The Battlefield Effect of Using Advanced Composite Structures

by Ben Godfrey

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Materials play a key part in our everyday life, and with the development of new and improved materials we are able to further advance our technologies, and with this our way of life. The impact of materials has been so fundamental to the advancement of mankind that important eras in history have recognised them in name (Bronze Age, Iron Age, etc.); even geography credits the importance of materials – for example Silicon Valley. It is widely accepted that the desire for new and improved materials is driven by such factors as the space race, and of course modern warfare.

Increasingly in modern engineering we are seeing the use of advanced composites in a variety of applications. So, why use composites? Let us first clarify what it is that makes a composite: composites are defined as being made up of two or more components where the combined materials' structural or functional properties differ from those of any of the individual constituent parts in isolation. A common form of composite is made from fibres held together by a resin matrix. These fibres are extremely strong along their length, but have little strength across it. This is where the matrix comes in – as well as holding the fibres together and in shape, they also add strength in this other plane. The fibres can be orientated in many different lay-ups depending on the requirement.

Composites can be made for more complex parts than can traditional materials; different sections of the part can include optimised or more substantial fibre lay-ups, depending on the requirement. This means that elements of a part can be strengthened at local points of high stress without the need for adding unnecessary weight to the whole part. Common fibres used include glass, carbon and aramid (Kevlar®) and are used in a variety of applications, from sporting goods to bullet-proof vests.

In this new era of modern warfare, the technology drive is for C4ISTAR/NEC-based solutions; one of the most talked about is the use of unmanned air vehicles (UAVs) and unmanned combat air vehicles (UCAVs). These units are remotely controlled and unmanned and can be considered almost expendable. With the speculation about the rises and falls of defence budgets, one thing remains constant – everyone wants more 'bang' for their buck, pound or euro. So what is the future of these new technologies with regard to military applications, and how will they impact on the battlefield?

Air

Looking historically at the initial use of advanced composites, they were prominently found in sub-structures such as ailerons and landing-gear doors. They are now being used more widely in primary structures, such as wings and fuselages. In modern fighter aircraft, like Eurofighter, F22 and Grippen, use of composites makes up anything from 20–40% of the structural weight compared to around 2% when they were first introduced in the F15.[1] Furthermore, advanced composites are reported to make up 38% and 40% of the structural weight of the F22 and Eurofighter respectively [2 3].

Continuing to look at UAVs and UCAVs, it can be said that in many ways they are more akin to guided weapons than conventional manned aircraft, in that they can operate in more extreme envelopes. Power issues aside, UAVs can happily loiter pretty much indefinitely at many thousands of feet, while continuing to supply information 24/7 without the need to change personnel.

Looking purely at guided weapons, the operating envelope can be much more extreme, as they can handle higher G-forces than pilots. So what is it that allows UAVs, UCAVs and missiles to push these envelopes? Obviously, aerodynamics, control systems, motors, engines, and many other considerations contribute, but ultimately the prime driver is the materials that are used at all assembly and sub-assembly levels and these need to be structurally capable of operating within the parameters of however and wherever the unit is designed to function. That is to say that a missile should not break up when pulling 25g after being heated on the ground to 50°C by a desert sun reflecting off a runway and then chilled within minutes at altitude to –30°C.

In the case of air vehicles, whether UCAVs or aircraft, composites play a vital role in increasing capability in reconnaissance, support or strike. Let's look at the engines, for example: the use of ceramic composites in engine components can greatly increase efficiency, as they can operate at higher temperatures than the metal equivalents and hence require less energy to be spent on cooling. An additional benefit is that ceramic composite parts weigh considerably less than the equivalent metal components, and this has a knock-on effect of increasing either range or payload, coupled with reduced emissions. Ultimately, this results in getting more flying hours out of the aircraft.

Land

Currently, one of the US requirements for the Future Combat Systems Program is to fit future ground vehicles into a C-130 aircraft, and the vehicles would be limited by a weight limit of 20 tons.

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With the current fleet, this can only be fulfilled by stripping down the vehicles before flight. Not only will this add extra time and manpower, but readying for combat when delivered in theatre could take four to six hours per vehicle, and this assumes that all parts and fuel are available.

The 'Plastic Tank' is a nickname given to the ACAVP (Advanced Composite Armoured Vehicle Platform) that was developed by QinetiQ and Vickers Alvis in a programme that began in the mid-nineties. The capability requirement behind this was for an easily deployable, composite-armoured vehicle. This type of vehicle has several advantages: it is considerably lighter than the metallic alternative (by approximately four tons); it is easier to deploy; it could be made stealthier with technologies built in to the composite to improve infrared and radar signatures; it has better fuel consumption which increases the range; and it is more suited to use in salt-water conditions due to improved corrosion resistance. An additional advantage of having a composite as the armour is that a separate spall liner would not be required since the composite could be designed to do this job as well.

With seven nations' commitment (Belgium, France, Germany, Luxembourg, Spain, Turkey and United Kingdom) to the order of 180 Airbus A400M airlifters, the requirement for deployable equipment is clear. Any emerging platforms that will need to be transported by air should endeavour to be mobile and deployable enough to be moved by this aircraft. The current requirement is for two light armoured vehicles to fit inside the hold, but if in the future this capability could be extended to just one Challenger-equivalent, composite-armoured fighting vehicle, then this would add an attractive extra capability.

Sea

One of the most important naval programmes currently under way is the American DD(X) Destroyer. The need is for a flexible platform with a 30-year life, and this is a similar case for the CVF (UK's Future Carrier Programme). The major factors that validate the case for using composites are:

- Larger all-in-one composite structures, which reduce the need for fastenings and help to save additional weight (between 25% and 50% over conventional materials).[5] Also, manufacturing times can be dramatically reduced by utilising larger modular structures.

- Cheaper manufacturing costs for composites than had previously been possible (some areas predict up to 20% reduction in the next few years).

- Enhanced corrosion protection compared to metallic structures, which is especially useful in marine environments.

- Stealth – an embedded array in the composite structure is proven to help reduce the radar signature. Additional benefits include improved performance against mines and other forms of electronic detection as composite structures are not susceptible to magnetic waves, as is conventional steel.[4]

Certainly the deckhouse of the DD(X) would benefit from manufacture from a suitable composite structure. The improved corrosion and stealth characteristics combined with the lower weight are highly desirable. Fabrication from fewer parts is also attractive in shipbuilding, one of the most complex forms of manufacturing.

There is also further potential for advanced composite use in littoral combat ships, where the same benefits can be clearly seen. The benefits of the enhanced stealth capabilities can be utilised not just in reconnaissance, but also in other missions and for covert operations by the Special Forces.

Currently there is a real need to determine how to provide the most effective metal-to-composite joint. Such a joint, be it bonded or fastened, must be effective and not detract from the advantage of using the composite in the first place. Industry will no doubt be looking at this as a vital manufacturing method to get right.

Repair and Maintenance

In-theatre repair and maintenance must be taken into account as composites do have a tendency to hide any flaws well, and this makes mobile flaw detection a key area in composite research. There are a number of methods that can be employed in systems to address this. Structural Health Monitoring is one such method in which a number of sensors are embedded inside the structure during manufacture. These sensors can then be stimulated and accessed by a number of methods to assess how the structure is performing – for example, when a squaddie drops a wrench on the wing, does it affect the safety and integrity of the structure?

Conclusions

Obviously there are key benefits that composites can bring to all platforms – weight-saving, better radar signatures, higher strengths and better corrosion resistance to name but a few. The question is whether or not the extra costs involved provide overall benefit.

With the publication of the Defence Industrial Strategy White Paper in December, the MoD has stated how keen it is to see an industry-led Technology Demonstrator Programme for UAVs and UCAVs. Such a programme will certainly continue to explore the benefits of advanced composites. ■

NOTES

1 Composites in Aerospace Applications, Adam Quilter, Head of Strength Analysis Group, ESDU International – http://engineers.ihs.com

2 Composites (Page 5, Paragraph 4) – http://oea.larc.nasa.gov/PAIS/Concept2Reality/composites.html

3 Composites in Combat, Lon Nordeen – http://www.global-defence.com/2003/uavs_03.htm

4 Ghost Ships: The Latest in Stealth Ship Technology - http://www.military.com/soldiertech/0,14632,Soldiertech_StealthShips,,00.html

5 Institute for Manufacturing and Sustainment Technologies Annual Report 2002 – https://www.arl.psu.edu/documents/iMAST/02_annual_rprt.pdf