Sections with Near Zero Pitching Moments — Good Choices for Plank Planforms?

While looking over our tailless aircraft plans collection, we were struck by the tremendous changes in airfoils through the decades and the increased performance which has been the result of this evolution. The airfoil characteristic which has changed the most during this process, particularly for plank planforms, is airfoil pitching moment. This month's column is devoted to exploring the reasons for this overall design tendency.

It is sometimes helpful to examine tailed aircraft before looking at tailless configurations, and this is particularly true in this case. A conventional tailed aircraft will always tend to fly at that speed where the force produced by the horizontal stabilizer exactly counterbalances the combination of the wing pitching moment and the downforce produced by center of gravity being ahead of the neutral point. These forces and their interactions are depicted in Figure 1.

The wing pitching moment in most cases is negative (nose down) due to camber. A center of gravity ahead of the aircraft neutral point also produces a nose down force. The more negative the wing pitching moment and/or the more forward the CG, the more downforce must be produced by the horizontal stabilizer. Note the horizontal stabilizer downforce is produced

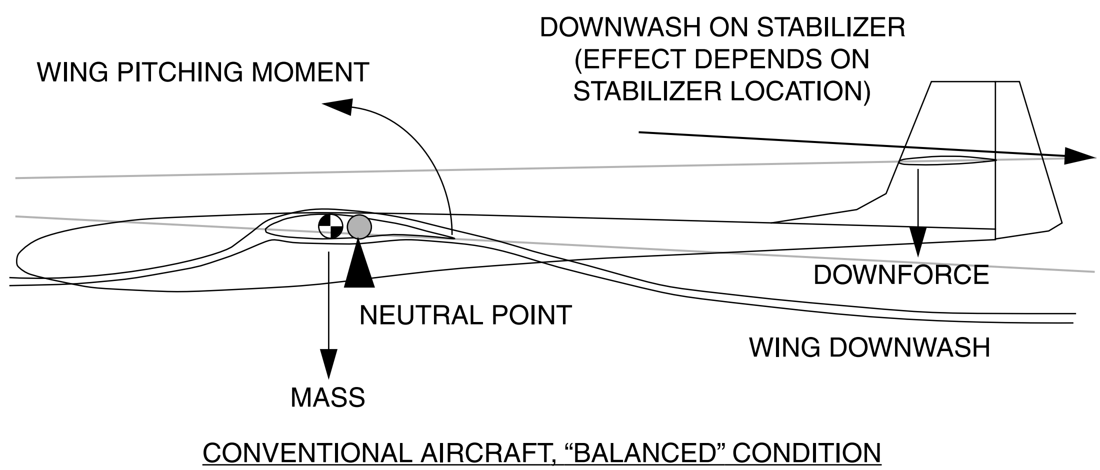

Figure 1

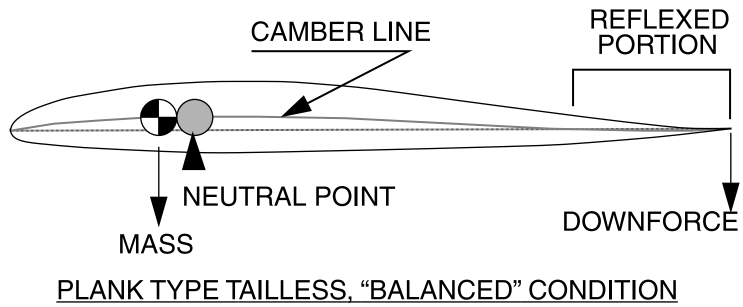

Figure 2

through a combination of angular difference between the wing and tail, and the downwash of the wing upon the tail.

A tailless planform is subject to the same aerodynamic laws as a conventional tailed aircraft. An advantage of tailless configurations, however, is that there is no downwash effect to calculate during the design process. The wing section will incorporate camber so as to achieve a higher maximum coefficient of lift, but since there is no horizontal stabilizer, the wing itself must also provide the down force required to achieve aerodynamic balance. For swept back wings, the down force is generated by the wing tips, while for plank planforms the rear portion of the airfoil is curved upward by a reversing (reflexing) of the camber line, as shown in Figure 2. This reflexing of the camber line must be carefully tailored to provide sufficient down force without unnecessary drag.

For a plank planform, section reflex directly determines speed. Imagine the actions of the aircraft at various velocities with the reflex remaining constant. If the aircraft is flying too slow, the CG ahead of the neutral point tends to pull the nose down, thus increasing speed. If, on the other hand, the velocity is too high, the reflexed area of the section produces a downforce which is greater than that of the effect of the CG. In this case the nose of the aircraft is forced up and the speed drops. These two cases are illustrated in Figure 3. For a given amount of reflex and a specific CG location there is one flying speed where the two forces are in balance.

For radio controlled and manned planks, a moveable CG may provide some speed latitude. The CG is moved forward for higher speeds and back for lower speeds. See Figure 4 for an explanation of how this works.
Free flight planks, which require large amounts of stability, have fixed forward CG locations and large amounts of reflex. For power models, the thrust line must be adjusted so any looping tendency due to higher speed while under power is counteracted by engine thrust.

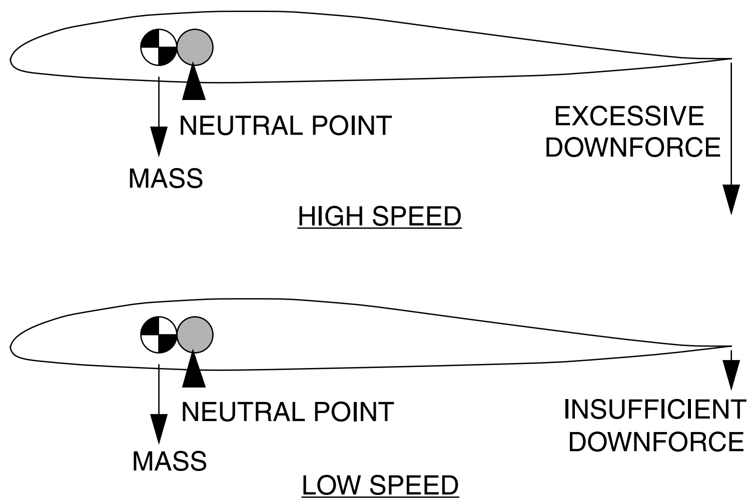

Figure 3

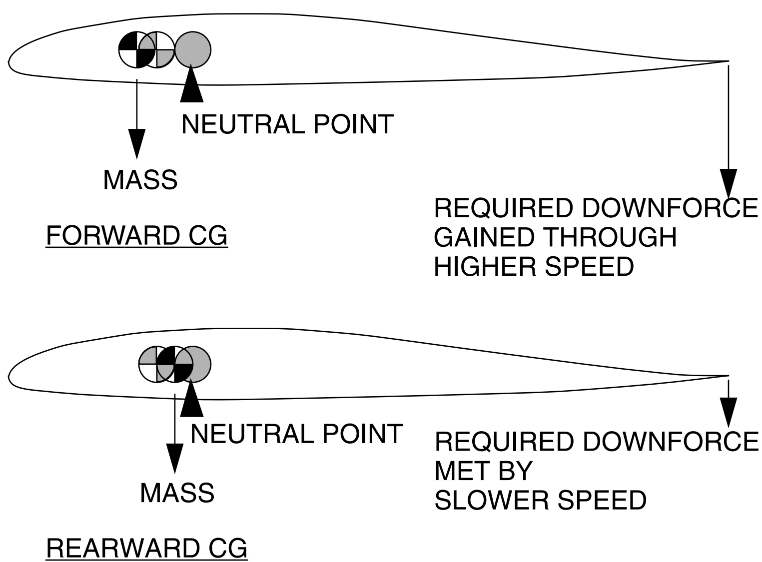

Figure 4

In the early days of tailless aircraft design, there was a trend to incorporate a large amount of reflex in the wing section, just as for free flight models. This dictated a forward CG position which made for very stable aircraft, but performance suffered due to high drag. In addition, excessive downforce robbed the aircraft of generated lift as some of the lift generated by the forward portion of the wing was counteracted by the down force generated by the rear portion.

Over time, the amount of reflex designed into airfoil sections for plank planforms, for both full size and model aircraft, has gradually decreased. Along with this reduction in reflex has come a reduction in section drag. The accompanying Table gives an overall idea of the evolution of sections deemed appropriate for plank planforms. Due to lack of published data, moment coefficients for this Table were frequently obtained through use of the cited Lounsbery code.

Speed can be controlled over a wide range by means of full span reflex trim. There is no need to resort to a moveable CG in this case. In addition, overall performance is improved because of lower drag during nearly all flight regimes when compared to identical planforms without such full span camber changing capability. The Bird Works (Kindrick) *Zipper* uses a full span camber changing system to excellent effect. The wing has a moderately positive pitching moment at low speeds due to up trim, but the pitching moment is near zero at very high speed when neutral trim is employed. See Figure 5.

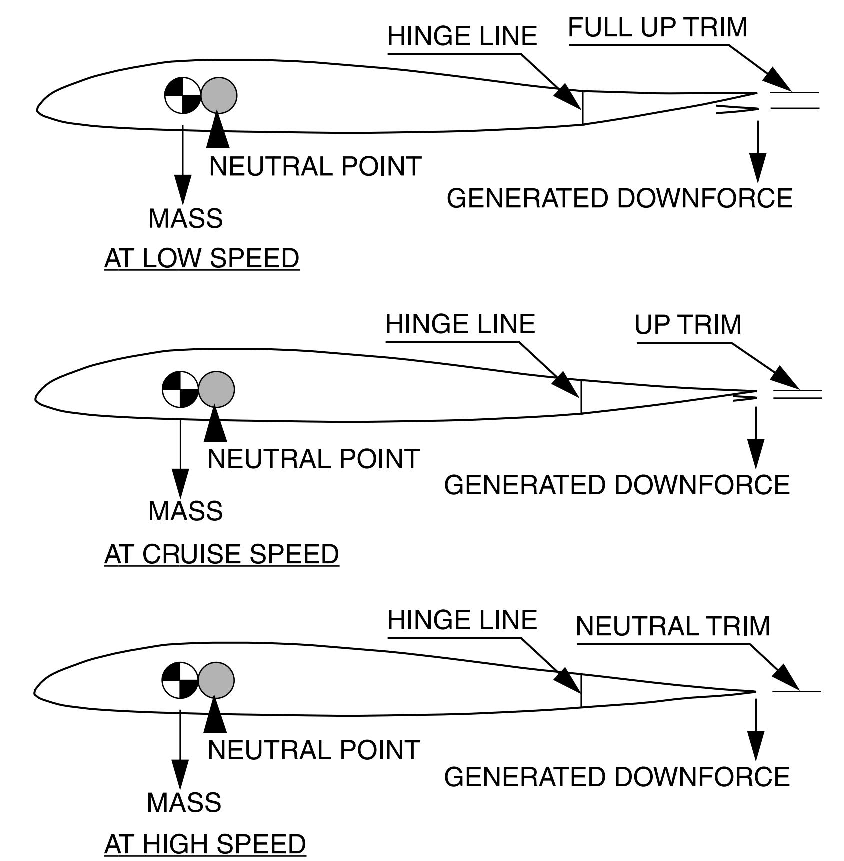

Figure 5

As can be seen from the Table below, referenced earlier, the pitching moment of sections designed for use on plank planforms has decreased markedly over the years. Parallel performance improvements have resulted. If you are considering design and construction of a plank planform, perhaps this month's column will entice you to consider using a section with a low pitching moment and appropriate control surfaces.

Designer/Builder: A/C Designation	Section (Year)	c_m
FULL SIZE		
Fauvel AV.361	Fauvel F2 17% (1960)	0.0685*
Marske Pioneer II-D	NACA 43012Ax.833-75 (root) NACA 43012A-75 (tip) (~1985)	0.0185* 0.0212*
Marske & Roncz Genesis 1	Genesis, proprietary (root) (1994)	0.0174*
MODEL		
Jones Raven and Blackbird 2M	CJ 3309 (1984)	0.0323*
Jones Blackbird 2M	CJ 25^2-09 (1993)	0.0249*
Jones/Kuhlman: Blackbird 2.3M.mod	S 5020 (1994)	0.000597
Kindrick: Zipper*	EH 1.0/9.0	0.000189

* calculated using Lounsbery code

<u>References and Sources:</u>

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