

EXPERIMENTAL INVESTIGATION ON PERFORATED CONE-CYLINDER
CONFIGURATIONS IN AXISYMMETRIC SUPERSONIC FLOW

EUGEN ȘERBĂNESCU *

ABSTRACT

An experimental investigation upon perforated cone-cylinder configurations (with vertex half angles of 21° , $22^\circ 30'$ and 25° , at Mach numbers of 1.38, 1.79 & 2.23) was performed in the Romanian Trisonic Wind Tunnel.

The results show that the total drag as well as the foredrag are affected in a positive way - especially below a Mach number depending on the vertex angle, on the porosity, on the plenum chamber volume and on the Reynolds number - by the occurrence of a secondary (inner) flow and by its interaction with the main stream.

The Schlieren pictures point out details of the complex phenomenon taking place, by indicating the disappearance of the expansion fan, which normally appears on the joint of a cone-cylinder body, as well as the occurrence of a separation streamline between the passive blown flow and the oncoming stream.

Drag reducing potential of the using of axisymmetric perforated configurations is demonstrated, provided that matching the outflow and inflow characteristics is mastered.

* Research Scientist, National Institute for Scientific and Technical Creation, INCREST, Bd. Păcii 220, Bucharest Romania

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INTRODUCTION

As part of the flight bodies drag reduction preoccupations, an investigation upon perforated cone-cylinder configurations with semi-vertex angles of 21° , $22^\circ 30'$ & 25° at zero incidence Mach numbers of 1.38, 1.79 & 2.23, was conducted in the Romanian Trisonic Wind Tunnel.

The purpose of these tests was both to verify in a first approach whether any appreciable drag reduction can be obtained by using a perforated axisymmetrical body in supersonic flow and also to reveal what kind of aerodynamical behaviour such a configuration could exhibit.

Intuitive reasons and a first theoretical study (accepted and scheduled for publication in Sept-Oct. 1985 by the Journal of Spacecraft & Rockets) show that the proximity of the overpressure loading the conical portion upstream the cone-cylinder junction with the depression acting on the cylindrical zone downstream the junction could be exploited in order to achieve - by interconnect the two zones - drag savings. This could happen, for example, by perforating the cone-cylinder body as well as by creating a plenum chamber located underneath the perforated surface, so that a secondary (inner) flow could be born.

Ref. / 1 - 3 / consider the existence of a mean of blowing or suction - and consequently a loss of power - while the present paper as well as - mutatis mutandis - Ref. /4/ are based on the using of passive perforated surfaces, that is no device or pump are required.

The objective of this work was to assess the drag reducing potential of what could be named as a self adapting aerodynamical system.

MODELS CONSTRUCTION AND INSTRUMENTATION

The three perforated configurations (Table 1) consisted of three interchangeable perforated cone-cylinder bodies, each of them supported by a 149 mm. diameter polished surface Duralumin cylindrical unchanged body. The inner solid body, that is the solid boundary of the plenum chamber was a 18° half angle cone.

For comparative purposes the geometrically similar solid cone-cylinder bodies have also been tested.

The model was rigidly connected to a six components strain gauge balance located inside the central body (Fig.1) and the balance was attached to the tunnel sting-strut combination.

The ratio of sting diameter to base diameter was 0.36. In order to allow the measurement of the base pressure distribution, the base model was provided with 4 rows of orifices located at 90° to each other. For the same reason the central body was also equipped with a scanivalve with 48 ports and 10 psid KT. transducer.

RANGE OF TESTS

All of the test results herein shown were obtained at a 0° angle of attack of the models.

Because of the operating characteristics of the tunnel, it was impossible to maintain a constant Reynolds number throughout the tests Mach number range. Reynolds numbers based on the cylinder diameter were $Re_1 = 3.5$ mil. for $M_1 = 1.38$, $Re_2 = 4.17$ mil. for $M_2 = 1.79$ and $Re_3 = 5.1$ mil. for $M_3 = 2.23$.

Blockage ratio of the model in the testing wind tunnel section was about 0.012.

Good data repeatability (± 1.3 % of the drag coefficient) was obtained.

DATA REDUCTION

All the experimental data were reduced to coefficient form based on the cylinder cross-sectional area and on the free-stream dynamic pressure. Corrections due to the effects of streamangle variation were found to be within the limits of accuracy of the data and have therefore been neglected.

Experimental values of the total drag were determined by means of strain gauge balance indications.

The base pressure drag was determined by integration of the base pressure distribution.

The foredrag was taken as the difference between the measured total drag and the base pressure drag, calculated as above.

RESULTS AND DISCUSSIONS

Flow Field

Both massive suction and massive blowing are involved in the present experiments. The suction appears through the conical portion, while the blowing occurs through the cylindrical portion. (Fig.2,a). Consequently a secondary (inner) stream is born, flowing through the plenum chamber, and affects the main (outer) stream development from the tip of the cone to the rear cylindrical zone.

In spite of the expectations, it has not to be too large.

By all means, the Fig.3 shows that further appreciable fore-drag reduction is to be expected in transonic Mach number range. This could be of a very important practical significance.

Remarcable total drag reducing point out the Fig.4. First of all the comparison with the corresponding solid configurations goes definitely in the favour of the perforated configurations, below Mach number of approx. 1.8. View to the Fig.3 vs. the Fig.4, it is apparent that strong base drag reduction is responsible for that significant total drag reduction. Again the evolution in transonic range seems to be very promissing, although the descending slope of the total drag coeficient seemsto be rather exaggerated.

But, there is an other interesting item : below a Mach number of 1.5, a perforated $22^{\circ}30'$ half angle cone-cylinder configuration presents even better results than the inner solid body (a 18° half angle cone-cylinder) does. View to this, the possibility of a total drag reducing of a solid shape by adding over it an appropriate perforated configuration has thus been demonstrated.

CONCLUDING REMARKS

An attempt to determine whether any appreciable drag savings can be achieved by the use of perforated cone-cylinder configurations has been carried out. The results show a very promising aerodynamical behaviour.

The plenum chamber volume is shown to be a powerful parameter, but neither the porosity - particularly the diameter holes and the perforated wall thickness - is less important. The effects upon the skin friction drag and wave drag are to be separately established. Getting an optimum porosity function, in order to obtain the best matching of the outflow and inflow characteristics, has also to be investigated.

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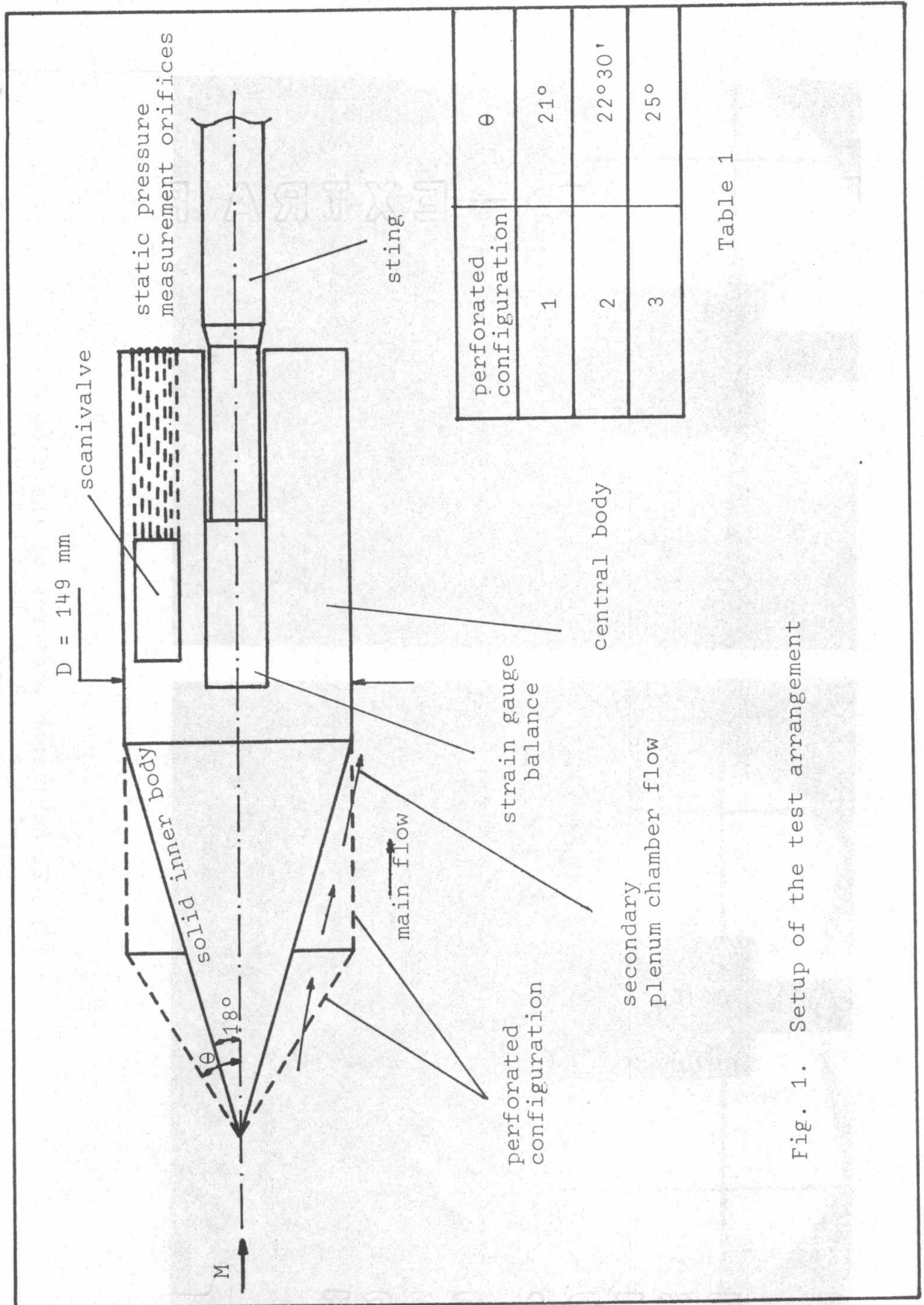
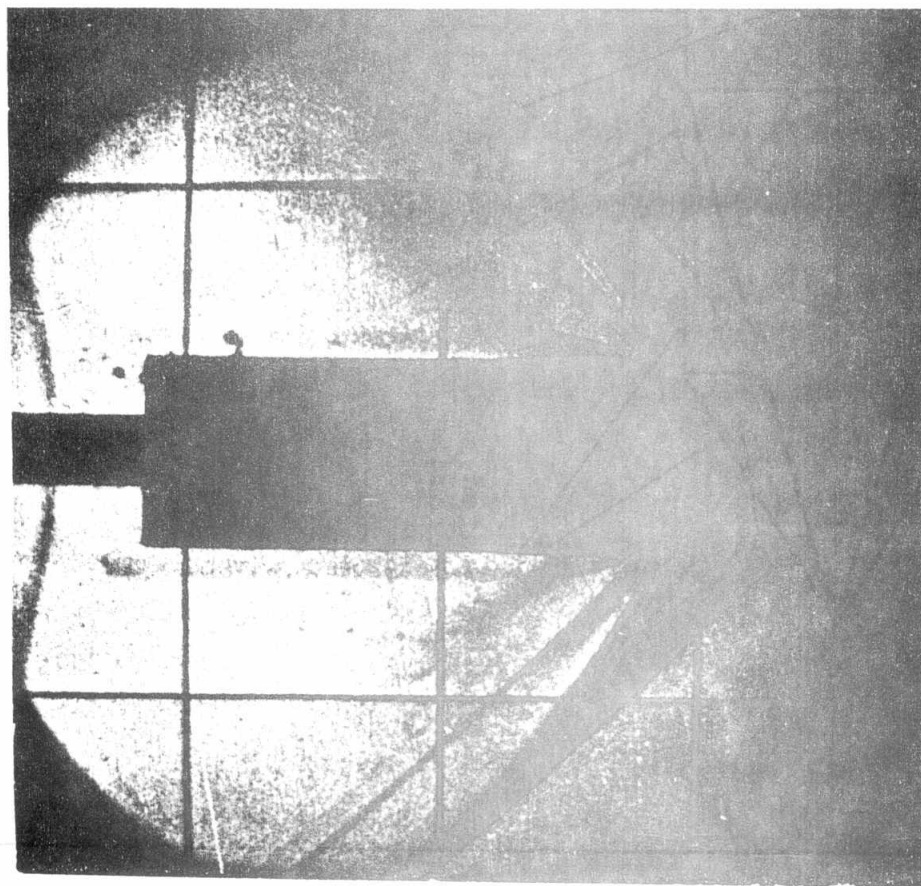
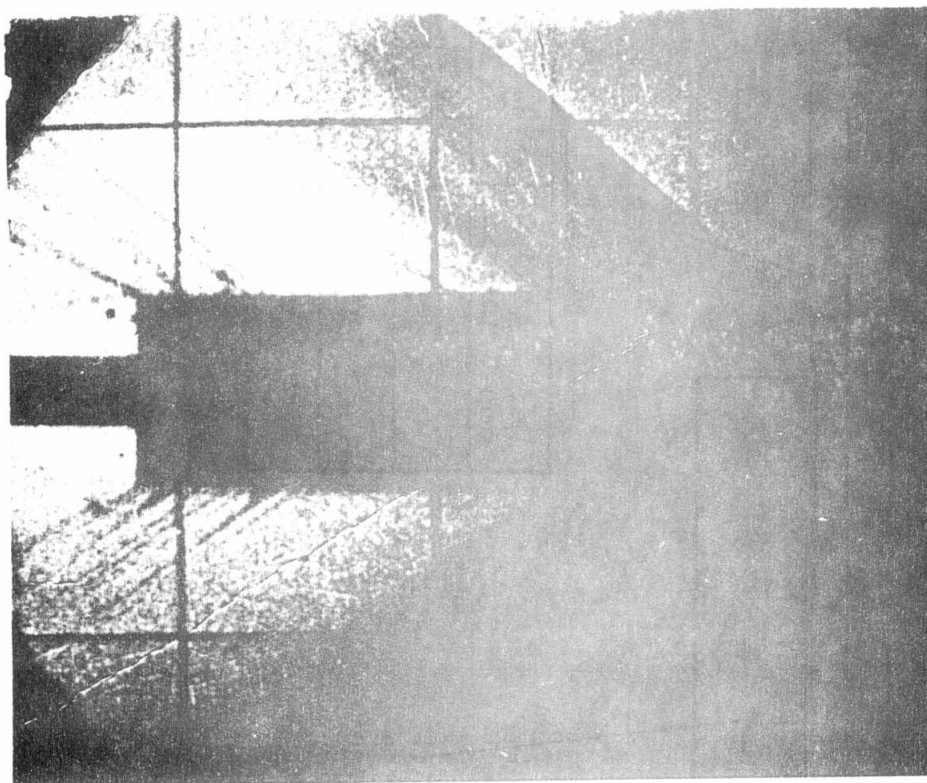


Fig. 1. Setup of the test arrangement



b

Fig. 2. Schlieren pictures of the flow
at $M = 1.79$ & $Re = 4.17$ mil.
a) over a $22^{\circ}30'$ perforated body
b) over a solid ogive

a

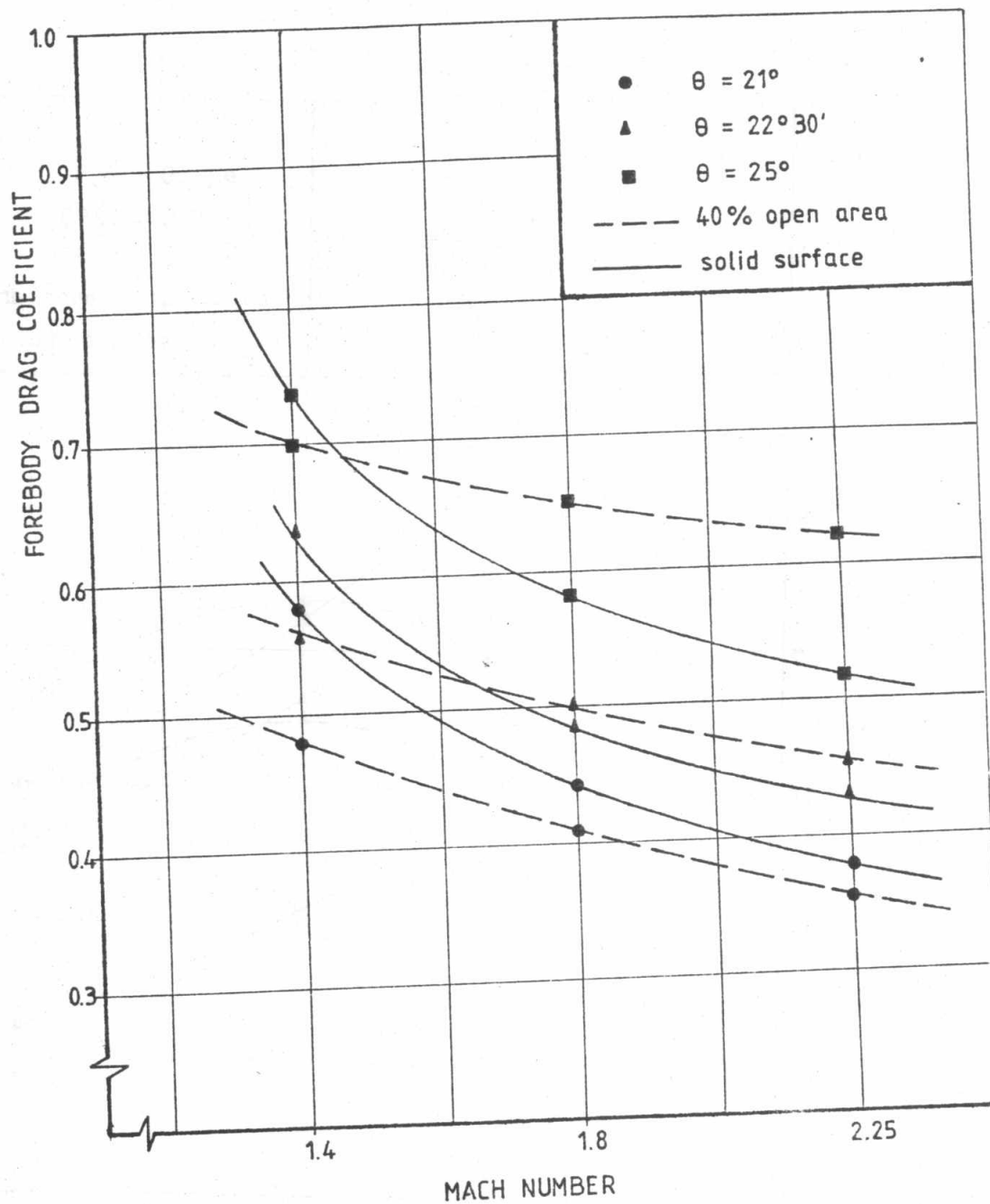


Fig. 3. Variation of the forebody drag coefficient with free-stream Mach number

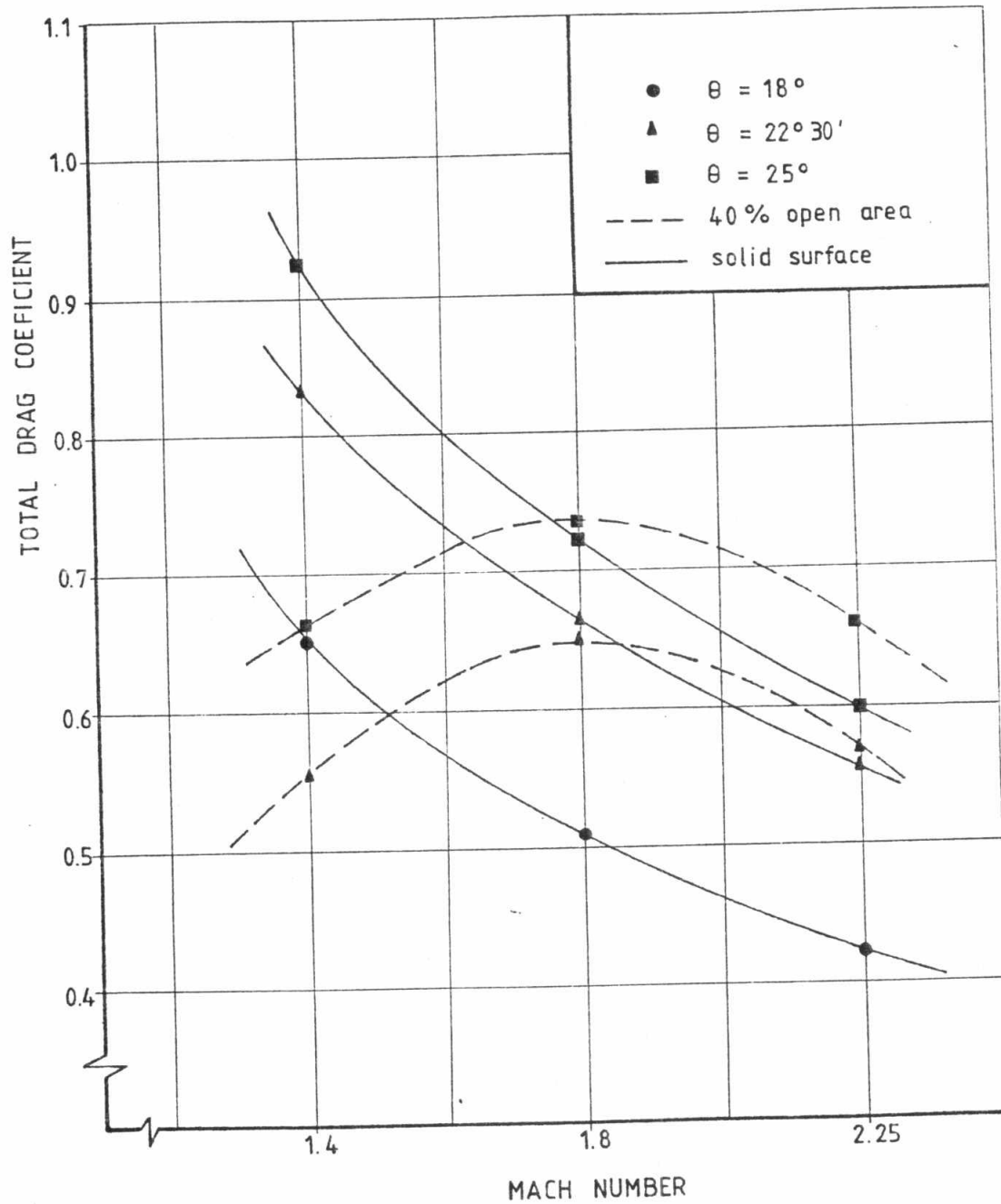


Fig. 4. Variation of the total drag coefficient with free-stream Mach number