Material Recycling of Thermoplastic FPC

Technically Feasible – But Is It Economical?

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Sustainable growth in the FPC industry presupposes successful recycling. Cost comparison analysis enables processors of thermoplastic fibre-plastic concepts to derive economic benefit from material recycling.

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Processes described in the literature [1–4] show that continuous-strand-reinforced thermoplastics can be recycled to high-quality parts. Apart from the development of a marketable product and securing an appropriate arisings stream, the economics of the overall cycle are a critical prerequisite when it comes to the

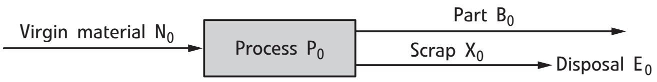

Fig. 1. Process schematic for reference process

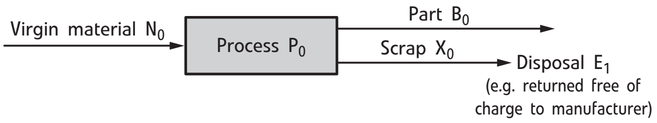

Fig. 2. Process schematic for third-party recycling

Item	Variant 1 (Semi-finished goods process)
X_0 – Quantity of recyclat [kg/a]	Variable
k_T – Transport costs [DM/(kg · km)]	0.00025
s_{E_0} – Distance to disposal site 0 (e. g., waste incineration) [km]	100
s_{E_1} – Distance to disposal site 1 (z. B. semi-finished goods manufacturer) [km]	300
k_{E_0} – Disposal costs 0 [DM/kg]	0.25
k_{E_1} – Disposal costs 1 [DM/kg]	N. A.

Table 1. Data used to calculate recycling costs of Variant 1

practical implementation of a recycling scheme. In the course of a cost comparison analysis at the IVW GmbH, Kaiserslautern/Germany, GMT scrap was chosen as an example for studying the economic benefits that accrue to processors from the recycling of FPC that has a thermoplastic matrix.

Comparison with Conventional Process Chain

Calculation of the business data was performed on an input-oriented basis, in the form of a static cost comparison [5]. The error that arises relative to an output-oriented calculation is negligible when the unreliable data material has been allowed for. All other assumptions are contained in [4].

Since the various recycling processes in existence generate materials having different properties which elude direct quantitation and comparison in the form of monetary parameters, a for conventional waste disposal process chain was compared with the corresponding mechanical recycling process. A conventional disposal process without waste recycling served as the reference process. In other words, the waste arisings for this process are either incinerated or landfilled (Fig. 1).

Third-party Recycling

Variant 1 provides for transfer of waste to a third-party recycler (Fig. 2). To our knowledge, GMT processors generally incur no costs for disposal other than the cost of transport to the recycler. On the other hand, however, they are not recompensed for the material which they supply. An example of this kind of third-party recycling is the semi-finished goods process [1].

The data used to calculate the recycling costs are shown in Table 1.

In-House Recycling within an Existing Process

An example of in-house recycling of waste within an existing process is the re-pressing process in which scrap parts and punching waste are reheated and converted into either the same parts or new, smaller parts. For this calculation, it was assumed inter alia that not all parts can be re-pressed, but that a certain amount has to be disposed of by conventional means (Fig. 3).

According to [1], the re-pressing of complete parts is suitable only for flat panels that are amenable to automatic handling. However, since most parts have a relatively complex structure, a manual insertion scenario was used for the calculation. In the worst case, therefore, extra personnel are necessary.

A further possibility is the use of large punched parts as semi-finished goods for smaller parts. If a company already has a production line in which these parts can replace virgin material, then the worst case involves costs for additional personnel and machinery for sawing the punched parts to size. The calculation also allows for non-recyclable cuttings of 20 wt. %. The data used to calculate the recycling costs of Variant 2 are summarised in Table 2.

In-House Recycling in a New Process

If there is no production line available for recycling recyclate (e. g. the plasticating press process, the bond press process or injection moulding), new investments will have to be made (Fig. 4). To simplify the calculation, only the most important machine and personnel costs were considered. The minimum proceeds for the sale of newly produced parts were taken to be the savings made on the purchase

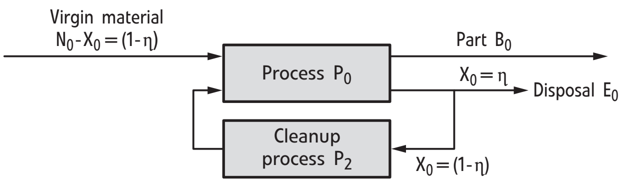

Fig. 3. Process schematic for in-house recycling within an existing process

Item	same part	new, smaller part
η – Proportion of waste for disposal [%]	10	20
k_{N_0} – Price of virgin material [DM/kg]	5.30	5.30
L_2 – Wage costs [DM/a]	80,000	80,000
I_2 – Investments (saw) [DM]	–	30,000
n – Useful life [a]	–	10
i – Interest rate used [%]	–	8
W_2 – Other costs [DM/a]	–	300

Table 2. Data used to calculate recycling costs of Variant 2

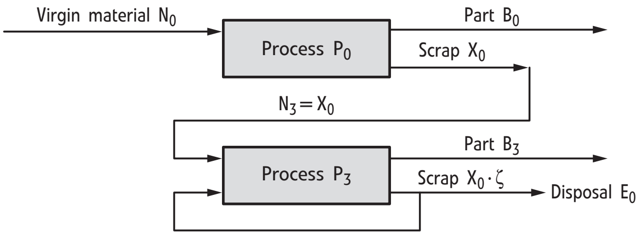

Fig. 4. Process schematic for in-house recycling in a new process

Item	Plasticating-pressing	Bond-pressing	Injection moulding
k_{N_3} Price of virgin material [DM/kg]	4.20 (CSG)	4.80 (GMT; reduced)	2.30 (granules)
Wage costs [DM/a]	80,000	80,000	80,000
Investments [DM]	3,100,000	3,500,000	2,600,000
Other costs [DM/a]	15,000	17,000	10,000
Proportion of waste [%]	10	10	–

Table 3. Data used to calculate recycling costs of Variant 3

price of the virgin material. Furthermore, a certain non-recyclable amount was allowed for.

The cost calculation for the plasticating press process assumed that, apart from the plasticator, another parts press, two moulds and a shredding unit have to be purchased. Additionally, one worker would be required to operate the plasticator and the parts press.

In the worst case, implementing the bond press process would require not only the purchase of a parts press and two moulds but also investment in a small furnace, a simple press and a multi-daylight mould. This calculation also took costs for additional personnel into account. The characteristics of recyclate from the bond press process are only about 80% (impact strength) of those of the starting material; this fact was accounted for by using a reduced virgin material price.

For injection moulding, the cost of employing a new worker in addition to the purchase price for an injection moulding machine, two moulds and a shredding device was factored into the calculation. It was assumed that injection moulding, unlike the other two processes, does not generate waste and that all the material could be returned to the process.

The data used to calculate the recycling costs of Variant 3 are shown in Table 3.

Using Production Scrap

The resultant profit relative to disposal is plotted in Fig. 5 as a function of quantity of recyclate. Because of the unreliable data material and a dependence on future developments in the price of virgin material and disposal costs, the results only represent underlying trends.

Transferring waste to a third-party recycler (Variant 1) is an economic alternative to landfill and incineration. However, it is profitable only while transfer to the recycler is free and no additional cleanup costs are incurred. The profit is much lower than 1 DM/kg. The profit margin can rise if the recycler pays for the recyclate.

Recycling of parts or scrap by re-pressing in existing processes (Variant 2) becomes an economic alternative once the annual quantity of waste arisings exceeds 20 t. Increasing profitability with rising waste levels is much greater than in Variant 1 since added value is created within the factory in addition to the savings made on disposal costs. Owing to the higher fixed costs and higher proportion of waste, re-pressing to smaller parts is somewhat less profitable.

However, if in-house recycling (Variant 3) necessitates new investment, recycling only becomes profitable when annual waste arisings exceed 120 t. The price of the virgin material replaced is crucial to the cost comparison for this scenario. Since better properties increase the price, the bond press and plasticating press processes are much more favourable than injection moulding, which only becomes profitable from an annual waste arisings of 175 t.

Recycling of Used Parts

All the previous scenarios assume non-contaminated production scrap whose polymer matrix is undamaged. If the cost comparison analysis is to be extended to recycling of used parts, further costs need to be factored in.

Assuming additional logistics and cleanup costs of 2.50 DM/kg, Variant 1 and injection moulding become uneconomical. The used parts will only come on stream after a few years and so it may be assumed that re-pressing to form the same parts must be excluded as a recycling process (owing to model changes). If the matrix is only slightly damaged, re-pressing to new parts, and the bond press and plasticating press methods become viable alternatives to disposal when arisings respectively reach 40 t/a and roughly 240 t/a and more.

Should post-stabilising of the matrix be necessary, however, only the plasticating press process is suitable, for process engineering and economic reasons. Assuming total costs of 3 DM/kg for cleanup and post-stabilising, it only turns a profit when waste arisings approach 350 t/a.

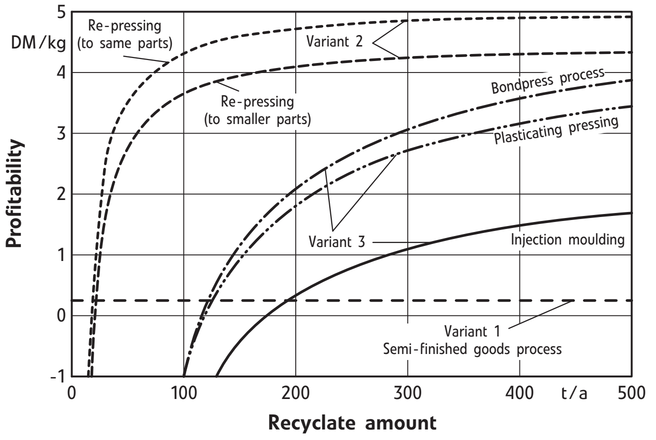

Fig. 5. Comparison of profitability of different recycling processes