HOW TO DESIGN FOR MANUFACTURE IN LIGHTWEIGHTING

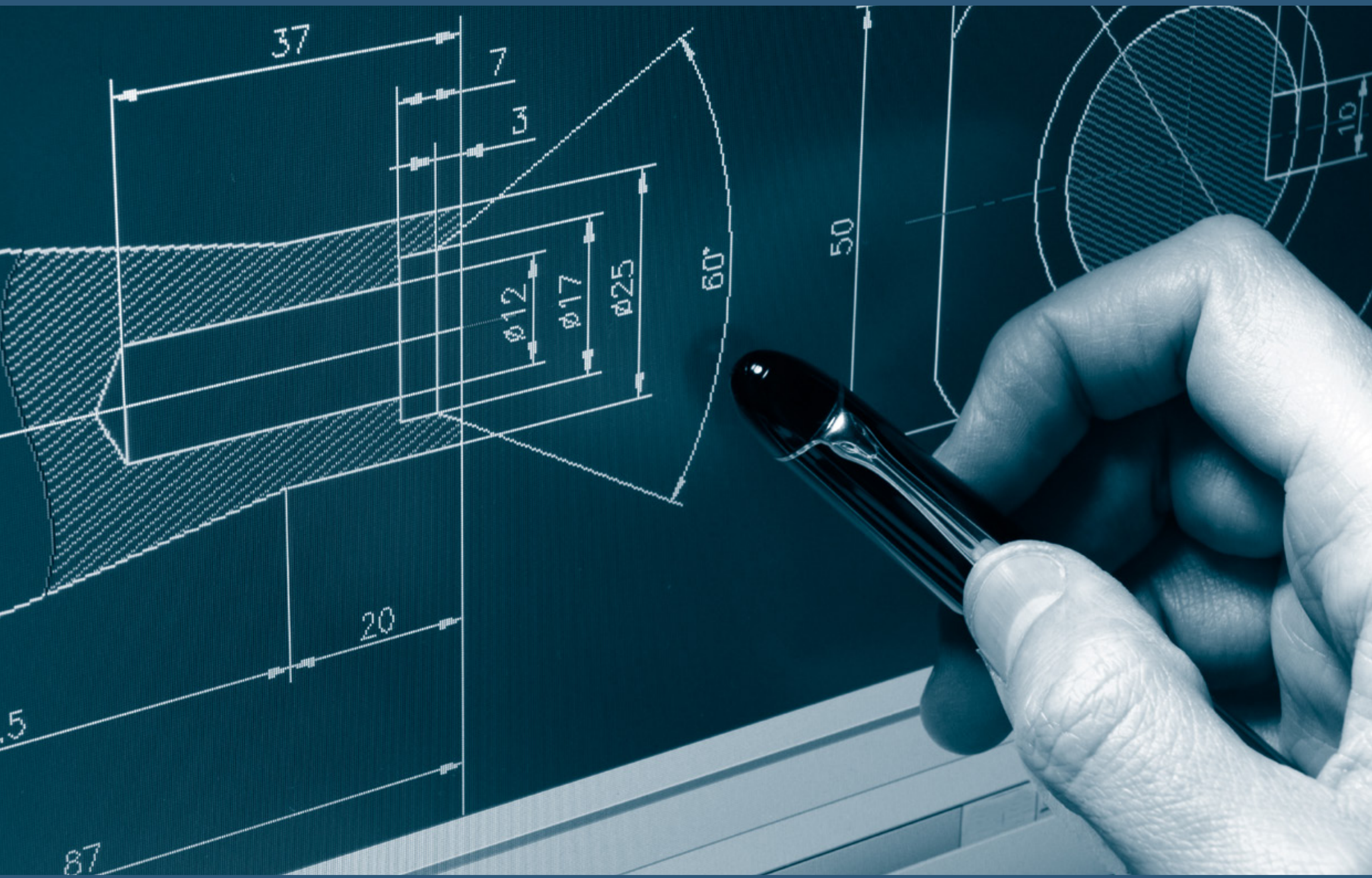
the ultimate guide for engineers and purchasing directors

sarginsons

LEADERS IN LIGHTWEIGHTING

Design for Manufacture is not new. When applied correctly, DfM – which is essentially a set of design principles – permits ease of engineering and manufacture. Designers quite literally **design for manufacture**, creating designs that will have accounted for how and where the product is built – as well as who is building it.

When its principles have been adhered to correctly – DfM will allow products to be created in a cost-effective way, address likely production problems at the earliest stage and reduce costs dramatically.



Get it right first time

David M Anderson writes in *Design For Manufacturability* that by the time a product has been designed only 8% of the total budget has been spent but the design has determined 80% of the cost of the product. Once this cost is locked in, it is difficult for manufacturing to remove.

It is easy to conclude that a considered DfM approach from concept to final design can have an enormous impact on cost-saving and, just as importantly, lead to a successful transition into full-scale production.

In a global marketplace where time to market is key, good product development can offer a distinct competitive advantage.

Ease of production is inherently determined by DfM, which can reduce technical delays and significantly shorten the development process. The lower the number of design iterations, tooling modifications, and assembly reconsiderations, the lower the costs. But it isn't always managed successfully in every industry – leading to breakdowns in assembly lines and escalating costs

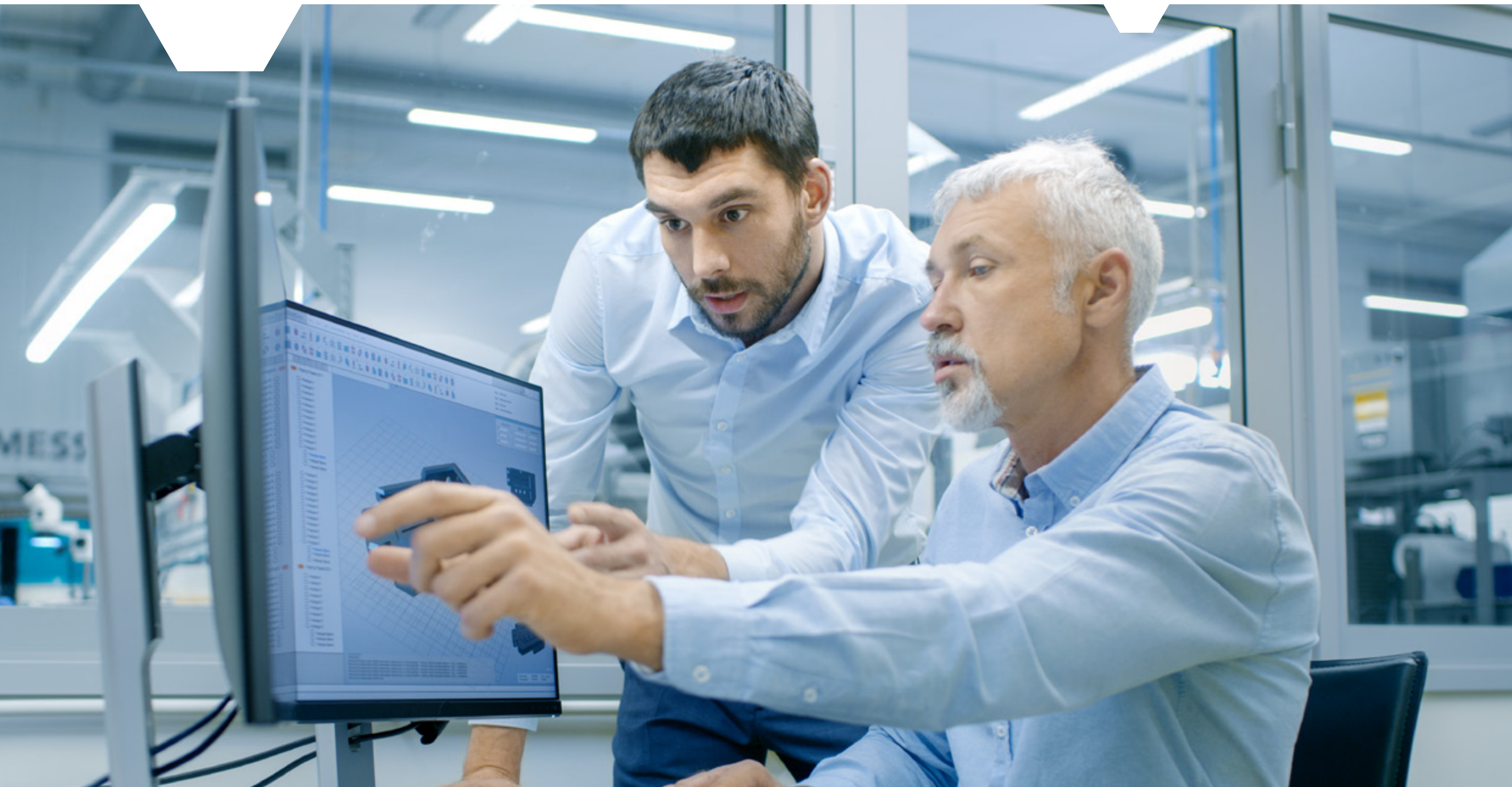
Knowledge is power

The biggest barrier to the widespread use of DfM is that design engineers lack the depth of experience in manufacturing that would enable them to understand the implications of their designs in full. When it comes to the manufacture of lightweight aluminium cast designs, the designer needs to be knowledgeable about the different processes that could be deployed in production i.e. sand, gravity, low or high pressure. Each approach has its benefits and limitations to consider such as cast tolerances, wall section limitations, surface finish and tooling cost. Each technique has a significant impact on post-machining and finishing requirements.

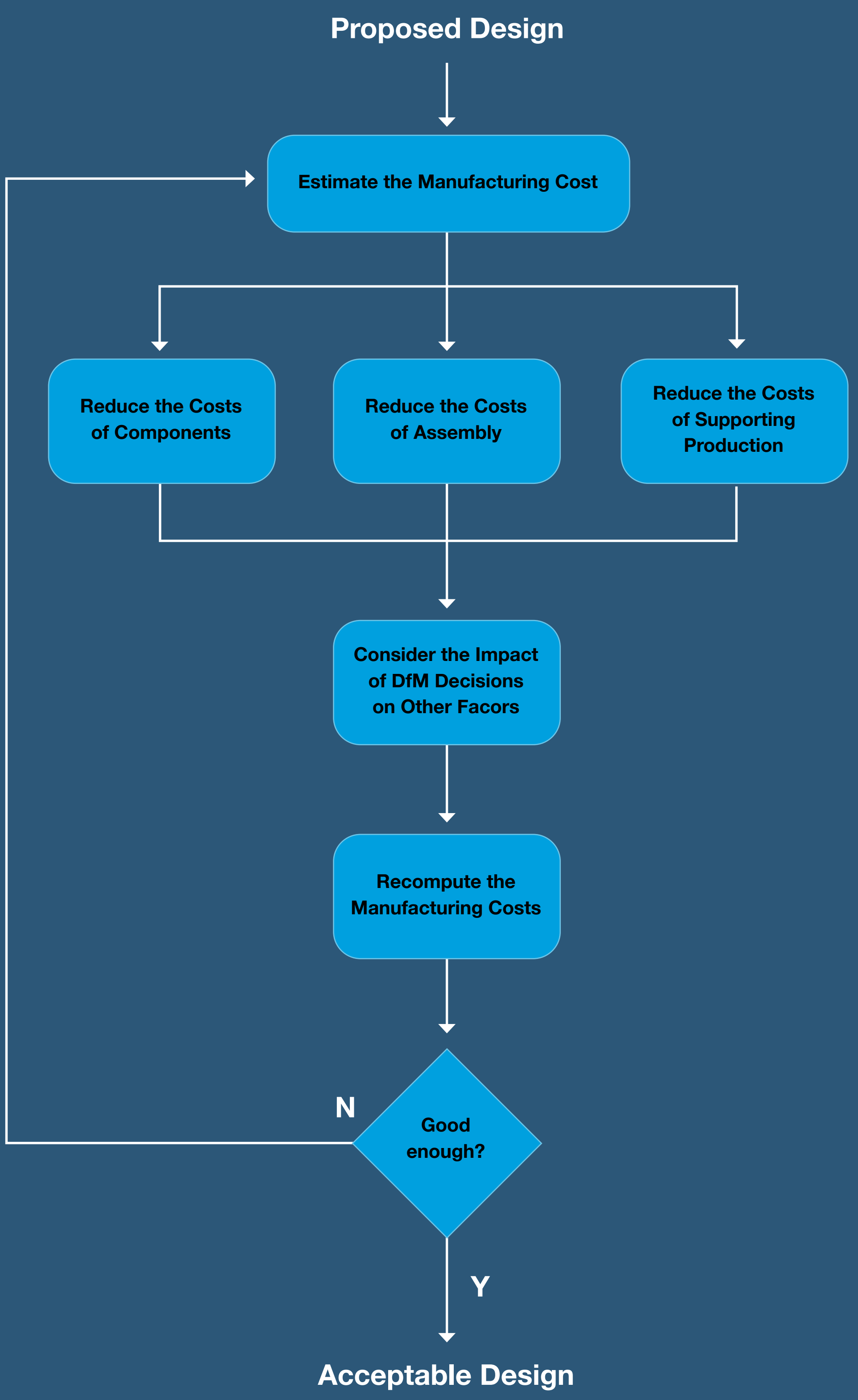
DfM has also suffered – to an extent – due to the ubiquitous use of CAD software. With CAD, complex forms can be easily created in compressed timescales and in a compartmentalised way that offers little regard to the manufacturability of the part. Designs are then transferred to manufacturers in a final form who often struggle to make necessary changes. "It's too late to change the design" becomes a common refrain, and manufacturers are then faced with launching an unsuitable part into production.

In order to gain this experience, design engineers must have regular access to factory floors so that they gain a working knowledge of processes. Qualifications alone are simply not enough. Producers must also act to request for DfM-led designs as early on in the process as possible.

With regards to the use of lightweighting or cast products, in design and manufacture – close co-operation with foundries and associated industries has been, and still is, key to determining best DfM practice. Producers keen to minimise costs and commit to ease of production must, therefore, seek out partners who are expert in DfM.



Our DfM-led manufacturing process



HOW DID DFM ORIGINATE?

DfM was established in the 1970s by industrial engineer Geoffrey Boothroyd who led research into manufacturing efficiency at the University of Massachusetts as a response to the rapidly changing way in which production lines were developing. His DfM and DfA work – **Product Design for Manufacture and Assembly**, originally published in 1983, was adopted by large automotive companies such as Ford and General Motors, who both claimed to have saved billions of dollars as a result.

The use of DfM in lightweighting

Further development since DfM's inception in the 1970s has focused on the creation of knowledge-based models that evaluate the ease of product assembly and manufacturability of individual parts. Areas that significantly reduce manufacturing costs have been documented, and ease of manufacture principles highlighted.

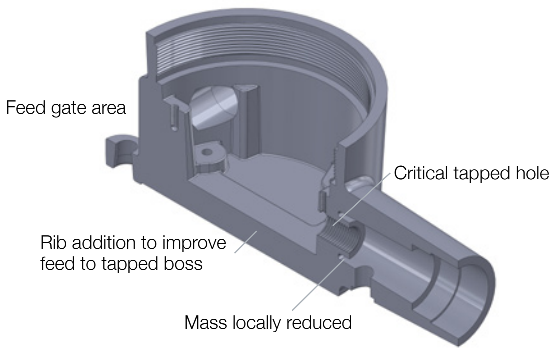
Tried and tested processes lead us to the following recommendations when manufacturing of lightweight aluminium cast designs:

a) Process. At an early stage consider the process to be employed – i.e. sand, gravity, low or high pressure. Each approach has its benefits and limitations to consider such as cast tolerances, wall section limitations, surface finish and tooling cost if new tools need to be created or purchased. Often dictated by projected production volume requirements, the proposed process will have a significant effect on post-machining and finishing requirements, so time to first samples, aesthetics, and functionality among other factors need to be built in at the design stage.

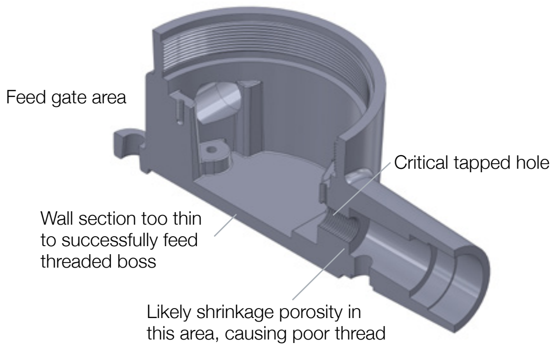
b) Specification of the correct alloy. The correct choice of material can have a significant bearing on the success of the cast design, as different alloys exhibit different mechanical properties – such as tensile strength, elongation, hardness and strength at elevated temperatures – and other properties such as machinability, conductivity, weldability, corrosion resistance and thermal expansion. Post-cast process requirements such as heat treatment are limited to certain alloys, and an understanding of their other properties should be considered at the design stage to ascertain suitability and casting limitations.

c) Isolated form. Avoidance of isolated thick or heavy sections within the casting design is extremely desirable from a manufacturing perspective. These types of features often exhibit poor feeding during solidification leading to issues with cavitation (or porosity) that can weaken the part, create areas that cannot be successfully machined, affect pressure tightness and impact on aesthetics (*see fig.2*). If a heavy section cannot be avoided then consideration should be given to feed paths to the feature through additional ribs, thicker surrounding wall sections, or through the introduction of pins or another form that could locally remove some of the mass (*see fig.1*). Resolving these issues after the tooling has been designed and manufactured can be difficult and costly and will lead to production delays.

Isolated Form - Good design (fig.1)

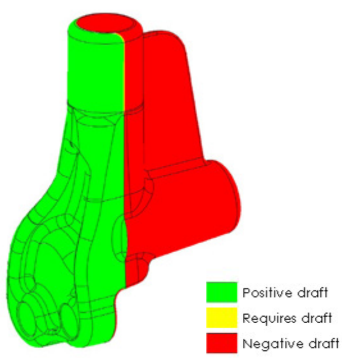


Isolated form - Bad design (fig. 2)

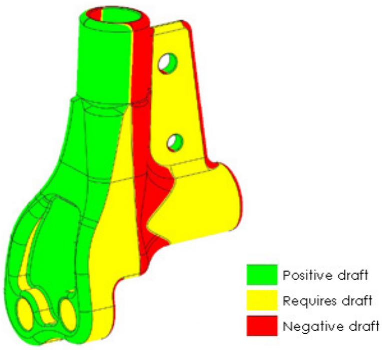


d) Consideration of split lines and extraction from the tooling. This is key to ensuring good and cost-effective tool design, allowing successful gating solutions and avoidance of weak areas in the mould that would compromise tooling life (*see fig.3 and fig.4*). If certain design features require sliding cores to release the form, thought should be given to the impact that this would have on tooling design and the additional cost that this would bring. Ejection requirements should also be carefully considered at the design stage to ensure the correct placement of ejector bosses (ejecting onto thin walls is to be avoided to prevent distortion) which allow for a successful extraction from the tool but do not impact on the functionality of the part.

Draft and split lines - Good design (fig.3)



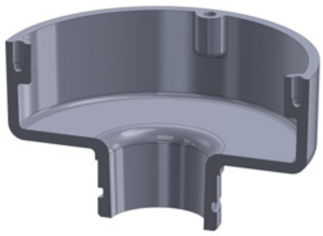
Draft and split lines - Bad design (fig.4)



e) Draft taper. It is essential that the correct draft taper is applied to all necessary surfaces in the direction of extraction. A too little draft can cause surface drag and tear, be difficult to remove from moulds, cause part distortion, and quickly damage tooling. The addition of drafted form can, however, create thick sections particularly with deep walls and bosses and the impact of this should be considered from a feeding and solidification perspective.

f) Undercut form. If at all possible it is preferable to avoid undercut features in lightweighting design as the techniques employed to tackle these, such as sand cores and extractable pieces add complexity and cost to the manufacturing process (*see fig5 and fig.6*). Sand cores, for example, require additional tooling to create and must be carefully handled and utilised during the casting procedure.

Die extraction not fully considered (fig.5)



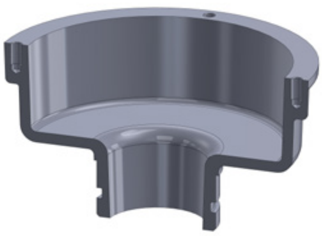
Boss draft is inverted, meaning conventional core extraction is not Possible

Undercut area would require a sand core to create this detail, adding cost and manufacturing complexity

Die extraction has been considered (fig.6)

External Flange maintains original diameter for connection to mating part

Fixing bosses now part of the external form and can be easily removed from the mould



They must also be successfully and fully removed from the part before further processing. The thermal characteristics of solidification are affected by the inclusion of these types of cores and if they are to be included this should be considered in depth at the design stage, with metal flow analysis employed to understand the solidification more fully.

g) Design for fixturing. Consideration of how a cast part is to be machined is key to cost-effectiveness and repeatable good quality. At an early stage, the location and clamping points on the part should be designed to ensure reliable holding and stability in the CNC machining centre and allow transfer to subsequent operations. The secondary operation should be minimised where possible to avoid tolerance issues. This is because removing a part to reposition for further machining lowers accuracy relative to cuts made in the original position.

Single set up machining is naturally less expensive also, with lower set up and overhead manufacturing costs.

h) Minimise cutting tools and specify tolerances wisely. If a casting is to be machined it is good practice to design these features to use the minimum number of tools. For example, common fillet radii in milled areas often allow for the use of a single cutting tool, simplifying manufacture and reducing costs. This approach also makes it more likely to keep cutter variety within the capability of the CNC tool changer.

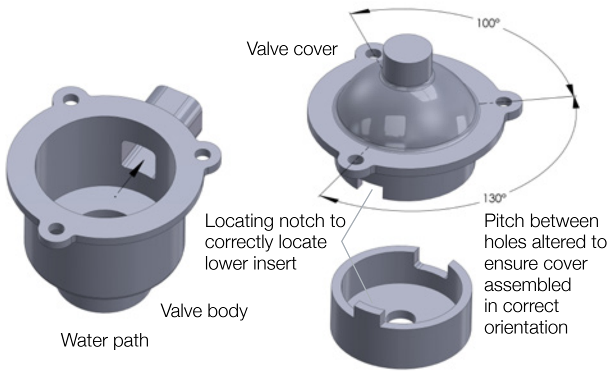
Keep it simple

When considering tolerances use the Design of Experiments – a systematic method to determine the relationship between factors affecting a process and the output of that process – to determine the effects on part quality and function. If a feature can be left ‘as-cast’ with the tolerances associated with this, additional processes can be avoided, costs reduced, and production simplified.

i) Design for assembly. When considering a new design, consideration should be given to its function within the assembly, and just as importantly – how it will be assembled (*see fig.7*). Create new designs in conjunction with mating parts, and not in isolation. Avoid mirrored parts where possible so that a cast product can function in both left and right applications. Immediately this will halve the tooling costs and streamline the route to market. If this is not achievable consider adding features to both right and left hand parts to make them the same. Use symmetrical design when possible, including drafted features, so that the part does not have to be orientated when assembled. This avoids a major quality issue with incorrect installation. Adding extra holes or feature to a design to create symmetry can easily justify its cost in not having to manufacture complex mechanisms for assembly and avoiding quality problems. If symmetry is not possible, however, then make the part very asymmetrical to avoid confusion at the assembly stage and the risk of wrongly forcing it in an incorrect orientation.

j) Optimise the use of standard parts. Consider designing new castings around the inclusion of off-the-shelf components as this removes the cost and time associated with new design, documentation, prototyping, testing and implementation. Manufacturers of standard parts are more efficient at their speciality with more experience, continuously improving quality, proven reliability and dedicated production facilities. The utilisation of these standard parts also allows focus on the lightweight design itself and drives relevant feature creation.

Design for assembly (fig.7)

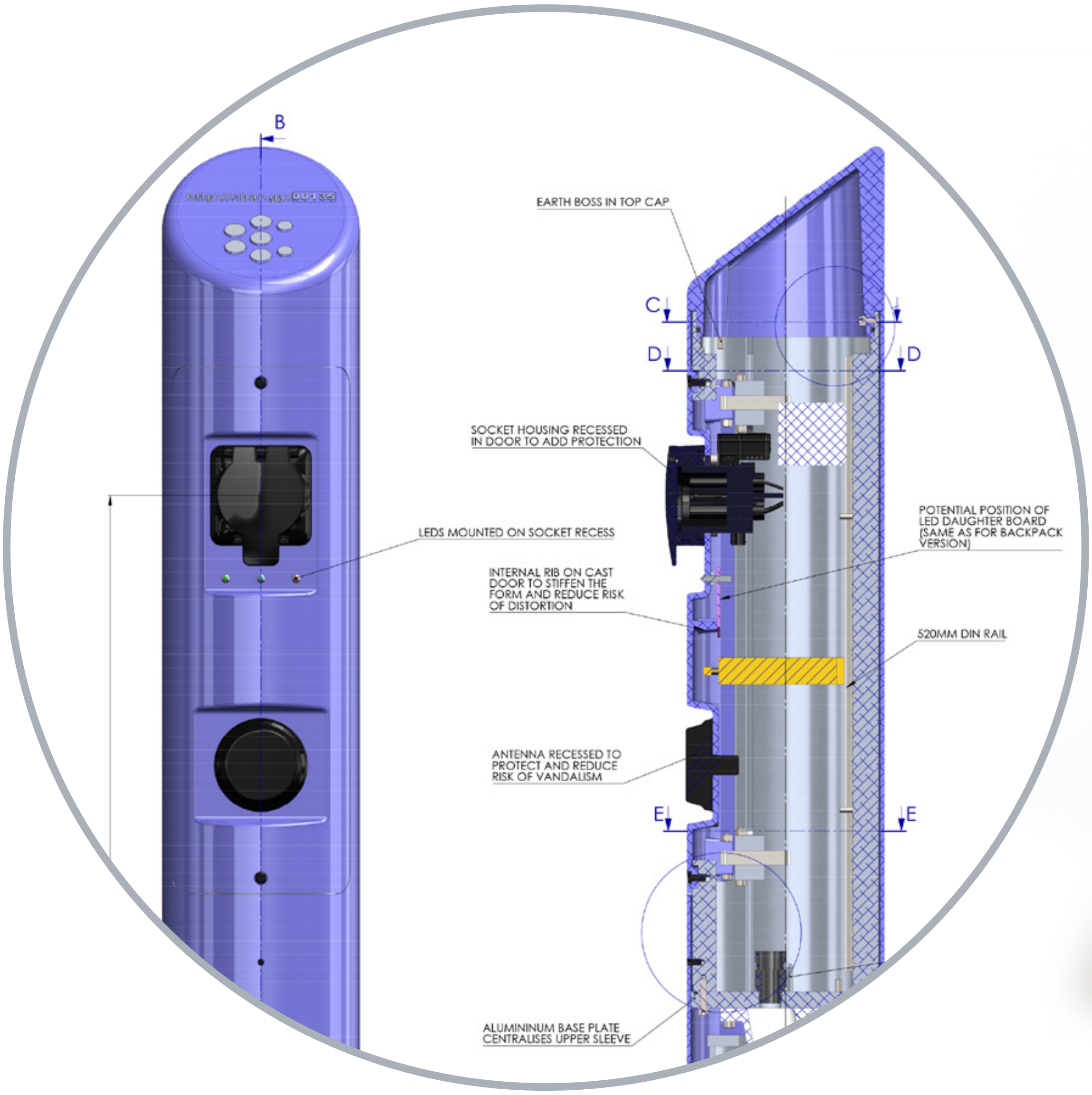


Case study: Bollard design for the EV charging market

A major challenge for the widespread adoption of electric vehicles is the lack of charging points in our cities. Charg.y produces charging points that utilise infrastructure such as lampposts as charging points. Expert in applying DfM to casting, the Sarginsons Technology Centre designed a charging bollard from concept to full-scale production using DfM principles at every stage. Complimenting a lamp-post mounted die-cast design, this flexible alternative incorporated many manufacturing elements, including:

- Sand and die castings, fully machined and powder coated
- Bespoke aluminium extrusions offering a sealed internal electrical component capsule
- Hidden hinge mechanisms, uniquely designed to allow controlled access for service and maintenance.
- Robotically applied liquid foam seals, offering weather-tight IP ratings
- A fully rotational street-level mounting solution offering short install and commissioning timescales
- 3D printed metal sintered bollard identification inserts.
- Vandal-proof charging sockets with gravity cast aluminium replacing plastic.

Each element of the assembly offered a solution that can be cast, extruded and machined in a practical and cost-effective manner that maintains the desired aesthetic and fully captured the design brief. Diecast tooling, machining fixtures, and test equipment were also designed and manufactured as part of the project. Once all elements were manufactured and assembled in-house, a full testing procedure was completed by Sarginsons ensuring safety compliance, operational effectiveness, and allocation of each bollard into the Char.gy control system.



Four steps to applying DfM to your own processes

1. Identify the right manufacturing process

The first step in implementing good DfM technique within a business is to correctly identify the correct manufacturing process. As lightweight production in the form of casting offers different solutions, with associated materials, benefits, and limitations, early liaison with technical support at the manufacturer can identify the ideal method that should be used for the proposal, or indeed if the process is unsuitable for the planned product.

2. Design out potential problems early

Only after the production approach has been determined can the detailed design of the part begin in earnest. This, naturally, should be compatible with the chosen method of manufacture and its associated limits with regards to tolerance, wall section, draft etc. Engaging with the manufacturer at the earliest stage of design allows for a proactive rather than reactive approach which ensures that potential problems are quickly ‘designed out’, correct materials are chosen, and ease of production considered, helping to create a knowledge base within the design team that can be used for current and future projects.

3. Get to know your manufacturers

Building a close technical relationship with manufacturers of lightweight cast parts can bring other significant advantages. Tooling costs can be relatively high and difficult and costly to modify if the part has not been successfully designed, so there is good reason to apply considered and collaborative DfM for this type of work. Discussing projects at the design stage with the technical partners at the foundry, toolmakers and machinists allow the engineer to tap into a wealth of knowledge and create a solution that can be far more easily and successfully manufactured.

4. Choose suppliers who are committed to research and development

Forward-thinking producers of lightweight parts are also continually looking to improve their processes, innovate with new materials and liaise with research centres, educational bodies and industry partners to find new solutions that can be applied in future DfM. For example, recent advances have been made in the application of robotically applied liquid foam seals for pressure-tight cast housings that remove the requirement for costly gaskets, simplifying the design of the part and reducing manufacturing times. The documenting of these types of developments may not be readily available to the design engineer but by creating new projects in tandem with manufacturing teams these new techniques and design approaches can be implemented.

Sarginsons Industries is a consultancy and foundry that leads with Design for Manufacture principles to collaborate seamlessly with suppliers, OEMs and external parties. If you need to discuss lightweight solutions for your project, get in touch with us today.

About Sarginsons Industries

Sarginsons Industries is a casting technology consultancy and aluminium foundry that specialises in the development of complex parts for the transport and energy industries. Sarginsons' award-winning projects include safety critical components made for hybrid and electric vehicles, trains, planes and wind turbines. Founded in 1936 and based in Coventry, Sarginsons has a rich past that is rooted in the manufacturing of WWII fighter jets – including the Spitfire. Now, working alongside leading universities, Sarginsons uses highly specialised techniques for manufacture including 3D cast simulations, FE analysis, 3D printing and low-pressure aluminium casting and can lay claim to designing and creating groundbreaking lightweight solutions for some of the world's best-known brands.