ACCESS OF HAZARDOUS AND METALLIC INTEGRATED OBJECTS AT DISMANTLING OF SANDWICH SHIP STRUCTURES THROUGH EFFECTIVE INFORMATION HANDLING

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ABSTRACT

Since polymer composites are difficult to recycle it is important to acquire comprehensive information about the constituents of these materials. A model has therefore been proposed for assessing different waste disposal techniques especially for polymer composite materials. In this model totally nine influencing internal factors have been identified. These are closely associated to the waste and the processing of the waste. The sandwich hull of the Visby Class Corvette, Royal Swedish Navy, was used as a case study for applying the suggested model. Obviously information about material content is necessary to achieve safe and effective waste treatment processing which in the end results in higher quality of recycled material and better economy.
In this paper especially the information need of two waste properties in the context of ship dismantling are discussed. These are hazardous content and metallic inserts. In especially sandwich structures metal inserts are necessary to enable fastening of different devices. Information of the hazardous content is important due to regulations connected to external environment and working environment.
The question is how to present this information, to whom and where. In relation to the dismantling process several actors are involved, ship builder, ship user, waste treatment company and labour. Especially for the two last actors the information concerning metallic content and the hazardous content is important. The metallic content represents a value and the hazardous content represents a responsibility causing costs. Through effective information at the right place and in the right form this information can result in an effective and safe dismantling process.

1. INTRODUCTION

Polymeric fibre composite materials are increasing especially in transporting products, as since the structural weight is decreased resulting in more payload and/or lower fuel consumption. In hull structures this material is used mainly in pleasure crafts, coastguard and fishing vessels and in navy vessels as mine sweepers. For larger transporting ships the composite material is mainly used in superstructures. An ongoing Swedish national project, Lightweight Construction Applications at Sea, LASS [1], is studying the introduction of lightweight materials in ship building, mainly for superstructures. The aim is to decrease the structural weight with 30 per cent, with unchanged performance, and with a life cycle cost reduction of totally 25 per cent, by using aluminium or polymer composite sandwich. Beside the structural design also fire performance and environmental effects over the life cycle are studied.

Polymer composite material consists of several types of materials. These are fibre, resin, additives, and core material in sandwich structures. The type of resin in most structural applications is thermoset, which is not possible to melt. These circumstances complicate the waste treatment process.

Also of importance for recycling, 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 joining with bolts and rivets. Considering a ship structure hazardous substances can be found in many places or released through processing during recycling.

The waste treatment generally starts with disassembly and dismantling processes. For large structures as ships Commonly these processes involve high intensity of manual work, especially for large structures as ships. By informing about hazardous content and metallic inserts the disassembly and dismantling processes could be made more effectively. This could also result in safe working environment and high quality of the recycled material. This information should in some way be connected to the personnel holding the cutting device. The suggestion to inform through effective labelling has also been discussed in an earlier paper [2].

2. BACKGROUND

Several issues calls for increased concern regarding waste treatment for some types of products, which here focuses on polymer composite materials in ship structures. The issues are the increased use of composites, mixing of different materials and legislation regarding disposal.

2.1 USE OF COMPOSITE MATERIALS

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 [3].

In traditional lightweight structures, as aircraft, where demands on low weight are strong, high performance composite materials, has been used for long. These composites are now increasingly being used by manufacturers of civil aircraft 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 [4]. 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.

2.2 MIXING OF MATERIALS

Composite material itself means a mixture of materials as already mentioned in the former section. Then there is a trend of combining several different types of materials in structures. Example ship hulls built in steel with superstructure in aluminium or polymeric sandwich, which is investigated in the Swedish LASS project.

2.3 LEGISLATION

The increased use of polymer composites 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 efficient 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 and pyrolysis. The use of polymer composite waste in cement manufacturing is now examined in larger scale [5].

Example on legislation is the producer responsibility, meaning that manufacturer of products is responsible for the take back and treatment of end of life products. This legislation is implemented for packaging materials, electrical and electronic products, end of life vehicles and tyres. 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 retardant (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]. This calls for the importance of preparing products for disposal already at the design stage.

3. WASTE INFORMATION MODEL

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.

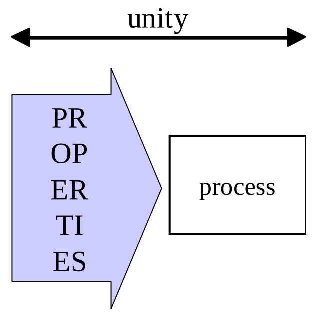

Figure 1. Process and properties as a unity.

3.1 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]

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

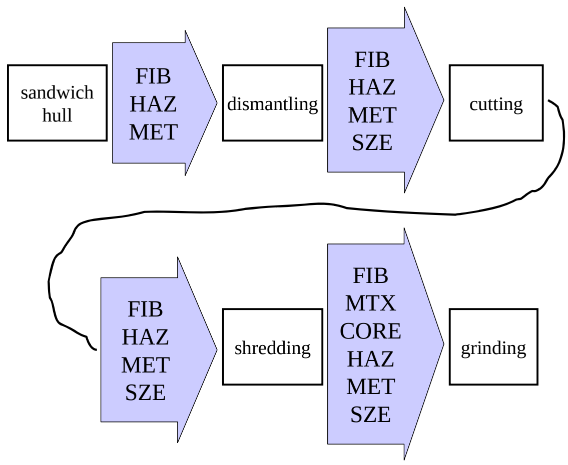

Figure 2. Scenario illustrating material recycling.

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.

4.1 **MET** AND **HAZ** FOR VISBY HULL

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 (threshold values [14])
- 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 for achieving an effective disposal.

5. EXISTING SYSTEMS FOR PRODUCT INFORMATION

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 [15]. 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) [16]. This database is aimed for dismantlers of end of life vehicles. The database contains information on composition of materials and dismantling instructions were also composite materials are included.

For composite materials a specific waste management concept has been introduced 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” [17].

Example on other initiatives is the introduction of a "Scrap Tag" by a Swedish company, Avvecklingsgaranti Sverige AB [18]. 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.

Especially for shipping structures there is the International Maritime Organisation which is a United Nations Agency concerned with the safety of shipping and cleaner oceans. Specific guidelines for ship recycling has been developed, which include the so called Green passport. This passport should include information which facilitates the ship recycling, accompanying the ship through is operating life. For example material information concerning especially hazardous content, and also design and equipment changes. But this is not a constraint, the ship owner decides the information to be included.

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

6. EXTENDED INFORMATION FOR 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**.

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.

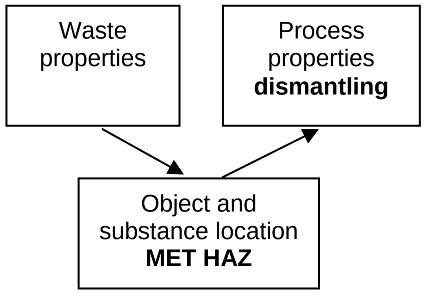

Figure 3. Knowledge for waste treatment.

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.

6.1 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 dots 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.

6.2 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.

7. CONCLUSIONS

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. This information is essential for the recycling process and should be included within the Green passport for facilitating recycling of ships including polymer composite materials. But this information should be complemented with more specific information of the two waste properties, metallic content **MET** and hazardous content **HAZ** through suitable labeling. This would facilitate the dismantling process.

ACKNOWLEDGEMENTS

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