LOAD CHARACTERISTICS OF A TRAILING WING

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ABSTRACT

Results of an experimental study on the effect of trailing cortices caused by a flapped large leading wing on a smaller trailing wing flaps are presented. For a leading wing at 5°, effects of lift, drag, pitching moments on the trailing wing are displayed for various angles of attack of the trailing wing. The research findings reveal that considerable reductions occur in lifting forces on the trailing wing as a consequence of the presence of the leading wing. There seems to be no effect on the slope of the lift curves, or on the maximum lift of the trailing wing. There is, however, a pronounced influence on the stall angle of the trailing wing; the stall angle increases with increasing flap angle of the leading wing. It is confirmed that, to maintain a given lift on the trailing wing, the drag of the trailing wing must be increased with increasing flap angles of the leading wing. It appears that the leading wing does not influence the stability margin of the trailing wing.

INTRODUCTION

Wake is known to exert significant effects on structures located in its vicinity. Wake-induced stresses may lead to failure of structures. Several accidents involving aircraft are commonly attributed to wake effects. In one such case, a commercial Junkers F 13 crashed, killing its two pilots and four passengers at Meopham on July 2, 1930 [1,2]. Eye witnesses reported seeing the aeroplane enter a could, hearing a loud noise almost immediately, and then seeing the fragments fall to the ground. Extensive investigations into the cause of the accident led to the following explanation: The plane, flying horizontally at high speed, suddenly entered a region of strong rising gusts. As results, there was a sharp increase in the angle of attack, with the formation of flow separation over the wing. The tail, situated in the wake of the wing, was subjected to intense forced vibrations that were caused by the turbulence in the separated flow, which brought about the accident.

It is also recognized that wake turbulence behind large aircraft has severe effects on aircraft flying nearby. These effects can be so severe as to cause light aircraft to roll over completely, and amy also force them to crash [3], as may be manifested by the following aviation accidents:

On July 25, 1980, a Piper PA-31-350 crashed while marking a visual approach at Philadelphia International Airport. The plane was sequenced to land behind a Boeing 727. When it was on its final approach, only 800 m from the runway, it rolled from side to side, pitched up, rolled inverted to the left, and flew into the ground, nose first, killing all three persons on board. Wake turbulence is through to be [4] the causing factor in this accident.

On April 17, 1983, a TriStar rolled suddenly to the left at an altitude of 200 ft during its approach to London's Heathrow Airport. The aircraft was re-levelled with difficulty before experiencing another right roll at 1700 ft. This roll was again corrected with difficulty. Finally, a third right roll was experienced at an altitude of 100 ft. It was realized later that a Boeing 747 was taxiing from the runway at the time, the wake turbulence of which caused the three rolls for the TriStar even through the standard separation of four miles for heavy aircraft was maintained [5].

On May 13, 1983, a small aircraft (model CE-402) was on an instrument approach to Logan International Airport in Boston, Mass. The aircraft was at an altitude of 4000 ft. It was behind an Airbus 30 when the CE-402 was advised of wake turbulence by the air traffic controller, and ordered to reduce his speed. The pilot of the CE-402 then felt a bump, and the aircraft rolled rapidly to an inverted position, after which it rolled right to about 40 degrees before control of the craft was regained [6].

In recognition of the significance of wake phenomena, we present below the results of an experimental study on the effect of a flapped leading wing at an angle of attack of 5° on a trailing wing with at different angle of attack.

APPARATUS AND EXPERIMENTAL PROCEDURE

A low speed, non-return type of wind tunnel, with a test section of $0.5x0.7x2.0\ m^3$, and a maximum speed of 45 m/s was utilized. An external three-component balance measured both lift and drag with an accuracy of 0.25%, and pitching moment with an accuracy of 0.5%. The angle of attack of the model was altered externally, without interfering with the flow in the tunnel.

Of the two models utilized, the leading wing was a NACA 0015 with rectangular planform, a chord length of 27.5 cm and a span of 50 m. Flaps at angles of 15, 30, and 45° were employed. The wing material was beech wood, and galvanized steel was used for the flaps.

The trailing wing was also rectangular in shape but with a chord of 7.62, and a span of 34.3 cm. Split flaps of 0.327 flap/chord ratio, and flap angles of 15, 30, and 45° were utilized. The trailing wing was aluminum, with 10% thickness and RAE 101 type airfoil.

Both wings were leveled be in the same horizontal plane Figure (1). The distance between the wings was 14.14 times the chord of the trailing wing. The leading wing was fixed at an angle of attack of 5°.

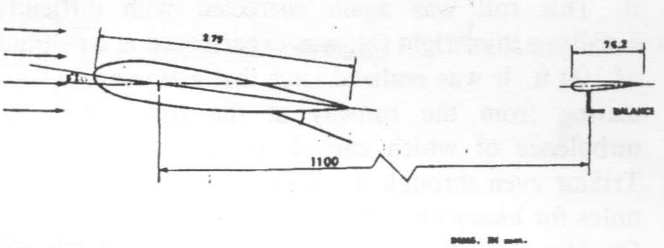

Figure 1. Schematic of the model.

All measurements were conducted at a velocity of 30 m/s, corresponding to an re of $1.5x10^5$ based on the trailing wing chord length . The trailing wing planform area, $0.02614\ m^2$, was used as the reference area.

RESULTS AND DISCUSSION

Curves of the lift coefficient for the trailing wing ar presented in Figures (2) to (5), clearly demonstratin the substantial influence of the leading wing (with an without flap) on the trailing wing. A remarkabl reduction in lift is observed, which tendency become stronger with increasing flap angles in the leadin wing. This phenomenon arises whether the wing fla is present or not.

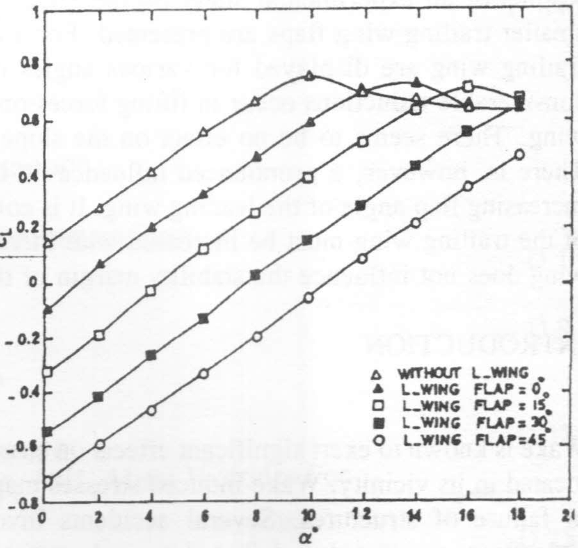

Figure 2. Lift coefficient of the trailing wing without flap.

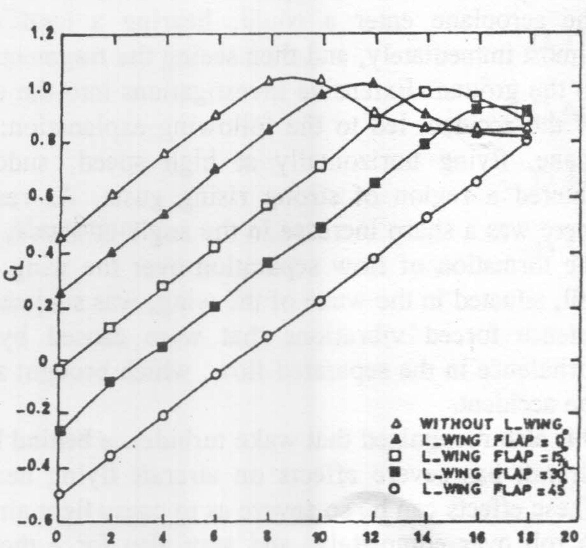

Figure 3. Lift coefficient of the trailing wing with 15° flap angle.

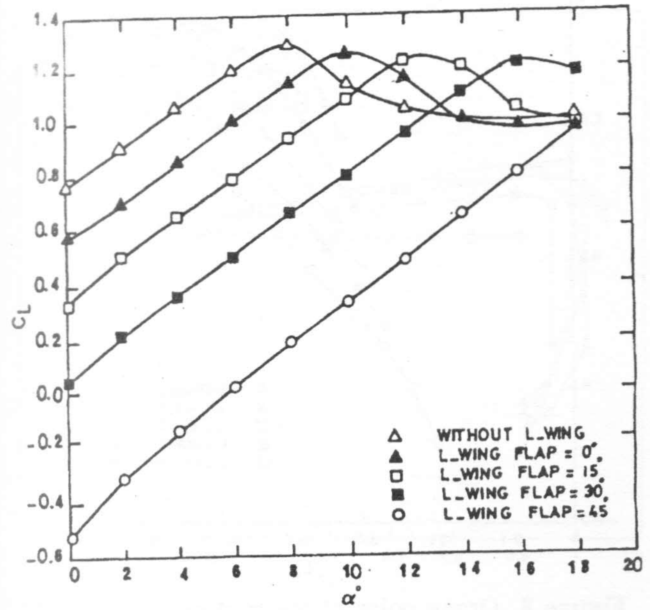

Figure 4. Lift coefficient of the trailing wing with 30° flap angle.

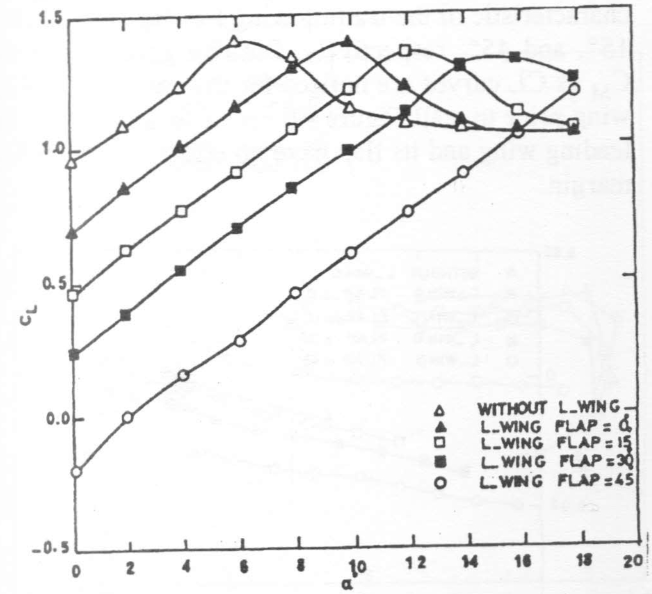

Figure 5. Lift coefficient of the trailing wing with 45° flap angle.

In the linear part of the lift coefficient curves, the reduction gradients have approximately the same values for trailing wing flap angles of 0° and 15° Figures (2) and (3). When trailing wing flap angles become 30° and 45°, this reduction gradient increases with increasing leading wing flap angle Figures (4) and (5).

It would thus be expected that a trailing aircraft would suffer the greatest loss of lift when the leading aircraft lower its flaps to the fullest extent; a common situation during takeoff and landing. The state becomes more acute when the speed of the trailing aircraft is low, as is the case during takeoff and landing. The situation is remedied somewhat by the fact that the trailing aircraft would normally employ its flaps too, there by alleviating the danger.

Experimental evidence further elucidates that the leading wing has no effect on either the slope of the lift coefficient curves or the maximum lift of the trailing wing. The leading wing does have a pronounced influence on the stall angle of attack, which increases with increasing flap angles of the leading wing. This suggests that the effect of the leading wing is to reduce the lifting force of the trailing wing, by disturbing the pressure distribution on the latter wing while increasing the linear part of the lift coefficient curves.

The data seems to lead to the conclusion that the main disturbance actually springs from the turbulence of the wake of the leading wing. The interaction of the wake of the leading wing with the flow field of the trailing wing affects the pressure distribution around the trailing wing.

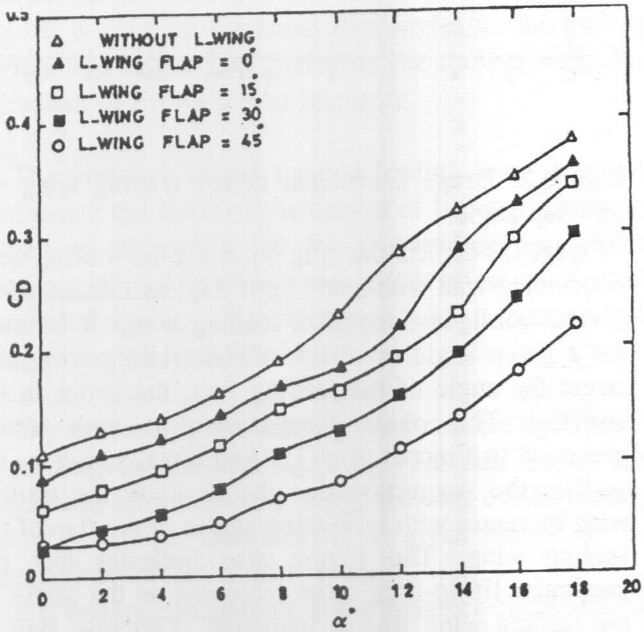

Figure 6. Drage coefficient o the trailing wing without flap.

Figures (6) and (7) illustrate the variation of the drag coefficient versus the angle of attack for the trailing wing with flap angles of 0° and 15°, respectively. The Figures demonstrate that the presence of a leading wing reduces the drag on the trailing wing. This phenomenon may be attributed to disturbances on the flow field of the trailing wing as caused by the mean and turbulent flow of the leading wing. The reduction of the drag on the trailing wing is observed to gain momentum when the flap of the leading wing is operated or its angle is increased.

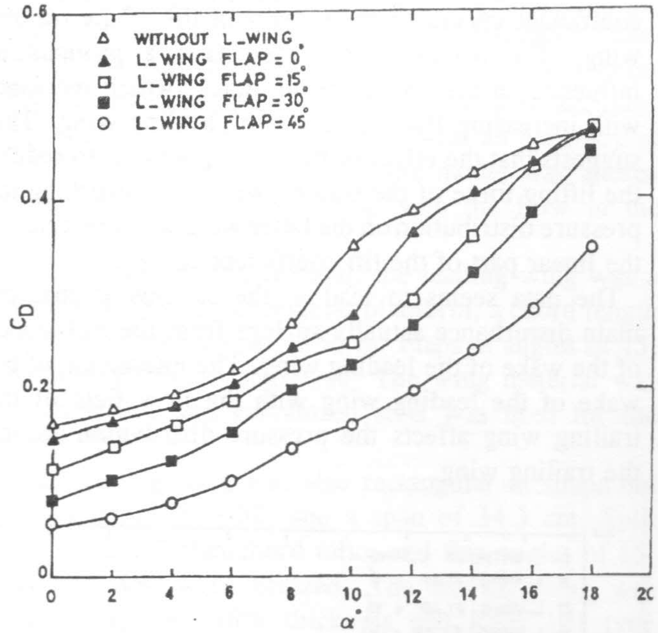

Figure 7. Drage coefficient of the trailing wing wit 15° flap angle.

Figure (8) depicts the drag polar for the trailing wing when integrated with a 45° split flap, as influenced by several configurations of th leading wing. It follows, for a given angle of attack of the trailing wing, the larger the angle of the leading flap, the drops in C_L and C_D. This observation is in line with results presented in Figures (2), (7). Additionally, Figure (8) verifies the suggestion that the drag on the trailing wing increases with increasing angles of the flap of the leading wing. The Figure also indicates that the maximum lift-to-drag ratio decreases as the angle of the leading wing flap is increased. Likewise stall is accompanied by an appreciable in drag and a modest in lift, whence it may be deduced that the maximum lifting force is not affected by the presence of the leading wing.

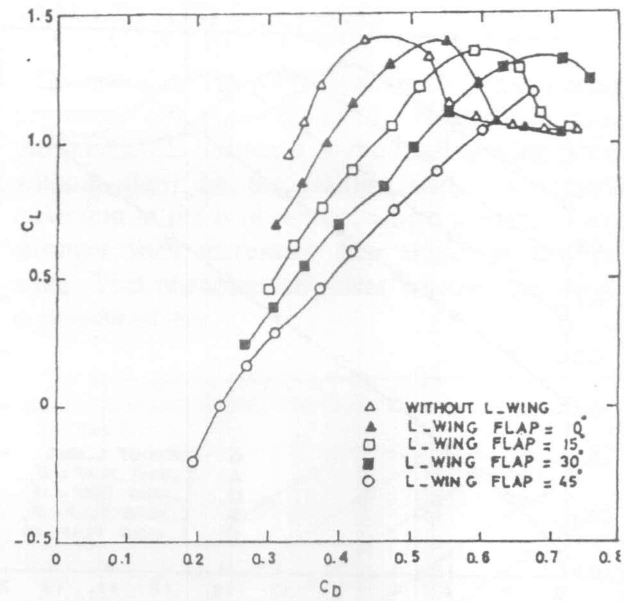

Figure 8. Drage polar of the trailing wing wit 45° flap angle.

Figures (9), (10) and (11) illustrate the effect of the wake of the large leading wing on the pitching moment characteristic of the trailing wing for flap angles of 0°, 15°, and 45°, respectively. Positive gradients for the C_M vs CL curves are noticed for the unflapped trailing wing prior to stall Figure (9) seems to suggest that the leading wing and its flap have no effect on the stability margin.

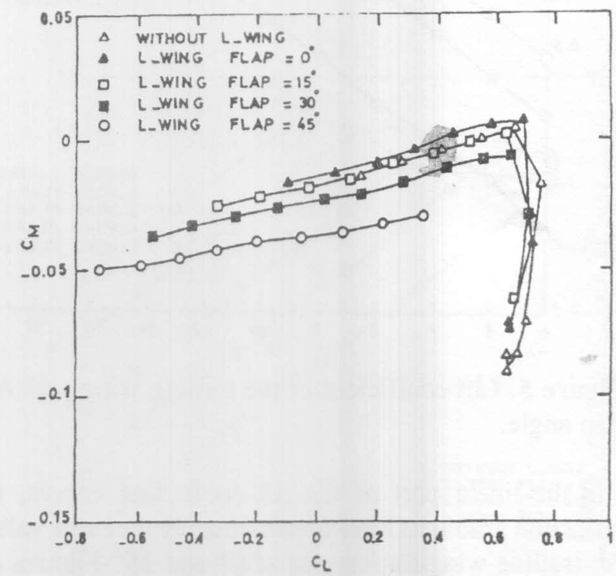

Figure 9. Pitching moment coefficient, C_M, versus lift coefficient, C_L, of the trailing wing without flap.

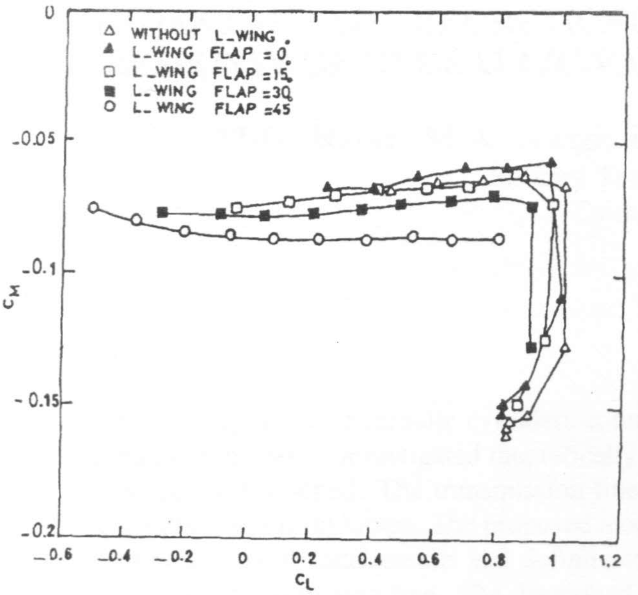

Figure 10. Pitching moment coefficient, C_M, versus lift coefficient, C_L of the trailing wing 15° flap angle.

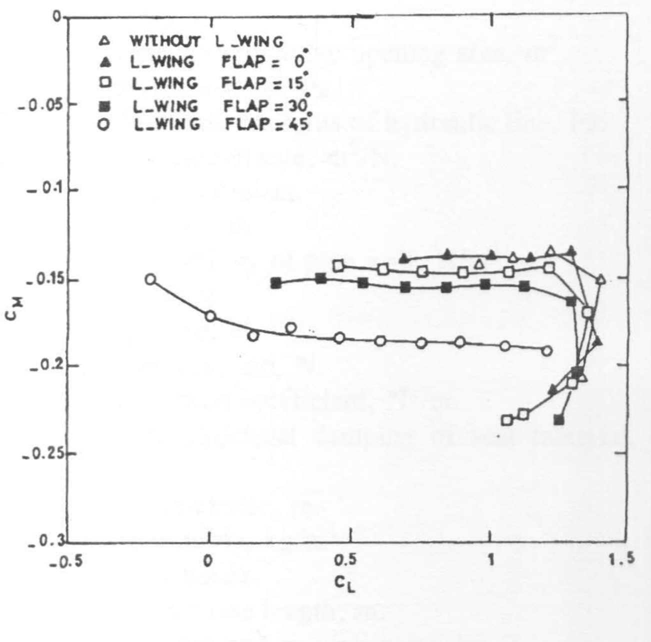

Figure 11. Pitching moment coefficient, C_M, versus lift coefficient, C_L, of the trailing wing 45° flap angle.

The main influence of the leading wing flap is confined to displacing the C_M-C_L curves of the trailing wing prior to its stall. This indicates that, in the presence of a leading wing, a constant pitching moment overrides the trailing wing. As the trailing wing starts to stall, the pitching moment coefficient drops suddenly due to the phenomenon of separation, and the effect of the leading wing and its flap appear to be small when compared to the stall.

Figures (9) and (11) further indicate that increasing the flap angle of the trailing wing decreases the stability margin of the wing towards the natural condition. The principal impact of the flap on the leading and trailing wings is confined to a margine of parasitic nose down pitching moment. The parasitic moment increases whenever flap angles of both wings are increased. These outcomes are throught to be results of the interaction between the wake of the leading wing and the flow field of the trailing wing.

CONCLUSIONS

The primary effect of a flapped leading wing at a small angle of attack (5°) on a smaller trailing wing is a remarkable reduction of the lifting forces on the latter. The loss in lift increases with increasing flap angles on the leading wing. The slope of the reduction in lift is constant for small flap angles on the trailing wing. For larger flap angles on the trailing wing, the gradient of lift reduction increases.

The presence of the flapped leading wing does not influence the slope of the curves of lift coefficients or these of maximum lift for the trailing wing. The leading wing does have a significant effect on the stall angle of attack, which increases with increasing flap angles on the leading wing.

The presence of the leading wing reduces the lift and the drag on the trailing wing. As flap angles are increased on the leading wing, the drag on the trailing wing must be increased if a given lift is to be maintained on the trailing wing.

It is further concluded that the presence of the leading wing does not affect the margin of stability of the trailing wing. The principal consequence of the presence of a leading wing is the advent of a uniform pitching moment that overrides the trailing wing.

REFERENCES

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[5] "Accident/Incident Briefs", Flight Safety Digest, July 1983.

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