MouldPulp

Title of the research project	**Development of Durable, Fully Bio-Based Thermoplastic Composites from Bioplastics and Pulp Fibres for Injection Moulding Applications (MouldPulp)**
Coordinator of the project	Thomas Wodke

BASIC PROJECT DATA

Project period	01.01.2011 - 31.12.2013
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URL of the project	http://www.mouldpulp.com
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Abstract

The motivation for the project was the promising wood-polymer concept DuraPulp® from cellulose pulp and the bioplastic (PLA). It is from fully renewable resources, shows good mechanical properties, a perceived naturalness, nice tactile properties, and can be dyed with clear colours. It won a lot of design awards and it became obvious the market should increase with a wider variety of plastics processing technologies available. Due to this the transnational project team from Sweden, Finland and Germany developed a processing technology that allows making injection moulded parts out of DuraPulp® but keeping the material identity.

Various formulations using different fibre types, PLA grades, and additives were investigated. The sample production was increased to industrial scale and the processing equipment for compounding and injection moulding was adapted. The injection mouldable MouldPulp material developed in the project is nearly 100% bio-based from wood and agriculture resources. The processing behaviour as well as the product properties fulfil the industrial and consumer requirements. Thin-walled injection moulded parts are producible on conventional injection moulding machinery in clear colours and with acceptable cycle times.

This technical development was continuously accompanied by the evaluation of the innovation potentials through a market survey, an analysis of the up-scaled processing technology and the costs, and a life cycle assessment (LCA). The measuring of the emotional performance of the MouldPulp material on test persons showed that the MouldPulp samples received on average significantly higher ratings than PP samples on quality and pleasantness.

1. Background

The Swedish research institute Innventia together with an industrial consortium has developed a promising wood-polymer material from cellulose pulp and PLA. This material is launched by Södra under the name DuraPulp®. The DuraPulp® composite differs from traditional Wood Polymer Composites, WPC's, due it is based on a fully renewable bio-based matrix polymer. Furthermore, the fully bleached fibre qualities allow a better dyeing with clear colours and the material feels less like plastic to the touch. The material is also biodegradable in an industrial compost environment. The Parupu® chair has demonstrated that the material has an appealing material identity including good mechanical properties, perceived naturalness and quality as well as nice tactile properties.

The DuraPulp® is delivered in the form of composite pulp bales, to be further processed by various techniques into final products. The only two products presented in DuraPulp® are the Kofes and the Parupu® chair, both manually produced using a suction moulding technique resembling similar e. g. to egg box production. Although these products won many design awards, there was a gap in the manufacturing methods regarding the use of established and efficient plastics processing techniques. However, the DuraPulp® process is not suitable to produce granules as easy feedable input material for conventional plastics processing machinery like injection moulding lines. In addition the flow characteristics of DuraPulp® are not appropriate for injection moulding and economically processes. Beside this, there was no other way of recycling than thermal recycling or composting developed so far.

2. Objectives

The overall aim of the MouldPulp project is to further develop DuraPulp® in terms of processibility (injection moulding) and applications. The innovative injection mouldable and fully bio-based composite shall keep the appealing naturalness material identity of DuraPulp® and thus will have market advantages as compared to other existing materials like WPC.

Matching with the novel material formulations the development of proper production processes is needed as well as a recycling strategy. The whole project was supported by a sustainability assessment where LCA and sustainability indicators were used to guide the researchers in their decisions.

3. Results

Mixing PLA and fibres results in higher Youngs modulus and lower elongation at break. This is well known and not interesting for investigations and innovations. Therefore the project team decided to adopt primarily customer- and process-orientated approaches: 100 % bio-based material formulation, natural impression and perception, and processing performance in injection moulding were the defined specifications. Mechanical performance would be answered related to the application, e.g. by material optimization or by means of the product design.

In order to achieve an excellent fibre-matrix adaption different fibre types were tested, especially with regard to reduce the yellowish discoloration of the injection moulded parts. During the compounding different additives as impact modifiers, coupling agents and bleaching agents were tested. Fibre contents up to 30 % were achieved. The mechanical properties of the compounded material were as expected comparable to other natural fibre reinforced PLA grades. The potentials for innovation and commercialization of the MouldPulp material are in the natural visual and haptic impression. The colouring of the compounded material during injection moulding (dry blend) was excellent possible with conventional masterbatches (Figure 1). Tests with colouring of pulp fibres were also successful (Figure 2), but due to the high costs and minor improvements compared to masterbatches the colouring of fibres was not further considered during the project.

Figure 1: Coloured gramules and test specimen

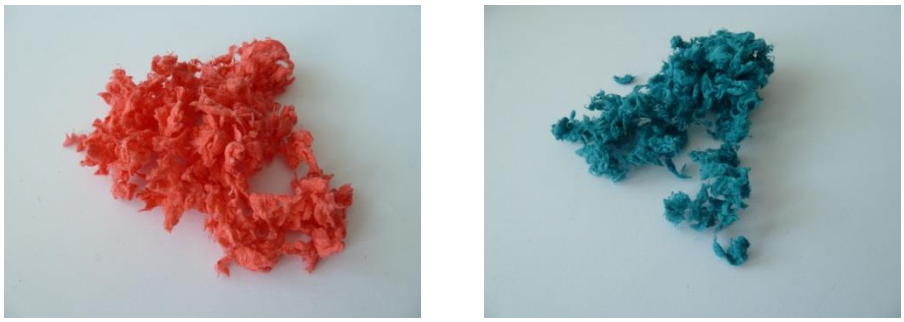

Figure 2: Coloured fibres

For the up-scaling of the compounding further trials and investigations for the pelletizing of the DuraPulp® material are still needed. The composite pulp bales and also the grinded composite pulp do not work with the gravimetric feeding systems of conventional industrial compounding lines as available in the project. Nevertheless, some 100 kg MouldPulp material were compounded on a lab-extruder for industrial injection moulding trials at Hammarplast. They produce one smaller container (12x9x10 cm) and a basket (38x28x10 cm, wall thickness 1.8 mm). Elastopoli produced an electronic lid and drum sticks from the material. The trials demonstrated that the MouldPulp material is processable on conventional injection moulding machinery and on hot runner moulds with acceptable cycle times.

Figure 3: Products from MouldPulp

In trials with respect to the development of a recycling system it was demonstrated that it is possible to separate the components of the MouldPulp material. As a result the thermal degradation to fibres and lactide is the most efficient method. The recycled materials, lactide and pulp fibres, can potentially be used in a variety of applications.

Test specimens with different surfaces and colours for visual and haptic tests were provided for the perception tests. Naturalness and quality of the demonstrators should be evaluated and compared to PP samples (Figure 4). MouldPulp samples received on average significantly higher ratings than PP samples on quality and pleasantness. Interestingly the tests showed it is not only the material but also the product design and the colour that determines the natural perception. For example the red MouldPulp samples are assessed as not sustainable while the light green or yellowish samples from identically material are assessed as environmentally friendly.

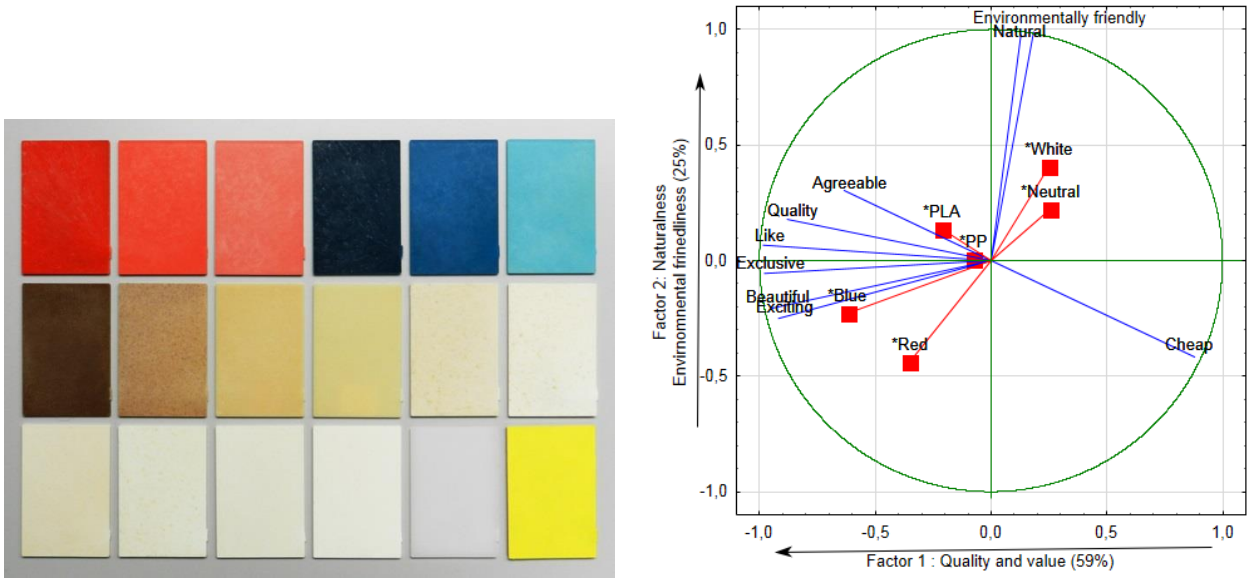

Figure 4: Samples for product semantic test and test results

The results of an initial market survey revealed a market potential across several branches, especially in consumer articles, electronics / IT and automotive. Most promising applications were seen in design and decoration, toys, and household items. Thereby, soft characteristics like clear colours in combination with natural appearance and natural touch were valued. At the same, limiting factors for the use of MouldPulp were mechanical properties like heat distortion resistance and material strength. Subsequent surveys showed that market actors are willing to pay an extra price, called Green Premium, for the additional emotional and strategic performance the buyer gets when choosing the bio-based alternative compared to the price for the (theoretical) conventional counterpart with the same technical performance.

The techno-economic and ecological assessment showed that the production of MouldPulp basically would have its contribution to positive social effects in terms of employment and food security. The market success would be slightly affected by avoiding the use of PLA from genetically modified organism (GMO) sources, which is scrutinized or refused by consumers in some countries. For the industrial implementation of the MouldPulp bioplastics GMO-free PLA is also available. Overall biomass demand and according land use for bio-based plastics is relatively small, for PLA even marginal as well as impacts on biodiversity through the use of North American farm land. Analogue effects coupled with the use of Swedish wood-cellulose fibres are neutral or even positive because of its contribution to sustainable production processes. Finally, according to the social and further environmental aspects analysed, MouldPulp is a preferable good: Positive social effects are accompanied by either sustainable production processes or (only) partly negative environmental effects, which, however, are at least manageable or even marginal.