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BIO-BASED ENGINEERING PLASTICS A TOOL TO REDUCE CARBON FOOTPRINT

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ABSTRACT

It is believed that the use of materials based on renewable resources can be used to improve the environmental performance of products. In this experiment the plastic used in a housing of a Residual Current Operated Circuit-Breaker (RCBO) was exchanged to two different partially bio-based plastics. The assembled prototypes were tested according to IEC-Standards and both bio-based plastics showed outstanding results. The reduction in carbon dioxide (CO_2) equivalents was around 40% for the housing itself, which unfortunately had a small impact on the final carbon footprint of the product. However, due to the large number of products produced per year the emission of CO_2 equivalents will be reduced by about 250 metric tons per year.

INTRODUCTION

Sustainable development has become an important topic for many companies, since reducing the carbon foot print of new products can result in a competetive advantage. It is believed that the use of materials based on renewable resources can reduce the amount of carbon dioxide accumulated in our atmosphere, since the carbon dioxide release at end-of-life is the same amount as the renewable resource harnessed during its cultivation (Krochta, 1997). The drawback with pure bio-based thermoplastics, like poly(lactic acid) or starch, is that they are biodegradable and many of them have inferior mechanical and thermal properties compared to the engineering thermoplastics used in power products today. Many power products have a long life-span, around 30 years, and it is important that the material properties stay the same during this time for safety issues.

Durable engineering thermoplastics based on renewable resources are currently available. Many of the large thermoplastic suppliers have a few bio-based materials in their portfolio. The durable bio-based thermoplastics use naturally occurring building blocks to form conventional thermoplastic materials, which perform equally to their fossil fuel base counterparts. Durable bio-based engineering thermoplastics are believed to have high growth potential, due to their vast area of use. It is currently possible to find bio-based polyamides, polyesters, polyolefins and polycarbonate blends. Polyamide is current the group of materials with the largest amount of variation of bio-based materials in the market: 4.10., 6.10, 10.10, 11 and polyphtalamide (PPA).

The goal of this work was to prove that the resources used to produce engineering thermoplastics will not affect the performance of the final material. To achieve this, two bio-based materials were incorporated into the housing of a low voltage product. A RCBO with over current protection was selected for the project, since this product has high demands on the housing due to the thermal environment inside the product during the breaking operation. The first material had a bio-based content of 49%, while the second material had 31%. The produced prototypes were type tested according to IEC-Standards. The bio-based materials showed outstanding results, which indicated that there is no problem using engineering thermoplastics that are partially based on renewable resources in low voltage applications. Life cycle analysis (LCA) of a circuit-breaker shows that the user phase stands for the highest emissions (ABB, 2005), which is a common phenomenon among ABB's products due to resistive losses and long life-spans. Low voltage products are often small and the material content is highly optimized. It is therefore important for ABB to look at all alternatives to improving the environmental performance of these products.

EXPERIMENTAL

Materials: The reference resin was a standard PA6 with 30 wt% glass fiber content and V2 performance. The bio-based materials tested were: DSM EcoPaXXTM Q-KGS6 (PA410, 30 wt% glass fiber, V0 with halogen free flame retardant) and RTP 2099 X 115387 B (PA610, 30 wt% glass fiber, V0 with halogen free flame retardant).

Manufacturing: A molding trial was performed on a conventional injection molding machine, using the existing production tools for the RCBO housing. The two parts produced are shown in Figure 1.

Characterization: The characterization of the bio-based resins was made on plates supplied by material producers, housings produced at the molding trial and on assembled products. The following tests were performed in this study: Glow wire test on molded RCBO prototypes (IEC 60695-2-10:2000 clauses 4-8), Moisture absorption using an internal standard (7 days at 30°C and RH 98%), Comparative Tracking Index (CTI) up to 600V and finally the assembled products were type tested according to IEC standard 61009-1:2010.

a) b)

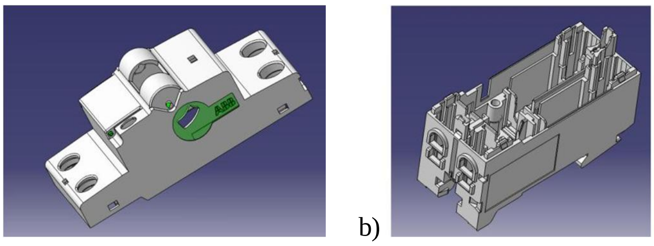

Figure 1 Drawings of the produced parts. a) Cover, b) Housing

RESULTS

The assembled prototypes passed the type testing according to the IEC standard 61009-1:2010, and the results clearly indicated that these materials can be used in low voltage applications.

The results from experiment also showed that the two tested bio-based materials had;

- Good dielectric properties, since no flashover or breakdown occurred during testing.
- High resistance against impulse voltages and short circuits.
- High reliability, since only a low temperature increase was detected during current testing.
- Low moisture absorption, which resulted in no deformation or warpage occurring during climate cycling with high humidity levels.

DISCUSSION

Bio-based engineering plastics – A tool to reduce carbon footprint

LCA of a RCBO shows that the user phase stands for the largest source of CO_2 (ABB, 2005), which is common among ABB's products due to resistive losses and long life-spans. Activities to reduce the carbon footprint of the product should therefore target the main cause behind the resistive losses. In this specific product the losses come from both resistive losses and contact losses. Contact losses are difficult to reduce; it often demands the use of alternative technologies. One can of course also try to reduce the weight and volume of the product, which will reduce the amount of material in the product and emissions due to transport. The RCBO used in this experiment has a low total weight (~200 gr) and contains about 80 parts. It is therefore easy to understand that weight optimization of individual parts is difficult to use as a route to reduce the carbon footprint of the product. Novel strategies are needed in order to reduce the carbon foot print of this type product. Using materials based on renewable resources can be such a strategy.

Bio-based materials are more CO_2 neutral than their fossil fuel based counterparts (Devaux). This can be explained by that CO_2 from biomass is part of a shorter carbon cycle compared to CO_2 from fossil fuel. CO_2 from biomass is fixed at an equal rate to which it is released and consumed. Figure 2 shows the sources of CO_2 emissions from the production of a bio-based polyamide (PA11). The emissions originate from both fossil fuel (agriculture and material production) and biomass (raw material). Using biomass as raw materials will reduce the CO_2 emissions of the final material, as shown in Figure 2. However, it is important that emissions from material production don't increase due to the incorporation of biomass.

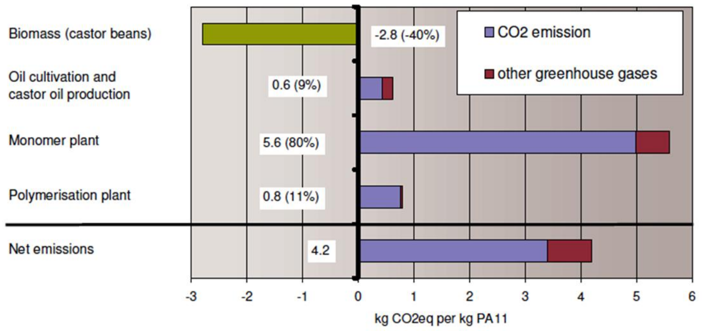

Figure 2 Breakdown of air emission by process step for the production of 1 kg PA 11 (Devaux).

In order to achieve sustainable development one also has to use renewable resources that do not cause any advert social effects. It is important that crops used for material production do not compete with crops used for food production. The renewable resource for bio-based polyamides is castor oil, which is derived from the seeds of the Ricinus Communis plant. This plant can grow on relatively poor soil, and therefore do not have to compete with crops for food production.

Arkema, a thermoplastic producer, has carried out an extensive LCA on their PA11 that is 100% based on biomass (Devaux). They showed that the global warming potential of their grade was less than half of an equivalent material based on fossil fuel (4.2 vs 9.1 kg of CO_2 eq / kg of plastic) (Boustead, 2005). In this experiment an extensive market search was carried out in order to identify bio-based materials that fulfilled the requirement specification. Unfortunately, no material fully based on biomass qualified, and therefore it was necessary to incorporate glass fiber reinforcement. By changing the material in the housing of the RCBO to a partially bio-based resin the change in CO_2 eq (100 years) / kg of resin will be reduced by around 40% (3.4 kg CO_2 eq (100 years) / kg of resin[1]). Even though the weight of the housing is low, about 70 grams, it will have a high impact due to the large number of products produced per year (~1.5 million products). The emission of CO_2 equivalents will be reduced by about 250 metric tons per year. This number corresponds to the emission from the use of 500000 kWh of electricity (European mix).

CONCLUSIONS

This work showed that small changes in carbon footprint on a single product can result in substantial reduction in emissions of CO_2 equivalents when looking at all the products being placed into the market. The product line's entire impact on the environment therefore always has to be considered besides the LCA results. Changing the resource for 7 grams of plastics in only one of ABB's large number of products can make a difference for the environment.

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[1] The figures are based on Arkema's calculations and a resin that is 70% bio-based (DSM EcoPaXX™ Q-KGS6.). Weight of glass fibers in the product has been removed.