Detroit Historical Museum

The 1930 Stout Skycar used wing tip ailerons. Note the plates between wings and ailerons, used to reduce interference troubles caused by air leaking through the gap between fixed and movable surfaces.

Facts On Wing-Tip Ailerons

By Bob Whittier

The appearance of member Harvey Mace's airplane in the December, 1959 issue of this magazine sparked interest in wing tip ailerons among many EAAer's. Since wing tip ailerons look so simple and logical, the question arises as to why they are not more frequently used.

It's a case of surface appearances being deceptive. The object of ailerons is to cause an airplane to roll, and having the aileron area at the extreme tips seems like a good way to get the rolling force as far outboard as possible. Then too, they seem to be very simple structurally.

Back in the 1930's the NACA (now NASA) conducted an exhaustive research program on the subject of airplane stability and controllability, seeking to improve the stalling and spinning characteristics of small airplanes. As part of this task a comprehensive study of ailerons and all factors entering into lateral stability was made. This work included an investigation of many forms of wing tip ailerons. Some were semicircular, some were rectangular, some were tapered, their aspect ratios varied, and even rectangular wings with four to five small fingerlike ailerons projecting from their tips were tested. NASA Technical Note No. 458, "Various Floating Tip Ailerons on Both Rectangular and Tapered Wings" is one result. Another is Technical Note No. 316, "Wind Tunnel Tests on a Model of a Monoplane Wing With Floating Ailerons".

These and other reports shed interesting light on tip aileron problems. The tests seemed to show that the essential rolling action provided by tip ailerons was good. Because conventional flap type ailerons tend to lose their effectiveness in flight at and near the stall, special attention was given to the characteristics of tip ailerons at high angles of attack. In general, they appeared to "hold on" well and were able to retain lateral control in the stalled region. An ordinary aileron is but a hinged after-portion of the main wing, and when the main wing stalls there is a direct effect on the aileron. A tip aileron amounts to an independent airfoil and logically is less subject to stalling effects created by the main airfoil. The writer would point out that a common untwisted wing will normally stall at the tip and the stall will progress inboard; this makes common flap type ailerons lose their effectiveness early in a stall. Modern design practice is to put a few degrees of twist into wings, with the outboard ends riding at a lower angle of incidence than the inner ends. This makes the wing root stall first and the tip stall last, with aileron control being retained appreciably farther into the stall.

One would assume that if a tip aileron had the same airfoil as the wing and there was no twist, and the tip stalled first, the tip ailerons would also "go out" first, with loss of vital lateral control early in the stall. This assumption of course must be modified by the knowledge that the tip ailerons are independent airfoils whose angle of incidence can be altered. The NASA notes mentioned are silent on this point, but obviously to be really sure of what is going to happen to any particular pair of tip ailerons at the stalling point of the wing, one has to study the matter carefully, up to and including the matter of making wind tunnel tests.

Another fault of plain ailerons is that they cause "adverse yaw effect"; the one which goes down gets the full blast of the wind stream but the one which goes up moves into a somewhat more sheltered region which exists on the wing's upper surface. You put the left aileron down to roll the plane into a bank and turn to the right. Putting the left aileron down causes more drag out on the left wing and the ship has a tendency to yaw to the left while at the same time rolling to the right. This is what the rudder is basically for; to trim the plane against unsymmetric forces such as this. Since tip ailerons are not shielded by the wing but operate in the full and direct air flow, it is logical to assume that the downgoing one will have no more drag than the upgoing one, and adverse yaw will not exist. Tests showed that this is substantially true—but not completely so, because of the disturbing effect of airflow interference between the outer edge of the wing and inner edge of the tip aileron. The experimental Stout Skycar of 1930 had tip ailerons and they put a vertical plate between the wing and aileron, doubtless in hopes of improving on the wing-aileron interference problem.

On the debit side, some real shortcomings exist. All NASA work showed very clearly that tip ailerons resulted in a noticeable reduction in rate of climb as compared to normal trailing edge ailerons. Wings fitted with tip ailerons had over twice the drag of wings with no ailerons. The reason appears to lie in the fact that tip ailerons, especially the required gap between them and the outer edge of the wing, materially affects the wing-tip vortice formation. In a climb, wing-tip vortices grow larger and increase the drag, hence climb suffers.

An ordinary aileron is attached to the wing with two, three, four or more hinges and the load is shared accordingly. A tip aileron is pivoted on its supporting shaft. The shaft must be strong enough to handle all the control forces and air loads at one point. Presumably a shaft or tube running out from the cabin to the wing tip will have to be of fairly large diameter to take the twisting forces without undue flexing, and will need fairly large support bushings at inboard and outboard ends, and possible in the middle. A common aileron may have its actuating horn located in its midspan, with the horn loads going out to each semi-span from the center. Torque loads on the aileron structure would then be lower than if the horn were mounted on the inboard end. A rectangular tip aileron, however, would doubtless have

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to be rather stiffly made to take **all** the control and air loads at its pivot point and distribute it without deflection. In short, tip ailerons and their controls can work out to be heavier and more complex than plain ailerons, and the problem grows more acute with increased span.

A tip aileron is of course an extension of the wing, and normally would have the wing's airfoil if a noticeable and objectionable discontinuity is to be avoided where wing ends and aileron begins. Given any commonly used wing airfoil, the center of pressure of a tip aileron will have that airfoil's normal amount of center of pressure travel with varying angle of attack. This quirk leads directly to problems of control linkage and leverage. NASA found that tip ailerons usually resulted in appreciably heavier control stick loads—up to three times as great for plain ailerons giving the same amount of rolling action. If the pivot point is located reasonably far back on the tip aileron, there is of course a greater aerodynamic balancing effect, which would be useful in reducing control loads if it were not for one thing . . . it appears to aggravate tip aileron flutter problems. You can stop flutter by moving the pivot point forward, but in so doing you reduce aerodynamic balance and increase the control forces. The use of aerodynamically efficient long, narrow tip ailerons leads to a reduction in structural stiffness and an increased proneness to flutter. To get away from this by going into short, wide tip ailerons leads to increased control loads because an airfoil of greater chord and consequently greater center of pressure travel is obtained.

In the end, the lightest, simplest, best-performing method of minimizing adverse yaw effect proved to be the Frise type aileron, and retention of aileron control well into the stall is now obtained by wing twist, which makes the root stall first and the tip stall last. Tip ailerons mess up the wing tip vortices and add drag, they spoil climb, they are structurally heavy, and pose so much of a flutter and control force problem that they seem a profitless path for designers to follow. This is not to say that they won't work or can't be made to work, but that since it is possible to gain the desired advantages more easily and reliably by using Frise ailerons and twisted wings, the fellow who wants to get into the air with minimum effort and maximum safety would do well to stick to common aileron forms. After all, common features of today's airplanes are used not because of the designer's lack of imagination but because they are the result of many decades of work to find the most practical ways of making airplanes! ●

BUSHBY'S "LONG MIDGET" . . .

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higher pitch prop would give an improvement. A controllable pitch prop would of course be the best.

The ship turned out to be heavier than the 525 lbs. empty weight of the original built by Dave Long - Bob's weighs 572 lbs. empty. Additional weight is due to the canopy, cowl and thicker spar stock used in the wing. Wing loading works out to about 10 lbs. per sq. ft. The ruggedness of the ship is evidenced by the 7½ G's registered in flight test.

Bob is completely sold on the superiority of metal construction over "tube and rag". He says the actual hours required for construction are no more for metal than the more common fabric job, if everything is counted. He figures that it's possible for the average builder to build a "Midget" in about two years of spare time work if he's not held up by a lack of capital, an overly-demanding full-time job, etc. Durability of metal over fabric, with economy of upkeep as an added feature, makes the former extremely attractive. He says he was comparatively inexperienced at the start but close study of CAM 18 and the assistance of available information helped a lot. In particular he found the "Tin Bender" articles by EAAer Jim Graham (see the EXPERIMENTER for July, September, October and November, 1957) to be very helpful.

Bob works in the research department of Sinclair Oil Co., and is a licensed A & E mechanic and a commercial pilot with flight instructor's rating as well. He does A & E work part time, and his "spare" time has been devoted to the "Midget" project. He has offered to assist other "Midget" builders in EAA - his home address is 14612 S. Edbrooke Ave., Dolton, Ill. ●

Error in "Tapered Wings"

An unfortunate typographical error appeared in John Thorp's article "Tapered Wings are for Birds - and Very Large Airplanes" in the April issue of SPORT AVIATION, which changed the meaning of one sentence. On page 7 at the bottom of the center column the sentence should read "The maximum lift coefficient of a wing section is a function of its **local** Reynolds number".

Author John Thorp is preparing other factual and educational articles which will appear in future issues of SPORT AVIATION. Next to appear will be "Which Airfoil Section?" in the June issue. "How Much Aspect Ratio?" and "Performance at a Glance" will be two in the series to follow. We indeed appreciate the opportunity to present this valuable information authored by one of aviation's outstanding aircraft designers.