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Aircraft Survivability and the Aerodynamics of Battle Damage

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1. Aircraft Survivability Assessments by Dr Andrew Irwin

Survivability is defined as the ability of an aircraft to survive and withstand a hostile combat environment. This excludes natural effects such as weather. Amongst other mechanisms, survivability can be maximised by carrying out a stand-off attack, being aware of the locations of ground defences and making use of the local terrain to prevent detection. In addition, ground threats may be removed or degraded by electronic warfare techniques.

The probability of detection may be reduced by reducing the aircraft radar, infra-red, visible and acoustic signatures. A Defensive Aids Suite (DAS) may be used to evade an attack once the aircraft has been detected. DAS includes a missile approach warner to cue the pilot on to an attacking missile and to launch decoy chaff and flares. It may also include Directional Infra-Red Countermeasures (DIRCM), which fire a high power infra-red laser at an approaching missile in order to “blind” the missile’s infra-red homing systems. Finally defensive manoeuvring may be used.

Fig. 1 – Battle Damaged A10 Warthog ground attack aircraft

The ability of an aircraft to survive an attack may be increased by minimising the effects of any damage. One example of this is to make certain non-critical parts of the aircraft “sacrificial” in order to protect other more critical parts such as the engines. This is a design feature of the A10 Warthog ground attack aircraft (Fig. 1). Incorporating well-spaced duplex and triplex systems is another example.

Threats include ground based small arms fire, anti-aircraft gun batteries, e.g. the Soviet ZSU23-4, shoulder launched missiles, surface-to-air missiles and, finally, air-to-air missiles. The resultant damage may be highly localised or be spread over a number of impact points. The damage will also depend on the type of material being impacted. It can also include hydrodynamic ram effects damage, especially to a fuel tank.

The damage to an aircraft’s structure, its flight systems and its mission systems must all be assessed before the overall vulnerability of an aircraft can be established. The work being carried out at Loughborough University is concentrated on providing a flexible predictive method for determining the aerodynamic consequences of aircraft damage. This is especially in respect of the probability of an aircraft remaining sufficiently airworthy to allow it to be flown back to base.

2. Effects of Battlefield Damage on Aircraft Aerodynamics by Dr Peter Render

Battlefield damage to an aerofoil section is random in shape, impact angle and location. Damage holes are often “petalled” around their circumference. The effects of this damage have been simulated by cutting circular holes into aerofoil sections, and then coating the sections with a suspension of French chalk and placing the sections in a wind tunnel. The French chalk was used to visualise the flow. Balance measurements were done to provide information on lift, drag and pitching moment.

The hole diameters were 5-40% of the aerofoil chords. The higher figure was considered to be the limiting hole diameter for there to be a reasonable probability of an aircraft being sufficiently airworthy to be flown back to base. The aerofoil sections included representative cavities inside the sections.

Limited tests were also carried out with holes in the form of a Star of David to simulate any effects due to petalling. The tests were an attempt to simulate the random non-circular shape.

Both 2D and 3D wind tunnel tests were carried out. In the 2D tests, the aerofoil sections were positioned across the width of the wind tunnel with the two vertical walls of the wind tunnel forming null points. The holes in the aerofoil sections were sufficiently far away from the nulls for the hole related aerodynamic perturbations not to be influenced by the null points. For the 3D tests, aerofoil sections were mounted vertically from the wind tunnel base with the top of the aerofoil section well clear of the wind tunnel top.

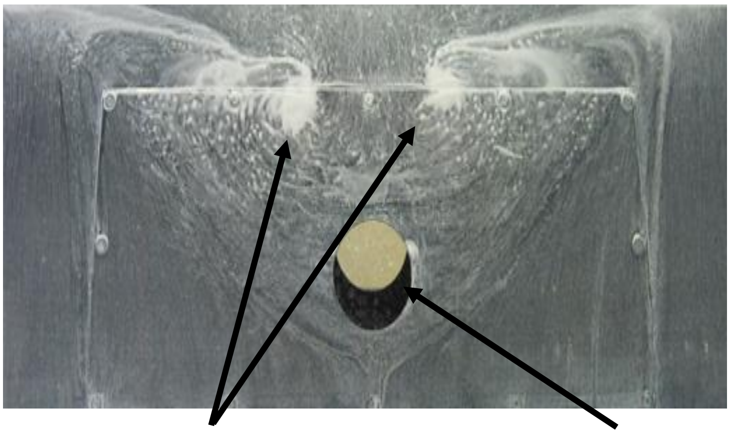

Fig. 2 – Vortices behind aerofoil damage hole

Fig. 2 shows a typical result. The air passing over aerofoil section deviates either side of the hole and combines with the air from the hole to form a "horse shoe" vortex behind the hole. The magnitude of these vortices depends very much on the hole diameter, with those associated with smaller holes being very much less pronounced than those for larger holes.

As expected, the effects of the holes were much more significant at a high incidence angle than at low angles. Air flowed through the holes from the high to the low pressure surface of the aerofoil section. At low angles of incidence this air formed a "weak" jet and hence caused relatively little turbulence and relatively small vortices. Conversely at high angles of incidence, the air formed a "strong" jet which penetrated significantly into the free stream air passing over the low pressure surface of the aerofoil section. The result was a very pronounced vortex. These tests also showed that the effects were influenced by the relative positions of the hole in the upper surface of the aerofoil section to its corresponding position in the lower surface: this means that the effect is dependent on the direction of attack.

Tests were also carried out on an aerofoil section looking like a "cheese grater"; incorporating a large number of small holes to simulate the effects of fragmentation damage. Such aerofoil sections were found to still produce lift but with a significant increase in drag.

The aerodynamic effects of damage may be expressed in terms of the aerofoil section lift coefficient (C_L), drag coefficient (C_D) and pitching moment (C_M). The delta changes to these values (ΔC_L, ΔC_D and ΔC_M) as a function of damage level may be used as inputs to the predictive method for assessing aircraft vulnerability.

A reduction in lift coefficient (negative ΔC_L) means an increased stall speed. This makes the aircraft more difficult to land, indeed some battle damaged aircraft have been lost on landing approach for this very reason. An increase in the drag coefficient (positive ΔC_D) results in increased fuel burn, which means that an aircraft may run out of fuel before reaching base. Similarly changes to the pitching moment (ΔC_M) make the aircraft less stable and hence more difficult to fly.

The lecture was attended by 80 people.

Notes written by Colin Moss, RAeS Loughborough Branch