its stalling lift coefficient simultaneously. Combined with the sharp stalling features of the aerofoils, this produces the harsh stall found in the flight evaluation.

Initial VSAERO calculations were made on a model of the Fw190A-8. This version of the aircraft was powered by a BMW 801D radial. Naturally, the question arose as to how the aerodynamics of this aircraft differed from the later, Junkers Jumo 213A powered Fw190D-9. The Jumo engine, an inline, is much longer than the BMW engine, giving the D-9 an elongated nose, which was counter balanced with a 500 mm plug added to the aft fuselage. The VSAERO model was modified to represent a D-9 by making these changes and by adding the bulged canopy found on Fw190D-9s. Each model was run at several angles of attack and the resulting integrated forces were used to calculate neutral points for each model of the aircraft. It was found from these results that the fuselage stretches designed by the Focke Wulf engineers had indeed resulted in a slight increase in stick fixed stability, with the neutral point moving from 35·8% MAC (FS 6·26) on the A-8 to 40·4% MAC (FS 9·63) on the D-9. It should be noted these results do not contain propeller slipstream effects, which were not modelled. Flight testing of an early model Fw190A indicated that the aircraft was "just statically stable; stick fixed and free, engine off; and statically unstable to a slight degree, engine on"[17]. During the continued development of the Fw190 series, the aircraft's CG moved rearward as fuel tanks and other equipment were added to the aft fuselage[23]. This neutral point shift during development of the Fw190D model would have been quite valuable in maintaining the continued growth of the design.

CONCLUSION

Important design features of three prominent World War II fighter aircraft have been examined by the use of a modern computational fluid dynamics method. Results presented here include:

- the windscreen of the Spitfire is excessively steep and has a region of separated flow at the base due to this
- much of the flow in the Spitfire cooling system inlet is separated because the wing lower surface boundary layer is ingested
- the cooling system of the Mustang has much smaller regions of separated flow
- laminar flow aerofoils used on the Mustang have the potential for extensive laminar flow, but must be properly finished to achieve this
- the aerofoils and twist used on the Fw190, combined with the wing's elastic properties are the cause of the aircraft's harsh stall characteristics
- modification of the Fw190 from the A-8 model to the D-9 model resulted in an increase in stick fixed longitudinal stability.

It is hoped that the results presented here will help to demonstrate some of the valuable lessons learned from an important era in fighter aircraft design. This information, while historical, still has relevance in today's world of aircraft design.

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