Progress in Aerospace Sciences 45 (2009) 169–202

Contents lists available at ScienceDirect

Progress in Aerospace Sciences

journal homepage: www.elsevier.com/locate/paerosci

Aircraft with outboard horizontal stabilizers, history, current status, development potential

John A.C. Kentfield

Department of Mechanical and Manufacturing Engineering, Schulich School of Engineering, University of Calgary, 2500 University Drive NW, Calgary, AB, Canada T2N 1N4

A B S T R A C T

The potential of using outboard horizontal stabilizers (OHS) to reduce aircraft drag, and hence improve fuel economy, was investigated historically, experimentally and theoretically. The feasibility of OHS configurations on the basis of the structural stress levels expected was also studied. The findings of the work showed that from simple, low Reynolds number, wind-tunnel tests, at a wing-chord-based Reynolds number of approximately 6×10^4 and also from theoretical analyses for a higher Reynolds number of 9×10^6, lift/drag (L/D) value increases in the region of 40–50% for wing and tail surfaces can be expected relative to corresponding values for conventional aircraft. When account is taken of fuselage and tail-support boom drag, the expected overall L/D increase is in the region of 30–35%. The analytical stress-level work showed that contrary to what, on a first thought basis, might be expected, there were no major stress problems. Flight tests at the University of Calgary, and by others elsewhere, employing radio-controlled, powered, model aircraft (i.e. UAVs) showed that aircraft of the OHS type were easily controlled in flight and were stable. An examination was made of additional areas that may contribute yet further to the development of the OHS concept.

Contents

Abbreviations: AC, aerodynamic center; AOA, angle of attack; BM, bending moment; c.g., center-of-gravity; CONV, conventional; Eq., equation; ERAST, environmental research aircraft and sensor technology; i.e., that is; L/D, lift/drag; MAC, mean aerodynamic chord; NACA, National Advisory Committee for Aeronautics; NASA, National Aeronautics and Space Administration; OHS, outboard horizontal stabilize; ONERA, Office National d'Études et de Recherches Aerospatiales; SAE, Society of Automotive Engineers; UAV, uninhabited air vehicle; vs., versus

E-mail address: kentfield@enme.ucalgary.ca

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doi:10.1016/j.paerosci.2009.07.001

1. Introduction

The reviewer's interest in aircraft configurations with outboard horizontal stabilizers (here termed OHS configurations) grew, a numbers of years ago, as a consequence of designing a university undergraduate research project in which the concept of placing aircraft horizontal stabilizers outboard, and aft, of the wing of a monoplane was investigated experimentally in a wind-tunnel. The objective was to place the horizontal stabilizers in the upwash component of the vortical flow generated from the mainplane wing tips with the similarly located vertical tail surfaces in the inwash component of the wing-tip flow. The hope was, therefore, to benefit from such a configuration by ensuring that the configuration also generated a modest lift from the horizontal stabilizers which were, additionally, intended to function in the normal manner as pitch-control devices with the possible bonus of an additional drag cancellation thrust from the vertical tail surfaces immersed in the wing inwash flowfields. The expectation was that such an arrangement would yield an increased lift/drag ratio compared with that obtainable from an otherwise comparable conventional configuration with a centrally located, non-lifting, horizontal tail immersed, wholly or partially, in the wing downwash flow. The results of the experiment, which will be described in more detail later, were sufficiently promising to encourage a further, more detailed, study following a literature review to establish the status of prior work in the OHS area.

1.1. Prior work, a brief history

In general terms very little detailed technical information is available relating to the early history of OHS configurations. It seems that what could be termed the pioneering application of an OHS aircraft configuration occurred in the USA during the 2nd World War. This resulted in an experimental ultralow-aspect ratio twin engined aircraft, the Chance-Vought V173. This aircraft was followed by a prototype fighter the Change-Vought XF5U-1 with a generally similar configuration to the V173. However, this latter aircraft was never test flown and the project was finally abandoned [1,2].

The next major OHS development took place, during the latter part of World War 2, in Germany. The Blohm und Voss Company prepared designs for a series of swept wing fighters with OHS tail arrangements. This program was brought to a premature halt, due to the end of the war in Europe, before any test-flying could take place. However, the Blohm und Voss work was quite detailed and sophisticated [3,4].

More recent work directed at the application of the OHS concept has been undertaken by C.W. McCutchen, of Washington, DC, resulting in model gliders incorporating OHS configurations. Yet more recently further research has been carried out on the OHS concept at the University of Calgary, Canada. The early phases of this work have been described in the AIAA Journal of Aircraft [5,6]. The work at the University of Calgary has taken a different path to that of Blohm und Voss which was directed solely at developing fast fighter aircraft with relativity short flight durations. Hence relatively little attention was paid to minimising drag but, instead, to maximising the potential advantage of the weight savings due to the minimised tail surface areas possible with OHS configurations. With the University of Calgary activities maximum attention was, and is, devoted to minimising aerodynamic drag and hence maximising, particularly for long flight-duration aircraft, the lift/drag ratios achievable while unavoidably sacrificing the relatively small advantage to be gained of reduced structural weight due to minimised tail surface areas.

Scaled Composites of Mojave, California has undertaken some work on OHS configurations. One design, identified as Alliance 1, based on University of Calgary research work, was for a large UAV for high altitude, long endurance, surveillance missions. This vehicle was designed by Scaled Composites but was built by them only in the form of a radio-controlled model. The model was test flown successfully by Scaled Composites. Subsequently, Scaled Composites used an OHS configuration in the design of their sub-orbital rocket-propelled vehicle Space-Ship-One employed, successfully, in a quest for the X prize awarded for pioneering non-government funded space flights.

2. Aircraft with OHS configurations

2.1. Chance Vought

During the 2nd World War, the Chance Vought Company, in the USA, produced an ultralow-aspect ratio light twin engine aircraft, the V173, illustrated in Fig. 1. This aircraft, it seems, incorporated the ideas of Charles Zimmerman, a recognized expert on the application of very low aspect ratio wings. It was intended to