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Technical Comments

Comment on "Equation for Additive Drag Coefficient at Static Conditions"

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ANY attempt to define a coefficient for the subsonic additive drag based on freestream dynamic pressure that is finite under static conditions is predestined to fail because the former (the numerator) is usually finite and the latter (the denominator) is always zero. This is understandable because the additive drag is due to the operation of the engine and is always positive when the throttle setting causes the freestream stream-tube area A_0 to be different from the physical inlet area A_1 (that is, either greater or less).

The analysis of Ref. 1 confirms this conclusion. The additive drag coefficient defined by Eq. (1) and evaluated by Eq. (40) is infinite at static conditions because A_0/A_1 is infinite when M_0 is zero. It is therefore preferable to base the additive drag coefficient on the behavior of the engine that is the source of the phenomenon. For example, Ref. 2 employs the quantity

$$\phi_{\text{inlet}} = \frac{\text{Additive Drag}}{\text{Uninstalled Engine Thrust}} \tag{1}$$

which, in general, can be written as

$$\phi_{\text{inlet}} = \frac{M_0/M_1\sqrt{T_1/T_0}\left(1+\gamma M_1^2\right) - \left(A_1/A_0 + \gamma M_0^2\right)}{(F/\dot{m}_0 a_0)(\gamma M_0)} \tag{2}$$

and reduces for the static case to

$$\phi_{\text{inlet}} = \frac{\left(1+\gamma M_1^2\right)\Big/\sqrt{1+(\gamma-1)M_1^2/2} - \left[1+(\gamma-1)M_1^2/2\right]^{(\gamma+1)/2(\gamma-1)}}{(F/\dot{m}_0 a_0)(\gamma M_1)} \tag{3}$$

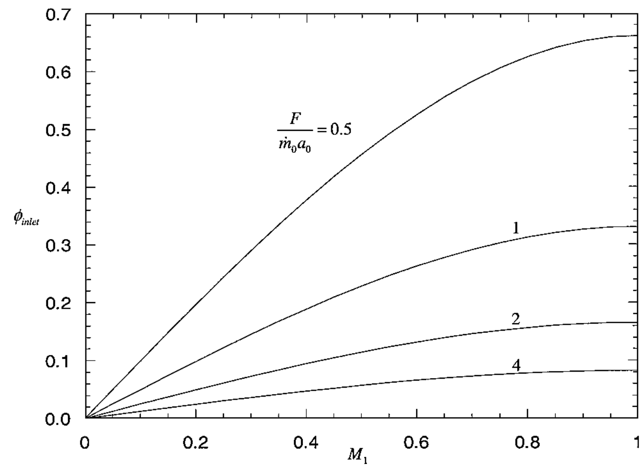

Fig. 1 ϕ_{inlet} as a function of M_1 for static conditions, $\gamma = 1.4$, and $0.5 < F/\dot{m}_0 a_0 < 4$. The range of $F/\dot{m}_0 a_0$ shown brackets the range of the turbofan family from high-bypass transport engines to low-bypass afterburning fighter engines.

Equation (3) highlights several important facts. First, because the dimensionless uninstalled specific thrust $F/\dot{m}_0 a_0$ is a fixed, inherent property of the engine then ϕ_{inlet} depends only upon M_1 and γ. Second, as Fig. 1 demonstrates, ϕ_{inlet} is always finite and well behaved, but it can be surprisingly large under static or takeoff conditions, particularly for moderate- to high-bypass-ratio transport engines. Finally, engine cowls and nacelles therefore usually provide the means (for example, blow-in doors) to increase A_1 and reduce M_1 during takeoff in order to reduce ϕ_{inlet} to acceptable levels.

In closing, we believe that the general formulation of Eq. (2) should be the standard practice because it is based on the underlying phenomena, and, in the final analysis, the additive drag is charged against the engine rather than the aircraft.

References

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