Image courtesy of GWR.

New Life for Old Rolling Stock

How GWR uses 3D printing to bring sustainability to the rails.

How do you accelerate the transition from fossil fuel-burning rail travel to a more earth-friendly electrified model? Great Western Railway (GWR) in the UK thinks it has found a way with the help of 3D printing.

Case Study

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A Greener Alternative to Rail Transport

GWR is a train operating company operating in the southwest UK. As a leading rail-industry innovator, the company is pioneering the country's only fast-charging battery train by converting older rail cars destined for the scrap yard. Much of the UK rail network is not electrified with standard overhead power cables, leaving expensive and polluting diesel trains as the only current alternative. But with a creative turn toward transport sustainability, GWR takes old D78 stock London District Line trains and refurbishes them into modern battery-electric units.

While electrified power lines remain the gold standard for electric rail transport, progress in expanding this infrastructure can be slow. "It's very costly, and logistically, it's very hard. And with those two parameters comes the inertia of getting it done," says Julian Fletcher, Technical Development Manager at GWR. "So then you look at battery trains and say, 'where do they fit in?' Over recent years, battery technology has meant that they're viable, and charging technology now means they're a practical option for shorter branch lines," Fletcher adds.

This means fast-charging battery-powered trains, such as the Greenford-to-West Ealing branch in North West London, will enable the UK to decarbonize commuter lines more rapidly. This is particularly important since battery-electric power offers a lower cost per mile than hydrogen or diesel alternatives, and air quality benefits too.

An example of a Class 230 train that GWR is converting to electrification.

Image courtesy of GWR.

Rapid Charging Keeps the Trains Running

GWR's battery train can operate a complete daily schedule and satisfy emergency conditions, but it must be recharged at some point. To achieve this, GWR developed an ingenious fast-charge "rail and shoe gear" system that recharges the batteries while the train is in the station. As the train pulls into the station, the shoe gear assembly is lowered, and then engages with conductive rails as the train comes to a halt. These rails then supply electricity from trackside batteries to rapidly charge the train in a matter of 10 minutes.

Achieving this innovative design was not without its difficulties, however. Covers are needed to protect the shoe gear components, but space restrictions underneath the train made their design a challenge. "You couldn't make them out of bent steel, and casting them was out of the question in our time scales. So industrial 3D printing was really the answer," says Fletcher. The high-strength, fire-resistant properties of ULTEM™ 9085 resin provided an appropriate material choice. Additive's design freedom also meant that GWR engineers could take advantage of the remaining space under the train to locate the sensors for the shoe gear.

The train is expected to operate in freezing British winters and the ever-increasingly hot summers. Thanks to the extensive Stratasys material test data available for ULTEM™ 9085 resin, GWR was able to obtain all the necessary mechanical performance specifications at a temperature range of -54 °C to 149 °C. Coupled with Stratasys EN 45545-2 European railway fire safety standard data, GWR engineers were satisfied that the material met all of their requirements.

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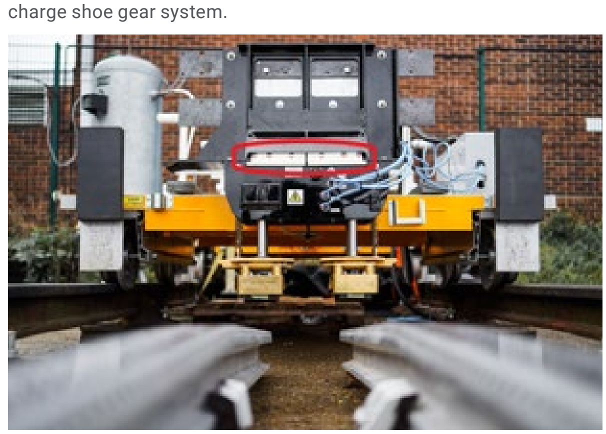
> These weren't a desktop print job. They had to be done in a controlled way. There are fire regulations to meet, so the material's got to be right and it has to be traceable. That's where Stratasys came in with the expertise, which means we had a controlled industrial partner to work with.

JULIAN FLETCHER,
Technical Development Manager at GWR

A view of the ULTEM™ 9085 resin parts installed on top of the fast-charge shoe gear system.



The test bed for the fast-charge system showing the location of the 3D printed ULTEM™ parts (circled).

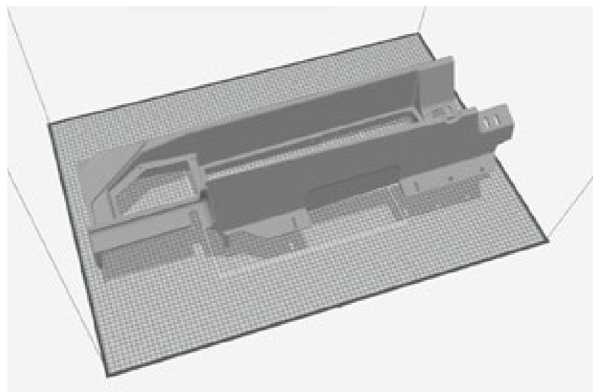
Proof of Additive's Versatility

A sterling example of one of additive's core benefits is its application diversity. It gives engineers the tools to find time- and cost-efficient solutions for a wide variety of problems. This is evidenced in GWR's ability to use 3D printing for multiple use cases to prep the train for its debut schedule under an extremely tight deadline.

In addition to the shoe gear covers, there was a need for a replacement driver dashboard. The original part was an aluminum casting, but a replacement part was plagued by porosity and other finish problems, causing serious delays in the train's operational readiness.

GWR engineers contacted Stratasys to obtain a 3D printed replacement dashboard since previous efforts to find a resource capable of printing large parts in fire-safe materials proved fruitless. In turn, Stratasys application engineers developed and printed a replacement dashboard on an F900® printer, which has sufficient build volume to produce sizeable parts.

In addition to receiving the part within the short lead time of a week, GWR engineers found that it was 57% lighter than the casting (3.5 kg vs. 8.1 kg) and didn't have the same geometry constraints on the system that designers previously needed to consider when working with a foundry casting. GWR Mechanical Design Manager Daniel Jones noted that once the dashboard was painted the same color as the rest of the cabin, the printed component was almost indistinguishable from the original.



A view of the dashboard model in GrabCAD Print™ file preparation software. The 860 mm long driver's dash easily fits in the F900's 914 x 610 x 914 mm build bed.

The 3D printed dash assembly installed in the train.

Polymer Materials
Provide the Answer

GWR engineers soon realized that besides the cost and weight savings, replacing metal components with 3D printed polymers yields additional benefits. For example, the upgraded trains are outfitted with metal air conditioning ducts and vents in the cabin ceiling. As the chilled air exits the ducting and meets rising humidity from the passenger compartment, condensation forms on the metal vent, which could drip onto passengers. To avoid this problem, polymer 3D printed vents that retain higher surface temperatures were selected to prevent condensation from forming.

The vent's design uses two printed brackets to enable it to be conveniently mounted into the existing holes from the previous design. Planning to ensure that these additive components would have a long service life, GWR engineers incorporated compression limiters that are press fitted after printing, providing a convenient method of ensuring sufficient compressive strength in polymer bolted connections.

A view of the 3D printed vent located in the train cabin ceiling (circled).

Replacing Old Parts With
3D Printed Alternatives

Following the success of the driver's dash, GWR engineers approached Stratasys to help solve a supplier issue with the driver-side display bezel. This time, Stratasys engineers suggested printing the part with a particular FDM® material to meet transportation regulations.

The Stratasys FDM material portfolio includes Validated Materials developed in partnership with third-party suppliers such as Kimya to bring new FDM materials to market faster. For this application, Stratasys engineers used Kimya PC-FR, a fire-retardant polycarbonate material for lower-requirement applications, offering a cost-effective alternative to more expensive thermoplastics. The result was a replacement part produced quickly and less expensively than alternatives while still meeting the highest HL3 railway fire hazard level.

The 3D printed bezel made with Kimya PC-FR material surrounding the driver's display panel.

As a reference, table 1 compares the Kimya validated material and several other polymers with FST (flame/smoke/toxicity) standards capability. It shows how thick each material needs to be to pass the EN45545-2 HL3 railway fire hazard level.

Material	Thickness to Pass HL3	Technology
Kimya PC-FR	3mm	FDM
ULTEM™ 9085 Resin	1mm	FDM
LOCTITE 3D 3955 HDT280 FST	3mm*	P3™ DLP

*(HL2)

Table 1

However, FST-rated materials may not be required in certain circumstances, and non-FST-rated Stratasys materials can be used successfully, as indicated in Table 2. For example, dispensation can be made when the part's weight is below a specific value. The EN45545-2 standards provide more documentation on combustible mass, surface area, part location, and grouping.

Location	Weight Below Which FST Rating Not Required	Suitability
Internal	100g	All Stratasys Technologies & Materials
External	400g	All Stratasys Technologies & Materials

Table 2

Additive Manufacturing – The Solution That's Hard to Beat

Most manufacturing problems have some form of solution, but the efficacy and elegance of those solutions vary widely. Additive manufacturing is one that arguably falls on the "elegantly effective" side of the ledger. Its ability to give GWR a fast, efficient, and effectual means of recycling trains is a testament to that fact. The right materials and the ability to create parts quickly, free from typical manufacturability constraints, made the difference, just as it has for countless other forward-thinking companies like GWR.

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