Thatcham Insight

Automotive insight for Members

No.10 April 2013

Hydrogen Fuel Cell vehicles development

Additive Layer Manufacturing

Honda Announces joining of aluminium and steel

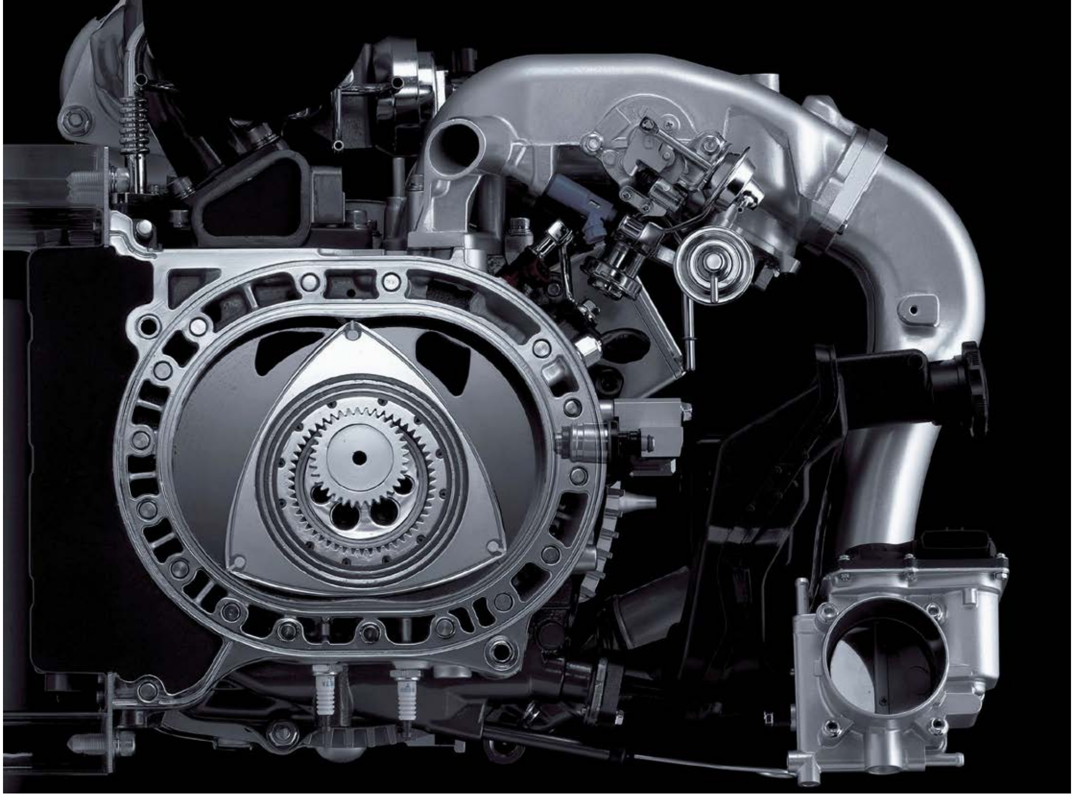
Development of Hydrogen Fuel CELLS VEHICLES

The development of Hydrogen Fuel Cell vehicles (FCEV) and development of the infrastructure required looks like it is gathering support, with a clear focus developing on Europe and the UK.

Even cynics do not seem to be disputing the CO2 emissions claims of 45g/km (from well to wheel) and that hydrogen will cost the same as diesel by 2025.

The vehicle manufacturers are continuing to develop partnerships with other technology providers, with a supporting fuel infrastructure top of their agenda. The UKH2Mobility project, comprising representatives of the government, suppliers, manufacturers, and retailers, all with interests in hydrogen mobility, reported in early February 2013 that as many as 1.5 million hydrogen vehicles could be on UK roads by 2030. They believe that by then the market will support 300,000 FCEV sales per year. But they called for a basic phased introduction of fuelling stations as necessary to make initial uptake of FCEV's viable, requiring an investment of £400million.

A major step forward, for the UK at least, was the announcement in February by Michael Fallon (Business and Enterprise Minister) that the government was preparing to invest that £400million into the first basic network of 65 hydrogen fuel stations. However, this is still a 10 – 15 year project so there is as yet no need to fear a sudden massive upsurge in FCEV availability.



The vehicle manufacturers are continuing to develop the technology. General Motors/Vauxhall claim to have logged 2 million miles testing Fuel Cell vehicles over the past 10 years, with Toyota claiming 20 years activity in Fuel Cell development and expects to launch a commercially available vehicle in 2015.

Honda has confirmed it will test its next generation FCEV in Europe. Previously testing and development has been in the USA and Japan only.

Honda is championing home refuelling stations, demonstrating, in Japan, a solar powered station that produces electricity which is then used for hydrogen production. It produces 1.5kg hydrogen in 24hours, but is also capable of storing 20kg of Hydrogen, enough to refuel 3 FCEV's. Indeed, a large portion of Honda's Research and Development has been toward cost reduction of the technology, possibly a lesson learned from the slow public take up of Battery Electric Vehicles.

Interestingly Honda has adapted its FCX Clarity vehicle with a power outlet so the car effectively becomes a zero-emission mobile generator.

Fuel
CELLS

Mazda are taking a distinctly different approach. Well known for their Wankel rotary engines they have adapted these to burn hydrogen as a fuel rather than to generate electricity. This has proved a logical fit for rotary engines and for hydrogen. The rotary is very efficient at its optimum of approximately 2000rpm, but is far less efficient during acceleration and braking. Hydrogen is also a good clean fuel but extremely flammable.

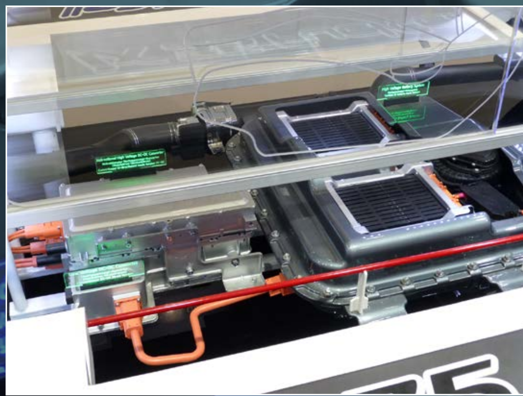
So, hydrogen is difficult to use as a fuel for reciprocating internal combustion engines as the residual high temperature of the spark plugs can ignite the fuel during induction. With a rotary engine the combustion chamber is separate from the intake, so this is far easier to control.

This has been tested on a Mazda RX-8, which operates as a dual-fuel vehicle by injecting hydrogen fuel as required as a cleaner burning alternative to the usual petrol driven operation.

Mazda's logical next step has been to optimise a hydrogen fuelled rotary engine as a range-extending generator for an electric vehicle, with the engine maintaining its 2000rpm optimum rotational speed.

Audi too has seen the benefit of a rotary generator in their e-tron development, so we could see Mazda providing this technology to other manufacturers.

Fuel
CELLS

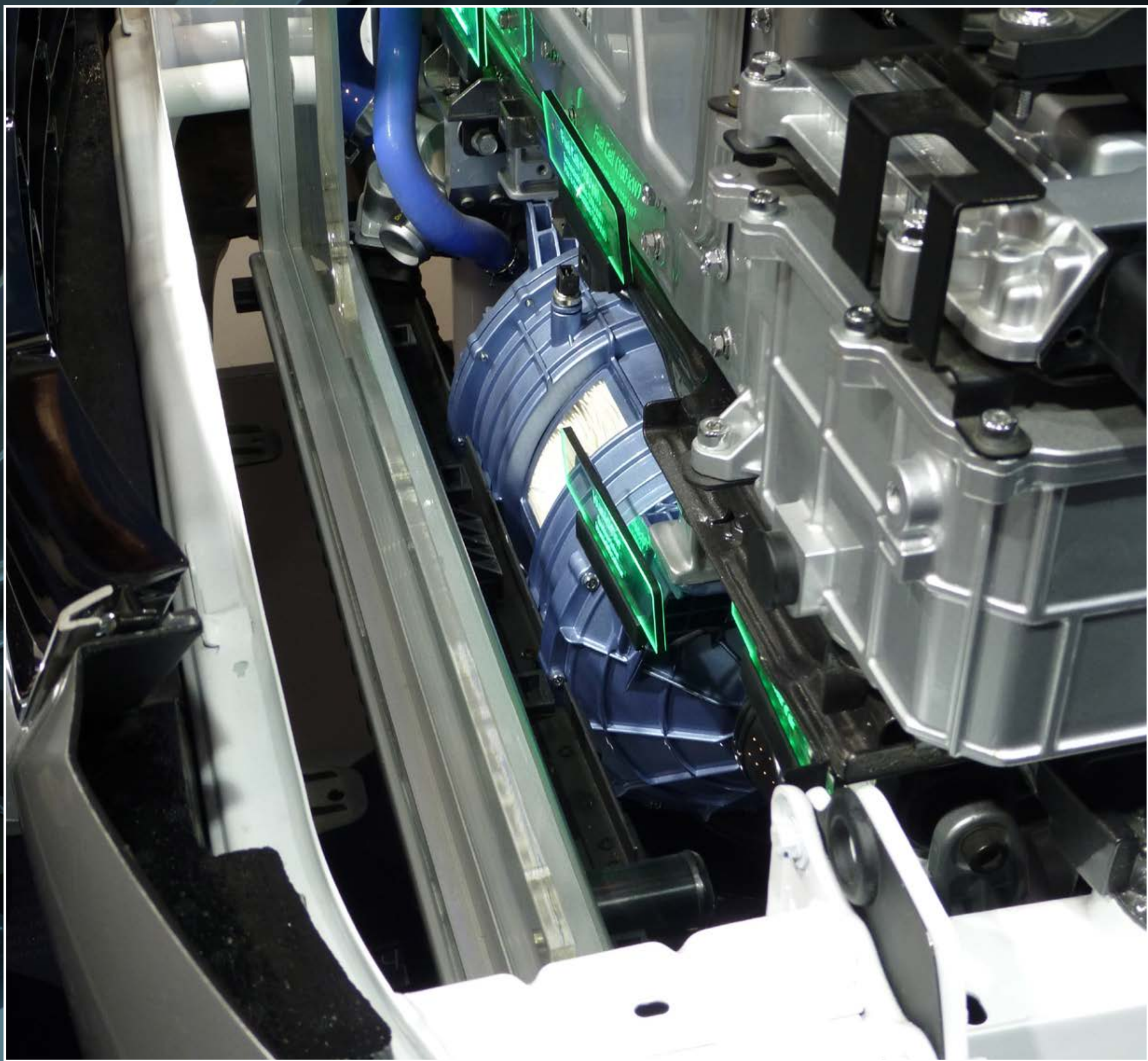


Hyundai is another manufacturer firmly behind the technology. Already Hyundai is testing its third generation of FCEV, the ix35 SUV (with a 325 mile range). Its initial production run of 1000 FCEV's began on the 26th February this year with assembly line production of fuel cells, primarily for European fleets.

This is seen as development prior to mass production for governments and fleet users globally scheduled for 2015.

So development continues for both vehicles and, more importantly, for infrastructure to support these.

COMMERCIAL SALES AND VOLUME PRODUCTION ARE STILL A LITTLE WAY OFF. BUT MANUFACTURER CONFIDENCE IN THE PRACTICALITY AND POTENTIAL OF THIS TECHNOLOGY IS GROWING, WITNESSED BY AN AGREEMENT, SIGNED IN JANUARY THIS YEAR, BETWEEN DAIMLER, FORD, AND RENAULT NISSAN TO COLLABORATE ON DEVELOPING COMMONALITY OF COMPONENTS AND PROTOCOLS TO ACCELERATE GROWTH OF THE INFRASTRUCTURE AND TECHNOLOGY.

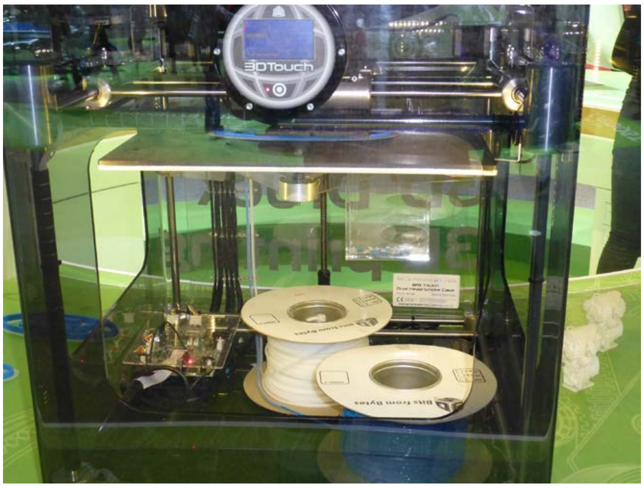


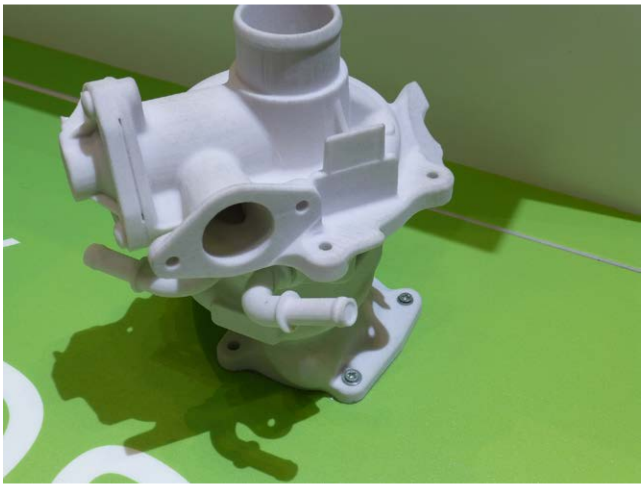
Additive Layer

Manufacturing

Additive Layer Manufacturing (ALM), Additive Manufacturing, or 3D printing as it is otherwise sometimes known, is a new technology rapidly gaining ground.

The equipment and software is readily available and any of us can order cheap plastic printed jewellery and household items from the internet.





But this is just the mass marketing aspect of the periphery of this technology and the boundaries are being expanded by much current research. The use of this technology is of relevance to the Automotive Industry. With the boundaries being pushed by motorsport applications and primary volume vehicle manufacturers who are investigating and assessing the benefits, this technology is advancing swiftly.

So what is Additive Layer Manufacturing?

The key word to understand this process is Layer. The component is built up slice by slice, just adding the material required by a tool passing overhead. This sort of explains the misnomer of "3D printing" as it appears in some ways similar to an inkjet printer.

It originated at the MIT (Massachusetts Institute of Technology) in 1993 where it was patented by Michael Cima and Emanuel Sachs. The original driver was to create 3D models and help speed up development of products such as medical devices by reducing time spent prototyping. Indeed, medical products are still a major volume product manufactured in this way.

The process typically involves a "stage", effectively a production platform that can be lowered incrementally by infinitesimal levels. At each level the platform is coated with a layer of powder; the depth of that layer dependent on the material being used for manufacture (typically 0.1mm for polymers).

A liquid binder is applied using a print head to bind the required powder together only where required for that layer/slice of the component. Then the platform is lowered and another layer added and the process repeats. Once sufficient layers have built up for the component to be complete the residual powder is removed and the surface of the component is finished if required.

The powder material can be of different compositions; metal, plastic or ceramic based, dependent on the component requirement.

Selective Laser Sintering (SLS) is a similar concept, but differs in that the material powder is fused together by a laser rather than a liquid binder. Also known as Selective Metal Melting or Generative Laser Melting, this is another additive layer manufacturing method that is being used for many metals including aluminium and titanium.

Why construct components using ALM?

The benefits, and potential benefits, are numerous;

• As the ALM machines are controlled by software linked to the original CAD model, production of a first component can be achieved quickly.

• For complex designs, with internal angles and changes in surface angles and dimensions, production in this way is far easier than milling from a solid billet or joining two of more parts to produce the design.

• More complex designs can be produced, not limited by assembly restrictions. Some developers of ALM process claim that in theory this process can produce whatever CAD can design.

• Material wastage is greatly reduced as the component is produced from only as much material as the component requires, without the swarf and wastage of machining/milling, and with the unused material powder being re-used. Some estimates suggest as much as 95% of material wastage can be removed.

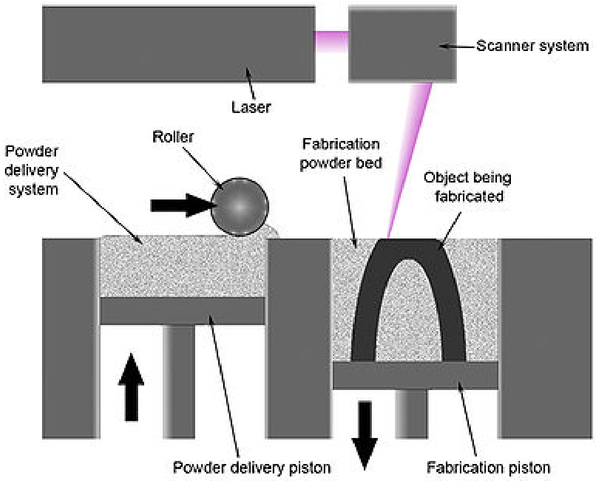
• As opposed to casting production methods for components produced from aluminium, there is no need for complicated moulds to be produced taking another risk of inaccuracy out of the process.

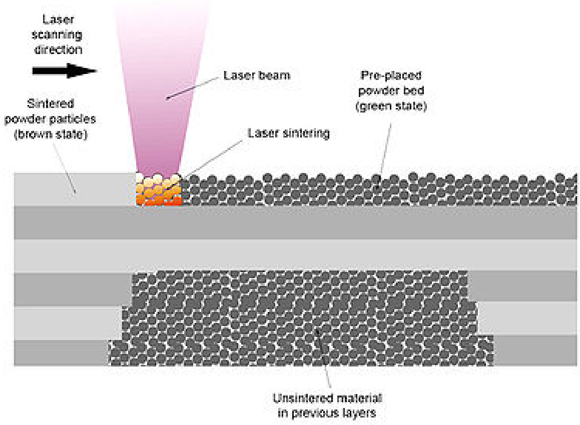
• Some multi-part components can be constructed in one piece, reducing subsequent assembly operations.

• As assembly tabs for machine handling/assembly are not required, the components can be produced with no additional or unnecessary weight.

• Much smaller production volumes can be undertaken accurately, but there is also greater potential for flexibility, with much easier amendment of dimensions of a component whilst the prototype component is being tested.

• For components that require internal voids this manufacturing process is far more accurate and efficient.





Where will we see ALM components?

Initially ALM has been used for production of design models and many plastic and polymer based medical products, but aerospace and automotive engineers are not being left behind.

The aerospace industry was quick in pushing for standards to be established so they could start integrating ALM components. The weight saving and component simplicity benefits of ALM are clearly attractive to them. Formula 1 teams and other motorsport manufacturers, including Daimler, Delphi and Bentley, have embraced the low volume production benefits of ALM, with quick improvements identified in testing which make it easier to integrate into production of low volume production runs by a quick modification to the pattern before printing.

Hydraulic components are another automotive market for ALM, with transmission gear change actuators that would previously have been constructed from 2 aluminium blocks assembled using bolts, being constructed as one piece using an ALM machine.

Complex fluid transfer components, such as heat exchangers and radiator matrixs, can be designed and engineered without the assembly limitations of conventional production processes and with greater structural integrity and less risk of consequential fluid leakage. To meet the demands of design packaging these components frequently need to fit into an irregular space and an ALM produced component is far easier to construct. For production volumes of vehicle manufacturers the reduction in production material wastage and speed to component development must make this process very attractive.

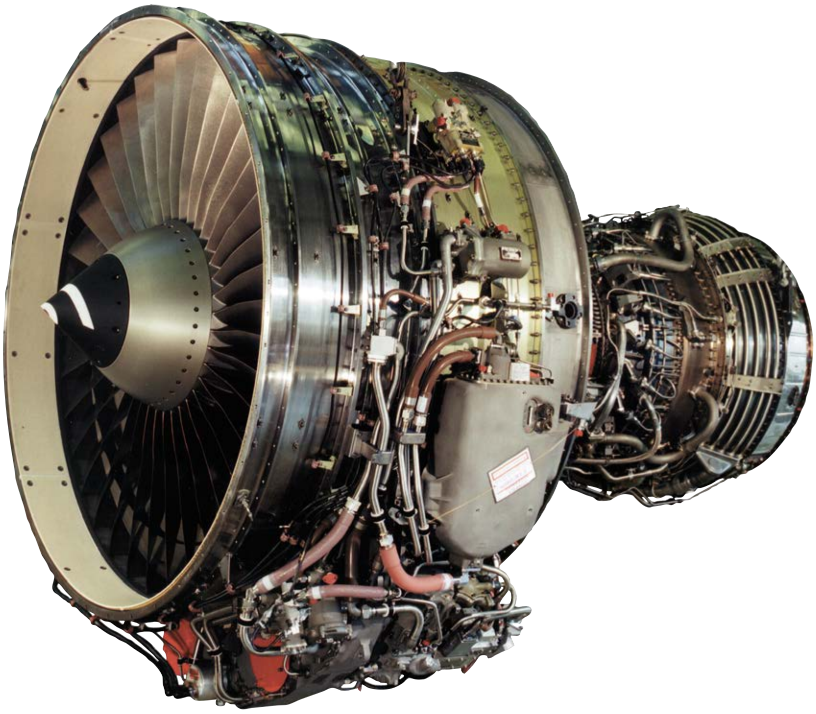
Many vehicle manufacturers believe that every joint between components is a potential squeak and rattle risk, so single-piece component and trim manufacture could be a future use.

NASA has been using this process to construct components for a new lower-cost (by NASA standards, less than the $63million per use Russian ISS system) rocket for delivering satellites into orbit. This is seen by NASA as not just cheaper and quicker than traditional production, but safer for rocket use as it reduces failure points inherent in material joining of multi-piece components.

ConceptLaser, a German supplier, has worked with NASA on this technology, but more significantly for us, has supplied a large chamber machine to Daimler. This machine was reportedly specified to have a chamber capable of ALM manufacture of an engine block and possibly even external body panels.

The future

The range of materials that can be integrated into ALM is increasing all the time. As research and development continues many major manufacturers, such as Boeing (that has used ALM components on the 787 Dreamliner) and GE Aviation, are getting involved and research projects are finding funding.



Some researchers, including the Massachusetts Institute of Technology, are looking at further enhancements that could be unique to this process; one such being Local Composition Control (LCC). This involves controlling the composition by adjusting the material powder and binder composition across the component at each individual layer. In this way different properties of the metal or plastic can be achieved, such as a soft lighter core with a hard external surface, or inherent but controlled flexibility.

This has already been trialled with prosthetic hip joints where this composition better matches human bones.

Different binders, different lasers, and enhanced software are giving further control over the ALM machine capabilities; the biggest limitation being the software at present.

Already there are ALM production machines with multiple heads (much like a colour inkjet printer) so that different binders and powders can be integrated into one component construction.

For some of the fluid cooling matrix components ALM has produced designs that are more efficient than those of conventional manufacture, with the ALM process allowing complex baffles to be included within the fluid chambers.

Some technology commentators are predicting a possibly significant upsurge in software and product development from single software developers, with some predictions of literally millions of inventors advancing this technology in their basements and garages, as with social media and smartphone apps. There is also expected to be a shift in production policy with many industries producing more in-house rather than contracting out to suppliers and manufacturers. NASA is just one example of a low volume production need being kept in-house already.

The impact of this on design and development speed has yet to be seen, but the number and calibre of the organisations assessing and acquiring this technology suggests it is seen as practical and mature enough to be adopted.

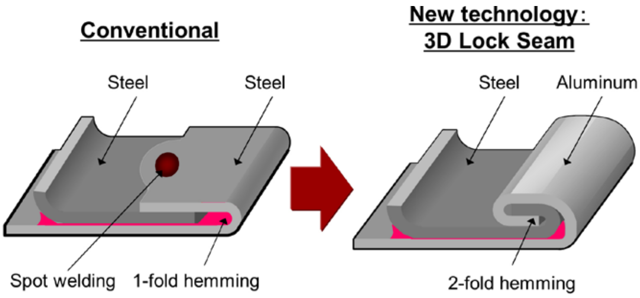
The aerospace industry, already used to large scale manufacturing, is watching and listening to developments, but is confident enough for GE Aviation to have acquired its own ALM manufacturer. So we can expect to see these components appearing in vehicles, probably initially prestige high value vehicles, fairly soon. How long before it becomes a mainstream part of vehicle production remains to be seen, but at the current rate of development it won't be long.

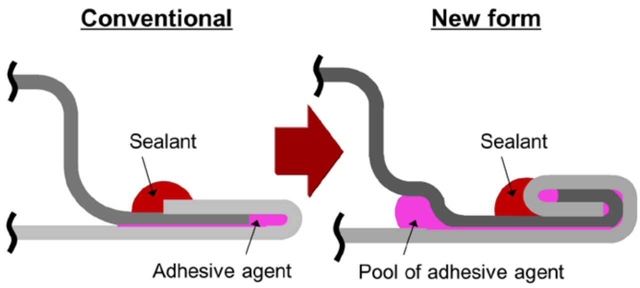
Thatcham will track introduction of these components and assess the materials involved, to establish the repairability of them and to keep a check on individual component prices which may be initially costly until economies of scale brings pricing down.

ANOTHER Honda JOINING METHOD IN THE USA

We have already seen Honda announce that it is using Friction Stir Welding for joining of aluminium and steel beginning with the front subframe on the 2013MY Accord. They have now also announced another process for the joining of two different materials, this time for an aluminium door skin onto a steel door panel.

HONDA HAS CALLED THIS PROCESS 3D LOCK SEAM (3DLS) AND IT PROVIDES A NUMBER OF BENEFITS. BY DOUBLING THE LAYERING AND HEMMING OF THE ALUMINIUM SKIN AROUND THE STEEL FRAME HONDA HAS REMOVED THE NEED FOR SPOT WELDING.





And this, together with the adoption of a low-elasticity adhesive, can be integrated into a regular production process in the manufacturing line. There is also a consequential elimination of the distortion that results from heat application inherent with welded processes of different materials. Better sealing is also a claimed advantage with the double hemming ensuring sealant completely fills the gaps.

Whilst not a new technology, it is new to automotive and has enabled Honda to further reduce the weight of the door panels of the Acura RLX (where it has debuted) by as much as 17%.

This vehicle is not destined for Europe, but as soon as 3DLS is released on a UK model Thatcham will research and provide repair methods.

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Automotive insight for Members

Colthrop Way, Thatcham
Berkshire RG19 4NR

t: +44 (0)1635 868855
f: +44 (0)1635 871346
w: www.thatcham.org

Thatcham Automotive Academy
Daytona Drive, Thatcham
Berkshire RG19 4ZD

t: +44 (0)1635 293174
f: +44 (0)1635 868863
w: www.thatcham.org

Thatcham (Thailand) Co., Ltd
128/208, 19th Floor Unit G,
Phayathai Plaza Building,
Phayathai Road,
Thung Phayathai,
Ratchathewi,
Bangkok 10400
Thailand

t: +66 (0) 2 612 0359
w: www.thatcham.org/thailand

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