Effects of Nose Strakes On Transport Aircraft

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Abstract

A low-speed wind tunnel investigation was conducted in the Langley 12-Foot Tunnel on a typical commercial transport configuration to determine the effect of adding nose strakes on the aerodynamic characteristics of the model. The fuselage and wings of the model were scaled versions of the McDonnell-Douglas DC-9 aircraft. A generic tail assembly was employed that was different from that of the DC-9. Three different strake configurations were tested at several inclination angles. One strake configuration was identical to that employed on the DC-9 aircraft. The model was tested through a range of angles of attack and sideslip angles. Tests were made both with and without strakes and also with the vertical tail removed.

Introduction

During this summer LARSS program, I worked with Mr. Gautam Shah on a research project involving strakes in use on transport aircraft. Strakes are small fins placed on the nose of an aircraft to aid in yaw stability and control(ability of an airplane to turn about its vertical axis). A low-speed tunnel investigation was undertaken to see if strakes placed on a transport model would provide any appreciable stability or control improvements. Information was also wanted on possible interaction between the strakes and the vertical tail.

Vertical tails and rudders of transport aircraft pose many problems for designers. Due to their large size, they add extra weight to an aircraft. In addition the vertical tail produces drag for the entire flight, therefore adding to the cost to operate the aircraft. Since transports fly at cruise most of the time, the rudder is inactive for a good portion of the flight time. Consequently there is a real desire to find a way to reduce vertical tail size without sacrificing either stability or yaw control. The use of nose strakes may provide a positive contribution in this area.

Nose strakes are currently employed on a number of McDonnell-Douglas commercial transports including their DC-9 aircraft. Since a scale model of a DC-9 fuselage and wing configuration was available for testing, this model was chosen for the research project. The DC-9 model tail assembly and engines were unavailable, however, a generic tail assembly was available and was substituted for these initial tests. Detailed drawings of the DC-9 aircraft and the strake configuration presently in use on the aircraft were supplied by McDonnell-Douglas so that a scale strake model could be constructed and mounted similarly on the wind tunnel model. The model with this strake served as the baseline for the present tests. Various strake sizes and inclination angles were employed during this investigation.

Background

Research on the use of nose strakes on fighter aircraft configurations has been conducted for over ten years. Currently, there are some fighter configurations which react well with strakes and research has shown that there is a benefit from their use. Strakes have been effective at high angles of attack (above 30 degrees) in providing yaw control power. Their use has been particularly appealing because conventional vertical tails and rudders lose their effectiveness from becoming immersed in the low energy wing wake at these high angles of attack. It is important to realize that strakes, while they have a tremendous effect at high angles of attack, produce almost no yaw control at low angles of attack. This is significant because fighter aircraft operate at wide ranges of angles of attack (up to 70 degrees), while transport aircraft operate over a much lower range(0 degrees to 30 degrees). If strakes as employed on fighter aircraft were as effective at low angles of attack as they are at high angles, then this technology could be utilized on transports as well as fighters with obvious gains to operators. The fact that strakes are used on transport aircraft indicates that the size, shape, placement, and effectiveness of these strakes influence the aircraft in a manner different than the strakes used on fighter aircraft. The use of such strakes is obviously beneficial since McDonnell-Douglas uses nose strakes in so many of their commercial transport designs.

Test Facility

The tests were conducted in the 12-foot Low-Speed Wind Tunnel. The 12-Foot Low-Speed Wind Tunnel is an atmospheric pressure tunnel completely enclosed in a 60-foot diameter sphere. The test section has a 12-foot diameter octagonal-shaped cross section and a length of 15 feet. The drive system consists of a single 15.8-foot diameter 6-blade drive fan with an adjustable fan speed up to a maximum of 750 RPM. Dynamic pressure up to a maximum of 7 psf is available as the test conditions. A sting system can position a model at any pitch angle from -10 degrees to 90 degrees, and sideslip angles from -90 degrees to 90 degrees. Smoke generation equipment is available for use in the facility to permit visual obversations of the flow field.

The Test

Only a limited number of tests were made during this wind tunnel entry, and data were obtained only for the model configured for the cruise configuration with leading and trailing edge flaps undeflected and the rudder and horizontal tails set to zero. Two different strake configurations in addition to the baseline were tested. One strake had the same span width as the baseline strake, but it had a 80% increase in the chord length. The other strake had the same chord length as the baseline strake, but a 50% increase in the span. All strakes were constructed from sheet metal in the technician's shop and mounted on the model such that the trailing edge of all three strakes was at the same location on the fuselage. Rotation of a strake about its trailing edge varied the strake inclination angle. Inclination angles of 0 degrees, +10 degrees, and +20 degrees were tested.

The model was placed in the 12-foot tunnel and installed on the proper force balance and sting as needed to ensure the model was properly placed for this test. Several stings and mounting brackets were tried before settling on the 20-in. sting with a 30-degree offset mounting block and a force balance rated for 120-lbs. Once the model was mounted and the equipment was checked out the tunnel was started and testing began.

The model was tested at a single dynamic pressure of 5 psf in two manners; alpha runs and beta runs. Alpha runs consist of placing the model at a certain beta angle, which is the angle between the direction of the airflow and the centerline of the aircraft on a horizontal plane, and sweeping through a series of pitch angles. Beta runs consist of placing the model at a certain pitch angle and sweeping through a series of sideslip angles.

The schedule of tests is as follows: first, the model was tested, as is, with no strakes. Then the baseline strake was added, then the larger span strake, and then the larger chord strake. After these tests were completed, the vertical tail was removed from the model, in order to test the model's characteristics without a vertical tail. We then proceeded to repeat the same sequence of strakes (strakes off, baseline, larger span, and larger chord). Once these tests were completed, the vertical tail was replaced and the baseline strake was pitched to +10 degrees from its original position. We also did this with the larger span strake. Once again the baseline strake was replaced and canted to +20 degrees After obtaining this data, the left baseline strake was removed leaving just the right baseline strake, which was tested at +20 degrees, +10 degrees, and 0 degrees The next test performed was to remove all the strakes and to deflect the rudder to -25 degrees. The last test performed was a smoke test, where smoke was blown past the model to determine the flow field around the model.

Results/Conclusions

Since my summer session at NASA Langley is ending and this particular test is not completed, results from the data collected thus far are inconclusive. The test did determine that the strakes do have an effect, but how much and how significant is still to be determined. We have ascertained that the strakes do interact with the vertical tail in actually yawing the aircraft, because with the vertical tail removed almost no yawing capability was observed. Obviously, more tests will need to be performed before more specific conclusions can be drawn that may result in an actual change in aircraft configurations of the future.