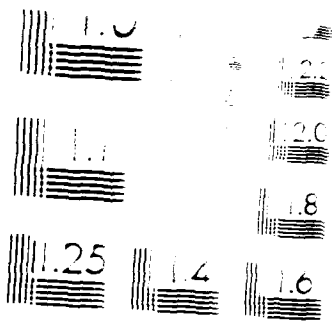


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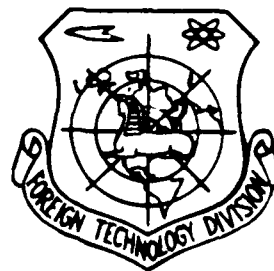
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STUDIES ON TRANSONIC DOUBLE CIRCULAR ARC (DCA) PROFILES OF
AXIAL FLOW COMPRESSOR-CALCULATIONS OF PROFILE DESIGN

by

Y. Ruqun and Q. Zhaoyan



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HUMAN TRANSLATION

FTD-ID (RS) T-0266-86

19 May 1986

MICROFICHE NR: FTD-86-C-001853

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English pages: 5

Source: Gongcheng Rewali Xuebao, Vol. 5, Nr. 4,
November 1984, pp. 342-344

Country of origin: China

Translated by: FLS

F33657-85-D-2079

Requester: FTD/TQTD

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STUDIES ON TRANSONIC DOUBLE CIRCULAR ARC (DCA) PROFILES OF AXIAL FLOW COMPRESSOR-CALCULATIONS OF PROFILE DESIGN

Yan Rugun and Qian Zhaoyan
(North Western Polytechnical University)

In this paper, the concepts and methods for design of high-Mach-Number airfoils of axial flow compressor are described. The correlation-equations of main parameters such as geometries of airfoil and cascade, stream parameters and wake characteristic parameters of compressor are provided. For obtaining the total pressure loss coefficients of cascade and adopting the simplified calculating method, several curves and charts are provided by authors. The testing results and calculating values are compared, and both the results are in better agreement.

1. Preface

The flow of transonic gaseous flow in the compressor cascade is highly three-dimensional and extremely complicated. Although high speed, large capacity computers are now available for applications, it is still quite difficult to solve practical, three-dimensional and compressible flow problems in the cascade. The design of modern axial flow compressor's high speed cascade, e.g., the design calculations of double circular arc (DCA) profile, can be completely carried out in accordance with the method based partially on experience, i.e. the method of combining theory and practicality, to find the correla-

This article was presented in the Fourth Annual Conference of the Chinese Society of Engineering Thermophysics in Sian in Oct. 1983.

tions between various main performance and geometric parameters of this transonic profile under a given operating condition. Then, substituting the various accumulated effective data of the cascade with said profile to solve for the best combination of main performance and geometric parameters of the cascade with this profile, it is possible to design a smaller total pressure loss and higher cascade efficiency in the cascade.

2. Basic Equations

According to Reference [1], the cascade total pressure loss coefficient is:

$$\omega = \tilde{M}_1 (\sin \beta_1 / \sin \beta_2)^2 (\theta_2 / b \cdot \sigma / \sin \beta_2) [1 - (\theta_2 / b) \cdot \sigma H_2 / \sin \beta_2]^{-3} \cdot 4H_2 / (3H_2 - 1) \quad (1)$$

where the subscript "1" represents the cross section 1-1 at the entrance of the cascade; subscript "2" represents the cross section 2-2 at the wake exit of the cascade. Let $\bar{\theta}_2$ be the momentum thickness parameter in the boundary layer, then

$$\bar{\theta}_2 = (\theta_2 / b) \cdot \sigma / \sin \beta_2 \quad (2)$$

and Equation (1) can be rewritten as:

$$\omega = \tilde{M}_1 (\sin \beta_1 / \sin \beta_2)^2 \bar{\theta}_2 (1 - \bar{\theta}_2 H_2)^{-3} \cdot 4H_2 / (3H_2 - 1) \quad (3)$$

where \tilde{M}_1 is the Mach Number parameter at the entrance of the cascade,

$$\tilde{M}_1 = f(M_1) = (1 - 0.5M_1^2)(1 + 0.5M_1^2) \quad (4)$$

For a given cascade, if the Mach Number M_1 at the entrance is known, then the \tilde{M}_1 value can be obtained from the \tilde{M}_1 - M_1 curves (Fig. 1) drawn by the authors. β_1 and β_2 are the profile entrance and exit angles, respectively; θ_2/b is the momentum factor of the boundary layer; θ_2 is the momentum thickness of the boundary layer; b is the arc length of the profile; $\sigma = b/t$ is the cascade density; H_2 is the geometric factor of the boundary layer.

In the design calculations of the profile, some of the various main parameters in the above correlation-equations can be selected

according to theory and practicality; other parameters can be calculated using this functional correlation to solve for the best combination. The authors of this article suggest that, since the calculations of Equation (1) are more cumbersome, the following curves be adopted to simplify the calculations.

3. Simplified Calculations

In Equation (1), there are two parameters that are relatively difficult to determine, i.e., the boundary layer geometric factor H_2 and the boundary layer momentum factor $E=\theta_2/b$. For the geometric factor H_2 within the cascade entrance Mach Number range of $M_1=0.20\sim 0.90$, the curves drawn by the authors can be adopted (Fig. 2); in high Mach Number range, the H_2-M_1 curves in Reference [2] can be adopted. For the momentum factor E within the cascade entrance Mach Number range of $M_1=0.20\sim 0.90$, the curves drawn by the authors can be adopted (Fig. 3); for the cascade with double circular arc profile in the transonic range, the momentum factor E of the cascade with double circular arc profile and the stream Mach Number curves in Fig. 4 can be adopted, based on the actual situations. With the sets of curves in Fig. 1 through Fig. 4, it is much easier to use Equation (1) herein to calculate total pressure loss coefficients of cascades with double circular arc profile or other similar cascades of transonic profile.

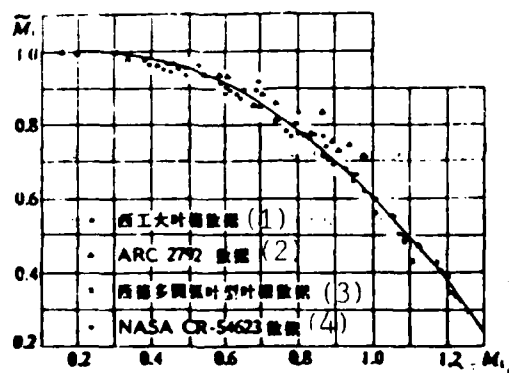


Fig. 1. \tilde{M}_1-M_1 Curve

Key: (1) North Western Polytechnical University Cascade Data; (2) ARC 2792 Data; (3) West Germany's Data for Cascade with Multiple Circular Arc Profile; (4) NASA CR-54623 Data.

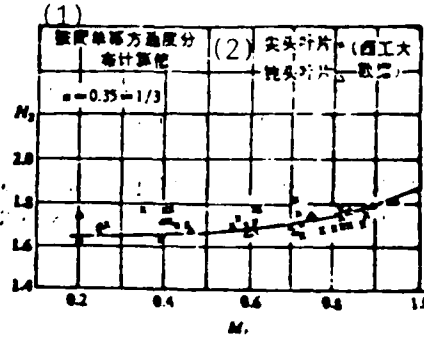


Fig. 2. H_2-M_1 Curve

Key: (1) Calculating Values of Velocity Distribution Using the Simplified Calculating Method $n=0.35=1/3$; (2) Pointed Blade x, Blunt-head Blade " (North Western Polytechnical University Data).

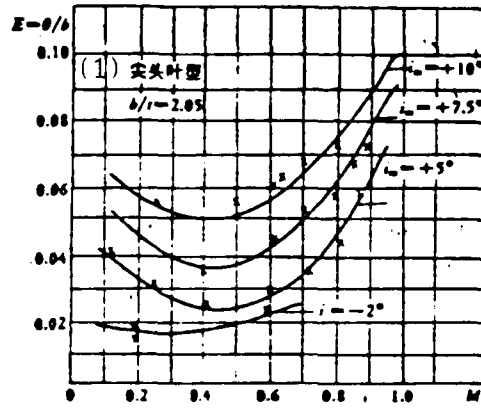


Fig. 3. $E-M_1$ Curves

Key: (1) pointed profile.

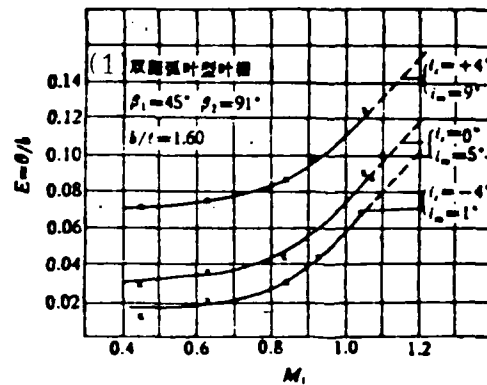


Fig. 4. $E-M_1$ Curves for cascade with double circular arc profile

Key: (1) Cascade with double circular arc profile.

The comparison between the simplified calculating values and the testing values: based on a given cascade with double circular arc profile under different operating conditions ($M_1 = 0.4 \sim 1.2$; $i_1 = 0 \sim +7.5^\circ$), simplified calculations adopting Equation (1) and using the curves herein were conducted to obtain various total pressure loss coefficient $\bar{\omega}$ values. Meanwhile, these calculated $\bar{\omega}$ values were compared with the testing values of total pressure loss coefficient $\bar{\omega}$ at the average radius of the double circular arc stator reported in Reference [3], and it was found that the values obtained from both methods were in better agreement. Therefore, the various main parameters of the correlation-equations derived herein for cascades with transonic profile are valid. In the meantime, the effects of adopting the curve method to simplify calculations of total pressure loss coefficient under different operating conditions for cascades with double circular arc profile or other similar cascades with transonic profile are relatively satisfactory, and the scope of applications for this approach is much wider.

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