RECYCLING SOLUTIONS FOR PULTRUSION

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Abstract:

Pultruded glass reinforced profiles are used in an increasing number of applications. High performance/weight ratio and good corrosion resistance are important attributes. Pultruded profiles are used in the telecommunication, transportation or chemical industries to name a few. In all these areas recycling already is or will be a must in future. Pultrusion has to face this challange. By using a newly developed sandwich fabric structure, the reuse and recycling of pultruded profiles is now possible. Recycled glass fiber materials can be applied during pultrusion. Other benefits of using fabrics can be combined. Detailed results and mechanical properties will be explained.

Introduction

The pultrusion industry, like other FRP manufacturers, is being forced to consider the re-use of composite materials due to the increasing disposal cost for production waste and more demanding environmental norms, such as ISO 14000. Legal initiatives, for example "Kreislaufwirtschatsgesetz" in Germany, have placed additional regulatory efforts to force producers to take back their products after the product life cycle. However, technologies developed for thermoplastic resin types can not be used for thermoset resins.

Currently several recycling solutions are available for specific processes and markets. These solutions are:

- Used parts and/or production scrap are milled to powder, which is than re-used as filler for polyester resin systems for injection and SMC [1].
- Used parts and/or production scrap are milled to granulate. These granulates are sprayed similar to a gun roving application together with resin system directly on a laminate. This requires an open mold process. [2].
- Used parts and/or production scrap are milled and chemically processed. By depolymerization of the resin, reinforcement materials are separated. Fibers and some of the depolymerized resin components can be reused [1].
- Pyrolysis or incineration…[1]

All of the solutions mentioned above are found to be limited in their potential applications. The pultrusion industry currently can use recycled FRP as a powder filler in place of mineral fillers, and a portion of waste can be incinerated as well. Both of these existing solutions should be considered as downgrading available material properties.

Within a compilation of the main requirements for the pultrusion industry regarding recycling, the following features should be mentioned:

- Versatile and easy processing of recycled materials
- No additional limitation in part design and shape when using recycled materials
- No related health risk during processing of recycled materials and use of new parts
- Products containing recycled materials shall be at the same cost level as standard materials
- The recycling technology shall allow multiple recycling cycles

A new approach has been taken and evaluated to use recycled materials in form of granulates embedded in textile sandwich structures. These sandwich structures can be used similar as veil, mat or fabrics [3,4, 5, 6]. Fig. 1 shows the construction of these fabrics.

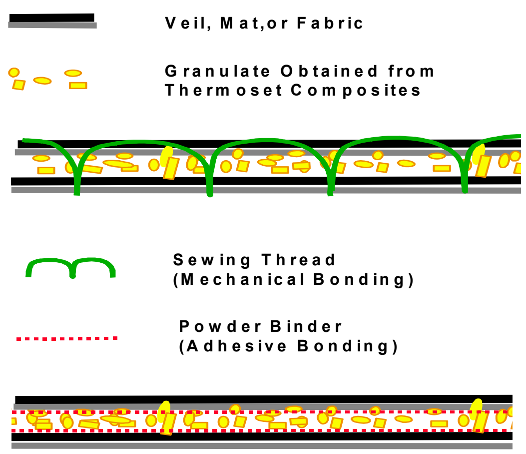

Fig. 1: Sandwich structure with recycled granulate, bonded mechanically or by adhesive [3, 4]

Material property calculation of recycled granulate systems

Mechanical laminate properties, which can be expected of any sandwich as shown in Fig. 1, can be calculated using existing models. This may help to understand several influence factors and to make appropriate use of these materials and where possible new features can be found.

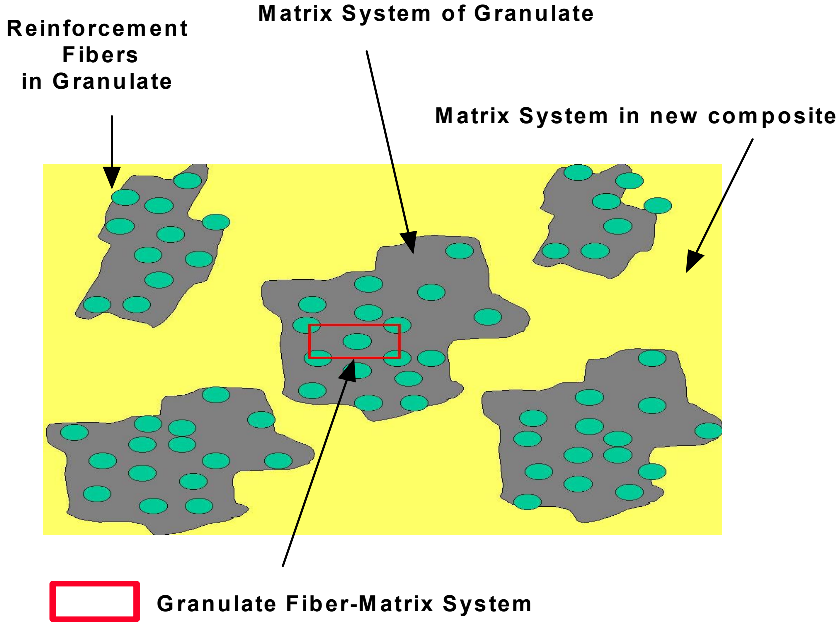

Fig. 2: Model for calculation of laminate properties using recycled granulates

A system of recycled FRP granulate particles within a new matrix system is shown in Fig. 2. Any grain or granulate particle of recycled FRP can be considered as a filled particle, having the reinforcement fibers out of plane direction. As the fibers in those granulate particles are relatively short, measured values vary between some parts of a millimeter to several millimeters, this approach can be justified. With the known properties of these granulates, the composite system composed of the new matrix and this granulates can be then calculated using the same concepts. Granulate particles are treated as if they are short fiber reinforcement materials or fillers. The same formula is applied [4, 5, 6].

Results obtained from these calculations indicate especially an increase in shear modulus for the granulate particle filled laminate ply. Depending on fiber fraction in the recycled granulate particles and packing density of the recycled granulate particles in the new laminate ply a considerable increase in shear modulus can be achieved. Taking as a basis a shear modulus of standard polyester resins of 3000MPa an increase of shear modulus from 30% to 40% can be expected. The calculation could be validated by experiment [5, 6].

Experimental

The studied recycled granulates were obtained from SMC waste, including used parts and production scrap. They were dust cleaned to obtain materials with lowest possible content of fine dust particles. Using these recycled granulates, sandwich structures were manufactured. The topside and bottom side of these sandwich materials were made by using glass fabrics or complexes, glass mat, and glass or polyester veils. The sandwich materials were bonded either mechanically by knit-bonding or by laminating equipment to achieve adhesive bonding. The work principle of the knit-bonding machine and of the laminating process is shown in Fig. 3.

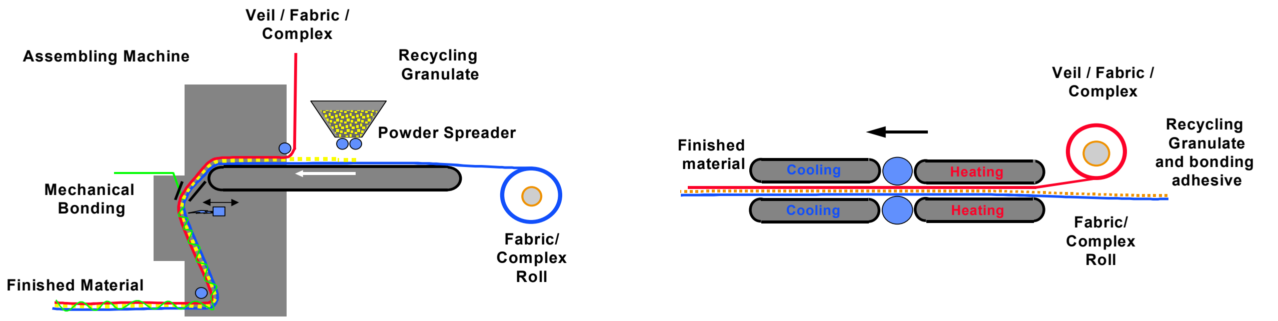

Fig. 3: Knit-Bonding (left) and Laminating process (right)

All sandwich materials laminate samples were build up using HLU (Hand Lay Up) according to DNV/Lloyds procedures or VARTM (Vacuum Assisted Resin Transfer Molding). All laminates were tested in tensile, compression and flexure. Furthermore, laminates having different standard fabric combinations without recycled granulates were made and tested accordingly for comparative analysis. Several complete industrial parts were produced by centrifugal casting and mechanical performance of these parts with and without recycled sandwich materials was measured. Additional work was carried out to measure resin flow properties of laminates containing recycled materials [5, 6]. Pultruded profiles were manufactured using a 40g/m^2 polyester veil sandwich (both topside and bottom side), and filled with 500g/m2 recycled granulate. Profile dimensions and laminate setup are shown in figure 4. From this profile, laminate specimens were cut and tested in production direction, referenced as 0º, and transversel to production direction, referenced as 90º.

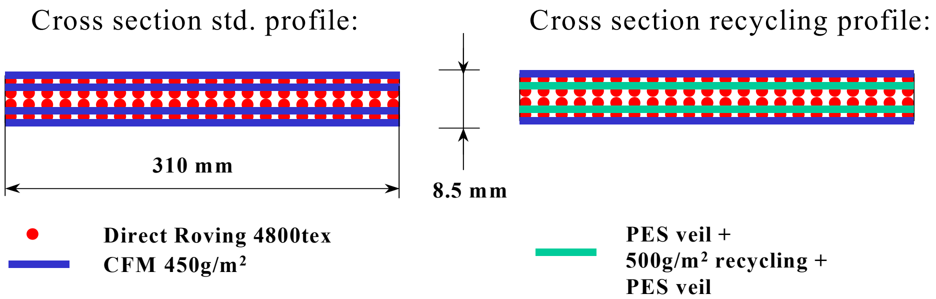

Fig. 4: Pultruded profile standard (left) and with recycled material (right)

Discussion

Our processing of the recycled granulates demonstrated that plies containing between 300 gr/m^2 and 1200gr/m^2 of recycled granulate content can be manufactured. Both processes (knitting and adhesive bonding) of assembling sandwich structures with recycled granulates as core material have shown their feasibility. Each process had its positive and negative characteristics. During the knit-bonding process the sandwich materials are pierced, and therefore better permeability and wet-out characteristics are achieved. However all mechanical elements experience a high wear. Additionally, very large recycled granulate particles can stop the knitting process. The adhesive bonding process is more productive and less sensitive with regard to wear and particle size, but requirres pre-bonded sandwich components as multiaxials, standard fabrics, veil or mat. In each of the tested applications, including centrifugal cast, HLU and VARTM, the sandwich materials showed similar behavior. The material can be cut, laid up and impregnated in the same way as current flat textile sheets.

The use and application of the recycling materials during pultrusion may be acomplished without significant problems. The recycled sandwich materials can be slit and adjusted easily for feeding into the dye. Impregnation of the sandwich is similar to current glass mat. Some granulate particles fall out of the sandwich, however appropriate actions can be taken to avoid these particles from appearing on the profile surface.

Laboratory results obtained on sandwich structures containing recycled granulates as core ply show that recycled granulate plies alone do not offer significant mechanical properties. However, laboratory tests on recycled materials embedded between new reinforcment material as UD (Uni Directional) fabrics show that similar mechanical properties can be obtained as if using a glass fiber mat as core material [5, 6]. These results are also observed during pultrusion, where instead of UD-fabrics, glass roving is feed directly into the dye. The corresponding results obtained with the pultruded profile and on VARTM laminates are shown in figure 5 and 6. These measurements of the pultruded profile were taken according ASTM D638, and D695, while measurements on VARTM laminates were taken according ISO 527-4, and ISO 8515.

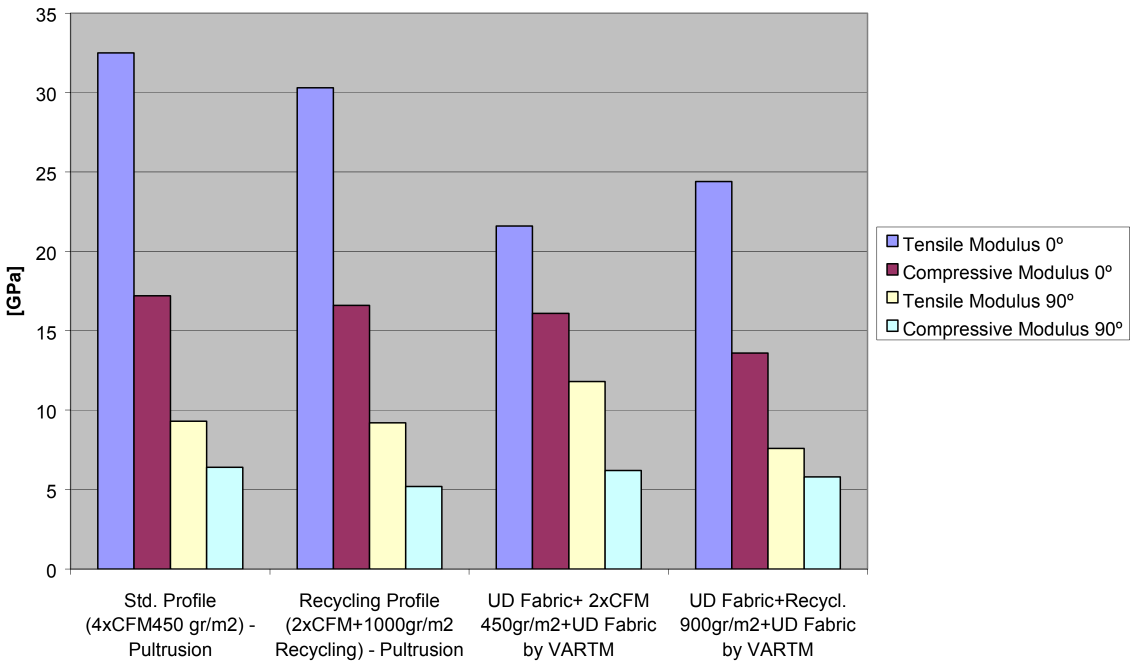

Fig. 5: Mechanical test results: Modulus

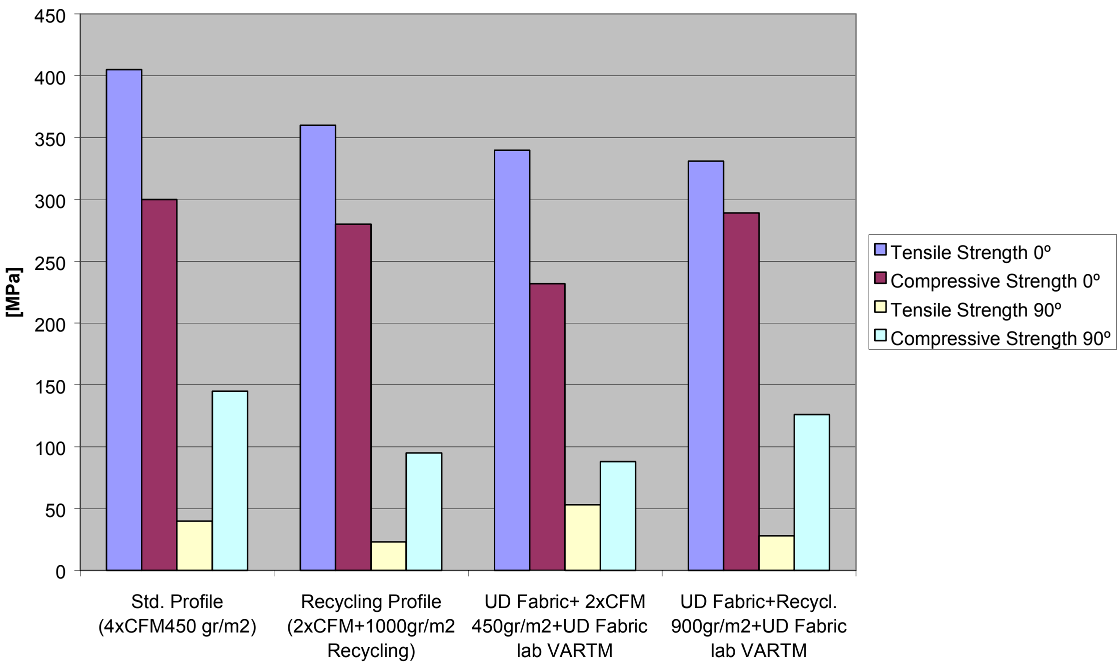

Fig. 6: Mechanical test results: Strength

These charts illustrate the effects of using recycled materials in UD-laminates. Additional data were obtained from telecommunication poles manufactured using similar UD laminates, produced by centrifugal casting [5, 6]. The amount of recycled material was 10% in case of the telecommunication pole, 12% in the pultruded profile, and 27% in the VARTM laminate. With an exception in the case of VARTM laminate where better properties could be observed in 0º, a loss of 10% to 15% in 0º and a loss of 30% and more in 90º can be seen in above figures. The telecommunication poles show a mechanical property loss of 10% when comparing standard pole and when using recycled materials [5, 6]. This means that in UD – reinforcement direction the observed loss of mechanical properties is very low and this behavior is similar to various application processes that does not depend much on the amount of recycled materials used. A potential solution to reduce the loss of mechanical properties in transversal or 90º includes the application of fabrics, whereby the amount of transversal or 90º and longitudinal or 0º reinforcement materials can be equalized.

Further analyzing these results, the sandwich structures show a feasible way to apply recycled materials in pultrusion and other processes as HLU and VARTM, or centrifugal casting. The loss of mechanical properties is very low. A recommendation for their application in products is to substitute core materials and/or mat in the neutral area inside of beams and profiles. An additional advantage for this placement is the increased shear modulus of plies containing recycled granulates. To provide a good distribution of granulates, ply area weights of 500gr/m^2 and more are recommended. For this reason, the wall thickness of profiles in pultrusion should be at least 3 to 4mm. Processing of sandwich materials with recycled granulates is similar to current standard materials. Interesting other features include a fast resin flow within the laminate.

Some considerations about costs

Recycled contents obtained in these study range between 10% and 30% of total laminate weight. Mechanical performance can be maintained nearly at the same level. For any manufacturer interesting in using these materials, no additional investments are needed, the materials can be cut, slit and feed with current equipment. All main production parameters as line speed and efficiencies can be maintained on their normal levels. Therefore, a cost study must take into account only the following parameters:

SAVINGS:

- avoiding the current cost for landfill, this can vary from region to region and this cost factor is anticipated to increase
- substitution of standard reinforcement materials like continuous filament mat, chopped strand mat etc.

SPENDINGS:

- parts to be recycled must be cut down to a reasonable size and shipped to be granulated
- costs to obtain appropriate recycled granulates, these cost are low if there will be a sufficient market demand
- cost to buy these here presented sandwich materials with desired recycled granulate type and amount, these cost can be compared to current reinforcement materials as fabrics, if there will be a sufficient market demand

New parts can already be designed to allow future use of recycled materials, and if their design allows the use of recycled materials, our current results show that this does not mean a cost increase. However a sufficient market demand is needed.

References

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