WORKSHOP ON HYBRID ENERGY STORAGE SYSTEMS ORIENTED TO MARITIME APPLICATIONS

Material considerations in designing batteries

Bernd Steinhoff
10.06.2022 /Hernani /Spain

01

Introduction: Requirements

Titelbild: © Bild-Copyright

»

**Choice of a material shall be based on a thorough understanding of all (engineering) requirements the material must fulfil.
The right material will automatically be best fulfilling economical *and* ecological aspects.«**

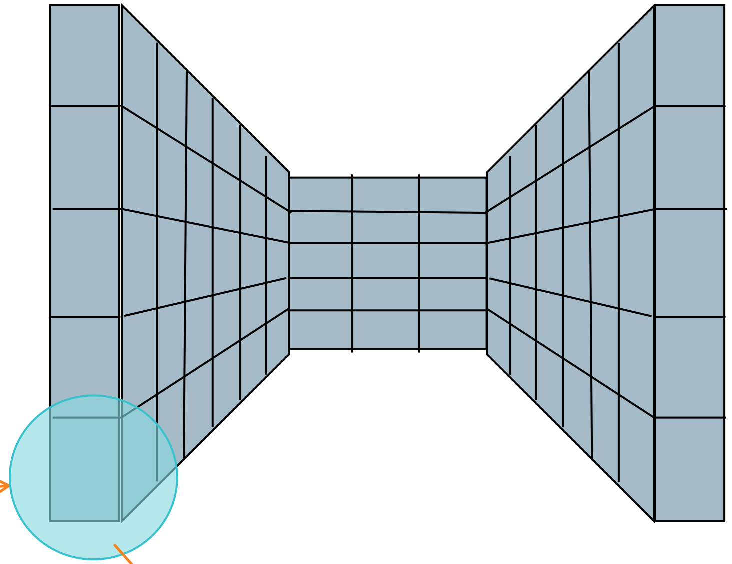
BS

Introduction

Battery packaging for marine applications

Design considerations

- No single huge housing taking all the cells
- Instead: modular approach:
  - Stacking of smaller packs, storing e.g. 6 kWh each
  - Size of single small pack of about 85 x 40 cm (e.g.), weight about 90 kg.
- Purpose of this approach: Minimize effort replacing defective cells
  - Due to the large total number of cells, probability of occurrence of defective cells will be high.



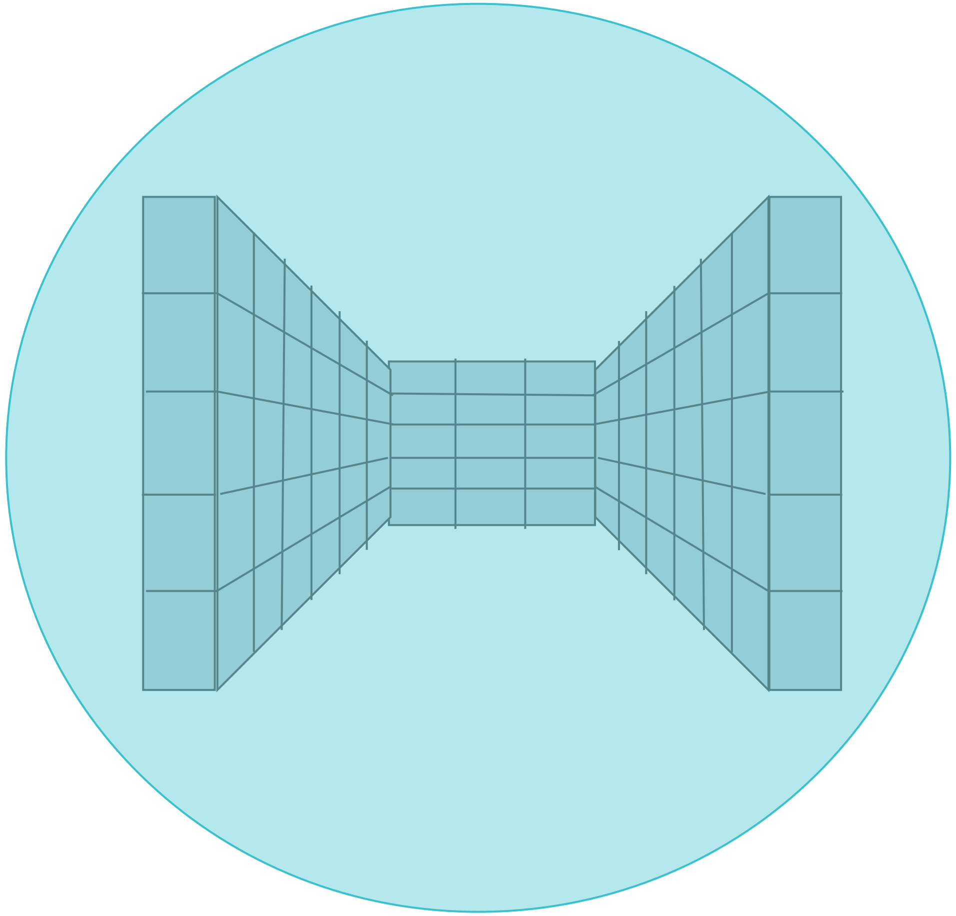
Introduction

Requirements / „boundary conditions“

Fire safety regarding pack storage location

Conception: All packs to be stored in a dedicated unmanned department, where the following is valid:

- Not be prone to exposure of excessive heat or cold
- To be positioned aft of the collision bulkhead
- Fulfilling highest fire resistance standards
- To be equipped with an appropriate fire extinguishing system.
  - Water mist extinguishing system be considered to be most effective.
  - Purpose of this system not only fire extinguishing but also cooling of modules heated-up by thermal run-away.



Introduction

Requirements / „boundary conditions“

Safety on pack level

Conception: Each pack shall encapsulate the implications of thermal run-aways as much as possible:

- The battery pack and inside components shall be made of a **flame-retardant** materials according to international Rules IEC 60092-101.
- The battery pack and inside components must withstand
  - the electrolyte in case of leakage of cells.
  - coolant/refrigerant in case of leakage of cooling loop
  - salt water, the salty marine atmosphere

Requirements / „boundary conditions“

Further requirements on the pack

- Housing of the pack should not contribute with too much additional weight.
  - Despite the fact weight being not that issue on ships, pack must be easy to handle to ensure smooth replacement
- Dismantling of the pack must be easy and not risky to ensure as much as possible recycling.

02

Materials

Materials

Materials suitable "at the first glimpse" for the housing

- Construction steel
- Stainless steel (e.g. 1.4401)
- Aluminium
- Thermoplastics (e.g. polypropylene, polypropylene/glass fibre, polyamide/glass fibre)
- Thermosets, fibre reenforced

Materials

Metals

Pros and cons

Material	Costs (material, mass production)	Weight	Strength	Flame retardance	Resistance against marine env.	Resistance against cell chemicals	Recycling
Construction steel	+ + +	– – –	+ + +	+ + +	– – –	– – –	+ + / – (established, but energy consuming)
Stainless steel	+ +	– – –	+ + +	+ + +	+ + (dep. on grade)	+ (most likely, test req.)	+ + / – (established, but energy consuming)
Aluminium	+ +	– / +	+ +	+ +	– – –	– – –	+ + / – (established, but energy consuming)
< >	+ +	– –	+ + +	+ + +	– – / +	– – / +	+ + / – (established, but energy consuming)

Materials

Thermoplastics

Pros and cons in general

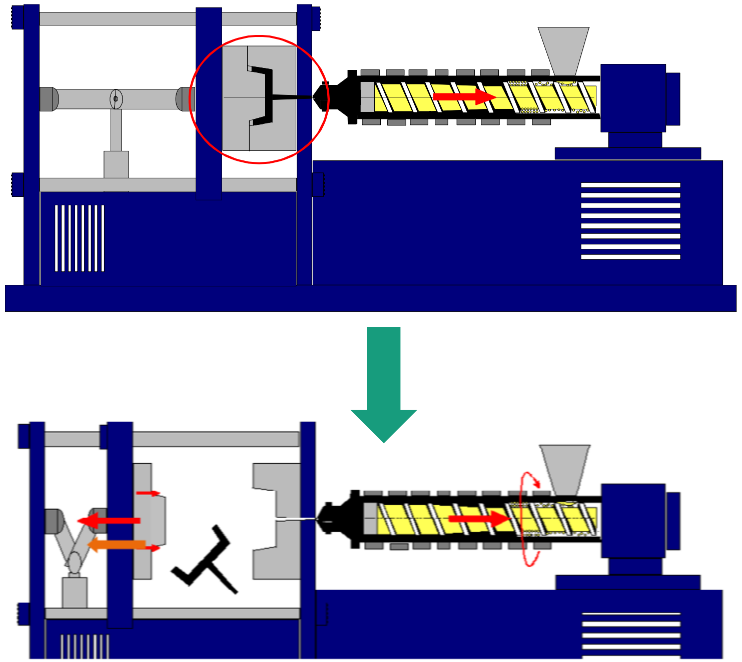
- Thermoplastics (e.g. polypropylene, polypropylene / glass fibre).

  Short or long fibre reenforced grads will be necessary to obtain enough mechanical strength.

  + Manufacturing by injection moulding possible -> *the* economic mass-production process.

  + Materials can be easily recycled

  - Low Y-modulus, decreasing with temperature; Y (80°C, GF50) about 1/7 Y (Aluminium)



Materials

Thermoplastics

Pros and cons individual thermoplastics

Material	Costs (material, mass production)	Weight	Strength	Flame retardance	Resistance against marine env.	Resistance against cell chemicals	Recycling
Polyolefine: PP or PE / GF	+ + +	+ +	–	– – – / + (grade dep. -> test)	+ + +	+ + +	+ + +
Polyamid PA6/66 / GF	+ + +	+ +	–	– – / + + (grade dep. -> test)	+ + +	+ (most likely, test req.)	+ + +
Polycarbonate PC / GF	+ + +	+ +	+	+ / + + (grade dep. -> test)	+ + +	– – –	+ + +
< >	+ + +	+ +	– / +	– / + (grade dep. -> test)	+ + +	+ (most likely, test req.)	+ + +

Materials

Thermosets

Pros and cons

- Thermosets, fibre reenforced. Well known since about 6o years for manufacturing of gliders, high-performance sailing boats, racing cars, rotor blades of wind engines, aerospace components…

  + Light weight structures with very high load carrying capability be possible

  + Coating for withstanding marine env. state of the art

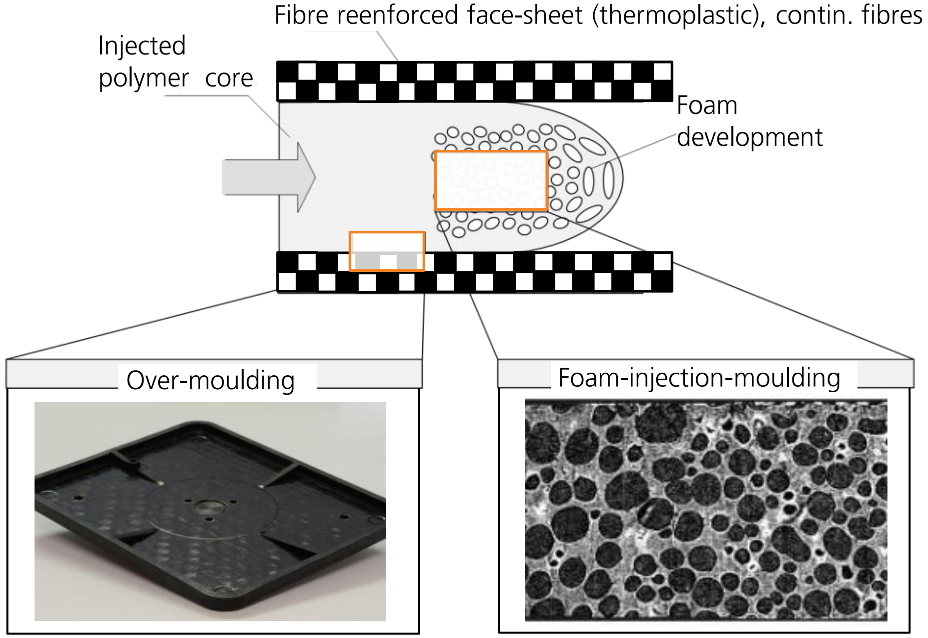
  +/- Resistance against cell chemicals to be tested

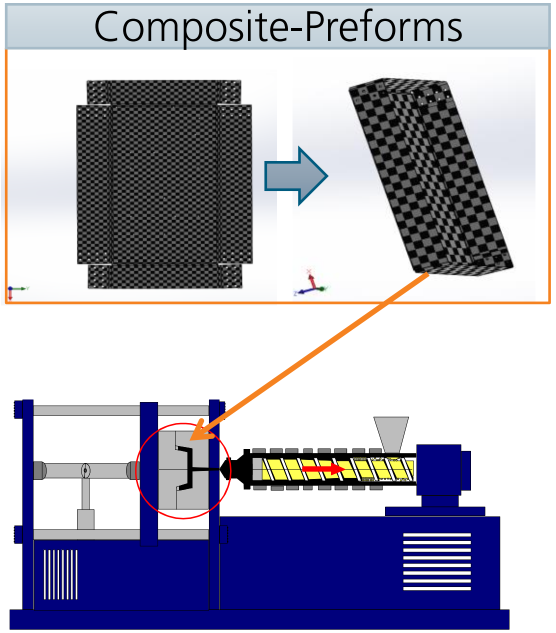
  - Not suitable for mass-production. Laminating process requiring high amount of manual work

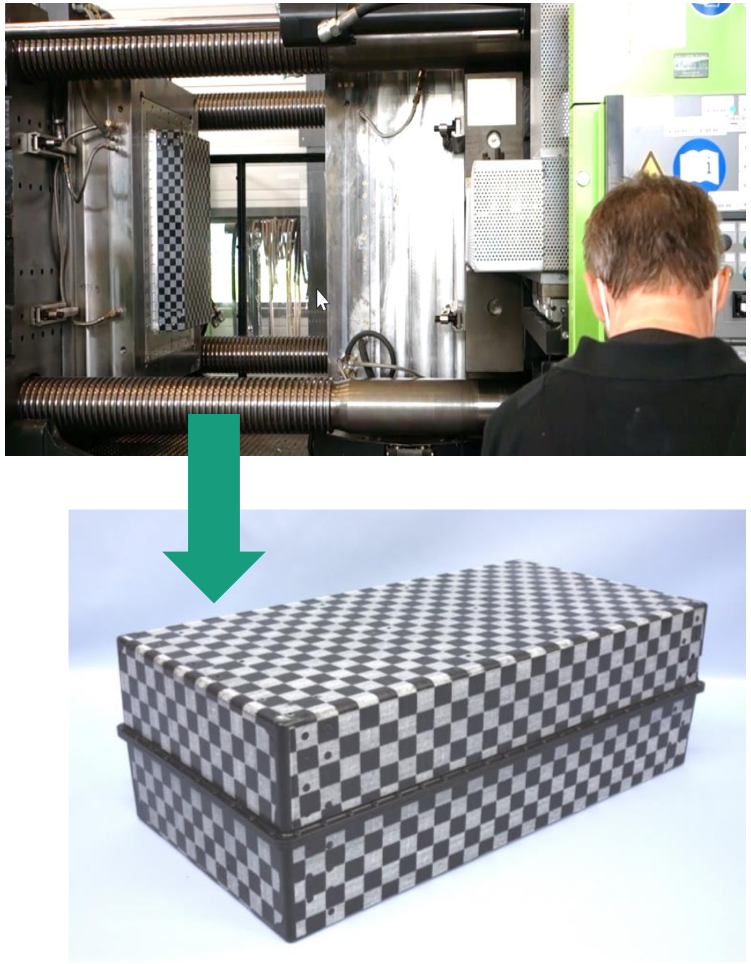
  - Until now no real recycling process available

Materials

Thermoplastic sandwich structures (Dr. Felix Weidmann, LBF)







Principle

Materials

Summary

Material	Costs (material, mass production)	Weight	Strength	Flame retardance	Resistance against marine env.	Resistance against cell chemicals	Recycling
<Metals>	+ +	– –	+ + +	+ + +	– – / +	– – / +	+ + / – (established, but energy consuming)
<Thermo-plastics>	+ + +	+ +	– / +	– / + (grade dep. -> test)	+ + +	+ (most likely, test req.)	+ + +
Thermosets	– – –	+ + +	+ + +	+ (grade dep. -> test)	+ + +	+ / – (test req.)	– – –
Thermoplastic sandwich	+ / + +	+ + +	+ + +	+ (compos. dep. -> test)	+ + +	+ (most likely, test req.)	+ + / + + +

03

Conclusion

Conclusion

- To fulfil the given requirements for a pack housing, a thermoplastic sandwich structure will be *the* solution.
- Metals, despite of their strength will no be the material of choice here.
- However, the following has to be kept in mind:
  - Light weight sandwich structures need more volume, because high strength + light weight is obtained by thicker housing walls (e.g. 6-10 mm).
  - Especially bending can be an issue at large areas under high load. To limit bending even thicker walls can be necessary.
  - But there might be size / volume restrictions, requiring use of the stronger metals.
  - Steel / metals exhibit "highest strength per volume" – plastics, esp. sandwich structures exhibit "highest strength per mass".
- If there are restrictions in volume as well as mass, a hybrid design with metals and polymers might be the answer.

Thank you very much for your attention

Fraunhofer
LBF

Contact

Dr. Bernd Steinhoff
Division Plastics
Tel. +49 6151 705-8747
Fax +49 6151 705-8601
bernd.steinhoff@LBF.fraunhofer.de