Metal Inserts and Hazardous Content in Light Weight Composite Structures in the Context of Recycling

Anna Hedlund-Åström[1], Conrad Luttropp[1]
[1]Royal Institute of Technology, Department of Machine Design, Sweden

Abstract

Polymer composite materials present many favourable properties. The low density results in high specific strength and stiffness, which makes these materials very interesting for applications within the transport field, including vehicles on land, at see and in air. Recently introduced legislation regarding waste treatment has put large demands on composite material producers and users. Although several methods exist they are not yet commercially available since composites is a rather new type of material. The waste treatment is complicated since composite materials consist of several materials, fibre, polymer matrix and additives. A model has therefore been proposed for assessing the different waste disposal techniques. The model focuses on the internal factors, which are defined as factors related directly to the waste and the processes of treatment in form of waste and process properties. In this paper two of these waste properties are identified as strategic for disposal of composite materials. These are the waste properties describing metal and hazardous content, **MET** and **HAZ**. To facilitate for future disposal two types of labels are suggested for these waste properties. The issue then is to decide the coordinates for how much information is needed and for whom. What, where and how?

Keywords

Fibre composite, Disposal, Metal insert, Hazardous content, Label

1 INTRODUCTION

The use of polymeric fibre composite materials is increasing especially in transporting products. Of large interest are composites containing carbon fibre in the automotive industry for example.

Polymer composite material consists of several materials, fibre, resin, additives and foam core material in sandwich structures. The type of resin in most structural applications is thermoset. Both these circumstances complicate the waste treatment process.

Other important recycling factors, which should be considered already at the design stage, are metallic and hazardous content. An example is the joining between two dissimilar materials as ships with steel hull and superstructure in composite materials. In order to enable this joint the composite structure must be provided with metallic inserts. For a ship structure hazardous substances can be found in many places but regarding just the composite material one example can be the content in the paint.

The waste treatment generally starts with disassembly and dismantling processes. For large structures as ships these processes commonly involve high intensity of manual work. By informing effectively through some kind of labelling or marking of both the content of metallic inserts and hazardous substances, disassembly and dismantling could be implemented more efficient resulting in safer working environment and higher quality of the recycled composite material.

2 BACKGROUND

2.1 Use of composite material

Carbon fibre composite has the potential to reduce weight by 60% compared to steel and by 30% compared to aluminium. New types of composite materials, such as advanced sheet moulding compound–ASMC are especially developed for car body parts [1]. Large research projects have also pointed out the possibility to replace a floorpan in steel with an equivalent structure in carbon fibre composite [2].

In traditional lightweight structures, for aircrafts, where demands on low weight are strong, high performance composite materials, has been used for long. These composites are now increasingly beeing used by manufacturers of civil aircrafts such as Airbus and Boeing.

One major consumer of especially glass fibre based composites, GRP, is the marine industry particularly leisure boats. The accumulated amount of GRP from 1965 until 1997, in Sweden, is estimated to the amount of 700 000 tons [3]. Also in more advanced military marine structures composites are used in form of sandwich structures. One example is the Visby Class Corvette a stealth surface attack ship built for the Royal Swedish Navy containing 50 tons of carbon fibres. In an ongoing Swedish research project the possibility of implementing composite materials in form of sandwich structures in the superstructure of both passenger and transport ships are investigated [4].

2.2 Legislation regarding disposal

This increased use results in larger amounts of waste, in form of manufacturing waste and in the future of course also waste from end of life products. Because of increasing environmental demands through legislation, the waste issue is concerning the composite industry. For this material group there exists no cost effective method yet, for recycling and no market for recycled material as for steel and aluminium. However, several techniques do exist at research scale as mechanical material recycling, pyrolysis and cement manufacturing. Some of these methods are now examined in larger scale in research projects [5].

Example on legislation is the producer responsibility, meaning that manufacturer of products are responsible for the take back and treatment of end of life products. The producer responsibility legislation is formed so that it promotes waste handling according to the waste hierarchy [6]:

- Prevention of waste
- Reuse
- Recycling
- Energy recovery
- Landfill

Especially in the EU Directive for End of Life Vehicle (ELV), tough levels of 95% of total recycling/recovery were 85% are set as minimum amount of reuse and recycling and maximum 10% for energy recovery [7]. Also in the new EU-directive for electrical and electronic products, WEEE [8], launched in August 2005 demands are set on a specific material recycling level of 75%. Coupled to this is the directive for Reduction of Hazardous Substances (RoHS), concerning six hazardous substances mercury, hexavalent chromium, cadmium, lead and flame retardants (PBB, PBDE) in new electrical and electronic products from July 2006 [9].

In addition there is also the regulation against landfill for both combustible and organic waste [10].

It is likely that the groups of products, which not are comprised by a specific producer responsibility directive, soon will be affected in some way. Discussions in EU include directives aimed towards complete responsibility for the product life cycle, from cradle to grave, named integrated product policy, IPP [11]. It is therefore necessary to prepare the structures for disposal.

2.3 Information model for waste treatment of polymer composites

As already mentioned composite material means a real challenge when it comes to disposal since it constitutes a mixture of materials. A model has therefore been developed for assessing possible future waste treatment scenarios especially for polymer composite materials [12]. This model, which includes information about the waste content and the processing, can also be useful in contacts between waste producer and contractors.

For development of the model totally six treatment methods were investigated. These are:

- Mechanical material recycling
- Material recycling and energy/chemical recovery by fluidised bed or pyrolysis
- Material recycling by cement manufacturing
- Energy recovery by incineration
- Hydrolysis
- Landfill

The suggested model is based on internal factors. These factors are related to the waste and to the involved processes. Each of the methods mentioned above includes a number of processes for example dismantling, cutting and grinding. For each process specific information, here named process properties, is needed in order to implement the process. The necessary process properties must be fulfilled by knowledge about the waste in form of waste properties, illustrated in figure 1.

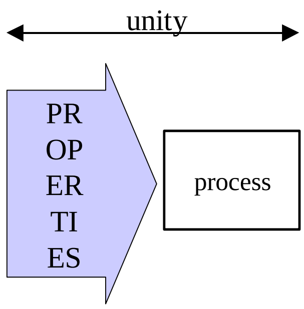

Figure 1. Definition of process and properties as a unity.

Waste properties

The following waste properties are identified as relevant for polymer composite materials. Each property is identified by a three or four letter abbreviation.

- Constituent materials, type of fibre **FIB**, matrix **MTX**, filler **FIL**, core **CORE** in volume [m^3] and/or weight [kg]
- Hazardous substances and performance, **HAZ**, type, and amount in [kg] and position
- Analysis of chemical content, **CHEM**, in % of weight
- **CHEM+**, characteristic - specific to landfill
- Metallic equipment and inserts, **MET**, type of metal and position
- Size, **SZE,** described by volume [m^3] and/or weight [kg]

2.4 Case study of the Visby Class Corvette

The suggested model has been used for forming scenarios to assess possible waste disposal methods for the hull of the Visby Class Corvette [12,13]. The necessary waste properties, according to the list above were identified except for the one named **CHEM+**. This property is coupled to the landfill alternative were specific chemical analysis of leakage properties for the hull material is needed.

In figure 2 one of six developed scenarios is presented, the one illustrating mechanical material recycling.

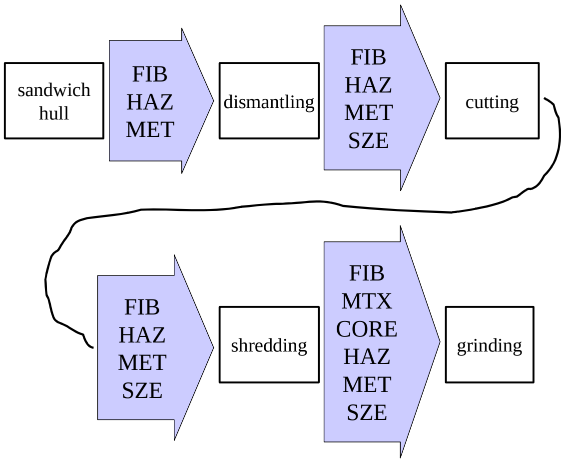

Figure 2. Scenario illustrating material recycling.

Since the model focuses on composite material the scenario starts with dismantling of the sandwich hull. The disassembly process is assumed as already implemented.

For each process, dismantling cutting, shredding and grinding the necessary waste properties are identified through the demands for implementing each process. In the waste property arrows it can be seen that the properties **MET** and **HAZ** occur generally. This is the case since it is assumed that there is no connection between the different processes.

Before shredding and grinding it is very important to have information on the incoming material especially regarding metallic and hazardous content. Metallic parts can damage the cutting device and hazardous substances should not be present in material aimed for material recycling. Working environment is also one issue to consider regarding hazardous content in waste.

For the Visby sandwich hull the following **MET** and **HAZ** is identified:

MET

- Position determined from drawings, for shredding and grinding large metallic parts are not allowed

HAZ

- Chlorine, (Cl), approximately 9000 kg contained in core, can result in forming hydrochloric acid, threshold value 5 ppm and dioxin
- Polyurea can transform to diisocyanates during heating, threshold value 0.002 ppm
- Styrene from uncured vinylester, threshold value 20 ppm
- Carbon fibres, requires medical controls, threshold value 0.2 fibre/cm^2
- Particles from all constituent materials, threshold value thermoset 3 mg/m^3, PVC 1 mg/m^3
- Noise, threshold value 85 dB
- Heavy metals
    - lead (Pb), approximately 400 kg contained in core
    - copper (Cu) in electrical devices and copper(I)oxide contained in anti-fouling bottom colour

Accumulation of both lead and copper in the nutrition chain have unwanted effects on health, it can causes nerve illness. Copper acts as a catalyst for forming dioxin in presence of chlorine.

By studying the presented list above it can be concluded that knowledge on **MET** and **HAZ** content in the Visby hull is essential in order to succeed in waste treatment. It can be said that **MET** and **HAZ** are strategic factors especially for material recycling.

3 PRODUCT INFORMATION AND DISPOSAL

3.1 Existing information in form of databases and labels

For products comprising the producer responsibility effective methods for disposal has been developed. One example is the Mercedes Recycling System (MeRSy) developed by Daimler Chrysler in 1993 [14]. The aim of this system is to “design and manufacture each new vehicle in a way that makes for easy segregation of materials”. Daimler Chrysler is also involved in an international consortium involving totally 25 vehicle manufacturers, International Dismantling Information System (IDIS) [15]. This is a database for end of life vehicle dismantlers. The database contains information on composition of materials and dismantling instructions were also composite materials are included.

A specific waste management concept has been introduced for composite materials to meet the increasing waste regulations and the fact that composites are difficult to dispose. Through a license fee manufacturer of composite products are guaranteed recycling of there products marked with the “Green FRP Label” [16].

Example on other initiatives is the introduction of a “Scrap Tag” by a Swedish company, Avvecklingsgaranti Sverige AB [17]. Connected to the “Scrap Tag”, applied on the product, is a database including information on how to accomplish future disposal. Also financial funding for the future disposal is available.

The earlier presented information regarding waste properties and scenarios for waste treatment of especially composite materials could very well be included in a database. Though, as already mentioned the waste properties **MET** and **HAZ** needs extra focus.

3.2 Extended information MET and HAZ

Through the dismantling procedure further treatment by shredding and grinding is guaranteed and at the same time the quality of the recycled material is enhanced.

In figure 3 a structure on the information knowledge, especially for dismantling is presented. Overall is the waste property knowledge connected to the process properties of dismantling. Coupled to these is the extended information for the waste properties **MET** and **HAZ**.

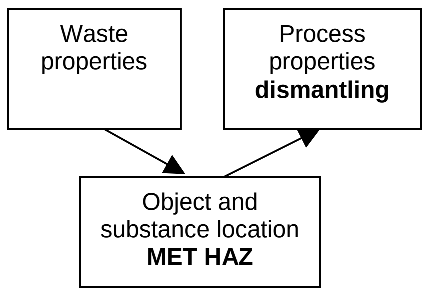

Figure 3. Knowledge for waste treatment.

As already mentioned dismantling involves high intensity of manual work. The extended information therefore should be connected to the dismantling personnel and to the product. The information should be language independent since products can be spread all over the world. A suggestion is to use symbols, which are easy to understand.

By applying standardised labels informing on **MET** and **HAZ** of the product these demands can be fulfilled. These labels should be easy accessible, easy to read and non-erasable. Two types of labels are necessary since the information includes knowledge about both concentrated and scattered substances. The two suggestions for denominating these are focus object label and focus substance label.

Focus object label

This label relates to content situated in limited locations of both **MET** and **HAZ**.

The metallic content is present in form of objects inside the composite sandwich structure to enable fastening of different types of equipment and structural parts in other materials.

Copper content in cables can be referred to both metallic content and hazardous content. In composite sandwich structures cables can be inserted in the core material. If the core material is of PVC the copper acts as catalyst for forming of dioxin when the material is incinerated.

This label should inform about were the object is, what it is and how to remove it.

In figure 4 a suggestion for focus object label for **HAZ** is presented. The label should be placed at the site of the focus object and the dotted frame reflects the breaking point, were to open for removal.

Figure 4. Example on focus object label for hazardous content.

The types of dot could be used to inform the personnel on how to make the removal, i.e. to give a signal of type of tooling for removal.

Focus substance label

This label refers to content which is spread over a non-specific area. Therefore it mainly will refer to **HAZ**. Examples can be found in the presented list of waste properties for the Visby hull. The aim of informing of hazardous content is two-fold. One part includes the working environment and the other to avoid hazardous substances in recycled material.

Regarding the working environment there are several substances within the Visby hull, which can cause harm to the personnel, e.g. forming of hydrochloric acid from chlorine when heating the core material by cutting or forming of small breathable carbon fibre particles also when cutting. The personnel the need information for personal protection as safety glasses, gloves and respirators.

For ship structures the bottom color is a typical substance containing hazardous substances. This type of color should of course be dismantled if the structure is aiming for mechanical material recycling.

The focus substance label has not the same demands on location as it is distributed within a specific material as the chlorine in the core and the copper in the paint.

4 SUMMARY

Polymeric composites contain several different materials, which complicate the end of life treatment. A model to assess different types of disposal methods especially for composite materials has therefore been developed. Through this model necessary information about the waste in form of waste properties are pointed out for accomplishing the different processes. In this paper the two waste properties, metallic content **MET** and hazardous content **HAZ**, are pointed out as strategic for the disposal of composite materials. By information through two types of product labels, focus object label and focus substance label, the dismantling process can be improved.

ACKNOWLEDGMENTS

This work has been accompliched within the LASS - project, lightweight construction application at sea, www.lass.nu. The project is funded by Vinnova, the Swedish Agency for Innovation Systems and LASS industrial partners.

The authors also would like to thank Jessica Lagerstedt at Bombardier Transportation for fruitful discussions.

REFERENCES

[1] Stachel, P., Schäfer, C., 2004, ASCM, a unique carbon fibre reinforced product for the automotive industry, COMPOSITES 2004 Convention and Trade Show American Composites Manufacturers Association.

[2] www.tecabs.org

[3] VAMP 18, 1999, Riktlinjer för återvinning av fiberkompositer, Inventeringsrapport, Dnr 98-5728, Vinnova.

[4] www.lass.nu

[5] Scori, J., 2005, Valorization og composite in cement kiln, presented at the international seminar – Practical solutions for thermoset composite recycling 2, Chambery, France.

[6] EU, 2003, Handbook for implementation of EU environmental legislation, Section 4, Waste Management Legislation.

[7] EU Directive 2000/53/EC

[8] EU Directive 2002/96/EG

[9] EU Directive 2002/95/EG

[10] EU Directive 99/31/EC

[11] Green Paper on Integrated Product Policy, COM(2001) 68 final.

[12] Hedlund-Åström, A., 2005, Model for end of life treatment of polymer composite materials, Doctoral Thesis, TRITA-MMK 2005:23, ISSN 1400-1179.

[13] Hedlund-Åström, A., Reinholdsson, P., Luttropp., C., 2005, Environmental friendly recycling of FRP-sandwich ship hulls, presented at the international RINA conference – Recycling of Ships & Other Marine Structures", 4-5 May, London.

[14] www.daimlerchrysler.com. Environmental report 2004.

[15] www.idis2.com

[16] Harbers, F., 2003, the European composite recycling concept, presentation at 6th Internationale AVK_TV Tagung, Baden-Baden.

[17] www.avvecklingsgaranti.se

CONTACT

Anna Hedlund-ÅströmRoyal Institute of Technology, Department of Machine Design, Brinellvägen 83, SE-100 44 Stockholm, Sweden, hedlund@md.kth.se