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RESEARCH MEMORANDUM

PRELIMINARY CORRELATION OF THE EFFECT OF COMPRESSIBILITY ON THE LOCATION OF THE SECTION AERODYNAMIC CENTER AT SUBCRITICAL SPEEDS

By

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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November 3, 1948

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RESEARCH MEMORANDUM

PRELIMINARY CORRELATION OF THE EFFECT OF COMPRESSIBILITY ON THE LOCATION OF THE SECTION AERODYNAMIC CENTER AT SUBCRITICAL SPEEDS

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SUMMARY

A correlation of available two-dimensional airfoil data to determine the effects of compressibility on the location of the section aerodynamic center at low lift coefficients has been made. The results indicate that large forward or rearward movements of the aerodynamic center with Mach number are possible. It appears that thickness ratio is an important parameter controlling the variation with Mach number. For the 6-percent-thick airfoils the aerodynamic center moved rearward with increasing Mach number, while for the thicker airfoils (9 and 12 percent) the movement was forward. It appears that airfoils of 7- or 8-percent thickness ratios might experience the least variation of the aerodynamic center with Mach number.

SYMBOLS

M	Mach number
a.c.	aerodynamic center
t	airfoil maximum thickness
c	airfoil chord
ϕ	trailing-edge angle (included angle between upper and lower surfaces at last 5 percent of chord), degrees

INTRODUCTION

A theoretical study (reference 1) has indicated that the rate of increase with Mach number for both the lift coefficient and the pitching-moment coefficient of a two-dimensional airfoil is very nearly the same at subcritical Mach numbers, and that, therefore, little shift in the aerodynamic center is to be expected. Experimental investigations (for example, reference 2), however, have indicated that shifts in the section-aerodynamic-center position as large as 0.05 chord have occurred within the subcritical Mach number range and that such shifts may be either forward or rearward. The present paper presents the results of a preliminary analysis of available data on the pitching-moment characteristics of airfoils at Mach numbers between 0.4 and the lift break, to determine what parameters control the variation of the section-aerodynamic-center position with Mach number.

BASIS OF ANALYSIS

The data used in the correlation were obtained from references 2 to 6, and a list of the airfoils used is presented in table I. The location of the aerodynamic center was determined from the slope of the pitching-moment curve in the low lift-coefficient range which, in some cases because of reversals, was limited to ±0.1. This correlation, therefore, is primarily concerned with the aerodynamic-center travel with Mach number near zero lift. All the data were obtained at Reynolds numbers less than 2×10^6 with free transition. Although the data for some of the airfoils examined extend to Mach numbers beyond the break in the lift force, the correlation is primarily limited to Mach numbers up to the lift break. The correlation begins at a Mach number of 0.4 due to the fact that the investigations from which the correlation was made began at a Mach number of 0.4. The results were obtained from tests of airfoils with thickness ratios of 6, 9, and 12 percent.

DISCUSSION

The results of the correlation of the various airfoils listed in table I are presented in figure 1. The various crosshatched regions in figure 1 define the measured limits of the shift in the aerodynamic-center location of the various airfoils relative to its position at a Mach number of 0.4 for various airfoil thickness ratios. The thickness ratio was selected because, from the data, it appeared to be the most influential parameter controlling the variation of the aerodynamic-center location with Mach number. The results indicate that for 6-percent airfoils the section aerodynamic center moves rearward with increasing Mach number with shifts as large as 12 percent of the chord being attained. For the thicker airfoils (9 and 12 percent) however, the section aerodynamic center moves forward with increasing Mach number.

It appears from interpolation of the data that airfoils with thickness ratios of 7 or 8 percent might be expected to experience the least variation of the aerodynamic-center position with Mach number.

A low-speed study of the effect of trailing-edge modifications on the pitching-moment characteristics of airfoils (reference 7) indicated that the trailing-edge angle had a large effect on the location of the aerodynamic center. In figure 1 the range of trailing-edge angles for each thickness ratio is presented, but there appeared to be no systematic variation with trailing-edge angle for a given thickness ratio. However, in the present correlation, changes in trailing-edge angles were always accompanied by other changes in the airfoil shape, while in reference 7 changes in trailing-edge angle were obtained by modifying the trailing edge of a given airfoil by means of bevels and cusps. Inasmuch as the effects of the various modifications which accompanied changes in trailing-edge angle could not be separated, no further refinements in the correlation appear to be possible at the present time.

It will be noted that none of the airfoils used in the correlation are of the low-drag type. Available low-drag data (reference 8) indicate that although large shifts in the aerodynamic-center position with Mach number are possible they do not consistently fall within the bands of figure 1. Until more low-drag data are available no definite conclusions with regard to low-drag sections can be made.

It should be kept in mind that section characteristics alone are not sufficient for predicting the characteristics of finite-span wings. The chordwise shift in the center of the induced load caused by the variation of the effective aspect ratio with Mach number and the chordwise shift due to the spanwise shift of the center of pressure with Mach number on swept wings may be appreciable.

CONCLUSIONS

Based on a preliminary correlation of the effect of compressibility on the location of the section aerodynamic center near zero lift, the following conclusions were reached:

1. Forward or rearward movements of the aerodynamic center as large as 12 percent of the chord were observed.

2. For 6-percent-thick airfoils the aerodynamic center moved rearward with increasing Mach number, while for the thicker airfoils (9 and 12 percent) the aerodynamic center moved forward with increasing Mach number.

3. It appeared that airfoils having thickness ratios of 7 or 8 percent might experience the least variations of the aerodynamic center with Mach number.

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TABLE I

AIRFOILS USED IN CORRELATION

Airfoil	Reference
NACA 0006-34	2
NACA 0006-63	2,3
NACA 0006-64	2
NACA 0006T	2
NACA 2306	2
NACA 2406	2
NACA M1 (6 percent)	2
NACA 16-306	6
NACA 16-506	6
NACA 16-009	4
NACA 0009-62	2,3
NACA 0009-63	2,3
NACA 0009-64	2,3,5
NACA 0009-93	3
NACA 0009-33	3
NACA 0009-03	3
NACA 2309	2
NACA 2409	2
NACA 2509	2
NACA 16-109	6
NACA 16-309	6
NACA 16-509	6
Davis (9 percent)	2
ETH 3609	2
NACA 0012-63	3
NACA 0012-64	2
NACA 0012-34	2
NACA 2312	2
NACA 2412	2
NACA 16-212	Unpublished
NACA 16-312	6
NACA 16-512	6

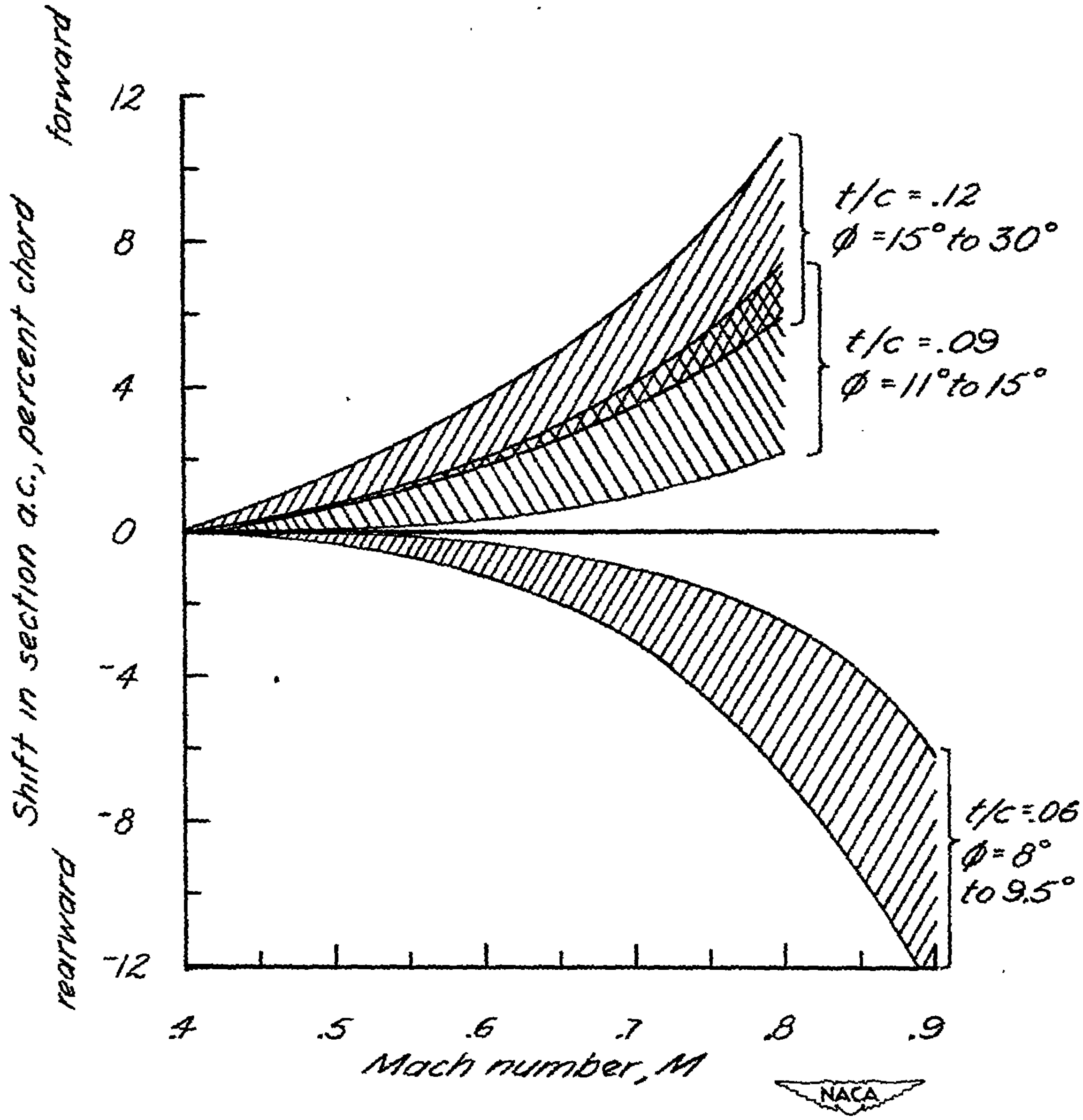

Figure 1.- Effect of Mach number on the location of the section aerodynamic center at low lift coefficients.

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