Progress makes perfect

Many of the processes used in volume production at Aston Martin are also being used to produce the One-77, as Julian Buckley finds out on a visit to both the supercar's dedicated build unit and the company's full manufacturing facility

In 2007, Aston Martin revealed that it was to produce a £1.2 million ($2 million) supercar. A technical tour de force, the car would feature a carbon fibre chassis with handmade aluminium body panels and a 7.3 litre V12 engine. Tentatively named One-77, the manufacturing run of the new car would be a suitably small 77 units.

Fast forward to August 2011 and production of the One-77 – the prototype name was carried over – will be completed by the end of the year. Yet while many of the features included in the supercar's build required development of techniques new to the carmaker, there is also considerable crossover between the One-77 project and Aston Martin's 'volume' production in the UK, which currently includes the DBS, DB9, Vantage and the new Virage.

Chris Porritt, Chief Engineer for the One-77 picks up the story. "The carbon fibre (CF) chassis is made up of one major part and a kit of smaller CF parts. These are made in Toronto, Canada, and kitted in the UK. The completed chassis is then delivered to our BIW supplier, where all the hand-made aluminium panels are bonded to the CF structure."

While no other Aston Martin has ever used a CF chassis - core models and racing versions (DBR9) are all based on a bonded chassis formed from extruded and forged aluminium parts - use of aluminium for outer body panels is standard across the range. The key differences here are the hand-forming of the panels and the adhesives used to complete the panel-chassis joins.

Porritt: "We get a number of different adhesives [for the One-77], from suppliers such as 3M, DOW and Sika, using the appropriate adhesive for each job. We use 3M product for joining structural parts, others for plastic-to-plastic and carbon-to-aluminium. Between the panels, the adhesive is effectively both a glue and a filler, but it must be silicone-free or else it could react with the paint."

As with any join between two different materials, a certain

Chris Porritt, Chief Engineer for the Aston Martin One-77

amount of elasticity must be present, though unlike more common steel-aluminium joins, only the aluminium in the CF-aluminium bond has the potential to expand. "In some areas the panels are allowed to flex, in other areas we restrain the panel. The big problem is with the back of the car; we call this the 'clamshell'. This is formed using a single sheet of aluminium that is created by TIG-welding smaller sections to a larger central part. It's structurally bonded [to the chassis] in places and in others it's allowed to move just slightly."

Where as the body panels for volume production are delivered by suppliers, Porritt says that it takes up to three weeks for a team of eight to produce the hand-made panels for one car, each working on a specific area of the body. A further two weeks is required to fit the panels to the carbon fibre chassis. He adds that while it takes approximately 220 man hours to produce a DB9, about 2,700 man hours are required to build a One-77, and that does not include production of the bodywork. Making the body in this way could seem excessive, but Porritt points out that to develop tooling for the very limited run of cars would have been prohibitively expensive.

Once the body panels have been applied, the car is delivered to the dedicated facility at Aston Martin where each car undergoes final assembly. Joe Healy, Production Manager for the One-77 says that the first step is to put the cars on the co-ordinate measuring machine. As there is only one unit, located in the main factory, and every manufactured vehicle is tested, One-77 models are usually processed at night. Paint is the next step - the cars are hand-painted in a dedicated area of the same paintshop that processes the volume models, using a range of model-specific colours. Upon completion, the car is returned to the assembly area, where all the painted panels are removed and stored in custom racking to preserve the finish; Healy points out that it also allows better access for assembly activities.

"The fenders are put on a jig and turned upside down for ease of access and then the [front] grilled is added. We do as much work as we can away from the car."

In much the same way that most cars are manufactured, the first assembly step for a $2m supercar is to add the wiring harness, while fixing studs are added for attaching other parts. Some of these are bonded to the CF chassis, while others require a little more work, as Chris Porritt explains: "Between the CF layers is an aluminium honeycomb; you can't bolt something directly through it or this will be pressed down. In these cases, we put in an aluminium insert and we can drill and tap these later on – there are about 140 of them on each chassis and each has a tag that is pulled out so a CNC machine can tap them all. This is done robotically, except where the robot cannot reach."

As other manufacturers are developing ways to use CF in mass-production, such as the BMW i3 and i8 models, does that in any way devalue the One-77 and its carbon fibre chassis? Porritt: "I don't think so. What we've got here is a motorsport process using a relatively expensive material - chassis builders MTC also produce Lola cars for the Indy Racing League. But the thing that makes the car so expensive is the labour. If you invest a lot of money, which is what the high-volume manufacturers are doing, and reduce the man hours, that takes the cost down. But the material is still expensive, it's the lightest, strongest available per unit kilogram. Some companies are substituting glass fibre for CF, which brings the cost down, but you lose some of the material's inherent properties, such as rigidity.

"For us, this is an opportunity to investigate the material and understand the structural benefits in a lower-volume, high-tech model, that could ultimately allow us to disseminate that knowledge down through the [Aston Martin] range."

Specific solutions

Asked if there were any problems associated with putting the One-77 into production, Porritt first offers a wry smile. "Yes, there were problems, but engineering is all about solving problems, finding solutions to problems before they get to the customer." One example he highlights was the development of the foot for the door mirror, which required a unique solution developed by CPP, the aluminium panel provider. The completed assembly now uses a machined aluminium part, production of which was further complicated by having a hollow interior, needed to feed the wiring through to the mirror unit.

Although the sculpted foot appears quite fragile, it underwent an unusual testing process that included Porritt standing on the attached part to test its strength. "It uses an welded overlap joint that is then finished back. But we had to attach [the mirror unit] which means adding quite a lot of mass onto a very thin structure, which could distort →

Core production

In June this year, Aston Martin announced that production of the Rapide four-door sports saloon would be moved from the dedicated facility at Magna Steyr, located in Graz, Austria, back to company headquarters. This will mean that core production will cover production of every Aston Martin model, an impressive mix in any plant.

Every vehicle built by Aston Martin starts with production of the bonded aluminium tub. Like at Graz, the area where the tubs are constructed is kept meticulously clean – all staff must change into special clothing to enter the shop. Would dust affect the performance of the adhesive used to bond the aluminium parts? Nick Lines, Head of Manufacturing at Aston Martin: "As part of the adhesive development process, we tested the tolerance of the bonds and while they can withstand a degree of contamination, we work on the idea that keeping the room clean will avoid the problem. It's better to start with that approach than risk a degree of contamination."

Cosworth delivers the 7.3 litre V12 engine for the One-77

Do customers unfamiliar with the technique sometimes worry about the process? "Customers are amazed, they think it's great," says Lines. "We put a lot of work into the robustness of the process making the tub, and every tub we make is equally robust.

"With every vehicle we produce, a set of coupons is made up of the same material that was anodized with the tub, using the same glue. For every vehicle, we break one of these tokens and assess energy, load, and other characteristics to validate the process."

He adds that how the tubs are constructed falls under the 'VH' or Vertical-Horizontal architecture. Essentially, this translates to how similar elements are apparent across the whole model range, a practise of sharing that Lines says allows the company to be both flexible and responsive to changes the market place.

when welded." For added strength the foot is also attached to the CF inner, but Porritt admits that if it was damaged, the whole door panel would likely have to be replaced.

The preference to machine rather than cast aluminium

The mirror foot is machined from solid aluminium

parts is apparent throughout the car, particularly in the engine bay. "Like the body panels, it's not viable to tool and then machine components. The engine bay sides are machined from solid. While we could have cast this part, it's better machined; it's a jewellery piece for the car. New craftsmanship is using machines to make something that is beautiful and still functional. You don't get the same thought and detail in higher-volume components."

Also under the bonnet is an engine air intake formed from CF. Instead of a separate part that is bonded onto the chassis, the intake is an integral part of the tub, which is even shaped to improve air flow. "It forms a plenum inside, which actually gave us a small increase in performance," says Porritt.

While there are many impressive elements on the front of the car, the most notable are the intakes incorporated into the headlights. Porritt says that when he first saw these, he imagined that they would act as cooling ducts for the brakes, but instead they now serve as entry points for the CF air intakes. "We thought they'd cool the brake pads, but they're in totally the wrong place. The laws of physics and design tend to clash sometimes."

Set into the bonnet, the vents are all handmade from stainless steel, with each vane positioned at a different angle to maximise air flow; a mix of function and form. The grille is the same, with each of the individual slats machined separately and then screwed together by hand. Engineers, says Porritt, like things to be at 90 degrees, but he confesses to thinking that the finished product 'looks fantastic'.

Interior parts

All of the aluminium trim parts for the One-77 are machined from solid, unlike the volume models which use cast aluminium or CF parts in the same areas. Chris Porritt explains that the parts are drilled and tapped as part of the machining process. The parts are trimmed with leather by a team of four employees hand-picked from the workshop next to the main production line who complete the whole package, from seats to the IP.

An example of this is the door handrail. As with all the interior parts, these are produced by Kussmaul, a German part manufacturer that also delivers parts for cars including the Bugatti Veyron. Brushed and anodized, the handrail is delivered ready to receive its leather cladding; the component even comes with the Aston Martin wings etched on the interior.

Joe Healy further says that the same attention to detail is included in the leather-wrapped instrument panel, which is based on the same extruded and cast aluminium frame used in all Aston Martin products. "We test as much as we can before anything goes in the car, including the IP. We've electronic kits that simulate the IP being in the car and we power up the fans, satellite navigation, all the electronics. It's a very similar process to the mainstream products."

Final stages

Healy says that once the mechanicals are completed the body panels are reattached. The first panel added to the car is the clamshell, with all others added in sequence from the rear to the front of the car. As the aluminium panels are fixed to the CF chassis, are there any problems related to setting panel gaps? "We have adjustments within the profiling set," he explains, "but the original panels are set to very tight tolerances."

He goes on to say that at every stage of the build process, an independent auditor (an Aston Martin employee who is not involved with building the car), carries out checks and tests. "On a small build like this," Healy explains, "we are able to react very quickly to any concerns that are raised. The defects-per-vehicle is very low."

As the cars are built up, rather than the vehicles coming

Ubisense gives Aston Martin production visibility

Aston Martin is using a real-time location solution from Ubisense to gain complete visibility of offline production processes at its headquarters in Gaydon, UK. The Ubisense solution provides engineers with visibility of each car as it progresses from the end of the assembly line through to its final point of departure from the manufacturing facility.

As every Aston Martin is unique, each car's journey through the factory, and in particular through the finishing process, is slightly different and therefore difficult to measure. As a result, Aston Martin engineers decided to automate the process using an active radio frequency identification (RFID) solution from Ubisense.

Production engineers outlined each stage of the finishing process in terms of a graphic area, such as rolling-road, wheel alignment, rectification, etc. If they could track each car in real-time as it entered and exited each area, this would enable measurement and analysis of each process step, determining where critical bottlenecks were located and where they could focus efforts on improvement.

The Ubisense solution was installed at Aston Martin in 2009. After a short initial installation and test phase it has been continuously operational ever since. The solution consists of a network of readers, sitting on a standard local area network, positioned throughout the plant. These sensors receive positional data from small ultra-wide band transmitters (active RFID tags) mounted inside the cars, which allow the system to compute the position of the car to within a foot of its location in the factory, in real-time. Such positional accuracy is fundamental in allowing each car to be traced as it makes its journey through the finishing part of the factory. Upon completion, the tag is removed and recycled.

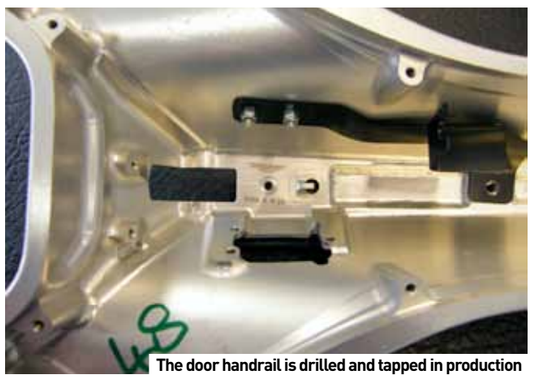
When it comes to analysing the information produced by the sensor network, Ubisense application software presents all users with a real-time view of where every car is in the factory via the company intranet, along with all associated data. Shown as a map, this allows users to determine exactly where each vehicle is in its process and critically, how long it has spent in each area. This information is logged for retrieval and analysis, providing process engineers with a further tool on which to base continuous improvements. The system is managed day-to-day by internal Aston Martin production employees.

The carbon fibre engine air intake and the engine bay wall on the One-77

to the workers on a line, the roles are reversed as specialist teams attend cars at fixed stations with sets of pre-kitted parts. Final checks include a paint rectification process that takes about three hours, where the finish is checked for attributes including paint thickness, brilliance and colour. "We have test data to show what we've done," says Healy. "We try to take the subjectivity away from it, so rather than 'I think', we have full test results."

Speaking with Chris Porritt, he explains that potential customers often ask how Aston Martin justifies the price of the One-77. "After you point out the details, they know why. They're buying a little bit of my engineering team's thought and skill, the energy that goes into making the panels, the CF lay up. You get that with our other cars, but it's not as apparent as it is with this model."

Nick Lines, Head of Manufacturing at Aston Martin, agrees that other elements of the One-77 build could be incorporated in volume production. "There are some innovative tool solutions being used for the car, and we will eventually deploy those in the main workshop." These include torque wrenches that deliver data via a wireless connection as each process is completed. In the One-77 shop, these tools are made of carbon fibre; while it's unlikely the same material would be used in volume production, the underlying technology could clearly benefit core production.



The door handrail is drilled and tapped in production

Lines adds that in terms of process efficiencies, these are usually measured over a timescale of about a year, so the One-77 has not been subjected to the same scrutiny as core production. That said, he notes that the engineering teams from both build areas have been in constant communication, creating a rich idea stream: "It really is a two-way flow."

Core production

In June this year, Aston Martin announced that production of the Rapide four-door sports saloon would be moved from the dedicated facility at Magna Steyr, located in Graz, Austria, back to company headquarters. This will mean that core production will build every Aston Martin model, an impressive mix in any plant.

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Although it is clear that adhesive bonding works as a chassis production methodology, do customers unfamiliar with the technique sometimes worry about the process? "Customers are amazed, they think it's great," says Lines. "We put a lot of work into the robustness of the process

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End of the BIW line for volume production

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He adds that how the tubs are constructed falls under the 'VH' or Vertical-Horizontal architecture. Essentially, this translates to how similar elements are apparent across the whole model range, a practise of sharing that Lines says allows the company to be both flexible and responsive to changes the market place.

Limited automation

The finished tubs are then fed through to the BIW line where the outer panels are bonded to each of the cars. After a precise amount of adhesive has been applied to the panels – in order to achieve the correct join without any panel deformation - they are loaded into tooling which closes around the tub, positioning the panels in order to achieve the join. Held in place, a blast of hot air sufficiently cures the adhesive to allow the car to move down the line. Once the panels have been added, the bolt-on structures, wings, bumpers and closures are applied.

In BIW and across the plant, Lines says that he looks very carefully at each instance of automation to see how it could affect efficiency or quality. "In some cases it can add to build consistency, but the craft skills we have here must be maintained in order to achieve the right quality level. For example, we use robots to apply the structural adhesive for the bodies, it's part of the build record. In the paintshop, we have a degree of automation for application, to achieve absolutely standard film builds, but special colours are still applied by hand."

Lines further explains that paintshop automation covers body interiors and exteriors, applying the base coat and the lacquer finish. Last year, the system was updated to include a system that allowed painting of any colour at any time, driven by the flexibility level in the BIW area. "We can achieve any sequence with almost no loss of paint," he says. While ABB provided the robotics, Lines believes that it is best to develop the skills needed to update their choreography in-house. "If there are specific things we need done, we'll call in our supplier, but we do a lot of the coding. It's clearly in our interest to train our employees to have those skills."

Adding the Rapide to production has brought about such changes in robotic motion, though not in the usual way. "For production of the Rapide, we had to look at the robots painting the car – it's longer, and it sits in different places in the booth. The way the system will work the car will move backwards and forwards, rather than the robots moving around it." This, Lines explains, is because reducing the amount of movement in the overhead-mounted robotics, there is less chance of any collected grime being dislodged from the tracking and falling on the car below. "Using this solution, we reduce the possibility of this issue."

Feeding the line

In BIW, and each successive shop, there is no batching; any model can be built at any time. In order to achieve this, Lines says that there is a heavy focus on build-to-sequence, meaning that once a car is launched into the system, parts must be made available for that model. He continues by saying the 50% of all inventory is held at the plant, with the other 50% in transit or at a warehouse about 20km away. "It didn't start like this," he says. "We have driven and driven for this and we don't accept where we are, as tomorrow it will be less."

After paint, the bodies are loaded by AGVs into bodystore before being delivered to either the low or high-volume line, the former of which Lines admits is acting more as an overflow capacity line. The Rapide, he says, will be added to production on the high-volume line, which currently builds the DBS, DB9, Virage and each of the soft-top versions. Will there be any problem supplying the variety of parts required for each individual model? "We've got agile systems and the employees are actively involved with pulling parts to the line. We won't accept a deviation from where we want to be and that includes sequencing."

A further part of line supply can be linked back to the project aimed at reducing the maximum height of lineside racking to 1.2 metres. This, says Lines, will improve visibility across the line, helping employees and visitors. "In reducing the racking you remove stock that isn't needed, you take out waste and that helps drive efficiencies and your quality. And customers will appreciate this, as the line is also a showcase for what we do here." The project has already reduced cost per car, he adds.

To help smooth introduction of the four-door model into series production, Lines says a lot more kitting of parts will be done, though by how much the current takt time of 37 minutes will have to be adjusted remains to be seen. Future plans aside, it is clear that production at Aston Martin has made great strides in terms of improved efficiencies since leaving its former headquarters in Newport Pagnell, UK. "Some of the people that worked in Newport didn't move with us but rejoined later on and they could see what we had put in place, how the company had moved on," says Lines.

But what will happen if annual production starts to approach its 2007 highpoint of 7,000 units? Could the plant as it is reach those figures with the increased model mix? Lines says that he knows where the bottlenecks are in the system, the curing oven and the paintshop. "We know each tub takes 29.5 minutes in the oven, and we know what the maximum volume is through the paintshop. Between these two areas we know what we need to do. If we need to, we will invest, but we're not chasing numbers."

With the One-77 build about to be completed and the Rapide sports saloon about to enter production at Gaydon, it will be interesting to see what the company will do next, but it's guaranteed to be worth a second look. ✱

Bodies are launched onto the assembly line by AGVs