above the tropopause.[24] Then from these data, and under the previous assumptions, we arrive at 1951 metric tons of carbon particulates from commercial jets emitted directly into the stratosphere each year (1774 metric tons emitted from the smaller aircraft, and 177.4 metric tons emitted from the larger aircraft).

Engine residue also consists of sulfur dioxide and sulfur trioxide particulates, which are oxidized in the lower stratosphere through photochemical reactions. Sulfur trioxide immediately hydrolizes[26] to form sulfuric acid, H_2SO_4, and samples show that these H_2SO_4 droplets usually are on the order of tenths of a micron in size.[27] Since the EI of sulfur dioxide is twenty times that of the carbon particulates, and the H_2SO_4 weight equivalent of sulfur dioxide is 98/64 times the sulfur dioxide, this increases the loading of particulates in the stratosphere to 39,000 metric tons/year due to sulfur dioxide alone; or about 59,700 metric tons/year of H_2SO_4 particulates.

Thus, commercial jet aircraft emit over 60,000 metric tons of particulates a year into the stratosphere. This is to be compared with volcanic activity, which injects particulates into the stratosphere at approximately twice this rate (120,000 metric tons/year, see the preceding). Since there are some reasons to believe that stratospheric particulates due to volcanic activity has influenced global climatic changes in the past,[12-15] that the present-day global climate is changing,[7-9] and that the present rate of man-made stratospheric particulate loading is half that of volcanic activity, then we should be concerned.

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Technical Comments

Comments on "Experimental Investigation of Subsonic Turbulent Separated Boundary Layers on an Airfoil"

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THE authors assert, in the introduction to their experimental paper,[1], that the referenced theoretical models (Refs. 2 through 6) work reasonably well up to the onset of flow separation or at most where the separated regions are small, but that they fail with large regions of separated flow.

It seems indeed unfortunate that the authors neglected to consider the Westinghouse[7] automated algorithm for the prediction of the pressure distribution on two-dimensional noncavitating lifting hydrofoils, isolated or in cascade, even

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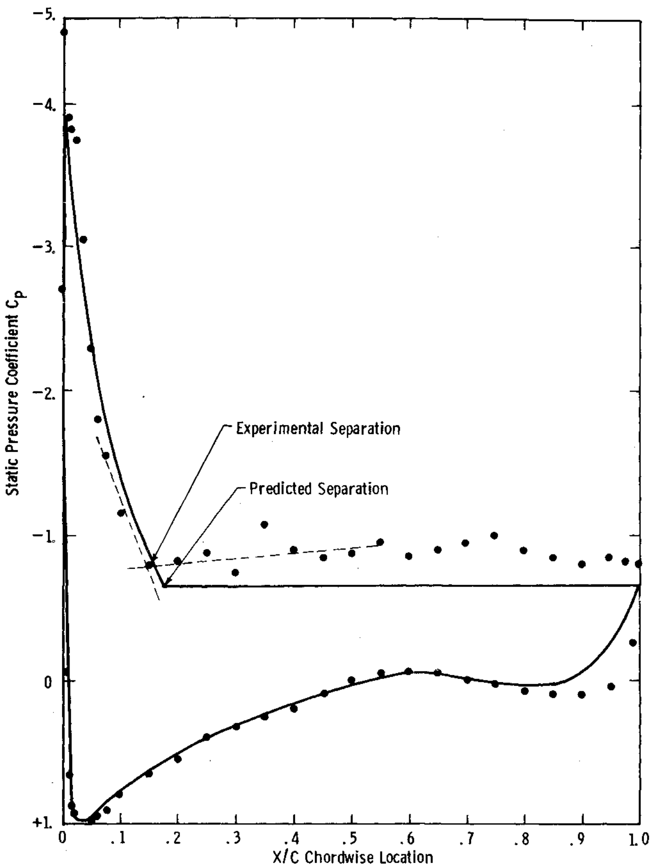

Fig. 1 Comparison of theoretical (automated algorithm) airfoil pressure distribution and of experimental data for NASA GA(W)-1 airfoil at 21.14 deg angle of attack.

with massive turbulent flow separation. The separation criterion employed in the algorithm was that of Goldschmied.[8]

The authors investigated experimentally the NASA GA (W)-1 airfoil up to 18° angle of attack, with turbulent separation up to 45% chord from the leading edge.

Figure 1 (reproduced from Ref. 7) presents the experimental and theoretical pressure distribution on the very same NASA GA(W)-1 airfoil at the extreme 21° angle of attack, where flow separation starts at 15% chord from the leading edge. As it can be readily seen, the agreement between theory and experiment is quite good, and 85% flow separation can be classified as massive. As a concluding comment, it can be said that our theoretical success at 21° is three times as significant as a similar success at 18°, in inverse proportion of the respective separation distance from the leading edge.

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Reply by Authors to F.R. Goldschmied

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UNFORTUNATELY, the results of the Westinghouse research[1] did not appear in the open literature until after the Wichita State University paper had been accepted for publication. The principal limitation of the Westinghouse method seems to be the necessity of using an experimental correlation to obtain the correct level of pressure in the separated flow region.

Another theoretical approach which is capable of determining the separation pressure theoretically and which accounts for the wake flow in some detail is currently being developed by Naik[2] and Zumwalt.

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