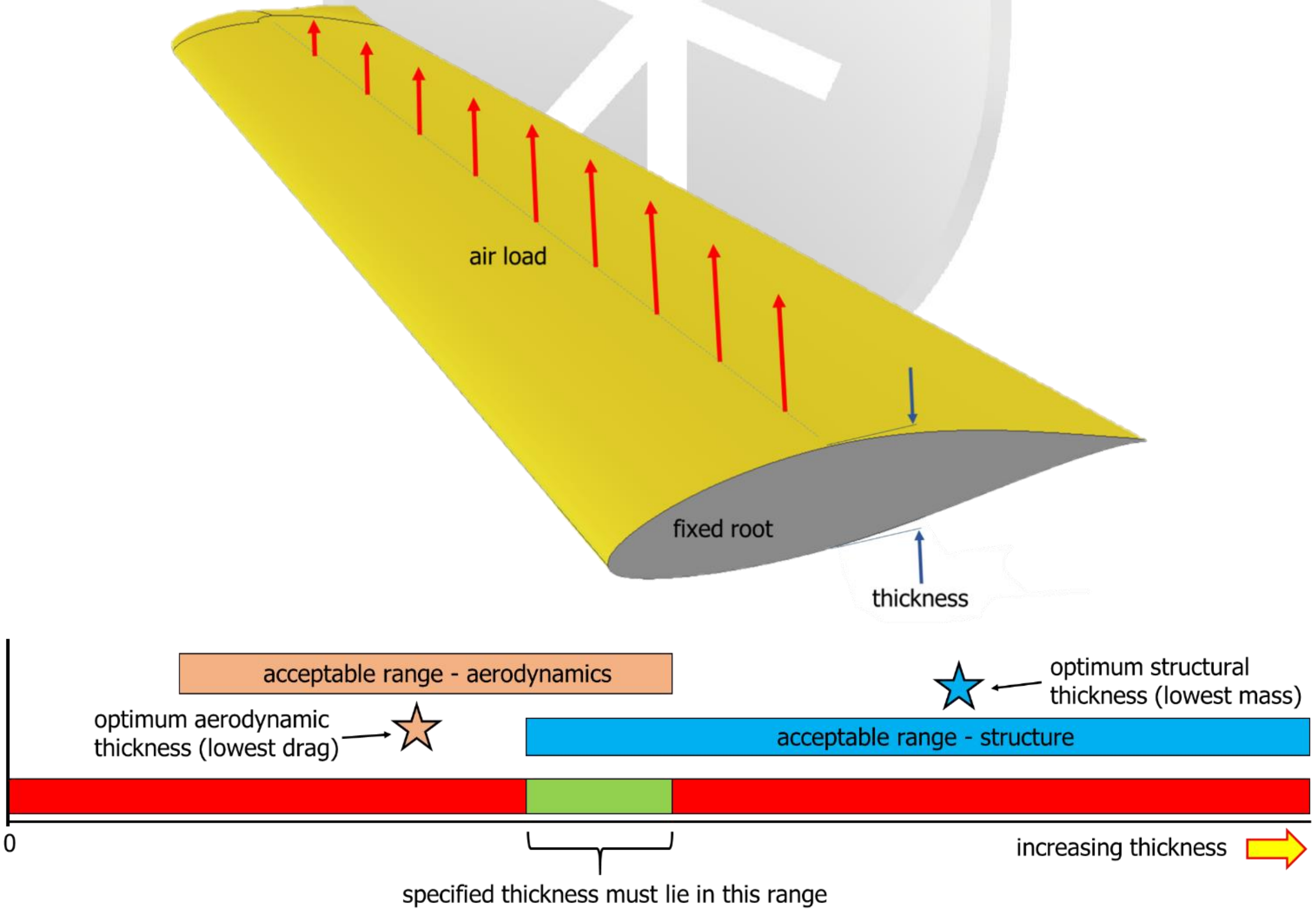
How to specify composite products

Getting the specification right is critical to the smooth running and ultimate success of any engineering project, and the design of composite structures presents no exception to this rule. In my experience, the projects with the most satisfactory outcome are those where care is taken at the start to formulate and agree a specification that is both *achievable* and *complete*. A good specification will also minimise the complications that arise during the design process, saving both time and money in the long run. In this article we review how best to approach the specification process, and check off the key items of content that must be pinned down in order to get a composites design project off to a great start.

Specification achievability

It's possible to put great care and considerable time into a comprehensive specification that cannot actually be realised. Usually this is the result of specification 'clashes' precipitated by inadvertent assumptions or oversights. A typical example of a specification clash is that of *Aerodynamics -vs- Loads:-* Sounds like a heavyweight title bout, but it's actually one of the most common trade-offs that we're called on to make in the composites design community. This probably stems from the fact that composites are often the solution of choice when it comes to high-performance structures that must fulfil both structural and aerodynamic (or hydrodynamic) functions.

In the case of a highly loaded cantilever structure (see below) that is constrained to lie within an aerofoil profile, we can quickly see that aerodynamic and structural considerations may exert conflicting pressures on the section thickness.



Unless the dice have landed extremely favourably, the optimum thickness for aerodynamic performance won't coincide with the optimum structural thickness (i.e. that which achieves the lowest mass or cost). If we're lucky, the optimum aerodynamic thickness may be structurally *acceptable* (if not optimum), and if we're less lucky (as shown in the diagram) then we may be limited to picking a thickness that is acceptable from the standpoints of both structure and aerodynamics but optimum from neither. It's likely that the customer will have a good handle on the aerodynamic considerations but that a composites specialist may need to complete the picture with regard to structural constraints. If the specification doesn't identify a thickness that is at least *acceptable* from both standpoints (preferably with a bit of elbow room), then we've lost before we even start!

The above case may be viewed as a problem that could arise if a specification is frozen prematurely. It's not the case that the specifier should have guessed better or performed some miracle of crystal ball gazing, but it is the case that the earlier involvement of a composites specialist could easily have helped to head the issue off with few simple calculations.

Completeness

Under-specification is often a recipe for confusion, wasted effort and mission creep so is best avoided! As discussed above, it's sometimes the case that not all the answers are known up-front. So it can be useful to engage a composites specialist before freezing the specification to ensure that all aspects are achievable. It should then be possible to produce a thorough specification, typically addressing the following issues, (as applicable) before the start of the detail design phase.

Purpose: Sharing the bigger picture is usually a good idea and will normally generate additional value during the design process: A proper understanding of what the structure or part does in the wider scheme may push buttons with the composites designer that the formal specification could otherwise miss.

Developmental stage: It's really important to know the developmental stage of the project. This enables the correct balancing of a number of considerations. For example, a part intended for volume production should force the prioritisation of low unit cost over low tooling and development cost. However, if only a single part is required, then the cost of tooling and manufacturing development become much greater contributors to the overall project cost: In such cases it's probably better to opt for a simple and well understood manufacturing solution, even if the unit cost of the actual part is somewhat higher than might eventually be achieved with a more production-oriented solution.

Production rate may or may not be a design driver. If it is, knowledge of the target will assist the designer to select the materials and manufacturing methods best suited to the application.

Design life is always one of the fundamentals. For how long must the part or structure last?

Applicable standards: It's important to identify which (if any) industry standards apply to the product in question. Standards can contain a lot of distilled wisdom and many useful insights. In any case, it may be difficult to arrange product liability insurance if the design is not completed in accordance with a relevant standard.

Safety level: What would be the consequences if the part or structure were to fail? The level of reliability required affects not only the safety margins applied during the design, but also the choice of production and inspection methods. Safety critical industries such as aerospace correctly demand extremely high levels of confidence to be proven in the design, manufacturing and inspection methodologies, however a company setting out to manufacture canoes to aerospace standards would probably find that their products were far too expensive to sell.

Operating environment: Where and in what medium does the structure operate? Media such as water (for example) can have a noticeable but easily manageable effect on the mechanical properties of composite materials. What is the operational temperature range and will the structure be subject to solar heating? This may be a driving factor in terms of resin and adhesive selection.

Loads: One of the primary functions of a structure is to resist applied loads, so we need to understand quite a lot about these. Loads may arise due to mechanical effects such as pressure, inertia, centripetal and gyroscopic loading, and / or thermal effects where the differential expansion of interacting parts can set up stresses. Loads are generally classified as 'Extreme', 'Fatigue' or 'Sustained'.

> ***Extreme loads*** are the highest loads that the structure is ever expected to experience. They should include any relevant 'fault' loads.
> ***Fatigue loads*** are repetitive loads, representative of those anticipated during operation. Most materials can't sustain the same load levels in fatigue as they can on a single occasion. Therefore it's important to understand mean load levels, amplitudes and associated number of cycles.
> ***Sustained loads*** are loads that are applied for a duration. It may be that creep deformation or stress-rupture associated with long-term loading is of concern.

Deflection limits or requirements: If the structure stretches / bends / twists by more than a certain amount, could this have implications for safety or function? An example of this is the deflection limits placed on wind turbine blades in order to avoid tower strike. Alternatively, it could be that it is necessary to achieve a certain deflection with the application of a given load or temperature.

Frequency response: Are there any natural frequencies to be avoided, and by what margin?

Other functional requirements: what else is the structure expected to do? Are access hatches required for a payload or instrumentation, for example?

Geometry: It's almost a given that the designer will need to know of any shape requirements or limitations to be placed on the part or structure. Such restrictions may be in the form of a 'keep-in envelope' consistent with the correct operation of a part, or far more comprehensive in the case of, say, a wind turbine blade, where the exact form is critical to performance. In any case, it's always essential to know the location and geometry of any interfaces with adjacent components. The tolerances associated with all dimensions and surfaces should also be stated.

Interfaces: Geometry aside, how is the composite structure expected to interface with the adjacent parts or structure? Interfaces have the potential to exert a controlling influence on the overall structural layout.

Finish: What finish is required? Does the part need to have cosmetic appeal, or a certain paint finish?

Operational hazards: What operational hazards are associated with the application? Is the structure at risk of impact (if so, what level), or perhaps marine organism fouling?

Handling / Transportation requirements: How is the structure or part to be transported from factory to installation? Is special packaging required? Is it necessary to split the structure into more than one part to enable transportation by standard shipping container, for example?

Maintenance / monitoring / inspection requirements: How often will the structure be accessible, and what are the target maintenance / inspection intervals, if any? Is any ongoing structural monitoring required?

Target Mass: Is the mass important? If so, what does it need to be? Are there any restrictions on mass distribution or balance (particularly in the case or rotating machinery)?

Target cost: Helpful to know this! There's often a balance to be struck between mass and cost.

Delivery: By when must the design (and subsequent hardware) be ready for delivery? The perfect solution is not perfect if it takes far too long to deliver!

Special considerations: The above issues are a list of typical considerations. If there's anything else pertinent to the application that might or might not be important, it's still best to raise the point up-front. It may be easily dismissed as a concern, or it might be incredibly important!