Question #

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Audience Question
It’s the Enron battery. It has a liquid system

Do you see battery enclosures transiting from today aluminum to mixed and CFRP materials?
VW MEB is also completly made of AL - different forming processes of course but exclusivly AL, also the cover

why aluminium brings a better autonomy ?
Andreas, is this comparison taking into account the possible difference in gauges when using between steel and aluminium?

There is plenty of data that does not support the 40% reduction number when using Aluminum to lghtweight vehicle structures. Seems a little too Convenient that it would always be exactly 40%. The 40 % number is based on a very basic bending formula. Complex body structures undergoing multiple directional loading and thus the assumption does not hold.

How is the interplay between design, perfromance, weight and cost altered in electric trucks?

Are there any BEV prototypes or OEM's that have indicated a shift back to steel or mixed-material design?

With the improved corrossion resistance of Aluminum you save on coatings and VOC's associated with the coatings used on steel so isn't this a compelling for the circular economy?

What aluminum alloys are best suited to battery enclosures and what is their recyclability?

Sorry. What is the preferred method for aluminum in manufacturing a battery enclosure structure? Casting or Extrusion or Both

How do aluminum enclosures compare with other solutions in crash cases when a thermal runaway of the battery occurs or a gasoline fire burns underneath the battery vehicle?
What are your units for Co2 content per Kg? 0.5, 2.3 what per Kg?

How about aluminum casting vs fabricated assemblies. What are the positives and negatives of each.
Does the life cycle analysis you mentioned include some assumption for deconstruction of the aluminum battery housing or is it more general

Can you discuss the aluminum battery enclosure's role in crash energy management -- does it have one, or is that all managed by the body in white? And how would the enclosure would be serviced following a crash?
It doesn't necessarily have to be cheaper, but it has to be within the range of ICE.

can you repeat..how many kg CO2 per kg Al is used by a smelter using renewable energy? thank you.

Currently, what percentage of aluminium in battery enclosures come from recycled scrap?

Do current applications typically include the battery enclosure as part of the structure of the passenger cell in a crash scenario?

What are the most common fastenting/joining techniques of aluminum enclosures? Are steel or aluminum fasteners preferred in mechanical fastening?

What do you think about immersive cooling ? Do you see any issue with your aluminium grade or cleanliness ?

How can aluminium protect against fire? It has low melting point. Is steel a better solution?
What’s the impact of the GTR20 legislation on the usage of aluminium?

Is there enough heat generated by the battery cells to be concerned with coarsening of precipitation hardening aluminums?

What is the typical material thickness for the aluminum top cover in order to protect passenger for fire?
Do you see packs and thus enclosures shrinking or growing, dimensionally? Or is size variable depending on the segmentation of the BEV?

Who are the primary players currently developing battery trays out of aluminum?

On slide 10's schematic of the batter pack, you show a housing tray under the aluminum crash structure. What is the housing tray made of and what performance is required for this?

The alloy has Mg in it, how come it doesn't burn?

is it easy to form the battery closure from 7075 t6?

To follow on from that, do we think if the unibody and structural element trend continues do you think joining and sealing will be more important?

The 4xxx alloy product in development, will that still in the same thickness range as the current options

What is image of cost increase %age from 6k series to 7k series?

IS purple and orange the same part/material?

How is an aluminum battery housing recycled today?

Is there enough recycled aluminum presently to meet demand for BEV enclosures, given future volume projections as we approach 2025?

How does the battery enclosure change when we move to solid state batteries?
GTR20 is coming. It's already in China and next year in Europe! It protects people during a battery run-away for 10minutes. Aluminium can not sustain this regulation

What about crevice corrosion?
Is there any correlation with aluminum in BEV and aluminum in FCEV? In terms of Amount of Aluminum used in the vehicle as a trend over time.

what are the prefered joining techniches - adhesive vs welding?
Excellent presenation. Are there any issues with dimesnional control, caused by welding distortion of the extrusions.

Dr. Andreas Afseth's Answers

Correct (assuming you mean E-tron)

I see transition to more mixed materials, but very little carbon fibre. CFRP makes sense in motorsports or ultra-luxury sports cars where cost is not an issue. Other, cheaper fibre reinfoced plastics may grow more.

It is indeed

I don't think the battery enclosure material plays a significant role in autonomy or ability to self-drive of a BEV. However, autonomy will most likely require additional components that will add more weight and could therefore benefit from light-weighting in the structure of the vehicle.

Yes, the gauge difference is accomodated for.

I fully agree. 40% is a only a ballpark figure and is not always the result. The actual weight saving depends very much on the part. A hood or a door may achieve around 45% lightweighting, while a B-pillar or other similar part may achieve in the order of 35% or slightly less.

Electric trucks will require very large batteries, maximum payload and minimum energy consumption (operating costs) and therefore there will continue to be a very high value of light-weighting, so I would expect aluminum to be the material of choice. As it already is for ICE trucks.

Yes. For example Tesla have reduced the amount of aluminum in the battery enclosure in the Models 3 and Y compared to what they used in S and X. Statements made public about the upcoming structural battery pack to be used first in Berlin also mention that the upper and lower covers are steel, not aluminum.

I agree. This saving also applies to other parts of the BiW and not only battery enclosures.

The most used and best suited alloys are of the 6000-series Al-Si-Mg-Cu family. These alloys are very well compatible with end of life recycling.

Mainly sheet and extrusion but also some cast parts. The big panels do make most sense in flat rolled sheet and depending on the design of the box and the volume it will be manufactured in the frame can make sense in extruded profiles, stamped sheet or roll formed sheet. The most cost optimized design will probably be different for a car that will be produced in 25'000 units per year compared to one that is produced in 250'000 units per year.

This is a good question and also pointed out by other attendees. Aluminum has very high thermal conductivity and the melting point is at 630C. A battery fire can reach 1200C or more and the aluminum casing will last only a short time before the metal melts. So for the top cover either a heavier steel sheet or a fire-retardant loaded polymer moulding will resist longer and give the passengers more time to evacuate.

Correct, kg CO_2 per Kg aluminum produced. Apologies if this was not clearly explained.

The benefit of using castings is that you can replace multiple sheet and or extrusion parts with one piece. This eliminates complexity as well as many forming and joining process steps. The drawbacks are that you have to use the same alloy and mechnical properties everywhere in the larger part, so miss out on some local optimization and lightweighting opportunities. The best and lowest cost solution will depend very much on the individual parts that are considreded.
Yes. The LCA always includes assumptions about end of life recycling - which percent of the material will be recycled and how much energy / CO_2 the recycling process requires.

Very good question. The battery enclosure has a critical role in the crash energy management both in terms of preventing intrusion into the battery cells as well as absorbing energy to protect the passengers. My understanding of servicing of the enclosure after it has been damaged in a crash is that the battery pack is replaced in the vehicle and the damaged pack gets returned to the OEM where it is either repaired / refurbished or it is recycled.
I quite agree.

4.0 kg CO_2 per kg aluminum produced.

We don't yet have this data on a part level, but the average recycled content of aluminum used in automotive applications in North America is published by the Aluminum Association.

The battery enclosure has a critical role in the crash energy management both in terms of preventing intrusion into the battery cells as well as absorbing energy to protect the passengers.
Extruded frames are commonly welded together. Sheet to frame may be either welded or mechanically joined in combination with adhesive bonding. Self piercing rivets and flow drill screws are commonly used. Steel rivets work well.

Aluminum alloys of the 3000, 5000 and 6000 series are very well compatible and completely resistant to common coolant liquids. I would not have any concerns with cleanliness.
This is a good question and also pointed out by other attendees. Aluminum has very high thermal conductivity and the melting point is at 630C. A battery fire can reach 1200C or more and the aluminum casing will last only a short time before the metal melts. So for the top cover either a heavier steel sheet or a fire-retardant loaded polymer moulding will resist longer and give the passengers more time to evacuate.

A very good question. Yes, this can be a concern for parts of the enclosure that are in direct contact with the cells or other part of the HV system that gets heated during charging or discharging. My main concern would be with alloys like 5182 which has more than 3.5 wt% Mg as these may over time develop a film of beta phase precipitates at the grain boundaries which can result in degraded properties. This is not a concern for the parts of the enclosure that are away from the cells, such as the bottom plate which is below the cooling plate and will not be heated by the cells.

A common gauge is around 1.5 mm
I think we will see them shrinking over time. I assume the battery cells will continue to improve in terms of volumetric density.

I think we are seeing some trends that the development of battery enclosures is being brought in-house to the OEMs rather than outsourced to Tiers. Most OEMs and start-ups developing BEVs are at least considering aluminum enclosures if not actively developing them.

The tray inside the enclosure is used in some designs and left out in other designs. The main function of the internal tray is to seal, so that the outer frame does not have to be completely water-proof. For designs with the inner tray, this will be a thin gauge of a similar alloy to the top cover (5000 or 6000). Other designs have the lower protection plate stamped into a tray so that it serves both functions.
I should first of all apologize for the comment about fire resistance of a potential magnesium enclosure. Solid magnesium is not flammable and will not catch fire even if the car burns. Magnesium catsings are used very widely in all kinds of cars and there are no problems with magnesium fires. Aluminum alloys are also completely safe from catching fire. They will melt at temperatures above 630C, but they will not catch fire.
It is certainly more difficult than forming a 5000 O-temper or 6000 T4. Options are: very limited cold forming, warm forming or, as I am sure you guys at Impression know well, hot stamping combined with press quenching.

Yes, I would agree that if the trend continues to eliminate the modules and then the enclosures and have cells directly integrated in the BiW, effective sealing and joining will grow in importance.
Correct. You can think of this high modulus 4000 series alloy as a "very excess" Silicon 6000 series alloy. Gauges, widths etc will be similar to 6000 series
A difficult question to answer while 7000 series alloys are in such limited use. I am sorry if that is not very helpful answer.

The inner frame and the outer frame re-inforcement in the protoype are two different alloys. The inner is a purely strength optimized alloys of the HSA6 family while the outer reinforcement is a ductile alloy of the HCA6 family. The inner frame's main function is to prevent intrusion into the cells even if it leads to fracture of the metal. The outer reinforcement is designed to crumple in a very controlled way without fracturing so that maximum amount of energy is absorbed. This protects the passengers.

Few BEVs have yet completed their life, but there are several companies developing recycling solutions for battery packs. All the aluminum will be sorted and then remelted back into similar alloys for use in new vehicles. The alloys that are used in the battery enclosure are the same as are using the rest of BiW and closures so the scrap streams are fully compatible.

This is a very good point. As BEVs as well as autmotive use of aluminum is a rapidly growing market and the life-time of the vehicles is long (~15 years) there is not enough end of life scrap available to meet the demand for either battery enclosures or other parts of the vehicle. So from a sustainabiliy point of view the most important factor is not really the recycled emtal content of the enclosures that are produced today, but the effective recycling of this enclosure when it gets to its end of life.
I think we may see some load-bearing function in the solid state battery cells themselves and therefore less strcutural demand on the enclosure.

I believe you might be right. See also question 12.

Crevice corrosion is an inherent risk with any design in metal. This is not really a material issue, but something that is easily solved by following simple guidelines. The design should not allow open crevices or other confined spaces in areas that are "wet". This is easily avoided by correct joining technology and sealants.

A very good question. There are still very few fuel cell vehicles, too few to make conclusions about material trends.

Extruded frames are commonly welded together. Sheet to frame may be either welded or mechanically joined in combination with adhesive bonding. Self piercing rivets and flow drill screws are commonly used.

Thank you. Yes, you are right that dimensional tolerances can be an issue but there are good practises for clamping to manage this.