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# RECYCLED PLASTIC FROM AHP (Absorbent Hygiene Products)

## *Extended abstract*

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### *Background*

Today, the post-consumer Absorbent Hygiene Products (AHP) waste represents about 2% of Municipal Solid Waste (MSW) and about 0.15% of total waste (EDANA, 2012). Currently, AHP waste is not recycled and belongs to "non-recyclable" municipal waste collection. It is typically disposed of via either land filling or incineration, thus causing loss of valuable material resources and high economic, environmental and societal costs. As the EU sensibly moves towards its recycling targets, AHP waste has quickly risen to represent already up to 15-25% of the residual waste.

As a consequence, consumers and stakeholders alike perceive AHP waste management as a growing sustainability issue that needs to be addressed in an integrated way. Public authorities are aware of this issue but due to the lack of large scale recovery technologies for such disposables, they remain unable to take actions to support the recycling of this waste stream.

Fater S.p.a., has developed a novel technical method for the recovery of AHP waste. The first application on the market of this method is co-funded by EU by the CIP Eco Innovation Project RECALL "Recycling of **C**omplex **A**HP waste through a first time application of patented treatment process and demonstration of sustainable business model**"**.

### *Objectives*

The aim of this study is to demonstrate the potential of the plastic recovered by RECALL process for valuable products manufacturing.

The analysis to assess such potentialities was carried out by CETMA. In particular here will be reported the properties of AHP recycled plastics, the identified methods for the improvement of such properties, the investigation of suitable plastic transformation processes.

The plastics are one of the raw material fraction coming from the novel technology developed by Fater S.p.a. to recover post-consumer AHP waste. This technology is based on autoclave process and therefore it allows to get sterilized, high quality plastics (PRF), in form of film and fibrous pieces, re-usable into valuable products.

The learning plan is outlined as follow:

- thermal properties have been analyzed directly on the plastic coming from the autoclave process, aiming at the evaluation of possible differences with the virgin plastics and with recycled plastics coming from most common waste recovery processes.
- physical properties were evaluated on plastics samples properly compounded by a double screw extruder.
- mechanical properties were measured on samples manufactured by injection molding process

Tests results showed that the recovery process developed by Fater permits to obtain a new typology of recycled plastic material consisting of polyolefin blends having a high purity level. The blend contains polypropylene and high density polyethylene and cellulose residues and has superior properties than the typical heterogeneous regenerated plastic coming from the recovery of the urban waste.

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The thermal analysis evidenced that sorting and sterilization processes do not cause chemical degradation of the plastic portion.

The Melt Flow Index values confirmed that the blend is suitable for a range of typical plastic molding processes.

A feasibility study confirmed the possibility to use the PRF for injection and rotational molding. Several prototypes were produced with different transforming processes

Additional analysis were carried out in order to evaluate the influence of cellulosic residues on PRF properties and to improve mechanical properties of the material, by the addition of suitable fillers.

### *Outline of the work*

This study had the following main scopes:

- rheological, mechanical and calorimetric analysis of PRF
- improvement of PRF properties by specific additives
- technical feasibility by usual process polymer technology.

### *Methods*

PRF coming from RECALL process is a blend of polypropylene (PP), polyethylene (PE), cellulose and traces of polyethylene terephthalate (PET) from different zones of the original nappy.

Calorimetric analysis was carried out on PRF using DSC - TA Instruments Test Machine Q200 according to ASTM D3418 in order to confirm the constituent materials. The sample was heated at 10°C/min from 50°C to 320°C. Results of calorimetric scanning are reported.

The melting temperatures evaluated by DSC analysis confirm the composition of PRF. In particular the melting peaks observed at 123°C, 160°C and 216°C can be referred respectively to PE, PP and PET while the endothermic signal at 360°C can be attributed to cellulose degradation (Yang et al., 2007).

A Physical, rheological and mechanical characterization was performed on PRF. A comparison with commercial recycled blends in terms of mechanical properties was carried out.

The PRF melt flow was measured according to ASTM D 1238 at 230°C and 2.16kg load by Atsfaar MELT index equipment. Steady rheological measurement on PRF was carried out using a Rheological Stresstech Rheometer. Tensile characterization was performed by MTS dynamometer equipped with a load cell of 2kN and an extensometer G.L. 25-634 according to ISO 527-1/2.

PRF properties were improved by melt blending with some specific additives using twin screw system HAAKE POLYLAB RheoDrive 7. In particular:

- a compatibilizer PP55EX maleic anhydride based provided by AuserPolimeri srl
- a stabilizer SILMASTAB AX 1854 by Silma srl
- a mineral charge, OMYALENE 102M, $CaCO_3$ based by Omya Spa

Ageing tests were carried out by using the QUV Accelerated Weathering Tester according to method A of ASTM D4329 on samples of stabilized and unstabilized PRF.

Finally PRF granules were processed by:

- injection moulding
- rotational moulding
- calendering.

### *Results and discussion*

Melt flow index (MFI) is useful for comparing different grades and average molecular weights for the same polymer type. Suitability of a particular grade for a specific processing method can often be stated in terms of the range of proper melt index values.

The ranges of melt index values suitable in each process technologies of thermoplastic polymer matrix are compared to the melt flow of PRF (Fig.1). PRF melt flow index is equal to 7.6±0.3 (g/10’) according to the value required by injection moulding, rotomoulding and film extrusion processes.

However, the MFI value of a polymer matrix can be modified through blending or chemical additives to extend the process ability range of the polymer to different technologies.

The evolution of viscosity as a function of shear rate at three different temperatures (205°C, 195°C, 185°C) was obtained. At each temperature, the PRF shows a shear thinning behavior: viscosity decreases with increasing shear rate. Moreover, viscosity decreases with increasing temperature; for these reasons, it can be concluded that the normal pseudo plastic behavior expected for a polyolefin blend is not affected by cellulose content in the PRF.

Tensile test was used to determine the average values of the maximum stress measured equal to 15.9±0.6 MPa and the average value of Young Modulus equal to 1076.3±8.6 MPa. The low standard deviation of mechanical data indicates the repeatability of the properties.

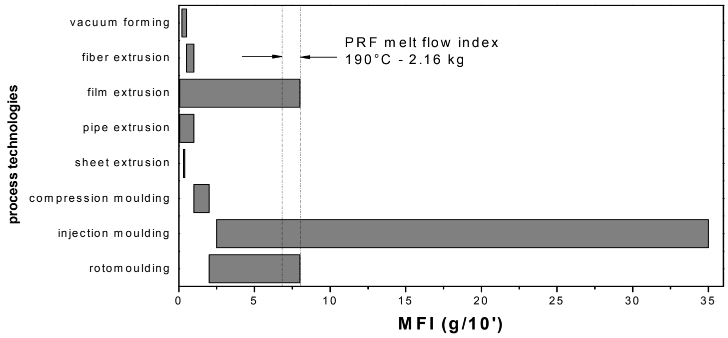

**Fig.1.** Comparison of PRF melt flow index with ideal range values for specific process technologies

The mechanical properties indicate the PRF can be suitable to replace the traditional polyolefin at performance no cost. Comparison of the Young Modulus between PRF and the recycled/virgin polyolefins is reported in Fig.2.

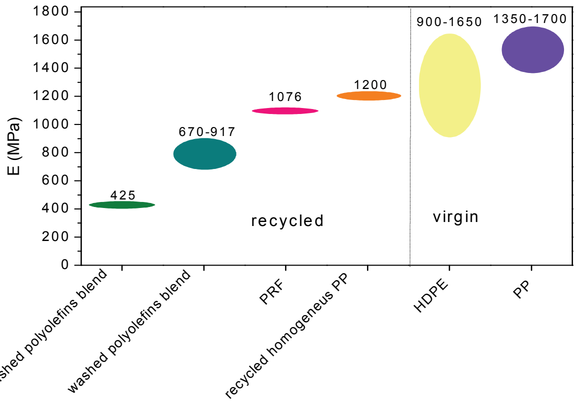

**Fig.2.** Comparison between the Elastic modulus of PRF and recycled/virgin polyolefins

PRF's Young modulus is comparable with that of some virgin homogenous polyolefins.

Specific additives, as reported previously in the materials description, were blended to PRF in order to improve some properties in spite of the material heterogeneity.

The elastic modulus was enhanced by 40% introducing Omyalene 25% $_{w}$. Addition of rigid particles to a polymer matrix improves the modulus since the rigidity of inorganic fillers is much higher than that of organic polymers (Sheles-Nezhad et al., 2013).

The UV resistance was raised by introducing Silmastab 3%. The chemical and physical changes induced by UV exposure were tracked by monitoring the changes in mechanical properties. Many studies indicate the elongation at break as direct indicator of degradation (Roy et al., 2007). The elongation at break was reduced by only 30% with respect to 50% for the unstabilized sample after 2 ageing cycles (24 h). Polymers, especially containing cellulose, are predominantly chain-scissioning polymers, and UV irradiation decreases the molecular weight. This is accompanied by the formation of oxidation products and reduction in crystallinity that explains the achieved results.

The immiscible polymer blends (PP, PE and cellulose) were melted and added with PP55EX 6% $_{w}$ to obtain a material having, at the same time, a stable morphology and improved performance under service conditions. The benefit of compatibilizer was detected by the toughness improvement of 60%, from 1.8 MJ/m$^{3}$ to 2.9 MJ/m$^{3}$, thanks to the improved interfacial adhesion between PP, PE and cellulose phases. As further proof, the melt flow index was reduced by 43%.The reduced fluidity is due to the increased average space occupied by polymer chains.

The possibility to transform PRF with conventional processing methods like extrusion, injection and rotational moulding and calendaring was explored via a feasibility study.

In Table 1, an evaluation of the technological feasibility of PRF is reported. The extrusion process is affected by some problems at the feeding step due to the morphology of the milled PRF. The process could be improved by two different approaches: an improved milling of PRF before the feeding stage or by designing a specific feeder to deal with the PRF morphology. During rotomoulding laboratory test, a pinholes issue was observed. There are several mechanisms that operate simultaneously to create bubbles and pinholes from the plastic melt during rotational moulding (Crawford et al., 2004).

**Table 1.** Feasibility evaluation of process technologies for PRF

| ***Process*** | ***PRF*** |
|---|---|
| Extrusion | very good |
| Rotomoulding | good |
| Injection Moulding | excellent |
| Calendering | fairly good |

It is difficult to isolate these due to the transient nature of the thermal processes that are taking place within the viscoelastic liquid. A hydrostatic pressure of 0.5bar for 60 seconds applied to the melt at the exit of the oven provided a physical mean to significantly reduce pinholes size and to accelerate the process.

The injection moulding process performed at conventional conditions used for the homogeneous polyolefins demonstrated the full suitability of PRF without any technical expedient.

Finally plastic sheets were successfully produced by calendering process reaching 300μ minimum thickness. The different rheological behavior of PP and PE part of the PRF would require a more complex calendering process to gain thickness lower than 300 μm. Indeed, the same temperature and stress applied during calendar process resulted in two different elongation deformations on the sheet, inducing tearing of the less deformable polymer.

Some prototypes were produced with the different process technologies. The following photos show some of these prototypes.

## *Concluding remarks*

The performed characterization shows the PRF are comparable in terms of mechanical and rheological properties with some virgin homogeneous polyolefins.

The feasibility study indicates the possibility to process PRF's with conventional plastic moulding process technologies, including rotomoulding and calendering that usually are not viable for recycled plastic material.

***Keywords:*** absorbent hygiene products, polyolefins, recovery method, recycled plastic, technical feasibility.

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