GRAINGER & WORRALL

PROTOTYPING GIGA CASTINGS WITH SAND CASTING

How the sand casting process supports creating giga cast components for the automotive industry.

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The manufacturing of automotive components is undergoing something of a revolution. Drivers such as sustainability, net zero, and consumer behaviour are influencing how the automotive industry thinks about design and manufacturing processes. Of recent interest has been “Giga Casting”, the term used to denote large, structural castings. Whilst this idea is not new, it has come to prominence in recent years with the much publicised GIGA Press - 6000T/9000T HPDC machine.

With increased interest in this manufacturing method, the drive for prototyping these large, structural components has increased. Grainger and Worrall (G&W) have developed a novel approach to prototyping giga castings using sand casting methodologies. Whilst much of the detail of the process remains commercially sensitive, we can discuss some of the things we’ve learned along the way.

In this eBook we’ll be covering:

- The drive for sustainability
- What is giga casting?
- An overview of sand casting methodologies
- Prototyping giga castings using sand casting methods

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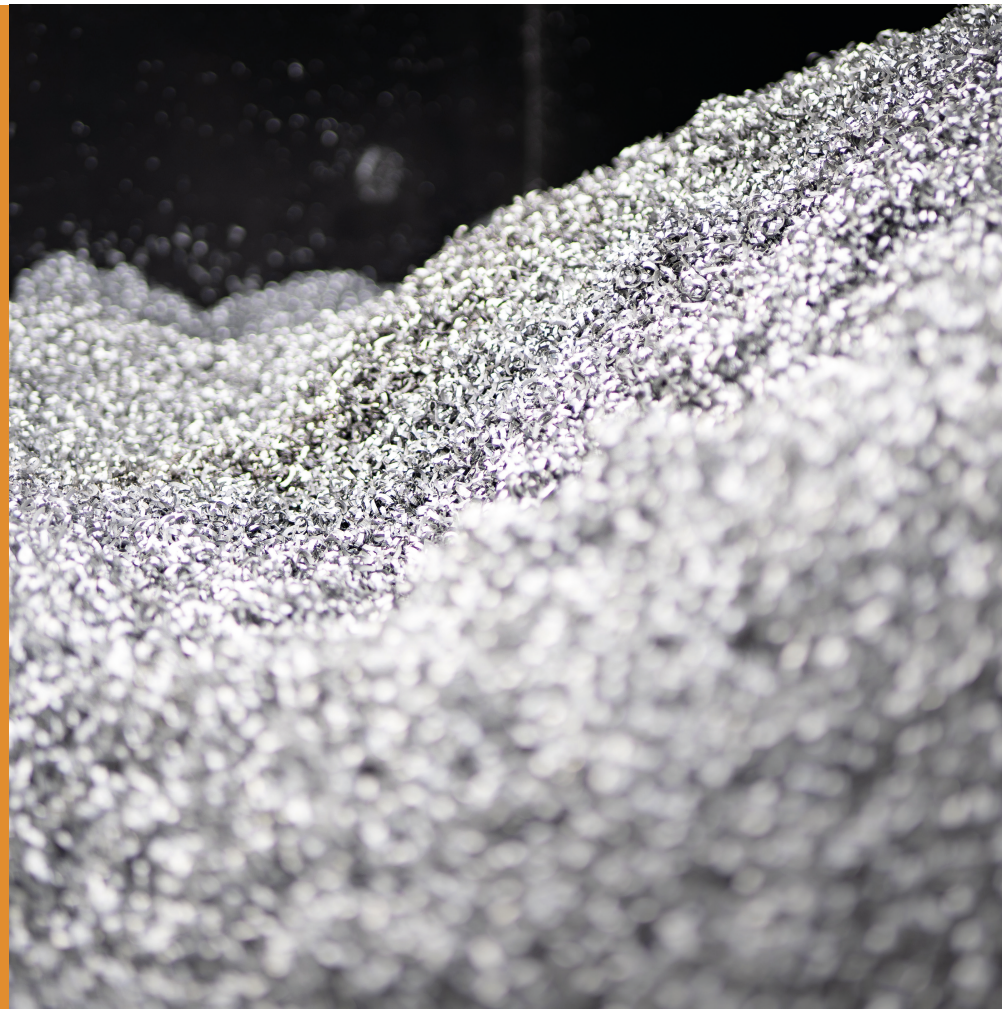
THE DRIVE FOR SUSTAINABILITY



THE DRIVE FOR SUSTAINABILITY

The automotive industry is under increasing pressure to become more sustainable through carbon reduction, innovative technology and optimised manufacturing processes. This is being driven by factors such as regulation and legislation such as the UK's plan to end of the sale of new petrol and diesel cars by 2030. In the UK, by 2035, all new cars and vans will need to be "zero emission" at the tail pipe. In the USA, President Biden announced that the goal was to have 50% of all new cars and light trucks to be zero-emission vehicles by 2030. In Europe, the aim is to end the sale of new CO2 emitting cars by 2035.

In response to this challenging, changing global backdrop, the automotive industry is re-thinking some of the previously held dogmas concerning its manufacturing processes. The direction of travel is now moving towards electric vehicles (EV) as manufacturers look to hit emission targets. This presents new challenges to manufacturers as they look to take EVs to a mass market. Reducing the cost of production is critical for mass adoption and hence part count reduction resulting in less assembly costs is an important consideration. Likewise, the impact of COVID-19 on global supply chains has increased the desire to reduce component count. Lightweighting of structural parts is also increasingly important for both EVs and ICE vehicles, which is driving new alloy development and manufacturing methods.

New technologies are emerging to meet these challenges – and one such technology is giga casting, which has the potential to reduce supply chain complexity and reduce costs. Giga casting is a process that allows the casting of large, complex body-in-white parts in a single piece typically utilising a die-casting process. It's an emerging technology that automotive manufacturers are increasingly embracing. However, given the relative expense of die-casting processes, it doesn't lend itself so readily to prototyping applications. G&W have developed a novel approach to rapid prototyping giga castings and produce the quantities required to support pre-production prototype build phases.

Given that the technology is relatively new, there needs to be more information surrounding the process, its potential and its value. Therefore, we've written this eBook to share the potential of prototyping giga castings and to begin a discussion around the importance of the process to the automotive industry.

“The need for increased sustainability in automotive manufacturing is driving casting innovation. Sand casting is playing a vital role in prototyping giga castings.”

SUSTAINABILITY AND GIGA CASTING

The automotive industry is striving to become more sustainable, driven by pressures such as consumer behaviour, net-zero regulation and legislation such as the 2030 UK Government ban on new ICE vehicles. However, in addition to increased sustainability, there's a commercial need to balance vehicle performance with vehicle cost. These differences will likely become more apparent when the difference between 'driving' and 'transportation' becomes more significant.

For mass EV adoption, vehicle costs must be reduced. This is creating the need to find new methods of manufacturing which reduce part count and thus assembly cost. Part of Tesla's mission is to 'accelerate the world's transition to sustainable energy through increasingly affordable electric vehicles'. Tesla has led the way in giga casting and alloy technology, enabling larger single-piece cast parts that simplify manufacturing.

A number of OEMs have proved the commercial and technical viability of giga casting structural components, other automotive manufacturers are following suit. However, this isn't only limited to automotive production – other manufacturers in other industries are also using this technology to reduce costs and simplify supply chains.

55%

The EU's target for reducing carbon emissions by 2030

2 Billion

How many EVs need to be on the road by 2050 to hit net zero

2035

Estimated year that every car and truck sold in the U.S. will be electric

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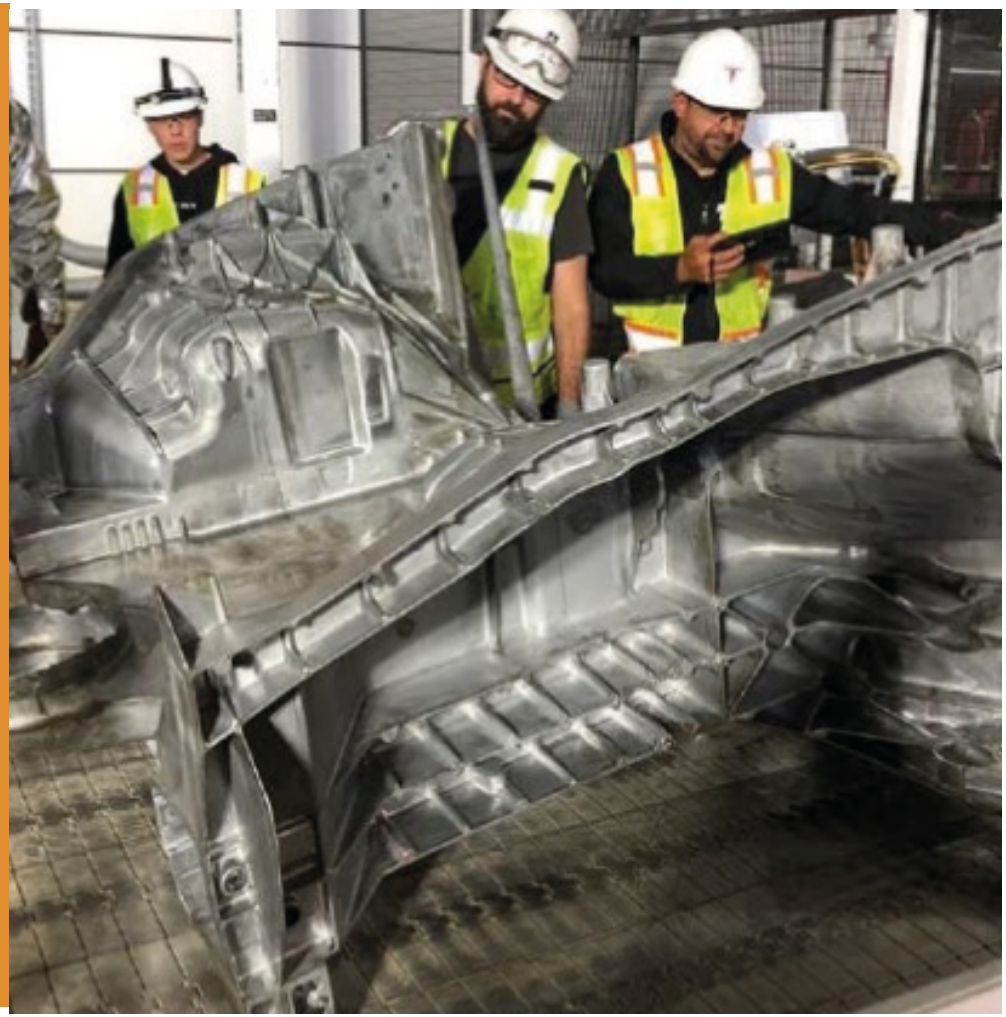
WHAT IS GIGA CASTING?



GIGA CASTING: REDUCING PART COUNT

Giga casting has been developed as a response to the need for new manufacturing approaches to achieve more sustainable automotive manufacturing. Giga casting delivers a key benefit: reducing part count.

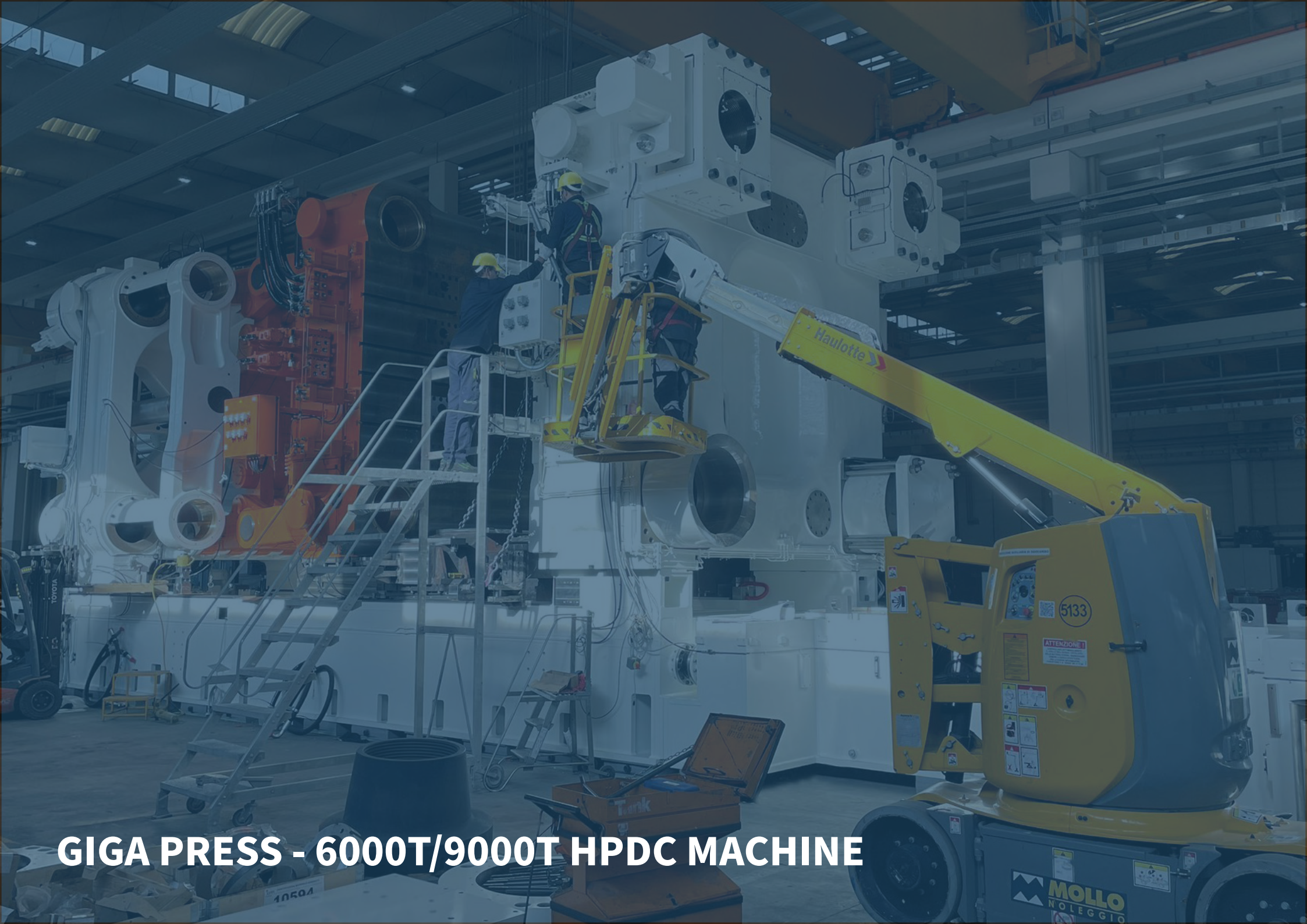
This ability to cast large, structural automotive components in a single cast piece enables engineers to create lighter vehicles, with fewer components requiring fewer steps in the supply chain.

Giga casting isn't the only solution to the challenge of reducing vehicle emissions, but it provides a route to creating lighter (and hence greener) vehicles. Additionally, removing steps in the manufacturing process also develops shorter and vertically de-risked supply chains, creating more cost-effective vehicles enabling greater potential for mass adoption.

Creating single piece body in white sections in a single piece has been made possible by the likes of the Buhler Group and the Idra Group. They have developed giga casting technology with its aluminium die cast machine. The large, high pressure machines weigh up to 430 tonnes and are capable of manufacturing body in white giga castings at impressive volumes. However, it is well recognised that die casting requires expensive moulds, significant investment and has limited opportunity to change casting design – making prototyping prior to mass manufacturing a vital stage to ensure casting validity and performance.

Die casting has high production volume capability for the mass manufacturing of giga cast structural parts. However, this also comes at a high cost. As well as the die-press machines required, the tooling needed to cast such large structures is extremely expensive. Die casting also offers limited design flexibility, requiring commitment to the design at the start of the casting process.

To validate part integrity and design, many automotive manufacturers have used sand casting to prototype components prior to moving to die-cast manufacturing. Historically, using sand casting to prototype body in white sections has presented challenges due to the spatial constraints, sand/mould requirements, and managing solidification rates with large castings.



GIGA PRESS - 6000T/9000T HPDC MACHINE

WHAT IS GIGA CASTING?

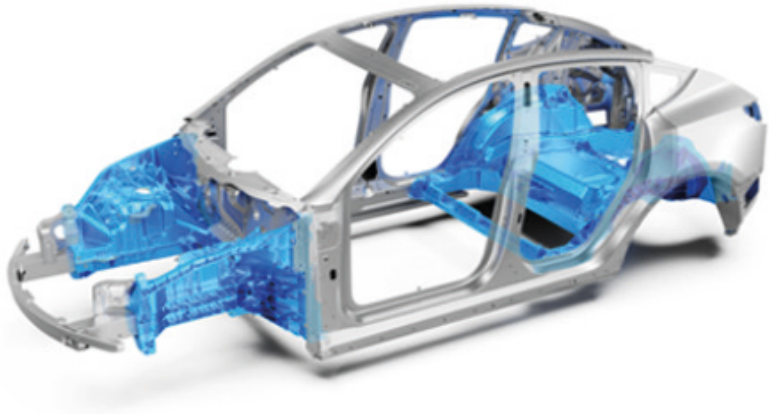
Giga castings are the consolidation of what has been traditionally extruded, stamped or cast metal into a single front end or rear end body structure. This allows automotive manufacturers to create large cast parts, or ‘giga castings’ in a single net piece.

To put this in perspective, the Tesla Model 3 required over 170 different pieces of sheet metal and over 1600 welds. In comparison, the Model Y replaces these parts with just a front and rear giga-casting, significantly reducing part count.

As well as lighter, faster vehicles, giga casting also offers potential benefits for logistics and emissions reduction, as well as increased flexibility in engineering the vehicle platform.

Model 3 body structure

171 pieces of metal highlighted



Austin-made Model Y body structure

2 pieces of metal highlighted

>1,600 fewer welds

WHAT ARE THE BENEFITS OF GIGA CASTING?

Giga casting allows for the ability to cast large, single-net structures has vast benefits for automotive production. Giga castings take a fundamentally different design and manufacturing approach to traditional vehicle manufacturing-casting single front and rear pieces.

The benefits of giga casting include the following:

- Reduced complexity in the vehicle structure reduces the cost and production time required.
- Extended use of aluminium contributes towards lighter vehicle architectures.
- Aluminium mega castings are more sustainable, increasing the use of scrap aluminium.
- Giga castings offer benefits as an architectural strategy. The nature of giga castings means a commitment to a design that will last a lifetime overproduction. While this does limit flexibility and the potential for design changes, this does drive vertical integration back into the supply chain.

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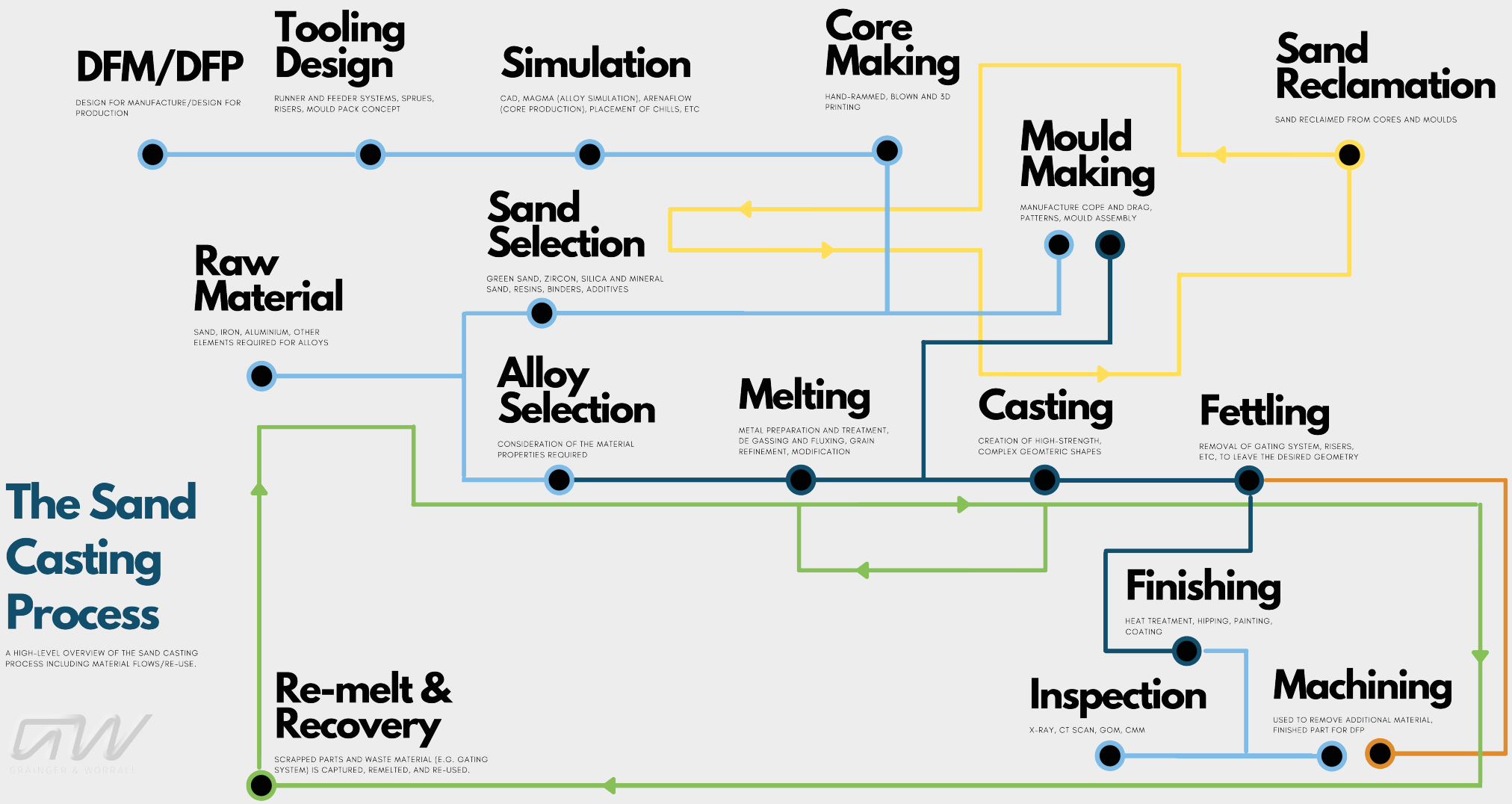
AN OVERVIEW OF SAND CASTING METHODOLOGIES



The Sand Casting Process

A HIGH-LEVEL OVERVIEW OF THE SAND CASTING PROCESS INCLUDING MATERIAL FLOWS/RE-USE.

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THE BASICS OF SAND CASTING

Sand casting involves pouring molten metal into a sand mould cavity, where it then cools and solidifies. After the metal has cooled, the mould is broken apart to remove the casting. Sand casting can produce complex net parts relatively quickly and cost efficiently compared to other processes. It' s also a nearly 100% circular process with all the raw materials (sand and metal) being able to be reused.

Sand casting is often misunderstood as a low tech production process. But this isn't true. While sand casting is one of the oldest production processes, modern sand casting uses technology to optimise the entire process; from initial enquiry stage through to production and inspection.

Data-driven science has evolved sand casting massively in just the last 20 years, delivering a process that can create the complex castings needed to meet global 21st century challenges. Sand casting has many advantages, especially in prototyping. It's a reliable, relatively quick, cost effective casting process; enabling highly complex parts to be created in almost any size, weight, or alloy and at low cost compared to other methods.

As a process, it's almost 100% circular in terms of sustainability. However, sand casting doesn't suit all applications. For example, volumes greater than 10,000 parts are not typically suitable for sand casting. However, the flexibility and potential of sand casting allows for changes and optimisation in almost any part of the process. These include materials (alloys and sand used), the casting process methods chosen, finishing and validation methods. All of these can optimise the function and material properties required for your part.

“Sand casting plays a huge role in prototyping giga castings. For a fraction of the price and with fast lead times, sand casting creates production representative parts - vital for proof of concept.”

Jay Schofield, Grainger & Worrall

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PROTOTYPING GIGA CASTINGS USING SAND CASTING METHODS

SAND CASTING AND PROTOTYPING GIGA CASTING

Create high-integrity prototype giga castings
Design for Manufacture and simulation software can help optimises part and process design to achieve innovative, complex castings. Utilising a Make Like Production (MLP) philosophy enables production specification in prototype parts.

Iterate designs quickly
Rapid prototyping techniques enabled by sand casting methods enable multiple iterations of product designs within tight timescales.

Develop bespoke alloys
One of the greatest advantages of sand casting is the ability to cast with a wide range of aluminium alloys. Different alloy compositions can be tailored to achieve specific attributes required for giga casting structural parts such as strength, durability, wall thickness and ductility.

A circular production process
Sand casting is a method of manufacturing that has the potential to be almost 100% circular. The sand and metal used can be recycled and reused across the process. This is of particular consideration with giga casting given the increased amount of sand and metal utilised in the prototyping process.

Additional manufacturing processes
Specific consideration needs to be given to finishing, machining and inspection capabilities to ensure they can handle the additional spatial complexities introduced by increased part dimensions.

"POURING A CASTING IS LIKE POURING A GUINNESS - IT'S ALL ABOUT CONTROLLING THE FLOW."

NEW METHODS OF PROTOTYPING AUTOMOTIVE COMPONENTS: THE TRANSITION TO GIGA CASTING

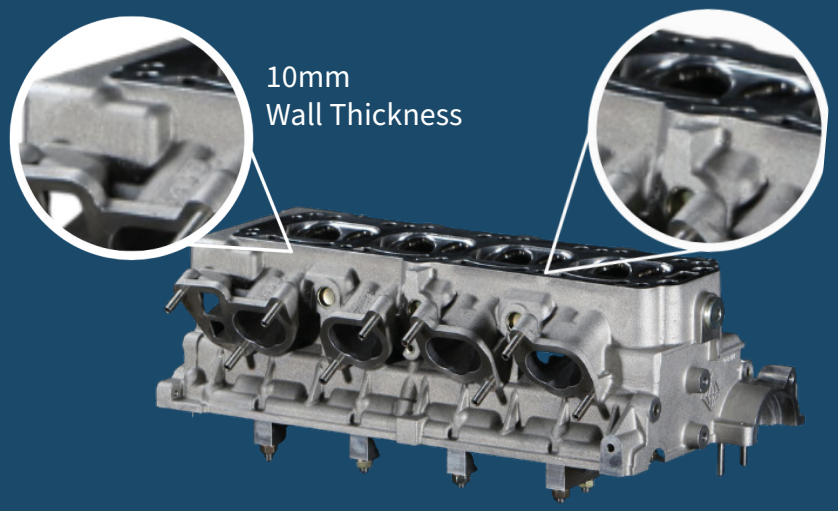
Sand casting has been favoured by OEM automotive manufacturers to prototype automotive components such as cylinder heads and blocks. Adopting a 'Make Like Production' approach to prototyping has helped shorten product development cycles. Before moving into the production phase, these prototype parts provide proof of concept and validate performance, design, safety, and material properties.

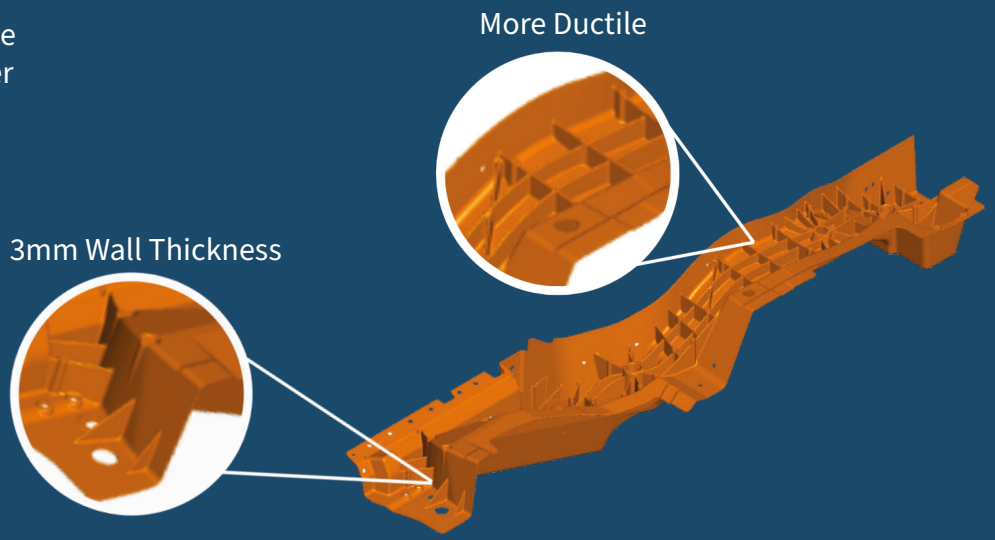
Making the transition from casting a complex prismatic structure such as an engine block towards casting thin-walled structural castings such as a structural underbody component, is not without its challenges. Whilst it may appear to be less complex to cast a battery tray for an EV compared to an engine block (with it's associated cores for cylinders, water coiling, etc.) this is not the case. The casting of large, structural components present challenges with respect to wall thicknesses, ductility, not to mention the unique specifications relating to how the part should "behave" given its specific function.

Sand casting has a considerable role to play in supporting the transition towards single piece parts made using a giga casting process. It enables the development of complex, large structural castings with specifically tailored alloys used for prototyping prior to mass production using die-cast methods.

Having spent decades developing casting technology for prismatic structures, G&W have evolved its capabilities and expertise to prototype large, structural, body in white components. The potential of this technology is being realised by an increasing number of customers looking to prototype structural parts to reduce component count, assembly time/cost. This innovative Giga Tile™ production method enables the potential to upscale of the prototype process to a small series supply, allowing us to meet the pre-production requirements of our customers.

COMPLEX PRISMATIC STRUCTURE VS LONGITUDINAL GIGA CASTINGS





CYLINDER HEAD COMPLEX PRISMATIC STRUCTURE		THIN-WALLED LONGITUDINAL GIGA CASTING
MATERIAL DENSE, COMPLEX CORE PACKAGE, HIGH STRENGTH REQUIREMENT.	DESCRIPTION	THIN WALL SECTION, LARGE SIZE, REQUIRES HIGH DUCTILITY.
10MM	WALL THICKNESS	3MM
300	STRENGTH MPa	220
4%	DUCTILITY	10%
95%	CASTING PREDICTABILITY	85%
90%	COMPLEXITY	100%

CHALLENGES OF PROTOTYPING GIGA CASTINGS

SIZE

The change in scale of giga castings is not incremental - it's a step change for the automotive industry. The size and scale of giga castings mean a different approach is required, across the entire manufacturing process.

This includes considerations such as:

- More physical manufacturing space is required.
- More sand is required for giga casting that can weigh over 7 tonnes.
- Different and bigger infrastructure is required to handle the casting.
- More space is needed to finish and machine the giga casting.
- The logistics of the supply chain pre and post production.

SHAPE

Giga castings have longer sections and thinner walls than traditionally cast components. The length of a single giga casting can **reach up to 1.5m**, requiring different handling.

Designing effective runner and feeder systems to control the rate of solidification in the giga casting is vital.

Longer, structural parts will also require different machining processes and equipment.

CHALLENGES OF PROTOTYPING GIGA CASTINGS

MATERIAL COMPOSITION

Giga castings have different material property and material composition requirements, both to allow the casting process and to achieve the desired final properties for the component.

Giga castings are required to flex and recover, requiring higher ductility and elongation compared to complex prismatic parts. Giga castings also need less strength to reduce brittleness.

Aluminium-silicon alloys can be developed to match these required properties at the prototyping stage, delivering robustness and elongation. Aluminium alloys allow thin-walled castings to be made as low as **2.8mm**, reducing the inherent mass volume of the part.

METHOD

Giga casting needs different approaches in design, heat treatment, machining and handling. This is creating a huge shift from traditional automotive manufacturing.

Giga castings require relatively fixed design architecture compared to traditional vehicle manufacturing. While this makes changes in the process difficult, this does drive discipline in the giga casting process- providing a ‘hard point’ which is important in automotive manufacturing.

Giga castings require a fundamental shift in engineering approach. Innovation is essential, using knowledge of casting to approach things differently.

HOW G&W HAVE EVOLVED THE PROCESS OF PROTOTYPING GIGA CASTINGS

THE "CONVENTIONAL" APPPROACH

Using conventional sand casting methods to prototype large (e.g. >1m) castings has a number of limitations.

Some challenges with the conventional approach are:

- Typically difficult to cast more than one part per week.
- Total weight of mould, sand, metal can be more than 5 tonne for Underbody castings presenting handling issues.
- Labour intensive process with greater risks due to monolithic moulds.
- One-off parts that may be reliant on repair and remedial processes (if one part of the casting is out of specification the whole mould pack needs re-designing).
- Customer process development hindered by prototyping lead-time.
- Not a sustainable approach to support real-life customer validation quantities.

THE "G&W" APPPROACH

G&W have developed an approach to prototyping giga castings that allows us to produce consistent, accurate structural parts much faster.

The G&W approach:

- More than one casting per day due to optimised process with greater repeatability.
- Engineered mould with 50% less sand solution for accuracy and sand removal.
- Moulds made from smaller cores that speed up production.
- Printed cores allow very fast changes to design.
- Rapid prototype development enabled by process infrastructure sized for ease of part handling and validation.

GW's approach to prototyping giga castings allows us to create large structural parts with complex functionality for body in white components.

FIRST GIGA CASTINGS AT GW

It was a moment that had been planned for what seemed like an age. Hundreds of hours had gone into the designing the mould pack to enable efficient handling and process repeatability.

Multiple simulations had been run to test sprue and riser placement before committing to tooling. These new giga castings had different shapes and structural properties compared to your classic engine block or cylinder head. What we thought would be less complex given the lack of holes and three-dimensional shapes turned out to be a fallacy. These large castings threw us a number of curve balls that had the most seasoned of G&W's engineers scratching their heads!

So here's what we did…

First we [redacted] After that we poured in the metal and [redacted] When we opened up the mould pack we noticed [redacted] but then we thought [redacted]

The dimensional properties of the [redacted] were accurate to [redacted] microns. This was due to the unique alloy composition using [redacted] to aid "make like production" characteristics.

So hopefully that gives you an overview of how the first giga casting went at G&W. If you need any further information feel free to get in touch.

Note – some details redacted due to commercial sensitivity.

“Giga casting requires a different mindset. It’s not difficult, but it is different.”

Jay Schofield,
Grainger & Worrall

We hope that this eBook has given you an insight into how sand casting can be used to prototype large structural parts for automotive components.

This is an emerging field of work but our body of knowledge increases on a daily basis with every giga casting we create. We recognise the giga casting structural parts is not going to be applicable for every automotive program. However, the technology now exists to rapidly prototype these structural castings at a rate and scale not previously possible. This provides automotive OEMs with flexibility to create new structural designs or adapt existing designs.

Whether its driven by an economic or environmental case, giga casting is revolutionising how the automotive industry is thinking about its manufacturing processes.

If you'd like to find out more about how G&W can help your company develop it's giga casting capabilities please get in touch.

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