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Analysis of Wind Tunnel Lateral Oscillatory Data of the F-16XL Aircraft

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Summary

Static and dynamic wind tunnel tests were performed on an 18% scale model of the F-16XL aircraft. Static tests provided force and moment measurements for an angle of attack range of 0° to 90°. Data with nonzero sideslip angles were obtained by taking measurements at various roll and yaw offset angles. Offset static measurements, however, were not considered in this report. Dynamic forced oscillation tests were performed at initial angles of attack from 0° to 75° for roll and from 0° to 90° for yaw, oscillation amplitudes from 5° to 30°, offset roll and yaw angles from 0° to 60°, and reduced frequencies from 0.073 to 0.269. A limited amount of data was obtained at different Reynolds numbers.

Harmonic analysis was used to estimate Fourier coefficients and in-phase and out-of-phase components. This estimation procedure provided standard errors of the derivative estimates and the total aerodynamic coefficients, as well as the coefficients of determination associated with each model. For frequency dependent data from rolling oscillations, a two-step regression method was used to obtain unsteady models (indicial functions), and derivatives due to sideslip angle, roll rate and yaw rate from in-phase and out-of-phase components. Frequency dependence was found for angles of attack between 20° and 50°. Reduced values of coefficient of determination and increased values of fit error were found for angles of attack between 35° and 45°. An attempt to estimate model parameters from yaw oscillations failed, probably due to the low number of test cases at different frequencies.

Symbols

AR	aspect ratio
A_0, A_j, B_j	Fourier coefficients
a	indicial function gain
b	wing span, m
C_a	aerodynamic coefficient
C_Y, C_l, C_n	side force, rolling-moment, yawing-moment coefficients
$C_A,\ C_N,\ C_m$	axial force, normal force, pitching-moment coefficients
$C_L,\ C_D$	lift, drag coefficients
$\bar{C}_{a_\beta}$	in-phase component of C_a
$\bar{C}_{a_p},\ \bar{C}_{a_r}$	out-of-phase components of C_a
$C_{a_{\dot\beta}},\ C_{a_{\dot p}},\ C_{a_{\dot r}}$	frequency dependent parameters
$\bar{c}$	wing mean aerodynamic chord, m
i	time index
j	harmonic index
k	reduced frequency $k = \omega\ell / V$
ℓ	characteristic length, $\ell = b/2$
LS	least squares
m	number of harmonics
N	number of measurements
p, r	rolling and yawing velocity, rad/sec
R^2	coefficient of determination
Re	Reynolds number
s, s^2	estimated standard error, estimated variance
t	time, sec
V	airspeed, ft/sec
u,v,w	velocity components along each body axis, m/sec
y	model output
z	measurement
α	angle of attack, rad or deg

β	sideslip angle, rad or deg
ε	measurement noise
θ	pitch angle, rad or deg
ϕ	roll angle, rad or deg
σ, σ^2	standard deviation, variance
τ	indicial function non-dimensional time constant
ψ	yaw angle, rad or deg
ω	angular frequency, rad/sec

<u>Superscript or Superscript over variable</u>

ˆ	estimated value
.	time derivative

<u>Subscript</u>

A	amplitude
a	$a = l, n, Y$
j	harmonic index
0	nominal value

<u>Aerodynamic parameters</u>

$$C_{a_\eta}(\infty) \equiv C_{a_\eta} = \frac{\partial C_a}{\partial \eta} \quad \text{for } \eta = \frac{pb}{2V}, \frac{rb}{2V}, \beta$$

1 Introduction

In recent years a significant amount of research has been conducted in the area of unsteady aerodynamics at high angles of attack. In order to support this research, data were collected mostly from various wind tunnel tests. The models tested varied from simple delta wing layouts to that of modern fighter aircraft. One of the tested planforms was the F-16XL, cranked-delta wing aircraft. The first in a series of wind tunnel tests on the F-16XL were conducted in the NASA Langley Research Center (LaRC) 30x60 Foot Full Scale Wind Tunnel are presented in references 1 and 2. Therein static and forced-oscillation data are summarized in graphic and tabulated form, and no other modeling attempts were made.

A second set of tests on the F-16XL were conducted in the NASA LaRC 12 Foot Low Speed Wind Tunnel to obtain forces and moments during forced oscillations and ramps in pitch over a large range of angle of attack. The data and analysis for these tests are described in references 3 to 5. From the analysis linear and nonlinear longitudinal aerodynamic model equations with unsteady terms were obtained.

A third set of wind tunnel data for the F-16XL aircraft was obtained from experiments in the NASA LaRC 14x22 Foot Subsonic Wind Tunnel. In this experiment the data from forced oscillations in roll and yaw with different amplitudes, frequencies, and angles of attack were collected. A limited amount of data was obtained at different Reynolds numbers and with different offsets in mean roll and yaw angles. Some results of a preliminary analysis were reported in reference 6. The purpose of this report is to summarize most of the data, static and oscillatory, and present an analysis of these data. The main effort will be to obtain models for aerodynamic coefficients using harmonic analysis and linear regression.

After the Introduction, the report proceeds with model and test description in Chapter 2 and 3, followed by a review of static and oscillatory data in Chapter 4. The data analysis is split into two parts, the rolling oscillations and yawing oscillations. Concluding remarks complete the report.

2 Model and Tests

A three dimensional view sketch of the 18% scale F-16XL model with moveable control surfaces is shown in figure 1 together with some basic model dimensions. Static and dynamic tests were conducted in the NASA LaRC 14x22 Foot Subsonic Wind Tunnel. For both tests the model was mounted on a dynamic test rig through a six-component strain-gauge balance. The dynamic test rig is powered by an electric motor with a flywheel to give nearly sinusoidal motion in each of the three axes. The model can be sting mounted either through the rear or through the top of the aircraft. The mounting arrangement allowed the model to be rotated in each axis over an angle of attack range of 0° to 90°. More about the apparatus can be found in reference 7. The moment reference center was located at $0.46\bar{c}$.

All data were obtained with a clean configuration and zero control deflections. For static data the dynamic pressure was set at 311 Pa (6.7 psf) resulting in a Reynolds number of 2.1×10^6 based on the mean aerodynamic chord. The data were obtained for pitch angles from 0^o to 75^o at five roll-angle offsets of 0°, 15°, 30°, 45°, and 60°, and pitch angles from 0^o to 90^o at four yaw-angle offsets of 0°, 15°, 30°, and 45°. For zero offset angles, pitch angle and angle of attack are equal. For nonzero offsets, angle of attack and sideslip change according to the relationships given in Appendix A.

Dynamic testing included forced oscillation about the roll and yaw body axes at angles of attack from 0° to 75° for roll and from 0^o to 90^o for yaw, at frequencies from 0.26 Hz to 1.13 Hz, and at four different amplitudes of 5°, 10°, 20°, and 30°. In addition, for both rolling and yawing oscillations with the amplitudes of 30° the effect of roll and yaw offset was investigated. Oscillatory data were mostly collected at the dynamic pressure of 311 Pa but some limited testing was performed at 95.8 Pa (2 psf) and 191.5 Pa (4 psf) corresponding to Reynolds numbers of 0.6×10^6 and 1.3×10^6. Data were sampled at 200 Hz with an inline 100 Hz anti-aliasing filter and further filtered during post processing with a 4 Hz low pass filter. Each run consisted of 40 cycles of the data. The test conditions for the roll oscillations and yaw oscillations are summarized in Table I and Table II, respectively.

3 Static Data

The force and moment coefficients for zero sideslip and zero offset in roll and yaw are presented in Table III. Drag, lift, and pitching-moment coefficients, from this table, are plotted against the angle of attack in figure 2. During the measurements with nonzero offsets in roll and yaw, the angle of attack and sideslip changed for each value of the pitch angle. The relation between the five angles is developed in Appendix A. For roll offset,

$$\alpha = \tan^{-1}(\tan\theta * \cos\phi) \quad (1a)$$

$$\beta = \sin^{-1}(\sin\theta * \sin\phi) \quad (1b)$$

and for yaw offset,

$$\alpha = \tan^{-1}(\tan\theta / \cos\psi) \quad (1c)$$

$$\beta = \sin^{-1}(-\cos\theta * \sin\psi)\ . \quad (1d)$$

The computed value of α and β for each test point are plotted in figure 3. The non-rectangular spread in data points made it impossible to compute conventional aerodynamic derivatives with respect to sideslip angle in the vicinity of β = 0. For that reason this part of static data is not included in this report.

4 Oscillatory Data

As shown in Tables II and III, the measured data in roll and yaw oscillations were obtained at different angles of attack, frequencies, and amplitudes. In addition, some of the measurements cover the effect of initial offset in roll and yaw, and the effect of Reynolds number. Some examples of measured data are presented in figures 4 to 10. Time histories of roll angle and lateral coefficients at various angles of attack, amplitudes, and offsets in roll are shown in figures 4 to 6. Similar data from yawing oscillations are introduced in figures 7 and 8. As expected, changes in simple harmonic responses for all three lateral coefficients occurred with increased amplitude of commanded roll and yaw angles, increased angle of attack, and by introducing an offset in roll or yaw. More pronounced changes can be observed in the yawing moment and side force rather than in the rolling moment.

Figures 9 and 10 demonstrate variations of the lateral coefficients with roll and yaw angle at selected angles of attack, amplitudes, and frequencies. For a linear aerodynamic model the variation of aerodynamic forces and moments should be in the form of an ellipse, or, in some cases, in the form of a parabola (see reference 3). Distortion of the oscillatory data from the linear-model curves can be ascribed to the effect of measurement noise and aerodynamic nonlinearity. For large amplitude oscillations, kinematic nonlinearity also contributes to the distortion since the small angle assumption for the linear model is violated for large bank angles (see Appendix A). As in the previous examples, this is mostly apparent in the side force and yawing moment at high angles of attack and large amplitudes.

The method of harmonic analysis (Appendix B) was applied to measured aerodynamic coefficients using 20 cycles of data and the sampling rate of 100 Hz. A mathematical model for the aerodynamic coefficients was postulated as

$$C_a(t) = A_o + \sum_{j=1}^{m} (A_j \cos\omega_j t + B_j \sin\omega_j t) \tag{2}$$

where C_a is either $C_l, C_n,$ or C_Y and $A_o, A_1, B_1, ..., A_m, B_m$ are the Fourier coefficients. The analysis provided estimates of these three aerodynamic coefficients and their standard errors together with estimates of the standard error of measured aerodynamics coefficients (fit error), $s(C_a)$, and coefficients of determination, R^2. The last term indicates how much information in the data is explained by the model (Appendix B).

For the model with linear aerodynamics and $A_0 = 0$, the coefficients A_1 and B_1 for roll-oscillatory data can be expressed as

$$\bar{C}_{a_\beta} = \frac{B_1}{\phi_A} = C_{a_\beta}(\infty)\sin\alpha - k^2 C_{a_{\dot{p}}} \tag{3a}$$

$$\bar{C}_{a_p} = \frac{A_1}{k\phi_A} = C_{a_p}(\infty) + C_{a_{\dot{\beta}}}\sin\alpha \tag{3b}$$

assuming

$$\beta(t) = \phi(t)\sin\alpha_o \tag{4}$$

Similarly for yaw-oscillatory data,

$$\bar{C}_{a_\beta} = \frac{B_1}{\psi_A} = C_{a_\beta}(\infty)\cos\alpha_0 + k^2 C_{a_{\dot{r}}} \tag{5a}$$

$$\bar{C}_{a_r} = \frac{A_1}{k\psi_A} = C_{a_r}(\infty) - C_{a_{\dot{\beta}}}\cos\alpha \tag{5b}$$

assuming

$$\beta(t) = -\psi(t)\cos\alpha_o \tag{6}$$

In equations (3) to (5) $\bar{C}_{a_\beta}$, $\bar{C}_{a_p}$, and $\bar{C}_{a_r}$ are the in-phase and out-of-phase components of $C_a(t)$, where ϕ_A and ψ_A are the amplitudes of commanded roll and yaw angles, k is the reduced frequency, α_0 is the initial value of the angle of attack, and $C_{a_\beta}(\infty)$, $C_{a_p}(\infty)$ and $C_{a_r}(\infty)$ are the "quasi-steady" values of aerodynamic derivatives.

In order to explain the variation of the in-phase and out-of-phase components with frequency these components were modeled in terms of indicial functions (see reference 8). After some simplifying assumptions the models for these components have the following form

$$\bar{C}_{a_\beta} = C_{a_\beta}(\infty)\sin\alpha_0 - a\frac{\tau^2 k^2}{1+\tau^2 k^2}\sin\alpha_0 \tag{7a}$$

$$\bar{C}_{a_p} = C_{a_p}(\infty) - a\frac{\tau}{1+\tau^2 k^2}\sin\alpha_0 \tag{7b}$$

for rolling oscillations and

$$\bar{C}_{a_\beta} = C_{a_\beta}(\infty)\cos\alpha_0 - a\frac{\tau^2 k^2}{1+\tau^2 k^2}\cos\alpha_0 \tag{8a}$$

$$\bar{C}_{a_r} = C_{a_r}(\infty) + a\frac{\tau}{1+\tau^2 k^2} \tag{8b}$$

for yawing oscillations, where τ is the nondimensional time constant and a scales the contribution of unsteady terms to the in-phase and out-of-phase components.

In equations (7) and (8) there are four unknown parameters for each oscillation axis: $C_{a_\beta}(\infty)$, $C_{a_p}(\infty)$ or $C_{a_r}(\infty)$, a and τ. They can be obtained from measured data by various estimation techniques, reference 9. For the present report a two-step linear regression is used. This method was proposed in reference 10 and is explained in Appendix C.

4.1 Rolling Oscillations

Results of harmonic analysis for the roll-oscillatory data are presented in the form of in-phase and out-of-phase components of the rolling and yawing moments, and the side force. These components, which correspond to the first harmonics in equation (2), are summarized in figure 11 to 14, 20 to 22, and 27, and partially in tables IV to XV. The tabulated values also include standard errors of the components as a measure of their accuracy.

Figures 11 to 13 show a variation of the components with the angle of attack, frequency and amplitude. Figure 14 presents some of the data for the rolling moment coefficient re-plotted in the form $\bar{C}_{\ell_\beta}(k;\alpha_0,\phi_A)$ and similarly for $\bar{C}_{\ell_p}$. The dependence of the components on frequency occurs for α within the interval of 20° to 50°. For that region the damping derivatives $\bar{C}_{a_p}$ can be formulated as

$$\bar{C}_{a_p}(\alpha) = C_{a_p}(\infty;\alpha) + C_{a_{\dot\beta}}(k;\alpha)\sin\alpha_0 \tag{9}$$

whereas for the derivatives outside the interval

$$\bar{C}_{a_p}(\alpha) = C_{a_p}(\infty;\alpha) + C_{a_{\dot\beta}}(\infty;\alpha)\sin\alpha_0 \tag{10}$$

where $C_{a_{\dot\beta}}(\infty)$ is a "quasi-steady" value of frequency dependent parameter $C_{a_{\dot\beta}}(k)$.

There are only relatively minor differences between the data for the amplitude of 5° and 10°. For the amplitude of 20° and 30°, however, larger differences emerge with respect to angle of attack and frequency. Variation in response with amplitude is characteristic of a nonlinear system. For the assessment of linear model adequacy in roll motion, the coefficient of determination and the fit error are plotted against the angle of attack for all four amplitudes and all available test frequencies and shown in figures 15 and 16. A significant decrease of R^2 and increase of s(C_a) is visible for the angles of attack 35° to 50° for all amplitudes and all frequencies, especially the low frequencies. This might indicate a sudden increase in measurement error or modeling error or both. For better understanding of changes in R^2 and $s(C_a)$, the measured and computed data were compared in figures 17 to 19 for two amplitudes, two initial angles of attack, and one frequency. The differences between the sets of data are pronounced at $\alpha = 45°$, whereas for $\alpha = 20°$ a linear model explains the measured data quite well regardless of the amplitude. Because of some degree of repeatability of $C_a(\phi)$ curves, it may be possible that modeling errors rather than measurement errors are significant contributors to the large difference between the model and measured data at $35° < \alpha < 45°$. On the other hand, the addition of higher harmonics into model equation (2) did not significantly improve the R^2 and $s(C_a)$ measures.

The in-phase and out-of-phase components for different values of roll offset, ϕ_0, are shown in figures 20 to 22. For these figures, the offset angle varies from 15° to 60° and the oscillation amplitude remains the same at 30°. Increased ϕ_0 results in decreased dependency on frequency in all three aerodynamic coefficients. The in-phase components vary with the offset over the whole range of α but the out-of-phase components remain almost the same for $0° < \alpha < 20°$. By considering time histories of the aerodynamic coefficients adequacy of the linear model structure can be qualitatively assessed. Time histories of the coefficients are plotted in figures 23 to 25 for all four values of ϕ_0, selected values of α, and one frequency k = 0.064. Distortions of time histories are visible mostly at increased values of the angle of attack and the initial offsets in roll. In these cases it was found that models with three harmonics were adequate for explaining variations in measured data. Figure 26 shows improvement obtained in the coefficients of determination by progressively adding harmonics to the model.

In figure 27 the components were obtained from data at Reynolds number, $Re = 0.6 \times 10^6$, whereas previous results were for data at $Re = 2.1 \times 10^6$. A possible effect of Re on the components is not investigated here, however, some indication of this effect can be seen in the estimated parameters in (6), as shown in the next set of figures.

The estimates of unknown parameters in the aerodynamics model equations (6) are presented in figures 28 to 30 for C_l, C_n, and C_Y. The results were obtained from data at

$$\phi_A = 5°, \quad \mathrm{Re} = 2.1 \times 10^6$$
$$\phi_A = 10°, \quad \mathrm{Re} = 2.1 \times 10^6$$
$$\phi_A = 10°, \quad \mathrm{Re} = 0.6 \times 10^6$$

The estimates also include their 2σ-confidence level and computed parameters $C_{a_{\dot{\beta}}}$ from the expression

$$C_{a_{\dot{\beta}}}(k;\alpha) = -\frac{a(\alpha)\tau}{1+\tau^2 k^2} \tag{11}$$

The estimated parameters from all three data sets are, in general, consistent with the exception of results at $\alpha = 45°$ and for the coefficient C_Y. As discussed previously, a linear model at $\alpha = 45°$ is in doubt due to low values of R^2 and large differences between computed and measured coefficient as demonstrated in figures 17 to 19. Different estimates of parameters τ and a for C_Y come from data at two different Reynolds numbers, see figure 30.

The values of time constant for $C_l(t)$ and $C_n(t)$ are very similar. For the side force, however, τ is about one third of the previous values. This difference indicates smaller unsteady effect on $C_Y(t)$ then on the remaining two coefficients. The β-derivatives from oscillatory data are compared with those from static wind tunnel data of reference 1. Differences between these two results are mostly in $C_{l_\beta}(\infty)$ at $35° < \alpha < 45°$, and in $C_{Y_\beta}(\infty)$ over the whole range of α. The best agreement exists for the derivative $C_{n_\beta}(\infty)$. For the p-derivatives at angles of attack between 30° to 40°, the unsteady term $C_{a_{\dot{\beta}}}(k)$ is the main contributor to the damping-in-roll, and to the yawing moment and side force due to rolling velocity.

4.2 Yawing Oscillations

Estimation of in-phase and out-of-phase components from yaw-oscillatory data was limited to three cases only. Figures 31 to 33 show the dependence of both components on the amplitude and frequency for Reynolds number $Re = 2.1 \times 10^6$. Similar results are presented in figure 34 for $Re = 0.6 \times 10^6$. From both results no significant changes due to Reynolds number are noticeable. The data in figure 34 were used in estimation of parameters in model equation (8). Unfortunately, this attempt failed probably due to the limited number of frequencies. Variation of components with four values of yaw offset is given in figure 35. As was the case for the roll-oscillation data, increased offset seems to reduce the effect of the unsteady term on the components. In addition, changes in components due to the offset also appeared in the low α-regime, mainly for the yawing moment and the side force.

5 Concluding Remarks

A wind tunnel experiment on an 18-percent scale model of the F-16XL aircraft was conducted at NASA Langley Research Center. The experiment included static tests, roll-oscillatory tests, and yaw-oscillatory tests. Static tests investigated the effect of the angle of attack and offsets in roll and yaw. Unfortunately, the spread of data points made it impossible to compute conventional aerodynamic derivatives with respect to sideslip angle in the vicinity of its zero value.

The measured data in roll and yaw oscillations were obtained at different angles of attack, amplitudes, and frequencies. Some of the measured data covered the effect of initial offsets in roll and yaw, and the effect of Reynolds number. The preliminary assessment of the data was obtained from time histories of the lateral coefficients and from a variation of these coefficients with either roll and yaw angles. A departure from a simple harmonic response of a linear system at a given frequency appeared with increased angles of attack, amplitudes, and initial offsets.

The harmonic analysis was applied to almost all oscillatory data available. The results contained the mean values of the Fourier coefficients and their accuracy. In addition the coefficient of determination and the fit error were also available.

5.1 Rolling Oscillations

The Fourier coefficients for a model with the first harmonic, known as the in-phase and out-of-phase components, were mostly plotted against the angle of attack with the reduced frequency as a parameter. Some of the components and their standard errors were summarized in tables. The dependency of the components on frequency occurred for angle of attack from 20° to 50°. There were only relatively minor differences between results for the amplitudes of 5° and 10°. For amplitudes of 20° to 30°, however, large differences emerged with respect to the angle of attack and frequency.

A significant decrease of coefficient of determination and increase of the fit error were visible mostly for increased values of angle of attack and initial offset in roll. Improvement was achieved by adding higher harmonics into the model.

The four unknown parameters, in an unsteady linear aerodynamic model, were estimated from the in-phase and out-of-phase components using two-step linear regression. The estimates and their confidence level were obtained for the angle of attack of 20° to 50° from data with two different amplitudes and Reynolds numbers. The estimated parameters for angle of attack less than 40° were quite consistent, with the exception of the Reynolds number effect on the lateral force. For angle of attack larger than 40°, however, there was a large scatter in the estimates, very likely due to limited information content in the data. The estimated time constant showed a strong dependence on angle of attack. The sideslip derivatives of rolling and yawing moment were in agreement with the derivatives obtained from static test. There was significant difference in the side force due to sideslip angle between oscillatory and static tests. The computed term expressing the effect of rate of change of sideslip indicated a substantial contribution of this term to the out-of-phase components at the angle of attack between 30° and 40°.

5.2 Yawing Oscillations

Estimates of the in-phase and out-of-phase components were obtained from a limited number of test data with different amplitudes, frequencies, initial offsets in yaw and Reynolds number. No significant conclusions from the results obtained could be made. One set of data was used for estimation of parameters in the aerodynamic models. This attempt failed, probably due to the low number of frequencies.

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8 Appendix A: Relationships between incidence and attitude angles

Let the angle of attack of the longitudinal body axis (x axis) be α. Then the velocity vector for ϕ=0 is

$$V_1 = V\begin{bmatrix}\cos\alpha\\0\\\sin\alpha\end{bmatrix} = V\begin{bmatrix}\cos\theta\\0\\\sin\theta\end{bmatrix} \tag{A1}$$

After rotation about the x axis through ϕ, the velocity vector V_1 is changed to V_2 by the transformation

$$\begin{aligned}V_2 &= L(\phi)V_1\\ &= \begin{bmatrix}1&0&0\\0&\cos\phi&\sin\phi\\0&-\sin\phi&\cos\phi\end{bmatrix}\begin{bmatrix}V\cos\theta\\0\\V\sin\theta\end{bmatrix} = V\begin{bmatrix}\cos\theta\\\sin\theta\sin\phi\\\sin\theta\cos\phi\end{bmatrix} = \begin{bmatrix}u\\v\\w\end{bmatrix}\end{aligned} \tag{A2}$$

From (A2) the expressions for the incidence angles can be obtained as

$$\begin{aligned}\sin\beta &= \frac{v}{V} = \sin\theta\sin\phi\\ \tan\alpha &= \frac{w}{u} = \tan\theta\cos\phi\end{aligned} \tag{A3}$$

For small ϕ

$$\begin{aligned}\beta &\approx \phi\sin\theta\\ \alpha &\approx \theta\end{aligned} \tag{A4}$$

When yawing through ψ about the z axis, the velocity vector is

$$\begin{aligned}V_2 &= L(\psi)V_1\\ &= \begin{bmatrix}\cos\psi&\sin\psi&0\\-\sin\psi&\cos\psi&0\\0&0&1\end{bmatrix}\begin{bmatrix}V\cos\theta\\0\\V\sin\theta\end{bmatrix} = V\begin{bmatrix}\cos\theta\cos\psi\\-\cos\theta\sin\psi\\\sin\theta\end{bmatrix}\end{aligned} \tag{A5}$$

Now the expressions for α and β have the form

$$\begin{aligned}\sin\beta &= -\cos\theta\sin\psi\\ \tan\alpha &= \frac{\tan\theta}{\cos\psi}\end{aligned} \tag{A6}$$

For small ψ

$$\begin{aligned}\beta &\approx -\psi\cos\theta\\ \alpha &\approx \theta\end{aligned} \tag{A7}$$

9 Appendix B: Harmonic Analysis

A periodic function $y(t) = y(t + 2\pi)$ with the period 2π is represented by a series of discrete values $y(i)$ at

$$t(i) = \frac{2\pi i}{N}, i = 1, 2, ..., N$$

It is assumed that $y(i)$ can be approximated by a trigonometric series

$$y(i) = A_0 + \sum_{j=1}^{m} A_j \cos j\omega_0 i + \sum_{j=1}^{m} B_j \sin j\omega_0 i \tag{B1}$$

where $\omega_0 = \frac{2\pi}{N}$. This series represents an orthogonal polynomial. It is further assumed that the values of $y(i)$ are obtained from measurements as

$$z(i) = y(i) + \varepsilon(i) \tag{B2}$$

where $z(i)$ are the measured values and $\varepsilon(i)$ is the measurement noise which white, zero mean with variance σ^2. The parameters A_0, A_j and B_j, known as Fourier coefficients, can be estimated from the measurement by applying the least squares (LS) criterion

$$\sum_{i=1}^{N} \left[z(i) - y(i) \right]^2 \to \min$$

then the LS estimates of parameters in (B1) are

$$\begin{aligned} \hat{A}_0 &= \frac{1}{N} \sum_{i=1}^{N} z(i) \\ \hat{A}_j &= \frac{2}{N} \sum_{i=1}^{N} z(i) \cos j\omega_0 i \\ \hat{B}_j &= \frac{2}{N} \sum_{i=1}^{N} z(i) \sin j\omega_0 i \end{aligned} \tag{B3}$$

The variance of parameter estimates is

$$\begin{aligned} s^2\left(\hat{A}_0\right) &= \sigma^2 \frac{1}{N} \\ s^2\left(\hat{A}_j\right) = s^2\left(\hat{B}_j\right) &= \sigma^2 \frac{2}{N} \end{aligned} \tag{B4}$$

for all j. The estimate of variance σ^2 is

$$s^2 = \frac{1}{N}\sum_{i=1}^{N}\left[z(i) - \hat{y}(i)\right]^2 \tag{B5}$$

where $\hat{y}(i)$ follows from (B1) by replacing the parameters by their estimates.

The adequacy of the model given by (B1) can be assessed by the coefficient of determination

$$R^2 = 1 - \frac{\sum_{i=1}^{N}\left[z(i) - \hat{y}(i)\right]^2}{\sum_{i=1}^{N}\left[z(i) - \bar{z}\right]^2} \tag{B6}$$

where

$$\hat{y}(i) = \hat{A}_0 + \sum_{j=1}^{m}\hat{A}_j \cos j\omega_0 i + \sum_{j=1}^{m}\hat{B}_j \sin j\omega_0 i$$

and mean measurement, $\bar{z}$, is estimated by

$$\bar{z} = \hat{A}_0.$$

10 Appendix C: Aerodynamic Model Using Two-Step Linear Regression

Aerodynamic model of an aircraft performing a one degree-of-freedom oscillatory motion about one of its body axes can be formulated in terns of the in-phase and out-of-phase components as for the rolling motion

$$\begin{aligned} \bar{C}_{a_\beta} &= C_{a_\beta}(\infty)\sin\alpha - af_1\sin\alpha \\ \bar{C}_{a_p} &= C_{a_p}(\infty) - af_0\sin\alpha \end{aligned} \tag{C1}$$

for the pitching motion

$$\begin{aligned} \bar{C}_{a_\alpha} &= C_{a_\alpha}(\infty) - af_1 \\ \bar{C}_{a_q} &= C_{a_q}(\infty) - af_0 \end{aligned} \tag{C2}$$

for the yawing motion

$$\begin{aligned} \bar{C}_{a_\beta} &= C_{a_\beta}(\infty)\cos\alpha - af_1\cos\alpha \\ \bar{C}_{a_r} &= C_{a_r}(\infty) + af_0\cos\alpha \end{aligned} \tag{C3}$$

where

$$f_1 = \frac{\tau^2 k^2}{1+\tau^2 k^2}$$
$$f_0 = \frac{\tau}{1+\tau^2 k^2}$$

and subscript a denotes appropriate force or moment coefficient. Expressing

$$\frac{\tau^2 k^2}{1+\tau^2 k^2} = 1 - \frac{1}{1+\tau^2 k^2}$$

equations (C1), (C2) or (C3) can be rearranged into a set of equations for n different values of k as

$$y(j) = a_0 + a_1 x(j),\ j = 1,2,...,n \tag{C4}$$

where for the rolling oscillations

$$x = \bar{C}_{a_\beta},\ y = \bar{C}_{a_p}$$
$$a_0 = C_{a_p}(\infty) + a_1\left(a + C_{a_\beta}\right)\sin\alpha$$
$$a_1 = -\tau$$

and similarly for the pitching and yawing oscillations. In the first step a linear regression is used in estimation of parameters a_0 and a_1 in (C4) from measured in-phase and out-of-phase components at n different values of k, n>2. The corresponding regression equation is

$$Y = X\Theta + \varepsilon \tag{C5}$$

where

$$Y = \begin{bmatrix} y(1) & y(2) & ... & y(n) \end{bmatrix}^T, \ \Theta = \begin{bmatrix} a_0 & a_1 \end{bmatrix}^T$$

$$X = \begin{bmatrix} 1 & x(1) \\ 1 & x(2) \\ : & : \\ 1 & x(n) \end{bmatrix}$$

and ε is a random zero mean and white measurement noise. The LS solution to (C5) is

$$\hat{\Theta} = \left(X^T X\right)^{-1} X^T Y \tag{C6}$$

with the parameter variance matrix

$$s^2(\Theta) = \sigma^2 \left(X^T X\right)^{-1} \tag{C7}$$

The estimate of σ^2 and coefficient of determination, R^2, are obtained from the residuals

$$e = Y - X\hat{\Theta} \tag{C8}$$

as

$$s^2 = \frac{e^T e}{n-2} \tag{C9}$$

$$R^2 = 1 - \frac{e^T e}{Y^T Y - n\bar{y}^2} \tag{C10}$$

$$\bar{y} = \frac{1}{n}\sum_{j=1}^{n} y(j) \tag{C11}$$

The second step of regression follows from equations (C1) to (C3) replacing τ_1 by its estimated value. The resulting regression equations are

$$\begin{aligned} y_1(j) &= b_0 + b_1 x_1(j) + \varepsilon_1(j) \\ y_2(j) &= c_0 + b_1 x_2(j) + \varepsilon(j) \end{aligned} \tag{C12}$$

or

$$Y = X\Theta + \varepsilon$$

where

$$Y = \begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix}, \ \Theta = \begin{bmatrix} b_0 & b_1 & c_0 \end{bmatrix}^T$$

$$X = \begin{bmatrix} \overline{1} & X_1 & 0 \\ 0 & X_2 & \overline{1} \end{bmatrix}$$

For the rolling oscillations the element of vectors Y_1, Y_2, X_1, X_2, and $\overline{1}$ are

$$y_1(j) = \overline{C}_{a_\beta}(j), \quad y_2(j) = \overline{C}_{a_p}(j)$$
$$x_1(j) = -f_1(j)\sin\alpha, \quad x_2(j) = -f_0(j)\sin\alpha$$

$\overline{1}$ is the n-dimensional vector of ones and

$$b_0 = C_{a_\beta}(\infty)\sin\alpha, \quad b_1 = a\sin\alpha, \quad c_0 = C_{a_p}(\infty)$$

Similar expressions are obtained for pitching and yawing oscillations. The LS parameter estimator is given by (C6) and the properties of the estimates by (C7) to (C9).

11 Tables

Table I. Test conditions for roll oscillations.

Run	Φ_A deg	Φ_o deg	qbar psf	V, ft/s	frequency, Hz	ω, rad/s	k	θ, deg
3	5	0	6.7	75	0.78	4.90	0.191	0 10 20 30 35 40 50 60 70 75
4	5	0	6.7	75	0.78	4.90	0.191	0 10 20 30 35 40 50 60 70 75
5	5	0	6.7	75	0.78	4.90	0.191	0 10 20 30 35 40 50 60 70 75
7	5	0	6.7	75	1.10	6.91	0.269	0 10 20 30 35 40 50 60 70 75
8	5	0	6.7	75	0.90	5.65	0.220	0 10 20 30 35 40 50 60 70 75
9	5	0	6.7	75	0.70	4.40	0.171	0 10 20 30 35 40 50 60 70 75
10	5	0	6.7	75	0.50	3.14	0.122	0 10 20 30 35 40 50 60 70 75
11	5	0	6.7	75	0.30	1.88	0.073	0 10 20 30 35 40 50 60 70 75
12	10	0	2	41	0.51	3.20	0.228	0 5 10 15 20 25 28 30 32 34 36 38 40 45 50 60 70 75
13	10	0	2	41	0.42	2.64	0.188	0 5 10 15 20 25 28 30 32 34 36 38 40 45 50 60 70 75
14	10	0	2	41	0.72	4.52	0.322	0 5 10 15 20 25 28 30 32 34 36 38 40 45 50 60 70 75
15	10	0	2	41	1.13	7.10	0.505	0 5 10 15 20 25 28 30 32 34 36 38 40 45 50 60 70 75
16	10	0	6.7	75	0.78	4.90	0.191	0 5 10 15 20 25 28 30 32 34 36 38 40 45 50 60 70 75
17	10	0	6.7	75	0.95	5.97	0.232	0 5 10 15 20 25 28 30 32 34 36 38 40 45 50 60 70 75
20	10	0	6.7	75	1.10	6.91	0.269	0 5 10 15 20 25 28 30 32 34 36 38 40 45 50 60 70 75
21	10	0	6.7	75	0.90	5.65	0.220	0 5 10 15 20 25 28 30 32 34 36 38 40 45 50 60 70 75
22	10	0	6.7	75	0.70	4.40	0.171	0 5 10 15 20 25 28 30 32 34 36 38 40 45 50 60 70 75
23	10	0	6.7	75	0.50	3.14	0.122	0 5 10 15 20 25 28 30 32 34 36 38 40 45 50 60 70 75
24	10	0	6.7	75	0.30	1.88	0.073	0 5 10 15 20 25 28 30 32 34 36 38 40 45 50 60 70 75
39	20	0	6.7	75	0.30	1.88	0.073	0 10 20 30 35 40 50 60 70 75
40	20	0	6.7	75	0.50	3.14	0.122	0 10 20 30 35 40 50 60 70 75
41	20	0	6.7	75	0.70	4.40	0.171	0 10 20 30 35 40 50 60 70 75
53	20	0	6.7	75	0.90	5.65	0.220	0 10 20 30 35 40 50
54	20	0	6.7	75	0.90	5.65	0.220	60 70 75
55	20	0	6.7	75	1.10	6.91	0.269	0 10 20 30 35 40 50 60 70 75
57	20	0	6.7	75	0.47	2.95	0.115	0 5 10 15 20 25 28 30 32 34 36 38 40 45 50 60 70 75
58	20	0	6.7	75	0.39	2.45	0.095	0 5 10 15 20 25 28 30 32 34 36 38 40 45 50 60 70 75

Table I. Concluded.

Run	Φ_A deg	Φ_o deg	qbar psf	V, ft/s	frequency, Hz	ω, rad/s	k	θ, deg
59	30	0	6.7	75	0.26	1.63	0.064	0 5 10 15 20 25 28 30 32 34 36 38 40 45 50 60 70 75
60	30	0	6.7	75	0.30	1.88	0.073	0 5 10 15 20 25 28 30 32 34 36 38 40 45 50 60
63	30	0	6.7	75	0.26	1.63	0.064	30 32 34 36 38 40 45
64	30	0	6.7	75	0.26	1.63	0.064	38 40
65	30	0	6.7	75	0.26	1.63	0.064	30 32 34 36 45
68	30	0	6.7	75	0.30	1.88	0.073	28 30 32 34 36 38 40 45
69	30	0	6.7	75	0.47	2.95	0.115	0 5 10 15 20 25 28 30 32 34 36 38 40 45 50 60 70 75
70	30	0	6.7	75	0.50	3.14	0.122	0 5 10 15 25 28 30 32 34 36 38 40 45 50 60 70 75
71	30	0	6.7	75	0.70	4.40	0.171	0 5 10 15 20 25 28 30 32 34 36 38 40 45 50 60 70 75
72	30	0	6.7	75	0.90	5.65	0.220	0 5 10 15 20 25 28 30 32 34 36 38 40 45 50 60 70 75
73	30	0	6.7	75	1.10	6.91	0.269	0 5 10 15 20 25 28 30 32 34 36 38 40 45 50 60 70 75
74	30	0	6.7	75	0.31	1.95	0.076	0 5 10 15 20 25 28 30 32 34 36 40 45 50 60 70 75
75	30	0	6.7	75	0.69	4.34	0.169	0 5 10 15 20 25 28 30 32 34 36 38 40 45 50 60 70 75
79	30	15	6.7	75	0.69	4.34	0.169	0 5 10 15 20 25 28 30 32 34 36 38 40 45 50 60 70 75
80	30	15	6.7	75	0.47	2.95	0.115	0 5 10 15 20 25 28 30 32 34 36 38 40 45 50 60 70 75
83	30	15	6.7	75	0.26	1.63	0.064	0 5 10 15 20 25 28 30 32 34 36 38 40 45 50 60 70
85	30	30	6.7	75	0.69	4.34	0.169	0 5 10 15 20 25 28 30 32 34 36 38 40 45 50 60 70 75
86	30	30	6.7	75	0.47	2.95	0.115	0 5 10 15 20 25 28 30 32 34 36 38 40 45 50 60 70 75
87	30	30	6.7	75	0.26	1.63	0.064	0 5 10 15 20 25 28 30 32 34 36 38 40 45 50 60 70 75
89	30	45	6.7	75	0.69	4.34	0.169	0 5 10 15 20 25 28 30 32 34 36 38 40 45 50 60 70 75
90	30	45	6.7	75	0.47	2.95	0.115	0 5 10 15 20 25 28 30 32 34 36 38 40 45 50 60 70 75
91	30	45	6.7	75	0.26	1.63	0.064	0 5 10 20 25 28 30 32 34 36 38 40 45 50 60 70 75
93	30	60	6.7	75	0.69	4.34	0.169	0 5 10 15 20 25 28 30 32 34 36 38 40 45 50 60 70
94	30	60	6.7	75	0.47	2.95	0.115	0 5 10 15 20 25 28 30 32 34 36 38 40 45 50 60 70
95	30	60	6.7	75	0.26	1.63	0.064	0 5 10 15 20 25 28 30 34 36 38 40 45 50 60 70 75

Table II. Text conditions for yawing oscillations.

Run	Ψ_A deg	Ψ_o deg	qbar psf	V, ft/s	frequency, Hz	ω, rad/s	k	θ, deg
101	5	0	6.7	75	0.78	4.90	0.191	0 10 20 30 35 40 50 60 70 80 90
102	5	0	6.7	75	0.78	4.90	0.191	0 10 20 30 35 40 50 60 80 90
103	5	0	6.7	75	1.10	6.91	0.269	0 10 20 25 30 32 34 36 38 40 45 50 60 70 80 90
104	5	0	6.7	75	0.30	1.88	0.073	0 10 20 25 30 32 34 36 38 40 45 50 60 80 90
105	30	0	6.7	75	0.69	4.34	0.169	0 10 20 25 30 32 34 36 38
106	30	0	6.7	75	0.53	3.33	0.129	40 45 50 60 70 80 90
108	30	0	4	58	0.39	2.45	0.123	0 10 20 25 30 34 36 38 40 45 50 60 70 80 90
109	30	0	4	58	0.37	2.32	0.117	0 10 20 25 30 32 34 36 38 40 45 50 60 70 80 90
110	30	0	6.7	75	0.31	1.95	0.076	0 10 20 25 30 32 34 36 38 40 45 50 60 70 80 90
111	30	0	6.7	75	0.26	1.63	0.064	0 10 20 25 30 32 34 36 38 40 45 50 60 70 80 90
112	30	15	2	41	0.53	3.33	0.237	38 40 45 50 60 70 80 90
113	30	15	2	41	0.69	4.34	0.308	0 10 20 25 30 32 34 36
114	30	15	2	41	0.37	2.32	0.165	0 10 20 25 30 32 34 36 38 40 45 50 60 70 80 90
115	30	15	6.7	75	0.24	1.51	0.059	0 10 20 30 35 40 50 60 70 80 90
119	30	30	4	58	0.53	3.33	0.167	0 10 20 30 35 40 50 60 70 80 90
121	30	45	4	58	0.53	3.33	0.167	0 10 20 30 35 40 50 60 70 80 90
122	10	0	2	41	1.13	7.10	0.505	0 10 20 25 30 32 34 36 38 40 45 50 60 70 80 90
123	10	0	2	41	0.72	4.52	0.322	0 10 20 25 30 32 34 36 38 40 45 50 60 70 80 90
124	10	0	2	41	0.51	3.20	0.228	0 10 20 25 30 32 34 36 38 40 45 50 60 70 80 90
125	10	0	2	41	0.42	2.64	0.188	0 10 20 25 30 32 34 36 38 40 45 50 60 70 80 90
126	10	0	6.7	75	0.95	5.97	0.232	0 10 20 25 30 32 34 36 38 40 45 50 60 70 80 90
127	10	0	6.7	75	0.78	4.90	0.191	0 10 20 25 30 32 34 36 38 40 45 50 60 70 80 90
128	20	0	6.7	75	0.47	2.95	0.115	0 10 20 25 30 32 34 36 38 40 45 50 60 70 80 90
129	20	0	6.7	75	0.39	2.45	0.095	0 10 20 25 30 32 34 36 38 40 45 50 60 80 90

Table III. Aerodynamic coefficients at different angles of attack and zero sideslip.

α, deg	C_N	C_A	C_L	C_D	C_m	C_Y	C_n	C_l
0.0	-0.1283	0.0230	-0.1283	0.0231	0.0135	-0.0016	-0.0010	0.0033
10.1	0.2857	0.0027	0.2808	0.0527	0.0038	-0.0005	-0.0010	0.0027
20.1	0.8125	-0.0245	0.7716	0.2558	0.0001	0.0025	-0.0016	0.0014
25.1	1.1158	-0.0393	1.0272	0.4375	0.0025	0.0042	-0.0019	0.0016
30.1	1.4328	-0.0517	1.2658	0.6731	0.0117	0.0112	0.0012	0.0000
32.0	1.5237	-0.0562	1.3224	0.7591	0.0169	0.0177	0.0035	-0.0023
34.0	1.5961	-0.0599	1.3565	0.8433	0.0239	0.0263	0.0061	-0.0056
36.1	1.6459	-0.0602	1.3658	0.9204	0.0292	0.0313	0.0064	-0.0043
38.1	1.6895	-0.0601	1.3671	0.9942	0.0306	0.0353	0.0053	-0.0002
40.0	1.7310	-0.0604	1.3651	1.0662	0.0297	0.0420	0.0035	0.0026
45.1	1.7110	-0.0521	1.2451	1.1748	-0.0028	0.0219	-0.0024	0.0049
50.1	1.5508	-0.0521	1.0244	1.1648	-0.0440	0.0203	-0.0008	0.0027
60.0	1.5292	-0.0397	0.8004	1.3037	-0.0848	0.0182	0.0039	0.0004
70.0	1.6144	-0.0416	0.6088	1.4964	-0.0933	0.0048	-0.0134	0.0016
80.0	1.5971	-0.0608	0.3312	1.5633	-0.1368	0.0179	-0.0043	0.0028
90.1	1.5983	-0.0672	0.0655	1.5983	-0.1780	0.0303	-0.0093	0.0002

Table IV. In-phase and out-of-phase components of rolling moment coefficient. $\Phi_A = 5$ deg.

Component	α, deg	k = 0.073	0.122	0.171	0.191	0.191	0.191	0.22	0.269
$\overline{C}_{l_\beta}$	0	0.0039	0.0038	0.0027	0.0014	0.0023	0.0023	0.0012	0.0012
	10	-0.0152	-0.0158	-0.0164	-0.0193	-0.0180	-0.0186	-0.0187	-0.0196
	20	-0.0605	-0.0633	-0.0678	-0.0720	-0.0708	-0.0706	-0.0713	-0.0799
	30	-0.1029	-0.1268	-0.1381	-0.1471	-0.1439	-0.1448	-0.1436	-0.1550
	35	-0.1060	-0.1587	-0.1742	-0.1684	-0.1726	-0.1775	-0.1886	-0.1868
	40	-0.0460	-0.1143	-0.1373	-0.1571	-0.1552	-0.1520	-0.1654	-0.1759
	50	-0.0531	-0.0579	-0.0549	-0.0583	-0.0588	-0.0541	-0.0539	-0.0631
	60	-0.0846	-0.0801	-0.0801	-0.0774	-0.0808	-0.0800	-0.0824	-0.0764
	70	-0.0865	-0.0852	-0.0857	-0.0895	-0.0861	-0.0825	-0.0829	-0.0845
	75	-0.0929	-0.0902	-0.0902	-0.0840	-0.0889	-0.0902	-0.0847	-0.0881
$s\left(\overline{C}_{l_\beta}\right)$	0	3.46E-05	4.78E-05	7.15E-05	1.02E-04	5.14E-05	5.52E-05	9.03E-05	1.55E-04
	10	6.47E-05	9.37E-05	1.21E-04	1.11E-04	9.72E-05	1.09E-04	1.59E-04	2.08E-04
	20	5.65E-04	7.02E-04	8.25E-04	9.37E-04	8.92E-04	9.25E-04	1.09E-03	1.13E-03
	30	1.35E-03	1.75E-03	1.85E-03	2.35E-03	2.07E-03	2.10E-03	2.38E-03	2.29E-03
	35	2.66E-03	3.40E-03	4.16E-03	5.40E-03	4.05E-03	4.28E-03	4.48E-03	4.76E-03
	40	4.87E-03	6.00E-03	7.73E-03	6.57E-03	8.50E-03	7.54E-03	8.90E-03	8.52E-03
	50	2.01E-03	2.58E-03	2.82E-03	2.79E-03	3.18E-03	2.79E-03	3.09E-03	3.28E-03
	60	1.40E-03	1.75E-03	1.95E-03	2.28E-03	2.10E-03	2.08E-03	2.31E-03	2.87E-03
	70	2.18E-03	2.85E-03	2.96E-03	3.19E-03	3.39E-03	3.23E-03	3.26E-03	4.64E-03
	75	2.29E-03	3.04E-03	3.39E-03	3.55E-03	3.64E-03	3.65E-03	4.50E-03	4.82E-03

Component	α, deg	k = 0.073	0.122	0.171	0.191	0.191	0.191	0.22	0.269
$\overline{C}_{l_p}$	0	-0.1983	-0.1962	-0.1964	-0.1942	-0.1915	-0.1942	-0.1939	-0.1884
	10	-0.2180	-0.2157	-0.2139	-0.2125	-0.2125	-0.2110	-0.2140	-0.2153
	20	-0.2874	-0.2719	-0.2305	-0.2328	-0.2171	-0.2290	-0.2191	-0.1878
	30	-0.7288	-0.5017	-0.3750	-0.3470	-0.3387	-0.3522	-0.3360	-0.2701
	35	-1.6359	-0.9758	-0.5616	-0.4765	-0.5207	-0.4460	-0.4079	-0.3270
	40	-1.7924	-1.2135	-0.7659	-0.6199	-0.7163	-0.7304	-0.5493	-0.5289
	50	-0.1472	-0.1881	-0.1898	-0.1583	-0.1945	-0.1915	-0.2011	-0.2011
	60	-0.1367	-0.1060	-0.1459	-0.1289	-0.1186	-0.1272	-0.1103	-0.1432
	70	-0.1866	-0.1499	-0.1557	-0.1397	-0.1581	-0.1612	-0.1493	-0.1492
	75	-0.1256	-0.1390	-0.1803	-0.1485	-0.1742	-0.1455	-0.1607	-0.1693
$s\left(\overline{C}_{l_p}\right)$	0	4.74E-04	3.92E-04	4.18E-04	5.36E-04	2.69E-04	2.89E-04	4.10E-04	5.78E-04
	10	8.86E-04	7.68E-04	7.10E-04	5.84E-04	5.09E-04	5.69E-04	7.23E-04	7.73E-04
	20	7.74E-03	5.75E-03	4.82E-03	4.91E-03	4.67E-03	4.84E-03	4.95E-03	4.20E-03
	30	1.84E-02	1.43E-02	1.08E-02	1.23E-02	1.08E-02	1.10E-02	1.08E-02	8.51E-03
	35	3.64E-02	2.79E-02	2.43E-02	2.83E-02	2.12E-02	2.24E-02	2.04E-02	1.77E-02
	40	6.68E-02	4.92E-02	4.52E-02	3.44E-02	4.45E-02	3.95E-02	4.04E-02	3.17E-02
	50	2.75E-02	2.11E-02	1.65E-02	1.46E-02	1.66E-02	1.46E-02	1.40E-02	1.22E-02
	60	1.92E-02	1.43E-02	1.14E-02	1.20E-02	1.10E-02	1.09E-02	1.05E-02	1.07E-02
	70	2.99E-02	2.34E-02	1.73E-02	1.67E-02	1.78E-02	1.69E-02	1.48E-02	1.72E-02
	75	3.14E-02	2.49E-02	1.99E-02	1.86E-02	1.91E-02	1.91E-02	2.05E-02	1.79E-02

Table V. In-phase and out-of-phase components of rolling moment coefficient. Φ_A = 10 deg.

		k =						
Component	α, deg	0.073	0.122	0.171	0.191	0.22	0.232	0.269
$\overline{C}_{l_\beta}$	0	0.0035	0.0035	0.0020	0.0008	0.0007	-0.0001	-0.0016
	5	-0.0029	-0.0029	-0.0040	-0.0061	-0.0051	-0.0065	-0.0068
	10	-0.0156	-0.0155	-0.0169	-0.0199	-0.0177	-0.0199	-0.0212
	15	-0.0379	-0.0393	-0.0419	-0.0438	-0.0421	-0.0451	-0.0457
	20	-0.0614	-0.0649	-0.0700	-0.0738	-0.0716	-0.0753	-0.0758
	25	-0.0932	-0.0969	-0.1000	-0.1019	-0.1026	-0.1054	-0.1079
	28	-0.1087	-0.1178	-0.1278	-0.1338	-0.1321	-0.1363	-0.1367
	30	-0.1162	-0.1356	-0.1494	-0.1564	-0.1539	-0.1583	-0.1630
	32	-0.1185	-0.1504	-0.1678	-0.1788	-0.1731	-0.1767	-0.1815
	34	-0.1081	-0.1546	-0.1754	-0.1858	-0.1848	-0.1871	-0.1916
	36	-0.0885	-0.1501	-0.1719	-0.1859	-0.1848	-0.1895	-0.1973
	38	-0.0675	-0.1258	-0.1600	-0.1645	-0.1685	-0.1735	-0.1860
	40	-0.0331	-0.0814	-0.1095	-0.1431	-0.1272	-0.1494	-0.1734
	45	0.0044	-0.0067	-0.0375	-0.0641	-0.0532	-0.0624	-0.0999
	50	-0.0578	-0.0608	-0.0618	-0.0632	-0.0611	-0.0610	-0.0695
	60	-0.0809	-0.0787	-0.0786	-0.0797	-0.0802	-0.0789	-0.0786
	70	-0.0897	-0.0871	-0.0861	-0.0862	-0.0854	-0.0860	-0.0844
	75	-0.0921	-0.0882	-0.0881	-0.0902	-0.0915	-0.0818	-0.0832
$s(\overline{C}_{l_\beta})$	0	2.26E-05	3.67E-05	7.87E-05	9.68E-05	7.12E-05	1.50E-04	1.82E-04
	5	2.21E-05	3.69E-05	6.32E-05	1.04E-04	7.90E-05	1.47E-04	1.82E-04
	10	4.38E-05	7.14E-05	1.08E-04	1.71E-04	1.33E-04	2.17E-04	2.28E-04
	15	1.37E-04	1.80E-04	2.20E-04	2.69E-04	2.66E-04	3.15E-04	3.41E-04
	20	3.08E-04	3.91E-04	4.60E-04	4.51E-04	4.69E-04	5.82E-04	5.64E-04
	25	4.96E-04	5.04E-04	5.76E-04	7.10E-04	5.54E-04	7.29E-04	6.93E-04
	28	7.00E-04	8.67E-04	8.56E-04	1.08E-03	9.58E-04	1.05E-03	1.05E-03
	30	8.15E-04	1.01E-03	1.28E-03	1.37E-03	1.19E-03	1.35E-03	1.41E-03
	32	1.06E-03	1.39E-03	1.46E-03	1.72E-03	1.66E-03	1.89E-03	2.02E-03
	34	1.33E-03	1.59E-03	1.95E-03	2.57E-03	2.05E-03	2.25E-03	2.34E-03
	36	1.36E-03	2.30E-03	2.83E-03	3.07E-03	2.86E-03	3.20E-03	3.33E-03
	38	2.07E-03	2.93E-03	3.59E-03	3.99E-03	3.77E-03	4.03E-03	4.26E-03
	40	2.56E-03	3.58E-03	4.37E-03	4.59E-03	4.62E-03	5.24E-03	6.15E-03
	45	2.68E-03	3.12E-03	3.89E-03	4.31E-03	3.50E-03	4.10E-03	3.97E-03
	50	1.12E-03	1.45E-03	1.53E-03	1.87E-03	1.79E-03	2.16E-03	1.95E-03
	60	7.32E-04	9.36E-04	1.00E-03	1.29E-03	1.17E-03	1.26E-03	1.38E-03
	70	1.06E-03	1.41E-03	1.51E-03	1.95E-03	1.69E-03	1.67E-03	1.88E-03
	75	1.27E-03	1.35E-03	1.69E-03	2.04E-03	1.90E-03	2.10E-03	2.21E-03

Table V. Concluded.

Component	α, deg	k = 0.073	0.122	0.171	0.191	0.22	0.232	0.269
$\overline{C}_{l_p}$	0	-0.1928	-0.1907	-0.1870	-0.2123	-0.1620	-0.1834	-0.1826
	5	-0.1589	-0.1556	-0.1525	-0.1739	-0.1317	-0.1494	-0.1490
	10	-0.2094	-0.2080	-0.2065	-0.2331	-0.1793	-0.2024	-0.2009
	15	-0.2066	-0.2058	-0.2031	-0.2307	-0.1770	-0.1987	-0.1951
	20	-0.2627	-0.2371	-0.2169	-0.2265	-0.1734	-0.1879	-0.1903
	25	-0.2445	-0.2119	-0.2122	-0.2280	-0.1678	-0.1932	-0.1868
	28	-0.4126	-0.3209	-0.2621	-0.2617	-0.1906	-0.2029	-0.1873
	30	-0.6983	-0.4695	-0.3230	-0.3083	-0.2565	-0.2543	-0.2148
	32	-1.0376	-0.6488	-0.4382	-0.3732	-0.3025	-0.2966	-0.2312
	34	-1.3769	-0.7755	-0.5023	-0.4171	-0.3664	-0.3494	-0.3097
	36	-1.7324	-0.9707	-0.5910	-0.5123	-0.4456	-0.3882	-0.3158
	38	-1.7193	-1.0063	-0.6851	-0.5789	-0.5118	-0.4807	-0.3980
	40	-1.6165	-1.1184	-0.7941	-0.7555	-0.6471	-0.6060	-0.5321
	45	-0.7917	-0.7710	-0.6662	-0.7225	-0.5904	-0.6233	-0.5695
	50	-0.2051	-0.2206	-0.2041	-0.2391	-0.1819	-0.2173	-0.1837
	60	-0.1148	-0.1421	-0.1314	-0.1595	-0.1170	-0.1385	-0.1285
	70	-0.1208	-0.1414	-0.1501	-0.1682	-0.1268	-0.1438	-0.1448
	75	-0.1130	-0.1442	-0.1418	-0.1476	-0.1193	-0.1422	-0.1535
$s\left(\overline{C}_{l_p}\right)$	0	3.09E-04	3.01E-04	4.61E-04	5.07E-04	3.24E-04	6.45E-04	6.75E-04
	5	3.03E-04	3.03E-04	3.70E-04	5.45E-04	3.59E-04	6.32E-04	6.77E-04
	10	5.99E-04	5.85E-04	6.30E-04	8.98E-04	6.03E-04	9.34E-04	8.49E-04
	15	1.88E-03	1.48E-03	1.29E-03	1.41E-03	1.21E-03	1.36E-03	1.27E-03
	20	4.22E-03	3.20E-03	2.69E-03	2.36E-03	2.13E-03	2.51E-03	2.10E-03
	25	6.79E-03	4.13E-03	3.37E-03	3.72E-03	2.52E-03	3.14E-03	2.58E-03
	28	9.59E-03	7.11E-03	5.00E-03	5.65E-03	4.36E-03	4.53E-03	3.92E-03
	30	1.12E-02	8.30E-03	7.50E-03	7.19E-03	5.42E-03	5.80E-03	5.24E-03
	32	1.45E-02	1.14E-02	8.54E-03	9.00E-03	7.54E-03	8.13E-03	7.51E-03
	34	1.82E-02	1.30E-02	1.14E-02	1.35E-02	9.31E-03	9.72E-03	8.70E-03
	36	1.86E-02	1.89E-02	1.65E-02	1.61E-02	1.30E-02	1.38E-02	1.24E-02
	38	2.83E-02	2.40E-02	2.10E-02	2.09E-02	1.71E-02	1.74E-02	1.58E-02
	40	3.51E-02	2.93E-02	2.56E-02	2.40E-02	2.10E-02	2.26E-02	2.29E-02
	45	3.67E-02	2.56E-02	2.27E-02	2.25E-02	1.59E-02	1.77E-02	1.48E-02
	50	1.53E-02	1.18E-02	8.93E-03	9.77E-03	8.12E-03	9.31E-03	7.24E-03
	60	1.00E-02	7.67E-03	5.87E-03	6.73E-03	5.33E-03	5.42E-03	5.12E-03
	70	1.45E-02	1.16E-02	8.81E-03	1.02E-02	7.68E-03	7.21E-03	7.01E-03
	75	1.73E-02	1.11E-02	9.87E-03	1.07E-02	8.66E-03	9.07E-03	8.20E-03

Table VI. In-phase and out-of-phase components of rolling moment coefficient. Φ_A = 20 deg.

		k =							
Component	α, deg	0.073	0.095	0.115	0.122	0.171	0.22	0.22	0.269
$\overline{C}_{l_\beta}$	0	0.0030	0.0030	0.0025	0.0021	0.0004	-0.0024		-0.0027
	5		-0.0037	-0.0043					
	10	-0.0153	-0.0177	-0.0182	-0.0166	-0.0182	-0.0220		-0.0227
	15		-0.0411	-0.0412					
	20	-0.0593	-0.0671	-0.0694	-0.0633	-0.0684	-0.0814		-0.0842
	25		-0.1004	-0.1046					
	28		-0.1172	-0.1237					
	30	-0.1077	-0.1297	-0.1394	-0.1290	-0.1416	-0.1669		-0.1681
	32		-0.1370	-0.1514					
	34		-0.1335	-0.1513					
	35	-0.0778			-0.1458	-0.1711	-0.2010		-0.2127
	36		-0.1012	-0.1329					
	38		-0.0501	-0.0702					
	40	-0.0102	-0.0296	-0.0418	-0.0431	-0.0884	-0.1357		-0.1713
	45		-0.0614	-0.0635					
	50	-0.0546	-0.0601	-0.0627	-0.0580	-0.0617	-0.0728		-0.0762
	60	-0.0787	-0.0857	-0.0863	-0.0781	-0.0781		-0.0862	-0.0852
	70	-0.0888	-0.0978	-0.0970	-0.0881	-0.0884		-0.0980	-0.0957
	75	-0.0926	-0.0999	-0.1002	-0.0918	-0.0917		-0.1007	-0.0971
$s\left(\overline{C}_{l_\beta}\right)$	0	3.21E-05	4.68E-05	5.50E-05	5.38E-05	8.02E-05	1.92E-04		4.58E-04
	5		4.25E-05	5.44E-05					
	10	3.43E-05	5.79E-05	6.90E-05	7.10E-05	1.36E-04	2.68E-04		5.04E-04
	15		1.30E-04	1.52E-04					
	20	1.78E-04	2.39E-04	2.80E-04	2.44E-04	3.10E-04	4.34E-04		6.03E-04
	25		3.78E-04	3.62E-04					
	28		5.00E-04	5.30E-04					
	30	4.93E-04	5.53E-04	5.92E-04	5.67E-04	7.52E-04	1.03E-03		1.31E-03
	32		6.14E-04	7.05E-04					
	34		8.07E-04	8.65E-04					
	35	9.80E-04			9.25E-04	1.19E-03	1.56E-03		2.10E-03
	36		1.41E-03	1.28E-03					
	38		1.73E-03	1.90E-03					
	40	1.50E-03	1.85E-03	1.97E-03	2.00E-03	2.38E-03	2.75E-03		3.00E-03
	45		1.84E-03	1.89E-03					
	50	5.51E-04	7.68E-04	9.04E-04	8.28E-04	1.21E-03	1.53E-03		1.76E-03
	60	3.61E-04	4.45E-04	4.95E-04	4.73E-04	6.28E-04		8.13E-04	9.07E-04
	70	5.10E-04	6.48E-04	6.45E-04	6.84E-04	8.50E-04		1.04E-03	1.06E-03
	75	5.84E-04	7.21E-04	8.07E-04	7.40E-04	8.95E-04		1.19E-03	1.38E-03

Table VI. Concluded.

		k =							
Component	α, deg	0.073	0.095	0.115	0.122	0.171	0.22	0.22	0.269
$\overline{C}_{l_p}$	0	-0.1905	-0.2055	-0.2025	-0.1838	-0.1806	-0.1946		-0.1885
	5		-0.1692	-0.1662					
	10	-0.2061	-0.2250	-0.2199	-0.2009	-0.1945	-0.2087		-0.2041
	15		-0.2303	-0.2225					
	20	-0.2501	-0.2676	-0.2555	-0.2318	-0.2091	-0.2090		-0.1934
	25		-0.3138	-0.2676					
	28		-0.4157	-0.3540					
	30	-0.6553	-0.5880	-0.4641	-0.4077	-0.2877	-0.2676		-0.2412
	32		-0.8490	-0.6887					
	34		-1.1599	-0.8955					
	35	-1.7265			-0.8667	-0.5668	-0.4295		-0.3416
	36		-1.5761	-1.2039					
	38		-1.6213	-1.3744					
	40	-1.2024	-1.2622	-1.1522	-1.0341	-0.8597	-0.7433		-0.6250
	45		-0.4955	-0.4601					
	50	-0.2084	-0.2382	-0.2262	-0.2255	-0.2083	-0.2230		-0.2250
	60	-0.1301	-0.1296	-0.1357	-0.1280	-0.1239		-0.1406	-0.1497
	70	-0.0893	-0.1284	-0.1138	-0.1134	-0.1230		-0.1403	-0.1308
	75	-0.0872	-0.1148	-0.1161	-0.1006	-0.1217		-0.1255	-0.1379
$s(\overline{C}_{l_p})$	0	4.39E-04	4.93E-04	4.78E-04	4.41E-04	4.69E-04	8.71E-04		1.70E-03
	5		4.47E-04	4.73E-04					
	10	4.70E-04	6.09E-04	6.00E-04	5.82E-04	7.94E-04	1.22E-03		1.87E-03
	15		1.36E-03	1.32E-03					
	20	2.44E-03	2.51E-03	2.43E-03	2.00E-03	1.81E-03	1.97E-03		2.24E-03
	25		3.98E-03	3.15E-03					
	28		5.27E-03	4.61E-03					
	30	6.75E-03	5.82E-03	5.15E-03	4.65E-03	4.40E-03	4.69E-03		4.89E-03
	32		6.46E-03	6.13E-03					
	34		8.50E-03	7.52E-03					
	35	1.34E-02			7.58E-03	6.97E-03	7.11E-03		7.79E-03
	36		1.48E-02	1.11E-02					
	38		1.82E-02	1.65E-02					
	40	2.05E-02	1.94E-02	1.71E-02	1.64E-02	1.39E-02	1.25E-02		1.11E-02
	45		1.94E-02	1.64E-02					
	50	7.54E-03	8.08E-03	7.86E-03	6.78E-03	7.08E-03	6.95E-03		6.54E-03
	60	4.95E-03	4.68E-03	4.30E-03	3.88E-03	3.67E-03		3.70E-03	3.37E-03
	70	6.99E-03	6.82E-03	5.61E-03	5.60E-03	4.97E-03		4.73E-03	3.94E-03
	75	8.00E-03	7.59E-03	7.02E-03	6.06E-03	5.23E-03		5.43E-03	5.14E-03

Table VII. In-phase and out-of-phase components of rolling moment coefficient. $\Phi_A = 30$ deg.

		k =								
Component	α, deg	0.064	0.073	0.076	0.115	0.122	0.169	0.171	0.22	0.269
$\overline{C}_{l_\beta}$	0	0.0030	0.0024	0.0025	0.0015	0.0019	0.0009	0.0004	-0.0015	-0.0052
	5	-0.0035	-0.0038	-0.0038	-0.0044	-0.0042	-0.0058	-0.0053	-0.0065	-0.0090
	10	-0.0163	-0.0169	-0.0168	-0.0179	-0.0178	-0.0189	-0.0198	-0.0220	-0.0245
	15	-0.0371	-0.0377	-0.0372	-0.0394	-0.0392	-0.0399	-0.0407	-0.0436	-0.0469
	20	-0.0589	-0.0594	-0.0601	-0.0640		-0.0686	-0.0693	-0.0749	-0.0769
	25	-0.0808	-0.0831	-0.0839	-0.0927	-0.0953	-0.1014	-0.1017	-0.1079	-0.1122
	28	-0.0913	-0.0962	-0.0981	-0.1107	-0.1137	-0.1241	-0.1246	-0.1327	-0.1379
	30	-0.0956	-0.1028	-0.1048	-0.1246	-0.1282	-0.1424	-0.1435	-0.1511	-0.1577
	32	-0.0835	-0.0927	-0.0999	-0.1340	-0.1386	-0.1585	-0.1573	-0.1709	-0.1777
	34	-0.0580	-0.0730	-0.0785	-0.1306	-0.1365	-0.1677	-0.1663	-0.1819	-0.1937
	36	-0.0412	-0.0527	-0.0531	-0.1017	-0.1125	-0.1523	-0.1577	-0.1830	-0.1977
	38	-0.0386	-0.0455		-0.0740	-0.0808	-0.1207	-0.1249	-0.1607	-0.1885
	40	-0.0496	-0.0517	-0.0546	-0.0745	-0.0772	-0.1039	-0.1041	-0.1352	-0.1633
	45	-0.0726	-0.0730	-0.0743	-0.0788	-0.0815	-0.0864	-0.0892	-0.0956	-0.1136
	50	-0.0645	-0.0642	-0.0647	-0.0694	-0.0696	-0.0754	-0.0755	-0.0808	-0.0850
	60	-0.0830	-0.0831	-0.0833	-0.0830	-0.0831	-0.0831	-0.0837	-0.0849	-0.0871
	70	-0.0974		-0.0969	-0.0961	-0.0973	-0.0979	-0.0971	-0.0953	-0.0993
	75	-0.1016		-0.1001	-0.0997	-0.1006	-0.1003	-0.0996	-0.0997	-0.1010
$s(\overline{C}_{l_\beta})$	0	4.01E-05	5.14E-05	5.27E-05	8.36E-05	8.49E-05	1.06E-04	1.10E-04	2.40E-04	4.67E-04
	5	3.08E-05	4.17E-05	4.19E-05	7.75E-05	8.01E-05	1.19E-04	1.14E-04	2.29E-04	4.01E-04
	10	4.24E-05	5.06E-05	5.52E-05	1.06E-04	1.14E-04	2.02E-04	2.15E-04	4.00E-04	5.97E-04
	15	9.31E-05	1.07E-04	1.16E-04	1.97E-04	2.24E-04	3.54E-04	3.73E-04	6.25E-04	8.42E-04
	20	1.93E-04	2.21E-04	2.27E-04	3.34E-04		5.25E-04	5.23E-04	7.93E-04	9.93E-04
	25	3.72E-04	3.89E-04	3.88E-04	3.80E-04	3.90E-04	3.79E-04	4.62E-04	7.43E-04	1.18E-03
	28	4.03E-04	4.03E-04	4.11E-04	4.21E-04	4.32E-04	5.58E-04	5.09E-04	8.89E-04	1.26E-03
	30	4.05E-04	3.74E-04	4.30E-04	4.24E-04	4.67E-04	7.08E-04	7.25E-04	1.17E-03	1.50E-03
	32	6.74E-04	6.29E-04	5.97E-04	5.42E-04	5.99E-04	8.80E-04	9.32E-04	1.46E-03	1.95E-03
	34	6.83E-04	7.72E-04	7.70E-04	8.34E-04	8.51E-04	1.11E-03	9.62E-04	1.79E-03	2.35E-03
	36	9.02E-04	9.78E-04	1.03E-03	1.16E-03	1.22E-03	1.39E-03	1.26E-03	1.80E-03	2.57E-03
	38	1.24E-03	1.30E-03		1.69E-03	1.74E-03	2.04E-03	2.18E-03	2.39E-03	2.65E-03
	40	1.51E-03	1.60E-03	1.62E-03	1.89E-03	2.01E-03	2.50E-03	2.34E-03	2.90E-03	3.15E-03
	45	1.01E-03	1.08E-03	1.10E-03	1.26E-03	1.34E-03	1.43E-03	1.49E-03	1.79E-03	2.16E-03
	50	5.01E-04	5.65E-04	5.64E-04	8.52E-04	8.82E-04	1.24E-03	1.25E-03	1.34E-03	1.37E-03
	60	2.52E-04	2.85E-04	2.86E-04	3.87E-04	4.21E-04	5.56E-04	5.81E-04	8.65E-04	9.29E-04
	70	3.43E-04		4.02E-04	5.31E-04	5.63E-04	6.77E-04	6.35E-04	8.66E-04	8.73E-04
	75	3.95E-04		4.67E-04	6.13E-04	6.14E-04	8.02E-04	7.19E-04	9.57E-04	9.87E-04

Table VII. Concluded.

		k =								
Component	α, deg	0.064	0.073	0.076	0.115	0.122	0.169	0.171	0.22	0.269
$\overline{C}_{l_p}$	0	-0.2047	-0.2054	-0.2042	-0.1983	-0.2026	-0.1929	-0.1938	-0.1877	-0.1812
	5	-0.1665	-0.1663	-0.1655	-0.1611	-0.1634	-0.1577	-0.1580	-0.1575	-0.1545
	10	-0.2166	-0.2185	-0.2160	-0.2105	-0.2146	-0.2045	-0.2060	-0.1962	-0.1887
	15	-0.2121	-0.2177	-0.2147	-0.2098	-0.2133	-0.2104	-0.2105	-0.2002	-0.1935
	20	-0.2518	-0.2624	-0.2613	-0.2484		-0.2232	-0.2298	-0.1999	-0.1938
	25	-0.3937	-0.3842	-0.3802	-0.3134	-0.2982	-0.2489	-0.2585	-0.2192	-0.2064
	28	-0.6004	-0.5577	-0.5382	-0.3960	-0.3854	-0.2976	-0.2894	-0.2329	-0.2116
	30	-0.8598	-0.7798	-0.7644	-0.5155	-0.4729	-0.3386	-0.3393	-0.2780	-0.2271
	32	-1.3677	-1.1934	-1.1661	-0.6710	-0.6377	-0.4233	-0.4263	-0.3040	-0.2491
	34	-1.6621	-1.4956	-1.5113	-0.9587	-0.8845	-0.5295	-0.5489	-0.3909	-0.2778
	36	-1.5149	-1.4497	-1.4193	-1.1402	-1.0764	-0.7522	-0.7294	-0.4905	-0.3669
	38	-1.2051	-1.1756		-1.0076	-0.9692	-0.7939	-0.7786	-0.5967	-0.4496
	40	-0.9205	-0.9068	-0.8680	-0.7759	-0.7775	-0.6873	-0.6501	-0.5450	-0.4469
	45	-0.3870	-0.3936	-0.3690	-0.3571	-0.3446	-0.3051	-0.3096	-0.2959	-0.2702
	50	-0.2056	-0.2269	-0.2221	-0.2345	-0.2388	-0.2116	-0.2127	-0.1928	-0.1793
	60	-0.1040	-0.1157	-0.1140	-0.1250	-0.1287	-0.1300	-0.1317	-0.1308	-0.1309
	70	-0.0799		-0.0841	-0.0968	-0.1188	-0.1106	-0.1025	-0.1205	-0.1010
	75	-0.0620		-0.0751	-0.0916	-0.1061	-0.1051	-0.1047	-0.1092	-0.1055
$s\left(\overline{C}_{l_p}\right)$	0	6.27E-04	7.05E-04	6.93E-04	7.27E-04	6.96E-04	6.25E-04	6.45E-04	1.09E-03	1.74E-03
	5	4.81E-04	5.71E-04	5.52E-04	6.74E-04	6.56E-04	7.07E-04	6.68E-04	1.04E-03	1.49E-03
	10	6.63E-04	6.93E-04	7.26E-04	9.20E-04	9.31E-04	1.19E-03	1.26E-03	1.82E-03	2.22E-03
	15	1.45E-03	1.47E-03	1.53E-03	1.72E-03	1.83E-03	2.10E-03	2.18E-03	2.84E-03	3.13E-03
	20	3.01E-03	3.03E-03	2.99E-03	2.90E-03		3.11E-03	3.06E-03	3.61E-03	3.69E-03
	25	5.82E-03	5.33E-03	5.11E-03	3.30E-03	3.20E-03	2.24E-03	2.70E-03	3.38E-03	4.40E-03
	28	6.29E-03	5.52E-03	5.40E-03	3.66E-03	3.54E-03	3.30E-03	2.98E-03	4.04E-03	4.70E-03
	30	6.32E-03	5.12E-03	5.65E-03	3.69E-03	3.82E-03	4.19E-03	4.24E-03	5.33E-03	5.56E-03
	32	1.05E-02	8.62E-03	7.86E-03	4.71E-03	4.91E-03	5.21E-03	5.45E-03	6.63E-03	7.26E-03
	34	1.07E-02	1.06E-02	1.01E-02	7.25E-03	6.97E-03	6.54E-03	5.63E-03	8.14E-03	8.72E-03
	36	1.41E-02	1.34E-02	1.35E-02	1.01E-02	9.98E-03	8.20E-03	7.39E-03	8.19E-03	9.55E-03
	38	1.93E-02	1.78E-02		1.47E-02	1.43E-02	1.21E-02	1.27E-02	1.09E-02	9.86E-03
	40	2.36E-02	2.19E-02	2.13E-02	1.64E-02	1.65E-02	1.48E-02	1.37E-02	1.32E-02	1.17E-02
	45	1.58E-02	1.48E-02	1.44E-02	1.10E-02	1.10E-02	8.44E-03	8.71E-03	8.12E-03	8.04E-03
	50	7.82E-03	7.74E-03	7.43E-03	7.41E-03	7.23E-03	7.35E-03	7.31E-03	6.11E-03	5.11E-03
	60	3.94E-03	3.90E-03	3.76E-03	3.37E-03	3.45E-03	3.29E-03	3.40E-03	3.93E-03	3.45E-03
	70	5.35E-03		5.29E-03	4.62E-03	4.61E-03	4.01E-03	3.72E-03	3.93E-03	3.25E-03
	75	6.18E-03		6.14E-03	5.33E-03	5.04E-03	4.74E-03	4.21E-03	4.35E-03	3.67E-03

Table VIII. In-phase and out-of-phase components of yawing moment coefficient. $\Phi_A = 5$ deg.

		k =							
Component	α, deg	0.073	0.122	0.171	0.191	0.191	0.191	0.22	0.269
$\overline{C}_{n_\beta}$	0	0.0027	0.0023	0.0021	0.0023	0.0023	0.0022	0.0021	0.0021
	10	0.0116	0.0115	0.0113	0.0119	0.0118	0.0122	0.0118	0.0120
	20	0.0206	0.0202	0.0208	0.0201	0.0199	0.0205	0.0204	0.0203
	30	-0.0094	-0.0015	0.0030	0.0066	0.0063	0.0114	0.0045	0.0070
	35	-0.0225	0.0004	-0.0010	0.0097	-0.0002	-0.0042	0.0062	-0.0022
	40	-0.0845	-0.0372	-0.0308	-0.0120	-0.0151	-0.0334	-0.0167	-0.0131
	50	-0.0815	-0.0738	-0.0985	-0.0944	-0.1398	-0.1051	-0.0513	0.0081
	60	0.0257	0.0066	0.0111	0.0140	0.0105	0.0089	-0.0040	-0.0019
	70	-0.0149	-0.0195	-0.0183	-0.0027	-0.0208	-0.0283	-0.0138	-0.0377
	75	-0.0480	-0.0440	-0.0425	-0.0602	-0.0538	-0.0627	-0.0519	-0.0573
$s\left(\overline{C}_{n_\beta}\right)$	0	4.11E-05	4.50E-05	5.61E-05	5.39E-05	5.18E-05	6.19E-05	6.84E-05	7.35E-05
	10	4.89E-05	6.59E-05	7.95E-05	6.57E-05	7.54E-05	8.27E-05	8.78E-05	1.01E-04
	20	2.82E-04	3.85E-04	3.99E-04	4.08E-04	4.31E-04	4.59E-04	4.95E-04	5.84E-04
	30	1.05E-03	1.37E-03	1.58E-03	1.72E-03	1.70E-03	1.93E-03	1.80E-03	2.01E-03
	35	2.05E-03	2.75E-03	3.04E-03	3.10E-03	3.07E-03	3.82E-03	3.63E-03	3.92E-03
	40	5.01E-03	6.26E-03	8.12E-03	8.07E-03	8.35E-03	7.27E-03	9.25E-03	1.09E-02
	50	6.05E-03	8.11E-03	8.30E-03	1.01E-02	9.35E-03	1.03E-02	1.00E-02	1.07E-02
	60	4.27E-03	6.19E-03	7.64E-03	8.09E-03	8.06E-03	1.01E-02	1.01E-02	1.24E-02
	70	1.13E-02	1.49E-02	1.71E-02	1.75E-02	1.71E-02	2.15E-02	2.05E-02	2.26E-02
	75	5.83E-03	7.50E-03	9.55E-03	7.63E-03	8.32E-03	7.47E-03	1.04E-02	1.17E-02

		k =							
Component	α, deg	0.073	0.122	0.171	0.191	0.191	0.191	0.22	0.269
$\overline{C}_{n_p}$	0	-0.0023	-0.0019	-0.0025	-0.0023	-0.0022	-0.0034	-0.0025	-0.0020
	10	-0.0290	-0.0283	-0.0280	-0.0297	-0.0286	-0.0295	-0.0283	-0.0287
	20	-0.0562	-0.0506	-0.0502	-0.0539	-0.0551	-0.0501	-0.0522	-0.0544
	30	0.1029	0.0033	-0.0336	-0.0477	-0.0489	-0.0528	-0.0416	-0.0686
	35	0.4381	0.1622	0.0087	-0.0829	-0.0143	-0.0355	-0.0663	-0.0840
	40	1.0268	0.5156	0.2344	0.2192	0.1890	0.1436	0.0830	0.0889
	50	0.3165	0.1476	0.1642	0.2049	0.1723	0.1964	0.2693	0.1736
	60	-0.1345	-0.1185	-0.0693	-0.0593	-0.0016	0.0591	-0.0559	0.0224
	70	0.0691	0.0044	0.1029	0.1000	0.1322	0.0698	0.1206	0.0543
	75	-0.0449	-0.0456	-0.0572	-0.0199	-0.0800	-0.0412	0.0179	-0.0504
$s\left(\overline{C}_{n_p}\right)$	0	5.63E-04	3.69E-04	3.28E-04	2.82E-04	2.71E-04	3.24E-04	3.11E-04	2.73E-04
	10	6.70E-04	5.40E-04	4.65E-04	3.44E-04	3.95E-04	4.33E-04	3.99E-04	3.74E-04
	20	3.87E-03	3.16E-03	2.33E-03	2.14E-03	2.26E-03	2.41E-03	2.25E-03	2.17E-03
	30	1.44E-02	1.12E-02	9.22E-03	9.02E-03	8.88E-03	1.01E-02	8.18E-03	7.48E-03
	35	2.81E-02	2.25E-02	1.78E-02	1.62E-02	1.61E-02	2.00E-02	1.65E-02	1.46E-02
	40	6.87E-02	5.13E-02	4.75E-02	4.23E-02	4.37E-02	3.81E-02	4.20E-02	4.07E-02
	50	8.29E-02	6.65E-02	4.85E-02	5.28E-02	4.89E-02	5.38E-02	4.57E-02	3.96E-02
	60	5.85E-02	5.07E-02	4.47E-02	4.24E-02	4.22E-02	5.30E-02	4.58E-02	4.62E-02
	70	1.54E-01	1.22E-01	9.98E-02	9.16E-02	8.94E-02	1.12E-01	9.30E-02	8.40E-02
	75	7.98E-02	6.15E-02	5.58E-02	3.99E-02	4.36E-02	3.91E-02	4.72E-02	4.33E-02

Table IX. In-phase and out-of-phase components of yawing moment coefficient. Φ_A = 10 deg.

		k =						
Component	α, deg	0.073	0.122	0.171	0.191	0.22	0.232	0.269
$\overline{C}_{n_\beta}$	0	0.0024	0.0021	0.0020	0.0019	0.0019	0.0018	0.0015
	5	0.0082	0.0080	0.0080	0.0081	0.0080	0.0081	0.0079
	10	0.0122	0.0120	0.0121	0.0120	0.0120	0.0120	0.0116
	15	0.0227	0.0227	0.0225	0.0222	0.0221	0.0225	0.0222
	20	0.0220	0.0219	0.0219	0.0217	0.0217	0.0220	0.0217
	25	0.0200	0.0241	0.0258	0.0264	0.0264	0.0264	0.0257
	28	0.0171	0.0224	0.0264	0.0262	0.0272	0.0270	0.0269
	30	0.0221	0.0285	0.0315	0.0324	0.0318	0.0332	0.0342
	32	0.0239	0.0331	0.0364	0.0370	0.0394	0.0371	0.0359
	34	0.0127	0.0293	0.0342	0.0377	0.0349	0.0355	0.0368
	36	-0.0134	0.0146	0.0217	0.0306	0.0273	0.0295	0.0268
	38	-0.0531	-0.0182	0.0003	0.0109	0.0007	0.0086	0.0120
	40	-0.1153	-0.0797	-0.0618	-0.0444	-0.0390	-0.0326	-0.0202
	45	-0.2384	-0.2263	-0.2033	-0.1849	-0.1800	-0.1777	-0.1471
	50	-0.1066	-0.1047	-0.0992	-0.0926	-0.0988	-0.0895	-0.0546
	60	0.0290	0.0263	0.0278	0.0263	0.0223	0.0300	0.0172
	70	0.0150	0.0128	-0.0005	-0.0131	-0.0219	-0.0111	-0.0177
	75	-0.0588	-0.0508	-0.0551	-0.0570	-0.0605	-0.0480	-0.0527
$s\left(\overline{C}_{n_\beta}\right)$	0	2.38E-05	3.08E-05	3.64E-05	3.77E-05	4.07E-05	4.02E-05	4.49E-05
	5	3.16E-05	4.21E-05	4.32E-05	4.66E-05	5.51E-05	5.80E-05	6.68E-05
	10	4.30E-05	5.42E-05	6.23E-05	6.30E-05	7.19E-05	7.30E-05	7.64E-05
	15	1.22E-04	1.63E-04	1.90E-04	1.96E-04	2.09E-04	2.30E-04	2.42E-04
	20	1.88E-04	2.51E-04	2.88E-04	3.28E-04	2.82E-04	3.19E-04	3.18E-04
	25	3.83E-04	4.92E-04	5.75E-04	5.46E-04	6.22E-04	6.23E-04	7.06E-04
	28	8.46E-04	1.11E-03	1.30E-03	1.40E-03	1.56E-03	1.63E-03	1.73E-03
	30	1.08E-03	1.48E-03	1.74E-03	1.86E-03	1.96E-03	2.13E-03	2.42E-03
	32	1.41E-03	1.93E-03	2.17E-03	2.36E-03	2.44E-03	2.70E-03	2.85E-03
	34	1.91E-03	2.41E-03	2.80E-03	3.08E-03	3.58E-03	3.44E-03	3.74E-03
	36	2.15E-03	2.52E-03	2.83E-03	3.54E-03	3.57E-03	3.91E-03	4.27E-03
	38	2.39E-03	3.06E-03	3.86E-03	4.15E-03	4.46E-03	4.82E-03	5.02E-03
	40	2.86E-03	4.26E-03	5.48E-03	5.60E-03	6.15E-03	6.56E-03	8.06E-03
	45	3.58E-03	4.50E-03	6.02E-03	5.31E-03	6.20E-03	6.19E-03	6.48E-03
	50	3.62E-03	4.54E-03	5.98E-03	6.04E-03	6.31E-03	6.45E-03	6.29E-03
	60	3.15E-03	4.46E-03	5.94E-03	6.87E-03	7.74E-03	7.97E-03	8.50E-03
	70	4.80E-03	6.21E-03	7.79E-03	8.60E-03	1.05E-02	9.10E-03	1.18E-02
	75	3.18E-03	3.97E-03	4.45E-03	5.42E-03	5.78E-03	5.86E-03	7.13E-03

Table IX. Concluded.

		k =						
Component	α, deg	0.073	0.122	0.171	0.191	0.22	0.232	0.269
$\overline{C}_{n_p}$	0	-0.0034	-0.0033	-0.0028	-0.0032	-0.0024	-0.0027	-0.0025
	5	-0.0214	-0.0206	-0.0197	-0.0202	-0.0203	-0.0203	-0.0196
	10	-0.0323	-0.0299	-0.0294	-0.0295	-0.0302	-0.0299	-0.0297
	15	-0.0538	-0.0504	-0.0493	-0.0473	-0.0471	-0.0468	-0.0449
	20	-0.0521	-0.0522	-0.0515	-0.0524	-0.0496	-0.0516	-0.0490
	25	-0.0023	-0.0478	-0.0555	-0.0699	-0.0706	-0.0728	-0.0766
	28	0.0402	-0.0137	-0.0549	-0.0690	-0.0700	-0.0774	-0.0870
	30	0.0696	-0.0075	-0.0626	-0.0757	-0.0797	-0.0862	-0.0983
	32	0.1227	0.0043	-0.0547	-0.0847	-0.0944	-0.1007	-0.1212
	34	0.2726	0.0363	-0.0572	-0.0754	-0.1096	-0.1092	-0.1245
	36	0.5811	0.1923	0.0053	-0.0294	-0.0620	-0.0900	-0.1149
	38	0.7932	0.3399	0.1582	0.0763	0.0444	0.0084	-0.0269
	40	1.0013	0.5949	0.3591	0.2954	0.2343	0.2016	0.1608
	45	0.6555	0.5824	0.5023	0.5574	0.4723	0.5044	0.4802
	50	0.1734	0.2078	0.1850	0.2257	0.2284	0.2673	0.2398
	60	-0.1540	-0.0906	-0.0872	-0.0867	-0.0770	-0.0878	-0.0505
	70	-0.4556	-0.3433	-0.2866	-0.2149	-0.2061	-0.1856	-0.0632
	75	-0.0359	-0.0522	0.0101	-0.0244	-0.0076	-0.0051	-0.0080
$s\left(\overline{C}_{n_p}\right)$	0	3.27E-04	2.52E-04	2.13E-04	1.97E-04	1.85E-04	1.73E-04	1.67E-04
	5	4.32E-04	3.45E-04	2.53E-04	2.44E-04	2.50E-04	2.50E-04	2.48E-04
	10	5.88E-04	4.44E-04	3.64E-04	3.30E-04	3.27E-04	3.15E-04	2.84E-04
	15	1.67E-03	1.33E-03	1.11E-03	1.02E-03	9.51E-04	9.89E-04	8.98E-04
	20	2.57E-03	2.05E-03	1.68E-03	1.72E-03	1.28E-03	1.37E-03	1.18E-03
	25	5.25E-03	4.04E-03	3.36E-03	2.86E-03	2.83E-03	2.69E-03	2.62E-03
	28	1.16E-02	9.11E-03	7.62E-03	7.33E-03	7.07E-03	7.03E-03	6.43E-03
	30	1.48E-02	1.22E-02	1.02E-02	9.72E-03	8.91E-03	9.17E-03	8.98E-03
	32	1.93E-02	1.58E-02	1.27E-02	1.23E-02	1.11E-02	1.16E-02	1.06E-02
	34	2.61E-02	1.97E-02	1.64E-02	1.61E-02	1.63E-02	1.48E-02	1.39E-02
	36	2.95E-02	2.06E-02	1.65E-02	1.85E-02	1.62E-02	1.68E-02	1.59E-02
	38	3.28E-02	2.51E-02	2.26E-02	2.17E-02	2.03E-02	2.08E-02	1.86E-02
	40	3.91E-02	3.49E-02	3.21E-02	2.93E-02	2.80E-02	2.83E-02	3.00E-02
	45	4.91E-02	3.69E-02	3.52E-02	2.78E-02	2.82E-02	2.67E-02	2.41E-02
	50	4.96E-02	3.72E-02	3.50E-02	3.16E-02	2.87E-02	2.78E-02	2.34E-02
	60	4.31E-02	3.65E-02	3.48E-02	3.59E-02	3.52E-02	3.43E-02	3.16E-02
	70	6.58E-02	5.09E-02	4.56E-02	4.50E-02	4.78E-02	3.92E-02	4.40E-02
	75	4.35E-02	3.25E-02	2.60E-02	2.84E-02	2.63E-02	2.52E-02	2.65E-02

Table X. In-phase and out-of-phase components of yawing moment coefficient. Φ_A = 20 deg.

		k =							
Component	α, deg	0.073	0.095	0.115	0.122	0.171	0.22	0.22	0.269
$\overline{C}_{n_\beta}$	0	0.0022	0.0025	0.0024	0.0020	0.0019	0.0017		0.0014
	5		0.0080	0.0081					
	10	0.0134	0.0127	0.0126	0.0134	0.0132	0.0122		0.0121
	15		0.0218	0.0216					
	20	0.0278	0.0240	0.0238	0.0278	0.0277	0.0233		0.0231
	25		0.0262	0.0267					
	28		0.0266	0.0284					
	30	0.0327	0.0284	0.0306	0.0389	0.0413	0.0344		0.0338
	32		0.0246	0.0294					
	34		0.0109	0.0196					
	35	-0.0288			0.0231	0.0385	0.0307		0.0340
	36		-0.0370	-0.0110					
	38		-0.1038	-0.0910					
	40	-0.1630	-0.1500	-0.1420	-0.1349	-0.0993	-0.0793		-0.0494
	45		-0.1736	-0.1732					
	50	-0.0787	-0.0833	-0.0865	-0.0833	-0.0741	-0.0692		-0.0761
	60	0.0053	-0.0007	-0.0020	0.0027	0.0010		-0.0061	-0.0114
	70	-0.0171	-0.0223	-0.0276	-0.0225	-0.0215		-0.0278	-0.0286
	75	-0.0473	-0.0548	-0.0522	-0.0500	-0.0521		-0.0592	-0.0537
$s\left(\overline{C}_{n_\beta}\right)$	0	1.56E-05	1.80E-05	1.84E-05	2.17E-05	2.82E-05	3.57E-05		4.69E-05
	5		2.22E-05	2.68E-05					
	10	4.19E-05	4.96E-05	5.38E-05	5.76E-05	6.61E-05	8.44E-05		1.02E-04
	15		9.18E-05	9.82E-05					
	20	1.78E-04	1.98E-04	2.13E-04	2.21E-04	2.53E-04	2.55E-04		2.71E-04
	25		3.29E-04	3.83E-04					
	28		5.28E-04	6.06E-04					
	30	6.18E-04	6.08E-04	7.01E-04	7.82E-04	9.12E-04	9.05E-04		1.07E-03
	32		8.12E-04	7.99E-04					
	34		1.26E-03	1.19E-03					
	35	1.77E-03			1.51E-03	1.53E-03	1.51E-03		1.61E-03
	36		2.01E-03	1.94E-03					
	38		1.86E-03	2.24E-03					
	40	1.66E-03	1.81E-03	1.99E-03	2.30E-03	2.64E-03	2.78E-03		3.03E-03
	45		2.04E-03	2.28E-03					
	50	1.76E-03	2.23E-03	2.56E-03	2.66E-03	3.49E-03	4.96E-03		5.12E-03
	60	1.66E-03	1.84E-03	2.06E-03	2.40E-03	3.21E-03		3.47E-03	4.02E-03
	70	1.85E-03	2.14E-03	2.35E-03	2.29E-03	2.93E-03		2.57E-03	2.84E-03
	75	1.95E-03	2.05E-03	2.44E-03	2.33E-03	2.82E-03		3.37E-03	3.94E-03

Table X. Concluded.

		k =							
Component	α, deg	0.073	0.095	0.115	0.122	0.171	0.22	0.22	0.269
$\overline{C}_{n_p}$	0	-0.0033	-0.0158	-0.0157	-0.0033	-0.0035	-0.0155		-0.0141
	5		-0.0311	-0.0316					
	10	-0.0331	-0.0467	-0.0463	-0.0305	-0.0317	-0.0436		-0.0420
	15		-0.0633	-0.0635					
	20	-0.0617	-0.0758	-0.0766	-0.0561	-0.0562	-0.0714		-0.0688
	25		-0.0483	-0.0562					
	28		-0.0457	-0.0572					
	30	0.0369	-0.0401	-0.0639	-0.0401	-0.0792	-0.1156		-0.1177
	32		0.0310	-0.0208					
	34		0.2305	0.1124					
	35	0.8744			0.2234	0.0432	-0.0664		-0.1084
	36		0.6522	0.4160					
	38		0.8852	0.7104					
	40	0.9295	0.7483	0.6521	0.7365	0.5810	0.3832		0.2521
	45		0.3183	0.2718					
	50	0.1095	0.1071	0.1299	0.1380	0.1624	0.1401		0.1523
	60	-0.1498	-0.1288	-0.1220	-0.1105	-0.1148		-0.1195	-0.1223
	70	-0.1960	-0.2094	-0.1592	-0.1272	-0.1034		-0.0870	-0.0410
	75	-0.1339	-0.0967	-0.1122	-0.0793	-0.0634		-0.0301	-0.0158
$s\left(\overline{C}_{n_p}\right)$	0	2.13E-04	1.90E-04	1.60E-04	1.78E-04	1.65E-04	1.62E-04		1.74E-04
	5		2.34E-04	2.33E-04					
	10	5.74E-04	5.22E-04	4.68E-04	4.72E-04	3.86E-04	3.83E-04		3.78E-04
	15		9.67E-04	8.54E-04					
	20	2.44E-03	2.08E-03	1.86E-03	1.81E-03	1.48E-03	1.16E-03		1.01E-03
	25		3.46E-03	3.33E-03					
	28		5.56E-03	5.27E-03					
	30	8.47E-03	6.40E-03	6.10E-03	6.41E-03	5.33E-03	4.11E-03		3.97E-03
	32		8.54E-03	6.95E-03					
	34		1.33E-02	1.04E-02					
	35	2.42E-02			1.24E-02	8.96E-03	6.84E-03		5.99E-03
	36		2.12E-02	1.69E-02					
	38		1.96E-02	1.95E-02					
	40	2.28E-02	1.91E-02	1.73E-02	1.89E-02	1.54E-02	1.26E-02		1.13E-02
	45		2.15E-02	1.98E-02					
	50	2.41E-02	2.34E-02	2.23E-02	2.18E-02	2.04E-02	2.25E-02		1.91E-02
	60	2.28E-02	1.94E-02	1.79E-02	1.97E-02	1.88E-02		1.58E-02	1.49E-02
	70	2.54E-02	2.25E-02	2.05E-02	1.88E-02	1.71E-02		1.17E-02	1.06E-02
	75	2.67E-02	2.15E-02	2.13E-02	1.91E-02	1.65E-02		1.53E-02	1.47E-02

Table XI. In-phase and out-of-phase components of yawing moment coefficient. $\Phi_A = 30$ deg.

		k =								
Component	α, deg	0.064	0.073	0.076	0.115	0.122	0.169	0.171	0.22	0.269
$\overline{C}_{n_\beta}$	0	0.0022	0.0022	0.0022	0.0021	0.0020	0.0018	0.0018	0.0016	0.0011
	5	0.0080	0.0079	0.0080	0.0079	0.0077	0.0079	0.0078	0.0077	0.0076
	10	0.0133	0.0134	0.0134	0.0132	0.0132	0.0132	0.0132	0.0129	0.0131
	15	0.0223	0.0224	0.0223	0.0223	0.0222	0.0224	0.0222	0.0221	0.0222
	20	0.0265	0.0265	0.0265	0.0264		0.0263	0.0264	0.0261	0.0268
	25	0.0284	0.0287	0.0286	0.0300	0.0301	0.0314	0.0319	0.0333	0.0345
	28	0.0253	0.0268	0.0270	0.0304	0.0307	0.0333	0.0336	0.0349	0.0360
	30	0.0177	0.0207	0.0213	0.0292	0.0304	0.0343	0.0339	0.0362	0.0376
	32	-0.0083	-0.0030	-0.0006	0.0218	0.0239	0.0318	0.0318	0.0346	0.0368
	34	-0.0481	-0.0374	-0.0356	-0.0007	0.0032	0.0221	0.0228	0.0301	0.0327
	36	-0.0755	-0.0688	-0.0709	-0.0405	-0.0344	-0.0091	-0.0042	0.0126	0.0221
	38	-0.0946	-0.0922		-0.0755	-0.0736	-0.0486	-0.0462	-0.0223	-0.0021
	40	-0.1063	-0.1046	-0.1046	-0.0926	-0.0901	-0.0729	-0.0739	-0.0543	-0.0330
	45	-0.1080	-0.1074	-0.1072	-0.1033	-0.1023	-0.0990	-0.0977	-0.0931	-0.0808
	50	-0.0797	-0.0766	-0.0788	-0.0798	-0.0797	-0.0767	-0.0754	-0.0699	-0.0644
	60	-0.0179	-0.0177	-0.0181	-0.0190	-0.0203	-0.0220	-0.0228	-0.0280	-0.0328
	70	-0.0335		-0.0359	-0.0357	-0.0370	-0.0408	-0.0401	-0.0417	-0.0458
	75	-0.0475		-0.0466	-0.0514	-0.0523	-0.0514	-0.0543	-0.0587	-0.0554
$s\left(\overline{C}_{n_\beta}\right)$	0	1.76E-05	1.94E-05	1.99E-05	2.46E-05	2.60E-05	3.17E-05	3.37E-05	4.48E-05	4.98E-05
	5	2.16E-05	2.43E-05	2.53E-05	3.67E-05	4.04E-05	5.77E-05	5.70E-05	8.23E-05	1.00E-04
	10	4.73E-05	5.14E-05	5.33E-05	6.84E-05	7.25E-05	8.51E-05	9.22E-05	1.14E-04	1.40E-04
	15	5.92E-05	6.51E-05	6.69E-05	9.13E-05	9.21E-05	1.16E-04	1.19E-04	1.61E-04	2.51E-04
	20	1.34E-04	1.44E-04	1.46E-04	1.78E-04		2.18E-04	2.17E-04	2.55E-04	3.02E-04
	25	1.96E-04	2.10E-04	2.20E-04	3.20E-04	3.40E-04	4.55E-04	4.66E-04	5.76E-04	7.52E-04
	28	3.35E-04	3.40E-04	3.35E-04	4.30E-04	4.66E-04	6.11E-04	6.41E-04	8.00E-04	9.79E-04
	30	5.47E-04	5.56E-04	5.53E-04	4.96E-04	5.23E-04	6.69E-04	7.06E-04	9.22E-04	1.07E-03
	32	1.09E-03	1.08E-03	1.12E-03	7.88E-04	7.54E-04	7.73E-04	7.14E-04	9.93E-04	1.18E-03
	34	1.03E-03	1.15E-03	1.23E-03	1.47E-03	1.33E-03	1.24E-03	1.20E-03	1.15E-03	1.39E-03
	36	8.69E-04	8.62E-04	8.94E-04	1.24E-03	1.38E-03	1.86E-03	1.79E-03	1.72E-03	1.75E-03
	38	1.20E-03	1.24E-03		1.31E-03	1.35E-03	1.63E-03	1.64E-03	1.81E-03	2.23E-03
	40	1.67E-03	1.76E-03	1.76E-03	1.97E-03	2.01E-03	2.10E-03	2.12E-03	2.16E-03	2.26E-03
	45	2.06E-03	2.21E-03	2.23E-03	2.62E-03	2.74E-03	2.89E-03	2.85E-03	3.03E-03	3.87E-03
	50	1.37E-03	1.55E-03	1.60E-03	2.08E-03	2.16E-03	2.62E-03	2.51E-03	3.12E-03	3.29E-03
	60	1.02E-03	1.16E-03	1.21E-03	1.64E-03	1.79E-03	2.17E-03	2.27E-03	2.27E-03	1.82E-03
	70	1.24E-03		1.43E-03	1.75E-03	1.77E-03	2.10E-03	2.04E-03	2.26E-03	2.30E-03
	75	1.22E-03		1.43E-03	1.72E-03	1.87E-03	2.06E-03	2.18E-03	2.50E-03	3.19E-03

Table XI. Concluded.

		k =								
Component	α, deg	0.064	0.073	0.076	0.115	0.122	0.169	0.171	0.22	0.269
$\overline{C}_{n_p}$	0	-0.0162	-0.0164	-0.0160	-0.0157	-0.0160	-0.0149	-0.0153	-0.0149	-0.0146
	5	-0.0317	-0.0317	-0.0310	-0.0297	-0.0301	-0.0299	-0.0280	-0.0282	-0.0266
	10	-0.0480	-0.0472	-0.0474	-0.0457	-0.0458	-0.0432	-0.0433	-0.0440	-0.0412
	15	-0.0661	-0.0631	-0.0634	-0.0612	-0.0612	-0.0545	-0.0555	-0.0554	-0.0519
	20	-0.0830	-0.0790	-0.0791	-0.0750		-0.0712	-0.0693	-0.0717	-0.0664
	25	-0.0588	-0.0581	-0.0581	-0.0635	-0.0710	-0.0733	-0.0710	-0.0808	-0.0827
	28	-0.0141	-0.0288	-0.0319	-0.0561	-0.0623	-0.0758	-0.0784	-0.0908	-0.0958
	30	0.1066	0.0673	0.0629	-0.0258	-0.0445	-0.0760	-0.0756	-0.0909	-0.1025
	32	0.4985	0.4014	0.3582	0.0653	0.0471	-0.0463	-0.0512	-0.0911	-0.1078
	34	0.8323	0.7308	0.6878	0.3100	0.2550	0.0417	0.0387	-0.0406	-0.0847
	36	0.8477	0.8237	0.7760	0.5660	0.5086	0.2734	0.2483	0.0741	-0.0059
	38	0.7082	0.6863		0.5562	0.5258	0.3917	0.3931	0.2552	0.1374
	40	0.5241	0.5095	0.4898	0.4221	0.4243	0.3642	0.3429	0.2765	0.2205
	45	0.1602	0.1732	0.1512	0.1397	0.1507	0.1353	0.1542	0.1435	0.1559
	50	0.1898	0.1604	0.1617	0.1542	0.1489	0.1357	0.1395	0.1256	0.0996
	60	-0.1132	-0.1142	-0.1187	-0.1049	-0.1061	-0.0944	-0.1004	-0.0994	-0.1058
	70	-0.1416		-0.1132	-0.0832	-0.0997	-0.0472	-0.0447	-0.0380	-0.0155
	75	-0.1373		-0.1062	-0.1092	-0.0906	-0.0635	-0.0564	-0.0308	0.0037
$s\left(\overline{C}_{n_p}\right)$	0	2.76E-04	2.66E-04	2.61E-04	2.14E-04	2.13E-04	1.88E-04	1.97E-04	2.04E-04	1.85E-04
	5	3.38E-04	3.32E-04	3.33E-04	3.19E-04	3.31E-04	3.41E-04	3.33E-04	3.74E-04	3.73E-04
	10	7.39E-04	7.04E-04	7.01E-04	5.95E-04	5.94E-04	5.04E-04	5.39E-04	5.16E-04	5.19E-04
	15	9.25E-04	8.92E-04	8.80E-04	7.94E-04	7.55E-04	6.89E-04	6.97E-04	7.32E-04	9.35E-04
	20	2.10E-03	1.98E-03	1.92E-03	1.55E-03		1.29E-03	1.27E-03	1.16E-03	1.12E-03
	25	3.06E-03	2.88E-03	2.89E-03	2.78E-03	2.78E-03	2.70E-03	2.72E-03	2.62E-03	2.80E-03
	28	5.24E-03	4.65E-03	4.41E-03	3.74E-03	3.82E-03	3.62E-03	3.75E-03	3.64E-03	3.64E-03
	30	8.55E-03	7.61E-03	7.27E-03	4.31E-03	4.29E-03	3.96E-03	4.13E-03	4.19E-03	4.00E-03
	32	1.70E-02	1.48E-02	1.48E-02	6.86E-03	6.18E-03	4.57E-03	4.18E-03	4.51E-03	4.39E-03
	34	1.62E-02	1.57E-02	1.62E-02	1.27E-02	1.09E-02	7.34E-03	7.03E-03	5.22E-03	5.16E-03
	36	1.36E-02	1.18E-02	1.18E-02	1.07E-02	1.13E-02	1.10E-02	1.05E-02	7.80E-03	6.52E-03
	38	1.88E-02	1.70E-02		1.14E-02	1.11E-02	9.65E-03	9.57E-03	8.22E-03	8.29E-03
	40	2.61E-02	2.42E-02	2.32E-02	1.71E-02	1.64E-02	1.24E-02	1.24E-02	9.81E-03	8.39E-03
	45	3.21E-02	3.02E-02	2.93E-02	2.28E-02	2.25E-02	1.71E-02	1.66E-02	1.38E-02	1.44E-02
	50	2.14E-02	2.12E-02	2.10E-02	1.80E-02	1.77E-02	1.55E-02	1.47E-02	1.42E-02	1.22E-02
	60	1.60E-02	1.59E-02	1.59E-02	1.43E-02	1.47E-02	1.29E-02	1.33E-02	1.03E-02	6.77E-03
	70	1.94E-02		1.89E-02	1.52E-02	1.45E-02	1.24E-02	1.20E-02	1.03E-02	8.54E-03
	75	1.91E-02		1.88E-02	1.49E-02	1.53E-02	1.22E-02	1.27E-02	1.13E-02	1.19E-02

Table XII. In-phase and out-of-phase components of side-force coefficient. Φ_A = 5 deg.

		k =							
Component	α, deg	0.073	0.122	0.171	0.191	0.191	0.191	0.22	0.269
$\overline{C}_{y_\beta}$	0	-0.0060	-0.0048	-0.0044	-0.0044	-0.0045	-0.0036	-0.0046	-0.0052
	10	-0.0802	-0.0787	-0.0753	-0.0755	-0.0745	-0.0754	-0.0734	-0.0694
	20	-0.1650	-0.1568	-0.1495	-0.1446	-0.1443	-0.1449	-0.1381	-0.1256
	30	-0.1902	-0.1759	-0.1592	-0.1509	-0.1489	-0.1389	-0.1391	-0.1114
	35	-0.1296	-0.1067	-0.0791	-0.0398	-0.0799	-0.0723	-0.0604	-0.0336
	40	-0.0074	0.0529	0.0757	0.1411	0.1393	0.0781	0.1187	0.1771
	50	0.1058	0.0924	0.1497	0.1627	0.1751	0.1612	0.2427	0.3388
	60	-0.0696	-0.0619	-0.0557	-0.0650	-0.0501	-0.0586	-0.0760	-0.0502
	70	-0.0614	-0.0628	-0.0773	-0.0718	-0.0787	-0.0601	-0.0715	-0.0673
	75	-0.1102	-0.1210	-0.1033	-0.1328	-0.1233	-0.1541	-0.1228	-0.1018
$s\left(\overline{C}_{y_\beta}\right)$	0	1.50E-04	1.73E-04	2.21E-04	2.01E-04	1.88E-04	2.19E-04	2.62E-04	2.41E-04
	10	1.67E-04	2.71E-04	2.68E-04	2.92E-04	2.34E-04	2.67E-04	3.54E-04	3.37E-04
	20	5.41E-04	6.71E-04	8.00E-04	7.40E-04	9.03E-04	7.89E-04	1.05E-03	1.13E-03
	30	1.35E-03	1.92E-03	2.47E-03	2.58E-03	2.62E-03	2.98E-03	3.06E-03	4.02E-03
	35	2.68E-03	3.43E-03	3.93E-03	4.03E-03	3.98E-03	4.05E-03	4.03E-03	4.84E-03
	40	8.12E-03	1.11E-02	1.39E-02	1.39E-02	1.45E-02	1.24E-02	1.66E-02	2.00E-02
	50	1.63E-02	2.26E-02	2.64E-02	2.95E-02	3.30E-02	3.05E-02	2.53E-02	2.73E-02
	60	8.36E-03	1.24E-02	1.60E-02	1.47E-02	1.49E-02	1.97E-02	2.21E-02	2.74E-02
	70	2.13E-02	2.87E-02	3.25E-02	3.21E-02	3.22E-02	4.13E-02	3.83E-02	4.46E-02
	75	1.18E-02	1.60E-02	1.88E-02	1.61E-02	1.84E-02	1.68E-02	2.16E-02	2.21E-02

		k =							
Component	α, deg	0.073	0.122	0.171	0.191	0.191	0.191	0.22	0.269
$\overline{C}_{y_p}$	0	-0.0003	-0.0030	-0.0001	-0.0011	-0.0016	-0.0011	-0.0014	-0.0005
	10	0.1153	0.1127	0.1119	0.1165	0.1101	0.1113	0.1102	0.1084
	20	0.2579	0.2311	0.2083	0.2198	0.2204	0.2001	0.1994	0.2003
	30	0.5005	0.4325	0.3929	0.4044	0.4128	0.4110	0.3780	0.3759
	35	1.0029	0.7361	0.6136	0.6164	0.5679	0.5690	0.5496	0.5076
	40	1.7640	1.4436	1.0978	1.0187	1.0379	0.9877	0.9362	0.8683
	50	-0.5999	-0.0379	0.2472	0.2594	0.2177	0.2905	0.5315	0.0364
	60	0.2097	-0.1482	-0.0680	-0.1195	-0.1232	-0.0895	-0.0903	-0.0628
	70	0.1253	-0.1990	0.0397	-0.0456	0.1194	-0.0074	-0.0792	0.0244
	75	-0.3113	-0.3605	-0.2758	-0.2704	-0.0868	-0.2485	-0.2745	-0.2315
$s\left(\overline{C}_{y_p}\right)$	0	2.05E-03	1.42E-03	1.29E-03	1.05E-03	9.86E-04	1.15E-03	1.19E-03	8.95E-04
	10	2.28E-03	2.22E-03	1.57E-03	1.53E-03	1.22E-03	1.40E-03	1.61E-03	1.25E-03
	20	7.40E-03	5.50E-03	4.68E-03	3.87E-03	4.73E-03	4.13E-03	4.78E-03	4.21E-03
	30	1.85E-02	1.57E-02	1.44E-02	1.35E-02	1.37E-02	1.56E-02	1.39E-02	1.49E-02
	35	3.67E-02	2.81E-02	2.30E-02	2.11E-02	2.08E-02	2.12E-02	1.83E-02	1.80E-02
	40	1.11E-01	9.12E-02	8.11E-02	7.25E-02	7.57E-02	6.51E-02	7.56E-02	7.42E-02
	50	2.24E-01	1.85E-01	1.55E-01	1.54E-01	1.73E-01	1.60E-01	1.15E-01	1.02E-01
	60	1.14E-01	1.01E-01	9.33E-02	7.71E-02	7.83E-02	1.03E-01	1.00E-01	1.02E-01
	70	2.91E-01	2.35E-01	1.90E-01	1.68E-01	1.69E-01	2.16E-01	1.74E-01	1.66E-01
	75	1.61E-01	1.31E-01	1.10E-01	8.41E-02	9.62E-02	8.77E-02	9.80E-02	8.20E-02

Table XIII. In-phase and out-of-phase components of side-force coefficient. $\Phi_A = 10$ deg.

		k =						
Component	α, deg	0.073	0.122	0.171	0.191	0.22	0.232	0.269
$\overline{C}_{Y_\beta}$	0	-0.0054	-0.0047	-0.0042	-0.0038	-0.0039	-0.0037	-0.0030
	5	-0.0408	-0.0396	-0.0379	-0.0377	-0.0365	-0.0363	-0.0338
	10	-0.0807	-0.0783	-0.0759	-0.0742	-0.0715	-0.0710	-0.0656
	15	-0.1061	-0.1024	-0.0987	-0.0957	-0.0910	-0.0900	-0.0835
	20	-0.1636	-0.1574	-0.1492	-0.1442	-0.1373	-0.1354	-0.1257
	25	-0.1908	-0.1870	-0.1789	-0.1712	-0.1620	-0.1579	-0.1431
	28	-0.1893	-0.1814	-0.1698	-0.1611	-0.1534	-0.1473	-0.1294
	30	-0.1749	-0.1597	-0.1451	-0.1373	-0.1235	-0.1180	-0.0996
	32	-0.1598	-0.1409	-0.1230	-0.1139	-0.1016	-0.0946	-0.0669
	34	-0.1392	-0.1227	-0.1014	-0.0840	-0.0700	-0.0664	-0.0452
	36	-0.1119	-0.0880	-0.0662	-0.0452	-0.0361	-0.0222	0.0043
	38	-0.0675	-0.0384	-0.0037	0.0166	0.0268	0.0396	0.0681
	40	0.0190	0.0579	0.0999	0.1174	0.1359	0.1597	0.1952
	45	0.0881	0.1234	0.2034	0.2574	0.2782	0.2759	0.3854
	50	0.0287	0.0390	0.1064	0.0841	0.1047	0.0856	0.1338
	60	-0.0314	-0.0342	-0.0417	-0.0320	-0.0332	-0.0238	-0.0355
	70	-0.0453	-0.0468	-0.0509	-0.0457	-0.0677	-0.0696	-0.0743
	75	-0.1345	-0.1322	-0.1339	-0.1268	-0.1237	-0.1466	-0.1513
$s\left(\overline{C}_{Y_\beta}\right)$	0	7.39E-05	1.02E-04	1.17E-04	1.16E-04	1.43E-04	1.35E-04	1.63E-04
	5	9.52E-05	1.35E-04	1.41E-04	1.33E-04	1.57E-04	1.74E-04	2.11E-04
	10	1.95E-04	1.79E-04	2.14E-04	2.23E-04	2.74E-04	2.90E-04	3.17E-04
	15	2.30E-04	3.84E-04	3.70E-04	4.03E-04	4.04E-04	5.02E-04	4.64E-04
	20	3.26E-04	4.78E-04	5.18E-04	5.35E-04	4.95E-04	6.74E-04	6.64E-04
	25	4.66E-04	7.36E-04	9.12E-04	9.00E-04	1.06E-03	1.10E-03	1.07E-03
	28	1.14E-03	1.59E-03	1.99E-03	2.16E-03	2.44E-03	2.50E-03	3.14E-03
	30	1.60E-03	2.28E-03	2.62E-03	3.01E-03	3.42E-03	3.60E-03	4.38E-03
	32	2.23E-03	3.39E-03	4.27E-03	4.29E-03	4.77E-03	5.17E-03	5.84E-03
	34	3.13E-03	4.25E-03	5.78E-03	6.14E-03	6.29E-03	6.88E-03	7.86E-03
	36	3.31E-03	4.44E-03	5.45E-03	6.37E-03	7.25E-03	7.74E-03	8.78E-03
	38	3.65E-03	4.94E-03	6.53E-03	7.40E-03	8.70E-03	9.13E-03	1.05E-02
	40	5.76E-03	8.17E-03	1.14E-02	1.24E-02	1.39E-02	1.50E-02	1.79E-02
	45	1.16E-02	1.59E-02	2.11E-02	1.95E-02	2.30E-02	2.40E-02	2.34E-02
	50	9.81E-03	1.38E-02	1.38E-02	1.36E-02	1.66E-02	1.60E-02	1.84E-02
	60	5.76E-03	9.49E-03	1.17E-02	1.35E-02	1.50E-02	1.58E-02	1.68E-02
	70	8.30E-03	1.24E-02	1.45E-02	1.53E-02	1.92E-02	1.67E-02	2.01E-02
	75	6.52E-03	8.06E-03	8.63E-03	1.02E-02	1.10E-02	1.09E-02	1.38E-02

Table XIII. Concluded.

Component	α, deg	k = 0.073	0.122	0.171	0.191	0.22	0.232	0.269
$\overline{C}_{Y_p}$	0	0.0014	0.0011	0.0004	0.0015	-0.0006	0.0000	-0.0018
	5	0.0866	0.0854	0.0819	0.0847	0.0847	0.0844	0.0807
	10	0.1322	0.1170	0.1130	0.1138	0.1183	0.1157	0.1144
	15	0.1339	0.1198	0.1216	0.1152	0.1145	0.1164	0.1084
	20	0.2500	0.2300	0.2150	0.2089	0.1986	0.2003	0.1820
	25	0.2879	0.2854	0.2514	0.2888	0.2672	0.2731	0.2613
	28	0.3784	0.3529	0.3277	0.3475	0.3204	0.3312	0.3220
	30	0.4938	0.4257	0.3920	0.3858	0.3705	0.3771	0.3613
	32	0.6613	0.5461	0.4849	0.4880	0.4576	0.4420	0.4402
	34	0.8223	0.6455	0.5756	0.5463	0.5248	0.5002	0.4901
	36	1.0849	0.8057	0.6744	0.6433	0.6018	0.5986	0.5694
	38	1.4133	1.0162	0.8341	0.8076	0.7275	0.7242	0.6605
	40	1.6443	1.2074	0.9844	0.9085	0.8847	0.8348	0.7917
	45	1.6233	1.5660	1.3549	1.2331	1.1734	1.1412	0.9706
	50	0.0028	0.2304	0.1408	0.4016	0.3057	0.4462	0.4296
	60	-0.0563	-0.1220	-0.0815	-0.0873	-0.1141	-0.0980	-0.0707
	70	-0.8093	-0.5118	-0.4960	-0.3889	-0.3932	-0.3741	-0.3014
	75	-0.2564	-0.2750	-0.2915	-0.2308	-0.4207	-0.2709	-0.2840
$s\left(\overline{C}_{Y_p}\right)$	0	1.01E-03	8.36E-04	6.84E-04	6.09E-04	6.50E-04	5.80E-04	6.05E-04
	5	1.30E-03	1.11E-03	8.27E-04	6.94E-04	7.15E-04	7.51E-04	7.85E-04
	10	2.68E-03	1.47E-03	1.25E-03	1.17E-03	1.25E-03	1.25E-03	1.18E-03
	15	3.15E-03	3.14E-03	2.17E-03	2.11E-03	1.84E-03	2.16E-03	1.72E-03
	20	4.47E-03	3.92E-03	3.03E-03	2.80E-03	2.25E-03	2.91E-03	2.47E-03
	25	6.38E-03	6.04E-03	5.33E-03	4.71E-03	4.80E-03	4.76E-03	3.99E-03
	28	1.56E-02	1.30E-02	1.16E-02	1.13E-02	1.11E-02	1.08E-02	1.17E-02
	30	2.19E-02	1.87E-02	1.53E-02	1.58E-02	1.56E-02	1.55E-02	1.63E-02
	32	3.05E-02	2.78E-02	2.50E-02	2.24E-02	2.17E-02	2.23E-02	2.17E-02
	34	4.29E-02	3.48E-02	3.38E-02	3.21E-02	2.86E-02	2.97E-02	2.92E-02
	36	4.54E-02	3.64E-02	3.19E-02	3.34E-02	3.30E-02	3.34E-02	3.26E-02
	38	5.00E-02	4.05E-02	3.82E-02	3.88E-02	3.96E-02	3.94E-02	3.90E-02
	40	7.89E-02	6.70E-02	6.65E-02	6.48E-02	6.32E-02	6.47E-02	6.64E-02
	45	1.58E-01	1.30E-01	1.23E-01	1.02E-01	1.04E-01	1.03E-01	8.71E-02
	50	1.34E-01	1.13E-01	8.06E-02	7.10E-02	7.56E-02	6.89E-02	6.83E-02
	60	7.89E-02	7.78E-02	6.85E-02	7.09E-02	6.82E-02	6.81E-02	6.25E-02
	70	1.14E-01	1.01E-01	8.48E-02	8.02E-02	8.72E-02	7.21E-02	7.48E-02
	75	8.94E-02	6.61E-02	5.05E-02	5.33E-02	5.02E-02	4.69E-02	5.13E-02

Table XIV. In-phase and out-of-phase components of side-force coefficient. $\Phi_A = 20$ deg.

		k =							
Component	α, deg	0.073	0.095	0.115	0.122	0.171	0.22	0.22	0.269
$\overline{C}_{Y_\beta}$	0	-0.0048	-0.0056	-0.0053	-0.0043	-0.0038	-0.0025		-0.0035
	5		-0.0426	-0.0429					
	10	-0.0818	-0.0877	-0.0866	-0.0808	-0.0766	-0.0773		-0.0729
	15		-0.1265	-0.1241					
	20	-0.1677	-0.1758	-0.1739	-0.1609	-0.1521	-0.1515		-0.1385
	25		-0.2068	-0.2041					
	28		-0.2085	-0.2055					
	30	-0.1891	-0.1980	-0.1938	-0.1779	-0.1625	-0.1589		-0.1331
	32		-0.1781	-0.1757					
	34		-0.1368	-0.1359					
	35	-0.0825			-0.1014	-0.0935	-0.0788		-0.0499
	36		-0.0409	-0.0588					
	38		0.0066	0.0295					
	40	-0.0137	0.0249	0.0445	0.0393	0.1073	0.1713		0.2027
	45		0.1224	0.1260					
	50	0.0015	0.0151	0.0230	0.0176	0.0327	0.0325		0.0712
	60	-0.0718	-0.0749	-0.0736	-0.0706	-0.0718		-0.0664	-0.0567
	70	-0.1028	-0.1004	-0.1097	-0.1054	-0.1030		-0.0920	-0.0962
	75	-0.1304	-0.1352	-0.1387	-0.1339	-0.1425		-0.1477	-0.1524
$s(\overline{C}_{Y_\beta})$	0	5.27E-05	6.29E-05	6.56E-05	6.49E-05	8.74E-05	1.24E-04		1.60E-04
	5		8.06E-05	9.36E-05					
	10	1.04E-04	1.53E-04	1.63E-04	1.64E-04	1.99E-04	2.53E-04		3.33E-04
	15		3.98E-04	4.16E-04					
	20	2.76E-04	3.45E-04	3.50E-04	3.38E-04	4.53E-04	4.35E-04		5.13E-04
	25		4.68E-04	5.50E-04					
	28		8.00E-04	9.33E-04					
	30	8.98E-04	1.06E-03	1.30E-03	1.37E-03	1.82E-03	2.35E-03		3.28E-03
	32		1.65E-03	1.76E-03					
	34		2.38E-03	2.42E-03					
	35	3.15E-03			2.91E-03	3.55E-03	4.18E-03		5.64E-03
	36		4.23E-03	4.09E-03					
	38		4.76E-03	5.51E-03					
	40	3.96E-03	4.90E-03	5.57E-03	5.93E-03	7.58E-03	8.70E-03		9.56E-03
	45		9.18E-03	1.01E-02					
	50	4.86E-03	6.59E-03	8.15E-03	8.38E-03	1.13E-02	1.43E-02		1.53E-02
	60	2.99E-03	3.54E-03	4.41E-03	4.64E-03	6.76E-03		9.16E-03	9.42E-03
	70	3.69E-03	4.15E-03	4.57E-03	5.06E-03	5.85E-03		6.52E-03	7.71E-03
	75	3.75E-03	4.46E-03	4.77E-03	5.26E-03	5.82E-03		6.78E-03	8.85E-03

Table XIV. Concluded.

		k =							
Component	α, deg	0.073	0.095	0.115	0.122	0.171	0.22	0.22	0.269
$\overline{C}_{Y_p}$	0	0.0018	-0.0019	-0.0018	0.0010	0.0014	-0.0031		-0.0032
	5		0.0879	0.0911					
	10	0.1302	0.1293	0.1309	0.1151	0.1212	0.1171		0.1134
	15		0.1515	0.1583					
	20	0.2678	0.2524	0.2585	0.2293	0.2189	0.2256		0.2098
	25		0.2843	0.2901					
	28		0.3950	0.3899					
	30	0.5152	0.4806	0.4746	0.4499	0.4174	0.4054		0.3737
	32		0.5250	0.5295					
	34		0.5342	0.5550					
	35	0.6012			0.5763	0.5427	0.5250		0.5162
	36		0.6620	0.6133					
	38		1.2395	1.0199					
	40	1.5419	1.4384	1.3691	1.2947	1.0371	0.8275		0.6454
	45		0.8638	0.8175					
	50	0.1486	0.1765	0.1172	0.0969	-0.0421	-0.0824		0.0437
	60	-0.1600	-0.1709	-0.1704	-0.2013	-0.1660		-0.1506	-0.1565
	70	-0.4224	-0.3849	-0.4024	-0.3179	-0.2710		-0.2845	-0.3489
	75	-0.5176	-0.4445	-0.3861	-0.3518	-0.3466		-0.3210	-0.3707
$s\left(\overline{C}_{Y_p}\right)$	0	7.21E-04	6.63E-04	5.71E-04	5.32E-04	5.11E-04	5.64E-04		5.94E-04
	5		8.48E-04	8.14E-04					
	10	1.43E-03	1.61E-03	1.42E-03	1.34E-03	1.17E-03	1.15E-03		1.24E-03
	15		4.19E-03	3.62E-03					
	20	3.79E-03	3.63E-03	3.05E-03	2.77E-03	2.65E-03	1.98E-03		1.91E-03
	25		4.92E-03	4.78E-03					
	28		8.42E-03	8.11E-03					
	30	1.23E-02	1.12E-02	1.13E-02	1.12E-02	1.07E-02	1.07E-02		1.22E-02
	32		1.73E-02	1.53E-02					
	34		2.50E-02	2.10E-02					
	35	4.32E-02			2.39E-02	2.08E-02	1.90E-02		2.10E-02
	36		4.45E-02	3.56E-02					
	38		5.01E-02	4.79E-02					
	40	5.43E-02	5.16E-02	4.84E-02	4.86E-02	4.43E-02	3.95E-02		3.55E-02
	45		9.67E-02	8.75E-02					
	50	6.66E-02	6.93E-02	7.09E-02	6.87E-02	6.62E-02	6.50E-02		5.68E-02
	60	4.10E-02	3.73E-02	3.83E-02	3.80E-02	3.95E-02		4.16E-02	3.50E-02
	70	5.05E-02	4.37E-02	3.97E-02	4.15E-02	3.42E-02		2.97E-02	2.87E-02
	75	5.13E-02	4.69E-02	4.15E-02	4.31E-02	3.40E-02		3.08E-02	3.29E-02

Table XV. In-phase and out-of-phase components of side-force coefficient. $\Phi_A = 30$ deg.

		k =								
Component	α, deg	0.064	0.073	0.076	0.115	0.122	0.169	0.171	0.22	0.269
$\overline{C}_{Y_\beta}$	0	-0.0049	-0.0048	-0.0048	-0.0050	-0.0045	-0.0041	-0.0042	-0.0045	-0.0033
	5	-0.0428	-0.0421	-0.0426	-0.0414	-0.0408	-0.0409	-0.0399	-0.0390	-0.0355
	10	-0.0880	-0.0884	-0.0879	-0.0860	-0.0861	-0.0832	-0.0835	-0.0785	-0.0728
	15	-0.1303	-0.1301	-0.1291	-0.1277	-0.1266	-0.1221	-0.1213	-0.1144	-0.1040
	20	-0.1776	-0.1760	-0.1769	-0.1721		-0.1626	-0.1632	-0.1506	-0.1377
	25	-0.2072	-0.2059	-0.2059	-0.1996	-0.1980	-0.1895	-0.1895	-0.1768	-0.1605
	28	-0.2037	-0.2032	-0.2026	-0.2015	-0.1987	-0.1889	-0.1898	-0.1741	-0.1543
	30	-0.1795	-0.1827	-0.1825	-0.1872	-0.1877	-0.1779	-0.1774	-0.1627	-0.1402
	32	-0.1223	-0.1244	-0.1319	-0.1590	-0.1604	-0.1573	-0.1591	-0.1406	-0.1181
	34	-0.0779	-0.0753	-0.0761	-0.0951	-0.0994	-0.1110	-0.1142	-0.1015	-0.0759
	36	-0.0702	-0.0622	-0.0590	-0.0336	-0.0298	-0.0206	-0.0291	-0.0267	-0.0084
	38	-0.0636	-0.0529		-0.0190	-0.0105	0.0307	0.0357	0.0640	0.0811
	40	-0.0480	-0.0436	-0.0371	-0.0046	-0.0045	0.0403	0.0408	0.0908	0.1353
	45	-0.0113	-0.0101	-0.0085	0.0028	0.0098	0.0312	0.0348	0.0648	0.1185
	50	-0.0477	-0.0477	-0.0471	-0.0332	-0.0345	-0.0201	-0.0225	-0.0062	0.0205
	60	-0.1027	-0.1045	-0.1019	-0.0990	-0.0998	-0.0924	-0.0905	-0.0764	-0.0586
	70	-0.1320		-0.1339	-0.1245	-0.1225	-0.1163	-0.1204	-0.1123	-0.0927
	75	-0.1402		-0.1451	-0.1476	-0.1426	-0.1407	-0.1440	-0.1363	-0.1393
$s\left(\overline{C}_{Y_\beta}\right)$	0	5.18E-05	5.80E-05	6.16E-05	7.73E-05	8.14E-05	9.68E-05	1.14E-04	1.45E-04	1.67E-04
	5	7.08E-05	7.59E-05	8.22E-05	1.12E-04	1.16E-04	1.59E-04	1.52E-04	1.98E-04	2.24E-04
	10	1.05E-04	1.09E-04	1.09E-04	1.53E-04	1.45E-04	1.89E-04	2.31E-04	2.99E-04	3.40E-04
	15	3.41E-04	3.63E-04	3.77E-04	4.79E-04	4.88E-04	5.40E-04	5.70E-04	7.01E-04	1.02E-03
	20	2.47E-04	2.71E-04	2.75E-04	3.50E-04		5.37E-04	5.10E-04	7.79E-04	1.12E-03
	25	3.80E-04	4.10E-04	4.49E-04	6.00E-04	6.37E-04	8.17E-04	8.53E-04	1.06E-03	1.69E-03
	28	6.86E-04	6.95E-04	7.20E-04	9.39E-04	1.02E-03	1.45E-03	1.51E-03	1.95E-03	2.49E-03
	30	1.33E-03	1.31E-03	1.38E-03	1.37E-03	1.38E-03	1.90E-03	2.02E-03	2.91E-03	3.85E-03
	32	2.60E-03	2.73E-03	2.71E-03	2.32E-03	2.33E-03	2.52E-03	2.45E-03	3.36E-03	4.53E-03
	34	2.39E-03	2.94E-03	3.03E-03	4.05E-03	4.10E-03	3.94E-03	3.89E-03	4.43E-03	5.20E-03
	36	2.05E-03	2.34E-03	2.50E-03	3.99E-03	4.33E-03	5.91E-03	5.85E-03	6.37E-03	7.59E-03
	38	2.62E-03	2.94E-03		3.93E-03	4.16E-03	5.24E-03	5.26E-03	6.69E-03	8.14E-03
	40	3.41E-03	3.74E-03	3.90E-03	5.46E-03	5.54E-03	6.80E-03	7.05E-03	7.87E-03	7.96E-03
	45	4.92E-03	5.19E-03	5.49E-03	6.85E-03	6.80E-03	8.62E-03	9.24E-03	1.21E-02	1.58E-02
	50	4.55E-03	4.80E-03	5.09E-03	6.83E-03	7.19E-03	9.34E-03	9.54E-03	1.09E-02	1.22E-02
	60	2.01E-03	2.18E-03	2.27E-03	3.21E-03	3.13E-03	5.12E-03	5.05E-03	7.46E-03	8.47E-03
	70	2.42E-03		2.84E-03	3.66E-03	4.31E-03	5.65E-03	5.14E-03	6.48E-03	7.65E-03
	75	2.39E-03		2.78E-03	3.63E-03	3.75E-03	4.89E-03	4.52E-03	5.82E-03	7.61E-03

Table XV. Concluded.

Component	α, deg	k = 0.064	0.073	0.076	0.115	0.122	0.169	0.171	0.22	0.269
$\overline{C}_{Y_p}$	0	0.0014	-0.0011	0.0007	-0.0020	-0.0014	-0.0010	-0.0004	0.0024	0.0018
	5	0.0945	0.0951	0.0934	0.0870	0.0892	0.0899	0.0809	0.0847	0.0788
	10	0.1454	0.1372	0.1440	0.1329	0.1319	0.1239	0.1224	0.1321	0.1192
	15	0.1920	0.1750	0.1794	0.1711	0.1705	0.1410	0.1439	0.1497	0.1342
	20	0.2947	0.2694	0.2752	0.2517		0.2317	0.2199	0.2316	0.2002
	25	0.3824	0.3449	0.3441	0.3139	0.3291	0.2812	0.2656	0.2602	0.2408
	28	0.4084	0.4123	0.4320	0.3508	0.3599	0.3211	0.3226	0.3181	0.3007
	30	0.3204	0.3511	0.3592	0.3829	0.3957	0.3760	0.3739	0.3482	0.3382
	32	0.0366	0.1008	0.1371	0.3535	0.3561	0.3946	0.3883	0.4053	0.3816
	34	0.3984	0.2942	0.2852	0.2519	0.2628	0.3831	0.3741	0.4009	0.4061
	36	0.9178	0.8457	0.8673	0.5088	0.4674	0.3545	0.3565	0.3833	0.3953
	38	1.2065	1.1866		0.9346	0.8743	0.6154	0.5886	0.4313	0.3629
	40	1.2434	1.2076	1.1776	0.9893	1.0012	0.7932	0.7714	0.6127	0.4879
	45	0.8400	0.8663	0.8186	0.7188	0.7025	0.5924	0.5891	0.5460	0.5190
	50	0.0843	0.1683	0.1595	0.1639	0.1423	0.1232	0.1613	0.1474	0.1494
	60	-0.0890	-0.1248	-0.0842	-0.0952	-0.1272	-0.1105	-0.0786	-0.1094	-0.1132
	70	-0.3033		-0.1997	-0.1938	-0.1478	-0.1877	-0.1678	-0.1900	-0.2315
	75	-0.4058		-0.3341	-0.3271	-0.2970	-0.3178	-0.3324	-0.2895	-0.3133
$s(\overline{C}_{Y_p})$	0	8.09E-04	7.95E-04	8.11E-04	6.72E-04	6.67E-04	5.73E-04	6.67E-04	6.57E-04	6.20E-04
	5	1.11E-03	1.04E-03	1.08E-03	9.71E-04	9.55E-04	9.39E-04	8.89E-04	9.00E-04	8.31E-04
	10	1.64E-03	1.49E-03	1.44E-03	1.33E-03	1.19E-03	1.12E-03	1.35E-03	1.36E-03	1.26E-03
	15	5.33E-03	4.98E-03	4.96E-03	4.16E-03	4.00E-03	3.19E-03	3.33E-03	3.19E-03	3.80E-03
	20	3.86E-03	3.72E-03	3.61E-03	3.04E-03		3.18E-03	2.98E-03	3.54E-03	4.17E-03
	25	5.94E-03	5.61E-03	5.91E-03	5.21E-03	5.22E-03	4.84E-03	4.99E-03	4.80E-03	6.29E-03
	28	1.07E-02	9.52E-03	9.48E-03	8.17E-03	8.37E-03	8.57E-03	8.80E-03	8.85E-03	9.27E-03
	30	2.07E-02	1.80E-02	1.81E-02	1.19E-02	1.13E-02	1.12E-02	1.18E-02	1.32E-02	1.43E-02
	32	4.06E-02	3.74E-02	3.57E-02	2.01E-02	1.91E-02	1.49E-02	1.43E-02	1.53E-02	1.68E-02
	34	3.73E-02	4.02E-02	3.99E-02	3.52E-02	3.36E-02	2.33E-02	2.28E-02	2.01E-02	1.93E-02
	36	3.20E-02	3.20E-02	3.29E-02	3.47E-02	3.55E-02	3.50E-02	3.42E-02	2.90E-02	2.82E-02
	38	4.09E-02	4.03E-02		3.42E-02	3.41E-02	3.10E-02	3.07E-02	3.04E-02	3.03E-02
	40	5.33E-02	5.12E-02	5.13E-02	4.75E-02	4.54E-02	4.02E-02	4.12E-02	3.58E-02	2.96E-02
	45	7.69E-02	7.11E-02	7.23E-02	5.96E-02	5.58E-02	5.10E-02	5.40E-02	5.49E-02	5.88E-02
	50	7.11E-02	6.58E-02	6.69E-02	5.94E-02	5.89E-02	5.53E-02	5.58E-02	4.97E-02	4.55E-02
	60	3.14E-02	2.99E-02	2.99E-02	2.79E-02	2.57E-02	3.03E-02	2.95E-02	3.39E-02	3.15E-02
	70	3.78E-02		3.74E-02	3.18E-02	3.53E-02	3.34E-02	3.01E-02	2.94E-02	2.84E-02
	75	3.73E-02		3.66E-02	3.16E-02	3.08E-02	2.89E-02	2.64E-02	2.65E-02	2.83E-02

Table XVI. In-phase and out-of-phase components of rolling moment coefficient. $\Phi_A = 30$ deg, $\Phi_0 = 15$ deg.

		k =		
Component	θ, deg	0.064	0.115	0.169
$\overline{C}_{l_\beta}$	0	0.0023	0.0015	-0.0005
	5	-0.0037	-0.0046	-0.0058
	10	-0.0158	-0.0174	-0.0192
	15	-0.0332	-0.0346	-0.0371
	20	-0.0547	-0.0578	-0.0623
	25	-0.0735	-0.0822	-0.0885
	28	-0.0832	-0.0990	-0.1070
	30	-0.0860	-0.1097	-0.1228
	32	-0.0882	-0.1164	-0.1330
	34	-0.0896	-0.1216	-0.1407
	36	-0.0831	-0.1180	-0.1389
	38	-0.0704	-0.1037	-0.1343
	40	-0.0638	-0.0921	-0.1217
	45	-0.0725	-0.0827	-0.0965
	50	-0.0785	-0.0791	-0.0851
	60	-0.0828	-0.0811	-0.0821
	70	-0.0960	-0.0938	-0.0923
	75		-0.0955	-0.0939
$s\left(\overline{C}_{l_\beta}\right)$	0	4.86E-05	8.75E-05	1.27E-04
	5	3.22E-05	7.13E-05	1.17E-04
	10	8.17E-05	1.70E-04	2.96E-04
	15	2.78E-04	4.44E-04	6.09E-04
	20	4.66E-04	7.75E-04	1.05E-03
	25	7.15E-04	9.90E-04	1.25E-03
	28	8.26E-04	1.24E-03	1.61E-03
	30	9.69E-04	1.47E-03	1.89E-03
	32	1.28E-03	1.80E-03	2.21E-03
	34	1.69E-03	2.32E-03	2.80E-03
	36	1.96E-03	2.70E-03	3.35E-03
	38	2.24E-03	3.11E-03	3.90E-03
	40	2.32E-03	3.51E-03	4.38E-03
	45	1.38E-03	2.33E-03	3.59E-03
	50	1.17E-03	1.63E-03	2.37E-03
	60	4.81E-04	7.54E-04	1.10E-03
	70	6.00E-04	9.40E-04	1.32E-03
	75		9.49E-04	1.31E-03

Table XVI. Concluded.

		k =		
Component	θ, deg	0.064	0.115	0.169
$\overline{C}_{l_p}$	0	-0.2031	-0.2024	-0.1945
	5	-0.1641	-0.1629	-0.1580
	10	-0.2068	-0.2092	-0.1991
	15	-0.2090	-0.2155	-0.2019
	20	-0.2286	-0.2189	-0.2025
	25	-0.3646	-0.3217	-0.2672
	28	-0.5691	-0.4096	-0.3115
	30	-0.8177	-0.5168	-0.3537
	32	-1.0082	-0.6410	-0.4129
	34	-1.0796	-0.6917	-0.4358
	36	-1.0440	-0.6873	-0.4523
	38	-1.0170	-0.6946	-0.4922
	40	-0.7984	-0.6899	-0.5170
	45	-0.4085	-0.3866	-0.3349
	50	-0.1160	-0.1755	-0.1885
	60	-0.1008	-0.1047	-0.1133
	70	-0.0249	-0.0752	-0.0842
	75		-0.0598	-0.0846
$s\left(\overline{C}_{l_p}\right)$	0	7.59E-04	7.61E-04	7.51E-04
	5	5.03E-04	6.20E-04	6.90E-04
	10	1.28E-03	1.48E-03	1.75E-03
	15	4.34E-03	3.86E-03	3.60E-03
	20	7.28E-03	6.74E-03	6.21E-03
	25	1.12E-02	8.60E-03	7.42E-03
	28	1.29E-02	1.08E-02	9.51E-03
	30	1.51E-02	1.27E-02	1.12E-02
	32	2.00E-02	1.57E-02	1.31E-02
	34	2.65E-02	2.02E-02	1.66E-02
	36	3.07E-02	2.35E-02	1.98E-02
	38	3.50E-02	2.70E-02	2.31E-02
	40	3.63E-02	3.05E-02	2.59E-02
	45	2.16E-02	2.03E-02	2.12E-02
	50	1.83E-02	1.42E-02	1.40E-02
	60	7.52E-03	6.56E-03	6.52E-03
	70	9.38E-03	8.17E-03	7.79E-03
	75		8.25E-03	7.76E-03

Table XVII. In-phase and out-of-phase components of rolling moment coefficient. $\Phi_A = 30$ deg, $\Phi_0 = 30$ deg.

		k =		
Component	θ, deg	0.064	0.115	0.169
$\overline{C}_{l_\beta}$	0	0.0005	-0.0006	-0.0008
	5	-0.0029	-0.0041	-0.0039
	10	-0.0110	-0.0122	-0.0123
	15	-0.0198	-0.0212	-0.0209
	20	-0.0315	-0.0339	-0.0344
	25	-0.0446	-0.0495	-0.0520
	28	-0.0588	-0.0654	-0.0676
	30	-0.0711	-0.0769	-0.0786
	32	-0.0814	-0.0861	-0.0849
	34	-0.0905	-0.0978	-0.0986
	36	-0.0973	-0.1075	-0.1090
	38	-0.0989	-0.1091	-0.1144
	40	-0.1011	-0.1087	-0.1138
	45	-0.0974	-0.1023	-0.1070
	50	-0.0897	-0.0870	-0.0859
	60	-0.0880	-0.0793	-0.0736
	70	-0.0994	-0.0874	-0.0810
	75	-0.0979	-0.0859	-0.0800
$s(\overline{C}_{l_\beta})$	0	5.32E-05	9.16E-05	1.51E-04
	5	3.93E-05	7.23E-05	1.26E-04
	10	1.78E-04	2.89E-04	4.23E-04
	15	4.10E-04	5.97E-04	7.69E-04
	20	6.97E-04	1.06E-03	1.36E-03
	25	8.86E-04	1.43E-03	1.94E-03
	28	1.09E-03	1.79E-03	2.38E-03
	30	1.37E-03	2.10E-03	2.69E-03
	32	1.64E-03	2.59E-03	3.23E-03
	34	1.67E-03	2.54E-03	3.32E-03
	36	1.88E-03	3.02E-03	3.82E-03
	38	1.80E-03	3.16E-03	4.40E-03
	40	1.54E-03	3.15E-03	4.56E-03
	45	1.50E-03	2.88E-03	4.51E-03
	50	1.41E-03	2.78E-03	4.25E-03
	60	1.41E-03	2.24E-03	2.99E-03
	70	1.35E-03	2.31E-03	3.19E-03
	75	1.30E-03	2.13E-03	2.97E-03

Table XVII. Concluded.

		k =		
Component	θ, deg	0.064	0.115	0.169
$\overline{C}_{l_p}$	0	-0.1870	-0.1833	-0.1783
	5	-0.1504	-0.1479	-0.1466
	10	-0.1835	-0.1802	-0.1761
	15	-0.1916	-0.1903	-0.1875
	20	-0.1955	-0.1879	-0.1820
	25	-0.2695	-0.2252	-0.2016
	28	-0.3173	-0.2323	-0.1934
	30	-0.3828	-0.2243	-0.1680
	32	-0.3635	-0.2026	-0.1235
	34	-0.3681	-0.1955	-0.1241
	36	-0.2730	-0.1654	-0.0952
	38	-0.1966	-0.1304	-0.0481
	40	-0.1002	-0.0870	-0.0646
	45	-0.0199	-0.0300	-0.0174
	50	0.1474	0.0741	0.0167
	60	0.0929	0.0349	0.0073
	70	0.2763	0.1492	0.0530
	75	0.2403	0.1317	0.0618
$s\left(\overline{C}_{l_p}\right)$	0	8.32E-04	7.96E-04	8.93E-04
	5	6.14E-04	6.28E-04	7.48E-04
	10	2.79E-03	2.51E-03	2.51E-03
	15	6.41E-03	5.20E-03	4.55E-03
	20	1.09E-02	9.19E-03	8.06E-03
	25	1.38E-02	1.24E-02	1.15E-02
	28	1.70E-02	1.55E-02	1.41E-02
	30	2.14E-02	1.82E-02	1.59E-02
	32	2.57E-02	2.25E-02	1.91E-02
	34	2.60E-02	2.21E-02	1.97E-02
	36	2.93E-02	2.63E-02	2.26E-02
	38	2.81E-02	2.75E-02	2.60E-02
	40	2.41E-02	2.74E-02	2.70E-02
	45	2.34E-02	2.50E-02	2.67E-02
	50	2.20E-02	2.42E-02	2.52E-02
	60	2.21E-02	1.95E-02	1.77E-02
	70	2.10E-02	2.01E-02	1.89E-02
	75	2.03E-02	1.85E-02	1.75E-02

Table XVIII. In-phase and out-of-phase components of rolling moment coefficient. $\Phi_A = 30$ deg, $\Phi_0 = 45$ deg.

		k =		
Component	θ, deg	0.064	0.115	0.169
$\overline{C}_{l_\beta}$	0	-0.0002	-0.0015	-0.0020
	5	-0.0009	-0.0023	-0.0029
	10	-0.0027	-0.0035	-0.0041
	15		-0.0040	-0.0047
	20	-0.0042	-0.0052	-0.0060
	25	-0.0131	-0.0140	-0.0140
	28	-0.0267	-0.0251	-0.0233
	30	-0.0416	-0.0347	-0.0283
	32	-0.0600	-0.0494	-0.0363
	34	-0.0688	-0.0610	-0.0488
	36	-0.0717	-0.0672	-0.0553
	38	-0.0698	-0.0676	-0.0571
	40	-0.0664	-0.0627	-0.0540
	45	-0.0538	-0.0534	-0.0450
	50	-0.0507	-0.0460	-0.0376
	60	-0.0507	-0.0469	-0.0418
	70	-0.0473	-0.0410	-0.0305
	75	-0.0456	-0.0390	-0.0286
$s\left(\overline{C}_{l_\beta}\right)$	0	4.47E-05	8.63E-05	1.41E-04
	5	5.99E-05	9.12E-05	1.46E-04
	10	2.72E-04	3.96E-04	5.14E-04
	15		6.66E-04	8.36E-04
	20	8.58E-04	1.15E-03	1.42E-03
	25	1.21E-03	1.80E-03	2.33E-03
	28	1.55E-03	2.19E-03	2.78E-03
	30	1.69E-03	2.32E-03	2.88E-03
	32	1.95E-03	2.57E-03	3.10E-03
	34	2.11E-03	2.89E-03	3.59E-03
	36	2.35E-03	3.26E-03	3.94E-03
	38	2.55E-03	3.64E-03	4.50E-03
	40	2.67E-03	4.01E-03	5.15E-03
	45	2.91E-03	4.56E-03	6.12E-03
	50	2.66E-03	4.10E-03	5.80E-03
	60	2.48E-03	3.71E-03	5.20E-03
	70	2.79E-03	3.87E-03	5.14E-03
	75	2.69E-03	3.70E-03	4.66E-03

Table XVIII. Concluded.

		k =		
Component	θ, deg	0.064	0.115	0.169
$\overline{C}_{l_p}$	0	-0.1913	-0.1850	-0.1795
	5	-0.1582	-0.1532	-0.1500
	10	-0.1787	-0.1723	-0.1680
	15		-0.1891	-0.1829
	20	-0.1993	-0.1908	-0.1839
	25	-0.1861	-0.1754	-0.1682
	28	-0.1399	-0.1271	-0.1241
	30	-0.0100	-0.0305	-0.0568
	32	0.0796	0.0607	0.0172
	34	0.0878	0.0926	0.0520
	36	0.1233	0.1170	0.0894
	38	0.1535	0.1406	0.1162
	40	0.1782	0.1750	0.1506
	45	0.1768	0.1747	0.1684
	50	0.2659	0.2237	0.1969
	60	0.2565	0.2173	0.1724
	70	0.3841	0.2563	0.2133
	75	0.3363	0.2695	0.2188
$s\left(\overline{C}_{l_p}\right)$	0	6.98E-04	7.50E-04	8.36E-04
	5	9.36E-04	7.93E-04	8.64E-04
	10	4.24E-03	3.44E-03	3.04E-03
	15		5.79E-03	4.95E-03
	20	1.34E-02	9.97E-03	8.38E-03
	25	1.89E-02	1.56E-02	1.38E-02
	28	2.42E-02	1.91E-02	1.64E-02
	30	2.65E-02	2.02E-02	1.70E-02
	32	3.04E-02	2.23E-02	1.84E-02
	34	3.29E-02	2.51E-02	2.12E-02
	36	3.66E-02	2.83E-02	2.33E-02
	38	3.98E-02	3.16E-02	2.66E-02
	40	4.18E-02	3.49E-02	3.05E-02
	45	4.54E-02	3.97E-02	3.62E-02
	50	4.16E-02	3.57E-02	3.43E-02
	60	3.87E-02	3.23E-02	3.08E-02
	70	4.36E-02	3.36E-02	3.04E-02
	75	4.21E-02	3.22E-02	2.76E-02

Table XIX. In-phase and out-of-phase components of rolling moment coefficient. $\Phi_A = 30$ deg, $\Phi_0 = 60$ deg.

		k =		
Component	θ, deg	0.064	0.115	0.169
$\overline{C}_{l_\beta}$	0	-0.0013	-0.0022	-0.0038
	5	0.0008	-0.0001	-0.0015
	10	0.0063	0.0055	0.0047
	15	0.0157	0.0153	0.0131
	20	0.0268	0.0261	0.0254
	25	0.0315	0.0329	0.0335
	28	0.0280	0.0333	0.0379
	30	0.0201	0.0308	0.0399
	32		0.0283	0.0404
	34	0.0202	0.0278	0.0383
	36	0.0255	0.0310	0.0413
	38	0.0345	0.0394	0.0479
	40	0.0424	0.0501	0.0621
	45	0.0567	0.0669	0.0807
	50	0.0647	0.0751	0.0881
	60	0.0625	0.0726	0.0848
	70	0.0769	0.0882	0.1008
	75	0.0795		
$s\left(\overline{C}_{l_\beta}\right)$	0	3.66E-05	8.20E-05	1.33E-04
	5	5.66E-05	9.23E-05	1.45E-04
	10	2.53E-04	3.45E-04	4.23E-04
	15	4.71E-04	6.35E-04	7.54E-04
	20	8.07E-04	1.09E-03	1.31E-03
	25	1.39E-03	1.87E-03	2.21E-03
	28	1.97E-03	2.39E-03	2.71E-03
	30	2.41E-03	2.75E-03	2.97E-03
	32		3.41E-03	3.45E-03
	34	3.11E-03	3.94E-03	4.20E-03
	36	3.31E-03	4.24E-03	4.71E-03
	38	3.53E-03	4.50E-03	5.05E-03
	40	3.73E-03	4.89E-03	5.52E-03
	45	4.00E-03	5.44E-03	6.22E-03
	50	4.29E-03	5.76E-03	6.91E-03
	60	4.71E-03	6.05E-03	7.25E-03
	70	4.80E-03	6.11E-03	7.20E-03
	75	4.79E-03		

Table XIX. Concluded.

		k =		
Component	θ, deg	0.064	0.115	0.169
$\overline{C}_{l_p}$	0	-0.1914	-0.1864	-0.1804
	5	-0.1670	-0.1619	-0.1575
	10	-0.1746	-0.1681	-0.1628
	15	-0.2016	-0.1929	-0.1867
	20	-0.2091	-0.1979	-0.1910
	25	-0.1784	-0.1698	-0.1690
	28	-0.0894	-0.1141	-0.1389
	30	0.0200	-0.0255	-0.0767
	32		0.0033	-0.0299
	34	0.0225	0.0138	-0.0028
	36	0.0492	0.0290	0.0134
	38	0.0896	0.0530	0.0329
	40	0.1189	0.0898	0.0479
	45	0.1545	0.1120	0.0873
	50	0.1516	0.1071	0.0888
	60	0.1226	0.1236	0.0965
	70	0.1916	0.1226	0.1065
	75	0.1458		
$s\left(\overline{C}_{l_p}\right)$	0	5.71E-04	7.13E-04	7.89E-04
	5	8.85E-04	8.02E-04	8.60E-04
	10	3.96E-03	3.00E-03	2.50E-03
	15	7.36E-03	5.52E-03	4.46E-03
	20	1.26E-02	9.51E-03	7.74E-03
	25	2.17E-02	1.63E-02	1.31E-02
	28	3.08E-02	2.08E-02	1.60E-02
	30	3.77E-02	2.40E-02	1.76E-02
	32		2.96E-02	2.04E-02
	34	4.86E-02	3.42E-02	2.49E-02
	36	5.17E-02	3.69E-02	2.79E-02
	38	5.52E-02	3.92E-02	2.99E-02
	40	5.83E-02	4.25E-02	3.26E-02
	45	6.25E-02	4.73E-02	3.68E-02
	50	6.70E-02	5.01E-02	4.09E-02
	60	7.37E-02	5.26E-02	4.29E-02
	70	7.50E-02	5.31E-02	4.26E-02
	75	7.49E-02		

Table XX. In-phase and out-of-phase components of rolling moment coefficient. $\Phi_A = 10$ deg, $Re = 0.6x10^6$.

		k =			
Component	θ, deg	0.188	0.228	0.322	0.505
$\overline{C}_{l_\beta}$	0	0.0016	0.0023	-0.0002	-0.0052
	5	-0.0050	-0.0048	-0.0057	-0.0092
	10	-0.0177	-0.0176	-0.0186	-0.0092
	15	-0.0415	-0.0423	-0.0441	-0.0448
	20	-0.0697	-0.0730	-0.0741	-0.0718
	25	-0.0946	-0.0974	-0.1016	-0.0993
	28	-0.1198	-0.1242	-0.1292	-0.1284
	30	-0.1439	-0.1482	-0.1489	-0.1526
	32	-0.1610	-0.1660	-0.1686	-0.1734
	34	-0.1726	-0.1789	-0.1834	-0.1919
	36	-0.1713	-0.1825	-0.1882	-0.2017
	38	-0.1623	-0.1634	-0.1840	-0.2016
	40	-0.1317	-0.1544	-0.1765	-0.1933
	45	-0.0703	-0.0881	-0.1227	-0.1158
	50	-0.0536	-0.0559	-0.0571	-0.0616
	60	-0.0769	-0.0765	-0.0682	-0.0583
	70	-0.0836	-0.0842	-0.0718	-0.0688
	75	-0.0822	-0.0860	-0.0758	-0.0691
$s(\overline{C}_{l_\beta})$	0	6.58E-05	6.83E-05	1.43E-04	5.16E-04
	5	6.53E-05	7.38E-05	1.35E-04	5.36E-04
	10	9.47E-05	1.06E-04	1.98E-04	5.36E-04
	15	1.98E-04	2.25E-04	2.78E-04	5.92E-04
	20	3.92E-04	4.24E-04	5.37E-04	8.49E-04
	25	4.95E-04	5.97E-04	7.34E-04	1.01E-03
	28	5.79E-04	6.62E-04	8.27E-04	1.19E-03
	30	7.21E-04	7.70E-04	8.45E-04	1.37E-03
	32	9.68E-04	1.18E-03	1.14E-03	1.66E-03
	34	1.26E-03	1.66E-03	1.74E-03	2.31E-03
	36	1.82E-03	2.17E-03	2.32E-03	3.41E-03
	38	2.66E-03	2.62E-03	3.03E-03	3.12E-03
	40	2.60E-03	3.25E-03	3.64E-03	4.18E-03
	45	3.59E-03	4.42E-03	4.18E-03	4.27E-03
	50	1.50E-03	1.77E-03	2.01E-03	3.41E-03
	60	9.72E-04	9.91E-04	1.14E-03	1.72E-03
	70	1.22E-03	1.30E-03	1.63E-03	2.25E-03
	75	1.52E-03	1.59E-03	1.77E-03	2.46E-03

Table XX. Concluded.

Component	θ, deg	k = 0.188	0.228	0.322	0.505
$\overline{C}_{l_p}$	0	-0.1834	-0.1789	-0.1732	-0.1628
	5	-0.1506	-0.1487	-0.1430	-0.1346
	10	-0.2061	-0.2022	-0.1943	-0.1346
	15	-0.2053	-0.2033	-0.1866	-0.1698
	20	-0.2121	-0.2020	-0.1727	-0.1494
	25	-0.2049	-0.2066	-0.1821	-0.1678
	28	-0.2610	-0.2486	-0.1983	-0.1645
	30	-0.2867	-0.2658	-0.2012	-0.1772
	32	-0.3658	-0.3129	-0.2269	-0.1837
	34	-0.4277	-0.3422	-0.2446	-0.1754
	36	-0.5086	-0.3877	-0.2916	-0.1877
	38	-0.5879	-0.4852	-0.3105	-0.1971
	40	-0.6364	-0.5536	-0.3439	-0.1755
	45	-0.5224	-0.4730	-0.2971	-0.1716
	50	-0.2493	-0.2524	-0.2346	-0.2072
	60	-0.1398	-0.1384	-0.1479	-0.1376
	70	-0.1362	-0.1379	-0.1431	-0.1598
	75	-0.1466	-0.1320	-0.1478	-0.1722
$s\left(\overline{C}_{l_p}\right)$	0	3.50E-04	2.99E-04	4.45E-04	1.02E-03
	5	3.47E-04	3.24E-04	4.19E-04	1.06E-03
	10	5.04E-04	4.67E-04	6.14E-04	1.06E-03
	15	1.05E-03	9.88E-04	8.65E-04	1.17E-03
	20	2.09E-03	1.86E-03	1.67E-03	1.68E-03
	25	2.63E-03	2.62E-03	2.28E-03	1.99E-03
	28	3.08E-03	2.90E-03	2.57E-03	2.36E-03
	30	3.83E-03	3.38E-03	2.63E-03	2.72E-03
	32	5.15E-03	5.18E-03	3.54E-03	3.29E-03
	34	6.69E-03	7.28E-03	5.41E-03	4.58E-03
	36	9.69E-03	9.54E-03	7.20E-03	6.75E-03
	38	1.41E-02	1.15E-02	9.41E-03	6.18E-03
	40	1.38E-02	1.43E-02	1.13E-02	8.28E-03
	45	1.91E-02	1.94E-02	1.30E-02	8.46E-03
	50	7.96E-03	7.78E-03	6.24E-03	6.76E-03
	60	5.17E-03	4.35E-03	3.54E-03	3.41E-03
	70	6.47E-03	5.72E-03	5.06E-03	4.46E-03
	75	8.09E-03	6.98E-03	5.51E-03	4.88E-03

12 Figures

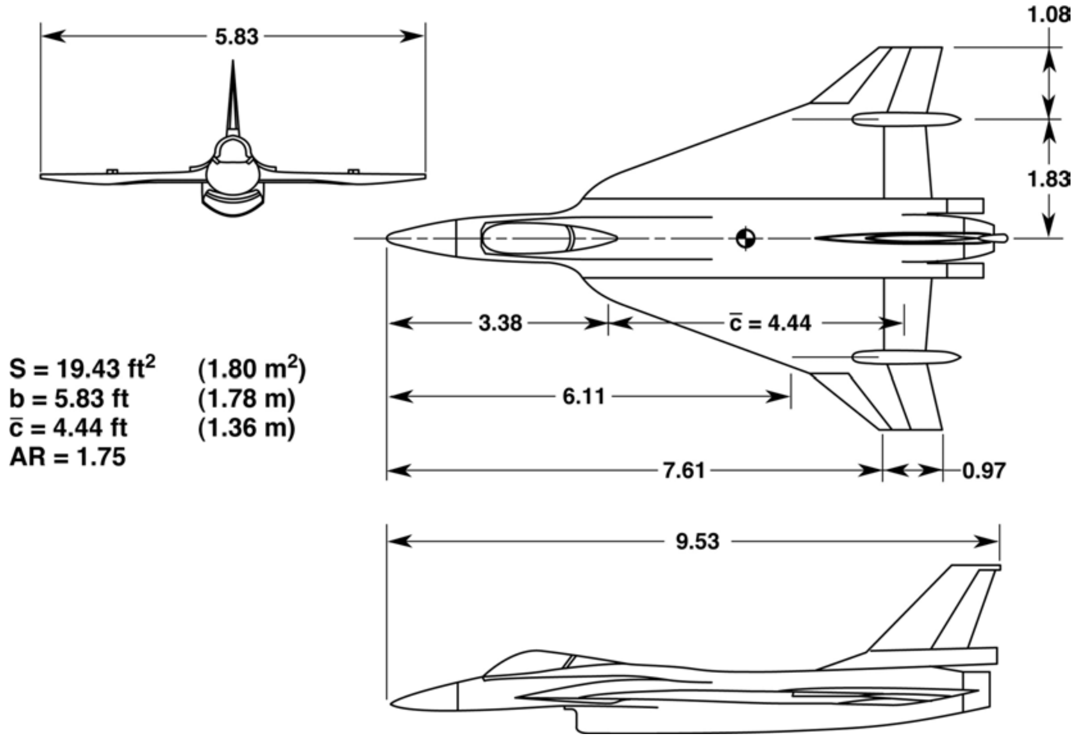


Figure 1. Three view sketch of F16XL 18% scale model (dimensions in feet).

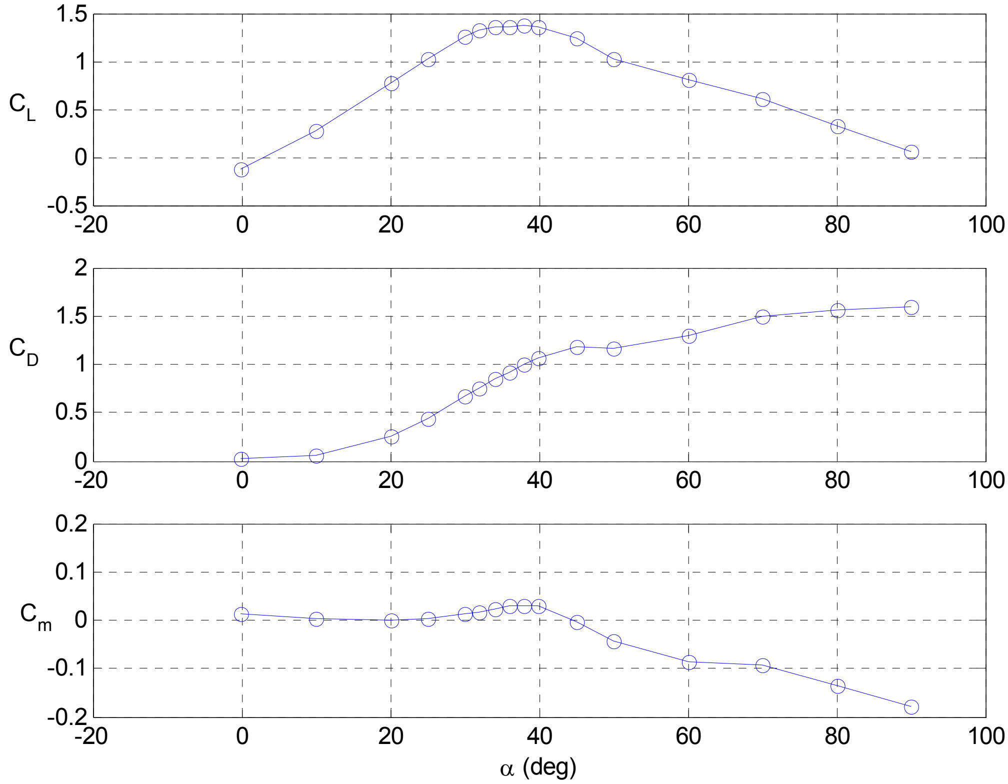


Figure 2. Variation of longitudinal coefficients with angle of attack.

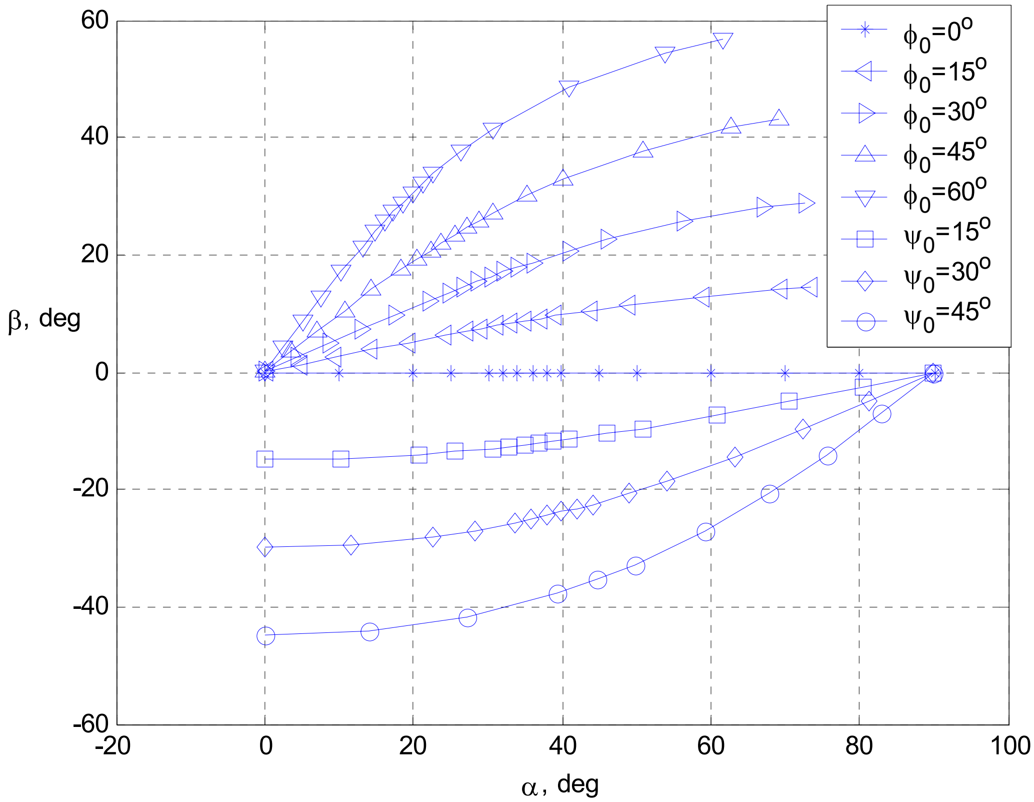


Figure 3. Computed values of α and β for each static measurement test point.

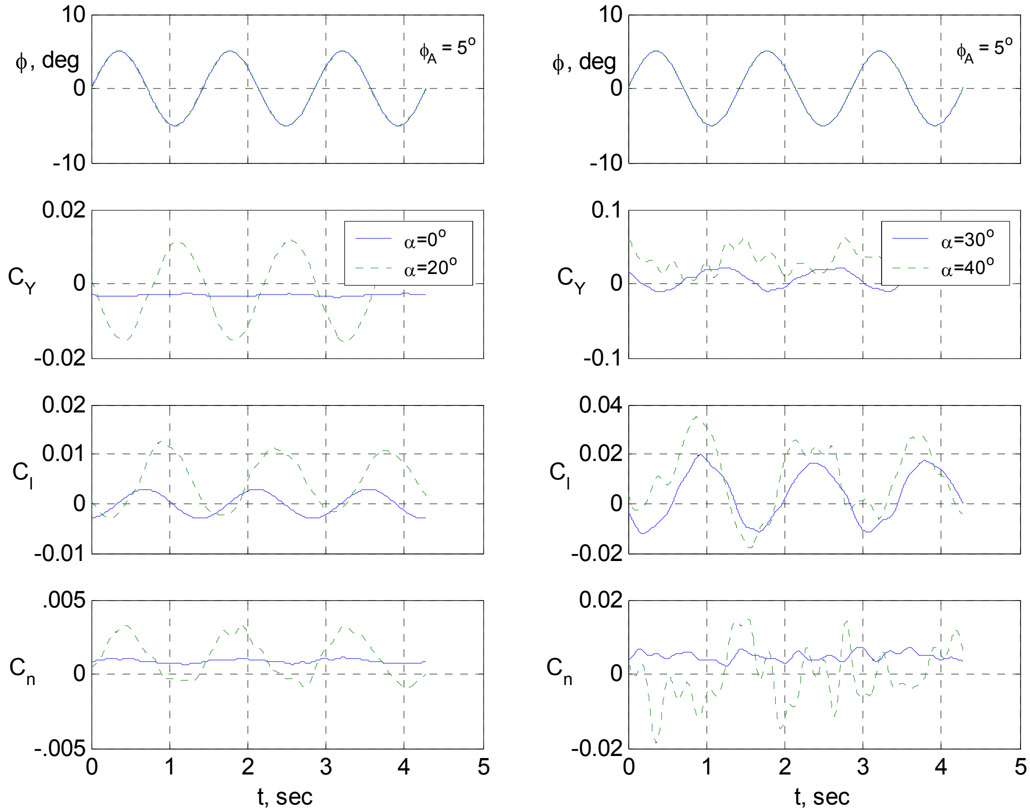


Figure 4. Time histories of roll angle and lateral coefficients, k=0.171.

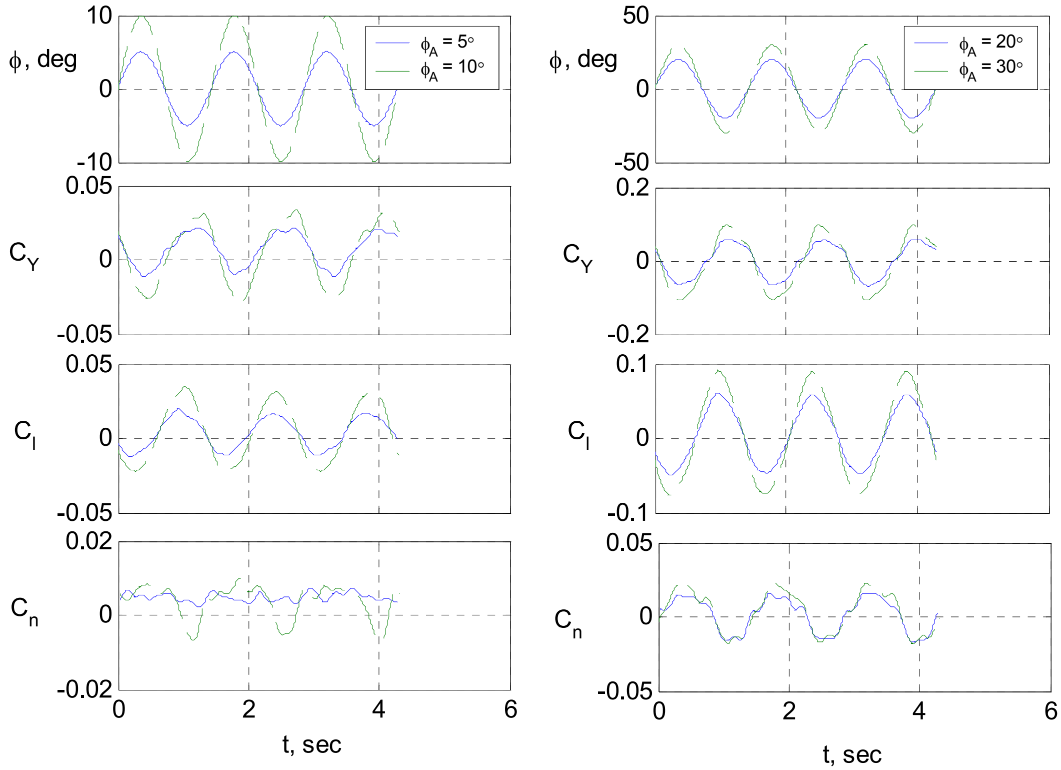


Figure 5. Time histories of roll angle and lateral coefficients, α_0=30^o, k=0.171.

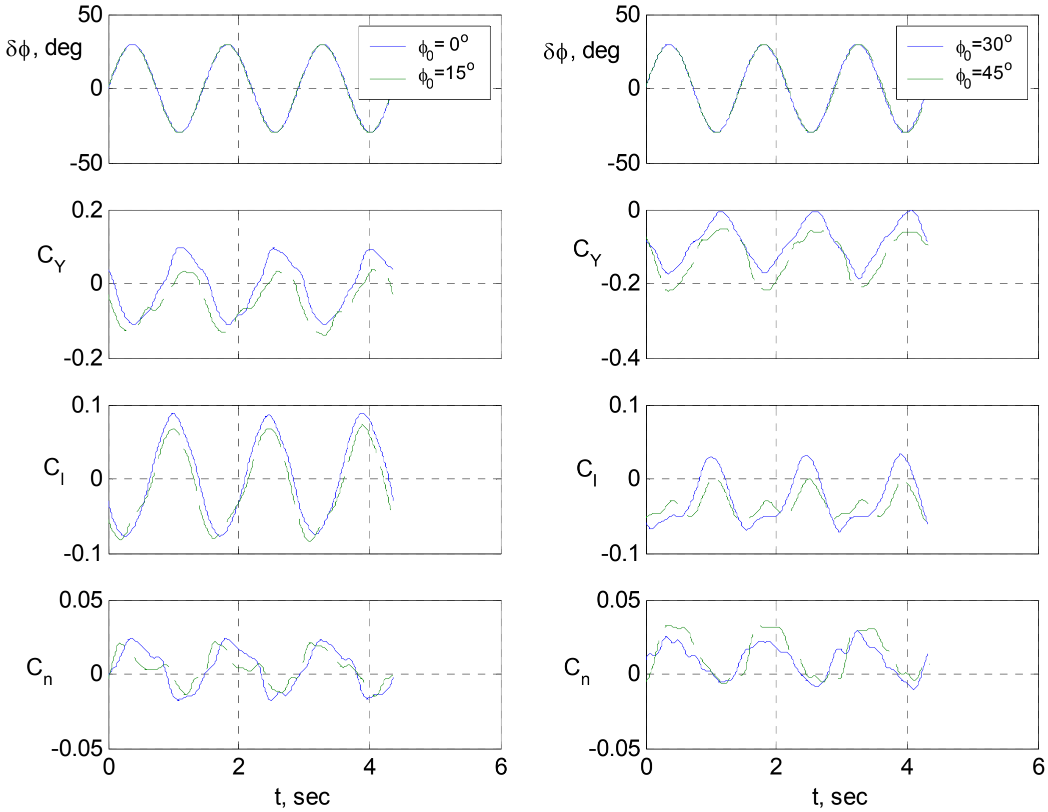


Figure 6. Time histories of roll angle, $\delta\phi = \phi - \phi_0$, and lateral coefficients, k=0.168, θ_0=30°, ϕ_A= 30°.

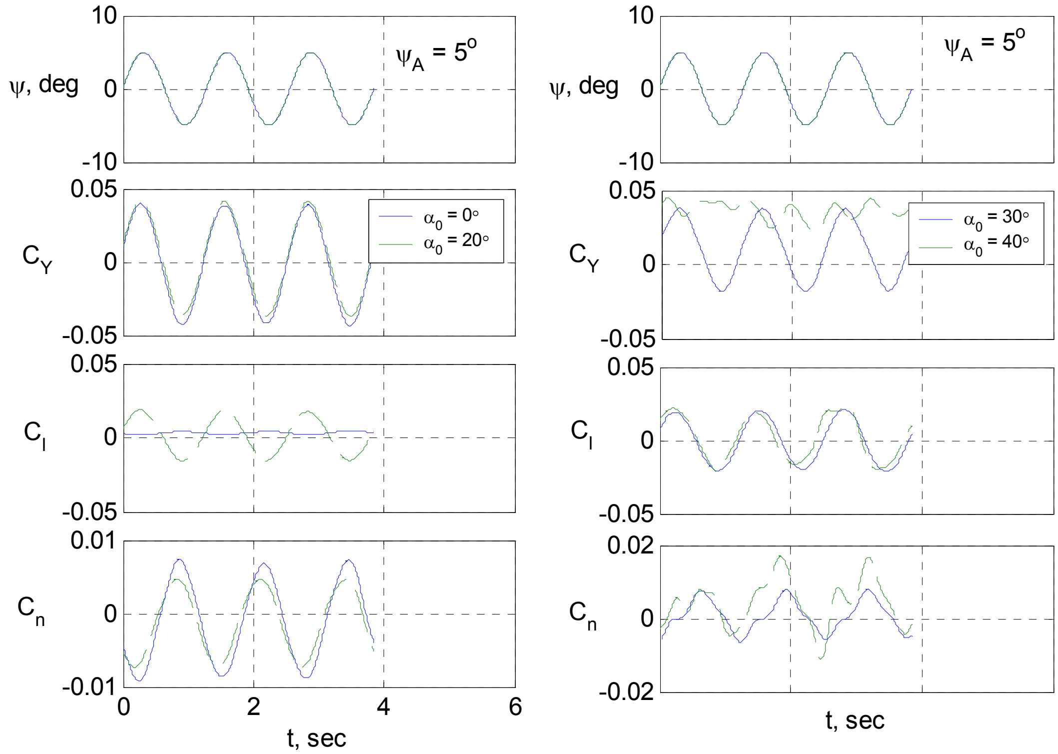


Figure 7. Time histories of yaw angle and lateral coefficients, k=0.190.

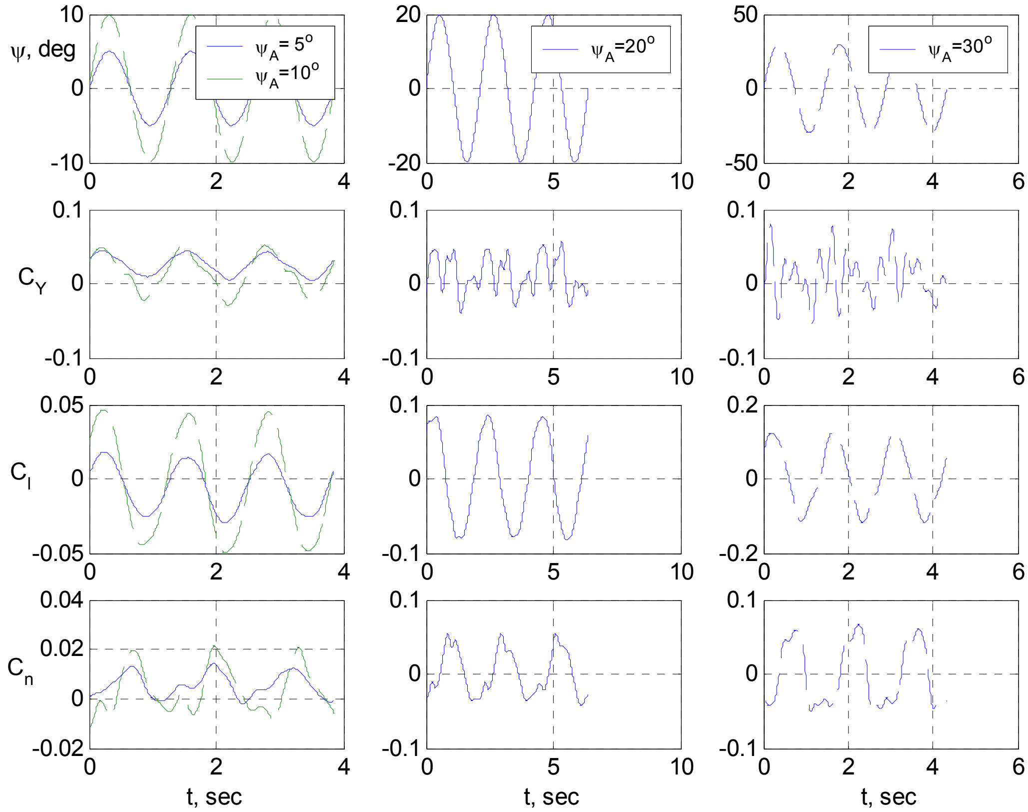


Figure 8. Time histories of yaw angle and lateral coefficients, k = 0.190, $\alpha_0 = 36^o$ (for Ψ_A=20, k=.115; for Ψ_A=30, k=.168).

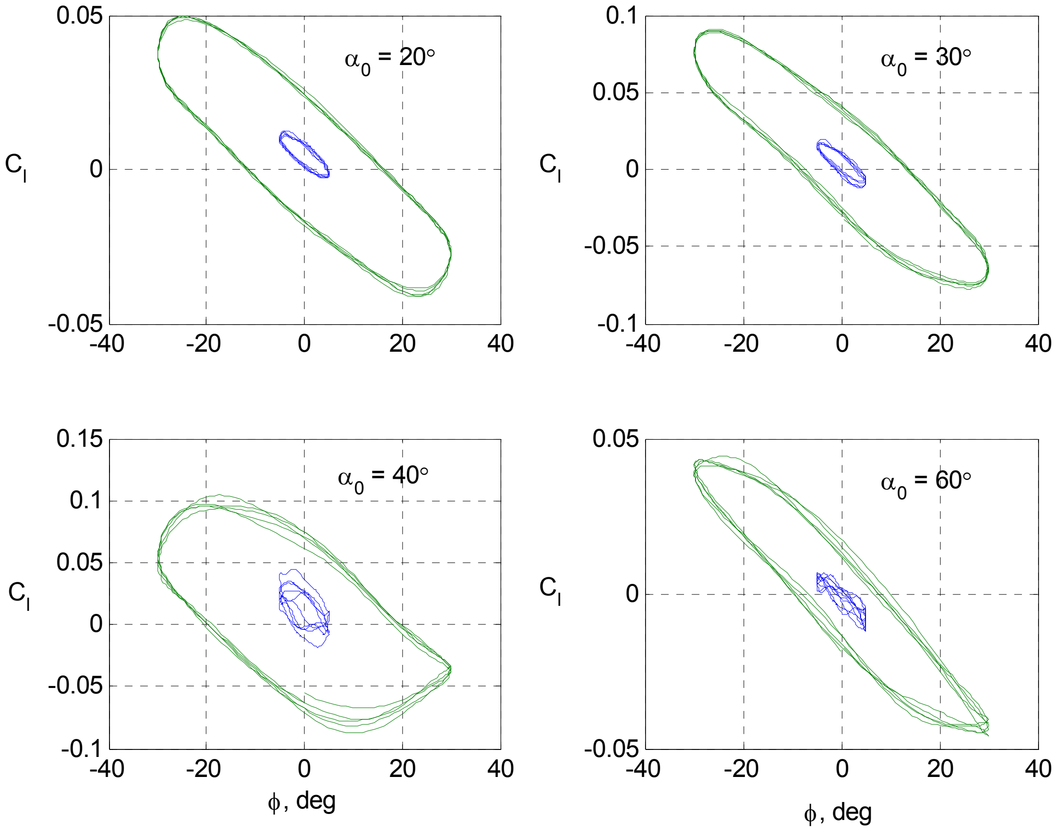


Figure 9a. Effect of angle of attack and amplitude on lateral coefficient, C_l, for rolling oscillations with k=0.190.

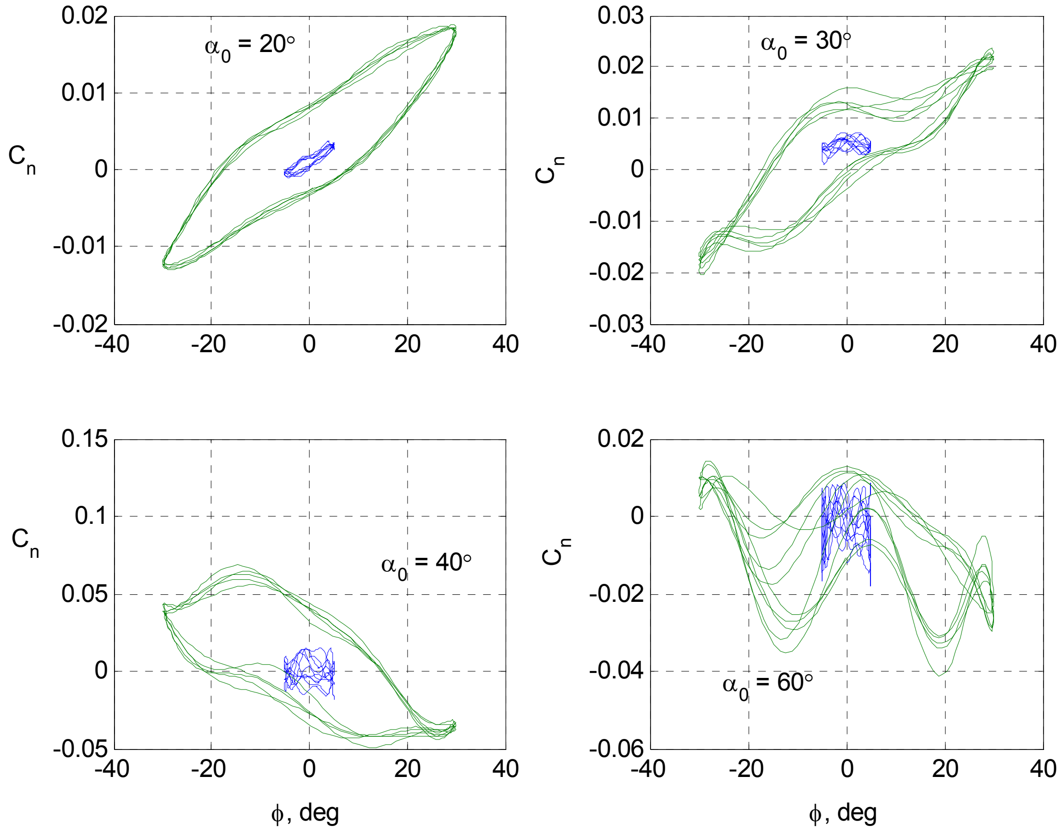


Figure 9b. Effect of angle of attack and amplitude on lateral coefficient, C_n, for rolling oscillations with k=0.190.

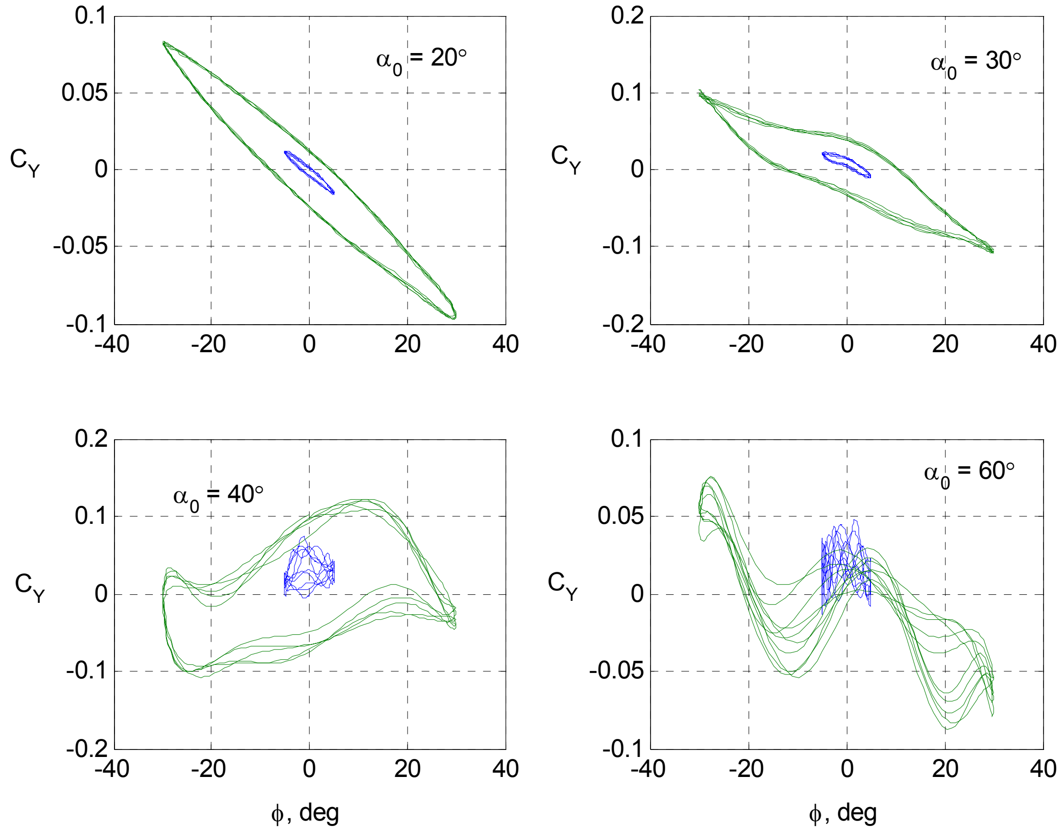


Figure 9c. Effect of angle of attack and amplitude on lateral coefficient, C_Y, for rolling oscillations with k=0.190.

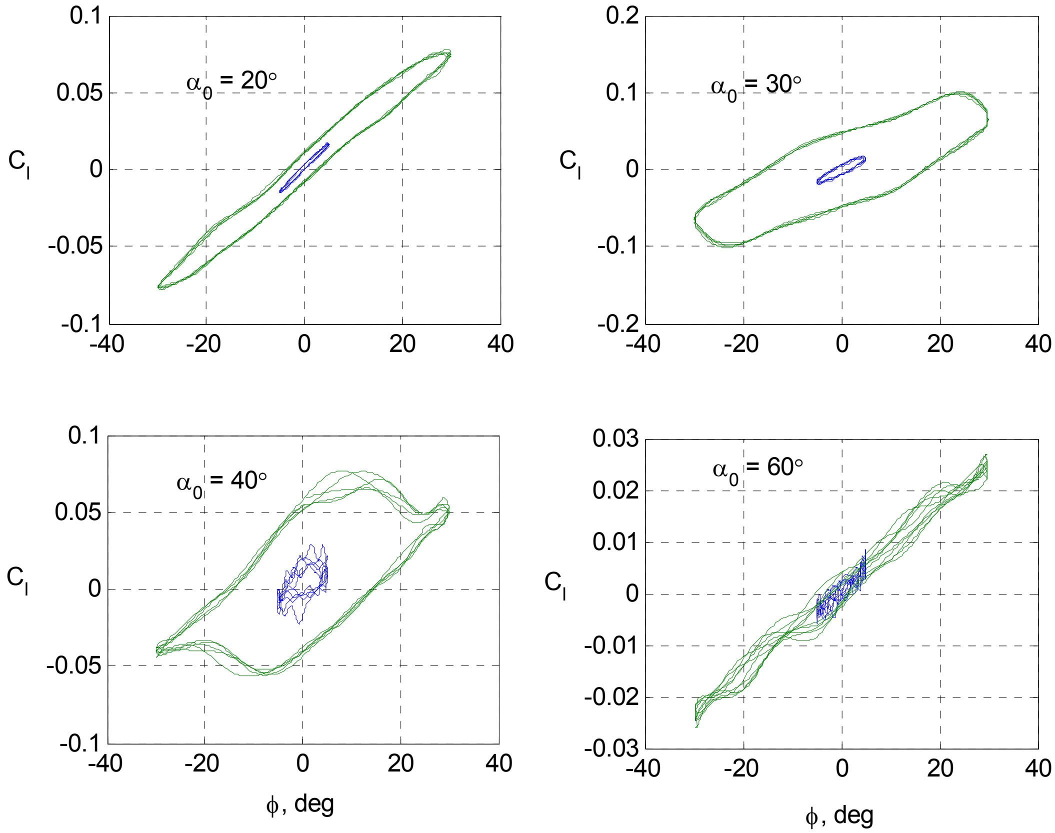


Figure 10a. Effect of angle of attack and amplitude on lateral coefficient, C_l, for yawing oscillations with k=0.073 (for Ψ_A=5°) and k=0.076 (for Ψ_A=30°).

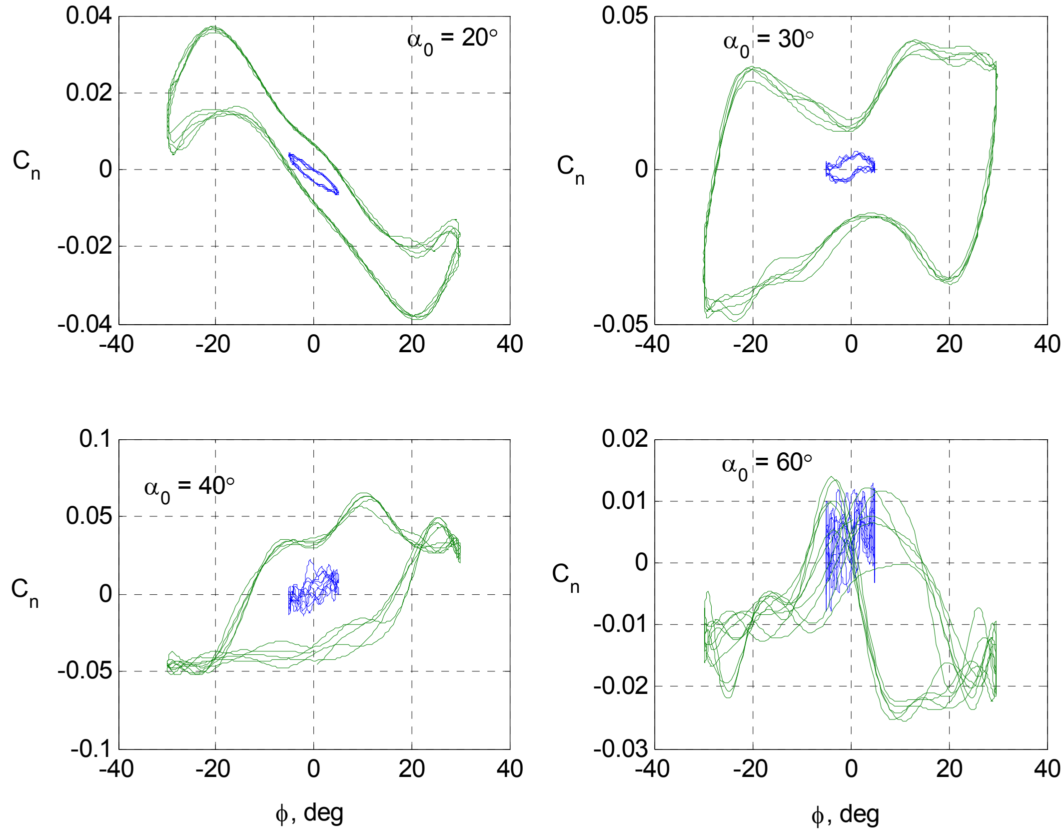


Figure 10b. Effect of angle of attack and amplitude on lateral coefficient, C_n, for yawing oscillations with k=0.073 (for Ψ_A=5°) and k=0.076 (for Ψ_A=30°).

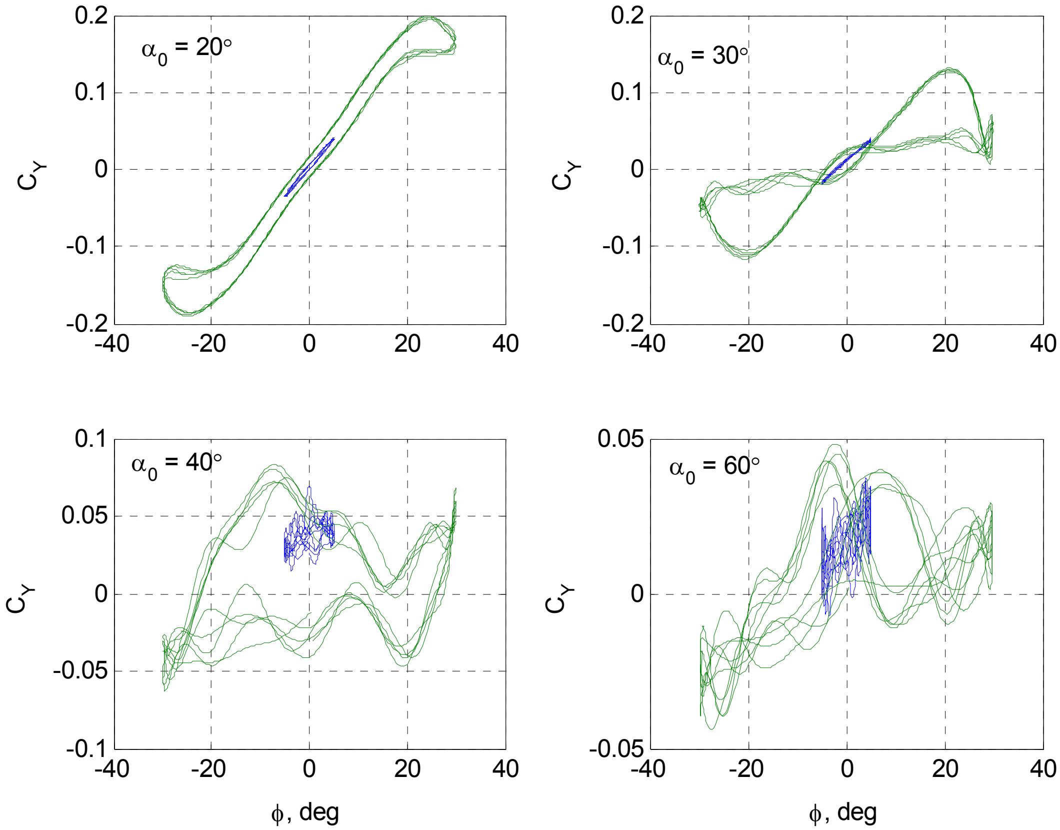


Figure 10c. Effect of angle of attack and amplitude on lateral coefficient, C_Y, for yawing oscillations with k=0.073 (for Ψ_A=5°) and k=0.076 (for Ψ_A=30°).

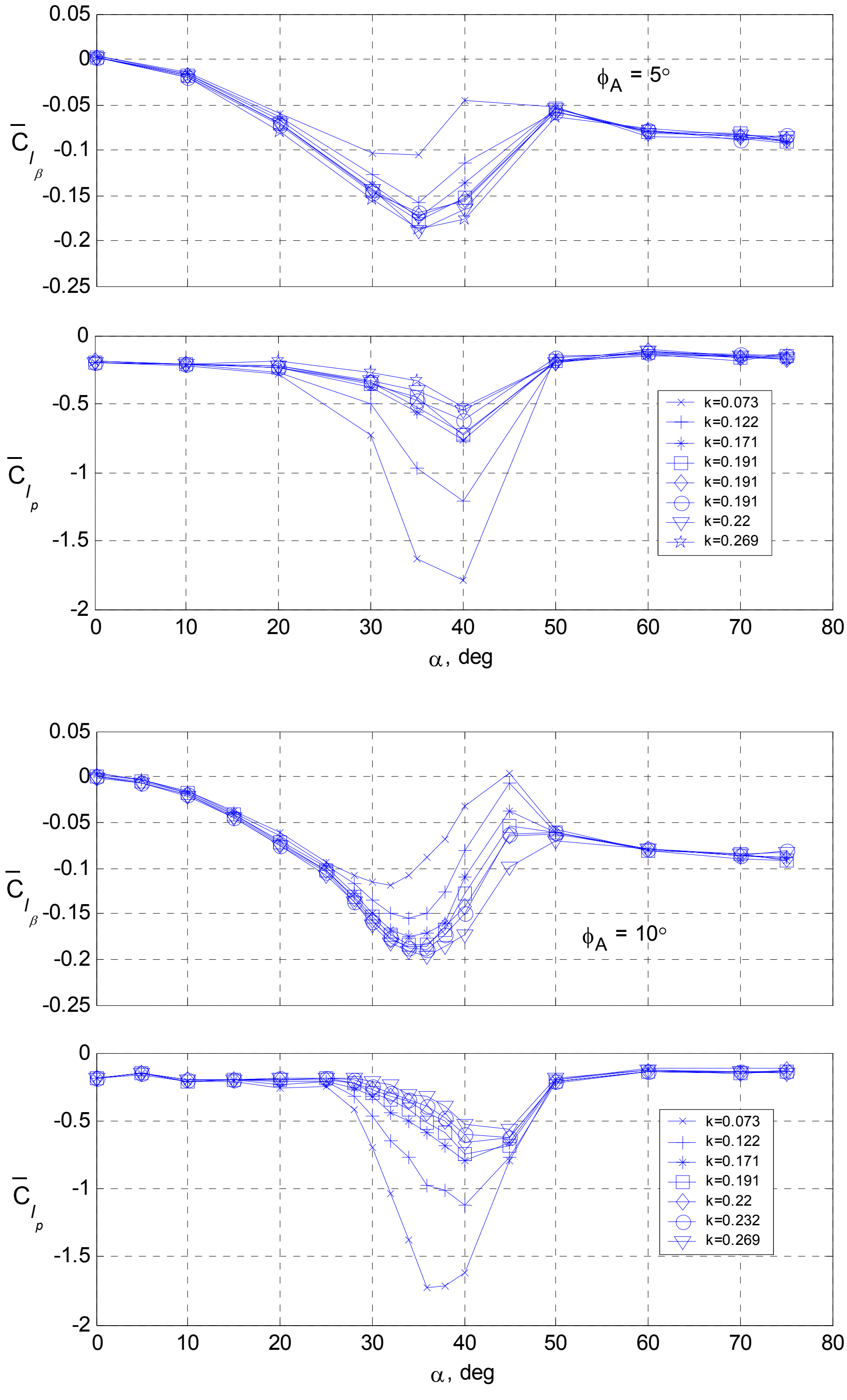
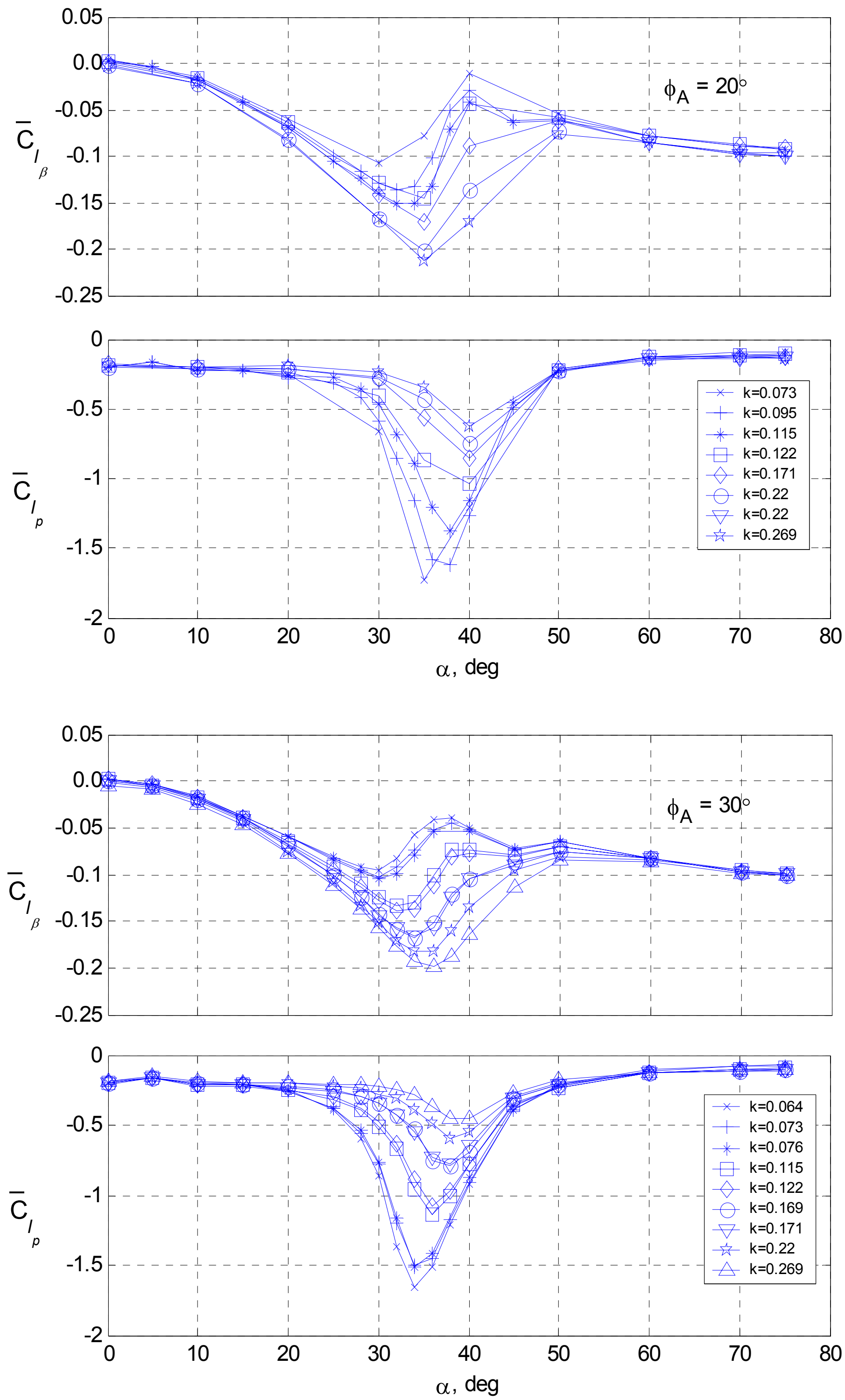


Figure 11. Variation of in-phase and out-of-phase components of rolling moment coefficient with angle of attack. Rolling oscillations.



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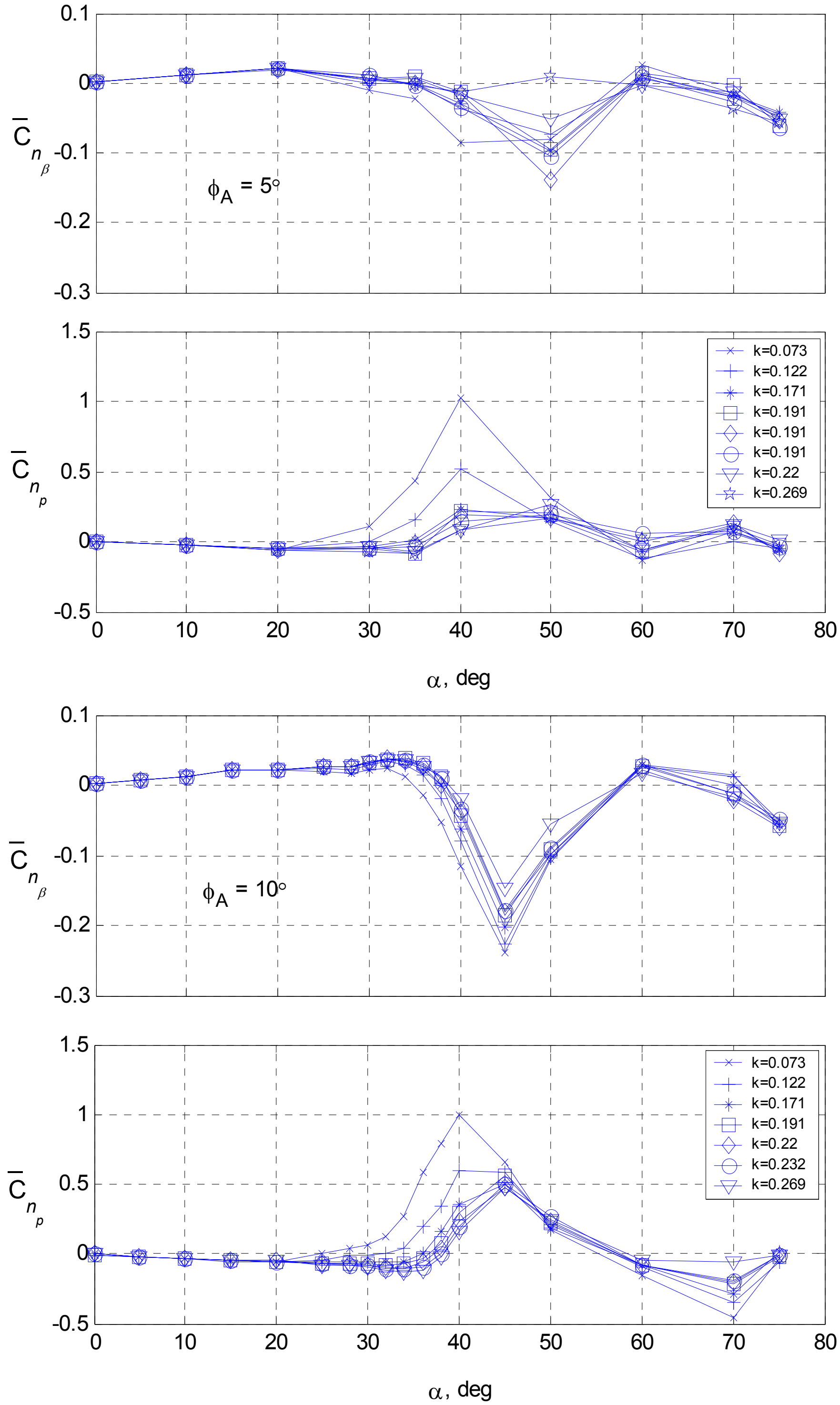
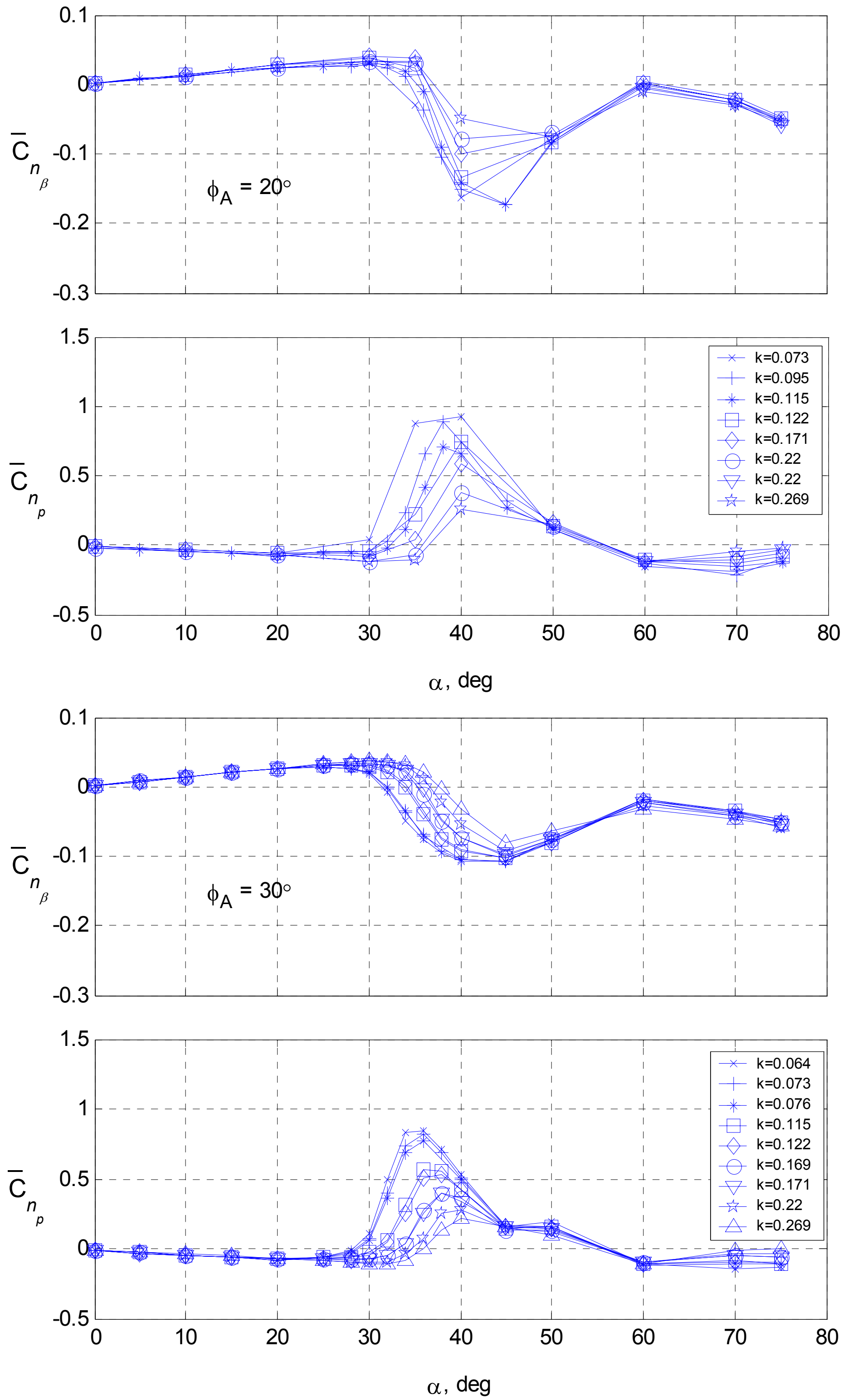


Figure 12. Variation of in-phase and out-of-phase components of yawing-moment coefficient with angle of attack. Rolling oscillations.



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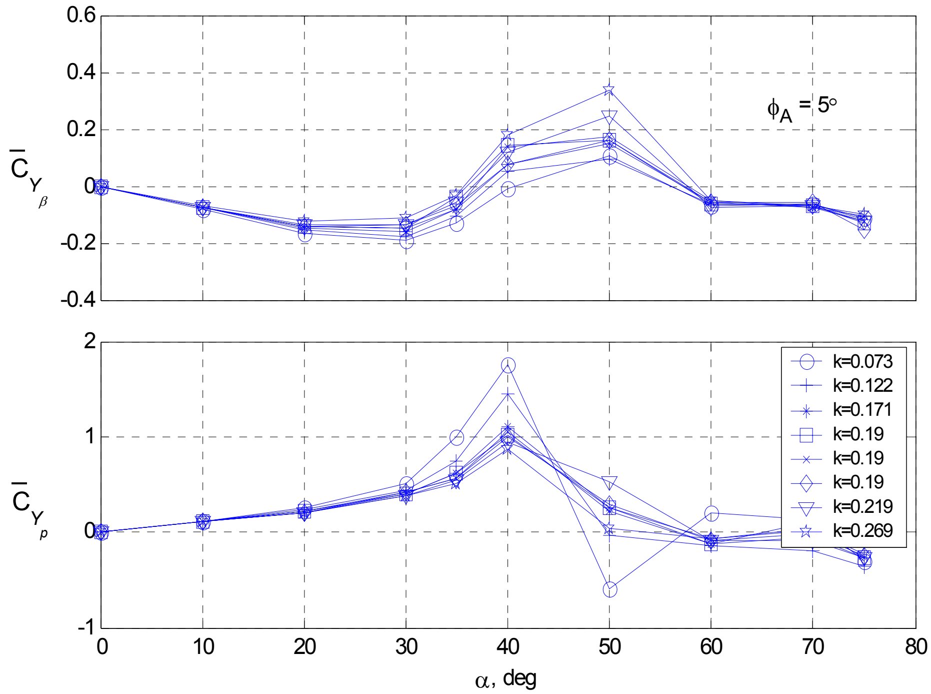


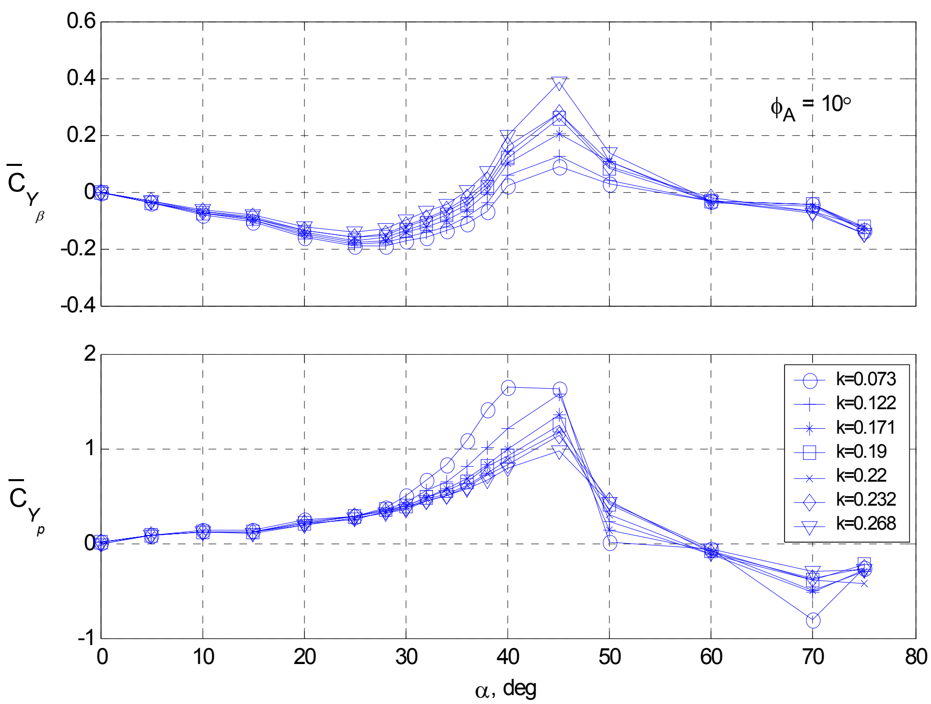
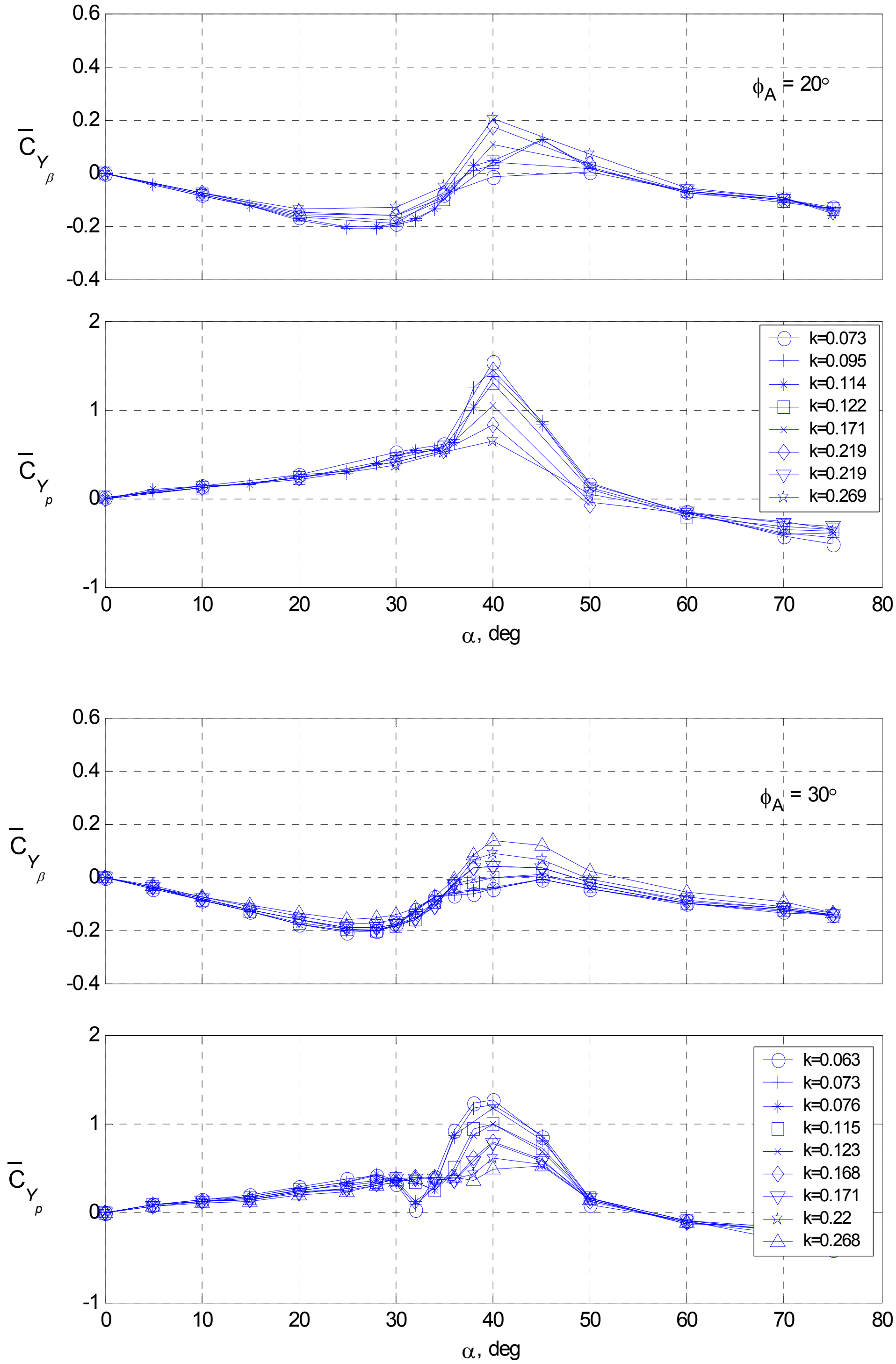


Figure 13. Variation of in-phase and out-of-phase components of side-force coefficient with angle of attack. Rolling oscillations.



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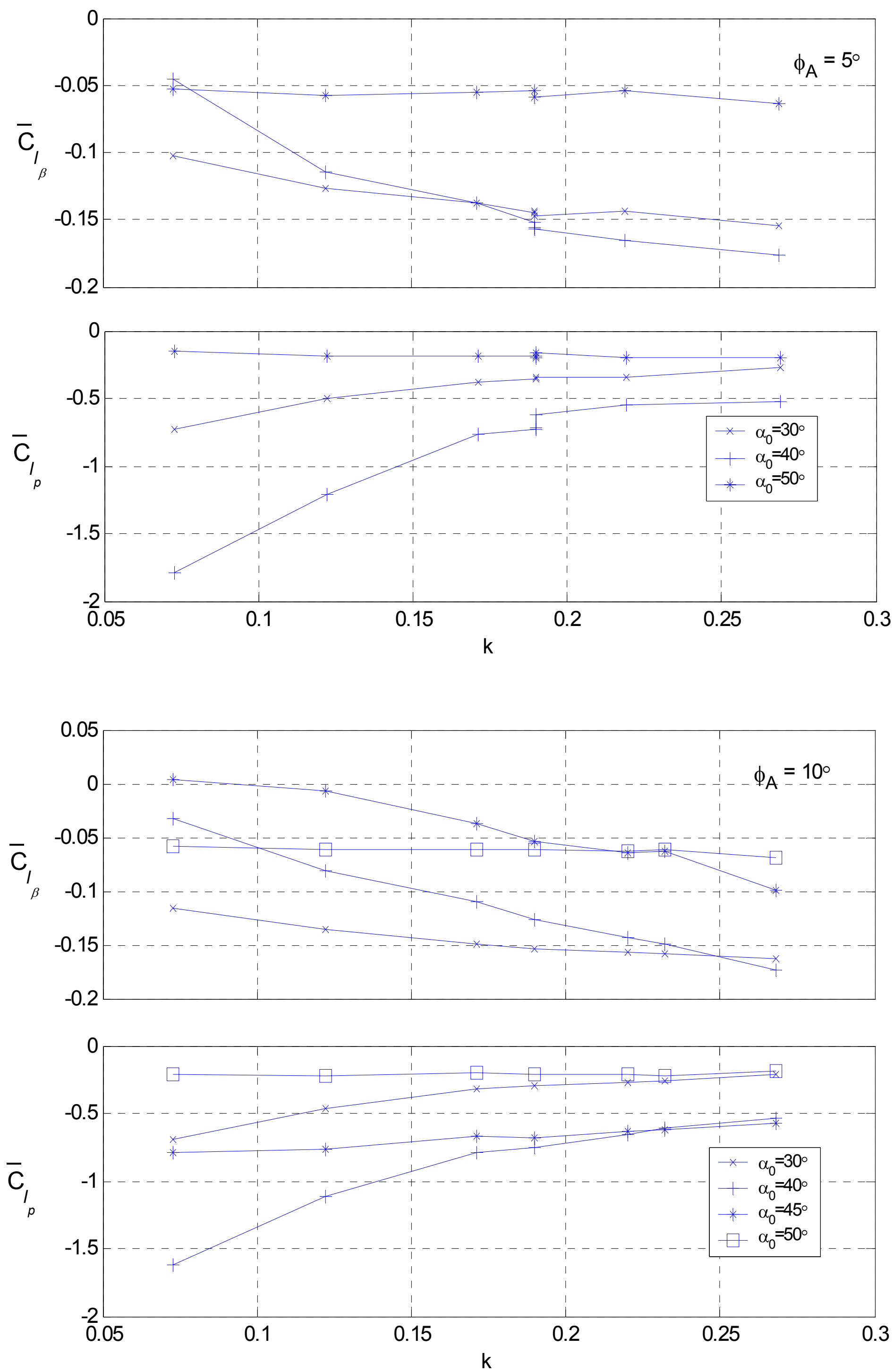
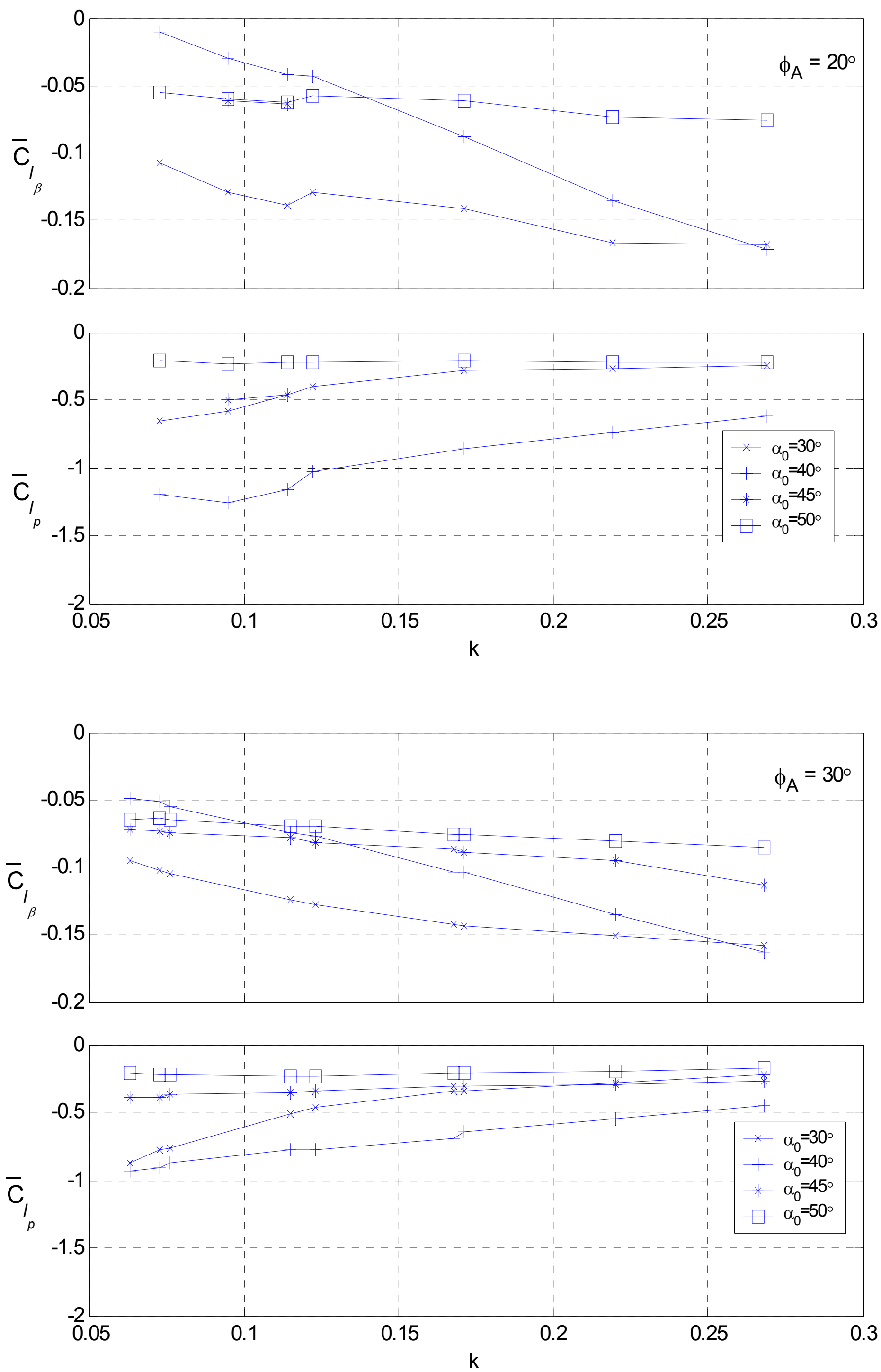


Figure 14. Variation of in-phase and out-of-phase components of rolling moment coefficient with frequency. Rolling oscillations.



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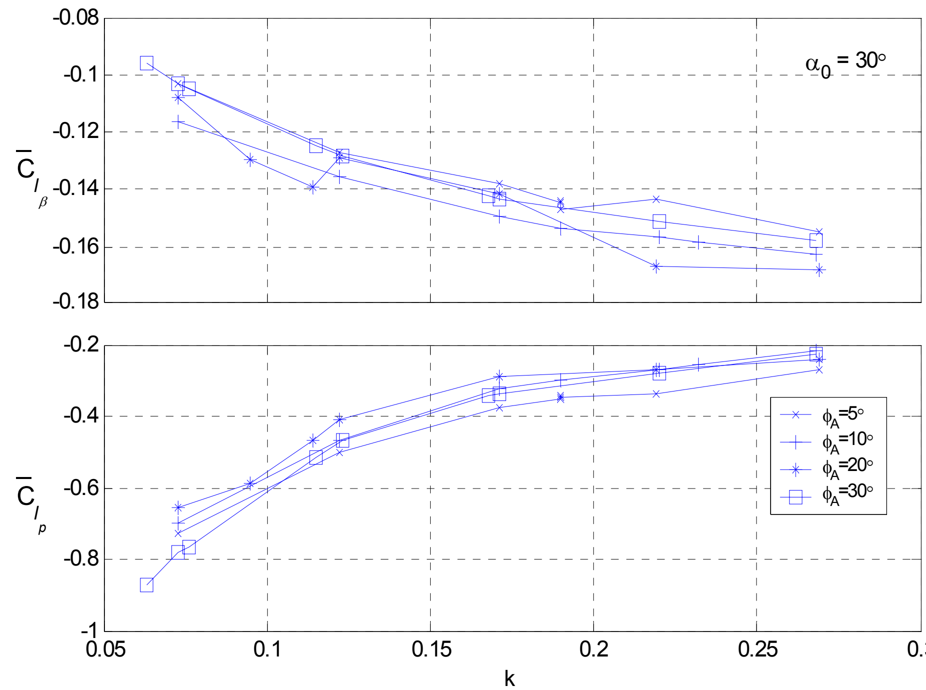

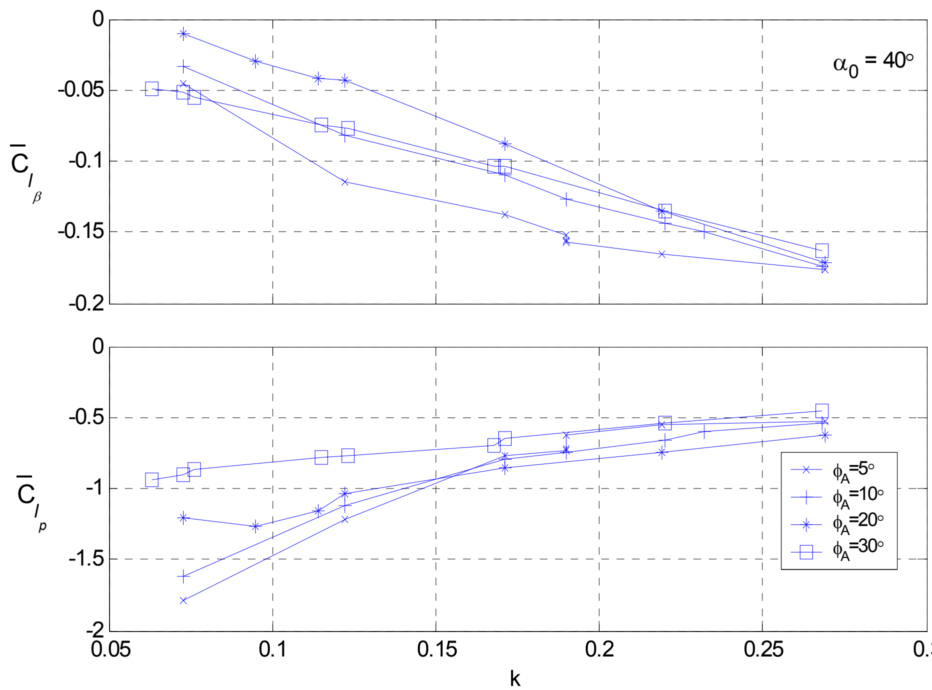

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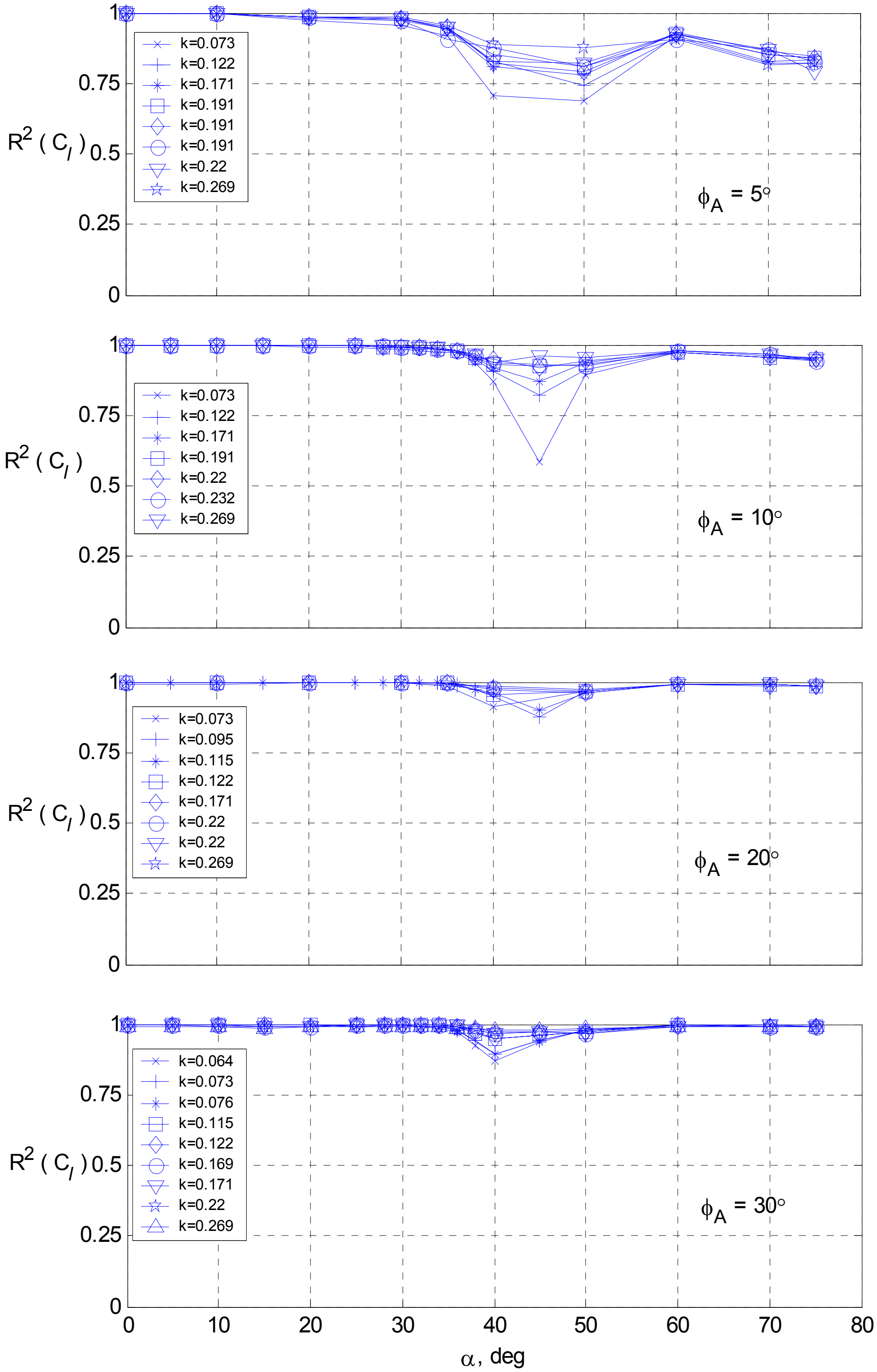


Figure 15. Variation of coefficient of determination for rolling-moment coefficient with angle of attack. Rolling oscillations.

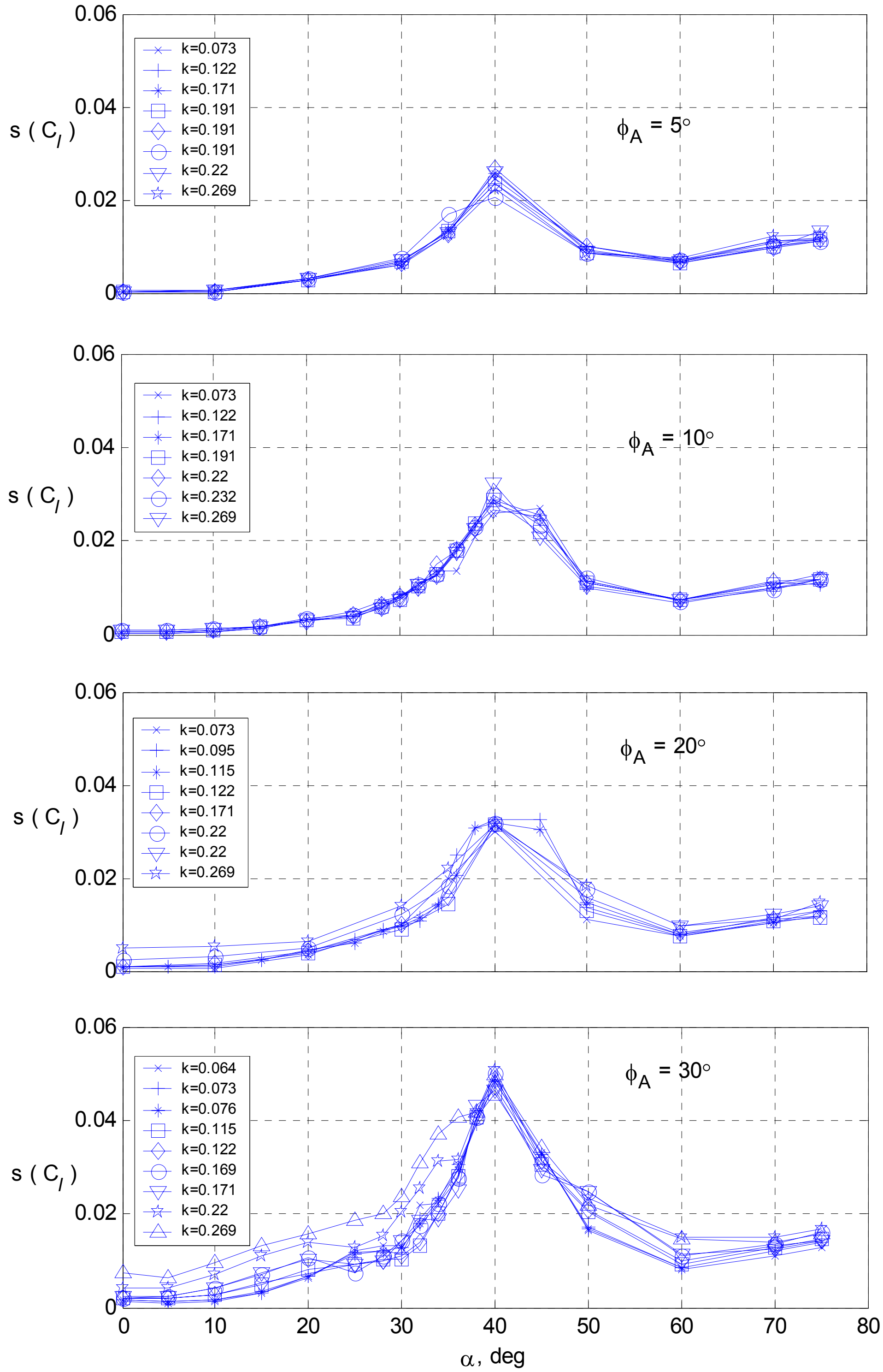


Figure 16. Variation of fit error of rolling-moment coefficient with angle of attack. Rolling oscillations.

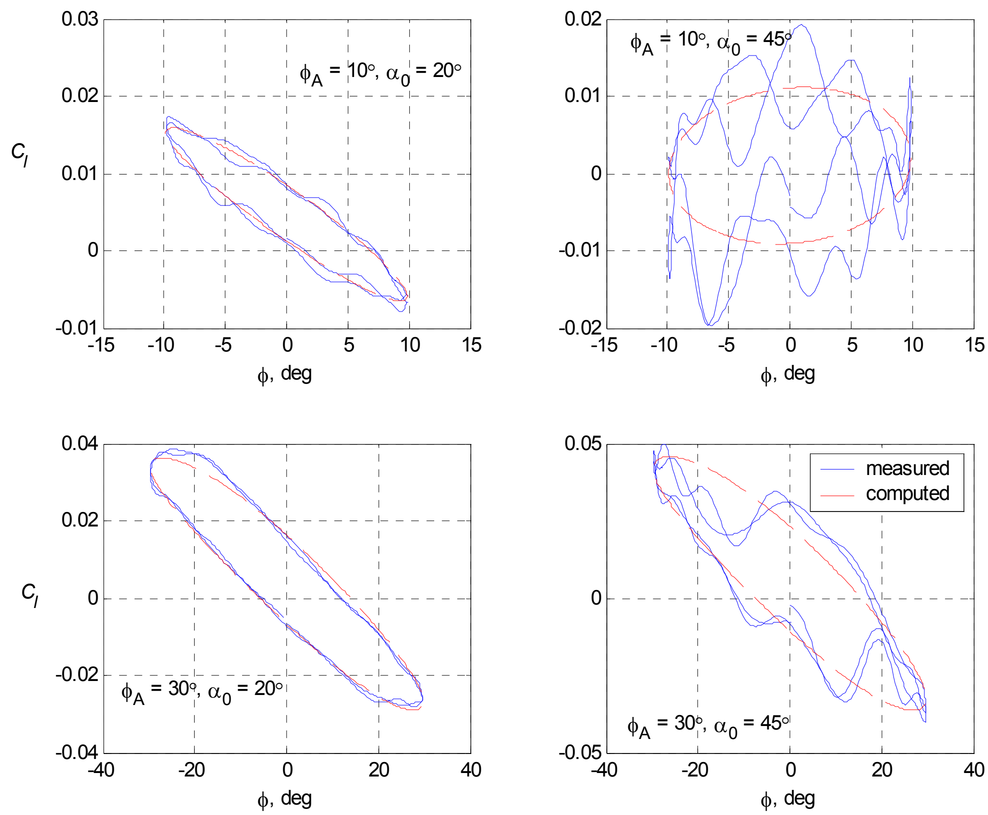


Figure 17. Comparison of measured and computed rolling-moment coefficient. Rolling oscillations, k=0.073.

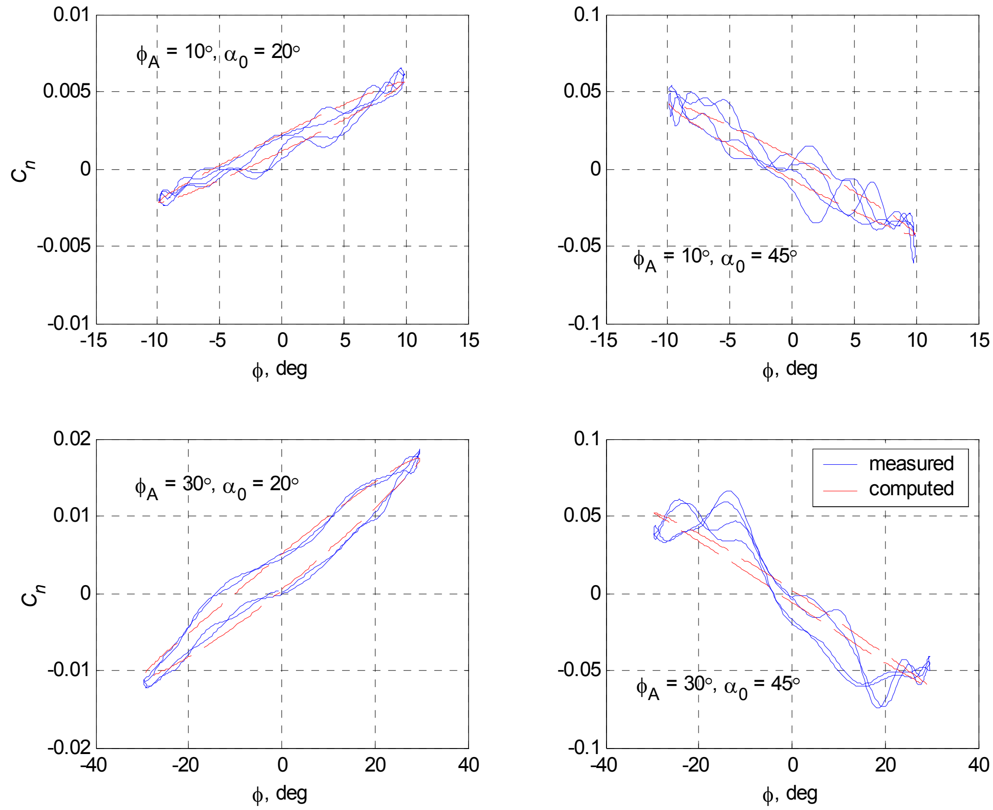


Figure 18. Comparison of measured and computed yawing-moment coefficient. Rolling oscillations, k=0.073.

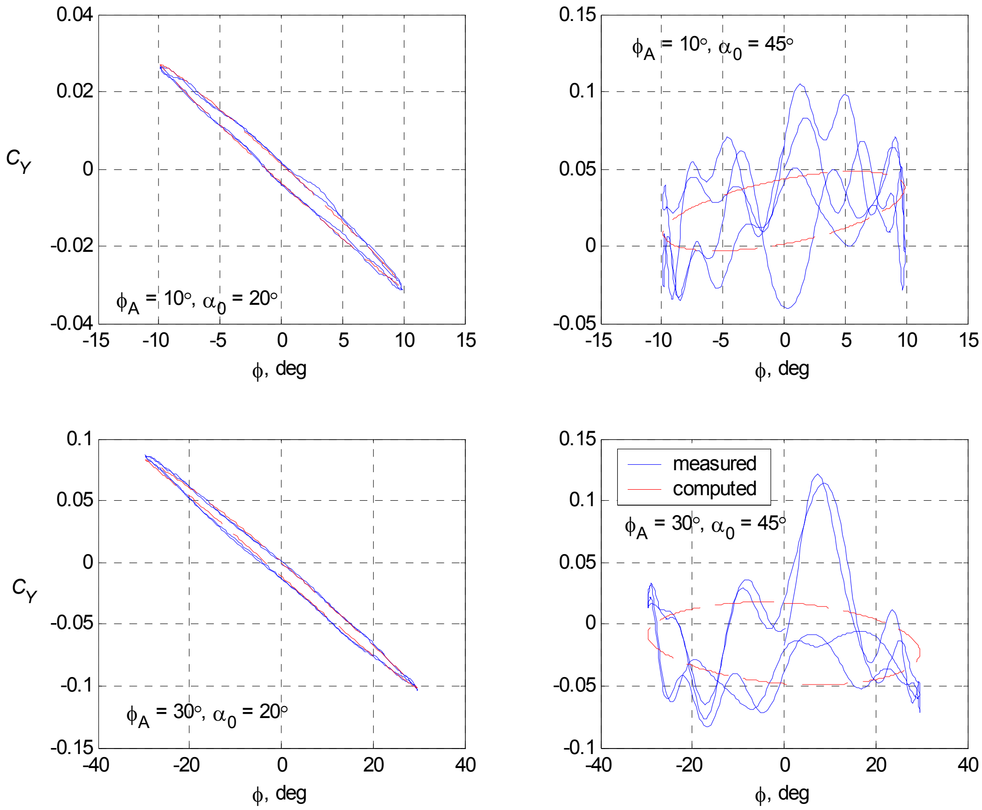


Figure 19. Comparison of measured and computed side-force coefficient. Rolling oscillations, k=0.073.

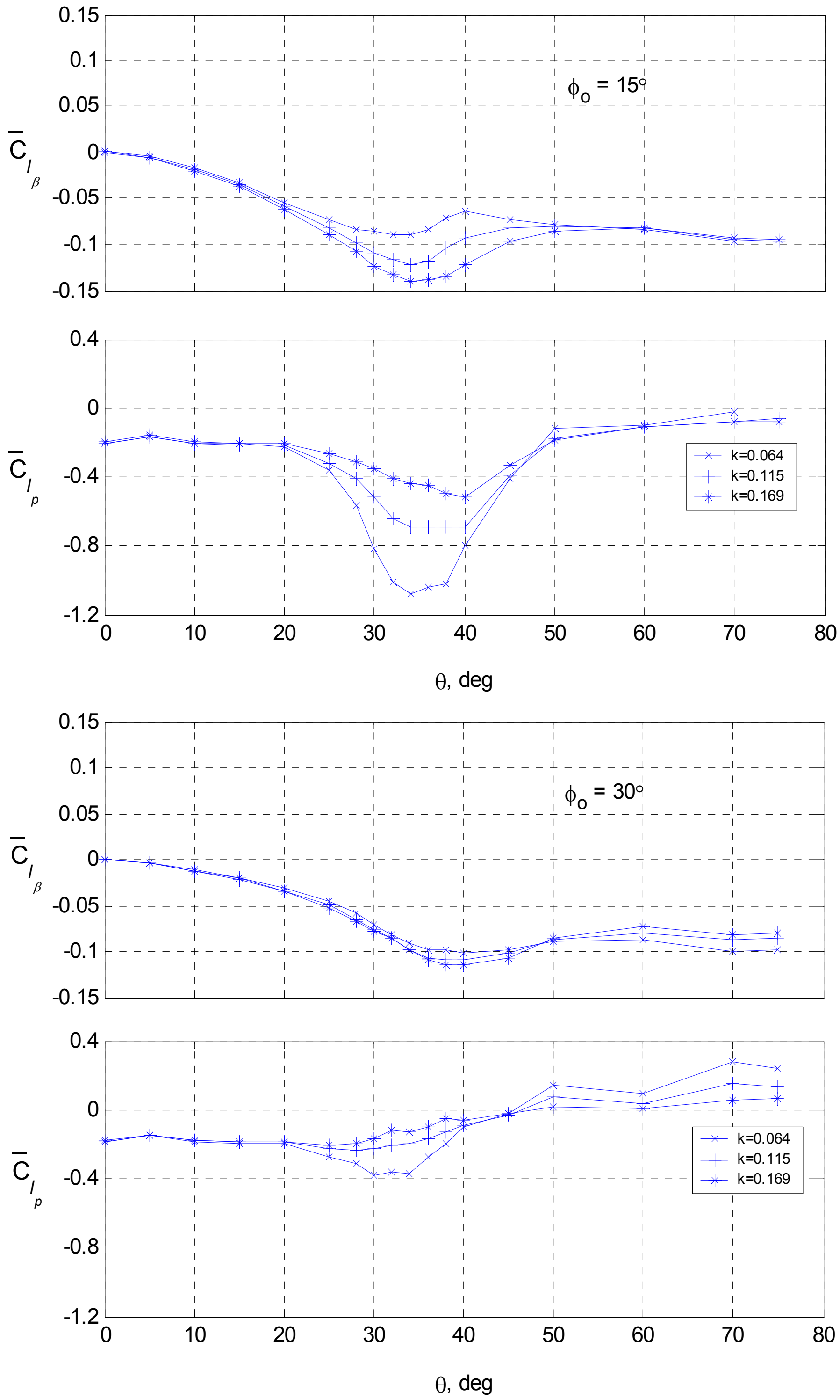
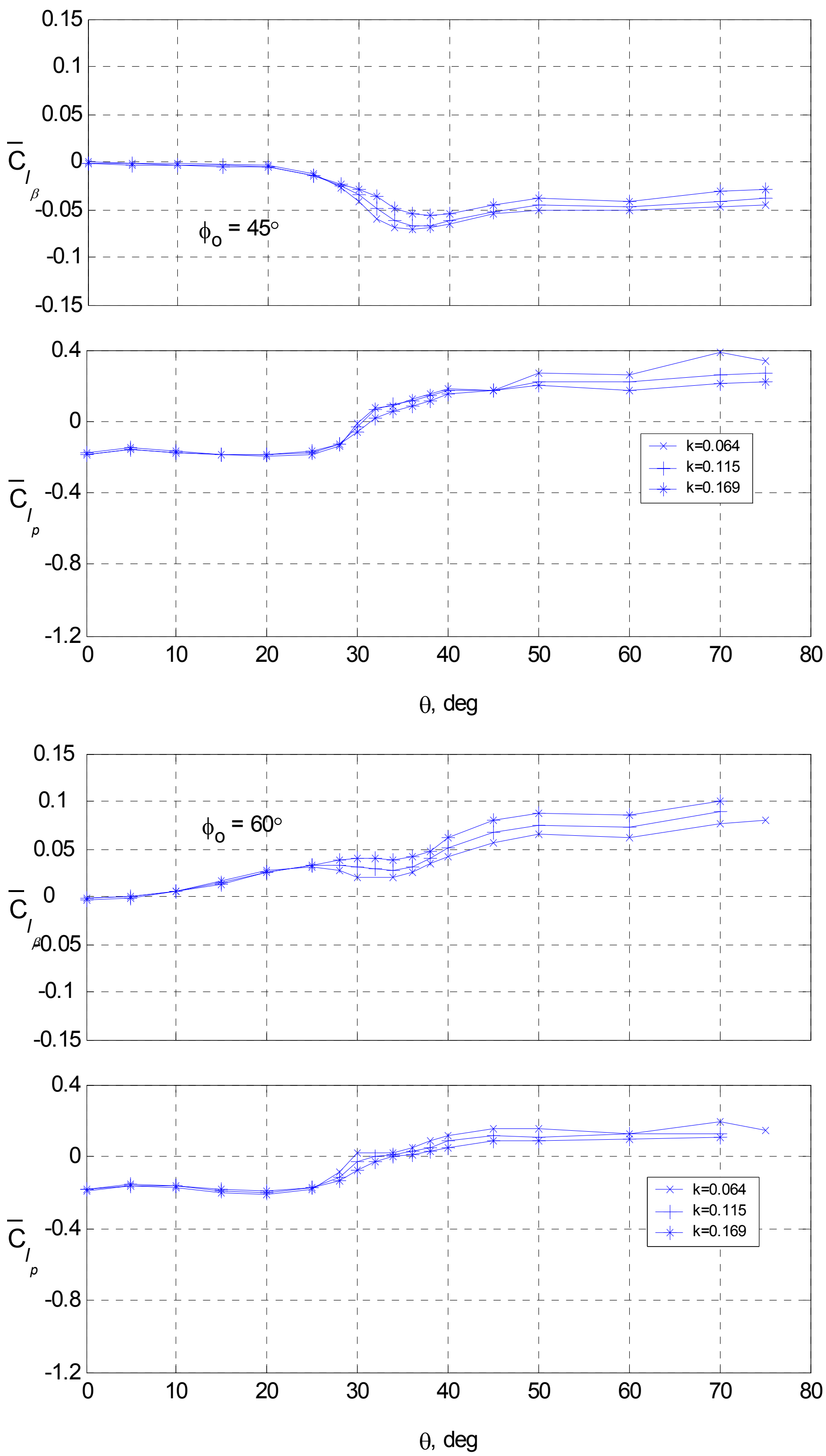


Figure 20. Effect of offset in roll angle on in-phase and out-of-phase components of rolling-moment coefficient. Rolling oscillations, ϕ_A=30°.



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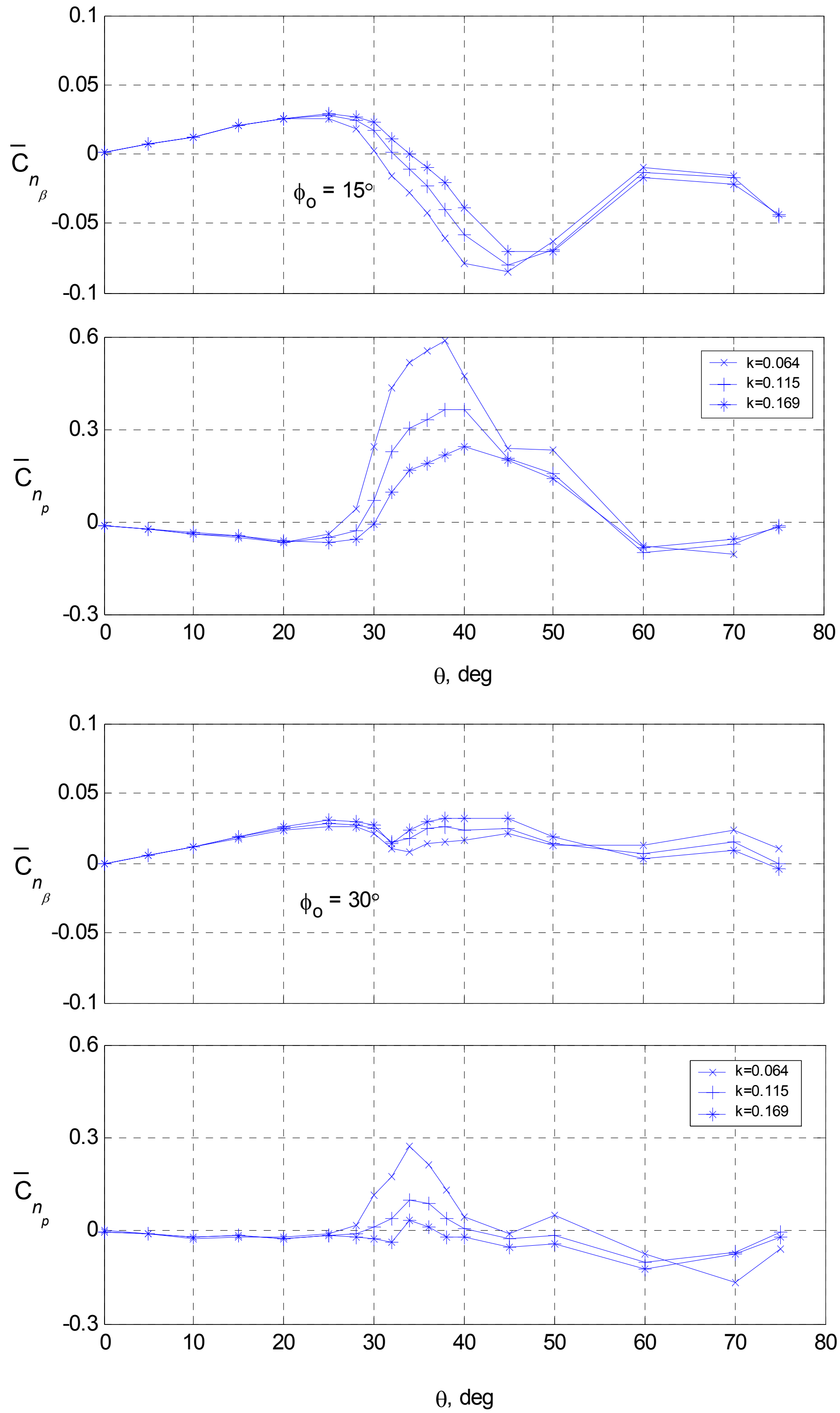
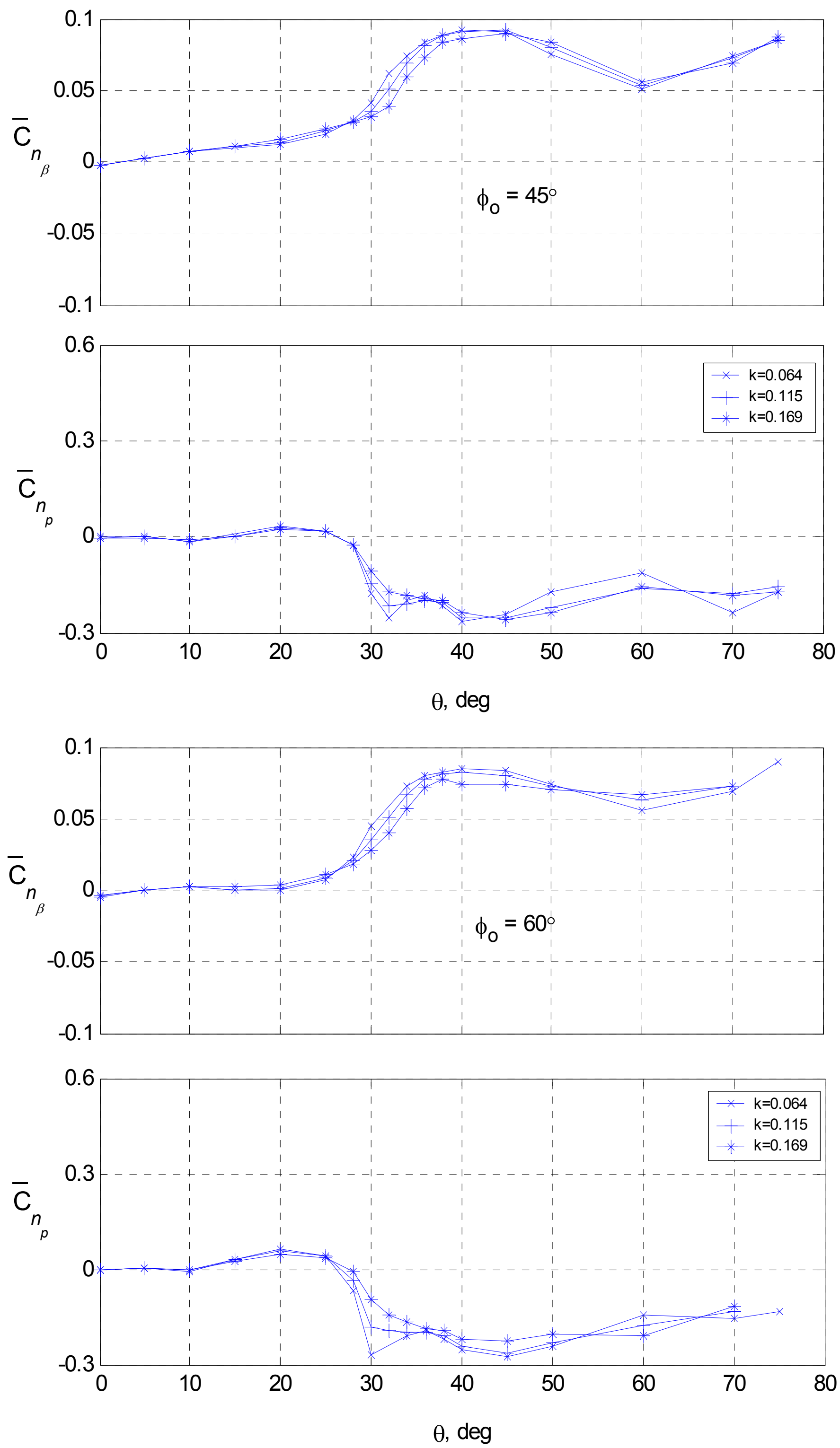


Figure 21. Effect of offset in roll angle on in-phase and out-of-phase components of yawing-moment coefficient. Rolling oscillations, $\phi_A = 30^o$.



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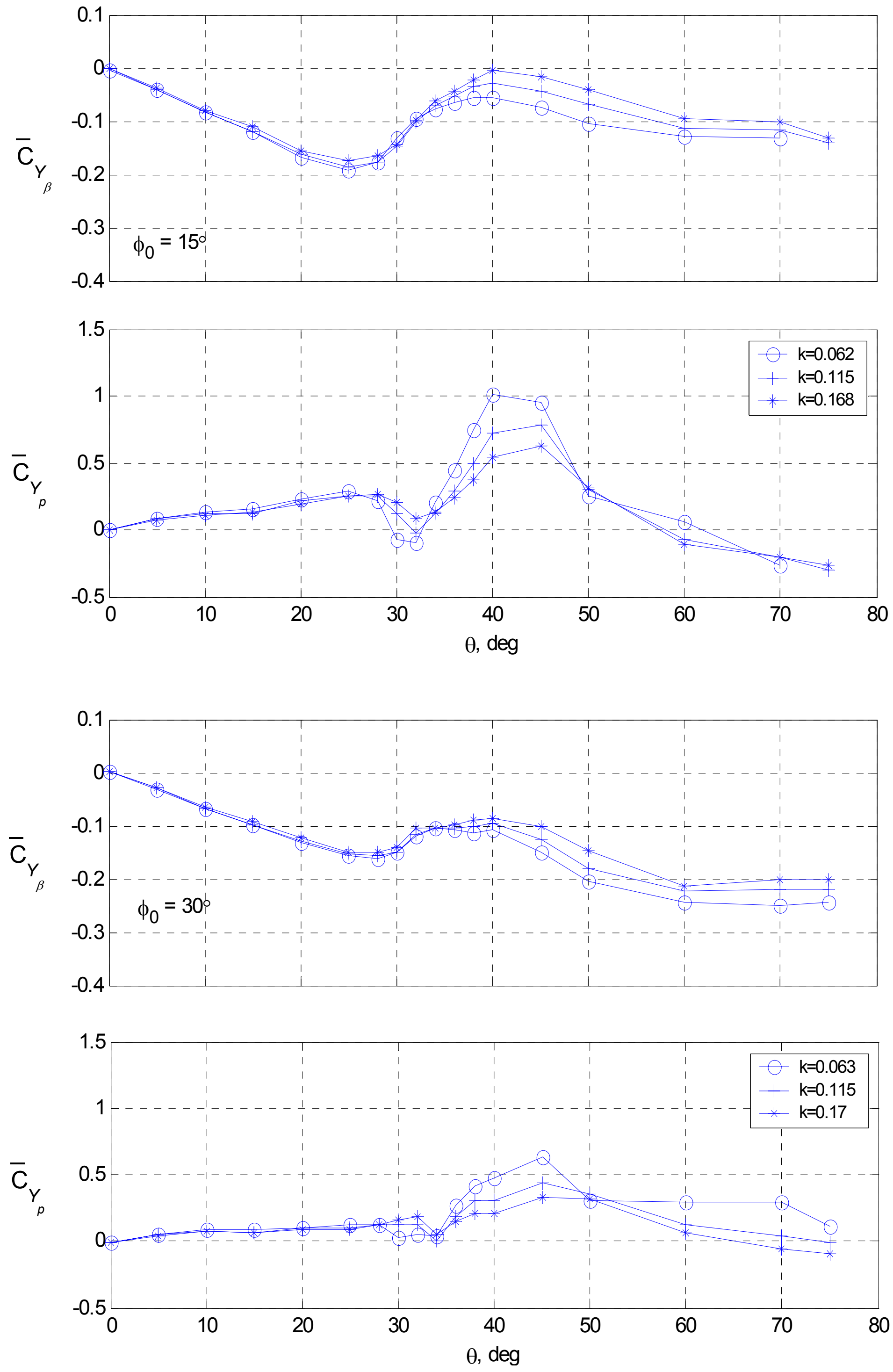
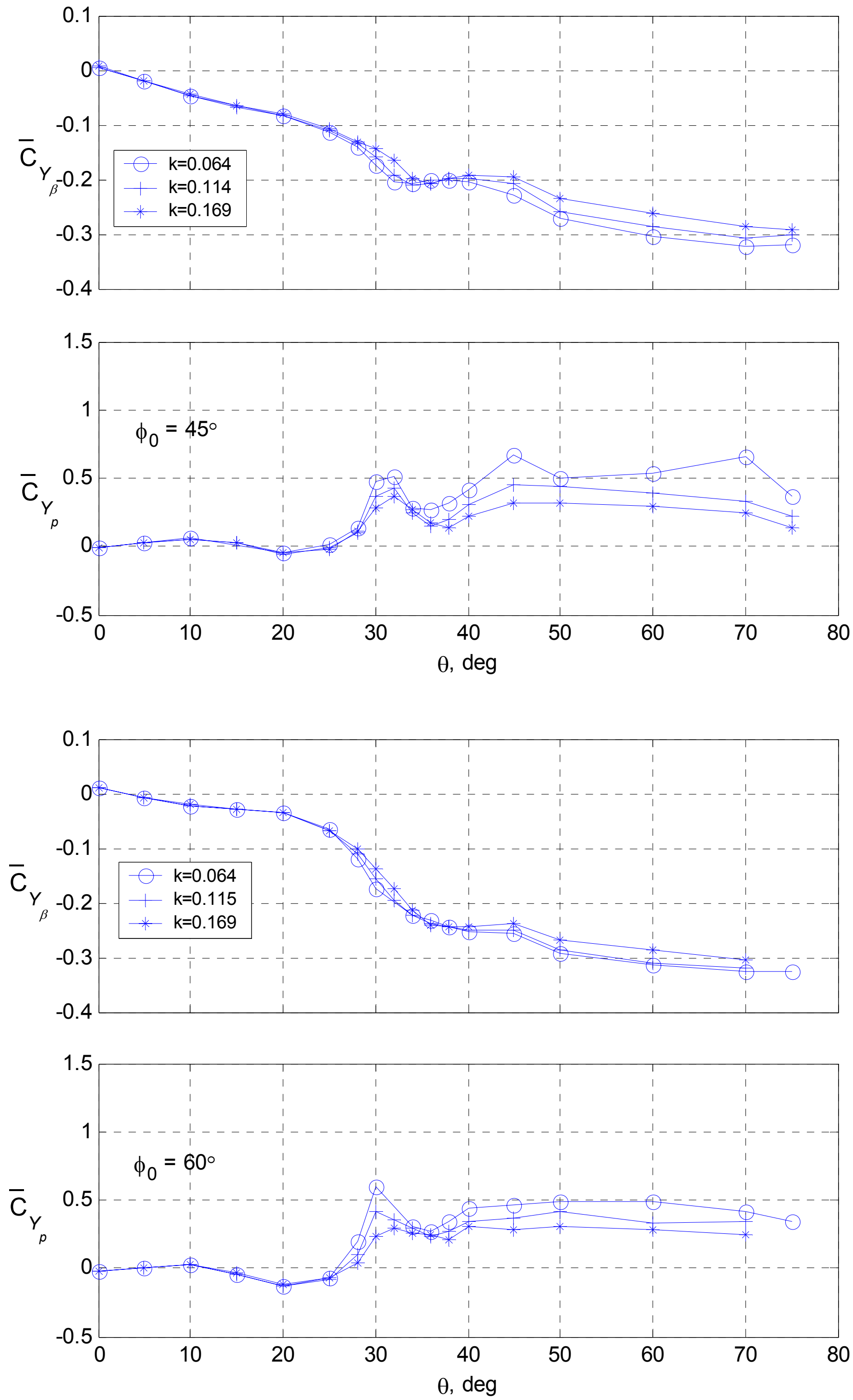


Figure 22. Effect of offset in roll angle on in-phase and out-of-phase components of rolling-moment coefficient. Rolling oscillations, ϕ_A=30°.



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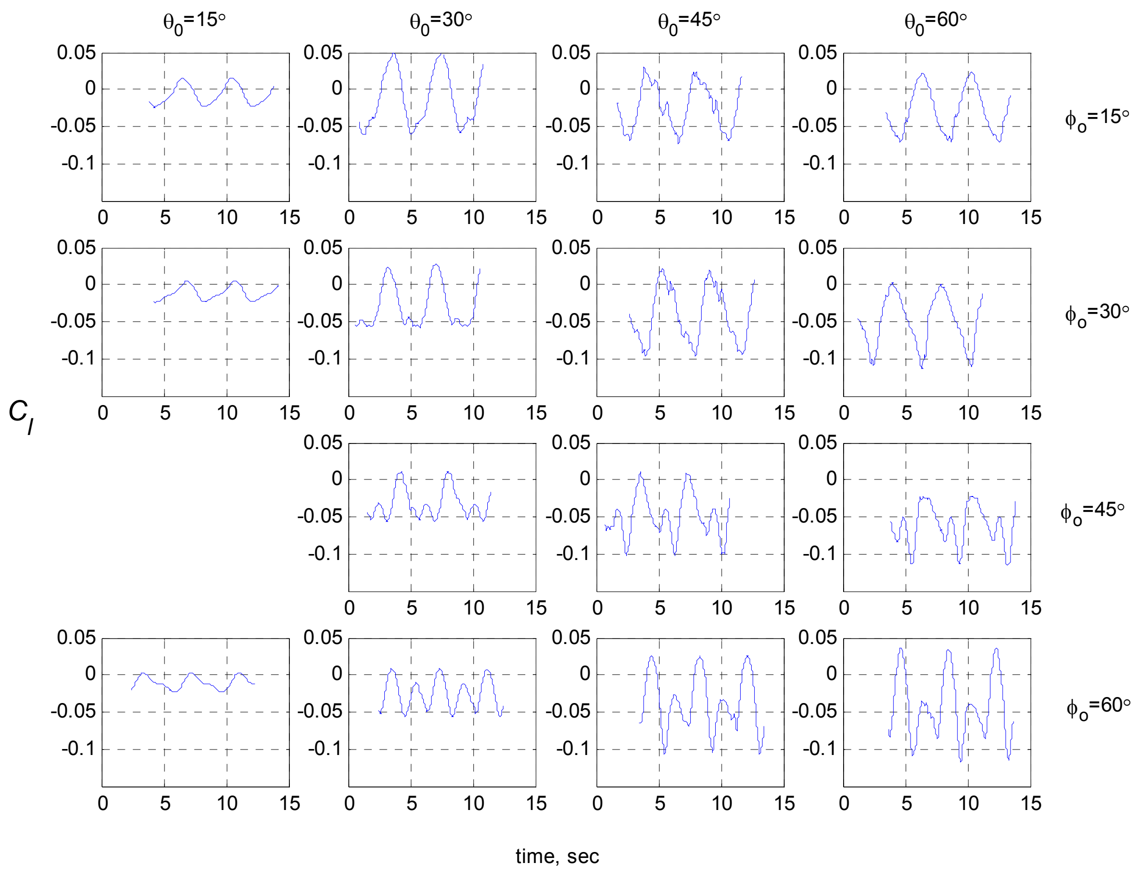


Figure 23. Time histories of rolling-moment coefficient. Rolling oscillations, ϕ_A=30^o, k=0.064.

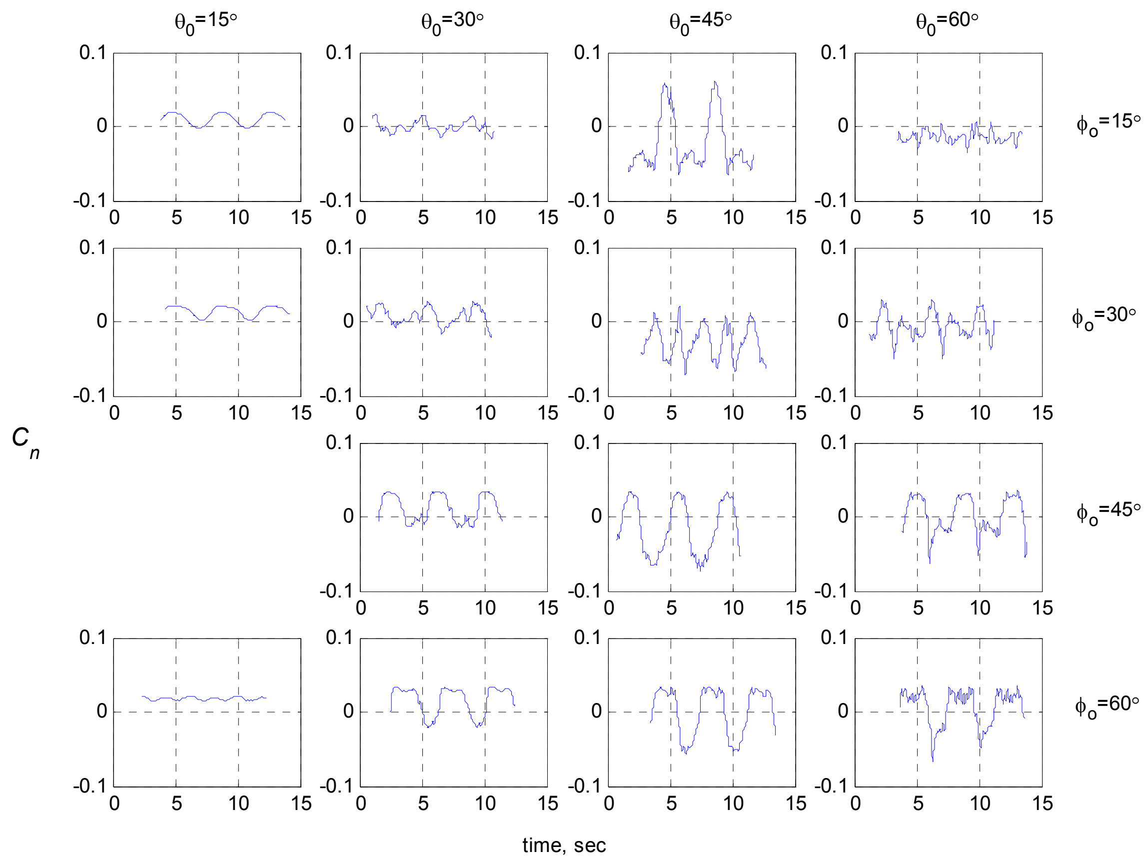


Figure 24. Time histories of yawing-moment coefficient. Rolling oscillations. ϕ_A =30°, k=0.064.

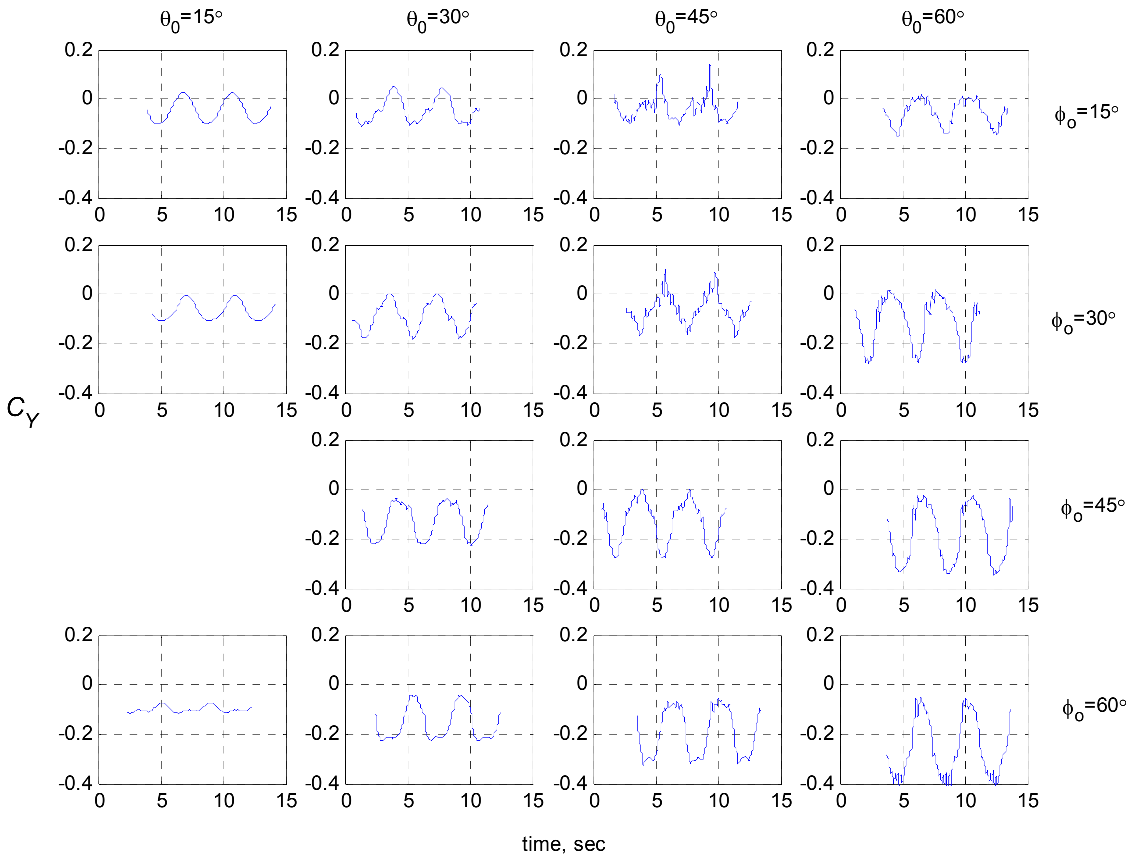


Figure 25. Time histories of side-force coefficient. Rolling oscillations, ϕ_A =30°, k=0.064.

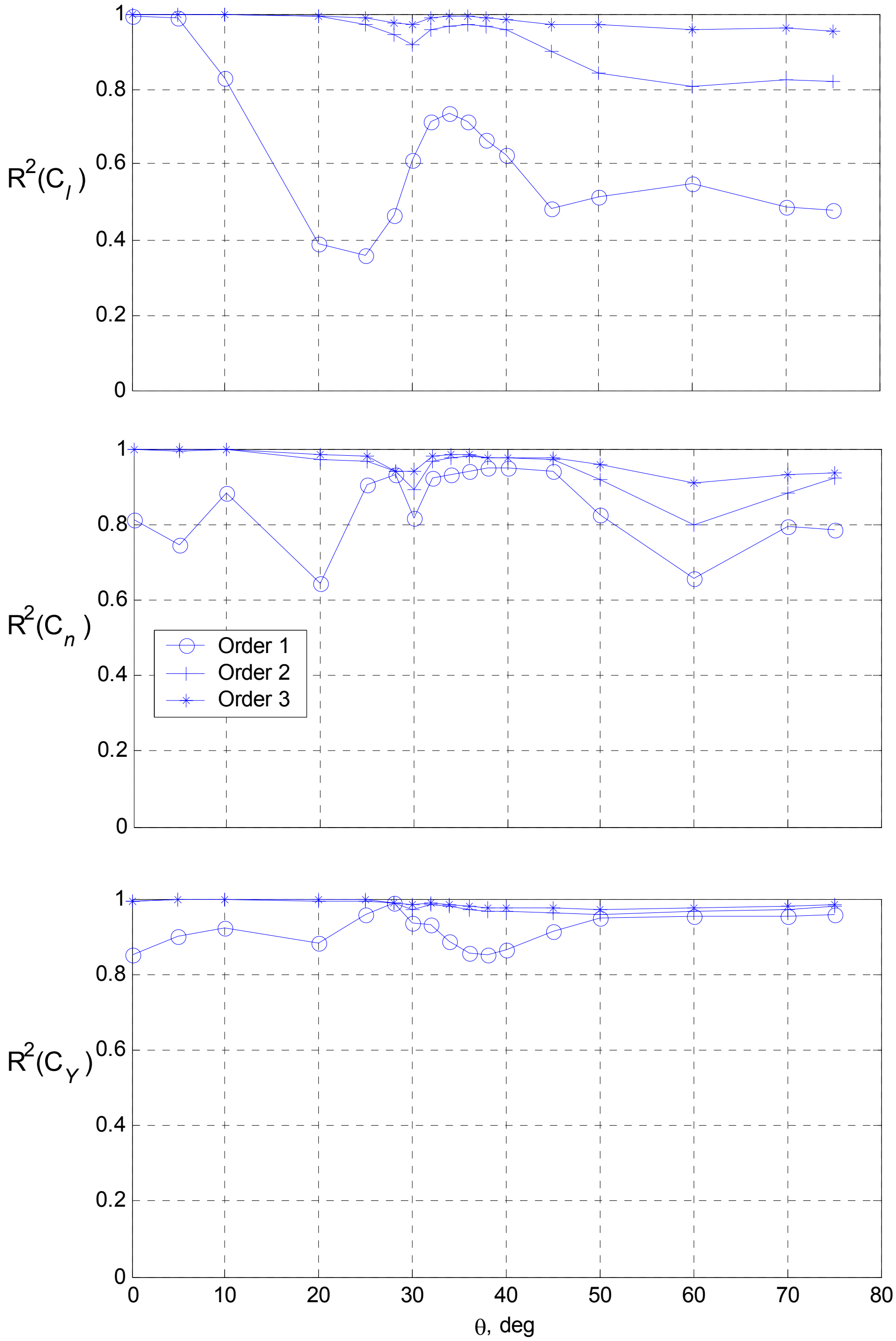


Figure 26. Variation of coefficient of determination for rolling-moment coefficient with angle of attack. Rolling oscillations, k=0.064, ϕ_A=30°, ϕ_0=45°.

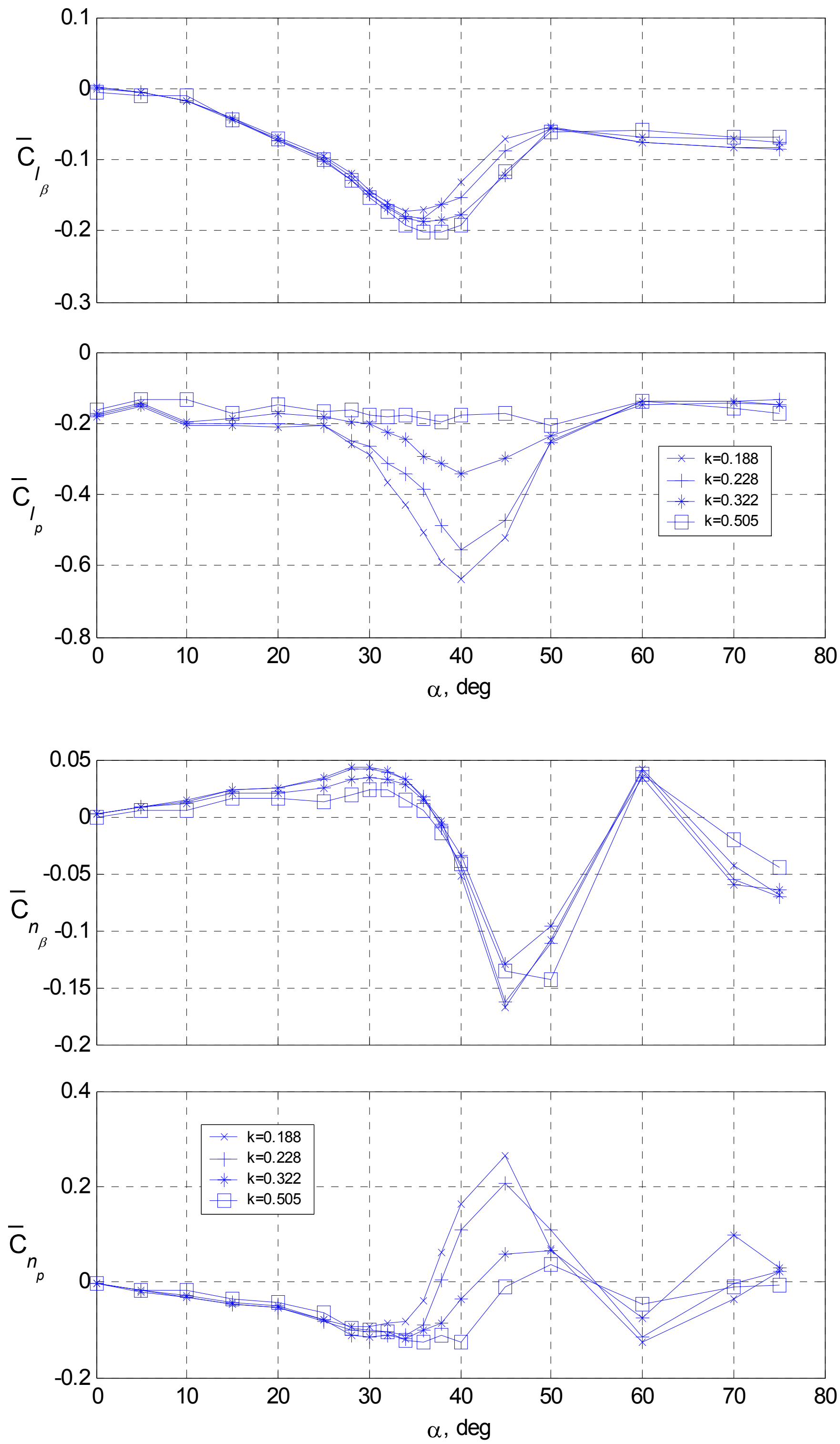
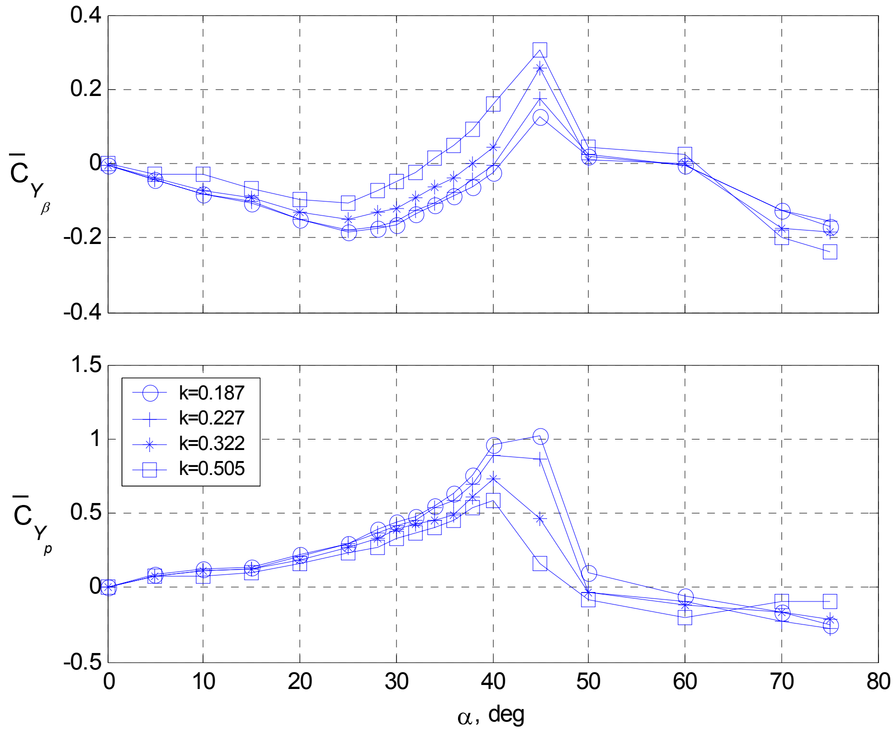


Figure 27. Variation of in-phase and out-of-phase components of lateral coefficients with angle of attack. Rolling oscillations, ϕ_A=10°, Re=0.6x10^6.



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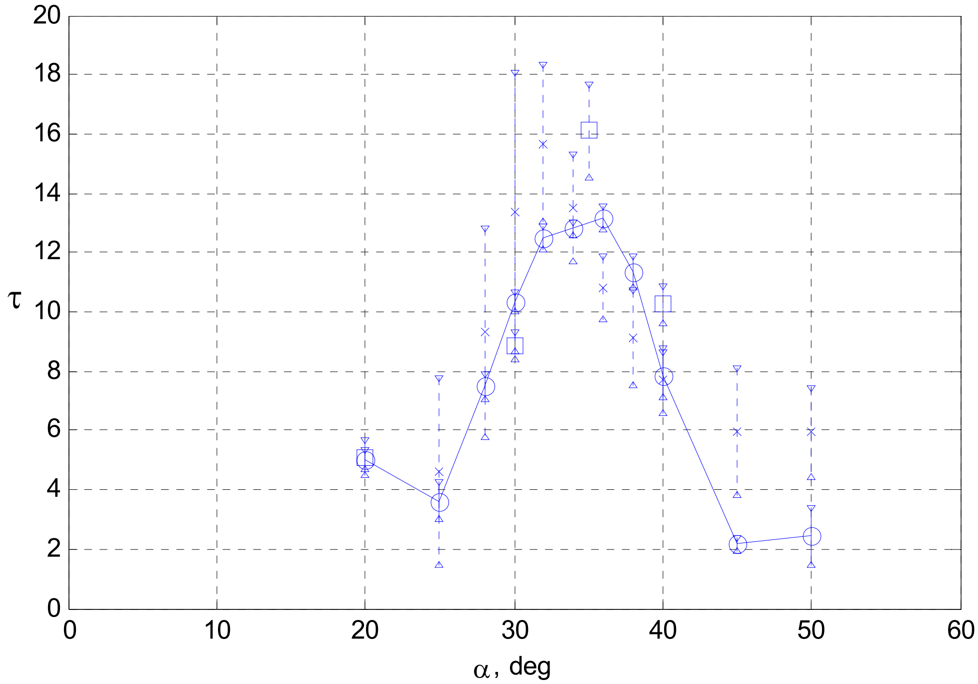


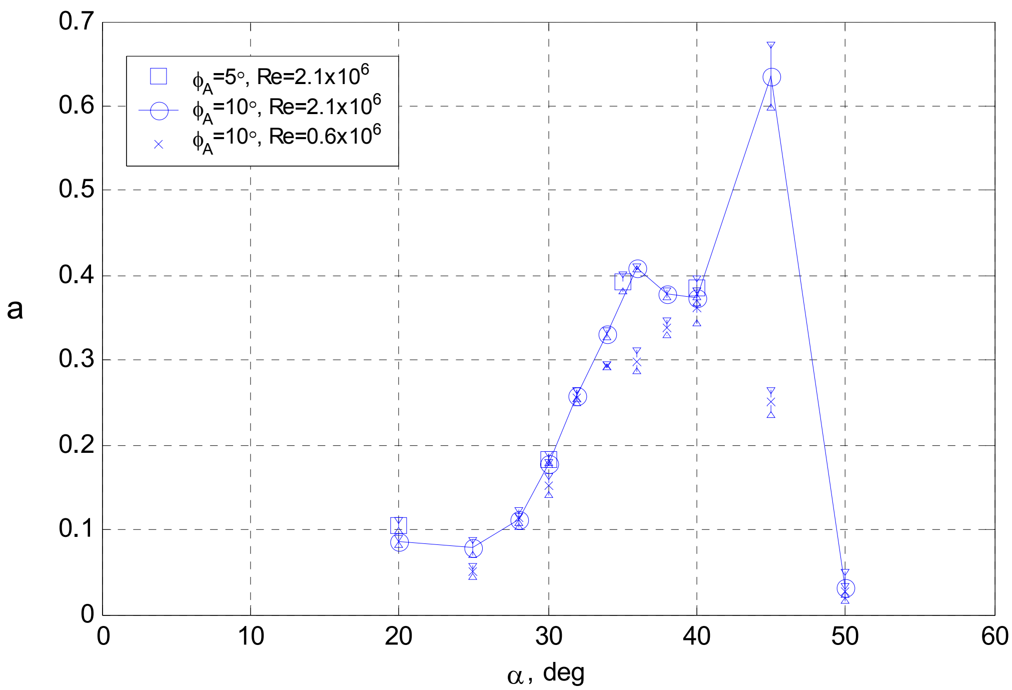
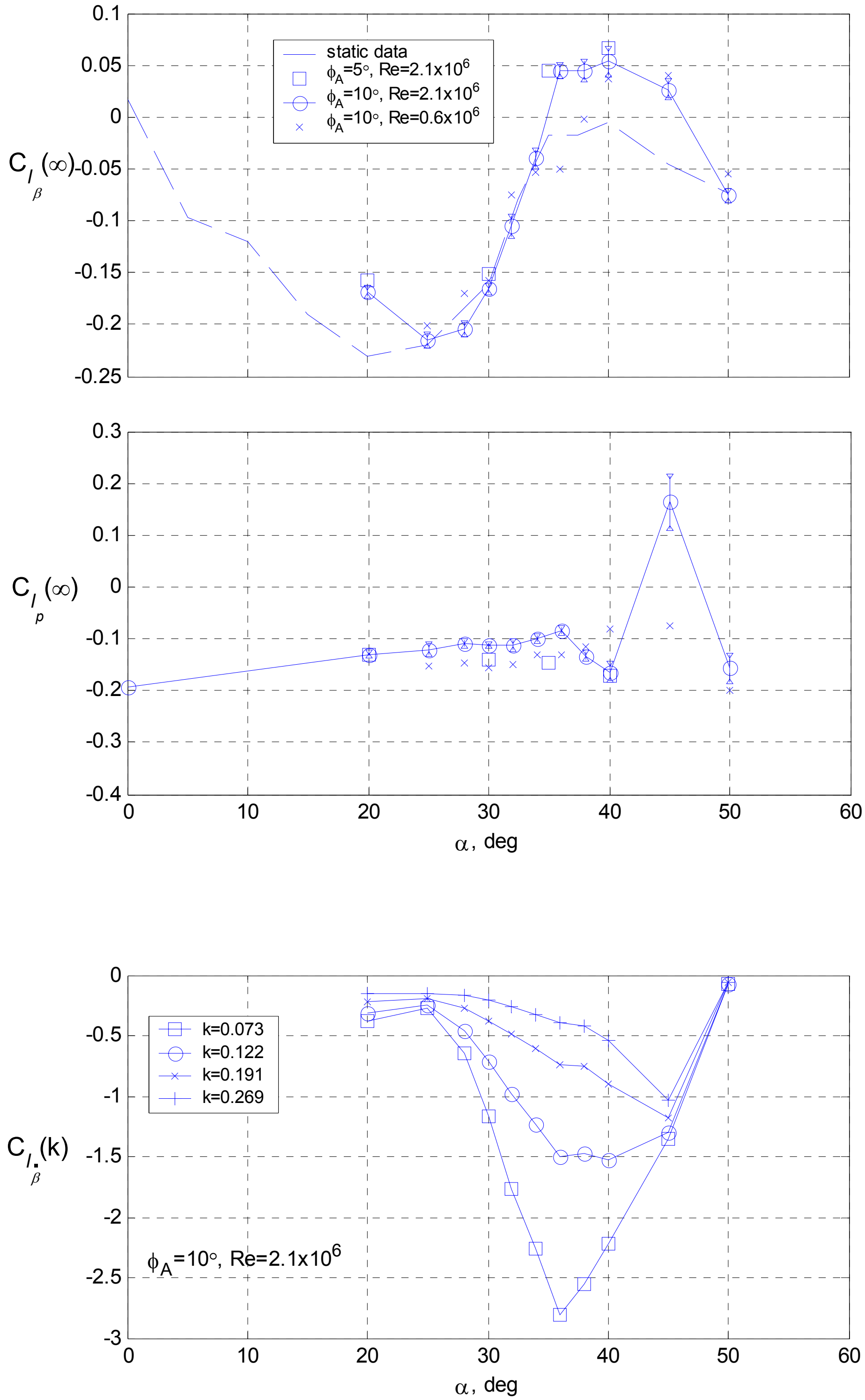


Figure 28. Estimated parameters, their 2-σ confidence intervals and computed unsteady term. Rolling-moment coefficient. Rolling oscillations.



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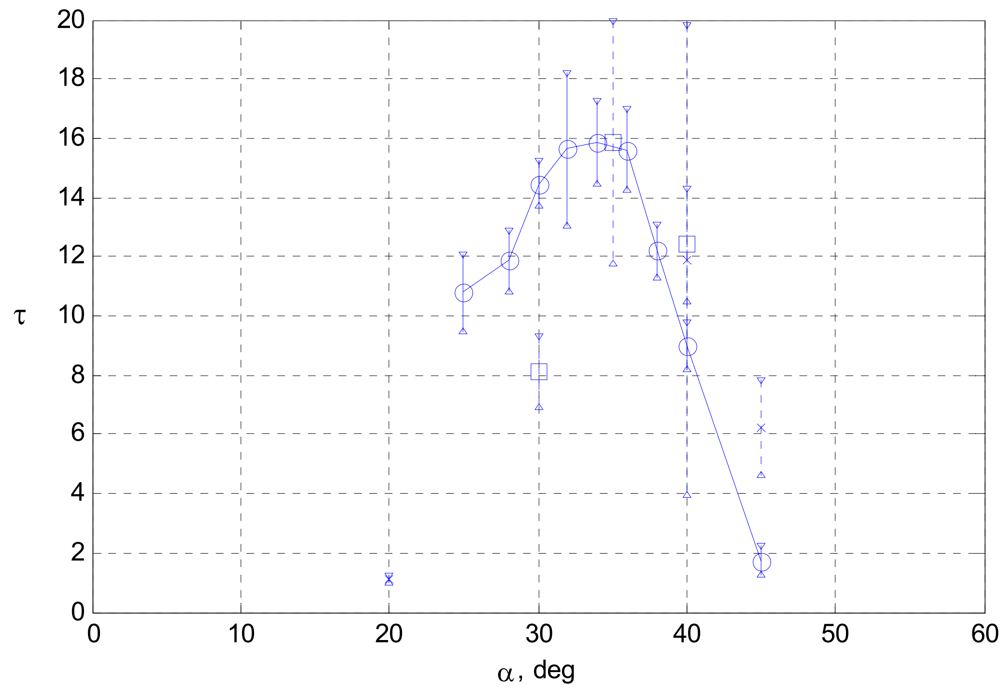


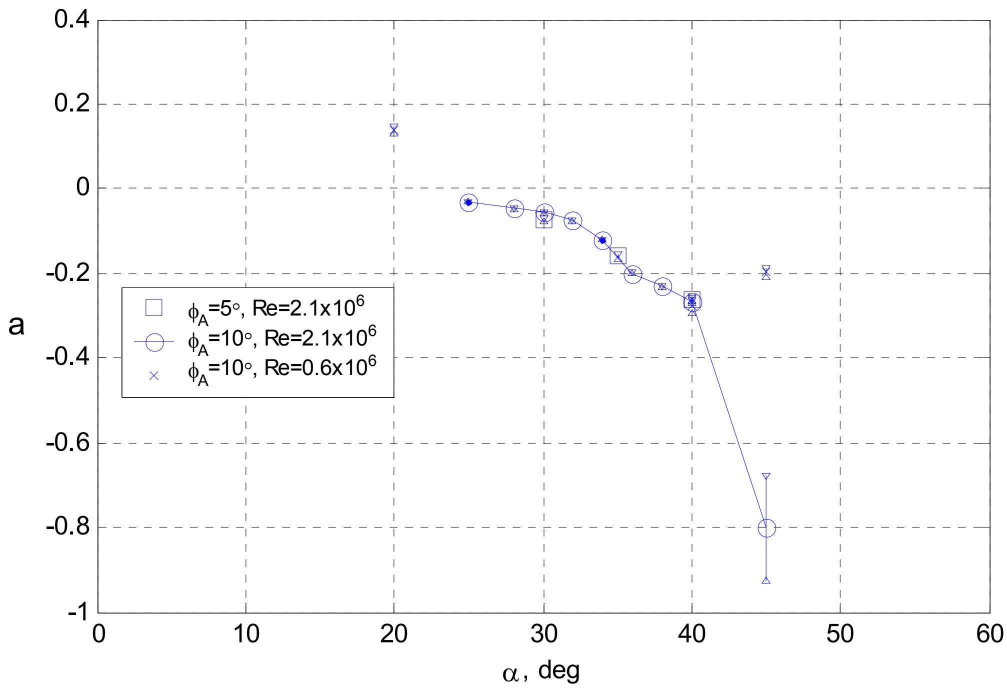
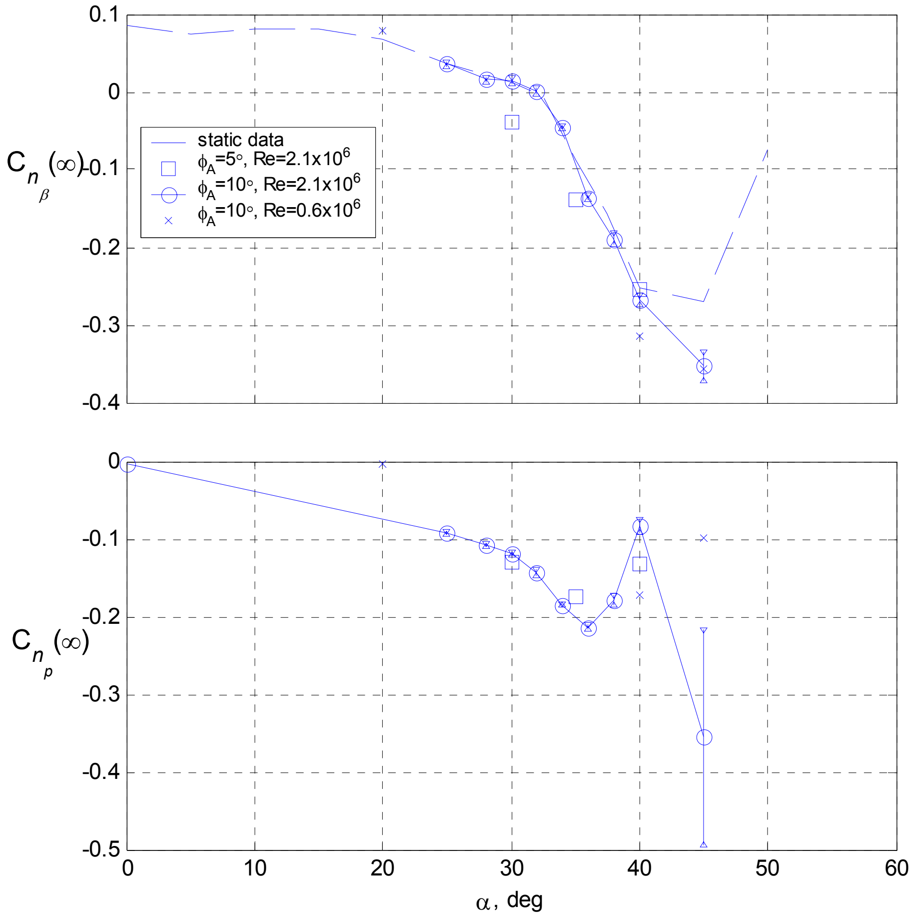
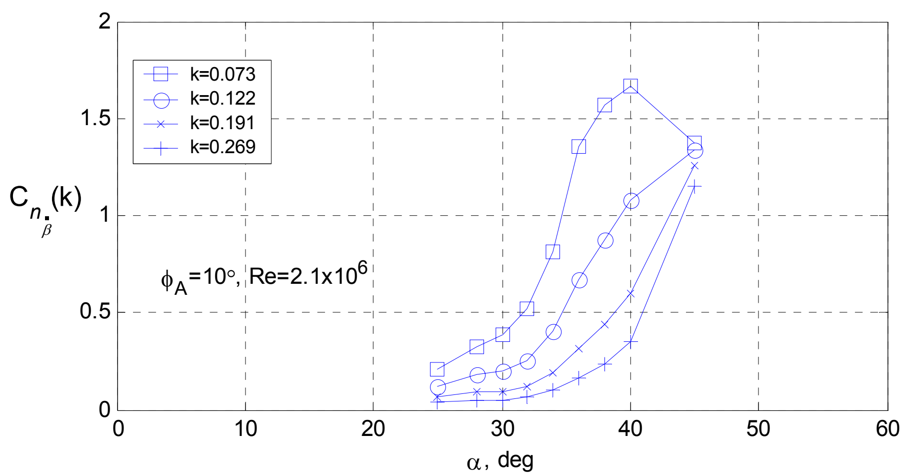


Figure 29. Estimated parameters, their 2-σ confidence intervals and computed unsteady term. Yawing-moment coefficient. Rolling oscillations.





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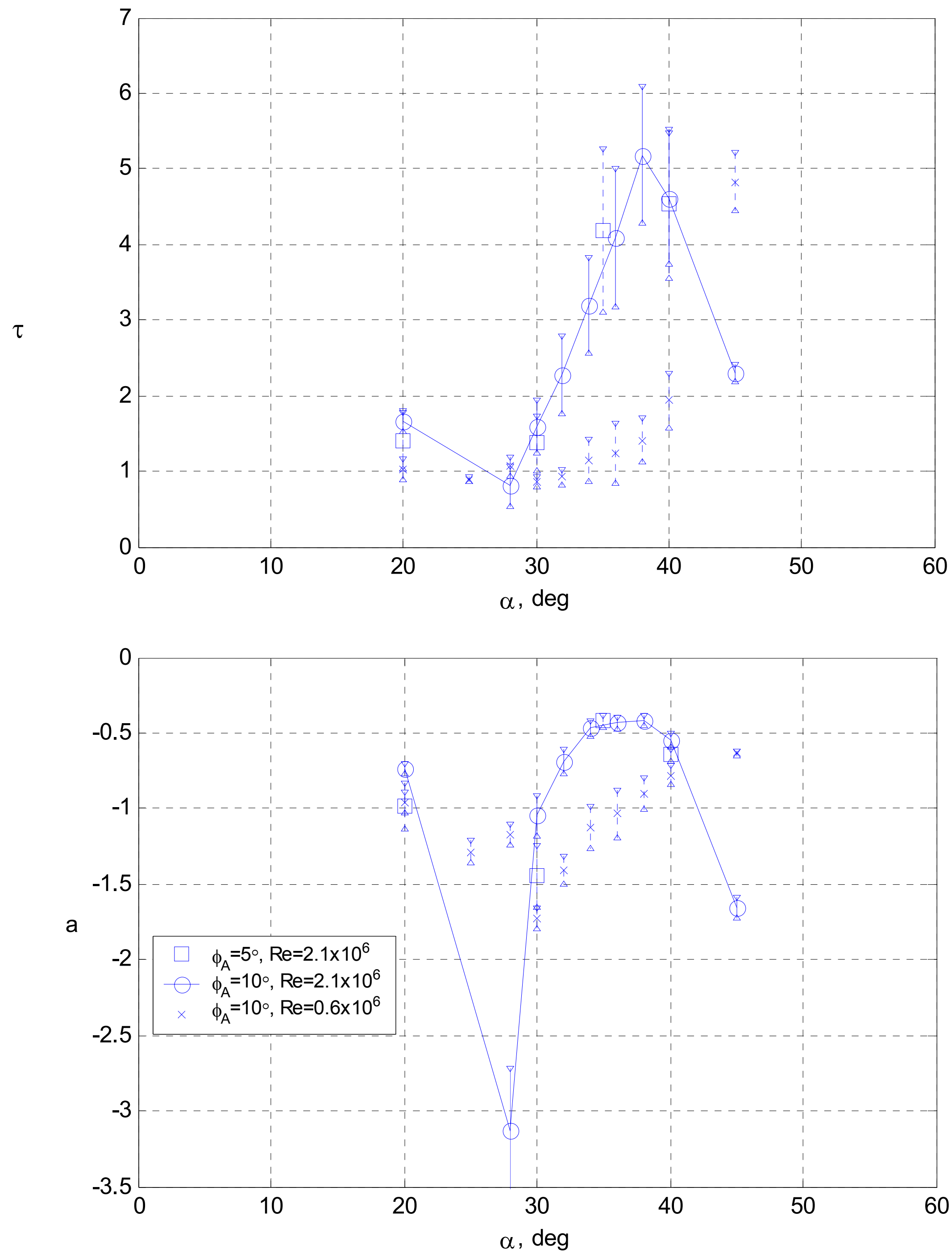
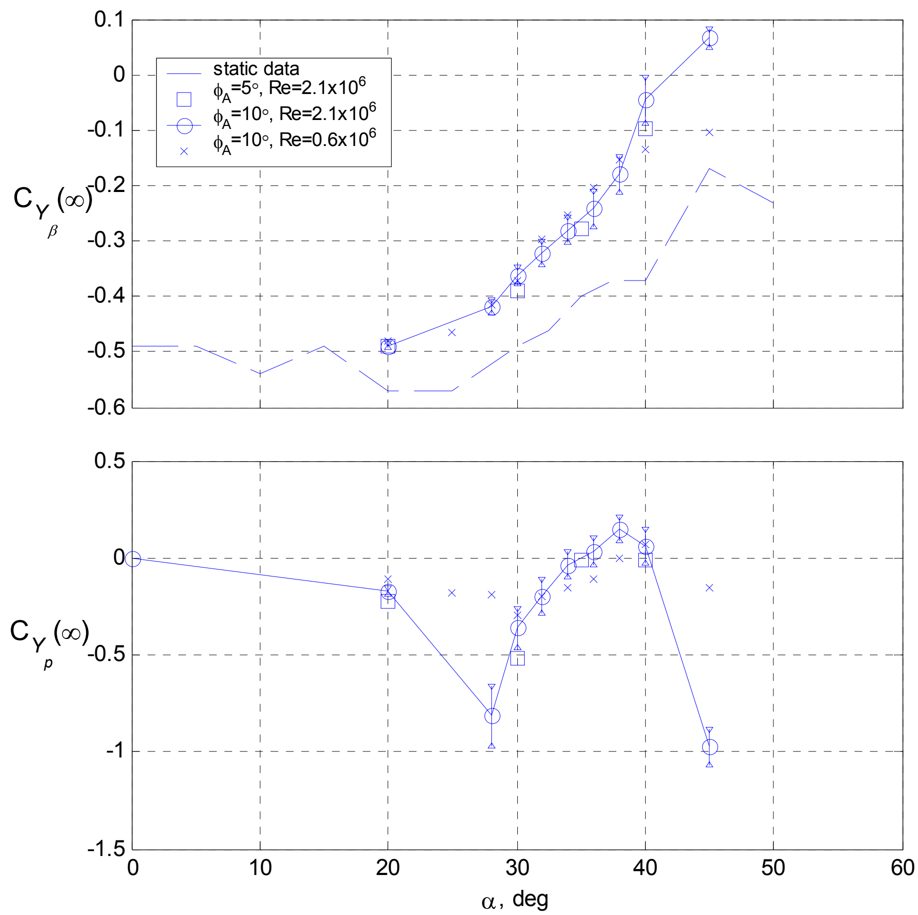
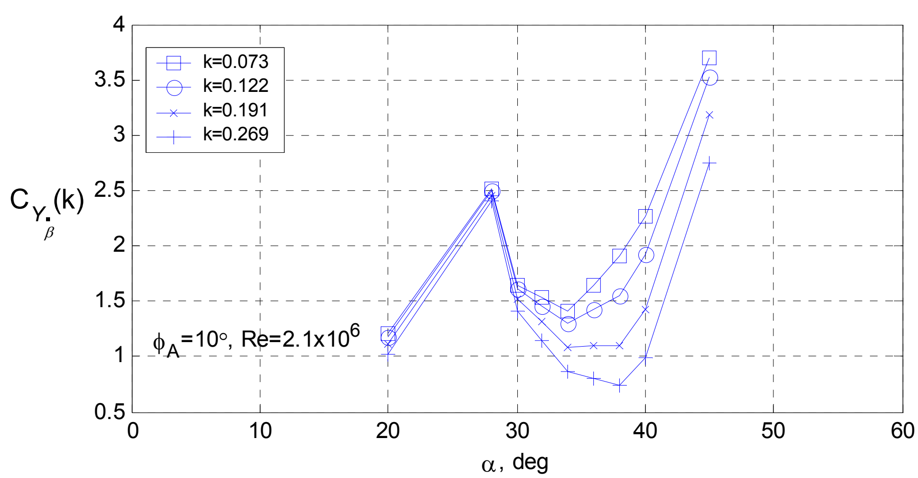


Figure 30. Estimated parameters, their 2-σ confidence intervals and computed unsteady term. Side-force coefficient. Rolling oscillations.





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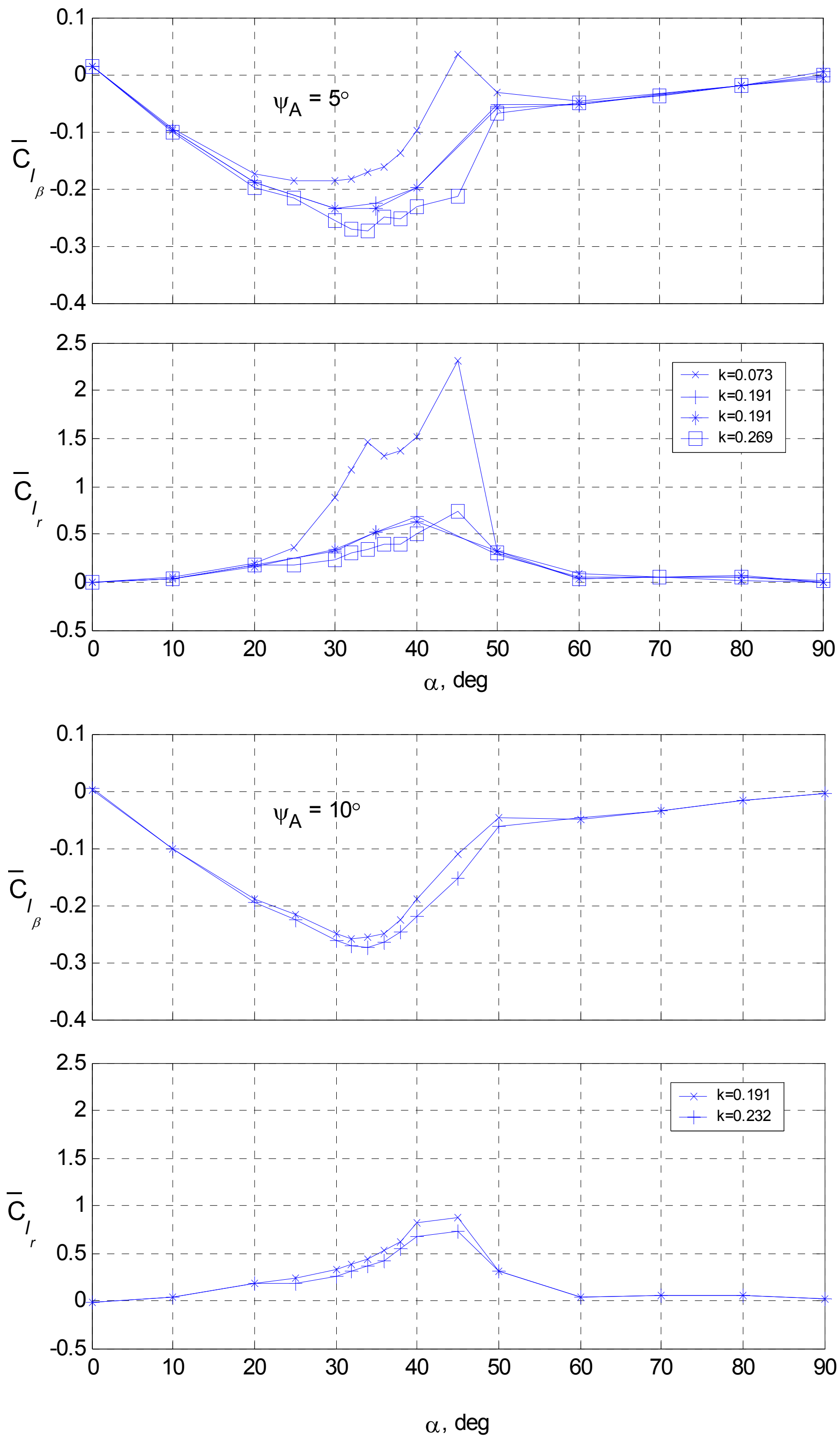
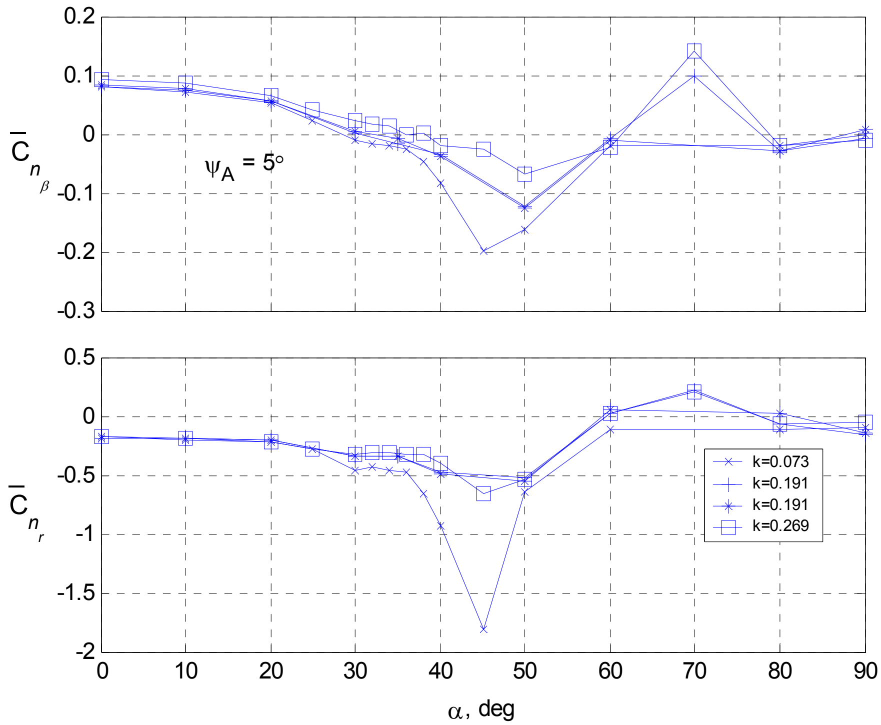


Figure 31. Variation of in-phase and out-of-phase components of rolling-moment coefficient with angle of attack. Yawing oscillations.



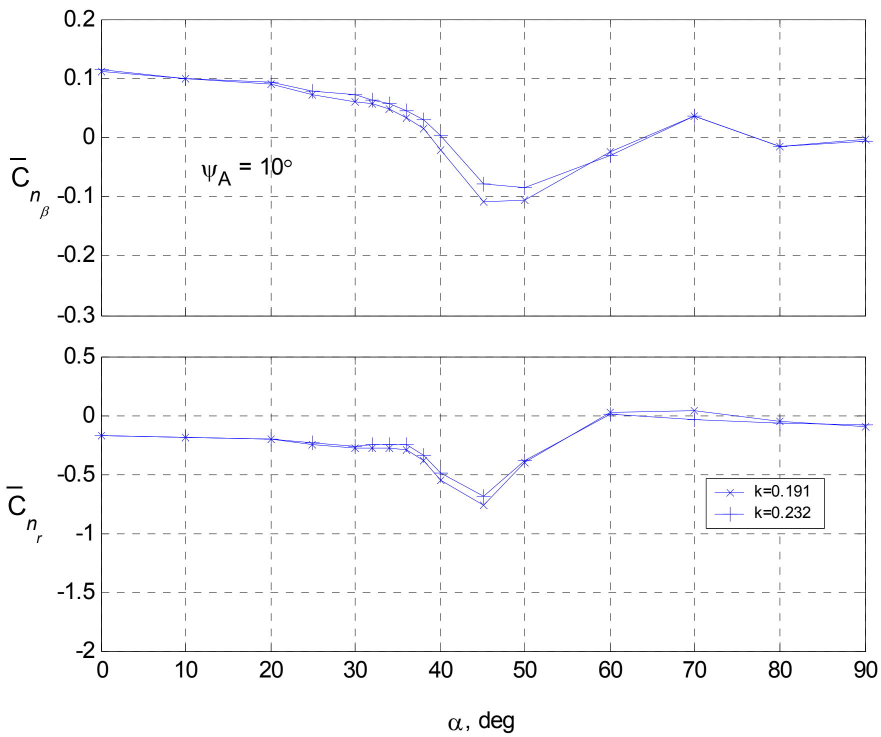


Figure 32. Variation of in-phase and out-of-phase components of yawing-moment coefficient with angle of attack. Yawing oscillations.

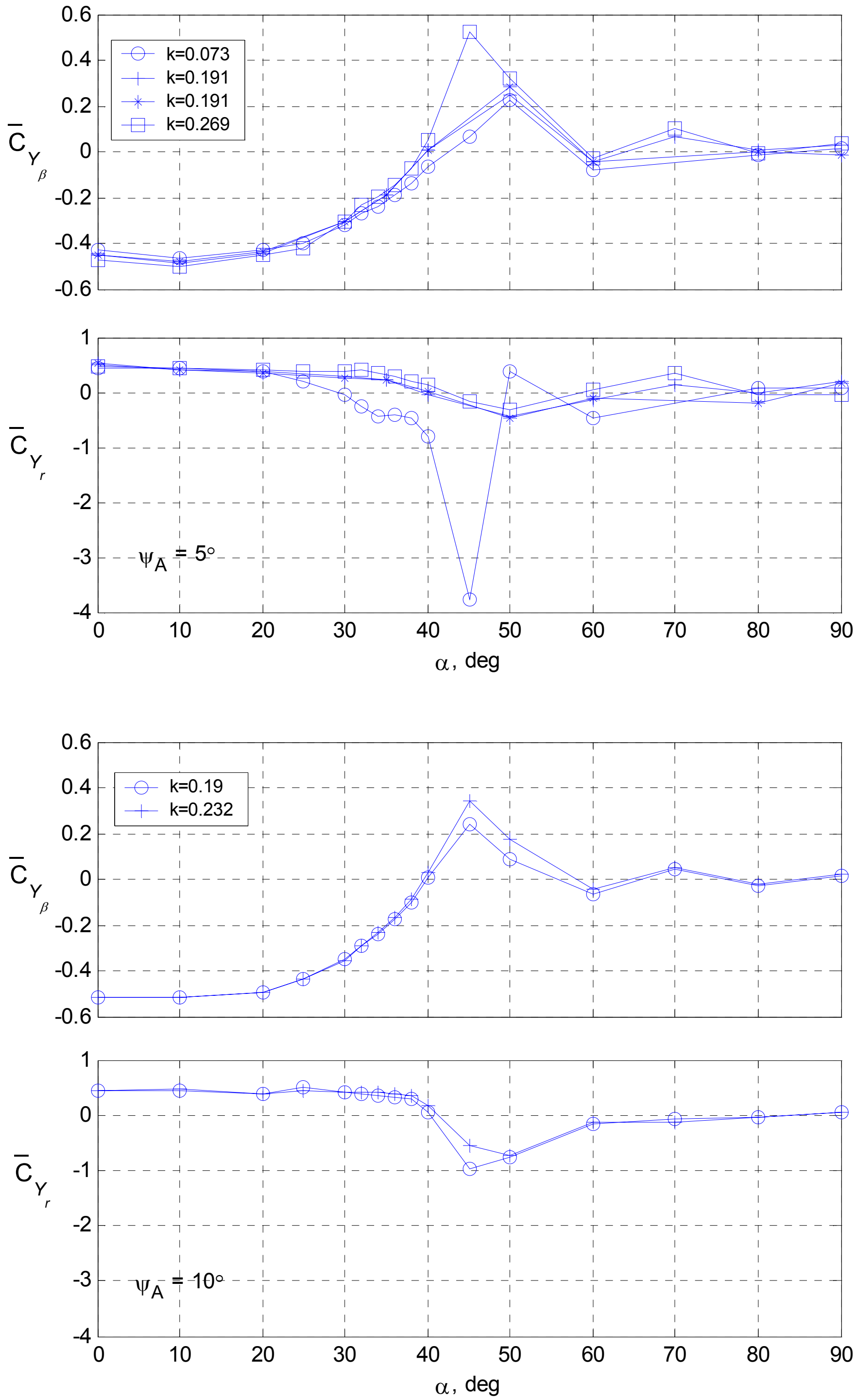


Figure 33. Variation of in-phase and out-of-phase components of side-force coefficient with angle of attack. Yawing oscillations.

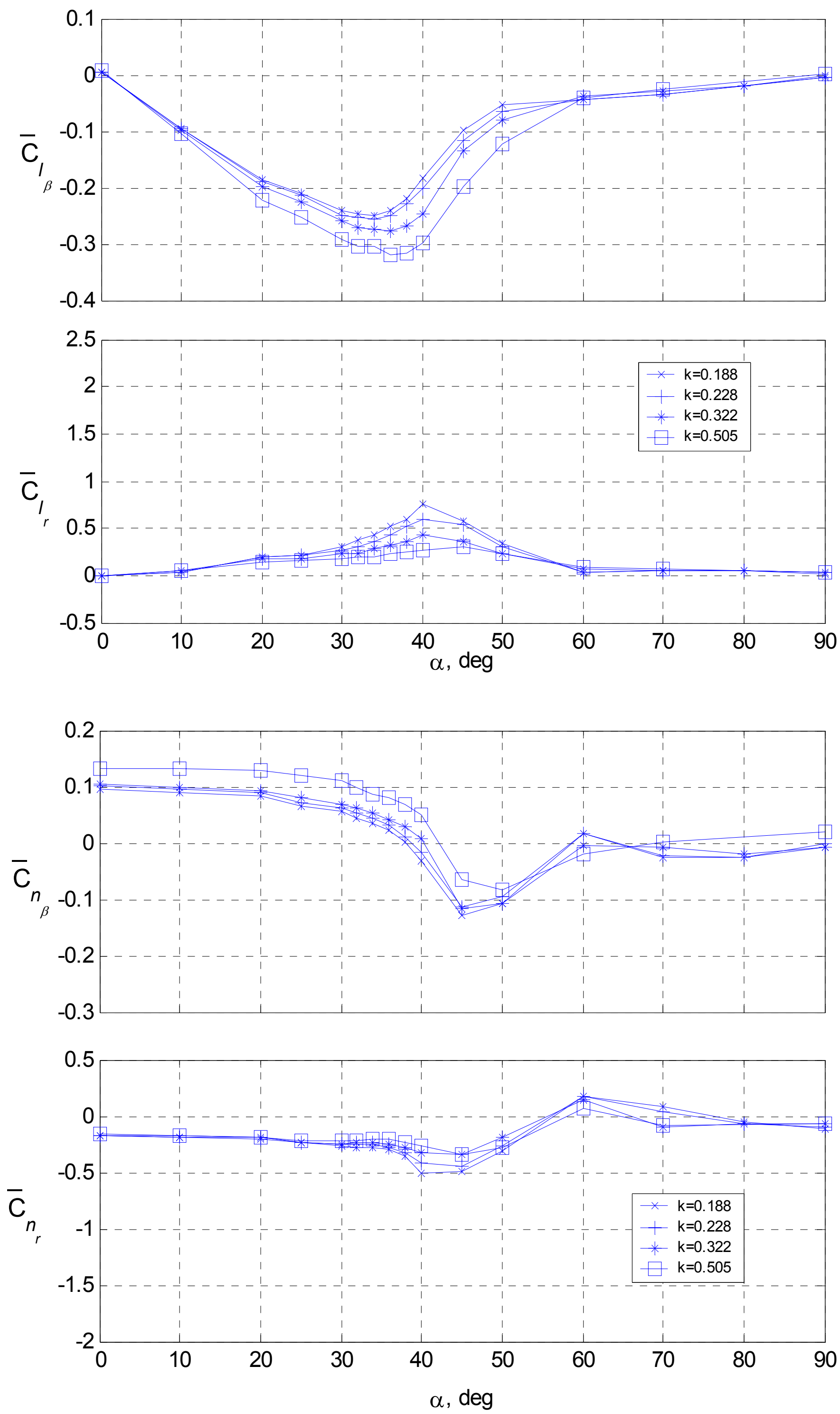
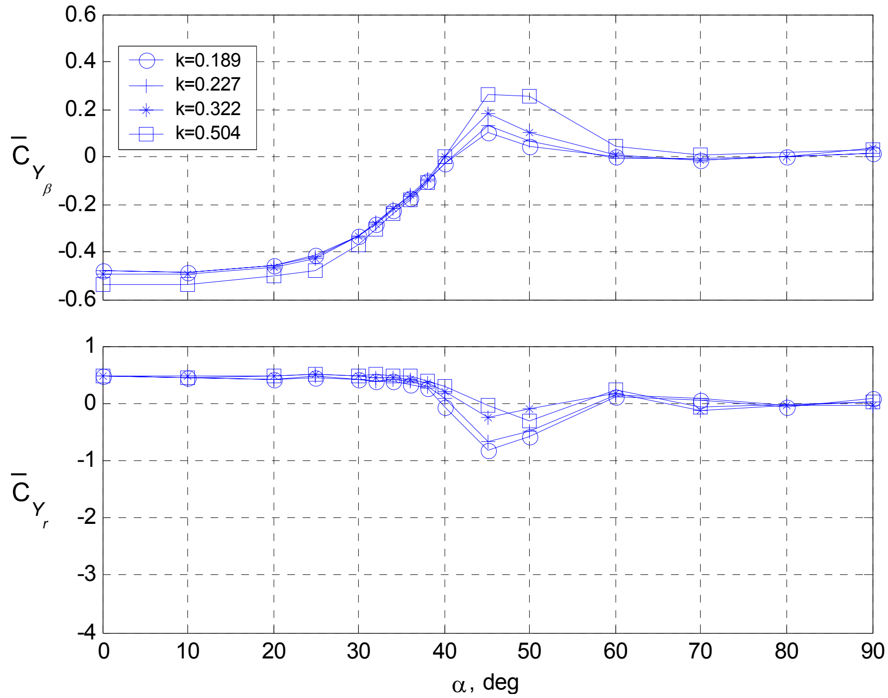


Figure 34. Variation of in-phase and out-of-phase components of lateral coefficients with angle of attack. Yawing oscillations, ψ_A=10^o, Re=0.6x10^6.



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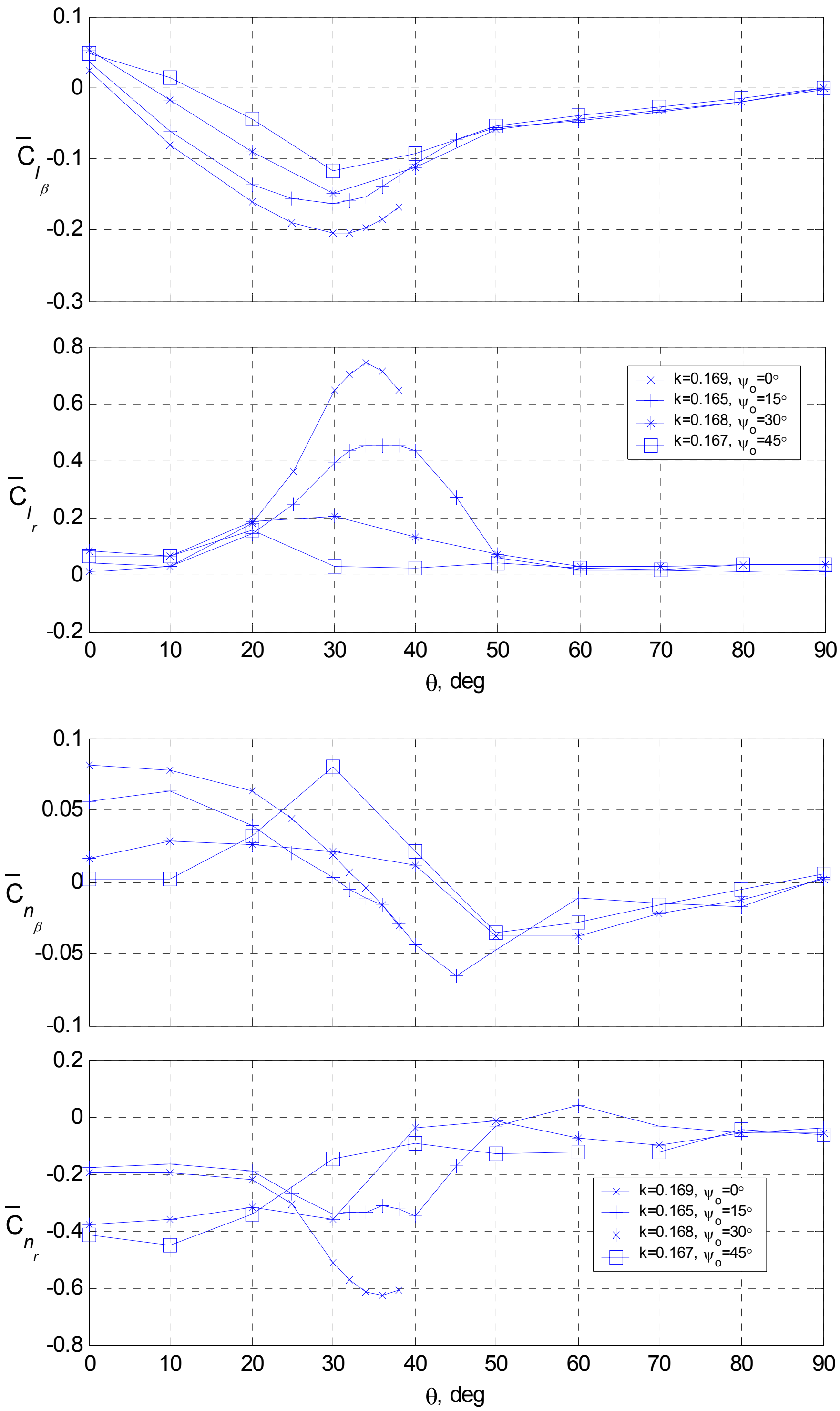

Figure 35. Effect of offset in yaw angle on in-phase and out-of-phase components. Yawing oscillations, ψ_A=30°.

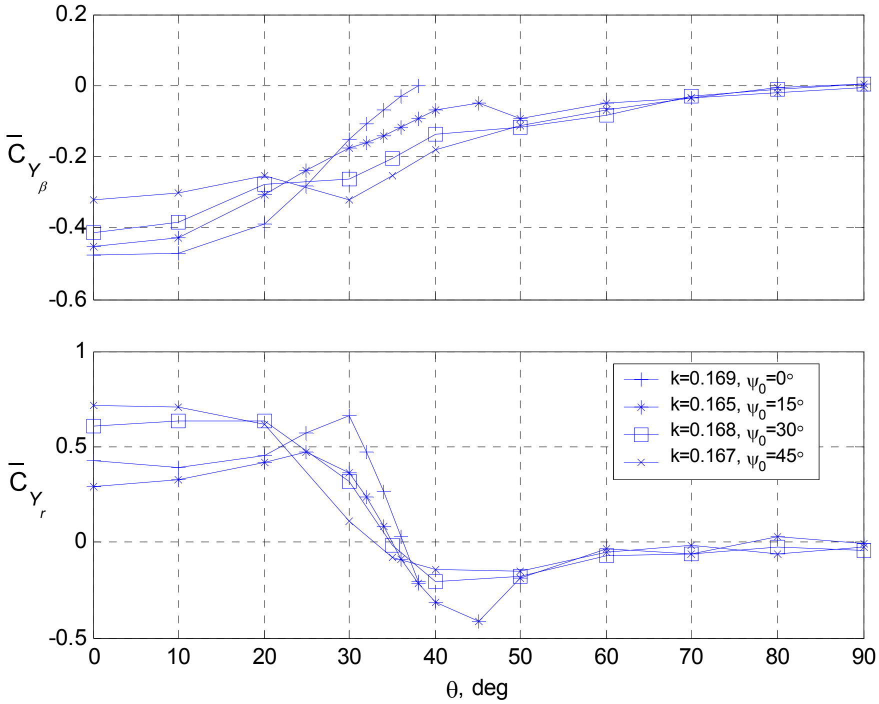

Figure 35. Concluded.

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14. ABSTRACT
Static and dynamic wind tunnel tests were performed on an 18% scale model of the F-16XL aircraft. These tests were performed over a wide range of angles of attack and sideslip with oscillation amplitudes from 5° to 30° and reduced frequencies from 0.073 to 0.269. Harmonic analysis was used to estimate Fourier coefficients and in-phase and out-of-phase components. For frequency dependent data from rolling oscillations, a two-step regression method was used to obtain unsteady models (indicial functions), and derivatives due to sideslip angle, roll rate and yaw rate from in-phase and out-of-phase components. Frequency dependence was found for angles of attack between 20° and 50°. Reduced values of coefficient of determination and increased values of fit error were found for angles of attack between 35° and 45°. An attempt to estimate model parameters from yaw oscillations failed, probably due to the low number of test cases at different frequencies.

15. SUBJECT TERMS
Dynamic wind tunnel tests; Indicial models; Unsteady aerodynamics; Harmonic analysis; Regression; Parameter estimation; System identification

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