



Development Work Notice

This document has been prepared as a notification of work in progress within the ESDU committees that will result in future product updates. It will be updated and re-issued throughout the development process.

ESDU Topic:

Aerodynamics 'Fixes' on Aircraft.

Scope:

Aerodynamic fixes are used to control unsatisfactory aerodynamic characteristics, normally (although not always) resulting from local or more extensive flow separation. The unsatisfactory characteristics may be at any angle of attack (AoA) or Mach number but are most usually found to occur over restricted ranges. Fixes may be used to improve flight stability or control characteristics or performance characteristics. They may also be used to alleviate buffet.

Some wing designers view the need for some fixes as part of the design process and prefer not to consider these as fixes. The reason for this is that even with the latest theoretical design tools some inadequacy may be highlighted during initial wind-tunnel model testing and can be corrected before finalisation of the design. For instance, if it had been found that the outboard wing stalled prematurely it could be fixed by modifying the leading-edge camber, or by adding an outboard leading-edge device such as a slat.

Careful attention to design parameters may avoid the need for fixes, but aerodynamic requirements and other configuration requirements may conflict, (for example the tailplane may need to be carefully positioned to ensure that the downwash field in which it is immersed leads to avoidance of aircraft pitch-up, but this position may not be physically achievable on the configuration due for example to ground clearance considerations at take-off or landing). Low and high angle of attack or low and high Mach number requirements may not be compatible. The need to minimise induced drag leads to high aspect ratio and the need to minimise profile drag at high subsonic Mach numbers leads to increased sweep, both resulting in increased tendency for outer wing flow separation problems. The resulting design is inevitably a compromise. It is hardly surprising that fixes are sometimes necessary.

Also, it should be noted that in many cases the requirement for, and development of, a fix resulted not from a failure to meet the original design requirement but from a new requirement to extend the available flight envelope for later development of the aircraft. Clearly such fixes are a cost-effective way of increasing the aircraft capability without the need for major re-design work. Some fixes become embedded into design practice. An example of this is leading-edge wedges or stall breaker strips where an aircraft manufacturer

has established from previous designs that the wing stall characteristics and buffet characteristics can be satisfactorily improved in this way. Wind-tunnel testing and flight testing would be aimed at defining the optimum location.

In this proposed Data Item any feature required to correct unsatisfactory aerodynamic characteristics is considered as a fix, irrespective of the stage of design or flight clearance at which the problem manifests itself. For example, an outboard wing flow separation found during early wind-tunnel model testing may be controlled initially by the use of vortex generators but subsequently by changing the outboard wing leading-edge camber or twist. They are both considered to be fixes.

The proposed Data Item is intended to provide an initial point of reference for aircraft designers who identify unacceptable aerodynamic characteristics during development, whether from wind- tunnel test data or from flight data.

Only those fixes which are passive have been included, so that, for example, slats which would require some form of actuation system have been excluded.

Design information will be provided where available.

Clearly, it is not possible to include all instances of the use of fixes, but it is hoped that the Item will include a sufficient number of fixes and their application, to help “problem solvers” to find an acceptable solution. It should be emphasised that good practice in identifying symptoms, carrying out diagnostic investigation and preparing possible solutions is essential to minimise the timescale to obtain a satisfactory solution. Case histories exemplify this process.

Keywords: Fences, Vortilons, Sawteeth, Notches, Vortex Generators, Leading-edge Wedges Stall Breaker Strips, Junction Flow Vanes, Fixed Slots, Strakes Dorsal Fins, Ventral Fins Tailplane Finlets, Camber Gurney Flaps, Trimming Tabs, Roughened Surfaces, Fillets, Wing Tip Sails, Winglets and Wing Tip Fences, Spoilers, Sealing, Local Shape Modification, Kuchemann Carrots Whitcombe Bodies.

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