Materials & the Electric Vehicle Revolution

How stainless steel answers 6 key challenges facing EV battery housings

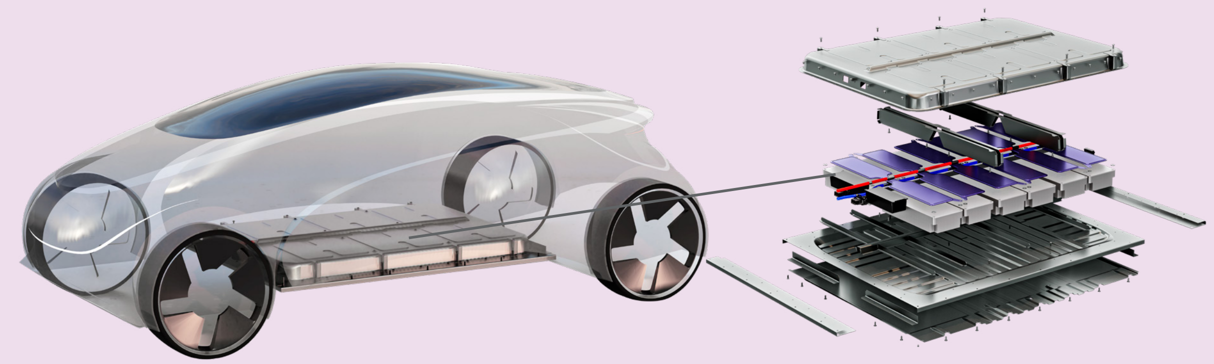
e-book

A new era for electric mobility

The electric mobility revolution is bringing about seismic shifts and imposing considerable technical challenges. For battery electric vehicles (BEVs), three priorities stand out: improving range, reducing costs and enhancing sustainability (with a focus on recyclability and reuse).

Achieving these priorities requires that the battery be fully integrated as a key component of the vehicle architecture. But with most innovation focusing on battery chemistry, this is easier said than done. What is needed is a more global perspective – one that prioritises vehicle performance and sustainability. This requires us to rethink the materials being used during the design stage, particularly as they apply to battery housings – which is exactly what Aperam has done.

In response to the six main challenges facing the automotive industry, Aperam now offers innovative battery pack solutions to support the growth of electric mobility.



SUMMARY

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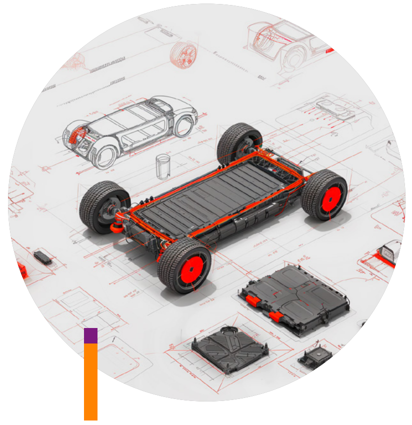
Stainless steel: The answer to e-mobility's challenges



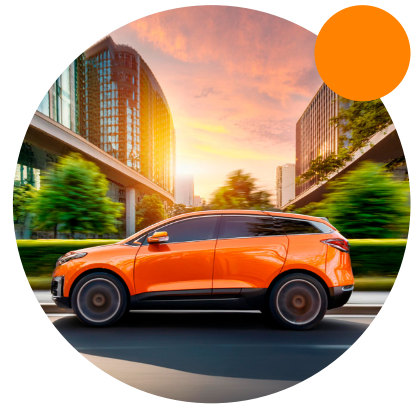
Weight reduction with safety in mind

While the choice of materials used for the battery housing is crucial to minimising the weight of the electric vehicle, one must also consider crash resistance.

Integrating the battery pack into the vehicle's structure (Body-in-White) opens the door to new possibilities for optimising both weight reduction and crash resistance, so long as the materials used have high mechanical properties.

Recyclability at the heart of design

Environmental constraints and regulations will become increasingly stringent in the future. This means manufacturers must work to reduce the environmental footprint of a vehicle over its entire lifetime, taking into account maintenance and repair, reuse, and end of life recycling. To succeed, these factors must be part of a vehicle's design, ensuring that new models are able to take full advantage of more sustainable materials.



Lower costs. Better performance.

Thanks to its versatility, corrosion resistance without post-treatment, thermal insulation and excellent fire resistance, stainless steel is the material of choice for battery housings.

Only stainless steel combines low carbon emissions, ease of processing and high mechanical properties to provide the durability and efficiency that today's electric vehicles demand.

Challenge #1

How to reduce weight – and costs

Electric vehicle batteries are heavy, and there aren't many options for reducing their weight without compromising the vehicle's range.
One option is to reduce the weight of other system components, such as the battery's structural parts. So long as the right materials are included in the vehicle's design stage, doing so offers significant potential for optimising both overall weight and costs.

Stainless steel: the strategic choice for reducing overall costs

Thanks to its unique mechanical properties, stainless steel is proving to be an effective solution for making battery housings lighter. However, choosing the best material requires that one look at the total cost of the solution (design cost + materials), as opposed to cost per tonne of base material.
Used in thin thicknesses and wide widths (up to 2,000 mm (78.74")), Aperam stainless steel reduces weight, increases available space and optimises manufacturing costs, particularly through cold stamping.

Comparing materials

Together with ACS, Aperam developed a small-scale prototype (~1/8 of a 75 kWh battery) to assess the performance of stainless steel. Designed according to common load case specifications used for carbon steel, aluminium and stainless steel, this prototype allows us to compare the weight of each material.

Without even optimising the design, stainless steel is already lighter than the carbon steel solution (8.4 kg (18.52 lb) vs. 10.3 kg (22.71 lb)). With optimisation, its weight is equivalent to, or even less than, aluminium solutions (see p. 16-17).

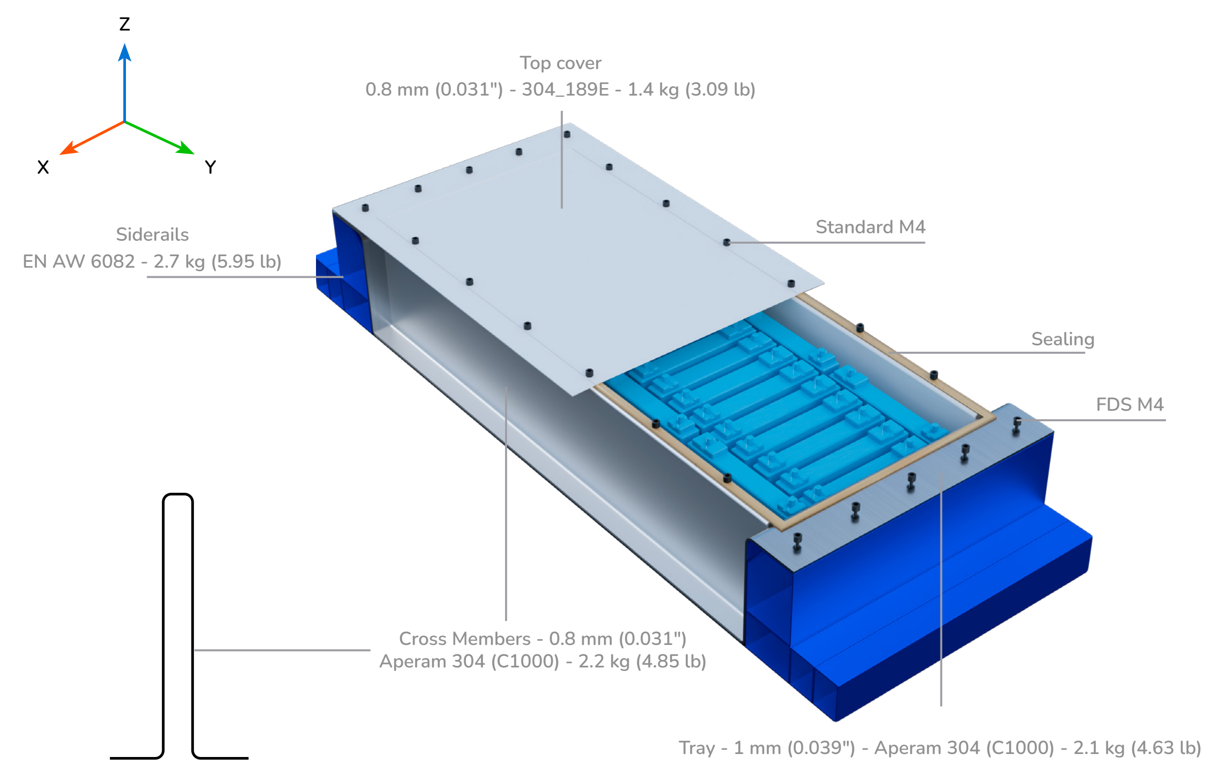
acs | automotive center SÜDWESTFALEN

ACS is an independent research centre globally recognised for its expertise in engineering, prototyping and validation testing.

Load case specifications

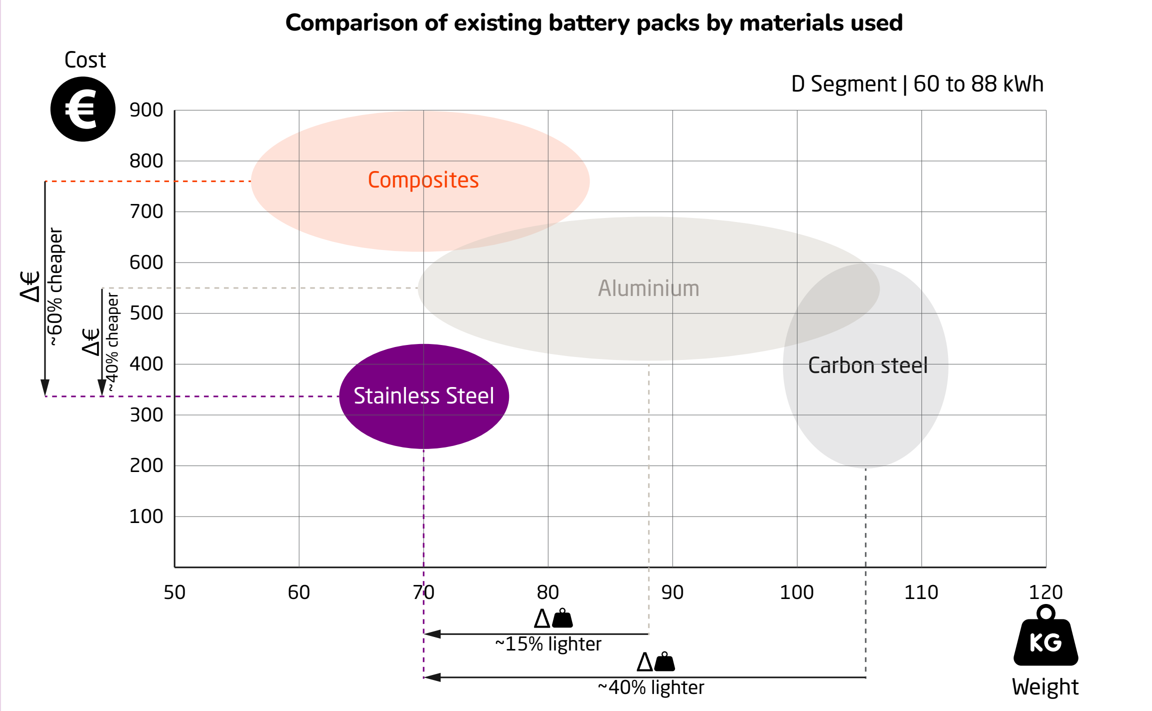
To be as representative as possible, three main load cases were selected for designing the prototype.

- **Y 100 kN crash test**
  Semi-circular column applying a quasi-static force of 100 kN to the most vulnerable point on each side of the battery.
- **Vehicle underbody jacking test**
  Using an incorrectly positioned jack, a load equivalent to 50% of the vehicle's weight is applied to the weakest point on the underside of the battery pack.
- **Noise Vibration and Harshness analysis (NVH)**
  The first natural mode must be above 35 Hz.



Aperam Stainless steel: up to 60% savings and 40% lighter battery housings

To complement ACS's technical approach and incorporate material properties, optimised concepts were developed in collaboration with Ricardo Engineering (p. 16-17).
Not only does stainless steel battery housings offer a significant reduction in weight – by as much as 15% – compared to aluminium, it achieves this weight reduction at significantly lower costs – saving 40% on manufacturing costs. Total savings are up to 60% compared to composites, while stainless steel offers a 40% weight reduction compared to carbon steel.
Contrary to preconceived notions that are based solely on €/tonne of base material, when one takes into account both the processes involved (shaping and assembly) and the versatility of stainless steel grades, it is clear that stainless steel can generate substantial savings.



Challenge #2

How to ensure safety in the event of an accident or impact

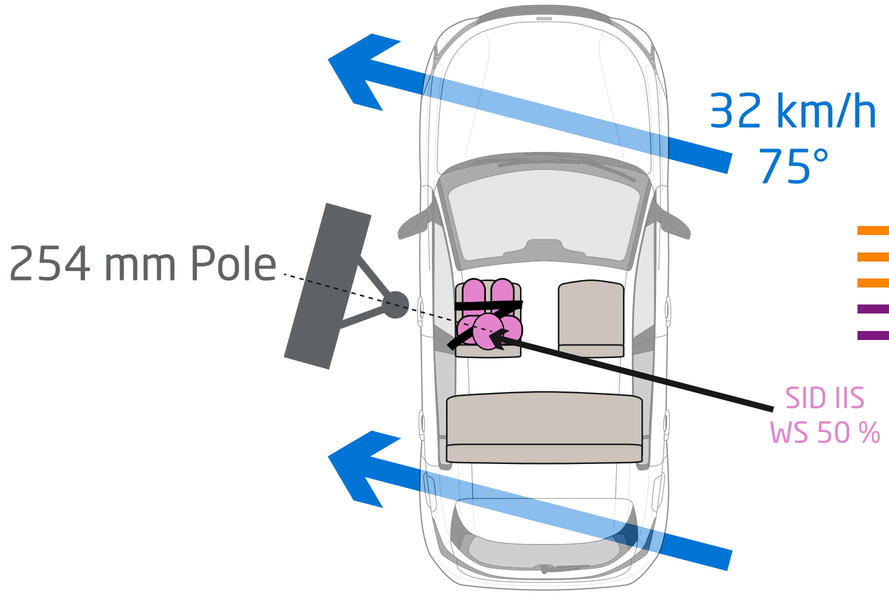
If the battery cells become damaged during an accident they could cause a fire or the leaking of toxic gases. Designed to protect the cells, the battery housing plays a critical role in guaranteeing passenger safety.

Stainless steel for a guaranteed strong battery housing

Stainless steel is the key to designing battery housings that offer improved crash resistance with a very low risk of tearing (particularly at the underbody).
Taking full advantage of Aperam's stainless steel's high mechanical strength, its battery housing provides better protection for the battery cells and, consequently, for passengers.
In fact, our tests have demonstrated a performance that is equivalent to or better than currently available solutions.

Protecting the vehicle's underbody

An electric vehicle's underbody is particularly vulnerable to damage, with road debris, automatic lifting bollards (traffic restriction zones) or incorrect lifting procedures (incorrectly positioned jack) being leading causes of cracking or breakage.
Although there are no specific regulations, all car manufacturers have developed their own in-house tests for evaluating the underbody's vulnerabilities.
Aperam used a jacking test (see below) to optimise the stainless steel battery housing designs, developed by Ricardo Engineering, to optimise our stainless steel designs (see p. 15-16).



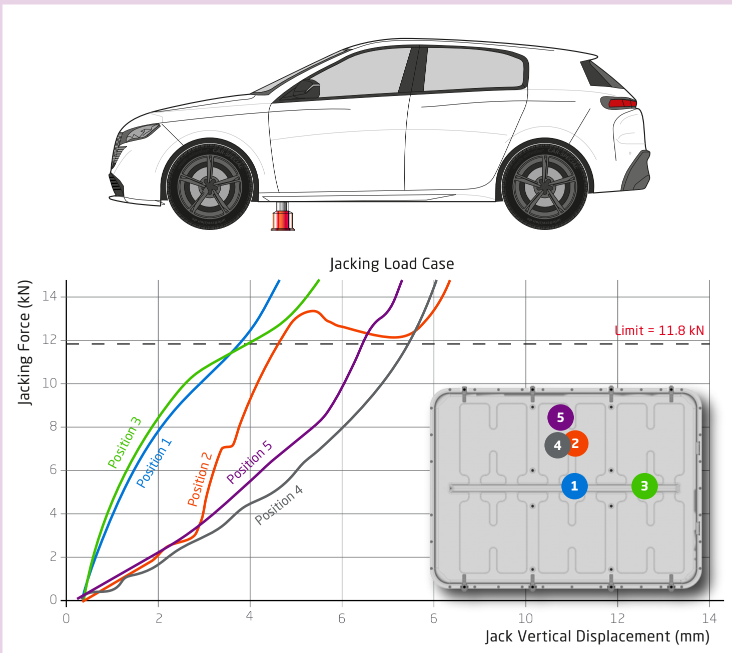
Side impact on pole

US NCAP* test at 32 km/h, 75-degree angle. This test allows car manufacturers to simulate a side impact accident, such as a vehicle hitting a pole.
Additional locations are often added to assess crashworthiness and battery protection in electric vehicles. The key requirement is that there is no contact between the vehicle structure and the battery module.

* United States New Car Assessment Programme

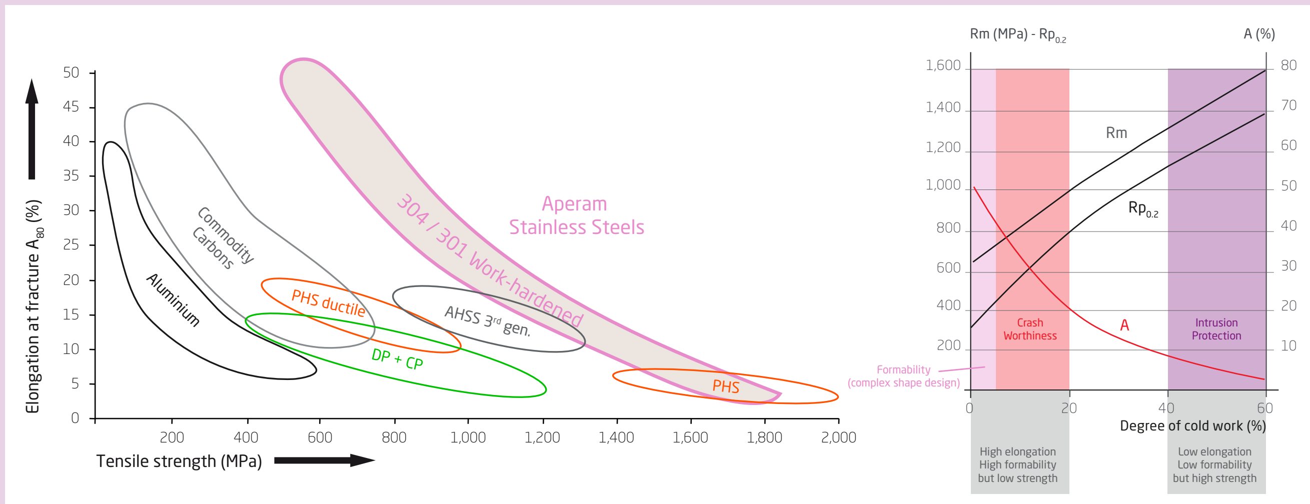
Underbody perforation test

In this test, a lifting pin 150 mm (5.906") in diameter applies a force of 11.8 kN, which represents 50% of the vehicle's unladen weight (i.e., 1,950 kg (4,300 lb)).
The battery housing passes this test if there is no breakage of the pack's structural elements and no contact between these structural elements and the modules.
Several positions of the lifting stud were evaluated.
As illustrated in the figure (opposite), the LW69 concept (see p. 15-16) passed this lifting test in Ricardo Engineering's finite element simulations.



Versatile mechanical properties

Aperam's austenitic stainless steel grades offer a wide range of performance advantages, including mechanical strength and elongation at break. Some grades, such as Aperam 301, generate martensite during deformation, which increases their strain-hardening rates during manufacturing. This improves the mechanical strength of the parts, thereby meeting important impact resistance specifications, including for high-speed deformations caused by accidents.



Consult Aperam product sheets

Challenge #3

How to optimise the thermal management of the battery housing

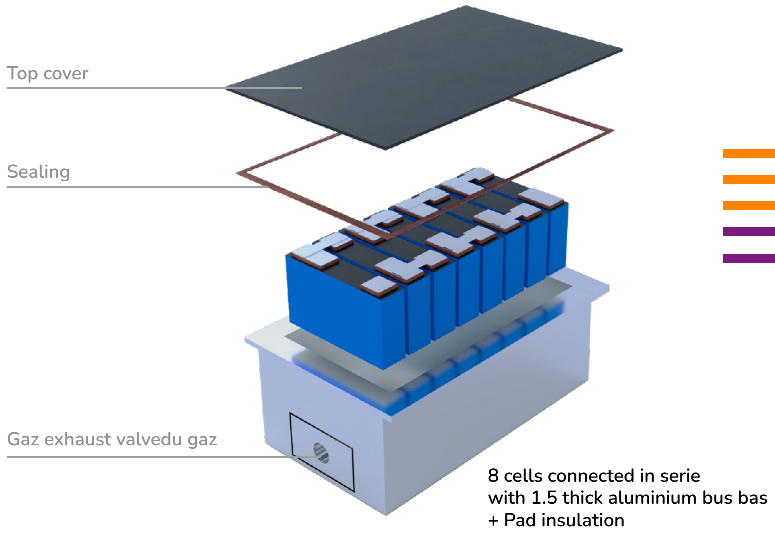
The thermal management of an electric vehicle's battery is essential to maintaining cell performance. It is also key to ensuring safety in the event of an accident, where cell temperature must be regulated and the dispersion of heat limited so that passengers can be safely evacuated.

Stainless steel offers exceptional thermal performance

Thanks to its low thermal conductivity, stainless steel can avoid thermal bridges, meaning it can help limit heat loss, particularly during periods of extreme cold.
Furthermore, its high melting point and stable mechanical properties at high temperatures ensure the integrity of the system in the event of a thermal accident. As a result, stainless steel helps slow the spread of heat and guarantees passenger safety in the event of an emergency.

Exceptional thermal insulation

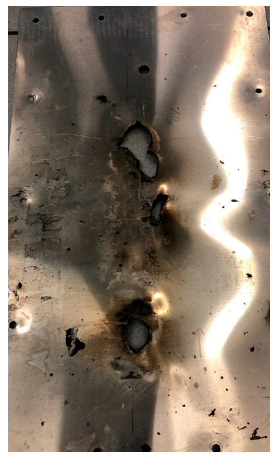
Battery cells must be kept cool at all times. While aluminium offers high thermal conductivity, which is advantageous for the efficiency of cooling systems, this alone is not enough. It is also crucial to limit the external environment's impact on the battery housing's internal temperature. In other words, the housing must not only provide the thermal management inherent in the battery, but also isolate the cells from the external environment to avoid energy losses. For example, in summer, heat must not be transferred to the interior of the vehicle via the battery housing cover. Similarly, in winter, the cold must not interfere with internal thermal control.
Because stainless steel has a low thermal conductivity, it can thermally insulate the battery housing from the variations in outside temperatures.

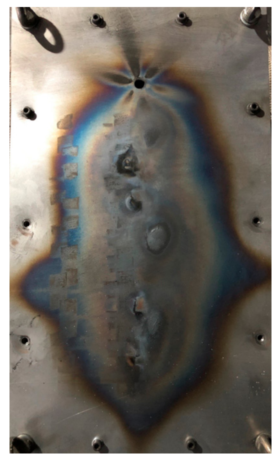


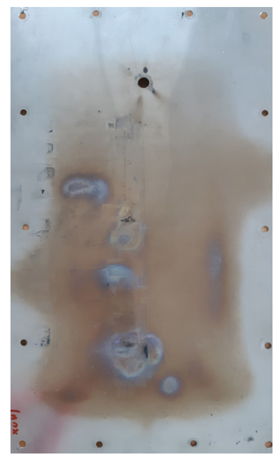
crepim MATERIAL & FIRE TEST EXPERT

High resistance to thermal runaway

With a high melting point and low thermal conductivity, stainless steel offers a high resistance against thermal runaway. When used in an electric vehicle's battery housing, it slows the spread of heat between modules, giving occupants time to leave the vehicle in the event of a fire.
This is important as a battery fire can reach 1,000°C. Whereas aluminium burns out in 5 minutes at 600°C, stainless steel can resist temperatures of up to 1,200°C for 10 minutes, guaranteeing greater protection and safety, without additional fire retardant pad.
In partnership with CREPIM, Aperam has demonstrated this superior performance both on the cover (see adjacent illustration) and on the complete module (ACS prototype, p. 5).


Aluminium (Al 6082)
Numerous holes + deformation


Carbon Steel (DC01)
Hot spots, deformation, and cracking

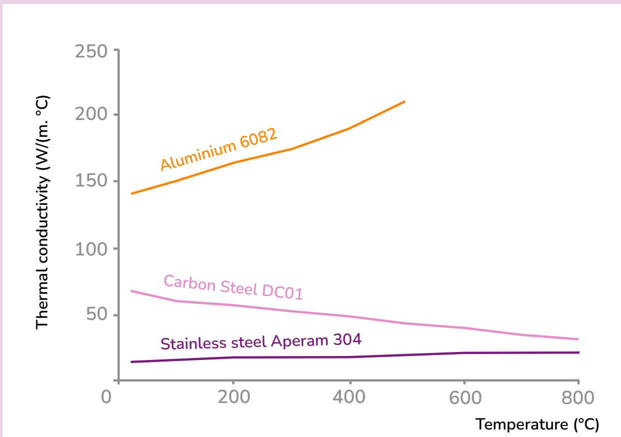

Stainless Steel (Aperam 304)
Deformation and discolouration


Stainless Steel (K44X)
Slight deformation

Comparative thermal conductivity

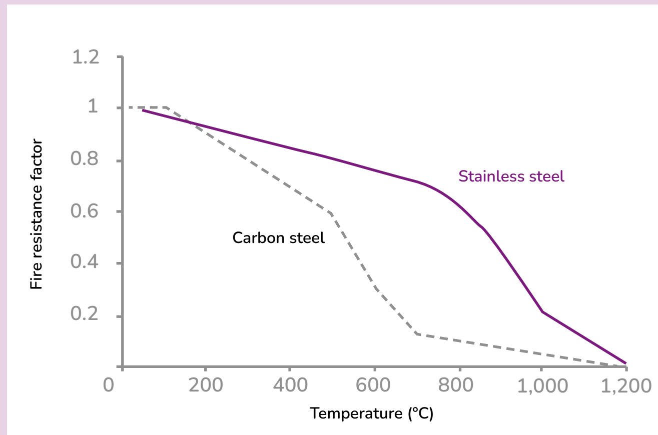
Thanks to its low thermal conductivity, stainless steel is an ideal material for the thermal insulation of battery housings.

As shown in the adjacent illustration, unlike other materials, stainless steel maintains a very low thermal conductivity across any temperature range.



The fire resistance factor

The stiffness reduction factor ($k_{E,\Theta}$) is defined as the Young's modulus E at elevated temperature Θ, normalised by the initial modulus at room temperature. This factor plays a key role in determining a material's ability to maintain its mechanical properties during a fire. In the event of a thermal runaway, the inside of the battery housing rapidly exceeds 500°C – a temperature above which stainless steel retains better mechanical performance than carbon steel. This increases the chance for passengers to be evacuated and for emergency services to safely intervene.



Challenge #4

How to optimise manufacturing processes

When designing battery housings, space must be optimised to ensure safety and facilitate easy assembly and disassembly. New solutions need to enable complex shapes and scalable integrations to improve energy density and reduce costs.

Stainless steel: overlooked no more

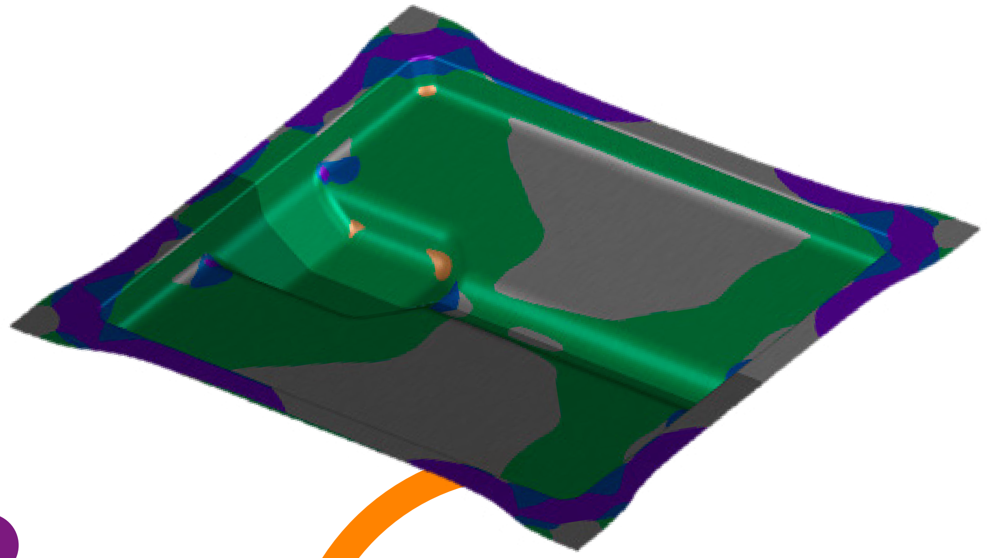
Often overlooked, stainless steel opens the door to innovative designs. It not only offers a wide range of grades with high formability (see forming limit curves or FLC), it also allows for the use of all available industrial assembly techniques. These characteristics make it easy to exploit those spaces that usually go to waste (e.g., cable routing, cooling systems, etc.). Furthermore, thanks to its inherent durability, stainless steel doesn't require the addition of coatings – making it the material of choice for optimising manufacturing processes and logistics.

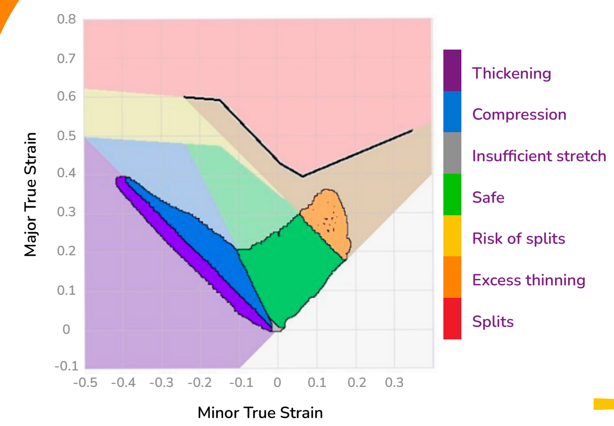
FORMING

Saving time, reducing costs

Thanks to its high formability, Aperam stainless steel can be used to produce large*, complex parts in a single step stamping – eliminating the need for numerous welds and the high costs that often accompany the use of aluminium. For example, Aperam 301 grade, available in a thickness of 1 mm (0.039"), can be used to create complex designs while improving mechanical properties through cold working, as illustrated by the design of the battery tray. This strengthens the structural integrity of battery housings and significantly optimises the manufacturing process.

* Aperam offers widths up to 2,000 mm (78.74")

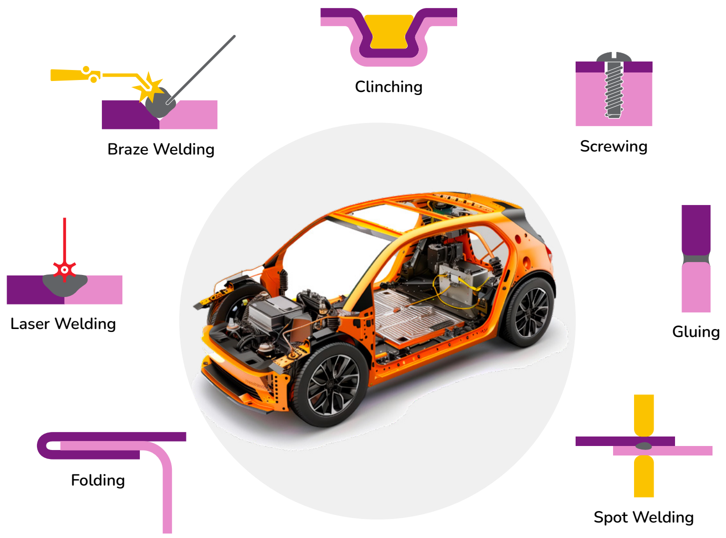




ASSEMBLY

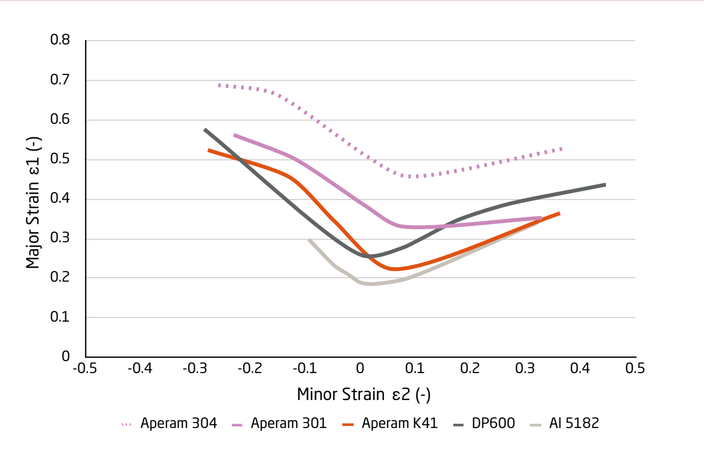
Versatile assembly

Thanks to its uncoated nature, high forming capacity and advanced mechanical properties, stainless steel can be used with a very wide variety of assembly methods. From bonding to welding or clinching, with stainless steel, these assemblies will have excellent mechanical properties – a fact that has been demonstrated by shear and tensile tests.
The choice of assembly method depends on the customer's specifications (industrial capability, usage specifications).
Using stainless steel also allows the manufacturer to reduce the number of assembly points, thereby increasing productivity and/or facilitating the product's disassembly for maintenance, repair or dismantling for reuse or recycling.



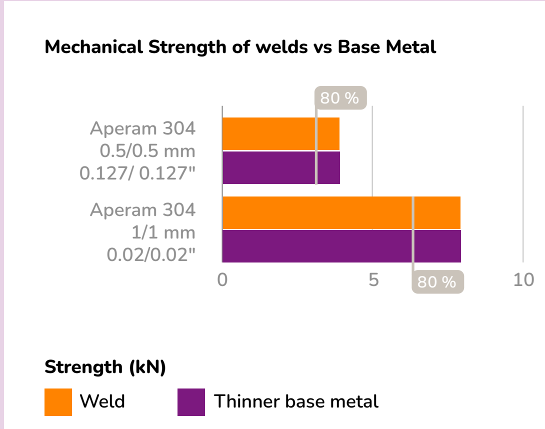
Comparing the forming limit curves of stainless steel, aluminium and carbon steel

Stainless steel's range of chemical compositions and work-hardenability gives the material a significant forming advantage over other materials. This is illustrated in the adjacent illustration of the forming limit curves (FLC) for a 1.2 mm (0.047") specimen thickness.
Stainless steel is also the champion of deep drawing, outperforming both aluminium and carbon steel.



The mechanical strength of laser welds on stainless steel

For most processes, austenitic stainless steels offer very good weldability. This is true even with such high-energy density welding techniques as laser welding.
The adjacent figure illustrates the mechanical strength of an Aperam 304 stainless steel butt joint using laser welding for two different thicknesses. We can see that the strength levels of the assemblies are very close to those of the base metals, easily meeting the established criterion of >80% of the mechanical strength of the thinnest base metal.



Challenge #5

How to ensure durability

Protecting batteries against external factors like corrosion is essential. That's because corrosion isn't just an aesthetic problem – it can cause perforations and compromise the watertightness of the battery housing, resulting in increased safety risks.
Thus, guaranteeing the watertightness of the system and preventing any corrosion-related degradation throughout the life of the electric vehicle remains a challenge.

Stainless steel: the champion of corrosion resistance

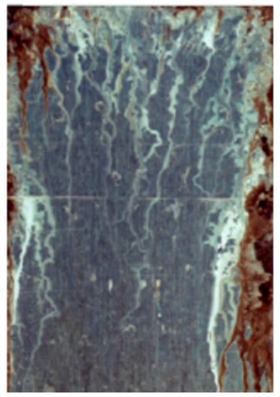
With their varied chemical compositions, stainless steel grades offer exceptional resistance against even the harshest of environments.

Comparing the salt spray behaviour of four materials

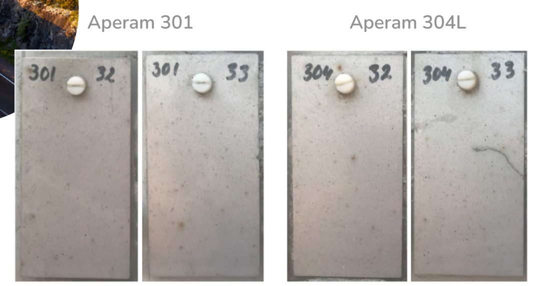
The salt spray test (standard ASTM B117) is commonly used to assess resistance to atmospheric corrosion. In the automotive industry, the duration of exposure is shorter than in the construction sector (1,000 h – see adjacent images), but long enough to be representative of the warranty period or the expected life of the components.
Aperam's stainless steel demonstrates outstanding resistance in these atmospheric conditions.


Carbon Steel AK212


Galvanised Steel Z275


Aluminium (Al 6060)


Aperam 304L



Superior performance in winter conditions

When used in the undercarriages of lorries, Aperam stainless steel has a proven track record for withstanding several winters of harsh weather and conditions (see photos above, results subject to road salt and accumulated sludge, humidity and temperature variations, all of which can accentuate the concentration of halide-type pollutants).

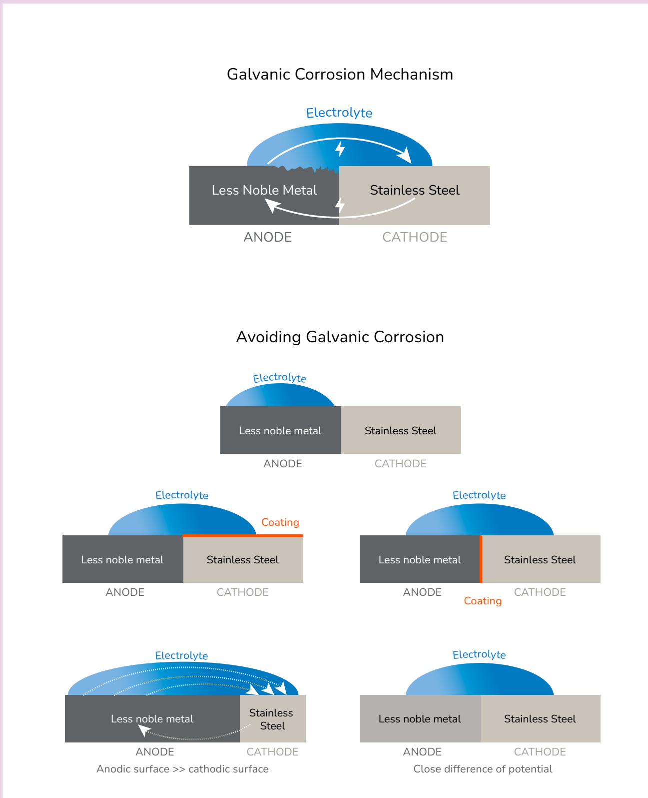
Stainless steel grades containing molybdenum, as well as super austenitic and duplex grades, are designed to withstand the harshest of environments, including those found in the oil and gas industry.
As such, these solutions are already well-suited to the most demanding specifications of the automotive and transport sectors.

Eliminating the risk of galvanic corrosion

When stainless steel is used as part of a multi-material solution in an electric vehicle, galvanic corrosion must be prevented. There are two ways of doing so:

- Stopping the flow of current by applying good electrical insulation practices within assemblies (see adjacent illustration).
- Significantly reducing the rate of corrosion induced by galvanic corrosion by decreasing current density. This can be achieved by choosing materials that are close in electrical potential or by taking into account the influence of the surface ratio of the materials involved in the corrosion current density (anodic surface should be greater than cathodic surface). In doing so, stainless steel will not accelerate the corrosion rate of the least noble material in the assembly.

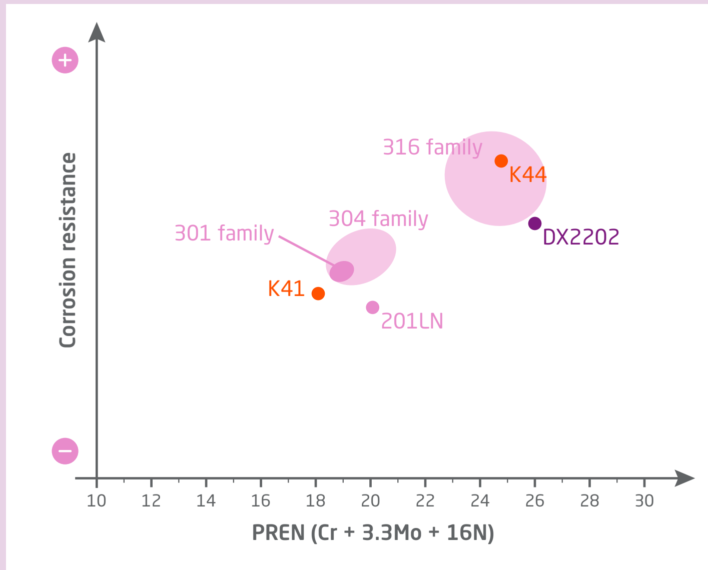
What this means is that stainless steel is an excellent solution that is already being used in construction and industrial applications (e.g., water treatment, transport structures).



Natural protection against aggressive environments and gravel

Stainless steel is a 'passive' material because it naturally forms a chromium-based protective layer that regenerates in the event of damage.

Depending on its chemical composition, stainless steel grades have different levels of resistance to corrosion. In the case of localised corrosion, which is primarily caused by chlorides, a material's degree of resistance is estimated by the Pitting Resistance Equivalent Number (PREN) index, as shown in the graph.



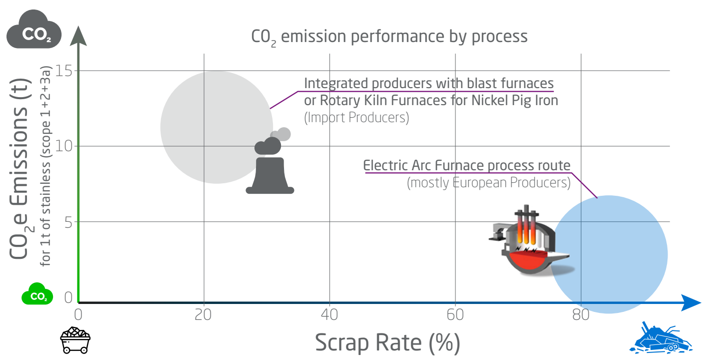
Challenge #6

How to minimise an electric vehicle's environmental footprint

Optimising the life cycle of electric vehicles is crucial to reducing their carbon footprint and ensuring their sustainability. This means minimising the environmental impact of every stage, from initial design to end of life.

Stainless steel increases durability

Thanks to its high recyclability, corrosion resistance and low carbon impact, stainless steel can help optimise the life cycle of electric vehicles. By using stainless steel, one not only ensures a long lifespan of the individual component, but also a reduced environmental footprint for the entire vehicle.



Not all stainless steels are produced the same way

Around 45% of stainless steel is produced using nickel pig iron and ferro-alloys – a process that requires a lot of energy. Furthermore, the majority of producers still use coal and thus generate a significant amount of CO_2e emissions.

To reduce the carbon footprint of the stainless steel manufacturing process, producers can maximise the use of low-carbon materials (particularly scrap), improve energy efficiency and use green energy. In Europe, for example, Aperam produces its stainless steel from recycled scrap (up to 98%) using electric furnaces, which significantly reduces its environmental impact. In Brazil, Aperam combines the use of scrap metal with renewable energy sourced from charcoal derived from our eucalyptus forests and from hydroelectric power.

The Circular Economy at the heart of our activities

Aperam's Triple Loop model uses three types of scrap sources as raw material in our stainless steel production process:

> Loop 1: Recycles scrap collected within Aperam's facilities.

> Loop 2: Regenerates scrap from manufacturers who incorporate stainless steel into their products.

> Loop 3: Collects and processes old scrap from end-of-life products, including vehicles.

Reducing EV's carbon footprint while increasing their recyclability

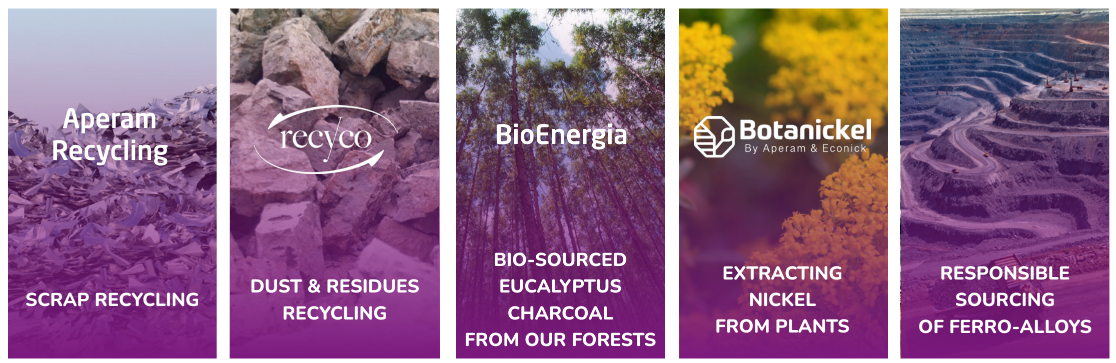
The European End-of-Life Vehicles Directive (2000/53/EC) mandates that 95% of the total weight of an end-of-life vehicle must be recovered, with at least 85% occurring through recycling.
But this is only the beginning, as the percentage of recycled materials to be incorporated into new products will increase over time.
With 100% recyclable concepts and by using more than 88% recycled content, Aperam's stainless steels meet the strictest regulations (with Aperam infinite™, the recycled content is even higher, exceeding 98%).
Using a fully circular approach, the RV90 concept, designed to optimise disassembly, allows for the easy extraction of battery cells, enabling the battery pack to be reused or completely recycled. This model, which integrates circularity at every stage – from design and production to end-of-life – demonstrates the tangible benefits of taking a sustainable approach while offering economic gains to all stakeholders involved.

In partnership with the RWTH Aachen University, Aperam launched a comparative life cycle analysis of our battery housing concept. This will ensure we continue to challenge ourselves and identify ways to further improve the impact of our solutions.

RWTH AACHEN UNIVERSITY

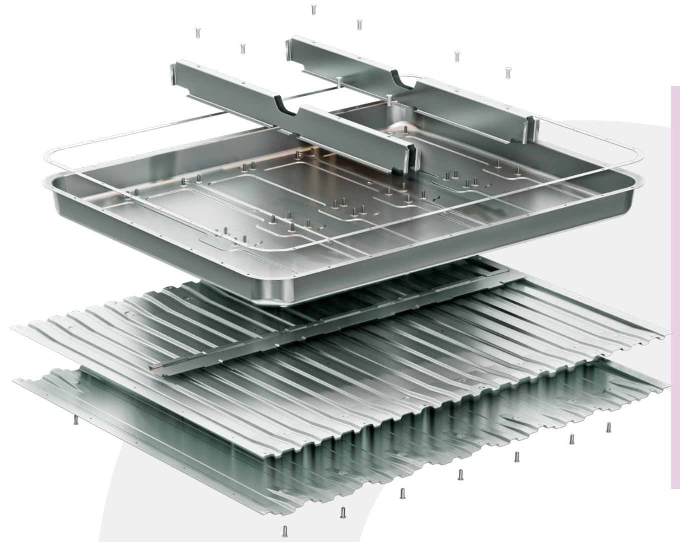
Production mixes that can reduce the carbon footprint of stainless steel.

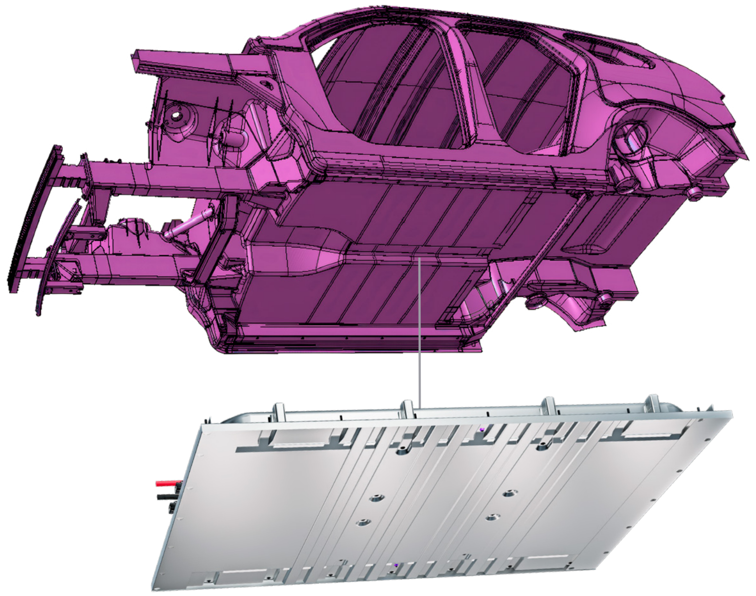
Materials producers are leveraging numerous factors to produce stainless steels with ever lower carbon footprints.
Here is an example of the levers used by Aperam.



Aperam innovation: battery housing concepts

To demonstrate stainless steel's ability to meet the specific needs of car manufacturers, Aperam, in collaboration with its partners, has developed two exclusive concepts. Both concepts are based on D-segment electric platforms.





These concepts, in whole or in part, can open the door to mixed solutions that can be integrated into multi-material environments.

CONCEPT LW69

Underbody puncture test: in-house

Impact test: SAE J2464

Pole impact at 32 km/h: FMVSS, UN R135

CONCEPT RV90

Pole impact at 32 km/h: FMVSS, UN R135

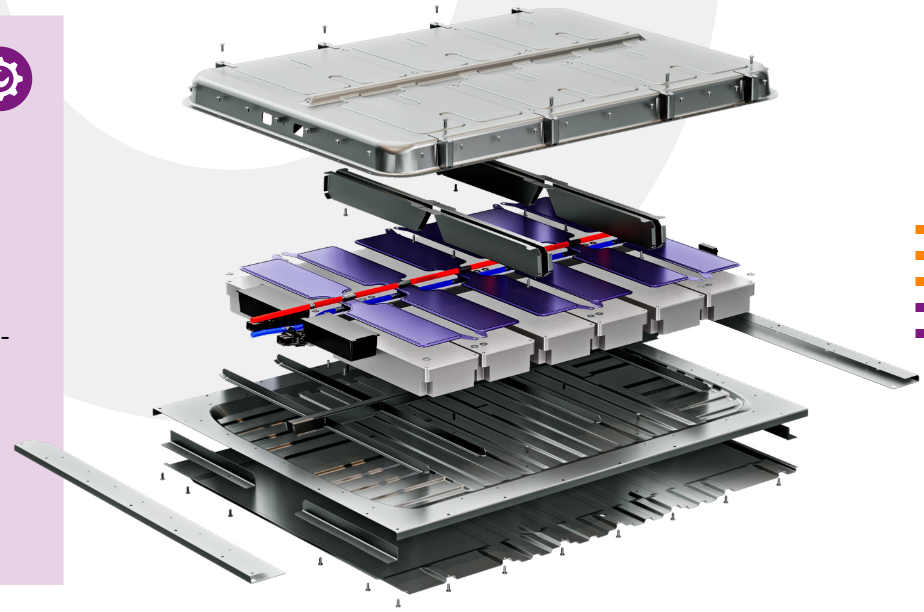
Underframe perforation test: in-house

Crash test at 100kN: GB/T 31467.3-2015 (7.6) amend.1

Drop test: GB/T 31467.3

Impact test: SAE J2464

Modal analysis: ISO 12405-2



Weight reduction and cost optimisation

Thanks to its synergy with the floor and large parts*, this concept weighs just 69 kg (152.12 lb) and has an energy density of 88 kWh. In comparison, equivalent concepts made from competing materials average around 90 kg (198.42 lb).

This concept also offers good performance in the event of a crash, due to the fact that it reinforces the vehicle's structural integrity. Furthermore, it does so at the same cost level as carbon steel solutions, which are less expensive than aluminium or composites. This is the result of the solution's use of large parts and the optimisation of the manufacturing processes (see graph, p. 5).

*2,000 mm (78.74") wide sheets can be supplied.

Volumetric energy density and easy reparability

By incorporating additional load cases (GB/T 31467.3 standards for interchangeable batteries), this concept is designed to optimise available space for the cells.
The assembly design also allows easy access for maintenance and repairs, as well as for end-of-life recycling or reuse (>95%).

All this at a lower cost than aluminium solutions.

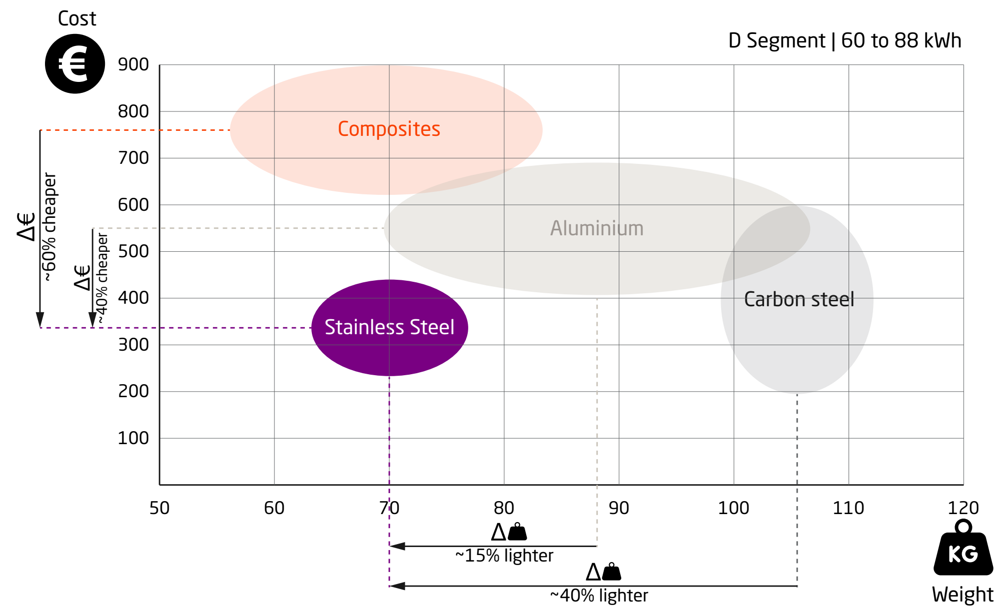
Our partners

RICARDO

RWTH AACHEN UNIVERSITY

These concepts are the result of the materials science expertise of Aperam and the automotive design skills of Ricardo Engineering and their Future Vehicle Architecture (FuVA).
Together with the RWTH Campus in Aachen, our R&D team continues to optimise the manufacturing process for large parts and assembly, using the latest industrial techniques to improve production processes and costs.

Cost/weight comparison of battery housing materials



Stainless steel: up to 60% savings and 40% weight reduction

See details, p. 5.

Your partner in innovation

We put our expertise and industrial capabilities at the service of our customers to help them innovate quality, cost-effective and sustainable solutions.

Committed to sustainability

We have always been committed to environmental issues. Committed to corporate social responsibility (CSR), we put sustainability at the heart of our business, with the aim of drastically reducing our carbon footprint by 2030. We also provide innovative and sustainable solutions that meet our customers' most demanding needs while helping them reduce their own carbon footprints.

One of the widest ranges of stainless steels and alloys on the market

Aperam is structured into four main segments:

- Stainless & Electrical Steel
- Services & Solutions
- Alloys & Specialties
- Recycling & Renewables

These activities cover the complete range of products and services in stainless and specialty steels.

A network of service centres

Aperam has an extensive network of service centres and sales offices, strategically located in Europe and around the world. These centres enable us to respond quickly and efficiently to the processing and distribution needs of stainless steel products. This network also ensures maximum proximity and flexibility for our customers, optimising delivery times, logistics and first-level processing costs.

Exclusive expertise in low-carbon stainless steel and the circular economy

Aperam is a pioneer in the production of low-carbon stainless steel, with a unique circular production process. Thanks to our innovative model, we buy back our customers' stainless steel scrap and re-integrate it into our production chain. This recycling system reduces our carbon footprint – and that of our customers.

Aperam is the first stainless steel producer to be certified by ResponsibleSteel™

Three research centres bring our customers the very best in materials innovation

Our research centres collaborate with our customers, as well as with world-renowned universities and other research centres. Together, they work on a wide range of challenges, including e-mobility, the energy transition and the development of solutions for reusable packaging. This network of expertise enables Aperam to remain at the forefront of industrial innovation.

Helping our customers meet the material challenges of e-mobility

Aperam is investing in e-mobility research and innovation, a key sector for achieving carbon neutrality by 2050. Using stainless steel, we are developing lighter and stronger solutions for batteries and other energy sources used by e-mobility, including hydrogen. We are also committed to optimising the safety and sustainability of these solutions – a commitment that supports the transition to low-carbon, efficient mobility.

Accelerating the energy transition

Aperam is actively supporting the energy transition through our innovative solutions in renewable energies and energy efficiency.
Our stainless steels and alloys play a key role in the production of sustainable energy, such as wind and solar power, as well as in the production, storage and transport of new energies like hydrogen. We are also developing solutions that can already be used in such applications as Carbon Capture, Utilisation and Storage (CCUS).

Providing realistic solutions for reusable packaging

Aperam's research into reusable packaging and food containers aims to meet new consumer expectations and regulatory requirements for reducing single-use plastics. Aperam is developing durable, resistant and hygienic solutions made from stainless steel that are suitable for the food industry and other sectors requiring reusable materials.

APERAM KEY FIGURES

11,500
Employees

2.20
Mt Shipments in 2023

40
Delivered countries

0.28
Tonnes of CO_2e/tcs
(Scopes 1 + 2 including the sequestration effect of our Brazilian forests in 2023)

32
14 Service centres
4 Transformation units (tubes & flat bars)
14 Sales agencies

3
R&D centres

150
R&D employees

For more information, contact us

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