HYPERSONIC VEHICLES PROPULSION

AERODYNAMIC PROBLEMS

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I - INTRODUCTION

Among the aerodynamic problems of flying vehicles able to sustain a hypersonic flight, those related to aerodynamic characteristics of simple shapes such as cones, flat plates or spherical noses have received much attention and there exists a great amount of published literature.

The scope is concentrated here on the aerodynamic problems of complete vehicles, and more specifically on the problems raised by the special characteristics of big, light structures integrated with very important engines.

In the limits of this review it was not thought possible to do more than indicate the anticipated ones, with examples when available; the review is therefore not exhaustive; it could anyhow not be so, for it is a constant fact of experience that many aerodynamic problems are discovered during the flight testing phase.

Comments are presented successively on :

- general problems of lift/drag ratio and of stability
- special problems bound to the air - breathing concept
- special problems of a proposed "Space Shuttle"
- elasticity induced problems
- fundamental problems such as heating, and prediction of the efficiency of the control surfaces.
- cost figures or at least trends for different concepts.

II - GENERAL PROBLEMS

It has been previously demonstrated that a hypersonic airplane project suffers a very great sensitivity to different parameters such as structural or propulsion efficiency and maximum cruise lift-over-drag ratio. The latter varies much from one author to the other as a consequence of a lack of published experimental values. Fig. 1 compares maximum lift/drag ratios as considered by Ferri and by Heldenfels in general studies, ref. in [1], experimental values obtained by ONERA on a very schematic shape with a thin airfoil (NACA 64 A 002.5) and without any control surface or engine nacelle and more recent values on complete shapes L1, L2, L3, with nacelles. Measured lift-drag ratios are notably inferior to the estimated ones.

It can be argued that on the present supersonic transport projects the measured values on sophisticated shapes are greater than the first experimental values on simple non-improved shapes. The improvement is obtained by careful, longitudinal curvature, lateral twisting and conical camber of the wings, and area ruling of the body, all leading to the best adaptation at the cruise Mach number, together with a slight, or no improvement at other speeds.

In the case of the XB 70 A maximum use was made of the concept of wave riding, that is the shock wave of the huge propulsion nacelle gave a supplemental lift while a part of the drag was cancelled. But indications exist that the disposition, promoted by Eggers from linear theory considerations, does not give much benefit at higher speeds. Fig. 2 is extracted from a survey of Langley tests, made by Becker, see ref. |1| ; it is clear that a Mach numbers higher than 3, an increasing discrepancy appears between the linear theory prediction and the measured values, and above Mach 7 the flat bottom configurations are better. Pressure measurements were made at the AEDC-VKF facility on such flat top configurations : they indicated that at Mach 5 to 8, the expected flow-field failed to materialize, and was replaced by a complicated wave-boundary-layer interaction pattern.

Another set of measurements at Mach 6.8, on rectangular and delta caret wings, all with simple wedge airfoils was collected by Becker - lower curves of Fig. 2 - ; a regular trend of the maximum lift-drag ratio is apparent