Reply by the Author to N. A. Cumpsty and C. Freeman

M.T. Schobeiri*
Texas A&M University,
College Station, Texas 77843-3123

THE shock-loss model described in Ref. 1 was one of the chapters of a comprehensive internal report by Schobeiri.[2] This report was internally published five years before the paper by Freeman and Cumpsty[3] appeared. The original version of the paper submitted to the *AIAA Journal* included only citation of those papers that were cited in Ref. 2. Consequently, the paper of Freeman and Cumpsty[3] was not included in the citations. In the review process, the paper by Freeman and Cumpsty[3] was brought to my attention, and I was asked to critically review their paper and put it in the context of my proposed model. Concentrating my critique on the model for the inlet region including Eq. (4) and Fig. 4 (Ref. 3), I noted an inaccuracy in Freeman and Cumpsty's[3] assumption in their region. My subsequent review was based on the implication of their assumption and its impact on their model.

In response to my review, Cumpsty and Freeman have presented two relative Mach number contours for near peak efficiency and near stall operation for a NASA rotor. The figures show Mach number distributions from the blade leading edge to the trailing edge. However, they cannot be used as a means to justify the assumption for neglecting the blade force in the chordwise direction. Incorporating this assumption, Freeman and Cumpsty[3] arrived at Eq. (4) and Fig. 4 as its graphic solution. As I briefly pointed out in my review, left-hand and right-hand sides of Eq. (4) are not equal. Thus, the plotted β_1 curves do not represent the flow angles that would correspond to a given cascade parameter t/s. Consequently, the resulting control volume exit Mach number is not accurately presented. Having the detailed flow information presented in contour plot, Fig. 2, it would have been an easy task to calculate the blade force in chordwise direction and then present a quantitatively substantiated argument about the validity of the assumption. Referring to a private communication, although acceptable, is not totally convincing.

The comments of Cumpsty and Freeman on the model I presented in Ref. 1 is unfortunately based on their misinterpretation of the location of point A and C in Fig. 2 of my paper.[1] Point A and C are located on the blade leading edge of two adjacent blades and not, as Cumpsty and Freeman state, on either side of the leading edge. Because of the lack of space, the location of the letter A was placed underneath of letter γ. This might have caused Cumpsty and Freeman to arrive at their conclusion. However, the explicit statement in the text (Schobeiri[1]), two lines below Fig. 4, reads: "As Fig. 2 shows, because of cascade periodicity, the pressure at point A is indentical to the pressure at point C." (See Fig. 1, which is

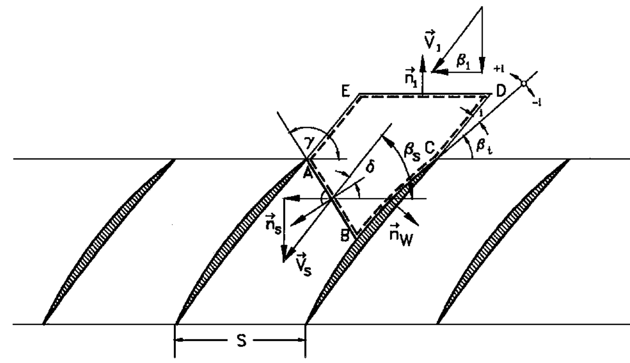

Fig. 1 Shock wave configuration, angle definition, and normal unit vectors from Schobeiri.[1]

Fig. 2 of Ref. 1.) With this clarification, the conclusion of Cumpsty and Freeman about the flaw in my model is wrongfully based and unjustified.

Although the contour plots Cumpsty and Freeman presented were not helpful in substantiating their argument about the validity of Eq. (4) and Fig. 4 in Ref. 3, interestingly they confirm the validity and accuracy of the model I presented. Here is the situation: As I indicated in my paper,[1] because of the cascade periodicity, the pressure at point A is identical to the pressure at point C. Furthermore, point B on the suction surface represents the common endpoint for both distances AB and CB. This means that the pressure distributions along AB and CB have exactly the same beginning and ending values, but, as stated in my paper, they may have different distributions between points AB and CB. I stated further that, assuming that the pressure integrals along the shock front AB and the blade contour portion CB are approximately equal, their projections in circumferential direction may cancel each other out. Looking at Cumpsty and Freeman's near peak efficiency contour plot, the iso-Mach adjacent to 1.4 originates from the leading edge, intersects (or better tangents) the suction surface of the adjacent blade, and extends upstream to the leading edge of this blade. Translating the Mach number into the static pressure, one notes that the projection of the pressure integrals in the circumferential direction will cancel each other to a high degree of accuracy. Thus, for the particular cascade presented by Cumpsty and Freeman, the pressure distributions along AB and CB have not only exactly the same beginning and ending values, but also have the same distribution between points AB and CB. This confirms the validity of the model presented in my paper.[1]

References

[1]Schobeiri, M. T., "Shock-Loss Model for Transonic and Supersonic Axial Compressors with Curved Blades," *Journal of Propulsion and Power*, Vol. 14, No. 4, 1998, pp. 470–478.

[2]Schobeiri, M. T., "Verlustkorrelationen für Transsonische Kompressoren," Brown Boveri-Studies, TN-78120, Baden, Switzerland, March 1987.

[3]Freeman, C., and Cumpsty, N. A., "Method for the Prediction of Supersonic Compressor Blade Performance," *Journal of Propulsion and Power*, Vol. 8, No. 1, 1992, pp. 199–208.

Received 1 October 1999; accepted for publication 11 March 1999.

*Professor, Department of Mechanical Engineering.