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by

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Aerodynamics Dept., R.A.E., Farnborough

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LOW-SPEED WIND-TUNNEL TESTS OF A NUMBER OF FIN CONFIGURATIONS ON A FLAT-PLATE GOTHIC WING OF UNIT ASPECT RATIO

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SUMMARY

Results are given of six-component balance measurements on a gothic wing of unit aspect ratio fitted either with a pair of fins, at various spanwise locations, or a single central fin. Each fin was triangular in shape, with a leading-edge sweep of 60 degrees and an area 12.5% of that of the wing.

* Replaces R.A.E. Technical Report 68269 - A.R.C. 31080

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1 INTRODUCTION

Ref.1 describes tests on a series of slender wings with sharp edges which were made to investigate the effects of planform shape, thickness and aspect ratio on their aerodynamic characteristics at low speeds. A typical model from this series of tests, a flat-plate gothic wing of unit aspect ratio, was chosen to investigate the yawing moment obtainable from various fin configurations, and to investigate whether any significant effects were produced on other force and moment components. Such information is needed by the aircraft designer because the choice of fin location on slender wings is bound up with layout questions such as engine position, and the design of trailing-edge control surfaces.

The tests were made in the 13ft × 9ft low-speed wind tunnel at the R.A.E., Bedford, during September 1957, and the results were then given a limited circulation. Since it is considered that the results are still of general interest, they are now being issued for wider distribution.

2 DESCRIPTION OF MODEL AND TESTS

The model used was wing 2 of the series of slender wings described in Ref.1, but to enable tip fins to be fitted the wing tips were cropped, reducing the wing span to 0.9 of its original value. This cropped planform was retained for the other fin positions. It should be noted that this model had a flat upper surface and bevelled edges on the lower surface only, resulting in a zero lift angle of approximately 2°. The fins were sharp-edged and triangular in shape with a leading-edge sweep of 60°, each fin having an area 12.5% of that of the uncropped wing. They were positioned with their centres of area level with the trailing edge of the wing, and could be fitted at various spanwise locations, η_F, where η_F is based on the semi-span of the uncropped wing. A drawing of the model is given in Fig.1.

The aerodynamic mean chord, $\bar{\bar{c}}$, of the uncropped wing has been retained in computing the results, with the mean quarter-chord point as the origin in the model for the force and moment axes. This gives a fin arm of $0.75\ \bar{\bar{c}}$ and a fin volume coefficient of 0.094 per fin. Force and moment coefficients (based on actual wing area) are quoted relative to stability axes, a diagram of the system being given in Fig.2.

The six-component balance measurements were made at a tunnel speed of 100 ft/s over an incidence range of 0 to 18 degrees, together with some flow visualisation tests to aid in interpretation of the results.

3 DISCUSSION OF RESULTS

It was found that tip fins, or fins near the wing tips, had a detrimental effect on the longitudinal characteristics of the wing; Figs.3 and 4 show that tip fins reduce the lift by about 15%, as well as producing a pitch-up (Fig.5). Flow visualisation indicated that this occurred because the rolled-up vortex sheets move away from the wing surface at the rear of the wing, the primary line of separation being the wing leading-edge over the fore part of the wing and the fin leading-edge at the rear.

To avoid a confusion of plotted points, only the results for tip fins have been plotted in Fig.3. In Fig.4, the reduction of lift from the basic wing case is plotted for different spanwise locations of the fins. It is seen that twin fins outboard of 0.6 of the semi-span cause a large reduction in lift, but that the reduction becomes smaller as the fins are brought further inboard, and is insignificant with a central fin. A similar effect occurs with the pitching moment, a pitch-up resulting with fins located near the wing tips, the lift coefficient at which pitch-up occurs being progressively delayed to a higher value as the fins are moved further inboard. Here again, it is found that a central fin has no appreciable detrimental effect. Twin fins located well inboard ($\eta_F \not> 0.32$), did not cause a significant change from the basic wing characteristics in the incidence range covered by the tests.

The static sideslip derivatives are plotted in Figs.6, 7 and 8 for the basic wing, for the wing with tip fins, with twin fins at $\eta_F = 0.32$, and with a single central fin. The derivatives were calculated from values measured at sideslips of $\pm 2\frac{1}{2}^{\circ}$.

The side force derivative obtained from tip fins varied appreciably over the incidence range, while that obtained from twin fins at $\eta_F = 0.32$ was more nearly constant. In both cases, a little less than twice the side force given by the central fin of half the volume is obtained, (Fig.6). Similar remarks apply to the yawing moment derivative (Fig.7); the central fin gives a mean value for $\frac{dC_n}{d\beta}$ of 0.25, twin fins at $\eta_F = 0.32$ about 0.45. The variation with incidence of the side force and yawing moment derivatives for fins near the wing tips, is due to the changing side-wash at the fin positions arising from the effect of the leading-edge vortex sheets.

Fig.8 shows the effect of the various fin configurations on the rolling moment derivative $\frac{dC_\ell}{d\beta}$. It is seen that tip fins give an undesirable negative contribution, while the twin fins at $\eta_F = 0.32$ and the central fin have only a small effect. This is due to the fact that pressures on fins on or near the centre-line of the wing affect the wing locally, giving a rolling moment opposing that from the fins themselves. With tip fins, pressures on their outer surfaces cannot affect the wing, and an adverse rolling moment results.

4 CONCLUSIONS

A single central fin was found to be the most efficient, a fin of area 12.5% of the wing, operating at an arm of 0.75 $\bar{\bar{c}}$, giving a value for the yawing moment derivative $\frac{dC_n}{d\beta}$ of 0.25. In this position, the fin does not affect the longitudinal characteristics of the wing, or give an appreciable rolling moment contribution.

Fins near the tips of the wing were unsatisfactory, giving a varying yawing moment contribution with incidence, an undesirable rolling moment, a loss of lift, and a loss of stability in pitch.

If the fin volume attainable with a central fin is inadequate twin fins located approximately one-third of the semi-span outboard of the wing centre-line should give satisfactory results. With this configuration, however, there will probably be a limiting range of incidence and sideslip, outside which the fins will be seriously affected by the leading-edge vortex sheets.

SYMBOLS

C_L	overall lift coefficient $= \dfrac{L}{\frac{1}{2}\rho V^2 S^1}$
C_m	overall pitching moment coefficient, referred to aerodynamic mean chord, taken about mean quarter-chord point $= \dfrac{m}{\frac{1}{2}\rho V^2 S^1 \bar{\bar{c}}}$
C_y	overall side force coefficient $= \dfrac{Y}{\frac{1}{2}\rho V^2 S^1}$
C_ℓ	overall rolling moment coefficient $= \dfrac{\ell}{\frac{1}{2}\rho V^2 S^1 b}$
C_n	overall yawing moment coefficient $= \dfrac{n}{\frac{1}{2}\rho V^2 S^1 b}$
$\dfrac{dC_y}{d\beta}, \dfrac{dC_\ell}{d\beta}, \dfrac{dC_n}{d\beta}$	sideslip derivatives, per radian
α	angle of incidence, degrees
β	angle of sideslip, degrees
η_F	non-dimensional spanwise fin location $= \dfrac{y_F}{b/2}$
c_o	wing root chord
c_F	fin root chord
b	uncropped wing span
$\bar{\bar{c}}$	aerodynamic mean chord of uncropped wing $= \dfrac{\int_{-b}^{+b} c^2\, dy}{\int_{-b}^{b} c\, dy}$
x, y	rectangular body co-ordinates
S_F	fin area
S	area of uncropped wing
S^1	area of cropped wing

REFERENCE

No.	Author	Title, etc.
1	D.H. Peckham	Low-speed wind-tunnel tests on a series of uncambered slender pointed wings with sharp edges. A.R.C., R. & M. 3186 (1958)

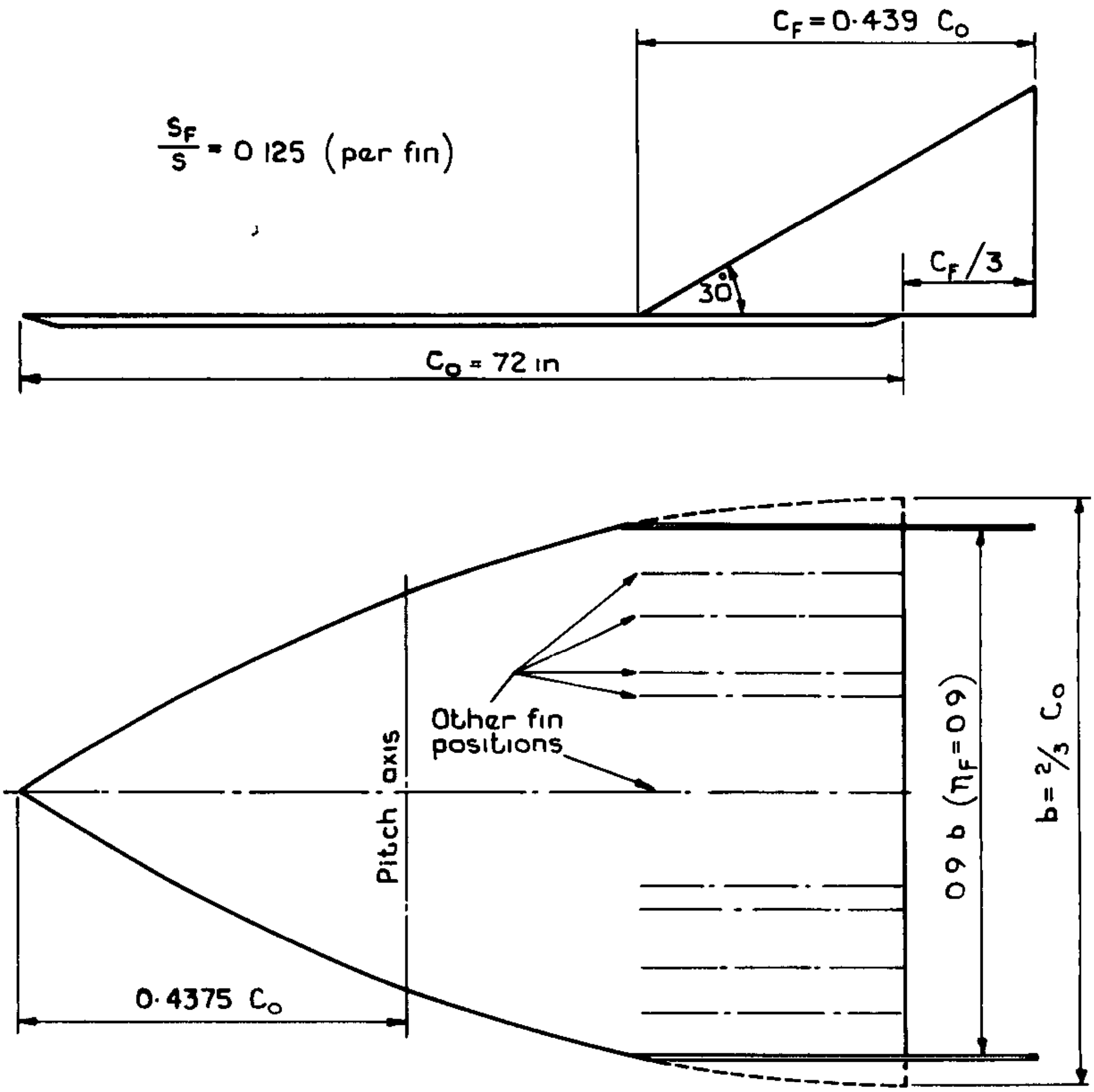

Fig.1 Model geometry (tip fins shown) other fin position:-
$\eta_F = 0, 0{\cdot}32, 0{\cdot}4, 0{\cdot}6, 0{\cdot}75$

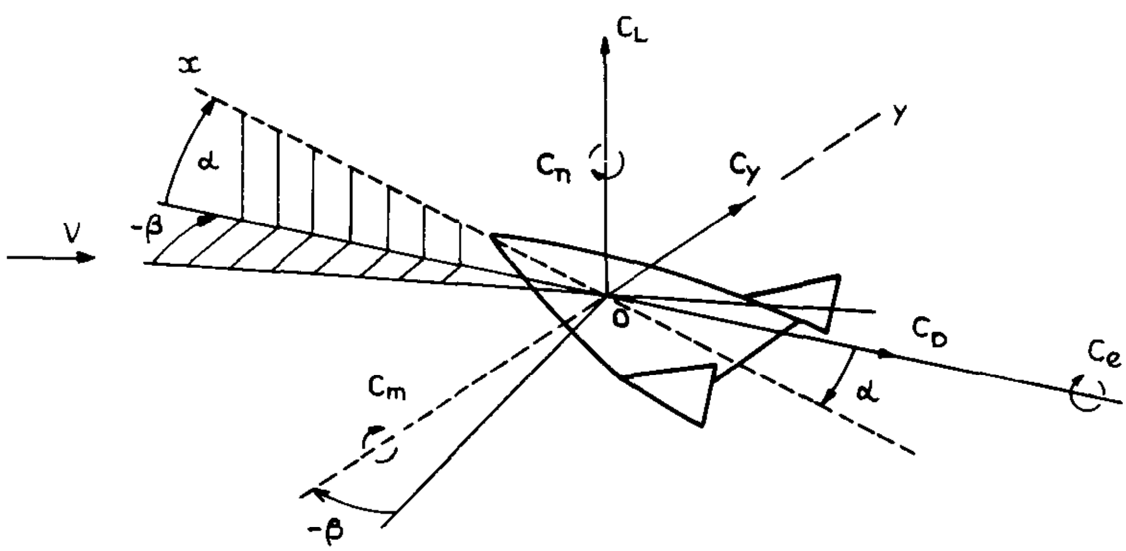

Fig. 2 Force and moment axes. ox, oy body axes
O-mean $\frac{1}{4}$ - chord point

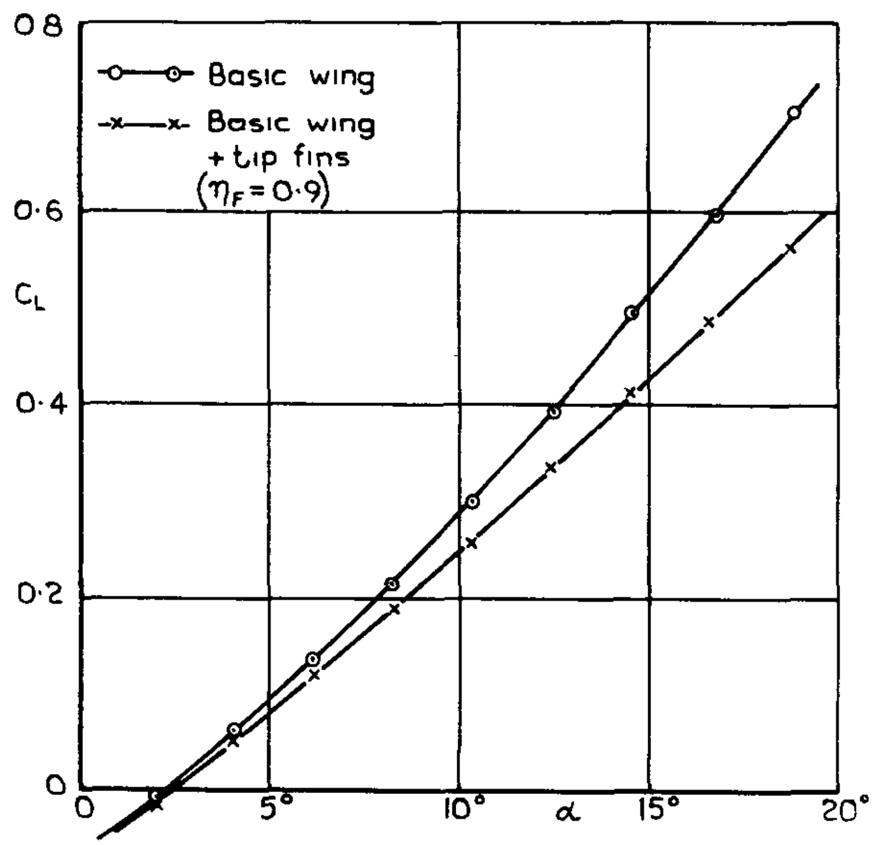

Fig. 3 Effect of tip fins on lift

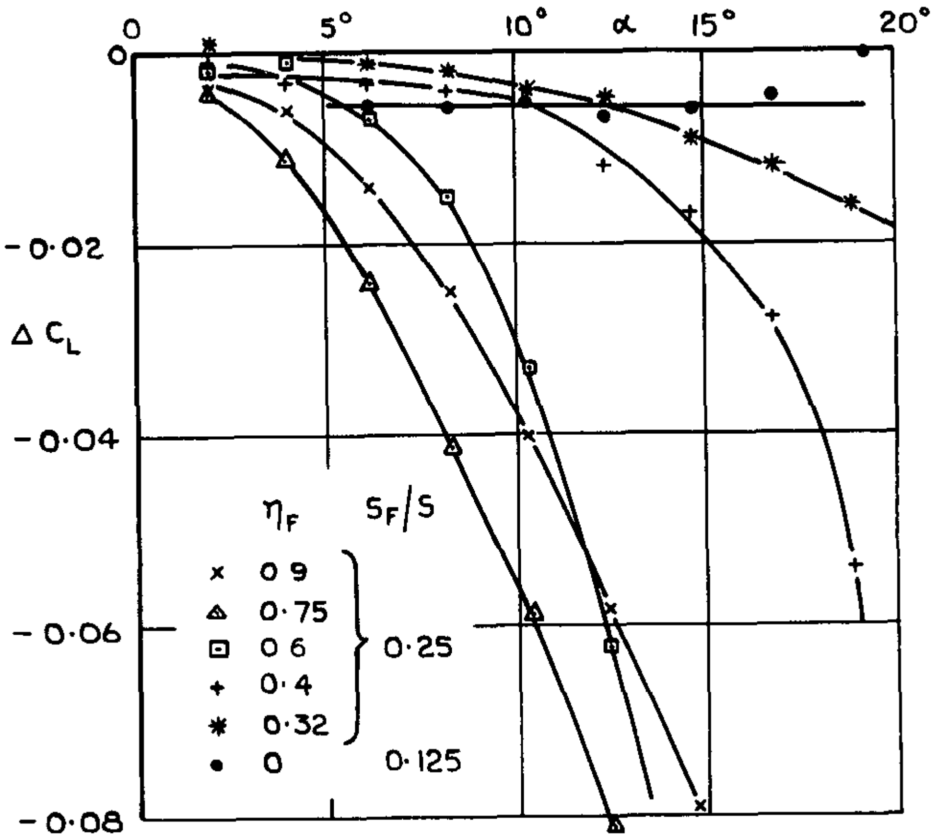

Fig.4 Reduction of lift due to effect of fins
$\Delta C_L = C_L$ (wing + fins) $- C_L$ (basic wing)

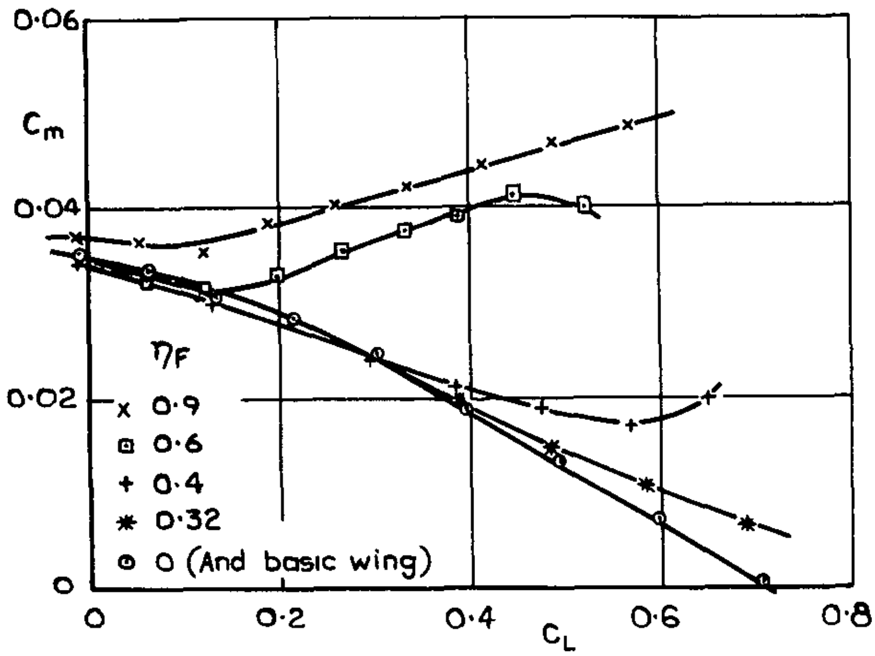

Fig.5 Effect of fin position on pitching moment

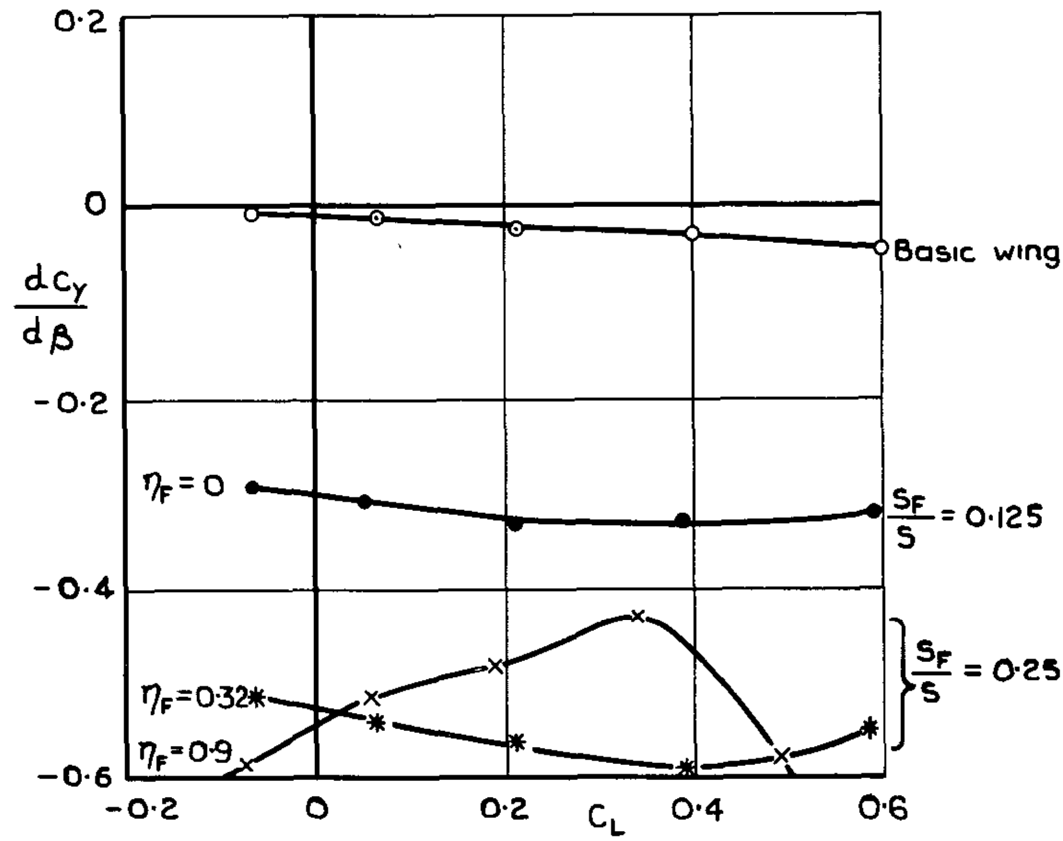

Fig. 6 Effect of fin position on side force derivative $\frac{dC_y}{d\beta}$

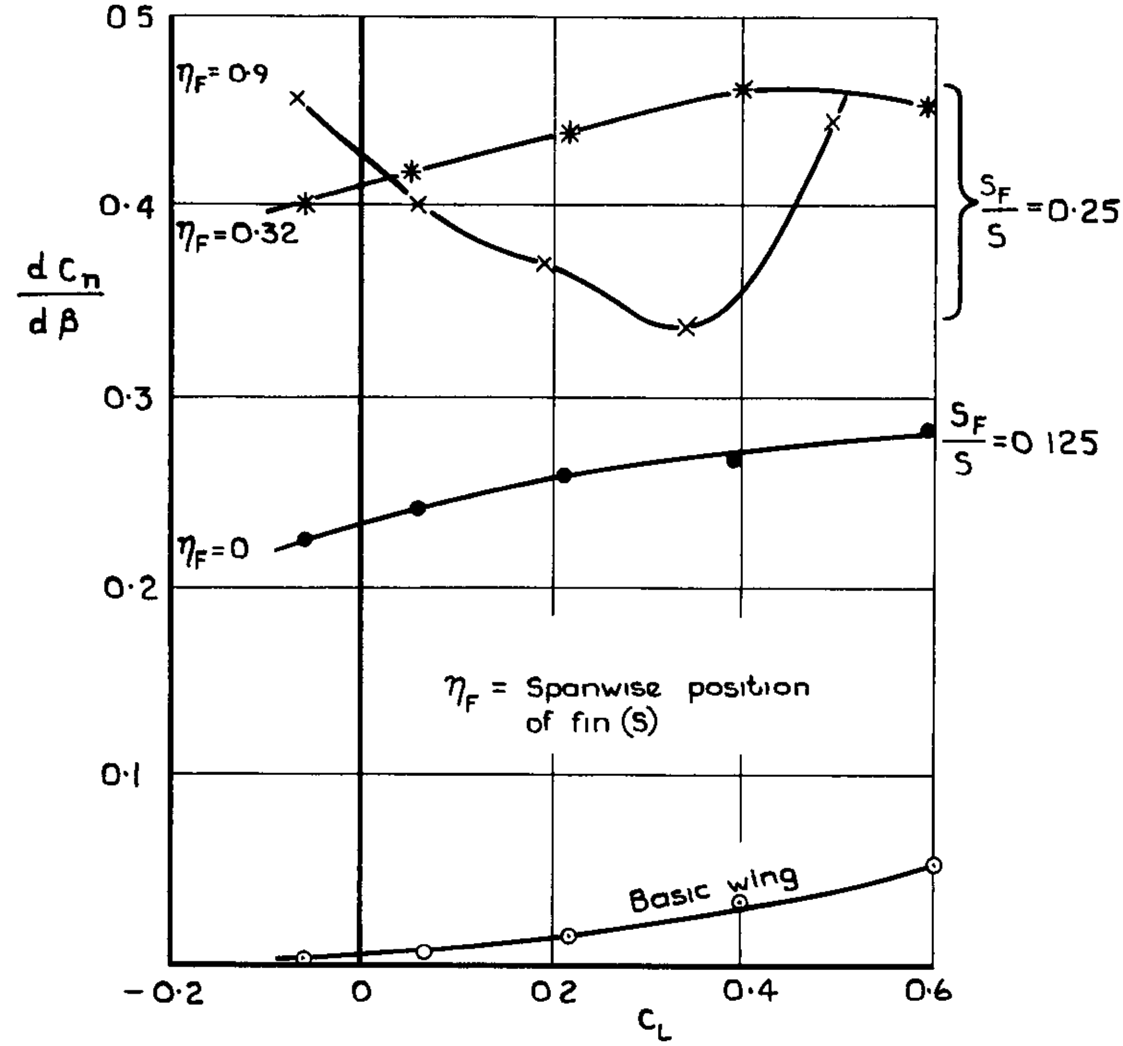

Fig.7 Effect of fin position on yawing moment derivative $\frac{dC_n}{d\beta}$

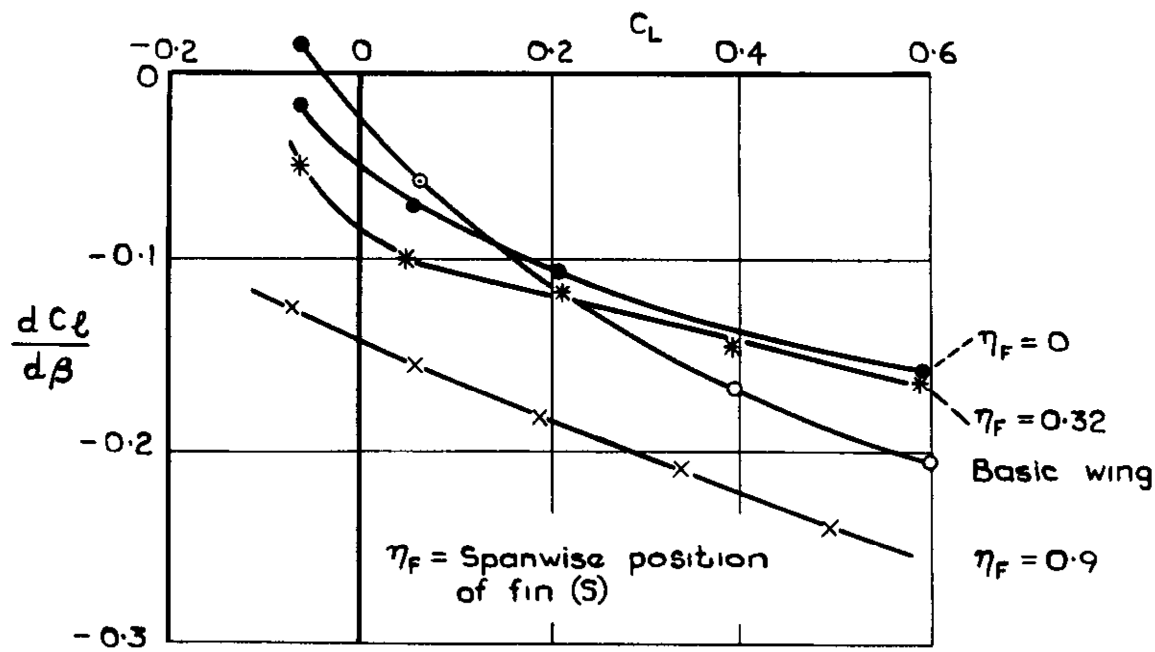

Fig.8 Effect of fin position on rolling moment derivative $\frac{dC_\ell}{d\beta}$

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