"WING PROFILES"

(PART II)

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In a former Note (Soaring, Jan.-Feb., 1949) we examined some of the wing profiles which have enjoyed a widespread popularity in the past and concluded with a few general remarks on mean lines and thickness forms.

As the mean line plays a leading part in determining airfoil characteristics, the purpose of this Note is to examine in some detail the properties of typical mean lines, with the object of demonstrating elementary design techniques which can be used to produce the airfoil section which is best for a given set of conditions.

Lift is produced when the air flowing past an airfoil is deflected downwards. This force is equal to the sum of all the pressure components around the section. It is independent of the distribution of these pressures because it depends only on the total rate of change of momentum imparted to the air.

When no lift appears on a section the total momentum change downwards must be zero, the "average" direction of the section is parallel to the undisturbed streamlines at some distance from the section and the angle between the undisturbed streamlines and a convenient datum in the section is called the angle of zero lift. At any other angle lift will appear but the amount will depend only on the change in the average direction of the section, not on the shape. This is important because it permits a discussion of airfoil shapes without constant reference to the total lift, comparisons are valid so long as the angle of attack is the same measured with respect to the zero lift direction. The section lift coefficient is then simply 6.28 times the angle of attack measured in radians.

The shape of the section becomes of first importance when drag or pitching moment comparisons are to be made or stalling phenomena are to be studied. Modern theory shows that these are very sensitive to the distribution of pressures around the airfoil and the distribution of pressures in turn is primarily a function of the section shape although the influence of the angle of attack cannot be ignored.

A knowledge of pressure distribution is essential to an understanding of airfoil characteristics. Theory and experiments show that the pressures around a section can be considered to be the sum of two effects, the first determined by section shapes and the second determined by the angle of attack measured with respect to a certain basic angle. The first effect can be further subdivided to advantage, for it can be treated as the sum of two components, the one dependent on the geometry of the mean line of the profile and the other a function of the total thickness of the section and the distribution of the thickness. We shall reserve thickness effects for discussion later and confine attention here to the pressures dependent upon mean line geometry, or "basic" distribution as it is frequently called and the so-called "additional" distribution which is dependent upon angle of attack.

The mean line of a profile is illustrated in Fig. 1. It is the curve which results when the thickness of the section is systematically reduced to zero. Since the mean line represents the average direction of the wing profile at each chordwise point it is not surprising that pressure distributions are closely dependent upon its shape. In fact as the insects and model

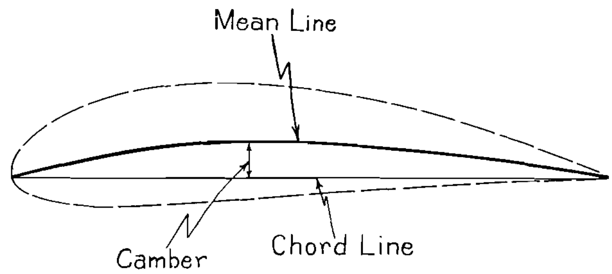

Fig. 1

airplane builders well know, the mean line, apart from structural limitations, is quite a useful airfoil in its own right. The most direct way to arrive at the "basic" and "additional" pressures mentioned above is to treat the mean line as an airfoil of zero thickness, in which condition it readily yields to theory.

A simple shape to begin with is the mean line of symmetrical sections such as the familiar NACA 0009 series widely used for control surfaces. This shape, lacking camber, has a zero "basic" pressure distribution and is therefore convenient for an examination of "additional" effects.

At zero geometric angle of attack the lift on the elementary airfoil is zero, which is hardly surprising. At moderate angles of attack the streamlines flow in

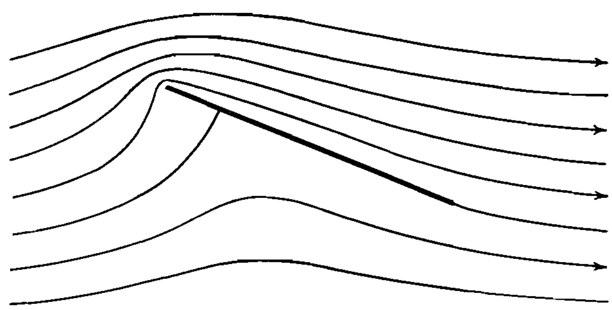

Fig. 2

the direction indicated in Fig. 2. There are two "stagnation" points where the velocity of the fluid is zero relative to the airfoil; one at the trailing edge and the other on the lower surface downstream from the leading edge. Around the nose the flow changes direction abruptly and the velocities are high. This is confirmed by the pressure distribution curve (Fig. 3) which indicates very low pressures at the leading edge. The height of this curve represents the pressure difference, or lift at any point on the chord and the area under the curve represents the total section lift. Since the shape of the curve remains the same for all angles of attack the balance point of the area does not move, and the pitching