A360

When to Use Composites	
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Introduction[edit | edit source]

The purpose of this document is to provide insight for assessing the suitability of a component for composites manufacturing process. The assessment will consider the component's geometry, design purpose, environment, production volumes, mechanical performance, and economics.

Background[edit | edit source]

Composites have various properties that make them advantageous over other materials in certain applications. For example, GFRP typically does not have issues with corrosion, which makes it well suited to marine applications. CFRP has high specific properties, which makes it well suited to many aerospace applications. Virtually all polymer matrix composites are well suited to producing parts that have organic geometries rather than conventional flat/straight parts that are common to metals. Some manufacturing processes are well suited to low production quantities. These types of considerations must be taken into account when selecting a composite material for an application.

A widespread misunderstanding about composites is that they are just "black metal," which refers to the design approach of substituting the metallic component with carbon fiber reinforced plastic (CFRP) in a dark color. While that may work in rare cases, it is never the best option or optimized scenario. From the composites manufacturing perspective, geometries that are common and easily produced using metallics are often difficult, expensive, or impossible to manufacture out of composites. Therefore the misconception that a designer can simply replace a metallic component directly with composite laminates is a mistake that will yield a part without the desired results.

There are many different composite manufacturing processes, each with its own pros and cons. The choice of manufacturing processes depends on the specific composite component being produced. For components focused on low costs and low performance, wet layup is a common composite manufacturing process that is used due to its low-cost materials, tooling, and labour requirements. For aerospace composite components or other high-end products, where weight, strength, and mechanical performance are the dominant drivers, autoclave pre-preg is very common. However, there are always cases where a composite solution is not necessarily the best application due to the component's requirements and characteristics. To better understand various composite manufacturing processes, please refer to the Composites manufacturing - A215 page.

Application[edit | edit source]

The assessment and identification of suitability for composites should be completed in the preliminary design phase of product development and could save development costs in the long run.

The approach to assessing the suitability of a component for composite manufacturing can be considered as a two-step approach:

Step 1 is the definition of the product's design requirements and objectives (DR&O). It is considered as the most important step to any product development, is the clear definition of the product's design requirements and objectives. There are no limitations as to what is defined in a typical DR&O document, but the few key items that are critical in completing step 2 of this approach are:

- Production volumes – annual and total
- Surface finishes (single side or both)
- Geometry (overall size, complex curves, tight areas, die-lock?)
- Costs
- Performance (stiffness & strength)
- Weight
- Environmental (operating temperature, moisture, UV, etc.)
- Flammability

Step 2 is the assessment of the compatibility of requirements and characteristics of the product to composite manufacturing. Once the DR&O has been defined in Step 1, assess the results of the DR&O and compare it to the suitability table for composite manufacturing. It is important to note that the composites manufacturing suitability table as shown below is just a general guideline and shall not be considered as anything more than recommendations. All items listed under "Difficult to Accommodate into Composites" do not mean that it is impossible, only that it would increase costs & complexity in the manufacturing process.

	Geometry
Well-Suited for Composites	Thin structures (<1 in) Complex curvature with gentle transitions and generous radii Large flat surfaces Flexible design envelope/unlimited design freedom Constant cross-sectional shapes Multiple components with potential for part consolidation Aesthetically-pleasing, stylish designs and shapes Complex double-curvature geometries
Difficult to Accommodate into Composites	Very thick structures (> 6 in) Sharp curvatures with tight features Large variations in part thicknesses and transitions Limited design envelope (space claim freedom) Very small components - i.e. < 2 in Very large components - i.e. any dimension > 10 ft Extremely tight tolerances - i.e. machined components Sharp and tight radii with no design freedom Die-locked geometry with no design freedom
	Mechanical Performance

Well-Suited for Composites	Unidirectional or simple loading scenarios Bending stiffness dominant designs Desire for ability to strategically tailor stiffness and strength High energy absorption - i.e. crash energy dissipation, ballistics High strength-to-weight ratio required Low energy impact resistance
Difficult to Accommodate into Composites	High energy impact/energy absorption without fracture Metallic equivalency with unknown performance requirements Large concentrated point loading scenarios Large number of structural joints - i.e. space frames
	Environmental Performance
Well-Suited for Composites	Sealed/painted surfaces Corrosive environments Interior components Low-to-average UV exposure Chemical exposure Anti-bacterial requirements Continuous moisture exposure
Difficult to Accommodate into Composites	Extreme heat - i.e. continuous exposure over 180°F or 80°C Extreme cold - i.e. continuous exposure below -40°F or -40°C Extreme UV exposure w/long life span requirement Flammability & fire retardant requirements Lightning strike requirements
	Miscellaneous
Well-Suited for Composites	Desire for weight reduction Surface finish not critical or only critical on one side Non-conductive structures Med - high production runs - i.e. 100-1000 parts per year Unique aesthetics - i.e. composite "look"
Difficult to Accommodate into Composites	Cost savings is only driving factor Class-A surface finish on all sides Conductive structures i.e. electrical, radio signals Very small production runs - i.e. < 10 parts per year Very high production runs - i.e. > 5,000 parts per year

One of the key challenges in conducting a suitability assessment lies in accurately gauging the level of difficulty, along with the subsequent rise in cost and complexity, particularly when a feature is categorized as "Difficult to Accommodate into Composites."

In addition to the recommended guidelines above, here are several key considerations:

- Per-part-cost-savings should not be the primary criteria when considering composites due to the many other benefits that composites can offer.
- Complexity can be achieved, but always at a cost. There are high-end composite materials and processes that are often advertised or discussed, such as Kevlar, carbon fibre, carbon ceramic, etc., but these may be prohibitively high in cost and difficult to process. Although it is suitable

for certain applications and industries such as aerospace, motorsports, military, etc.
- Design freedom is paramount to the capacity to develop a successful composite component. A product development with unlimited or highly-flexible design freedom empowers the designer to optimize designs for composite suitability. While this doesn't guarantee seamless integration into composites, the production quality is often higher when the design is optimized based on composite manufacturing suitability.
- Composites suitability assessment is qualitative. Different designers and manufacturers will have differing limits to suitability for each criterion. Therefore it is always valuable to gather feedback from multiple sources.

Practice (Case Studies/Examples)[edit | edit source]

Glass Fibre Spring[edit | edit source]

A suitability assessment for composites manufacturing was required during the preliminary feasibility study phase of a product development project. The product is an alloy steel leaf spring component. The client was encountering manufacturing tolerance issues with the twist angle and thus was searching for an alternative manufacturing process and/or material. The primary function of the product is to serve as a spring. The DR&O was defined with the client to gather a full understanding of what criterion are critical to the function of the product as shown in the table below.

Category	Description	Requirements	Notes
Economics	Selling Price	Less than $60	Current sell price is approx. $50-$60 CAD
Physical	Component Weight	Weight savings not important	No specific weight limitation.
Aesthetics	Surface Finish	Smooth aesthetic surface	Would be preferable to have compatibility with current paint formulation
Geometric	Angles & Tolerances	± 1°	
	Hole Locations & Tolerances	Per drawing	
	Interface Location Flatness	Per drawing	
	Installation Spacing	14.2" (centre to centre)	
Service Environment	Service Temperature Range	-40°C to +40°C	Approx. range based on outdoor use in a variety of environments
	Humidity / Moisture Exposure	Dry to wet (0-100% RH)	
	Chemical Exposure	1-2% bleach solution	Based on exposure to cleaning chemicals
	UV Exposure	Direct sunlight	

Mechanical Performance	Maximum Deflection	6" at loading of 800 lbf	Load/deflection relationship is based on client test data and equivalence with current steel twist shank design
		Minimum 3-5 years	Longer service life desired
Production/Manufacturing	Estimated Production Volume	5,000 annually	2500 of each - LH & RH part. Quantity may go up significantly based on sales.
Interfaces	Connecting Components	Steel tube, rotating disc	
	Connection Type	Bolted	

Based on the information gather from the DR&O and general component geometry from client-supplied CAD models, the suitability assessment can be completed. A summary of the assessment is shown in the following table.

Geometry	
Thin structure	The thin structure of this component is well-suited for composites manufacturing.
Complex curvatures	The complex curvature of this component is well-suited for composites manufacturing because it can be built directly into the tooling.
Tight Tolerance	The component requires tight angle tolerance, an issue in the existing metallic component. This geometrical twist angle tolerance can be built directly into the tooling and thus it is also well-suited for composites manufacturing.
Design Freedom	No indication for level of design freedom for this component's redesign. The understanding of the limits of design freedom would be very helpful in this assessment.
Mechanical Performance	
Deflection & Loading	This component is a bending stiffness dominant design with a simple unidirectional loading scenario. If required, the component can also be optimized with tailored stiffness regions. Hence these are all well-suited for composites manufacturing.
Environmental Performance	
Service temperature	The component's service temperature is within the acceptable range for composites.
	The wet environment is well-suited for composites manufacturing.
	The chemical exposure is well-suited for composites manufacturing.
	The direct UV exposure will need to be addressed during material selection of the design.
Miscellaneous	
Production Volume	At 5,000 units annually, this is well-suited for composites manufacturing. Due to the small size of the component as well, this production volume can be easily achieved.
Weight Savings	No specific weight savings are required.
Service Life	A service life of 3-5 years is well within reason for a composites component with direct UV exposure.

Costs	A price limit of $60 is specified, which is the upper price limit of the existing metallic component. This suggests that the client requires this to be equivalent or lower in costs as the existing metallic design. This will be challenging and would have to be assessed at a later phase since it is difficult to estimate costs at this stage in the preliminary feasibility study.
Flammability	No specific flammability requirements were specified.

The outcome of the composites manufacturing suitability assessment is relatively positive and the product can be considered to be well-suited for composites manufacturing. There are several criterions that are non-ideal for composites, such as costs and design freedom, but neither of these is exceedingly unsuitable for composites.

Conclusion and Further Information[edit | edit source]

This article provided a high-level introduction to a method for assessing the suitability of a component for composites manufacturing. The results from this qualitative assessment method will vary depending on the assessor and their experience with composites manufacturing. The critical step to this assessment is the development of the DR&O document with quality input and feedback from any and all stakeholders in the product.

Finally, it is important to understand that “Difficult to Accommodate” does not mean impossible. It is recommended to consult multiple sources (such as different fabrication shops, manufacturers, and designers) for feedback and opinions when assessing suitability. In most case, it can be achieved, but at the sacrifice of cost, quality, strength, or a combination.

Return to Fundamentals of composite materials[edit | edit source]

About **Help**

The continuous material phase that binds the reinforcement together, maintains shape, transfers load, protects the reinforcement from environment and damage, and provides the composite support in compression.

Desirable characteristics:

- Moisture/chemical resistance
- Low density
- Processability

Engineered materials (designed to have specific properties) made from two or more constituent materials with different physical or chemical properties. The constituents remain separate and distinct on a macroscopic level within the finished structure.

Carbon fibres are composed of large aromatic sheets similar to those in graphite. These graphitic layers form the basic structural units in the shape of ribbons. The structure of carbon fibre ribbon is believed to be a columnar arrangement of disoriented graphite crystallites parallel to the ribbon length. The idealized tetragonal crystallites are stacked above one another, with slight disorientation between the crystals in the direction of fibre axis, trapping sharp needle like voids, where the boundaries between the stacks represent the disordered regions.