Technical Comments

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Comment on "Afterbody Configuration Effects on Model Forebody and Afterbody Drag"

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IN the above paper[1] Thompson and Smith show an appreciable difference between pressure drag values obtained from AEDC and DFVLR pressure measurements (see Fig. 1). As the basic data, i.e., the measurements of the pressure distributions, were obtained at DFVLR ten years ago in a small wind tunnel[2] and also with much smaller effort in instrumentation, the unprejudiced reader will certainly assume the DFVLR data to be incorrect. However, what Thompson and Smith present as DFVLR drag data is in fact a not sufficiently accurate integration of the original DFVLR pressures.

From their reported need to use for the integration also the stagnation pressure at the nose of the body and from the discrepancy between the two drag distribution curves it is clear that they have conducted a trapezoidal integration of $C_P = f(R^2)$ instead of $RC_P = f(R)$, with R being the radius of the body varying with x. Particularly, if there are so few pressure orifices in the nose region, as was the case with our model, the first method used by Thompson and Smith will result in a too large forebody pressure drag. This is because the errors due to the trapezoidal approximation in the regions of over- and underpressure, respectively, add to each other, while with the second integration method used by us they are partly compensated, as shown in Fig. 2.

Note that these two methods of approximating one single set of tabulated DFVLR data (C_P and R) result in very different forebody pressure drag coefficients, the magnitude of which differs by more than a factor of 5 if only the actually measured DFVLR pressures are used. The drag value according to the less accurate method No. 1 yields a forebody pressure drag coefficient of +0.0162, which agrees perfectly with the "DFVLR" forebody pressure drag given by Thompson and Smith (Fig. 1). The above two integrations were performed in November 1981, after we had seen the original version of the Thompson and Smith paper. The purpose was to understand their integration of the DFVLR data.

In our earlier data reduction in 1972 and 1974 we had further improved method No. 2 by obtaining additional C_P values for the polynomial approximation through interpolation of the $C_P = f(x)$ values. Depending on the number of interpolated C_P's, the above forebody pressure drag coefficient is raised from −0.003 to 0.001 or 0.004. Our 1972 data,[3] which have been added in Fig. 1 to the results presented by Thompson and Smith,[1] are found to agree very well with their data, both forebody and afterbody drag. Similar statements hold also for afterbody No. 5.

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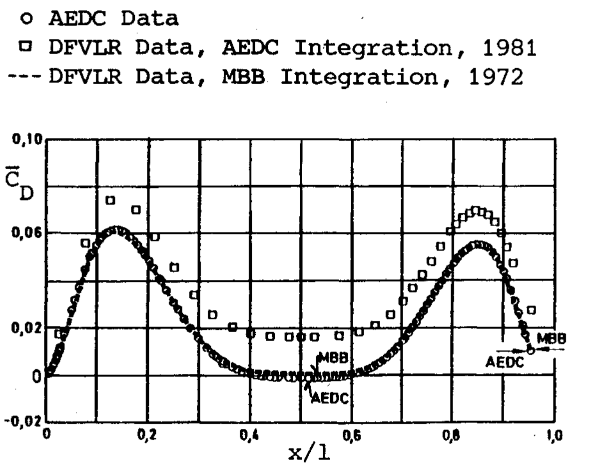

Fig. 1 Drag integration comparison for afterbody 1 at Mach number 0.8 and Reynolds number 15.708 × 10⁶ (MBB data 1972, Ref. 3, added).

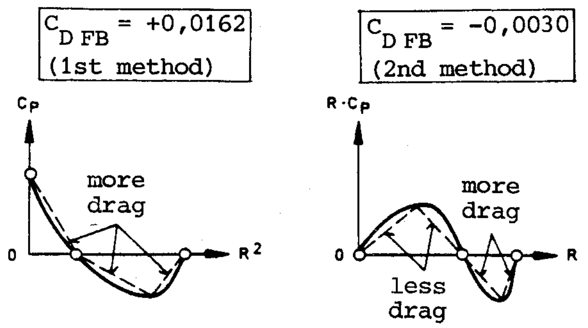

Fig. 2 Two different methods of trapezoidal approximation, schematic.

The main issue, however, of our previous papers[2,4] was not so much to quote absolute drag values but rather to show the drag changes on a nonmetric forebody induced by changes in afterbody geometry.

Thompson and Smith[1] criticize our early statement made in Ref. 5, August 1974, in which we said that afterbody changes may predominantly alter the drag of the (nonmetric) forebody. This statement was part of the advance information about a contribution we were to make to the AGARD study on "Improved Nozzle Testing Techniques in Transonic Flow." In the final reporting[2,4] we corrected these early statements, indicating that this afterbody/forebody flowfield interaction—while still correct in principle—had quantitatively been somewhat overestimated by us: "...these upstream influences are quite often overlooked. This, however, is acceptablz as long as the measurements need not be very accurate. Typical errors for such relatively short isolated fuselages are about 1 to 2% of the total drag (pressure + friction) of the complete fuselage."[2]

These corrected, new findings[2] were based on two additional test series, Nos. 3 and 4, conducted in 1974. For these tests the model was rebuilt. The forebody was attached to a very sensitive balance while the different afterbodies were nonmetric. Therefore we are very confident that our numbers for the forebody drag *changes* published in 1975[2] and 1977[4] are correct in magnitude. Besides, the AEDC results[1,6] confirm the order of magnitude of this upstream influence.

Table 1 Effect of afterbody geometry on forebody drag change

	Ref.	$\Delta C_{D,FB}$	"Metric break" at $x/L=0.5$ Obtained from	M_∞	Afterbody change
MBB	2,5	0.0022	Inviscid computation	0.8	No. 1→No. 3
MBB	2	0.0020	FB balance	0.8	No. 1→No. 3
AEDC	1	0.0030[a]	Pressure integration	0.9	No. 1→No. 5
AEDC	6	0.0018	Pressure integration	0.8	$\beta=15$ deg →cylindrical

[a] Afterbody No. 5 had steeper boattailing than No. 3.

Table 2 Comparison of afterbody and forebody pressure drag changes

1	2	3	4	5	6	
			Change of forebody drag relative to			
Source	Change in afterbody boattailing	Metric break at x/L	Complete body pressure drag $\frac{\Delta C_{D,FB}}{C_{D,CB}}$, %		Change in afterbody pressure drag $\frac{\Delta C_{D,FB}}{\Delta C_{D,AB}}$, %	
Ref. 1, Fig. 13	AB 1→AB 5	0.5	23	3.6	+4.5	A
Ref. 6, Fig. 14	15 deg →cylindrical	0.5	29	4.7	−5.3	B
	Cylindrical→ contoured	0.8	35	10	+16	C
	15 deg →contoured	0.8	10	5.8	−12	D

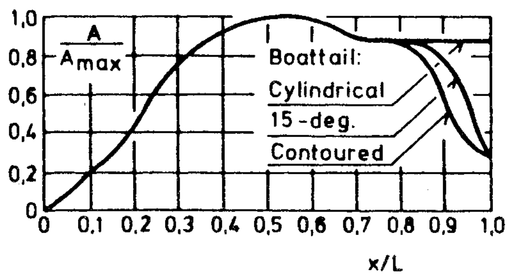

Fig. 3 Model cross-sectional area distribution (Ref. 6).

Since the orders of magnitude agree, as is shown in Table 1, there can now only be a dispute about their relevance for actual aircraft research and development. According to Thompson and Smith[1] such a difference represents "essentially no change in the corresponding data for the forebody." We disagree entirely. At MBB we do care for such changes on the forebody (FB). Table 2 relates typical forebody drag changes obtained by AEDC to the pressure drag of the complete body (columns 4 and 5). For example, replacing the cylindrical boattail by the contoured one (defined in Fig. 3) raises the forebody pressure drag by 35 and 10%, respectively, depending on whether referred to the pressure drag of the complete body with the low or high drag afterbody (AB) (line C). Column 6 relates the pressure drag changes on the forebody to those on the afterbody. The negative sign indicates that the corresponding changes on forebody and afterbody vary in opposite directions. In line D, for example, 12% of the afterbody improvement is compensated by the associated drag increase on the forebody. That is, in high quality afterbody testing with the forebody being nonmetric, the forebody drag changes induced by variations in the afterbody must be taken into account by measured or computed corrections.

In testing actual aircraft geometries with nonmetric forebodies, the metric break is often placed near the trailing edge of the wing, i.e., downstream of the maximum fuselage cross section. With variable wing sweep aircraft this station may be as far downstream as $x/L=0.7$ up to 0.8. Normally the wing is also nonmetric, i.e., it can be regarded here as part of the forebody. At subsonic speeds any changes in afterbody flowfield will also affect the wing,[2] in particular when the wing is in its swept back position.

For a typical afterbody flowfield variation, like afterburning on/off, this induced pressure drag change on the wing is estimated to be of the order of 5% of the pressure drag of the complete fuselage. For a complete tradeoff this value has to be added to column 4 in Table 2.

Conclusions

The reason for the seeming discrepancy in forebody pressure drag reported in Ref. 1 has been found to result from the use of an inadequate method of integration. Applying the more suitable method of Refs. 2 and 5 together with added, interpolated pressures in the nose region of the DFVLR model, the experiments performed at AEDC and DFVLR are in agreement with each other and with inviscid flow calculations and show a noteworthy and measurable upstream influence induced by changes in afterbody geometry.

References

[1] Thompson, E.R. and Smith, C.L., "Afterbody Configuration Effects on Model Forebody and Afterbody Drag," AIAA Paper 81-1443, July 1981; see also, *Journal of Aircraft*, Vol. 19, Sept. 1982, pp. 739-743.

[2] Aulehla, F. and Besigk, G., "Fore- and Aftbody Flow Field Interaction with Consideration of Reynolds Number Effects," AGARD-AG-208, 1975, Chap. II-F.

[3] Besigk, G., "Halbempirische Theorie zur Bestimmung des Heckwiderstandes," Messerschmitt-Bölkow-Blohm Report No. UFE 907-72, Dec. 1972.

[4] Aulehla, F., "Drag Measurement in Transonic Wind Tunnels," Paper 7 presented at the AGARD Specialists Meeting on Aircraft Performance Prediction Methods, Paris, Oct. 1977; see also AGARD-CP-242, Chap. 7, May 1978.

[5] Aulehla, F. and Besigk, G., "Reynolds Number Effects on Fore- and Aftbody Pressure Drag," AGARD-CP-150, 1974, Chap. 12.

[6] Spratley, A.V., Thompson, E.R., and Kennedy, T.L., "Reynolds Number and Nozzle Afterbody Configuration Effects on Model Forebody and Afterbody Drag," AIAA Paper 77-103, Jan. 1977.