy resins, aging mechanisms cause them to lose mass during high temperatures exposure, resulting in the reduction of the free volume. This implies chemical degradation, causing changes in molecular structure.

A way of reducing those degradations is to use a hybrid resin based on dammar. The dammar resin is obtained from the exudation of damar trees from India, Malaysia and Indonesia (Shorea and Hopea of Dipterocarpaceae family trees). The resin is mainly composed in polysaccharides and is a viscous clear substance, with low acidity and good optical properties. The Dammar has a complex structure, that makes difficult to determine its exact composition. It can be found in colors like yellow, brown or white in the form of crystals, powders, flakes or glitter. Using Dammar alone, over time, its color becomes more yellow, cracks occur, and it becomes brittle [8].

With a hybrid resin of 60% dammar and 40% of epoxy, thermos-gravimetric analysis subjected samples to temperatures up to 800ºC. The mass loss was monitored at different temperatures. The great loss was situated between 300ºC – 450ºC [9].

The motor vehicle cabin's components are exposed at high temperatures but mainly at ultraviolet (UV) radiations. The biocomposite materials will start to degrade having effect over their visual aspect, turning to yellow. This yellowing is an irreversible process [10], making those materials to be avoided at components where the aesthetic is a concern.

The ultraviolet rays from the sunlight or artificial sources can significantly impact the properties of the resin materials, breaking the chemical bonds in the resin's molecular structure. The effect is the degradation and discoloration of the resin. The degradation of the product can introduce chromophores, which absorbs the light in the visible spectrum creating the yellowish appearance.

To reduce the resin yellowing is necessary to incorporate in the material's structure UV stabilizers or antioxidants like hindered Phenol antioxidant or to isolate the material from the air by using protective coatings [11], [12].

STUDY PREPARATION

The study was made for four types of biocomposite hybrid materials with fibers of wool, wool & cotton, bamboo and bamboo & cotton. The used resins were formed of 50% of epoxy – Resotech 1050 and 50% dammar.

Figure 1. The biocomposite material preparation (left – cutting the woven fabrics; right – the biocomposite material layering)

The reinforcement fibers were in the form of a woven fabrics, to create a homogeneous material (Figure 1). This type of insertion has a major advantage of resistance compared with insertion of yarns, mainly at cotton and wool composites.

The obtained materials were scanned to determine their color, grain, texture, bump, material flakes and emissivity. Those data were saved in Deltagen's Library in a SBSAR file format.
For every 3D model of the cabin components was chosen the material in the Deltagen. Every component is meshed in polygon-based shapes with the surface normal representing the depiction of the orientation of those polygons.

Figure 2. The reference grid and polygons normal orientation

The input data like the material, the meshing and the declared UV will necessitate a check of the reference grid. With a good mesh, the UVs between parts will be consistent obtaining realistic images that will be studied with the CAVE (Audio Visual Experience Automatic Virtual Environment), seeing the real color, material texture and the light reflection.
All the components were assembled, obtaining a 3D realistic model (Figure 3 – left side). With the CAVE is possible to simulate different status of the light like sunrise, middle day, sunsets with all the sun positions – front, back, lateral. It was possible to simulate the tunnel entrance/exit or midnight all of them to determine the dashboard reflections and the visibility through the exterior mirror on the left side.

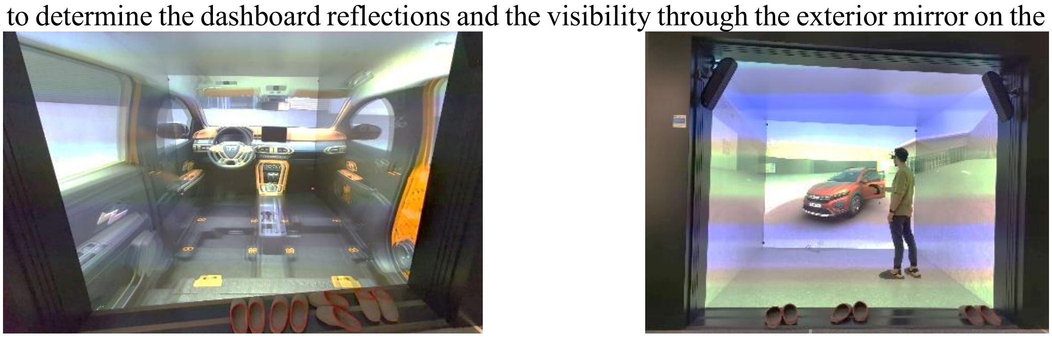

Figure 3. The realistic images of the studied model

The CAVE, situated in Titu, Dâmbovița district - Romania, has five active walls (including the floor). With a pair of 3D glasses, the user perceives a realistic representation of the designed model at a normal scale (Figure 3 – right side). By walking in the room or using a Flystick, as a controller, is possible to observe the virtual model. The images are projected by 4K Barco video-projectors. Each wall has two projectors whose light is reflected through highly reflexive mirrors to create 3D images. Every projector has its own processing computer - Hewlett Packard Z8 model. They have an Intel Gold 5120 CPU @ 2.20GHz (28CPUs), 64GB of RAM, Nvidia P6000 graphic board.
Before the assembly, the parts are designed in CATIA occupy 9GB of memory. They will be merged and rendered at a resolution of 4096x2160 pixels for a high-quality image output to enable a good observation at 10cm. The resulting size of the Mock-Up model is about 1.3GB making possible for a smooth navigation.

RESULTS AND INTERPRETATION

The first results are obtained in Deltagen/CAVE software as images of different shapes and formats of the cabin components. Those images are presented on a display with a tone mapping that scales the material and its colors to approximate the aspect of High-Dynamic-Range (HDR), obtaining a realistic look.
Starting from a 3D vehicle preparation and checking materials, the light (UVs) and the environment, an exhaustive and qualitative numerical mock-up is built. Thus, is created a virtual prototype and environment, adapted to the project reality.
The cabin's vehicle has a single layer of glass and a windshield of 5mm thickness.

The results can be view in real time with 3D glasses or extracted by the software. The obtained images were for an eye position of Ref50, where 90% of the customers are situated (see SAE standard - J941_201003 [13]). The forward inclination of the vehicle was adjusted in the case that the motor-vehicle has a driver and a full fuel tank, without passengers.
Some of the moving parts, like in real life, can be set-up. For example, the left side mirror was adjusted to obtain a side view with the line of horizon at a heigh of ¾ of the general image and a 30mm visible bodywork. The interior mirror has the center point of view same as the rear window.

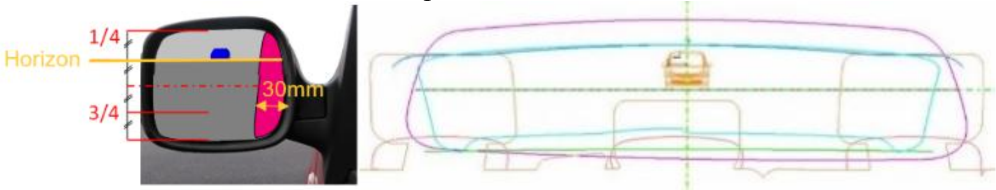

Figure 4. The mirrors' configuration

The four materials were applied to the dashboard, vents, sun visors, door panels, A&B trim pillars, center console and different decorative elements.
After every application of the four materials, two subjective reflection analyzes can be done on 2D images and inside the CAVE (Figure 5).
The quality of the 2D images is 4K - 4096x2160 and making possible to analyze the texture, grain, shines, reflection and emissive color mainly of the dashboard. The light dispersion on the door panels will highlight the texture of the material and can influence the color property of hiding technical construction details.

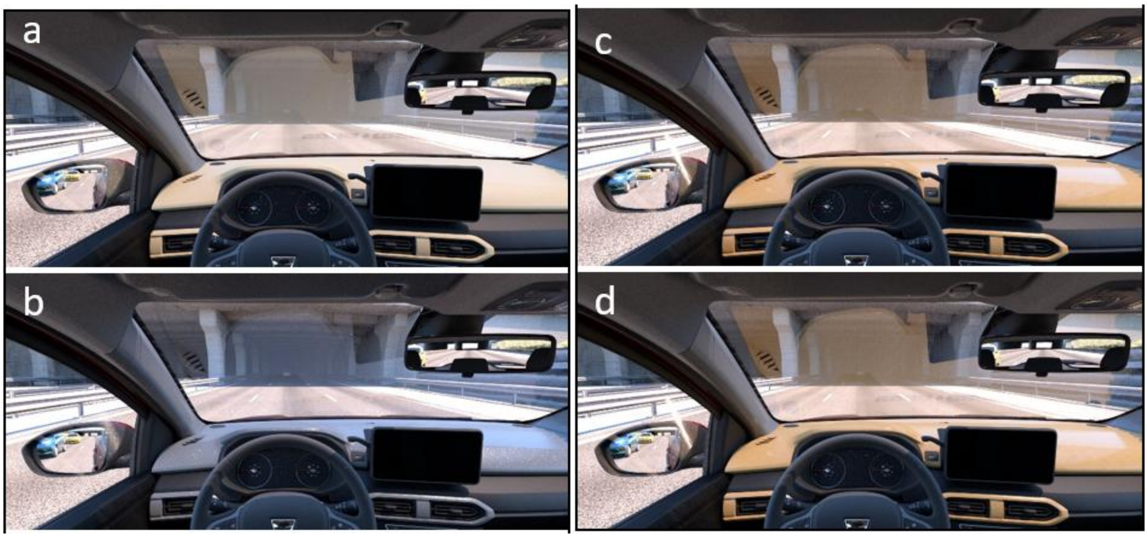

Figure 5. 4K Images of different materials used at the dashboard (a. wool, b. wool&cotton, c. bamboo, d. bamboo&cottone)

The second analyze was made inside the CAVE by the quality engineers, depending on the requirements of the project. They must make an analysis of what eyes of a customer will see. Mainly, the major problem is raised by the bamboo and bamboo & cotton materials. In the case of a midday light, the dashboard will reflect the light in the windscreen, causing visibility problems to the driver. Another psychical problem is represented by the yellow color that initially will calm down the driver but in time will tire the driver. The wool-based material will reflect a small part of the light but not affecting the driver too much. From all the materials of the dashboard the best is the one with wool & cotton, having the smallest reflection in the windshield and a color close to the asphalt. This way the driver's eyes are not forced when they focus from the front panel to the front of the vehicle and back.
When the subjective analyze is done in CAVE, the user can mark with visibility flags certain elements, depending on the necessity of that element to be shown or hide or even change its shape.
The colors and further the materials repartition can be done in a short amount of time to create a visual harmony that will make the customer, mainly the driver, feel comfortable. This way is possible to avoid the claustrophobic effect of dark colors over some customers.

CONCLUSIONS

The European standards stipulate for the motor-vehicle producers to use more biodegradable materials. Some of them have the advantage of being cost effective, but is necessary to investigate their properties, mainly of the hybrid biocomposite ones.

A hybrid biocomposite that uses woven fabrics will be easily recycled at the End of Life of the vehicle.The fibers inside the materials will increase the wear resistance of the components that comes directly in contact with the customer, like the door panels.

Comparing to the textile coatings it will be easily to be maintain, having an aesthetic look that can be kept for long by varnishing them, thus avoiding the yellowing process.

Using the CAVE technology it's easy to identify which material are the most feasible to apply to various automotive components like the dashboards, the pillar trims, decorative elements etc.

The analysis concluded that the bamboo and bamboo & cotton-based materials are not suitable for the dashboard, and they can replace decorative chrome elements on some markets.

Using those materials can attract new customers that consider innovation and ecology a landmark.

In conclusion, the CAVE analyze saves time and money, mainly in the application of new materials on the automotive industry. The time for obtaining components, preparing, assembling and testing the prototypes is substantially reduced as is the money spent with those products and physical operations.

REFERENCES

[1] European Union Commision *End-of-Life Vehicles* [Interactiv]. Available: https://environment.ec.europa.eu/topics/waste-and-recycling/end-life-vehicles_en#timeline. [Accessed 22nd Jun 2024].

[2] F. Khan, N. Hossain, J. J. Mim, S. M. Rahman, M. J. Iqbal, M. Billah, M. A. Chowdhury *Advances of composite materials in automobile applications – A review Journal of Engineering Research*, 2024.

[3] A. Wazeer, A. Das, C. Abeykoon, A. Sinha și A. Karmakar *Composites for Electric Vehicles and Automotive Sector: A Review* Green Energy and Intelligent Transportation, 2022.

[4] G. Koronis, S. Arlindo, *Green Composites for Automotive Applications*, 2018.

[5] D. Bolcu, M. M. Stanescu *A Study of the Mechanical Properties of Composite Materials with a Dammar-Based Hybrid Matrix and Two Types of Flax Fabric Reinforcement.* Polymers (Basel), vol. 12, nr. 8, p. 1649, 2020.

[6] M. S. Sarfraz, H. Hong, S. S. Ki *Recent developments in the manufacturing technologies of composite components and their cost-effectiveness in the automotive industry: A review study*. Composite structures, vol. 226, nr. 16, 2021.

[7] S. Jeyanthi, J. Rani *Influence of natural long fiber in mechanical, thermal and recycling properties of thermoplastic composites in automotive components*. International Journal of the Physical Sciences, vol. 7, nr. 43, pp. 5765-5771, 2012.

[8] N. Andrikopoulos, A. Kaliora, A. Assimopoulou, V. Papapeorgiou *Biological activity of some naturally occurring resins, gums and pigments againstin vitro LDL oxidation*. *Phytotherapy Research,* vol. 17, nr. 5, p. 501, 2003.

[9] V. Georgeanu, M. Stanescu, D. Bolcu, I. Ciuca, M. Bogdan, A. A. Sabo-Iordache *Study of Chemical Composition and Some Material Properties for a Hybrid Resin Based on Dammar*. Materiale Plastice, vol. 58, nr. 1, pp. 47-56, 2021.

[10] A. Krauklis, A. Echtermeyer *Mechanism of yellowing: carbonyl formation during hygrothermal aging in a common amine epoxy.* Polymers, vol. 10, nr. 9, p. 15, 2018.

[11] T. TK. *Thermo-Oxidative Aging of Composite Materials*. *Journal of Composite Materials,* vol. 29, nr. 3, pp. 410-422, 1995.

[12] C. Wu, B. C. Meng, L.-h. Tam, L. He *Yellowing mechanisms of epoxy and vinyl ester resins under thermal, UV and natural aging conditions and protection methods.* Polymer Testing, vol. 114, 2022.

[13] Society of Automotive Engineering *Standard of Motor Vehicle Drivers' Eye Locations - J941_201003*. SAE, 2010.