Composite Tooling: Trend, Applications and Market

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Tooling for large composite aerospace parts, Source: Boeing

Introduction

In composites industry, aerospace, wind energy, marine and automotive molders/fabricators are looking for conventional tooling (metal & alloys) replacements due to their part design, dimensional stability, part's weight, thermal stability and others external and internal factors. The success of composites tooling will be depending upon part design, material selection, preform design, part removal, handling and the anticipated part outcome. Composite tools are made from similar matrix and reinforcement materials to those the end product is about to be manufactured. It can be made in-house (wind blade) as well as outsourced (aerospace & automotive).

For the prototypes tooling, materials such as fibreglass, high-density foams, epoxy boards, wood and plaster models are suitable because parts are cured at low temperature and tight control of dimensional accuracy is not required, but where high-performance composite parts are manufactured the tools can be made from carbon fibre, epoxy, monolithic graphite, and ceramics.

Composite tooling has the advantage of close coefficient of thermal expansion (CTE) to be part produced which leads to dimensional stability during cure and even controls shrinkage and thermal expansion. The other tooling materials such as C-20 steel and aluminium are less expensive and usually involve shorter lead times but during cure they show mismatch CTE between the tool material and the composite parts. Invar, alloys of nickel and steel offer closer CTE to the composite parts as for example, Invar has CTE very near to that of carbon fibre composites.

Carbon fibre tooling material is the utmost choice of aerospace and automotive industry manufacturers that can withstand thousands of autoclave cure cycles, like Invar does. To increase the durability of composite tooling, several suppliers offer hybrid tool designs that combine, for example, a thin Invar facesheet with a composite backup structure, or a carbon foam core with a composite facesheet. In automotive industry, Formula 1 (F1) is widely used

composite tooling for their exterior and high end applications. Aerospace industry leaders like Boeing and Airbus used composite tooling for the fuselage, wing parts, and Nacelle and thrust reversers production.

In wind energy and marine industry almost glass fibre/polyester based composites tooling is used but with increasing the wind blade length as well as boat hull length , carbon/epoxy is going to be used, meanwhile It is expected that in the next 5-6 years the wind blade length is to be increased from 63 m to 90 m. In India almost all wind blade fabricators are switched over from metal tooling to composites tooling. Metal tooling, still used by some manufacturers of smaller blades, is generally regarded as too heavy. For an example, metal tool for a 40 m blade weigh approx 16-18 tons but for the same composite tool weigh around 5-6 tons, automatically saves 10 tons materials. Due to longer size demand of the boat (upto70 ft), an example is the racing yacht hull, prepreg tooling is used. Prepreg is the preferred tooling material because a boat builder is already geared up to lay up the hull in prepreg.

Major raw material suppliers for the composites tooling:

- ACG
- Hexcel
- Cytec
- Airtech
- Amber

Major composite tools suppliers:

- Weber Manufacturing Technologies Inc
- GrafTech International
- Janicki Industries
- North Coast Composites Inc.
- Reno Machine Company Inc.
- RocTool France
- CTS Composites Inc.
- Carver Composites Tooling
- Remmele
- Touchstone Research Laboratory
- Advance integration technology

Why composites tooling?

- Low coefficient of thermal expansion (CTE): Compared with traditional metal tooling, composite tooling provides low and closer CTE to be part produced. A low coefficient of thermal expansion (CTE) is necessary that has to be matched as closely as possible to the thermal expansion characteristics of the composite component to be made on the tool.

- Light weight: It has huge benefits in the term of lighter weight, can be 1/3 the weight of metal, the sheer size and weight of the tools make them difficult to machine, move and store. Low material density will reduce the mass of the tool and allow its easy handling and storage.

- Composites tooling having low thermal mass, reduces production time (Fast heat up & cool-down rates) by 25 % compared to Invar tooling. However, for complex shaped composite parts which need close dimensional tolerances, the thermal expansion behaviours of the tool and the components have to be matched as closely as possible.

- It can provide a lower cost of production and easier handling and storage even accommodate any part shape.

- Faster heat-up and cool-down rates than metal tools.
- Low tool fabrication and life cycle costs compared to Invar.
- Able to produce parts within 0.25 mm tolerance.
- Able to survive 500 autoclave cure cycles at up to 2040C.

Nova-Tech Engineering (Lynnwood, Wash.), using carbon foam covered with carbon/bismaleimide prepreg. Source: Nova-Tech Engineering

Composite Tooling Prepreg (resin pre-impregnated) Materials for Aerospace and Automotive Industry: Source: Advanced Composite Group (ACG)

- Corrosion resistant.
- Low production cost.
- Low lead time.
- It is cost effective, UV resistant, damage tolerant and able to resist environmental degradation.

Key Drivers:

- Aerospace, wind energy, marine and automotive industry
- Low CTE for better dimensional accuracy
- Heats and cools faster than metals which leads to low cycle time and high production output
- Light weight, easy to transport and handle, saves transportation cost (even internal)
- Less stress on the post-processed part
- Low manufacturing cost
- Low lead time

Challenges:

- Multiple thermal cycles tend to micro-crack and eventually cause vacuum/pressure leaks
- Microcracking occurs after 100 & 200 thermal cycles

- Few high quality vendors available
- High initial cost

New Developments:

For the dimensions and mould stability purpose epoxy/carbon fibre together is used, epoxies have higher heat performance capabilities, so in any application where elevated temperature curing is going to be used, epoxy becomes a good choice.

ACG has developed "ZPREG" for low-pressure molding of paint-ready automotive body panels which is able to withstand thermal cycling and thus provides a high-quality tooling surface.

Hexcel has developed carbon fibre/bismaleimide (BMI) "HexTOOL" composite tooling material which is having lighter weight and faster heat-up/cool-down rates than metal, tight tolerances, low coefficient of thermal expansion (CTE) match with carbon/epoxy parts, suitable for 500 autoclave cure cycles at maximum temperatures of 204°C.

DURATOOL 450 BMI/carbon fibre tooling prepreg from Cytec Engineered Materials is a high-performance tooling system that is capable of continuous service at 190°C and short-cycle service at 204°C.

The latest innovation is CNC machining direct to moulds that is eliminating the step of making a pattern from the mould-making process.

Northrop has used epoxy-based composites tooling materials for its F/A 18 A/B Hornet project. Amber Composites and Airtech Advanced Materials offer the epoxy tooling prepregs and epoxy tooling resins respectively. GrafTech International's GRAFOAM® carbon foam can be used successfully in composite tooling applications as a core material.

Touchstone Research Laboratory offers CFOAM®, a structural material made from coal in a cost effective, high pressure proprietary process that is used in a range of applications, including composite tooling.

Remmele has developed hybrid tooling Invalite™ which reduces 50% weight over conventional Invar tooling.

American Consulting Technology and Research has developed polyurethane based 3X Tooling system designed to be sprayed on any metal or composite tools.

Composites Horizons has developed CARE-MOLD, a very high temperature washout mandrel system for complex parts with internal recesses that would be impossible to design with a metal mandrel.

KaZak Composites Inc has developed a method by which a CAD drawing and a low-CTE tool can be generated, using only a digital photo of a part as the start point.

RocTool continues to develop its Cage System Technology, which uses inductive heating for instantaneous heating of the mold face.

Weber Manufacturing Technologies Inc is specialized in nickel vapor deposition technology for nickel-shell molds which is an alternative to aluminum, epoxy, Invar and steel tools used to manufacture advanced composite parts for aerospace by autoclave technique. Nickel has three times the heat transfer capacity of P20 steel, offering substantial cycle-time reductions.

Nanotechnology also has found use in coatings designed to harden and prolong the life of composite tooling. Integran Technologies Inc., a nanostructured materials supplier is targeting its metal tool facing.

Market Prospects

Although composite tooling demand is low and limited to only aerospace, wind energy, marine and automotive industry it is expected to rise with the new high end product development. The composites market for composites tooling would be $ 3.5 billion (2009) with high consumption in aerospace just before wind energy. By the regional analysis, North America possesses 48% market share while Europe stands at second position with 38 % and APAC has 14% market share value especially Japan and Korea. Advanced Composites Group (ACG) has dominated materials market with more than 50% market share and thereafter Hexcel while rest is captured by Amber, Airtech, Cytec and others. In future composites tooling market will grow heavily in Japan, Korea, and China due to aerospace and wind energy market penetration.

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Conclusion

Composites tooling is being driven by aerospace, wind energy, marine and automotive (high end applications) industries toward their compelling demands of light weight, dimensional stability, low CTE, thermal stability, fast heat up and cool-down rates. Invar is going to be replaced by composite tooling in aerospace industry due to close CTE, tight tolerance and light weight. For an example, Invar tooling for fuselage structures can weigh as much as 300000 lbs, which limits the lay-up rate for automated fibre placement and extends thermal cycle times for autoclave curing.

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