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MODEL SUPPORT SYSTEM INTERFERENCE ON ZERO-LIFT DRAG AT TRANSONIC SPEEDS

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Abstract

In this paper the support system interference on the zero-lift drag of an axisymmetric and an aircraft type models is discussed. Two different techniques were adopted for the two models tested to evaluate the support sting interference. It is found from these tests that the presence of a rear sting support would result in a reduction in the zero-lift drag of as much as 20 to 50 percent of the true value. This apparent reduction in drag is found to be a strong function of the free stream Mach number close to unity. Detailed pressure measurements over the aft-body of the axisymmetric model suggests that due to the positive pressure field imposed by the sting over the boat-tail region of the model the free stream Mach number at which the shocks appear in the boat-tail region will be higher when the sting is present than that without it. This will result in an increased drag divergence Mach number for the model in the presence of the sting. It is argued that because of this reason the sting effect on zero-lift drag strongly depends on the Mach number close to unity.

List of Symbols

C_{DF}	Zero-lift fore drag coefficient
C_{DT}	Zero-lift total drag coefficient
ΔC_D	Increment in the drag Coefficient due to sting
$\Delta C_{D\beta}$	Increment in the boat-tail drag coefficient due to sting
ΔC_{Db}	Increment in the base drag coefficient due to sting
ΔC_{DA}	Increment in aft body drag coefficient due to sting $\Delta C_{DA} = \Delta C_{D\beta} + \Delta C_{Db}$
D	Maximum diameter of the model
d_s	Sting diameter at the base of the model
d_b	Model base diameter
M	Free stream Mach number
l	Length of the constant diameter portion of the sting.

I. Introduction

It is well known that due to the upstream influence of the rear sting support system, the model aerodynamic characteristics get affected during wind tunnel testing. The magnitude of this influence mainly depends on the sting and model geometry at the base. This upstream influence is quite marked at subsonic and transonic speeds but is relatively small at supersonic speeds. The aerodynamic characteristic which gets affected most, because of the support sting interference, is the zero-lift drag of the model and generally the value decreases. This apparent decrease in drag turns out to be a strong function of Mach number at transonic speeds for certain type of sting geometry.

The present paper discusses the support system interference on the zero-lift drag of two models in the Mach number range of 0.5 to 1.2. The first model was an axisymmetric one for which the zero-lift drag was force measured using a rear sting support. The support sting interference for this model was evaluated by integrating the pressures over the boat-tail surface and the base of the model. These pressures were obtained by using a pressure model mounted on a separate strut support, with and without the presence of the dummy sting located at the model base.

The second model was of aircraft type. In this case the zero-lift drag was also force measured by the same rear sting support. But the support sting interference was evaluated by making additional force measurements on the same model, supported from a "slender sting."

With the above method of evaluation of the support system interference it is hoped that bulk of the interference, which is attributable to the support system in the immediate neighbourhood of the model base, is measured. In fact, there is some indirect evidence to this effect.

II. Description of the Models and the Support System

Fig. 1 gives the geometrical details of the model and the two support systems used for the axisymmetric model. Fig. 2 gives support system details of the aircraft type model. All the relevant geometrical parameters of the stings are also marked in Figs. 1 and 2. Both the models had suitable boundary layer tripping

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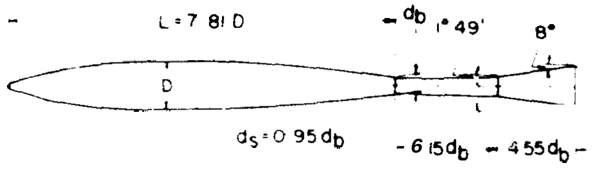
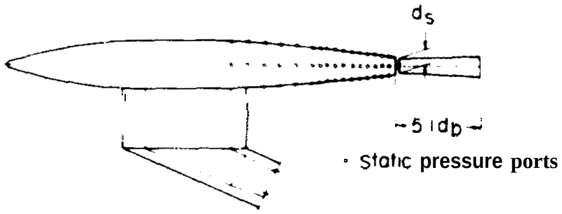
devices to obtain turbulent boundary layer over the models.

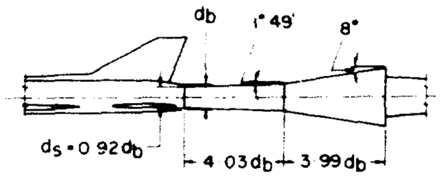


(a) FORCE MODEL ON 'REGULAR STING' SUPPORT



(b) PRESSURE MODEL ON STRUT SUPPORT WITH A DUMMY STING

Figure 1. Details of the axisymmetric model and support system.



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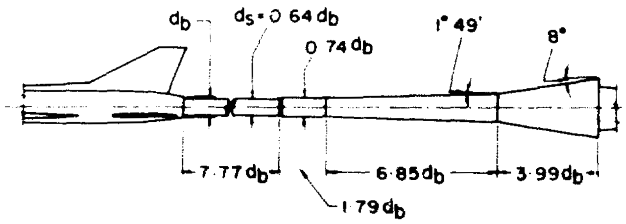

(b) MODEL ON 'SLENDER STING'

Figure 2. **Details of the support system for aircraft type model.**

III. Test Facility and the Test Programme

The tests were conducted in the 1.2M Trisonic blowdown Tunnel of NAL in the Mach number range of 0.5 to 1.2. A test incidence range of -2° to +4° was covered, during all the force measurements with the "regular sting," to get the zero-lift drag variation with Mach number. However, while evaluating the support sting interference, the incidence was kept at zero degrees for both the models. The stagnation pressure was held constant at all the test Mach numbers and consequently the unit Reynolds number varied from 17 x $10^6/M$ to 26 x $10^6/M$ in the test Mach number range.

IV. Results and Discussions

The test incidence has been corrected for the support sting deflection, if any, due to air loads on the model. For the axisymmetric model the total zero-lift drag coefficient (C_{DT}), and for the aircraft type model the zero-lift foredrag coefficient (C_{DF}) have been computed. In computing C_{DF}, the base drag has been subtracted from the measured total drag.

fig. 3 gives the variation of the zero-lift drag with Mach number for the axisymmetric model. The values of C_{DT} obtained

i) from force measurements with the "regular sting" and

ii) after applying the two sting corrections namely $\Delta C_{D\beta}$ due to the changes in the model boat-tail pressures and ΔC_{Db}, due to changes in the model base pressure, both obtained from the pressure model data,

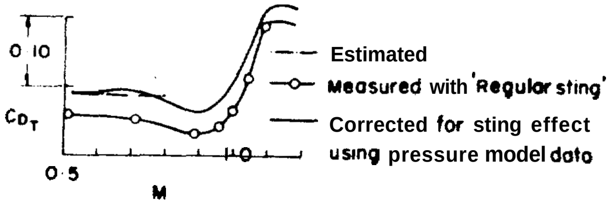

Figure 3. Zero-lift drag of axisymmetric model.

have been plotted in this figure. The reduction in the zero-lift drag because of the support sting influence on the boat-tail and base pressures of the model is quite marked (almost 50% to 100% of the measured value). Also plotted in this figure is the estimated subsonic zero-lift drag coefficient (using Ref. 1). If this estimate is assumed to be close to the true value it appears from the figure that bulk of the support system interference has been evaluated, atleast at low subsonic speeds, from the present method of support sting interference evaluation.

fig. 4 shows the variation of the incremental aft-body drag ΔC_{DA}, due to support sting interference, with Mach number. The variation of the boat-tail drag component ($\Delta C_{D\beta}$) is also plotted in this figure. The incremental base drag ΔC_{Db}, ($\Delta C_{DA} - \Delta C_{D\beta}$) is found to be constant upto M = 1.0. But $\Delta C_{D\beta}$, though remains nearly constant upto about M = 0.9, increases rapidly and reaches a peak value around M = 1.0. Beyond M = 1.0 both $\Delta C_{D\beta}$ and ΔC_{Db} decrease very rapidly. The reasons for the enhanced sting effect

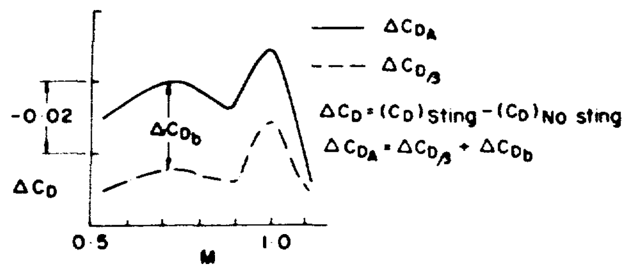

Figure 4. Incremental boat-tail and aft-body drag of axisymmetric model.

at Mach number approaching unity and its reduction beyond M = 1.0 are given below.

A detailed study of the boat-tail pressure has shown that for free stream Mach numbers above 0.95, the flow on the boat-tail region of the axisymmetric model becomes supersonic and undergoes a sudden compression through a nearly normal shock, located well ahead of the model base. This shock modifies the pressure distribution on the boat-tail surface considerably and increases the boat-tail drag at Mach numbers above 0.95 (See fig. 5). Further, the presence of the sting causes an upstream movement of the shock. Alternatively, it can be argued that for the same shock position on the model the free stream Mach number will be slightly higher in the presence of the sting than that without it. This will result in a higher drag rise Mach number for the model when the sting is present. The foregoing observations will provide a plausible explanation for the rapid increase in the sting effect (ΔC_D) as the Mach number approaches unity. As can be expected, with increase in the free stream Mach number the rear shock is swept further downstream the model and the sting effect (ΔC_{D_A} or ΔC_{D_β}), after reaching a maximum value around M = 1.0, decreases rapidly to almost zero value when the shock is at the model base.

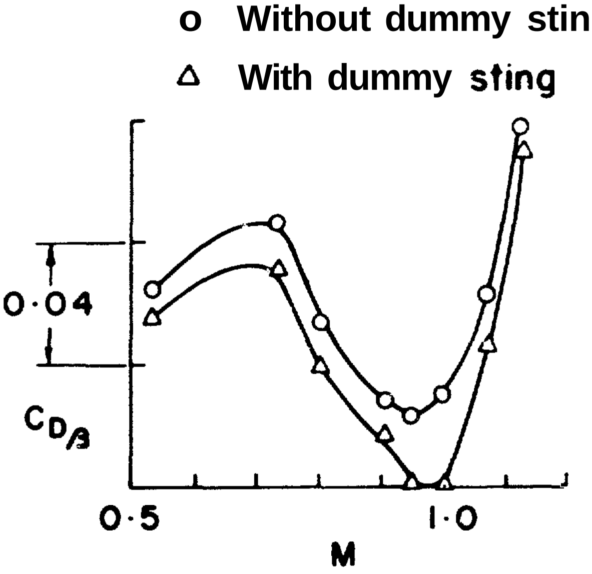

Figure 5. Boat-tail drag of axisymmetric model.

fig. 6 shows the variation of the foredrag coefficient of the aircraft type model with Mach number for both the "regular sting" and the "slender sting" cases. In this case the reduction in the zero-lift drag, due to the sting influence is about 20% of the measured value at M = 0.9. It should be noted here that the reduction in C_{DF} seen in this case is mainly because of the changes in the boat-tail pressures alone.

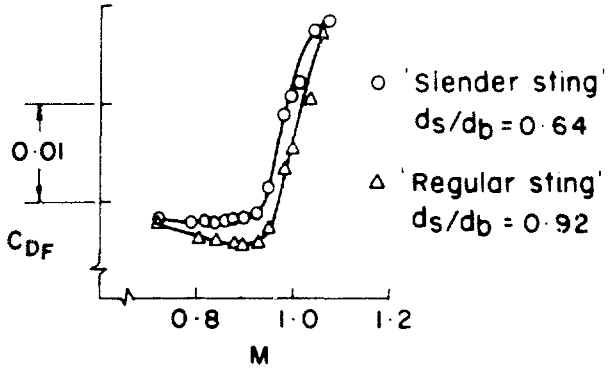

figure 6. Zero-lift foredrag of aircraft type model.

further, it can also be noticed from Fig.6 that the dip in the zero-lift drag occurring around M = 0.9 (which can be attributed to the varying effect of the sting, in this Mach number range, on the boat-tail pressures of the model) has practically disappeared in the case of slender sting.

The drag divergence Mach number is over predicted to an extent of 0.05 (See fig. 6) in the presence of the "regular sting" than that with the "slender sting."

fig. 7, which gives the variation of

$$\Delta C_{D_F} = (C_{D_F})_{'Regular\ sting'} - (C_{D_F})_{'Slender\ sting'}$$

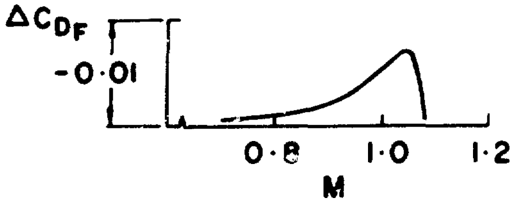

Figure 7. Incremental zero-lift foredrag of aircraft type model.

ΔC_{DF} with Mach number, also shows a similar trend as that of the axisymmetric model, excepting that the peak value of ΔC_{DF} occurs around $M = 1.05$ for the aircraft type model. Tho value of ΔC_{DF}, as seen in the case of the axisymmetric model, drops rapidly beyond $M = 1.05$ indicating the decaying influence of the sting beyond the Rach number of 1.05.

V. Conclusions

Tests have shown that at subsonic and transonic Mach numbers the model support sting/system has considerable influence on the model boat-tail and base Pressures and the combined effect is to reduce the zero-lift drag of the model.

For reasonably boat-tailed bodies supported by sting, where the sting geometry is such that $d_s/d_b \simeq 1.0$ and $l/d_b = 0$ the apparent reduction in zero-lift drag could be as much as 20 to 100 percent of the measured value.

Though it is mentioned in Ref. 2 that the support sting interference is a weak function of the free stream Mach number at least upto $M \leq 1.0$, under limiting conditions of the body and sting geometries, such as the ones reported here, significant increase in sting effect can be noticed at Mach numbers approaching unity. most of this increase can be attributed to the changes in the boat-tail pressures alone.

The overall effect of the support system on the drag divergence Mach number is to over predict it to the extent of 0.02 to 0.05.

The support system interference on the model zero-lift drag decreases rapidly at or slightly beyond a free stream Mach number of unity.

References

1. Royal Aeronautical Society data sheets.
2. Sykes, D.M., Sting interference effects on afterbodies at transonic speeds, AGARD CP 124, 1973.

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