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SUMMARY

The results of wind tunnel tests on a rudder operating downstream of a propeller and hull combination are presented. The tests used the 3.5m x 2.5m low speed wind tunnel at the University of Southampton. This report presents the results for two rudders, one all-movable the other a semi-balanced skeg-rudder. The rudders both have a mean chord of 667mm and NACA 0020 sections, but with varying taper ratio. A four bladed, 800mm diameter, adjustable pitch propeller was used. This propeller is a modified version of the Wageningen B4.40 series. Open-water results for the modified design were validated against published data. The rudder propeller combinations were tested both in a freestream and in way of a representative Mariner stern hull form.

The tests consisted of a series of parametric studies into the effect of the longitudinal and lateral distance between the propeller and rudder, propeller thrust loading, presence of a hull, and presence of a hull at a yaw angle. A five-component strain-gauge dynamometer was used to measure lift, drag and three moments on the rudder. A rotating strain gauge dynamometer measured the developed thrust and torque of the propeller. In addition, both spanwise and chordwise pressure distributions were measured on the rudder and hull surface to provide a detailed knowledge of the distribution of forces over the hull and the rudder. A tunnel wind speed of 10m/s was used and propeller revolutions were varied between 0 and 2100 rpm

Results are presented in the form of non-dimensional coefficients of lift (C_L), drag(C_D), spanwise(CP_S) and chordwise (CP_C) position of the centre of pressure variation with incidence for the rudder. The influence of rudder on propeller performance is given in terms of non-dimensional thrust (K_T) coefficient variation with advance ratio (J). The surface pressure measurements on the rudder are presented as both a spanwise distribution of the local lift coefficient and as a surface pressure distribution. The surface pressure measurements on the hull are presented as spanwise and chordwise distributions together with integrated normal force coefficient over the range of rudder angles.

The results provide data for detailed rudder design, for numerical modelling of the rudder/propeller and hull interaction problem and for use in manoeuvring simulations.

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NOMENCLATURE

A	Rudder Area (S.c)
AR_G	Geometric aspect ratio
c	Rudder chord
D	Propeller diameter
CP_c	Centre of pressure chordwise, %c, measured from leading edge
CP_s	Centre of pressure spanwise, %S, measured from root
C_D	Drag coefficient ($d/\frac{1}{2}\rho AV^2$)
C_D^*	Drag coefficient ($d/\frac{1}{2}\rho AK_Tn^2D^2$)
C_L	Lift coefficient ($L/\frac{1}{2}\rho AV^2$)
C_L^*	Lift coefficient ($L/\frac{1}{2}\rho AK_Tn^2D^2$)
C_n	Normal force coefficient, normal to rudder per unit span
C_T^*	Propeller thrust coefficient ($8T/\rho\pi D^2[V^2+(0.7\pi nD)^2]$)
C_Q^*	Propeller torque coefficient ($8T/\rho\pi D^2[V^2+(0.7\pi nD)^2]$)
d	Rudder drag force, body (ship) axis
L	Rudder lift force, normal to body (ship) axis
N	Normal force, normal to centreline of rudder
n	Propeller revs per sec
V	Wind speed (free-stream)
Q	Propeller torque
T	Propeller thrust
J	Propeller advance coefficient (V/nD)
K_T	Propeller thrust coefficient ($T/\rho n^2D^4$)
K_Q	Rudder torque coefficient ($Q/\rho n^2D^5$)
S	Rudder span
t	Rudder section thickness
X	Longitudinal distance, propeller plane to rudder leading edge in line with propeller axis
Y	Lateral distance between propeller axis and rudder stock
Z	Vertical distance between rudder root and propeller axis
ψ	Propeller advance angle ($\tan^{-1}[J/0.7\pi]$)
∂	Rudder angle relative to body(ship) axis
$\propto$	Net inflow angle
ρ	Mass density

1. INTRODUCTION

This report represents part of a continued programme under the MOSES (Manoeuvring of Ships Estimation Schemes) contract.

Extensive work has been carried out on all-movable rudders under the contract, but with the increasing use of skeg-rudders in ships and large yachts further investigation of performance of a skeg-rudder in the wake of a propeller and/or hull is considered necessary.

This report presents the results from a detailed wind tunnel investigation into the performance of a skeg-rudder and all-movable rudder downstream of a propeller and hull combination. The experiments were carried out in the University of Southampton 3.5m x 2.5m low-speed wind tunnel.

A comprehensive presentation is made of the results obtained in two weeks of wind tunnel testing carried out in March 1995. Section 2 details the rudder and propeller models used. The test rig and the tests carried out are described in sections 3 and 4.

Sections 5 and 6 detail respectively the data reduction and its presentation. Section 7 discusses the results. Conclusions and recommendations are presented in Section 8.

2. DESCRIPTION OF MODELS

2.1 Rudders

For these tests, two rudders were used, designated Rudder No. 2 and Rudder No. 0 (using the same designations as in Refs. 1-4). Rudder No.2 is rectangular with a chord of 667mm, a NACA 0020 section, and a span of 1000mm. Rudder No. 0 is a skeg rudder with a mean chord of 667mm, a NACA 0020 section, a span of 1000mm and a taper ratio of 0.8. A detailed description of the method of manufacture of the rudder models is given in Ref. 5. Table I presents the particulars of the rudders used in the current investigation and Figure 1 their overall dimensions. The rudders had pressure tappings to give complete coverage of the rudder surface as detailed in Figure 1. The manufacturing technique for the pressure tappings is outlined in Ref. 2.

For the tests carried out, the rudders had a roughness strip attached with its leading edge 5.7% of the chord from the leading edge on both sides of the rudder. The roughness strips were manufactured from 12mm wide double-sided tape densely covered with 100 grade carborundum grit (0.15mm diameter).

2.2 Propeller

A representative propeller design, based on the Wageningen B4.40 was used. The propeller has four blades, a diameter of 800mm and a blade area ratio of 0.40. Modifications made to the basic Wageningen design are detailed in Ref. 6 and consisted of altering the blade root shape to allow an adjustable pitch design with four separate blades and a split hub, removing rake and decreasing blade sweep to reduce centripetal loading moments at the root and also increasing the hub/diameter ratio from 0.167 to 0.25. Overall propeller details are summarised in Table II and a comparison of the basis and modified Wageningen B4.40 can be seen in Figure 2.

The split hub was manufactured from aluminium alloy and a positive clamping action allows the four blades to be rotated and clamped to the desired pitch ratio setting. The four blades were manufactured using hybrid carbon/glass fibre laid up in the same split female mould to produce identical blades. The production of the composite blades is detailed in Ref. 7 and the machining of the female mould in

Ref. 6. In appearance the hub/blade root region is very similar to that of a typical controllable pitch propeller.

2.3 Mariner Stern Form Hull

The Mariner form (Ref. 13) was used as the representative ship stern thus allowing the results to be used in conjunction with those from the rest of the MOSES managed research programme. A scale factor of 8.4 matches the existing rudder-propeller rig to that of the Mariner stern geometry. If the whole Mariner form were represented this would give an impractical model length of 19m as illustrated in Figure 3 for the inverted hull form. The outline of the wind tunnel working section is shown for comparison. Vertically, the floor of the working section is aligned with the design waterline. Physically, of primary importance with regard to rudder-propeller-hull interaction, is the direction imparted to the flow by the stern and the velocity profile within the hull wake. A physically representative stern flow can be achieved through the use of an exact stern shape upstream of the propeller for a proportion of the ship length and correct thickening of the model wake through the use of boundary layer stimulation.

The stern extends from the propeller plane to section 17. A total model length of 2.69m from propeller plane to model leading edge will allow drift angles of up to ±15° to be achieved without undue tunnel blockage effects. The final stern design uses the exact Mariner form to section 18 and then fairs using elliptical section to the front of the model. The shape of the resulting model waterlines is similar to that of an aerofoil and should not cause undue problems with flow separation for drift angles up to 15°. Calculations based on the typical wind tunnel speed of 10m/s, showed that the thickness of the boundary layer on the Mariner stern model needed to be doubled to achieve approximate similitude with full-scale. This can be achieved through the use of surface mounted studs. Schematics of the rudder, propeller and stern model arrangement are shown in Figures 4 and 5. Construction of the model is detailed in Ref. 12 with a table of offsets and pressure tappings.

3. APPARATUS

3.1 General

The tests were carried out in the 3.5m x 2.5m low-speed wind tunnel at the University of Southampton. The overall rig for testing the interaction of ship rudders and propellers is shown in Figure 6. The rig consists of two independent units which allow free-stream (open-water) tests to be carried out independently on rudders and propellers as well as the investigation of their interaction.

3.2 Rudder Rig/Dynamometer

The rig consists of a steel structure attached to the floor which supports a five-component strain gauge dynamometer below the tunnel working section. A description of the design and calibration of the dynamometer is given in Ref. 8. The rudder is bolted directly to the dynamometer. The dynamometer is levelled and adjusted vertically so that there is a small gap of approximately 2.5mm (0.004c) between the rudder root and the floor of the wind tunnel working section.

3.3 Propeller Rig

Full details of the propeller rig are given in Ref. 5. The rig is designed in such a way that the propeller can be adjusted vertically, longitudinally and at an angle of attack to the flow if required. The tests reported on were carried out with the propeller's axis of rotation 600mm above the wind tunnel floor. The propeller rotates anti-clockwise when viewed from aft (looking upstream).

An in line strain gauge dynamometer mounted close to the propeller measures the delivered thrust and torque. The design and static calibration of this dynamometer is detailed in Ref. 9. The two measurement components of the dynamometer are connected via a slip-ring assembly to Fylde Bridge balance units with a built in stabilised power supply. The bridge balance output voltage is measured directly (without amplification) using a Schlumberger Minate Digital Voltmeter.

A variable frequency inverter is used to control the 30kw electric drive motor and the propeller rpm can be continuously varied in small discrete steps between 0 and 3000 rpm. An optical shaft encoder was used to measure propeller revolutions and gives a voltage proportional to shaft rpm.

3.4 Data Acquisition System

The large number of individual data readings required the use of an automated system for data acquisition. An enhanced acquisition system has been established involving a new faster PC and new interface cards. The system is essentially the same as detailed in Refs. 1 and 2. but the software has been enhanced and changed to suit the new acquisition cards together with several added facilities.

Bridge output signals from the five-component rudder dynamometer, the rudder pressure transducers, and the propeller thrust/torque dynamometer are measured using a digital voltmeter connected to the data acquisition PC via an IEEE interface. Supply voltages for the dynamometers are measured using an analog to digital acquisition card inside the PC and control of the scanivalve unit is executed via a parallel interface also located on the card. Both the parallel and analog ports are connected via an interface box to allow versatile connection and more than one control function. All acquisition is controlled by software running on a the RM personal computer and the results stored on hard disk for subsequent analysis. A control system schematic can be seen in Figure 7.

4. TESTS

4.1 General

Results are reported from a 10 working day session of testing in the 3.5m x 2.5m low speed wind tunnel. The basic propeller-rudder tests were carried out at a nominal Reynolds number of 0.4×10^6, based on a free stream velocity of 10m/s.
Velocities induced by the propeller at the higher thrust loadings led to effective Reynolds numbers of up to 1.0×10^6 over much of the rudder based on rudder chord. English (Ref. 10) indicated that a satisfactory Reynolds number, based on propeller diameter and rpm, to avoid scaling problems would be greater than 1.4×10^6. The lowest rpm used on these tests was 800rpm which for an 800mm diameter propeller gives a Reynolds number, based on propeller diameter and rpm, of 1.53×10^6.

Rudder No. 2 was tested in the base position with the propeller axis 600mm above the wind tunnel floor, zero lateral separation, and a longitudinal separation X/D=0.39. A four-bladed propeller configuration with a pitch ratio setting, P/D=0.95, was used. This arrangement corresponded to the mid-longitudinal position used in previous tests reported in Ref. 1. Correspondence of results between test sessions was good and demonstrated the repeatability of the test methodology. The flow alignment was found to be +0.8 degrees for the all-movable rudder No. 2 and +0.2 degrees for the skeg-rudder No. 0. Open-water tests were also carried out with four blades at a pitch ratio of 0.95 at a range of positive revolutions for wind speeds of 10m/s and 15m/s.

4.2 Rudder-Propeller Interaction

The skeg-rudder No. 0 was the main concern in this part of the investigation with rudder No.2 being used mainly for verification.

In the base position the skeg-rudder No. 0 was tested at advance ratios, J=0.94, J=0.51 and J=0.35 which corresponds at a freestream velocity of 10m/s to a rate of revolution of the propeller of 800rpm, 1460rpm and 2100rpm respectively. Measurement of the propeller and rudder force dynamometers were made at incidence increments of 5° between -35° and +35°. For the investigation of rudder torque the rudder dynamometer measurements were taken for the movable rudder part only (excluding skeg) and for the investigation of manoeuvring forces the total rudder plus skeg forces were taken. Surface pressure surveys were carried out at 10° increments between -30° and +30°. Measurements were taken for the rudder-propeller combination with a lateral separation Y/D=+-0.25 and Y/D=+-0.125. These positions were all tested for manoeuvring forces with the position of Y/D=+0.25 tested for torque forces also. With a position of Y/D=-0.25, at one single advance ratio of J=0.35, the skeg angle was also changed to +-5° with rudder angles of -5°,0° and +5°

The rudder was tested with the wind tunnel fan stationary to simulate the bollard pull condition (J=0). The flow induced by the propeller drove the tunnel flow at a slow but measurable speed thus giving an effective advance ratio of J=0.17. The steady-state wind speed imparted by the propeller to the air in the tunnel was measured using a Betz manometer connected to the tunnel pitot-static tube upstream of the rudder-propeller rig. It should be noted that velocities induced by the propeller at the higher revs. led to effective Reynolds Numbers of up to $0.75x10^6$ over much of the rudder. Results presented in Ref. 10 indicate that tests at these conditions should preclude any significant scale effect. The test procedure and results obtained from an earlier preliminary study are described in Ref. 11.

4.3 Rudder-Propeller and Hull Interaction

The Mariner stern form was initially installed at a drift angle of 0°. In the base position the skeg-rudder No. 0 was tested for the 'freestream' (prop stationary) case in way of the rudder and hull combination and in the bollard pull (J=0) condition. A pressure survey over the hull model surface and dynamometer forces were measured at 10° increments between -30° and +30°.

For the three advance ratios, J=0.94, J=0.51 and J=0.35 dynamometer forces were measured at 5° increments between -35° and +35°. A pressure survey over the hull was conducted at 10° increments between -30° and +30°. The rudder was tested for two other longitudinal positions of X/D=0.52 and X/D=0.64 as well as the base position of X/D=0.39. In all cases, measured forces and pressures were taken in the same manner as for the base position.

5. DATA REDUCTION AND CORRECTIONS

5.1 Introduction

A computer program, described in Ref. 1, was used to provide the data in coefficient form. The program incorporates the rudder dynamometer five-component interaction matrix and correction formulae and the resolution of forces and moments from instrument axes to stream axis as necessary. A cross plot of raw rudder data yielded the angular misalignment of the rudder rig and this correction was applied to all measured angles before insertion in the program.

The acquisition of rudder and hull surface pressures, together with reference static and dynamic pressures from the tunnel, allowed direct calculation of the local static pressure coefficient Cp. Chordwise integration of Cp is carried out to give the normal force coefficient Cn for each span position.

The analysis program incorporates the propeller dynamometer calibrations hence allowing direct calculation of the propeller coefficients.

Tunnel boundary corrections were investigated but found to be unnecessary, as effects such as tunnel blockage for the 3.5m x 2.5m working section were found to have a negligible effect for the rudder size and propeller diameter tested.

5.2 Propeller Forces

The static calibration carried out on the Torque-Thrust dynamometer gave a linear response to loading of both thrust and torque with negligible interactions (Ref. 9)

Using the relevant wind speed V (m/s) and revolutionsn (revs/sec) the advance ratio J is calculated as:

$$J = \frac{V}{nD}$$

where D is propeller diameter. The non-dimensional thrust coefficient (K_T) and torque coefficient (K_Q) are given by:

$$K_T = \frac{T}{\rho n^2 D^4} \qquad K_Q = \frac{Q}{\rho n^2 D^5}$$

where ρ is the air density. The propeller efficiency η is:

$$\eta = \left(\frac{J}{2\pi}\right) \times \left(\frac{K_T}{K_Q}\right).$$

5.3 Rudder Forces

For the free stream tests and advance ratios J of 0.94, 0.51 and 0.35 the non-dimensional coefficient form of the rudder forces are obtained as follows:

$$C_L = \frac{L}{\frac{1}{2}\rho U_0^2 A} \qquad C_D = \frac{d}{\frac{1}{2}\rho U_0^2 A}$$

$$C_{Mz} = \frac{Mz}{\frac{1}{2}\rho U_0^2 Ac} \qquad C_{Mx} = \frac{Mx}{\frac{1}{2}\rho U_0^2 AS} \qquad C_{My} = \frac{My}{\frac{1}{2}\rho U_0^2 AS}$$

For the nominal bollard pull case where the advance ratio J=0.17, the coefficients are non-dimensionalised using $K_T n^2 D^2$ which is based on the theoretical velocity at J=0. These non-dimensionalised coefficients are designated by C_L' and C_D' etc. and are defined as follows:

$$C_L' = \frac{L}{\frac{1}{2}\rho A K_T n^2 D^2} \qquad C_D' = \frac{d}{\frac{1}{2}\rho A K_T n^2 D^2}$$

$$C_{Mz}' = \frac{Mz}{\frac{1}{2}\rho A c K_T n^2 D^2} \qquad C_{Mx}' = \frac{Mx}{\frac{1}{2}\rho A S K_T n^2 D^2} \qquad C_{My}' = \frac{My}{\frac{1}{2}\rho A S K_T n^2 D^2}$$

Where U_0 is the free stream velocity (m/s), S the rudder span, c the mean rudder chord, and A the total rudder area (A=S.c). The position of the centre of pressure on the rudder in the spanwise and chordwise directions is obtained as follows:

$$CP_c = \left(\frac{M_z}{N} + W\right) \times \frac{100}{c} \qquad CP_S = \left(\frac{M_N}{L} - V\right) \times \frac{100}{S}$$

Where W is the distance of the dynamometer rudder stock from the leading edge and V the distance from the dynamometer measurement centre to the rudder root.

In comparing the propulsive effect of the two rudders, two effective propeller thrust coefficients are defined. The net thrust of the propeller and rudder combination $K_{T(R+P)}$ is defined as:

$$K_{T(R+P)} = K_T - K_D$$

and the net thrust excluding the free-stream drag of the rudder $K_{T(st)}$ defined as:

$$K_{T(st)} = K_T - (K_D - K_{D0})$$

where K_D is the drag of the rudder and K_{D0} the free-stream drag of the rudder. K_D is defined as:

$$K_D = \frac{d}{\rho n^2 D^4} = \frac{1}{2}\frac{A}{D^2} J^2 C_D$$

Useful measures of the performance of rudders are its lift curve slope at zero incidence $dC_L/d\alpha$ and the corresponding drag at zero incidence C_{D0}. These values are obtained directly from the rudder performance data.
The influence of upstream body and/or propeller slipstream on the effective angle of drift seen by the rudder is defined as a flow straightening factor γ:

$$\gamma = \frac{\alpha_0}{\beta_R}$$

where β_R is the geometric yaw (or drift) angle at the rudder and α_0 the angle of rudder incidence for zero sideforce at that drift angle.

The actual incidence that the rudder encounters or the effective rudder angle α_E is defined as:

$$\alpha_E = \partial - \gamma \beta_R$$

5.4 Surface Pressures

The four differential pressure transducers used in conjunction with the rotary scanivalve give a maximum of 144 individual pressure measurements for any test. The no-wind pressure transducer output voltage V_{P0} was measured at the beginning of each test. The reference pressure connected to all four transducers was the static line of the main wind tunnel pitot-static probe. This line was also connected to one input port for each transducer to give a 'real' zero pressure difference value V_{P0}. The pitot line was connected to another input port to give a voltage V_{DP} proportional to the total tunnel dynamic pressure.

For each pressure port measurement V_P, the non-dimensionalised pressure coefficient C_P is obtained directly as:

$$C_P = \frac{V_P - V_{P0}}{V_{DP}}$$

This expression does not require an explicit value for the calibration constant of the particular pressure transducer, since the transducer has a linear response.

As the location of each pressure measurement on the rudder surface is known, integration of C_P around the chord of the rudder for a constant span allows the local non-dimensional Normal Coefficient C_n to be calculated. The integration was carried out using a quadratic numerical procedure similar to Simpson's rule but with variable spacing.

6. PRESENTATION OF DATA

The notation of rudder incidence and coefficients used in the presentation is given in Figure 8. The propeller rotates in an anti-clockwise direction when viewed from aft as shown in the diagram.

The main types of graphical presentation used in this report are:

1) Rudder performance

Rudder sideforce, drag, Cpc and Cps are plotted against rudder incidence. Lift and drag are always perpendicular and parallel to the ship axis even for cases where a drift angle is imposed on the bodies.

2) Propeller performance

Propeller thrust and thrust augment (the difference between actual and open-water propeller thrust) are plotted against advance ratio J.

3) Sectional rudder performance

Integration of rudder surface pressure measurement allows the spanwise variation in rudder sideforce to be obtained. The sectional force coefficient Cn is presented to a base of rudder span for different rudder incidence.

4) Rudder chordwise pressure distributions

The rudder surface pressure coefficients are presented in terms of chordwise pressure distributions with the solid line representing the positive side of the rudder and the dotted line the negative side of the rudder.

5) Hull pressure distributions

The hull surface pressure coefficients are presented in terms of chordwise and spanwise pressure distributions, with both sides being presented for varying J values.

6) Hull forces

Integration of the hull surface pressure coefficients allows hull forces to be obtained. The forces are non-dimensionalised with respect to rudder area for direct comparison between hull and rudder forces.

Additional forms of presentation are described within the discussion.

7. DISCUSSION OF RESULTS

7.1 Parameters which Control Rudder-Propeller Interaction

In investigating the various independent parameters on which rudder forces depend, an underlying understanding of the physics of the flow of an isolated rudder and propeller should be obtained. This understanding then gives guidance when addressing the cumulative problem of a hull, rudder and propeller combination. Free surface effects and cavitation are not considered primary in determining the operating conditions of the hull, rudder and propeller combination and were not investigated in this study.

In discussing the parameters which govern the interaction it is convenient to group them into four categories. These are discussed in Ref. 2 and can be summarised briefly as:

i) Flow variables which control the magnitude of the forces developed:
Time dependent variables free-stream velocity (V) and propeller rate of revolution (n). Fluid properties density (ρ) and dynamic viscosity (μ). The yaw angle (β) between the rudder-propeller combination and the free stream.

ii) Rudder geometric variables:
Rudder incidence (α), span (S), mean chord (c), stock position (W), thickness (t), section shape , sweep and twist.

iii) Propeller geometric variables:
Diameter (D), pitch (P), boss diameter, sweep, pitch and thickness distributions, number of blades and blade area ratio.

iv) Relative position and size of the rudder and propeller.
separation longitudinally (X), laterally (Y) and vertically (Z) and the relative size defined by the coverage ξ.

The flow parameters in non-dimensional form become Reynolds number, Rn and Advance Ratio, J. The remaining three categories consist of solely geometric parameters. Figure 8 illustrates the geometry of a rudder-propeller combination and corresponds to the wind tunnel arrangement used.

7.2 Influence of Propeller on Rudder Performance

Figures 9 to 13 show the effect of different thrust loadings on rudder performance for the rudder-propeller geometries tested. The overall shape of the rudder lift drag curves varied little for the rudders tested. The effect of increasing thrust loading, as reported in Molland and Turnock (Ref. 1), is to:

i) increase the lift-curve slope above that of free-stream;
ii) significantly delay stall, even for low thrust loading (high J);
iii) stall is no longer the same for positive and negative incidence;
iv) drag component due to lift increases;
v) CP_c moves forward from free stream position;
vi) CP_s increases for positive incidence and decreases for negative incidence.

It is the propeller thrust loading (K_T/J^2) which controls the manoeuvring performance of the rudder and this is clearly demonstrated in Figures 9 to 13

7.2.1 Rudder Plus Skeg Forces

Figures 10 and 11 show the influence of thrust loading on the forces developed on the skeg and all-movable part of the semi-balanced Skeg Rudder No. 0. The lift curve slope of the skeg rudder shows a drop in the lift curve slope, for all J values, at an incidence of -5 degrees. This is thought to be due to the gap flow between the skeg and the movable part of the rudder thus causing a pressure drop that decreases the lift. This phenomenon only occurs at about -5 degrees due to the additive effect of the influence of the propeller on the pressure difference at that incidence. At +5 degrees the pressure difference will be less due to the influence of the propeller. This will limit or halt the gap flow and thus no drop in lift is experienced. A similar, associated change is seen in the drag characteristics. The chordwise and spanwise centre of pressure behave in a similar manner to the all-movable Rudder No. 2.

7.2.2 Rudder Alone Forces (Rudder Torque Considerations)

Figures 12 and 13 show measured forces solely for the movable part of the rudder (excluding skeg) of Rudder No. 0. The main result is a force offset such that zero force does not occur at a rudder incidence of 0 degrees. This is due to the asymmetric flow of the propeller. At higher propeller thrust loadings (lower J values) the effect becomes more apparent and the offset increases. This is also seen in the spanwise centre of pressure with CP_S moving towards the rudder tip for positive incidence.

The rudder lift and drag are, in general, lower for the rudder alone compared to rudder plus skeg forces.

7.3 Influence of Lateral Separation on Rudder Performance

Figure 14 to Figure 17 show the effect of lateral separation of the rudder and propeller. The general result of separating the rudder laterally from the propeller is to cause an offset in the lift curve slope so that zero lift no longer occurs at a rudder incidence of 0°. A negative shift of incidence for zero rudder force is experienced for positive separation and conversely a positive shift of incidence is experienced for negative lateral separation. Rudder drag is generally larger for all values of lateral separation compared to Y/D=0.

Figure 18 shows the effect of one lateral position on rudder alone forces. The effect is the same as the rudder plus skeg result but the magnitudes of the forces are less.

7.4 Influence of Hull and Propeller on Rudder Performance

Figures 19 to 21 show rudder force characteristic for Rudder No. 2 for the model hull upstream of the rudder-propeller combination for various thrust loadings.

Figure 19 shows that for all values of J, lift on Rudder No.2 has decreased and drag has increased with the presence of the hull . Chordwise centre of pressure has moved backwards towards the trailing edge and spanwise centre of pressure has moved down towards the root due to the presence of the hull.

Figures 20 and 21 show that for all values of J, lift and drag on the Skeg Rudder No.0 have followed the same pattern as for Rudder No.2. The change is not so marked as for Rudder No.2 with the lift drop being less and the drag increase being only a small percentage larger than that without the hull upstream. It is interesting to note the change in slope at -5° is still present.

Figure 22 shows the freestream results with the propeller stationary. Results are as expected with the lift and drag being considerably less than that of the propeller in operation especially at high thrust loadings (low J values). The decrease in the lift-curve slope is 53% which, based on a lift identity, corresponds to an equivalent Taylor wake fraction of 0.27.

7.5 Influence of longitudinal Separation on Rudder Performance for Hull and Rudder-Propeller Combination

Figure 23 to Figure 25 show the effect of longitudinal separation of the rudder and propeller-hull combination for various thrust loadings.

The change in lift with increased longitudinal rudder propeller separation is small with a slight decrease for Rudder No.2 and Skeg-Rudder No. 0. Longitudinal separation does alter the drag on the rudder and increased separation appears to reduce drag, particularly at lower advance ratios. The centre of pressure chordwise and spanwise does not alter significantly with increased separation.

7.6 Influence of Yaw Angle on Rudder Performance for Hull and Rudder-Propeller Combination

Figure 26 shows forces for the skeg-rudder, propeller and hull combination at a yaw angle of -7.5° for various thrust loadings. The forces shown are for the ship axis with lift being perpendicular to the hull centreline and drag parallel to the hull centreline.

The main result of introducing a yaw angle on the combination is to produce an offset such that lift is experienced at zero rudder incidence. Another effect of yaw angle is that zero force is not experienced at the same angles for varying J. This phenomenon is due to the straightening effect of the propeller. For higher thrust loadings (lower J value) the offset will be greater and tend towards -7.5° as the flow is curved towards the ship axis due to the action of the propeller.

Figure 27 shows forces for only the all-movable part of the skeg rudder. The effect is similar to that of the total skeg and rudder forces but the influence of the propeller is greater when accounting for torque. The offset at higher J values tends to an angle greater than -7.5° and this is due to the cumulative effect of the flow straightening and the twisting of the flow mentioned in Section 7.2.2 and shown in Figure 12.

7.7 Influence of Rudder on Propeller Thrust Loading

The results presented are for three values of advance ratio J. These advance ratios, for a given pitch ratio, have a known open-water thrust coefficient K_T. However, Figures 29 to 39 show the influence of the rudder type, the hull, the longitudinal and lateral separation, and the yaw angle on the measured propeller thrust coefficient at zero incidence, These are to be compared with the propeller open-water characteristics, given in Figure 28.

Figures 29 and 30 show the thrust and thrust augment experienced with Rudder No. 2 and Skeg-Rudder No. 0 respectively. These indicate that the general influence of a rudder, in way of the propeller race, on the propeller performance is to lead to a positive thrust augment to the open water characteristics. The thrust augment is due to the blockage of the flow by the rudder causing an effective reduction in speed of inflow into the propeller.

With increasing thrust loading (lower J) the thrust augment, due to the rudder blockage, generally increases.

7.8 Influence of Lateral Separation on Propeller Performance

Figure 31 show the influence of lateral separation of the Skeg-Rudder-Propeller combination on thrust and thrust augment. As the rudder is moved away from the centreline The thrust augment experienced is not linear this is more clearly shown in Figure 32. Depending on the advance ratio, maxima and minima are experienced at various lateral positions. For the higher thrust loading (J=0.51) the asymmetry of the flow is apparent with maxima experienced at +0.125 and -0.25 and minima experienced at +0.25 and -0.125 for the limited lateral separation tested. The non-linearity is due to the non-uniform flow induced by the rudder through the propeller and therefore these positions experience different thrust augments when the lateral position of the rudder is varied.

7.9 Influence of Hull and Rudder on Propeller Performance.

Figures 33 and 34 show the propeller thrust and thrust augment with the hull present for Rudder No. 2 and Skeg-Rudder No.0 respectively. The thrust augment experienced is greater than that of just the rudder and propeller. This is again due to the fact that there is an effective speed reduction of inflow due to the presence of the hull.

7.10 Influence of Longitudinal Separation on Propeller Performance.

Figures 35 and 36 show the propeller thrust and thrust augment for varying rudder propeller longitudinal separation for the hull and Rudder No.2 and the hull and Skeg-Rudder No. 0 respectively. Thrust augment is non-linear with separation. As the rudder moves aft the thrust increment decreases and then starts to increase again and this is more clearly shown in Figure 37. For all three advance ratios there is a minimum around a longitudinal separation of X/D=0.52. It is thought likely that this effect is propeller pitch dependent.

7.11 Influence of Yaw Angle on Propeller Performance.

Figure 38 shows the thrust and thrust increment for a Yaw angle of -7.5 degrees for the Skeg-Rudder No.0 and Hull. The thrust augment experienced over all the J values was larger than that of zero yaw angle. This is due to the angle of flow entering the propeller obliquely and altering the propeller performance from that in a uniform flow.

7.12 Spanwise Distribution of Local Normal Force Coefficient.

Figures 39 to 41 show the spanwise distribution of local normal force for All-Movable Rudder No. 2 and Figures 42 to 44 for Skeg-Rudder No. 0 for three J values of 0.94, 0.51 and 0.35 respectively. The increase in rudder lift caused by the tip vortex is apparent at the higher values of rudder incidence.

The influence on the force distribution of the increase in thrust loading can clearly be seen. At high J values the force coefficient outside the impinging propeller slipstream is of the same order as that within the slipstream whereas at low J values the slipstream local force coefficients dominate the loading on the rudder.

The lift distribution of the skeg-rudder in the region of the skeg is lower than that for the all movable region. This is due to zero skeg incidence and therefore the lift induced by the split portion of the rudder is less. There is a noticeable discontinuity at 500mm span corresponding to the tip of the skeg.

7.13 Chordwise Rudder Pressure Distributions

Figures 45 to 47 show the chordwise variation in local pressure coefficient for All-Movable Rudder No. 2 and Figures 48 to 50 for Skeg-Rudder No. 0. These are investigated for rudder incidence and propeller advance ratio. In general the results are of similar nature. The high leading edge values of C_P for high thrust loading arise from use of freestream velocity in the calculation of C_P. The plots are given for completeness and to allow the comparison of theoretical rudder surface pressure distributions. They also provide valuable data for carrying out structural analysis of semi-balanced skeg rudders.

7.14 Hull Pressures

7.14.1 Chordwise Pressure Distributions (along hull waterlines)

Figure 51 to Figure 56 show chordwise pressure distributions over the hull at 4 spanwise (draught) positions. Figure 51 shows the freestream results for the hull. The pressure distributions show little change over the range of rudder angles.

Figure 52 shows the pressure distribution for varying thrust loading and it can be seen that as thrust loading increases (lower J) the pressure distribution at the trailing edge separates whereas the distribution at the leading edge of the hull remains the same for all J values. The pressure distributions in general again do not vary considerably with rudder angle.

Figures 53 and 54 show the distributions for the longitudinal separations of X/D=0.52 and X/D=0.64 respectively. The influence of longitudinal separation is not great but as the separation is increased to X/D=0.64 a larger effect is experienced further upstream on the hull with varying J values. Figure 55 shows the distribution for a high thrust loading of J=0.17 at a longitudinal separation of X/D=0.64. This case shows a slight asymmetry with respect to the positive and negative side of the hull due to the axial inflow from the propeller. It is suspected that there may have been questionable results around the leading edge for this particular case due to the scanivalve not operating properly. These results are not consequential as the results have shown that the pressures at the bow are not important with respect to the investigation of the influence of the propeller on the hull.

Figure 56 presents the chordwise pressure distribution for the hull but with a yaw angle of -7.5 degrees. The difference on the positive and negative side is clear showing a resultant lift on the hull as expected. Again thrust loading does have an effect on the afterbody of the hull but still with little influence on the forebody.

7.14.2 Spanwise Pressure Distributions (over hull transverse sections)

Figures 57 to 61 show spanwise pressure distributions over the hull at 3 aft chordwise (longitudinal) positions. For the freestream case Fig. 57. it can be seen that the pressure distribution is largely symmetrical over the range of rudder angles and also does not alter much. With propeller thrust loading (Figure 58) the pressure distributions become asymmetric with one side experiencing, in general, a lower pressure coefficient than the other corresponding to an increased speed of flow due to the propeller. It can also be seen that for the pressure distributions closer to the propeller (i.e. X=2.364m) the influence gets larger, whereas the distribution nearest the bow experiences little effect from the propeller and rudder combination.

Figures 59 and 60 show the influence of longitudinal separation of the rudder and propeller having little effect on the pressure distribution over the hull. Figure 61 shows the effect of drift angle on the hull pressure distribution. The asymmetry of the flow can clearly be seen causing a larger separation of positive and negative side pressure coefficient even towards the bow.

In general, the small changes in pressure due to different incidence and thrust loading measured on the forebody validates the use of a shortened hull stern model.

7.15 Hull Forces

Figures 62 to 65 show the force data from integrating the pressures over the hull. The forces are presented for varying rudder angles and thrust loading. It can be seen that the general trend is similar to that on the rudder. A negative force is experienced on the hull for negative rudder incidence and similarly a positive force is experienced for a positive incidence. This is evident for all cases including the freestream case (Figure 62). It can be seen that for the free stream case the linear regression shows an offset at 0 degrees of incidence this may be due to a slight asymmetry to the model and also a slight misalignment to the wind tunnel axis.

For increasing thrust loading (lower J) the force magnitude on the hull is greater. When the hull is yawed an offset on the force is experienced.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 The overall shape of the rudder lift and drag curves varied little for the parameters tested including rudder geometry.

8.2 In considering the torque effects of a skeg rudder, measuring the movable part forces only, the results reveal a zero offset in the lift and drag curves at zero degrees of rudder incidence due to the propeller flow.

8.3 In general the effect of having a skeg rudder as opposed to an all-movable blade rudder shifts the spanwise centre of pressure towards the tip and a drop in the lift and drag curve is experienced at a round -5 degrees due to skeg gap flow and asymmetric propeller race.

8.4 Lateral separation of the rudder stock from the propeller axis causes a shift in rudder incidence for zero lift. This shift in incidence for zero lift increases with thrust loading. In other respects the rudder characteristics are unchanged.

8.5 Longitudinal and lateral separation of the rudder stock from the propeller axis influence the thrust augment experienced by the propeller due to the rudder in a non-linear manner.

8.6 Hull sideforce is produced due to the rudder propeller combination and the main influence is near the propeller plane. Rudder incidence and propeller advance ratio have an influence and increase in lift was found to be of the order of 10% of actual rudder lift for a given rudder incidence.

8.7 The work reported enables a better understanding of skeg-rudder performance behind a hull and propeller combination. It also gives an indication of the influence of the rudder and propeller combination on the manoeuvring performance of the hull.

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REFERENCES

1. Molland, A.F. and Turnock, S.R. 'Wind Tunnel Investigation of the Influence of Propeller Loading on Ship Rudder Performance'. University of Southampton, Ship Science Report No. 46, 1991.

2. Molland, A.F. and Turnock, S.R. 'Further Wind Tunnel Tests on the Influence of Propeller Loading on Ship Rudder Performance'. University of Southampton, Ship Science Report No. 52, 1992

3. Molland, A.F. and Turnock S.R. 'Wind Tunnel Investigation of the Influence of Propeller Loading on Ship Rudder Performance'. RINA, (Paper W3 for written discussion), 1992

4. Molland, A.F. and Turnock, S.R. 'The prediction of Ship Rudder Performance Characteristics in the Presence of a Propeller'. Proc. of Conf. Manoeuvring and Control of Marine Craft, MCMC92, University of Southampton, 1992.

5. Turnock, S.R. 'A test Rig for the Investigation of Propeller/Rudder Interactions'. University of Southampton, Ship Science Report No. 45, 1990.

6. Turnock S.R. 'Computer Aided Design and Numerically Controlled Manufacture of a Split Mould for a Composite Model Ship Propeller'. University of Southampton, Ship Science Report No. 42, 1990.

7. Molland, A.F. and Turnock S.R. 'The Design and Construction of Propeller Blades in Composite Materials for a Wind Tunnel Model', University of Southampton. Ship Science Report No. 41, 1990.

8. Molland, A.F. 'The Design, Construction and Calibration of a Five-Component Strain Gauge Wind Tunnel Dynamometer'. University of Southampton, Ship Science Report 1/77, 1976.

9. Molland, A.F. and Turnock, S.R. 'The Design, Construction and Calibration of a Thrust and Torque Dynamometer for a Wind Tunnel Propeller Model'. University of Southampton, Ship Science Report No. 44, 1990.

10. English, J.W., and Bain, D.C., 'Some manoeuvring devices for use at zero and low ship speed', Trans. NECEIS, Vol. 88, 1971/72.

11. Molland, A.F. and Turnock, S.R. 'Preliminary wind tunnel investigation of the influence of propeller loading on a ship rudder in the bollard (J=0) condition'. University of Southampton, Ship Science Report No. 49. 1993.

12. Molland, A.F. and Turnock, S.R. 'Wind Tunnel Tests on the Effect of a Ship Hull on Rudder Performance at Different Angles of Drift.' University of Southampton, Ship Science Report No. 76. 1995.

13 Russo, V.L. and Sullivan E.K., 'Design of the Mariner-Type Ship.' SNAME Transactions, Vol. 61 1953.

TABLE I: PARTICULARS OF THE TWO RUDDER MODELS

Rudder No.	0 (Skeg Rudder)	2
Chord c mm	667	667
Span S mm	1000	1000
Geometric Aspect Ratio AR_G	3.0	3.0
Taper Ratio C_T/C_R	0.8	1.0
Thickness/ chord Ratio t/c	0.20	0.20
Section	NACA 0020 constant section with square tip	

TABLE II: PROPELLER DETAILS - *Modified Wageningen B.4.40 Series*

Number of Blades	4
Range of revolutions rpm	0 to 3000
Diameter mm	800
Boss Diameter (max) mm	200
Mean Pitch Ratio	0.95 (set for tests)
Blade Area Ratio	0.4
Rake (deg)	0
Blade thickness ratio t/D	0.050
Sections shape	Based on Wageningen B series
Blade outline shape	Based on Wageningen but with reduced skew

APPENDIX A RUDDER FORCE DATA

Unless otherwise stated X/D=0.39, Y/D=0.0 and Z/D=0.75
RUDDER DYNAMOMETER

yprj11.rud
800 rpm **Rudder No. 2** **10 m/s**

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-30.8	-1.245	0.481	35.726	49.5091	-0.076	-0.85	0.296
-25.8	-1.484	0.329	27.982	49.1283	0.03	-0.988	0.221
-20.8	-1.299	0.208	23.43	46.7435	0.084	-0.831	0.143
-15.8	-0.973	0.119	21.525	45.6152	0.082	-0.61	0.089
-10.8	-0.657	0.066	20.554	43.938	0.062	-0.401	0.055
-5.8	-0.349	0.042	19.867	40.4896	0.036	-0.201	0.037
-3.8	-0.238	0.032	21.612	37.1357	0.02	-0.129	0.032
-2.8	-0.175	0.033	23.6	34.3931	0.011	-0.09	0.03
-1.8	-0.12	0.034	26.113	28.2231	0.005	-0.055	0.029
-0.8	-0.065	0.033	34.27	11.5431	-0.00267	-0.019	0.029333
0.2	-0.003	0.036	556.886	-911.106	-0.013	0.022	0.03
1.2	0.052	0.037	-10.759	94.8657	-0.022	0.059	0.03
2.2	0.107	0.038	1.988	68.1389	-0.03	0.092	0.031
4.2	0.508	0.116	36.432	-1.793	0.033	0.082	-0.008
9.2	0.514	0.087	15.799	52.0777	-0.074	0.359	0.052
14.2	0.818	0.146	19.015	50.6333	-0.091	0.561	0.083
19.2	1.12	0.228	21.466	50.7516	-0.097	0.772	0.134
24.2	1.333	0.357	24.789	52.4144	-0.071	0.951	0.208
29.2	1.482	0.501	29.798	52.7407	-0.003	1.069	0.303
34.2	1.568	0.675	33.868	52.9234	0.065	1.154	0.402

yprj21.rud
1460rpm **Rudder No. 2** **10 m/s**

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-30.8	-2.668	0.903	31.912	45.2373	-0.053	-1.644	0.617
-25.8	-2.535	0.552	23.149	47.2165	0.172	-1.622	0.395
-20.8	-2.062	0.348	20.766	46.065	0.189	-1.298	0.254
-15.8	-1.56	0.198	19.145	44.28	0.169	-0.955	0.154
-10.8	-1.068	0.101	18.789	40.8925	0.12	-0.619	0.084
-5.8	-0.579	0.05	19.665	34.2841	0.06	-0.297	0.051
-3.8	-0.39	0.048	20.307	27.9107	0.038	-0.176	0.043
-2.8	-0.288	0.044	21.43	20.4212	0.025	-0.108	0.041
-1.8	-0.193	0.022	20.616	5.5378	0.018	-0.044	0.032
-0.8	-0.099	0.033667	41.264	-39.0174	-0.00967	0.021	0.041333
0.2	-0.005	0.032	640.866	-1980.73	-0.028	0.09	0.04
1.2	0.097	0.034	-14.326	142.8877	-0.043	0.156	0.041
2.2	0.191	0.041	0.643	97.9541	-0.057	0.221	0.043
4.2	0.379	0.051	8.301	74.9714	-0.083	0.351	0.049
9.2	0.848	0.114	13.422	62.9583	-0.142	0.683	0.084
14.2	1.321	0.217	16.827	59.7085	-0.176	1.025	0.149
19.2	1.8	0.368	19.355	57.7826	-0.194	1.364	0.251
24.2	2.244	0.577	22.1	57.0307	-0.18	1.687	0.397
29.2	2.619	0.903	27.239	56.0493	-0.075	1.955	0.612

yprj31.rud

2100rpm Rudder No. 2 10 m/s

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-30.8	-4.326	1.206	22.607	47.9057	0.32	-2.798	0.841
-25.8	-3.665	0.81	20.441	46.9988	0.349	-2.331	0.591
-20.8	-2.945	0.486	18.879	45.6327	0.325	-1.829	0.386
-15.8	-2.235	0.251	17.884	43.4158	0.268	-1.339	0.23
-10.8	-1.093	0.189	42.852	36.6013	-0.143	-0.612	-0.007
-5.8	-0.808	0.012	20.901	30.6188	0.073	-0.384	0.055
-3.8	-0.54	0	24.192	19.9112	0.031	-0.2	0.038
-2.8	-0.406	0.002	27.177	9.6865	0.011	-0.109	0.033
-1.8	-0.265	-0.001	34.837	-13.781	-0.013	-0.009	0.029
-0.8	-0.13967	-0.00933	67.6583	-87.4174	-0.05267	0.097667	0.030333
1.2	0.143	-0.004	-42.153	197.8051	-0.103	0.307	0.032
4.2	0.558	0.023	-0.656	91.5329	-0.171	0.607	0.046
9.2	1.22	0.113	7.803	71.9401	-0.271	1.09	0.107
14.2	1.879	0.269	9.987	66.4443	-0.377	1.581	0.213
19.2	2.526	0.483	12.825	64.1801	-0.437	2.074	0.363
24.2	3.208	0.792	15.779	62.4522	-0.462	2.589	0.579
29.2	3.853	1.177	18.989	61.565	-0.433	3.086	0.859

ypsj13.rud Rudder plus skeg forces

800rpm Skeg-Rudder No. 0 10 m/s

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-35.2	-1.15	0.517	36.922	18.1247	-0.019	-0.339	0.284
-30.2	-1.089	0.395	35.149	18.1203	0.003	-0.341	0.222
-25.2	-0.9	0.294	32.038	17.8358	0.031	-0.284	0.176
-20.2	-0.752	0.216	30.55	17.9001	0.038	-0.243	0.139
-15.2	-0.669	0.15	27.305	19.185	0.055	-0.232	0.104
-10.2	-0.488	0.079	19.737	19.2989	0.077	-0.173	0.064
-5.2	-0.451	0.072	49.983	12.1086	-0.067	-0.146	-0.116
-3.2	-0.1725	0.0465	-5.034	36.6148	0.0555	-0.084	0.001
-2.2	-0.13	0.041	7.804	14.9153	0.036	-0.042	0.008
-1.2	-0.083	0.035	-2.837	11.3495	0.032	-0.024	0.026
-0.2	-0.0086	0.0354	-201.186	17.2472	0.0342	-0.0032	0.0248
0.8	0.029	0.03	157.979	28.1147	0.037	0.013	0.035
1.8	0.062	0.036	68.274	25.7562	0.021	0.026	0.031
2.8	0.129	0.039	40.287	35.8268	0.005	0.071	0.031
4.8	0.214	0.044	39.844	20.1666	0.01	0.078	0.05
9.8	0.462	0.076	33.659	20.9504	-0.008	0.171	0.068
14.8	0.644	0.15	39.369	21.6377	0.026	0.24	0.105
19.8	0.771	0.218	40.699	19.0913	0.043	0.264	0.131
24.8	0.671	-0.027	117.702	3.2363	0.492	0.032	0.226
29.8	0.99	0.364	40.452	20.6054	0.053	0.328	0.224
34.8	1.155	0.473	42.369	20.2706	0.085	0.361	0.287
39.8	1.241	0.563	43.624	19.0536	0.108	0.341	0.34

ypsj23.rud Rudder plus skeg forces

1460rpm Skeg-Rudder No. 0 10 m/s

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-35.2	-2.369	1.051	36.721	32.5593	-0.034	-1.098	0.65
-30.2	-2.319	0.814	33.779	33.1514	0.039	-1.114	0.517
-25.2	-2.133	0.598	29.855	33.4838	0.121	-1.045	0.395

-20.2	-1.763	0.391	25.933	33.1052	0.169	-0.866	0.269
-15.2	-1.331	0.241	21.721	30.8103	0.184	-0.628	0.17
-10.2	-0.868	0.139	16.81	28.3	0.163	-0.391	0.099
-5.2	-0.702	0.124	40.925	14.7869	-0.039	-0.24	-0.103
-2.2	-0.22	0.077	-0.257	4.2048	0.079	-0.048	0.007
-1.2	-0.125	0.072	-25.891	-19.262	0.077	0.003	0.027
-0.2	0.009	0.065	2155.688	1191.964	0.102	0.055	0.031333
1.8	0.164	0.069	80.867	71.0935	0.075	0.146	0.039
4.8	0.427	0.079	47.18	49.1102	0.051	0.284	0.062
9.8	0.857	0.14	36.93	42.9985	0.013	0.516	0.1
14.8	1.302	0.249	35.639	41.5385	0.003	0.764	0.165
19.8	1.728	0.387	36.43	40.8383	0.018	0.999	0.25
24.8	2.037	0.602	40.118	41.7592	0.1	1.192	0.391
29.8	2.134	0.789	43.205	40.0651	0.175	1.197	0.508
34.8	2.252	0.971	44.637	41.1599	0.222	1.272	0.64

ypsj33.rud **Rudder plus skeg forces**
2100rpm **Skeg-Rudder No. 0 10 m/s**

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-35.2	-4.006	1.789	36.601	38.4294	-0.052	-2.137	1.147
-30.2	-3.718	1.271	30.69	38.9111	0.181	-2.032	0.829
-25.2	-3.4	0.948	26.746	39.0065	0.301	-1.874	0.635
-20.2	-2.661	0.555	22.027	37.2834	0.359	-1.43	0.38
-15.2	-1.993	0.319	18.446	34.74	0.34	-1.026	0.22
-10.2	-1.319	0.161	13.227	30.5941	0.294	-0.629	0.11
-5.2	-0.888	0.121	27.188	16.6262	0.073	-0.317	-0.114
-2.2	-0.285	0.065	-23.7	-7.5203	0.17	-0.029	-0.008
-0.2	-0.02467	0.066	4.0623	31.1583	0.161667	0.109	0.020333
1.8	0.234	0.078	93.215	94.8256	0.137	0.264	0.032
4.8	0.632	0.103	50.182	62.5866	0.094	0.508	0.065
9.8	1.256	0.2125	38.673	52.8355	0.042	0.885	0.139
14.8	1.892	0.377	34.97	50.6426	-0.008	1.292	0.249
19.8	2.522	0.598	34.91	49.4865	-0.012	1.692	0.392
24.8	3.122	0.903	36.303	49.3417	0.03	2.086	0.604
29.8	3.652	1.302	39.817	49.6353	0.169	2.445	0.887
34.8	3.933	1.739	44.032	49.5199	0.365	2.623	1.183

ypsj019.rud **Rudder plus skeg forces**
1460rpm **Skeg-Rudder No. 0 3m/s**

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-35.2	-1.008	0.377	26.561	16.987	0.092	-0.31	0.183
-30.2	-0.901	0.269	23.74	15.1593	0.106	-0.269	0.131
-25.2	-0.752	0.193	21.711	13.4857	0.104	-0.217	0.094
-20.2	-0.597	0.127	19.309	10.636	0.097	-0.158	0.062
-15.2	-0.449	0.074	16.608	6.6948	0.085	-0.103	0.039
-10.2	-0.314	0.039	13.334	1.0134	0.07	-0.056	0.021
-5.2	-0.204	0.018	24.903	-3.1475	0.022	-0.035	-0.055
-2.2	-0.061	0.005	-36.32	-66.911	0.044	0.029	-0.021
-0.2	-0.01167	-0.00033	-266.653	-509.001	0.032333	0.052	-0.00267
1.8	0.047	0.002	85.881	155.4636	0.024	0.082	-0.003
4.8	0.144	0.012	46.169	64.7607	0.016	0.118	0.008
9.8	0.3	0.046	34.506	44.8714	-0.003	0.187	0.03
14.8	0.444	0.092	31.905	37.3447	-0.016	0.241	0.059

19.8	0.588	0.153	30.902	34.8601	-0.027	0.305	0.088
24.8	0.737	0.223	32.127	33.4027	-0.025	0.367	0.131
29.8	0.878	0.31	32.759	33.1608	-0.024	0.428	0.186
34.8	1.007	0.411	33.839	33.3417	-0.016	0.481	0.254

ypaj120.rud **Rudder alone forces**
800rpm **Skeg-Rudder No. 0 10m/s**

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-35.2	-0.853	0.472	49.213	14.8033	-0.134	-0.192	0.271
-30.2	-0.817	0.382	46.921	14.0861	-0.104	-0.2	0.221
-25.2	-0.638	0.27	43.404	13.8176	-0.055	-0.156	0.176
-20.2	-0.531	0.193	41.754	12.4719	-0.036	-0.128	0.141
-15.2	-0.496	0.115	38.645	14.784	-0.017	-0.142	0.104
-10.2	-0.325	0.05	32.465	12.9271	0.01	-0.09	0.066
-5.2	-0.093	0.006	-9.312	15.5674	0.042	-0.035	-0.046
-2.2	-0.095	0.018	65.611	-9.7945	-0.029	-0.008	-0.019
-0.2	0.017	0.008	0.0977	177.3129	0	0.023667	0.022667
1.8	0.086	0.007	40.944	38.1859	0.005	0.047	0.025
4.8	0.173	0.007	27.987	29.3012	-0.013	0.077	0.044
9.8	0.347	0.039	31.168	24.4815	-0.015	0.138	0.064
14.8	0.528	0.1	36.461	24.2179	0.006	0.206	0.097
19.8	0.701	0.196	42.667	22.4377	0.053	0.261	0.13
24.8	0.77	0.261	43.079	20.6907	0.062	0.26	0.174
29.8	0.807	0.338	44.904	19.7441	0.083	0.248	0.218
34.8	0.892	0.421	47.143	19.971	0.114	0.256	0.27

ypaj220.rud **Rudder alone forces**
1460rpm **Skeg-Rudder No. 0 10m/s**

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-35.2	-1.63	0.939	48.882	33.2839	-0.253	-0.728	0.618
-30.2	-1.622	0.747	45.706	34.2727	-0.183	-0.77	0.507
-25.2	-1.454	0.528	41.917	33.5232	-0.101	-0.689	0.381
-20.2	-1.158	0.341	38.132	32.9551	-0.033	-0.551	0.264
-15.2	-0.833	0.197	35.727	29.599	-0.003	-0.372	0.168
-10.2	-0.495	0.101	34.301	22.126	0.005	-0.184	0.105
-5.2	-0.232	0.072	56.794	-4.0071	-0.051	-0.033	-0.009
-2.2	0.006	0.032	-735.692	1945.438	-0.033	0.084	0.01
-0.2	0.171	0.018	26.675	79.987	-0.015	0.166667	0.037333
1.8	0.282	0.018	26.282	66.2186	-0.026	0.236	0.036
4.8	0.488	0.026	27.925	54.8599	-0.036	0.35	0.057
9.8	0.82	0.067	29.398	49.219	-0.049	0.539	0.089
14.8	1.157	0.161	32.207	47.0797	-0.037	0.735	0.15
19.8	1.524	0.303	35.966	45.5262	0.009	0.946	0.232
24.8	1.807	0.521	40.153	45.6857	0.089	1.123	0.37
29.8	1.98	0.717	43.591	44.5756	0.17	1.194	0.507
34.8	2.026	0.889	45.853	45.0339	0.227	1.213	0.634

ypaj320.rud **Rudder alone forces**
2100rpm **Skeg-Rudder No. 0 10m/s**

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-35.2	-2.852	1.528	45.489	41.902	-0.325	-1.575	1.076
-30.2	-2.595	1.149	41.492	42.4508	-0.172	-1.481	0.817
-25.2	-2.197	0.774	37.375	41.5256	-0.046	-1.24	0.578

-20.2	-1.69	0.467	33.691	38.9305	0.03	-0.914	0.372
-15.2	-1.155	0.262	32.047	34.8653	0.039	-0.581	0.225
-10.2	-0.64	0.135	32.821	25.1979	0.017	-0.26	0.131
-5.2	-0.202	0.073	65.013	-28.0073	-0.062	0.023	0.008
-2.2	0.148	0.024	-3.475	136.513	-0.057	0.226	0.006
-0.2	0.28	0.00725	-1.6002	74.773	-0.0435	0.27375	0.02975
1.8	0.567	0.019	22.728	70.2075	-0.072	0.497	0.029
4.8	0.553	-0.319	161.564	81.3334	0.662	0.538	-0.206
9.8	1.379	0.116	26.459	57.3398	-0.123	1.026	0.12
14.8	1.911	0.261	28.363	54.5969	-0.134	1.367	0.227
19.8	2.432	0.472	30.808	53.7941	-0.112	1.724	0.365
24.8	2.956	0.754	33.681	54.1685	-0.051	2.106	0.568
29.8	3.452	1.088	36.866	53.8886	0.052	2.443	0.815
34.8	3.769	1.531	41.732	53.6531	0.252	2.653	1.13

ypaj021.rud **Rudder alone forces**
1460rpm **Skeg-Rudder No. 0 3m/s**

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-30.2	-0.597	0.242	32.26	6.9817	0.02	-0.114	0.115
-20.2	-0.347	0.11	29.661	-5.0322	0.021	-0.028	0.055
-10.2	-0.105	0.032	41.061	-58.0836	-0.006	0.048	0.016
-5.2	-0.035	0.026	161.374	-214.565	-0.047	0.069	-0.041
-0.2	0.11267	0.041	73.5073	75.059	0.014667	0.106333	-0.04167
4.8	0.261	0.01	19.642	52.9792	-0.041	0.184	0.006
9.8	0.397	0.029	22.577	42.7912	-0.051	0.238	0.023
19.8	0.685	0.116	27.848	35.5863	-0.052	0.359	0.076
29.8	0.917	0.252	30.103	34.8148	-0.049	0.46	0.167

ypsy1124.rud **Rudder plus skeg forces** **Y/D=+0.25**
800rpm **Skeg-Rudder No. 0 10m/s**

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-30	-1.055	0.371	36.008	14.0328	-0.007	-0.301	0.171
-20	-0.738	0.207	32.244	16.0671	0.024	-0.234	0.106
-10	-0.471	0.081	23.393	15.973	0.057	-0.155	0.041
-5	-0.212	0.035	7.922	16.0071	0.059	-0.074	-0.021
-2	-0.107	0.036	20.622	8.0823	0.016	-0.028	0.007
0	-0.006	0.0335	-138.547	-167.854	0.006	0.004	0.02
2	0.08	0.032	27.37	33.8321	-0.007	0.041	0.019
5	0.219	0.039	23.271	22.0884	-0.027	0.086	0.023
10	0.448	0.066	24.473	20.6504	-0.049	0.169	0.036
20	0.886	0.191	33.27	18.4789	-0.019	0.31	0.093
30	0.972	0.318	36.29	15.2289	0.009	0.282	0.166

ypsy1224.rud **Rudder plus skeg forces** **Y/D=+0.25**
1460rpm **Skeg-Rudder No. 0 10m/s**

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-30	-1.743	-0.331	13.654	43.829	0.292	-0.794	0.273
-20	-1.365	0.349	24.877	27.3516	0.147	-0.595	0.202
-10	-0.532	0.147	10.383	14.8421	0.137	-0.166	0.083
-5	-0.16	0.11	-16.143	-25.4437	0.087	0.015	0.018
-2	0.084	0.094	129.325	129.8306	0.076	0.121	0.042
0	0.226	0.093	60.4975	65.6723	0.057	0.188	0.0555
2	0.369	0.098	44.886	53.4406	0.035	0.262	0.06

5	0.572	0.113	36.435	44.9987	0.006	0.358	0.072
10	0.938	0.173	31.327	39.5465	-0.039	0.534	0.105
20	1.599	0.376	31.182	36.7055	-0.069	0.861	0.219
30	1.951	0.708	35.39	35.7816	0	1.011	0.426

ypsy1324.rud **Rudder plus skeg forces** **Y/D=+0.25**
2100rpm **Skeg-Rudder No. 0 10m/s**

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-30	-3.233	1.117	30.199	36.2758	0.174	-1.689	0.686
-20	-1.838	0.517	20.085	30.5087	0.291	-0.861	0.307
-10	-0.513	0.22	-14.685	5.0372	0.272	-0.102	0.129
-5	0.038	0.18	1004.45	803.2953	0.217	0.19	0.062
-2	0.395	0.167	84.415	82.3511	0.191	0.392	0.094
0	0.61	0.173	62.434	65.5884	0.165	0.5065	0.1145
2	0.825	0.192	51.303	58.52	0.132	0.628	0.125
5	1.117	0.226	42.917	53.1075	0.085	0.789	0.157
10	1.626	0.332	35.946	48.3448	0.009	1.07	0.223
20	2.63	0.688	31.582	44.6431	-0.103	1.63	0.438
30	3.224	1.196	32.625	44.8861	-0.093	1.994	0.776

ypsy2225.rud **Rudder plus skeg forces** **Y/D=+0.125**
1460rpm **Skeg-Rudder No. 0 10m/s**

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-30	-2.405	0.823	32.55	34.0488	0.071	-1.193	0.504
-20	-1.576	0.406	25.125	31.5088	0.166	-0.754	0.249
-10	-0.715	0.168	15.963	23.7559	0.142	-0.289	0.102
-5	-0.293	0.12	1.226	8.2331	0.103	-0.073	0.053
-2	-0.039	0.098	-169.756	-133.464	0.088	0.051	0.056
0	0.1285	0.0975	89.0825	88.9577	0.068	0.1355	0.058
2	0.288	0.103	51.438	58.6997	0.047	0.22	0.06
5	0.533	0.119	39.041	47.3125	0.02	0.346	0.073
10	0.94	0.18	33.248	41.8433	-0.02	0.557	0.11
20	1.724	0.429	33.199	38.0051	-0.039	0.955	0.245
30	2.099	0.792	38.623	37.5602	0.072	1.13	0.481

ypsy2325.rud **Rudder plus skeg forces** **Y/D=+0.125**
2100rpm **Skeg-Rudder No. 0 10m/s**

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-30	-3.742	1.249	27.544	39.4055	0.303	-2.073	0.809
-20	-2.356	0.617	20.783	35.974	0.354	-1.235	0.399
-10	-1.007	0.273	8.251	25.9628	0.282	-0.429	0.171
-5	-0.364	0.198	-23.777	-0.7816	0.225	-0.055	0.096
-2	0.036	0.18	678.981	577.3079	0.191	0.18	0.106
0	0.2935	0.178	90.9025	95.0938	0.163	0.3305	0.1095
2	0.542	0.189	59.559	73.1061	0.133	0.493	0.117
5	0.941	0.226	45.015	59.0285	0.092	0.723	0.142
10	1.533	0.327	36.559	52.5465	0.018	1.077	0.209
20	2.675	0.736	33.983	47.812	-0.039	1.752	0.467
30	3.45	1.382	37.602	47.5493	0.082	2.237	0.912

ypsy3226.rud **Rudder plus skeg forces** **Y/D=-0.125**
1460rpm **Skeg-Rudder No. 0 10m/s**

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy

-30	-2.196	0.835	32.693	35.358	0.062	-1.097	0.551
-20	-1.659	0.412	27.171	33.058	0.14	-0.813	0.278
-10	-0.89	0.16	23.393	29.9482	0.108	-0.415	0.115
-5	-0.54	0.11	25.274	26.3028	0.055	-0.236	0.051
-2	-0.285	0.088	20.859	22.8216	0.042	-0.114	0.063
0	-0.133	0.0875	16.7505	8.2309	0.025	-0.0345	0.0665
2	0.027	0.087	38.564	173.6631	0.001	0.055	0.067
5	0.265	0.103	26.628	53.9458	-0.024	0.189	0.076
10	0.673	0.158	27.069	44.4327	-0.057	0.415	0.111
20	1.533	0.392	31.037	42.3313	-0.068	0.907	0.261
30	2.273	0.867	39.014	41.9017	0.087	1.317	0.572

ypsy3326.rud **Rudder plus skeg forces** **Y/D=-0.125**
2100rpm **Skeg-Rudder No. 0** **10m/s**

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-30	-3.159	1.412	34.262	39.9377	0.039	-1.735	0.95
-20	-2.567	0.658	25.184	39.6972	0.269	-1.432	0.476
-10	-1.472	0.278	25.052	36.1459	0.155	-0.778	0.214
-5	-0.89	0.196	28.189	32.1684	0.065	-0.44	0.127
-2	-0.537	0.165	30.081	24.1824	0.029	-0.222	0.13
0	-0.287	0.163	37.642	6.1591	-0.0065	-0.068	0.1285
2	-0.028	0.162	191.168	-470.545	-0.035	0.097	0.128
5	0.34	0.18	17.36	77.6514	-0.064	0.327	0.14
10	0.952	0.264	22.97	57.9095	-0.122	0.718	0.2
20	2.254	0.636	28.887	51.9175	-0.152	1.561	0.45
30	3.477	1.36	35.89	51.4339	0.019	2.383	0.961

ypsy4227.rud **Rudder plus skeg forces** **Y/D=-0.25**
1460rpm **Skeg-Rudder No. 0** **10m/s**

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-35	-2.469	1.053	32.175	37.37	0.084	-1.27	0.699
-30	-2.202	0.8	31.122	36.1328	0.098	-1.126	0.525
-20	-1.569	0.387	27.589	34.0212	0.125	-0.786	0.26
-10	-0.919	0.158	25.028	34.1403	0.097	-0.468	0.117
-5	-0.569	0.095	23.858	37.673	0.066	-0.314	0.047
-2	-0.39	0.092	28.879	38.5096	0.026	-0.218	0.066
0	-0.246	0.088	33.771	41.4284	0.004	-0.145	0.0685
2	-0.111	0.084	53.784	44.3302	-0.02	-0.069	0.067
5	0.11	0.099	-0.514	31.2979	-0.042	0.051	0.073
10	0.509	0.148	21.417	35.9571	-0.074	0.268	0.101
20	1.399	0.381	30.783	37.9305	-0.066	0.766	0.237
30	2.129	0.824	38.804	40.244	0.077	1.193	0.539
35	2.434	1.078	41.407	41.5016	0.157	1.373	0.727

ypsy4327.rud **Rudder plus skeg forces** **Y/D=-0.25**
2100rpm **Skeg-Rudder No. 0** **10m/s**

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-35	-3.709	1.605	27.923	44.4414	0.295	-2.191	1.146
-30	-3.346	1.239	27.39	43.3912	0.281	-1.962	0.885
-20	-2.408	0.626	25.673	41.8949	0.24	-1.397	0.462
-10	-1.547	0.292	27.481	41.6771	0.124	-0.905	0.232
-5	-1.09	0.215	32.646	41.9974	0.03	-0.648	0.137
-2	-0.779	0.183	37.595	42.2695	-0.017	-0.464	0.144

0	-0.578	0.174	43.884	42.0202	-0.049	-0.344	0.141
2	-0.369	0.166	58.911	37.5454	-0.085	-0.205	0.135
5	-0.034	0.178	661.171	-121.84	-0.117	0.007	0.14
10	0.543	0.243	8.204	52.5707	-0.157	0.378	0.181
20	1.818	0.558	26.268	49.8733	-0.173	1.217	0.398
30	3.056	1.218	35.269	50.1131	-0.004	2.039	0.871
35	3.668	1.667	38.576	50.2158	0.127	2.438	1.194

ypay1155.rud **Rudder alone forces** **Y/D=+0.25**
800rpm **Skeg-Rudder No. 0** **10m/s**

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-35	-0.888	0.468	46.632	12.8171	-0.112	-0.215	0.22
-30	-0.811	0.365	45.062	11.1461	-0.086	-0.196	0.168
-25	-0.645	0.263	42.258	10.8213	-0.048	-0.156	0.132
-20	-0.537	0.185	41.104	9.3843	-0.032	-0.126	0.101
-15	-0.477	0.106	38.915	10.6591	-0.017	-0.125	0.064
-10	-0.336	0.04	32.618	11.3703	0.009	-0.094	0.028
-5	-0.217	0.024	48.955	5.1651	-0.03	-0.053	-0.04
-2	-0.064	0	42.589	-6.3732	-0.005	-0.008	-0.015
0	0.016	-0.004	11.898	116.5343	-0.00367	0.021	0.004667
2	0.081	-0.011	27.061	40.8852	-0.007	0.047	0
5	0.186	-0.01	26.918	24.4729	-0.016	0.077	0.007
10	0.356	0.022	29.133	22.1449	-0.022	0.139	0.023
15	0.541	0.078	35.124	20.9571	-0.001	0.202	0.054
20	0.701	0.169	41.239	18.9285	0.042	0.246	0.087
25	0.804	0.236	41.585	16.7259	0.051	0.255	0.124
30	0.769	0.284	41.794	17.3893	0.052	0.232	0.162
35	0.887	0.392	44.925	16.7111	0.091	0.244	0.219

ypay1255.rud **Rudder alone forces** **Y/D=+0.25**
1460rpm **Skeg-Rudder No. 0** **10m/s**

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-30	-1.545	0.659	41.364	31.0286	-0.1	-0.707	0.393
-20	-0.955	0.285	32.035	25.8692	0.033	-0.395	0.175
-10	-0.308	0.101	16.087	2.5587	0.062	-0.053	0.067
-5	-0.043	0.069	-16.438	-185.783	0.025	0.081	-0.013
0	0.279	0.042	44.307	62.9852	0.025	0.224667	0.031
5	0.554	0.051	33.976	46.8182	-0.008	0.355	0.045
10	0.836	0.104	31.576	42.685	-0.032	0.5	0.077
20	1.418	0.317	33.924	38.8308	-0.021	0.793	0.195
30	1.696	0.645	38.384	37.0824	0.054	0.903	0.39

ypay1355.rud **Rudder alone forces** **Y/D=+0.25**
2100rpm **Skeg-Rudder No. 0** **10m/s**

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-30	-2.435	1.012	37.576	36.9479	-0.057	-1.281	0.628
-20	-1.229	0.413	25.095	28.6287	0.133	-0.541	0.263
-10	-0.183	0.176	-41.386	-46.7669	0.162	0.081	0.103
-5	0.244	0.135	87.717	118.1124	0.121	0.316	0.024
0	0.5405	0.08325	-12.0123	81.5357	0.06775	0.44075	0.05375
5	1.145	0.166	38.576	54.5878	0.037	0.826	0.11
10	1.561	0.257	34.222	50.726	-0.018	1.066	0.171
20	2.404	0.609	32.494	47.1108	-0.071	1.559	0.378

30	2.954	1.107	33.532	46.631	-0.058	1.899	0.702

ypuj137.rud

800rpm Hull & Rudder No. 2 10m/s

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-35	-1.056	0.599	47.883	22.4684	-0.151	-0.347	0.346
-30	-1.218	0.464	41	24.6618	-0.072	-0.463	0.284
-25	-1.212	0.332	36.115	25.2632	-0.009	-0.489	0.204
-20	-1.031	0.209	32.712	24.2408	0.028	-0.414	0.131
-15	-0.789	0.128	31.386	22.0433	0.032	-0.303	0.085
-10	-0.531	0.078	31.163	19.407	0.023	-0.192	0.052
-5	-0.282	0.045	32.922	14.8947	0.007	-0.09	0.035
-2	-0.13	0.041	38.477	9.5317	-0.004	-0.035	0.03
0	-0.03933	0.036	65.126	-23.1892	-0.01167	0.002	0.029667
2	0.053	0.037	3.74	55.5189	-0.017	0.039	0.03
5	0.189	0.044	20.655	32.8737	-0.028	0.094	0.034
10	0.427	0.071	25.339	27.875	-0.043	0.19	0.051
15	0.688	0.121	28.574	27.3621	-0.047	0.301	0.082
20	0.955	0.202	30.791	28.3432	-0.044	0.424	0.131
25	1.213	0.312	33.121	29.2756	-0.028	0.543	0.198
30	1.486	0.451	35.679	30.2794	0.004	0.669	0.287
35	1.565	0.63	40.061	31.3098	0.077	0.701	0.396

ypuj237.rud

1460rpm Hull & Rudder No. 2 10m/s

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-35	-2.865	1.148	32.127	37.2233	0.098	-1.486	0.745
-30	-2.517	0.844	29.914	36.0384	0.142	-1.292	0.549
-25	-2.14	0.594	28.555	34.2448	0.15	-1.07	0.386
-20	-1.708	0.381	27.35	32.5389	0.139	-0.832	0.255
-15	-1.295	0.232	26.675	30.4102	0.114	-0.608	0.158
-10	-0.876	0.126	27.044	26.6382	0.074	-0.381	0.09
-5	-0.459	0.061	30.492	18.9163	0.023	-0.165	0.05
-2	-0.203	0.047	40.559	-0.881	-0.011	-0.033	0.036
0	-0.04667	0.043	103.244	-135.412	-0.031	0.054333	0.033667
2	0.107	0.046	-10.759	117.9636	-0.05	0.146	0.033
5	0.346	0.056	12.19	63.786	-0.081	0.281	0.04
10	0.757	0.104	19.653	50.177	-0.12	0.512	0.071
15	1.142	0.199	22.585	47.1627	-0.148	0.738	0.132
20	1.548	0.336	25.789	46.4095	-0.151	0.985	0.227
25	1.951	0.544	28.619	46.0247	-0.135	1.231	0.364
30	2.312	0.792	31.698	45.3252	-0.088	1.433	0.531
35	2.596	1.168	37.491	44.2494	0.059	1.565	0.775

ypuj337.rud

2100rpm Hull & Rudder No. 2 10m/s

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-35	-4.322	1.886	27.85	41.8119	0.348	-2.479	1.239
-30	-3.815	1.402	26.385	40.2224	0.36	-2.141	0.914
-25	-3.214	0.936	24.714	39.0068	0.353	-1.769	0.631
-20	-2.53	0.58	22.965	36.4817	0.32	-1.337	0.391
-15	-1.85	0.33	21.569	33.4112	0.259	-0.926	0.226
-10	-1.23	0.168	21.556	28.6801	0.171	-0.56	0.12

-5	-0.596	0.071	26.422	15.5051	0.054	-0.194	0.056
-2	-0.261	0.048	37.669	-23.383	-0.006	0.017	0.032
0	-0.016	0.034	352.8603	-1084.79	-0.04867	0.163	0.026
2	0.241	0.027	-1.735	117.0986	-0.09	0.325	0.022
5	0.575	0.033	9.826	76.9575	-0.147	0.543	0.026
10	1.065	0.072	13.472	64.5916	-0.233	0.875	0.056
15	1.638	0.202	17.603	59.312	-0.291	1.261	0.144
20	2.223	0.402	20.649	56.4568	-0.328	1.649	0.283
25	2.858	0.692	24.12	54.8885	-0.325	2.075	0.489
30	3.48	1.094	28.065	53.9361	-0.261	2.494	0.767
35	4.081	1.59	31.096	53.1965	-0.182	2.891	1.116

yphj129.rud **Rudder plus skeg forces**
800rpm **Hull & Skeg-Rudder No. 0** **10m/s**

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-35	-1.139	0.498	40.432	13.2251	-0.062	-0.284	0.247
-30	-1.134	0.394	38.391	14.9498	-0.035	-0.327	0.199
-25	-0.97	0.286	34.969	15.683	0.004	-0.293	0.158
-20	-0.822	0.209	33.366	16.2413	0.017	-0.26	0.119
-15	-0.674	0.132	30.364	15.3303	0.034	-0.212	0.079
-10	-0.471	0.073	25.423	14.9433	0.047	-0.148	0.05
-5	-0.335	0.065	39.445	9.0071	-0.014	-0.095	-0.048
-2	-0.088	0.036	-17.031	9.0624	0.047	-0.024	-0.015
0	-0.03133	0.04	-20.061	-24.8446	0.017333	0.002667	0.017333
2	0.063	0.037	60.287	37.0804	0.016	0.034	0.016
5	0.174	0.05	34.398	25.2967	-0.002	0.074	0.031
10	0.382	0.076	31.56	21.6537	-0.015	0.147	0.047
15	0.581	0.126	33.322	20.8747	-0.012	0.216	0.076
20	0.82	0.194	38.251	20.5233	0.024	0.3	0.107
25	0.984	0.285	39.595	22.0723	0.043	0.366	0.163
30	1.117	0.381	41.253	21.5245	0.068	0.393	0.224
35	1.177	0.471	43.303	22.1515	0.098	0.398	0.285

yphj229.rud **Rudder plus skeg forces**
1460rpm **Hull & Skeg-Rudder No. 0** **10m/s**

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-35	-2.165	1.084	40.604	31.5914	-0.125	-0.986	0.641
-30	-2.097	0.796	36.988	31.4717	-0.036	-0.975	0.479
-25	-1.856	0.587	33.706	32.1608	0.032	-0.886	0.367
-20	-1.583	0.393	30.433	30.8875	0.08	-0.744	0.25
-15	-1.208	0.242	27.288	28.7047	0.099	-0.547	0.153
-10	-0.818	0.14	23.995	25.5963	0.095	-0.348	0.086
-5	-0.481	0.105	30.408	16.0022	0.024	-0.167	-0.033
-2	-0.195	0.078	13.751	-2.956	0.043	-0.029	-0.002
0	-0.02267	0.067	-162.081	-320.506	0.039333	0.058	0.024667
2	0.132	0.07	57.471	89.584	0.03	0.143	0.024
5	0.363	0.079	36.287	56.5262	0.003	0.271	0.042
10	0.729	0.132	32.318	46.8509	-0.023	0.471	0.076
15	1.093	0.227	33.645	43.6921	-0.019	0.669	0.14
20	1.495	0.377	36.402	42.627	0.016	0.899	0.225
25	1.797	0.555	38.963	43.6294	0.067	1.093	0.351
30	1.937	0.807	44.808	42.8319	0.196	1.158	0.505
35	2.095	0.982	45.831	43.4118	0.238	1.245	0.642

yphj329.rud Rudder plus skeg forces

2100rpm Hull & Skeg-Rudder No. 0 10m/s

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-35	-3.715	1.708	35.682	39.1766	-0.012	-2.018	1.093
-30	-3.367	1.256	32.22	38.9681	0.112	-1.841	0.813
-25	-2.87	0.873	28.61	37.9329	0.201	-1.551	0.57
-20	-2.312	0.571	25.738	35.9142	0.228	-1.211	0.371
-15	-1.717	0.347	23.285	33.7229	0.211	-0.868	0.22
-10	-1.125	0.189	20.626	27.4604	0.168	-0.501	0.116
-5	-0.586	0.091	14.304	16.7871	0.125	-0.207	-0.033
-2	-0.244	0.084	0.859	-15.9809	0.085	-0.004	-0.003
0	-0.02967	0.067	-251.438	-599.38	0.065667	0.133667	0.018667
2	0.202	0.067	56.633	119.5855	0.043	0.28	0.019
5	0.536	0.085	38.171	75.1849	0.015	0.5	0.042
10	1.036	0.153	34.808	61.4414	-0.006	0.823	0.093
15	1.596	0.295	34.025	56.5402	-0.022	1.188	0.194
20	2.169	0.514	35.51	54.0062	0.003	1.563	0.332
25	2.791	0.823	37.154	52.8307	0.051	1.976	0.551
30	3.331	1.19	39.332	51.8238	0.137	2.321	0.805
35	3.69	1.678	45.111	50.8648	0.388	2.535	1.13

yphj036.rud Rudder plus skeg forces

1460rpm Hull & Skeg-Rudder No. 0 3m/s

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-30	-0.863	0.292	23.422	15.6059	0.107	-0.263	0.136
-20	-0.584	0.143	18.989	11.3645	0.098	-0.16	0.065
-10	-0.318	0.046	14.613	2.5478	0.067	-0.062	0.021
0	-0.00633	-0.005	-89.1193	-336.508	0.025667	0.035667	-0.00933
10	0.289	0.022	38.918	45.3476	0.01	0.182	0.01
20	0.569	0.125	35.626	36.6042	0.001	0.307	0.07
30	0.864	0.293	35.883	33.6924	0.004	0.428	0.175

ypsjf60.rud Rudder plus skeg forces

Hull & Skeg-Rudder No. 0 10m/s Freestream

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-30	-0.447	0.189	49.459	-61.4753	-0.068	0.255	0.017
-20	-0.315	0.084	41.917	-74.6793	-0.021	0.203	0.013
-10	-0.165	0.021	43.159	-82.6758	-0.013	0.11	-0.002
0	0.0285	0.0005	-4.2695	26.0773	-0.008	0.0105	-0.0065
10	0.214	0.022	37.285	-62.469	0.004	-0.099	0.004
20	0.369	0.079	43.642	-64.2517	0.031	-0.195	0.026
30	0.473	0.185	49.182	-56.0829	0.069	-0.263	0.069

ypux2240.rud X/D=0.64

1460rpm Hull & Rudder No. 2 10m/s

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-35	-2.189	1.231	44.687	30.2427	-0.233	-0.954	0.718
-30	-2.58	0.773	28.989	34.9929	0.168	-1.299	0.501
-25	-2.186	0.535	27.246	33.5333	0.18	-1.081	0.348
-20	-1.745	0.335	25.861	31.8981	0.167	-0.843	0.219
-15	-1.307	0.183	24.591	29.7159	0.141	-0.606	0.126
-10	-0.887	0.086	23.859	25.6867	0.102	-0.379	0.061

-5	-0.468	0.032	25.68	18.031	0.046	-0.165	0.023
-2	-0.214	0.011	31.071	1.0504	0.009	-0.039	0.011
0	-0.059	0.0105	63.5755	-98.2549	-0.017	0.0475	0.008
2	0.104	0.01	0.874	118.4255	-0.036	0.141	0.008
5	0.348	0.02	15.39	61.8277	-0.07	0.276	0.013
10	0.744	0.069	20.056	49.4942	-0.114	0.5	0.04
15	1.147	0.16	22.981	46.2945	-0.143	0.732	0.1
20	1.531	0.294	25.48	44.6507	-0.152	0.948	0.191
25	1.944	0.5	28.338	43.703	-0.139	1.182	0.324
30	2.297	0.754	31.34	44.1222	-0.096	1.398	0.495
35	2.58	1.091	36.06	43.976	0.019	1.549	0.724

ypux2340.rud **X/D=0.64**

2100rpm **Hull & Rudder No. 2** **10m/s**

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-35	-4.064	1.819	33.324	39.4468	0.09	-2.234	1.15
-30	-3.786	1.177	24.964	37.7664	0.403	-2.038	0.744
-25	-3.191	0.79	22.897	37.3529	0.403	-1.714	0.51
-20	-2.576	0.502	21.394	35.2423	0.363	-1.334	0.332
-15	-1.914	0.264	19.96	32.8675	0.296	-0.951	0.183
-10	-1.239	0.105	19.43	28.1638	0.198	-0.56	0.077
-5	-0.64	0.006	22.221	14.681	0.084	-0.205	0.014
-2	-0.263	-0.018	28.43	-20.5411	0.018	0.008	-0.011
0	-0.039	-0.026	107.609	-406.786	-0.028	0.151	-0.017
2	0.193	-0.034	0.118	141.1909	-0.067	0.305	-0.02
5	0.567	-0.015	11.402	78.0981	-0.135	0.542	-0.018
10	1.068	0.037	14.574	64.7059	-0.22	0.879	0.021
15	1.62	0.169	19.003	60.1415	-0.264	1.261	0.12
20	2.236	0.386	21.356	55.7559	-0.313	1.643	0.267
25	2.863	0.669	24.45	53.2991	-0.315	2.032	0.462
30	3.379	1.066	28.697	52.7327	-0.231	2.388	0.724
35	3.879	1.577	32.674	52.0886	-0.111	2.707	1.087

yphx1132.rud **Rudder plus skeg forces** **X/D=0.52**

800rpm **Hull & Skeg-Rudder No. 0** **10m/s**

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-35	-1.079	0.495	40.933	12.4323	-0.065	-0.249	0.254
-30	-1.09	0.397	39.741	12.2478	-0.05	-0.283	0.19
-25	-0.964	0.28	35.198	14.1847	0.002	-0.278	0.147
-20	-0.837	0.195	33.643	13.534	0.015	-0.246	0.097
-15	-0.661	0.11	29.488	15.5286	0.039	-0.212	0.06
-10	-0.528	0.069	30.184	12.5762	0.028	-0.157	0.03
-5	-0.281	0.041	28.076	8.5565	0.021	-0.073	0.015
-2	-0.157	0.03	26.638	2.9343	0.014	-0.032	0.011
0	-0.043	0.026	3.6293	-20.6166	0.013	0.000667	0.024333
2	0.055	0.025	52.26	41.4853	0.009	0.032	0.026
5	0.186	0.038	34.409	23.3115	-0.002	0.075	0.029
10	0.39	0.059	30.359	20.3565	-0.02	0.144	0.042
15	0.585	0.116	31.365	20.8737	-0.024	0.216	0.075
20	0.77	0.184	35.595	20.0399	0.002	0.273	0.115
25	0.947	0.271	37.494	20.083	0.021	0.326	0.165
30	1.034	0.362	39.677	19.51	0.046	0.333	0.22
35	1.103	0.447	42.366	20.5541	0.081	0.345	0.277

yphx1232.rud Rudder plus skeg forces X/D=0.52

1460rpm Hull & Skeg-Rudder No. 0 10m/s

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-35	-2.032	0.997	41.298	29.9	-0.132	-0.873	0.601
-30	-1.874	0.754	39.131	28.9884	-0.075	-0.813	0.451
-25	-1.743	0.546	34.199	29.9029	0.021	-0.787	0.344
-20	-1.547	0.365	30.505	29.8498	0.077	-0.711	0.231
-15	-1.214	0.205	27.5	26.6554	0.097	-0.524	0.136
-10	-0.833	0.112	25.299	24.1881	0.085	-0.343	0.069
-5	-0.437	0.044	21.348	15.2024	0.062	-0.142	0.028
-2	-0.208	0.042	15.635	-3.3479	0.041	-0.029	0.018
0	-0.04767	0.029333	-24.117	-135.555	0.027667	0.055667	0.026
2	0.119	0.028	49.243	99.0565	0.017	0.139	0.027
5	0.347	0.037	33.045	58.7982	-0.008	0.264	0.034
10	0.728	0.092	30.959	47.2718	-0.032	0.471	0.066
15	1.075	0.182	32.075	44.8842	-0.036	0.666	0.128
20	4.958	1.177	42.426	-18.5689	0.357	-0.028	-0.082
25	1.809	0.521	38.285	42.5526	0.054	1.07	0.347
30	1.863	0.721	44.194	42.7331	0.174	1.095	0.481
35	2.041	0.912	45.048	42.6283	0.212	1.179	0.617

yphx1332.rud Rudder plus skeg forces X/D=0.52

2100rpm Hull & Skeg-Rudder No. 0 10m/s

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-35	-3.48	1.617	37.348	38.2962	-0.074	-1.847	1.038
-30	-3.185	1.207	34.97	36.4797	0.014	-1.648	0.774
-25	-2.825	0.819	29.285	36.6499	0.177	-1.485	0.54
-20	-2.306	0.521	25.772	35.067	0.225	-1.188	0.341
-15	-1.74	0.287	23.003	31.9321	0.217	-0.847	0.192
-10	-1.17	0.131	20.626	27.043	0.173	-0.516	0.088
-5	-0.602	0.043	16.114	13.2559	0.116	-0.184	0.027
-2	-0.25	0.012	2.456	-24.6202	0.082	0.018	0.006
0	-0.02467	0.009667	-205.817	-676.012	0.057667	0.157667	0.013667
2	0.223	0.008	52.105	121.0687	0.037	0.309	0.012
5	0.573	0.026	36.434	74.692	0.006	0.528	0.023
10	1.082	0.096	33.321	62.9916	-0.022	0.873	0.069
15	1.638	0.233	33.026	56.708	-0.039	1.217	0.167
20	2.213	0.45	34.272	54.213	-0.025	1.59	0.313
25	2.825	0.751	35.581	51.9117	0.006	1.962	0.52
30	3.335	1.113	38.632	51.8868	0.112	2.312	0.775
35	3.622	1.571	44.79	50.4064	0.364	2.456	1.072

yphx2134.rud Rudder plus skeg forces X/D=0.64

800rpm Hull & Skeg-Rudder No. 0 10m/s

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-35	-1.008	0.482	40.748	8.6054	-0.059	-0.18	0.245
-30	-0.944	0.362	38.369	9.8856	-0.03	-0.205	0.192
-25	-0.89	0.268	34.93	10.9099	0.004	-0.223	0.14
-20	-0.761	0.2	33.439	11.7642	0.015	-0.206	0.104
-15	-0.642	0.132	31.347	11.2223	0.026	-0.175	0.071
-10	-0.447	0.071	27.584	11.1292	0.035	-0.124	0.044
-5	-0.229	0.042	22.194	5.4443	0.031	-0.051	0.028

-2	-0.103	0.037	17.205	-1.9665	0.019	-0.015	0.023
0	-0.02433	0.031	-24.127	-49.3754	0.013667	0.008	0.023333
2	0.056	0.032	36.015	50.0508	0	0.038	0.024
5	0.173	0.046	27.751	25.3911	-0.013	0.074	0.027
10	0.381	0.066	28.361	20.1698	-0.027	0.141	0.04
15	0.572	0.111	30.768	18.9144	-0.027	0.201	0.067
20	0.753	0.18	35.881	17.0953	0.004	0.244	0.107
25	0.916	0.256	37.833	18.1113	0.023	0.297	0.154
30	1.013	0.343	40.058	17.0857	0.049	0.302	0.202
35	1.06	0.423	42.566	17.1268	0.08	0.288	0.259

yphx2234.rud **Rudder plus skeg forces** **X/D=0.64**

1460rpm **Hull & Skeg-Rudder No. 0** **10m/s**

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-35	-1.954	0.968	41.198	29.2056	-0.125	-0.801	0.612
-30	-1.76	0.715	37.84	26.8754	-0.046	-0.708	0.443
-25	-1.576	0.53	34.621	27.047	0.013	-0.66	0.326
-20	-1.476	0.355	30.335	27.4137	0.076	-0.64	0.222
-15	-1.161	0.197	26.205	26.3139	0.108	-0.497	0.13
-10	-0.79	0.096	22.782	23.0217	0.1	-0.315	0.067
-5	-0.404	0.04	17.043	12.5248	0.074	-0.12	0.031
-2	-0.17	0.024	3.953	-7.7913	0.054	-0.016	0.019
0	-0.02267	0.018	-174.591	-393.43	0.038333	0.068667	0.014667
2	0.13	0.022	53.538	98.7526	0.024	0.152	0.014
5	0.371	0.032	36.223	55.9376	0.003	0.273	0.02
10	0.727	0.074	32.088	46.4168	-0.024	0.464	0.051
15	1.097	0.173	33.517	43.5029	-0.021	0.668	0.11
20	1.489	0.315	34.883	41.3625	-0.008	0.87	0.204
25	1.812	0.492	38.58	41.0394	0.059	1.043	0.326
30	1.902	0.703	44.343	40.6187	0.179	1.076	0.459
35	2.017	0.884	45.366	41.5547	0.216	1.143	0.591

yphx2334.rud **Rudder plus skeg forces** **X/D=0.64**

2100rpm **Hull & Skeg-Rudder No. 0** **10m/s**

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-35	-3.362	1.609	37.944	36.6091	-0.094	-1.711	1.025
-30	-2.977	1.16	35.6	35.6291	-0.007	-1.502	0.753
-25	-2.637	0.815	31.316	34.9528	0.111	-1.333	0.534
-20	-2.256	0.49	26.063	33.9911	0.213	-1.135	0.326
-15	-1.714	0.268	22.423	30.8407	0.224	-0.814	0.183
-10	-1.116	0.11	19.182	26.2722	0.181	-0.482	0.083
-5	-0.572	0.019	12.615	11.2125	0.13	-0.163	0.022
-2	-0.229	-0.006	-6.287	-34.1162	0.095	0.038	0.002
0	0.00733	-0.013	-143.914	-552.485	0.07	0.177	-0.00733
2	0.237	-0.011	55.272	118.2389	0.047	0.322	-0.011
5	0.602	0.002	38.3	73.5167	0.017	0.548	0.002
10	1.113	0.06	35.809	60.5706	0.005	0.869	0.048
15	1.654	0.206	34.374	56.0024	-0.017	1.219	0.139
20	2.216	0.413	36.305	53.0433	0.021	1.567	0.283
25	2.824	0.715	36.13	51.1163	0.021	1.94	0.486
30	3.32	1.058	38.57	51.3352	0.108	2.285	0.729
35	3.636	1.537	44.126	49.5394	0.338	2.423	1.051

ypswj141.rud		Rudder plus skeg forces			Yaw Angle -7.5 degrees		
800rpm	Hull &	Skeg-Rudder No. 0		10m/s			
Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-42.5	-1.206	0.723	40.523	18.4854	-0.071	-0.36	0.341
-37.5	-1.184	0.609	37.754	21.0223	-0.031	-0.407	0.299
-32.5	-1.161	0.5	35.408	24.082	0	-0.453	0.254
-27.5	-1.048	0.389	33.843	24.8549	0.017	-0.426	0.199
-22.5	-0.895	0.284	30.246	27.3146	0.048	-0.393	0.146
-17.5	-0.675	0.19	26.65	29.1667	0.061	-0.311	0.099
-12.5	-0.437	0.118	22.388	31.6894	0.059	-0.214	0.065
-9.5	-0.286	0.082	17.013	38.0107	0.054	-0.158	0.051
-7.5	-0.2	0.069333	12.4487	43.6469	0.047333	-0.12167	0.045333
-5.5	-0.109	0.054	-0.495	60.5944	0.041	-0.085	0.04
-2.5	0.021	0.045	192.311	-229.463	0.03	-0.038	0.037
2.5	0.234	0.049	40.37	-2.0558	0.012	0.035	0.04
7.5	0.439	0.067	36.589	7.4339	0.005	0.104	0.057
12.5	0.647	0.108	37.655	10.4402	0.015	0.168	0.086
17.5	0.825	0.184	40.192	14.3084	0.04	0.239	0.133
22.5	0.84	0.261	43.405	14.3613	0.07	0.23	0.174
27.5	0.952	0.331	44.296	14.6226	0.089	0.243	0.228

ypswj241.rud		Rudder plus skeg forces			Yaw Angle -7.5 degrees		
1460rpm	Hull &	Skeg-Rudder No. 0		10m/s			
Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-42.5	-2.234	1.429	40.024	34.5266	-0.121	-1.052	0.864
-37.5	-2.158	1.174	37.578	36.032	-0.053	-1.081	0.726
-32.5	-2.113	0.948	34.633	37.002	0.017	-1.101	0.596
-27.5	-1.898	0.709	31.35	36.5368	0.081	-0.993	0.445
-22.5	-1.52	0.475	27.783	36.2941	0.121	-0.8	0.299
-17.5	-1.097	0.292	24.414	35.4711	0.124	-0.572	0.184
-12.5	-0.686	0.172	19.706	30.9584	0.111	-0.328	0.103
-9.5	-0.431	0.111	13.447	31.2592	0.097	-0.207	0.071
-7.5	-0.27467	0.060333	-5.4177	26.9235	0.114	-0.12167	0.027
-5.5	-0.142	0.066	-10.668	10.3548	0.068	-0.038	0.038
-2.5	0.108	0.048	76.349	62.8833	0.044	0.087	0.03
2.5	0.474	0.055	38.53	43.9658	0.015	0.291	0.037
7.5	0.893	0.103	33.912	39.7239	-0.013	0.509	0.073
12.5	1.314	0.194	34.158	39.0664	-0.016	0.738	0.134
17.5	1.698	0.324	35.857	38.9609	0.008	0.944	0.23
22.5	2.022	0.529	40.569	39.7296	0.107	1.132	0.364
27.5	2.209	0.731	43.381	40.0619	0.184	1.232	0.496

ypswj341.rud		Rudder plus skeg forces			Yaw Angle -7.5 degrees		
2100rpm	Hull &	Skeg-Rudder No. 0		10m/s			
Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-42.5	-3.722	2.336	35.646	42.7563	-0.011	-2.134	1.526
-37.5	-3.392	1.827	31.976	42.919	0.13	-1.972	1.205
-32.5	-2.946	1.349	27.925	42.0806	0.239	-1.708	0.878
-27.5	-2.42	0.954	24.727	41.2975	0.276	-1.394	0.617
-22.5	-1.934	0.661	22.043	39.5657	0.272	-1.087	0.416
-17.5	-1.435	0.422	19.507	36.578	0.237	-0.767	0.255
-12.5	-0.916	0.235	16.027	29.8411	0.183	-0.429	0.134
-9.5	-0.583	0.154	10.509	23.7023	0.149	-0.236	0.086

-7.5	-0.33	0.104667	-0.722	9.9573	0.123333	-0.087	0.059
-5.5	-0.159	0.088	-20.675	-34.5617	0.093	0.033	0.044
-2.5	0.212	0.063	61.894	105.5718	0.056	0.259	0.026
2.5	0.806	0.08	35.996	57.8324	0.005	0.608	0.038
7.5	1.388	0.172	31.535	54.0373	-0.054	0.996	0.102
12.5	1.971	0.28	34.035	50.3104	-0.027	1.335	0.198
17.5	2.613	0.505	34.406	49.5956	-0.026	1.753	0.34
22.5	3.166	0.757	36.442	49.7828	0.034	2.122	0.528
27.5	3.749	1.162	40.759	48.6948	0.208	2.467	0.797

ypawj142.rud **Rudder alone forces** **Yaw Angle -7.5 degrees**
800rpm **Hull & Skeg-Rudder No. 0** **10m/s**

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-37.5	-0.89	0.564	47.192	19.435	-0.124	-0.277	0.276
-27.5	-0.736	0.353	44.357	23.9524	-0.073	-0.288	0.18
-17.5	-0.452	0.152	37.677	29.2833	-0.011	-0.208	0.082
-7.5	-0.0775	0.042	35.5435	68.7476	0	-0.0665	0.0285
2.5	0.266	0.028	30.421	1.5551	-0.013	0.05	0.025
12.5	0.599	0.09	37.822	10.4371	0.015	0.157	0.07
22.5	0.817	0.246	43.938	14.509	0.073	0.226	0.164

ypawj242.rud **Rudder alone forces** **Yaw Angle -7.5 degrees**
1460rpm **Hull & Skeg-Rudder No. 0** **10m/s**

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-37.5	-1.583	1.105	47.651	38.0206	-0.237	-0.824	0.685
-27.5	-1.281	0.646	43.405	38.2805	-0.115	-0.69	0.407
-17.5	-0.655	0.254	40.442	35.8166	-0.035	-0.343	0.155
-7.5	0.0365	0.049	-91.971	113.6947	-0.0345	0.0405	0.0235
2.5	0.661	0.009	23.937	39.2903	-0.076	0.375	0.011
12.5	1.337	0.125	30.902	38.8897	-0.06	0.748	0.1
22.5	1.953	0.479	40.547	39.4041	0.103	1.089	0.327

ypawj342.rud **Rudder alone forces** **Yaw Angle -7.5 degrees**
2100rpm **Hull & Skeg-Rudder No. 0** **10m/s**

Angle	Cl	Cd	Cpc	Cps	Cmz	Cmx	Cmy
-37.5	-2.51	1.609	39.387	44.8558	-0.119	-1.505	1.082
-27.5	-1.658	0.808	33.497	42.233	0.035	-0.967	0.528
-17.5	-0.77	0.335	34.163	35.7395	0.01	-0.403	0.199
-7.5	0.186	0.042	-4.006	77.3904	-0.0705	0.1725	0.0115
2.5	1.145	-0.001	21.774	50.7354	-0.156	0.781	0.001
12.5	2.167	0.187	27.192	49.3257	-0.177	1.444	0.145
22.5	3.284	0.656	33.647	48.8861	-0.057	2.166	0.47

APPENDIX B PROPELLER FORCE DATA

PROPELLER DYNAMOMETER

yprj11.pro
800 rpm **Rudder No. 2** **10 m/s**

Angle	Kt	Kq	Cq	Ct
-30.8	-0.03954	0.02526	0.0113	-0.0176
-25.8	-0.07749	0.02421	0.0108	-0.0346
-20.8	-0.07452	0.0232	0.0104	-0.0333
-15.8	-0.06987	0.02265	0.0101	-0.0312
-10.8	-0.05924	0.02231	0.01	-0.0264
-5.8	-0.06682	0.02196	0.0098	-0.0298
-3.8	-0.04405	0.02197	0.0098	-0.0197
-2.8	-0.03802	0.02165	0.0097	-0.017
-1.8	-0.02737	0.02113	0.0094	-0.0122
-0.8	-0.09773	0.0222	0.0099	-0.04363
0.2	-0.08668	0.02216	0.0099	-0.0387
1.2	-0.09732	0.02216	0.0099	-0.0434
2.2	-0.0958	0.02234	0.01	-0.0428
4.2	-0.12149	0.02282	0.0102	-0.0542
9.2	-0.1399	0.02216	0.0099	-0.0624
14.2	-0.13214	0.02179	0.0097	-0.059
19.2	-0.13838	0.02216	0.0099	-0.0618
24.2	-0.15643	0.02179	0.0097	-0.0698
29.2	-0.13971	0.02196	0.0098	-0.0624
34.2	-0.13214	0.02265	0.0101	-0.059

yprj21.pro
1460rpm **Rudder No. 2** **10 m/s**

Angle	Kt	Kq	Cq	Ct
-30.8	0.33008	0.04224	0.0211	0.1648
-25.8	0.32569	0.04346	0.0217	0.1626
-20.8	0.32016	0.04159	0.0208	0.1599
-15.8	0.33169	0.04132	0.0206	0.1656
-10.8	0.27114	0.04072	0.0203	0.1354
-5.8	0.27004	0.04059	0.0203	0.1349
-3.8	0.27424	0.0406	0.0203	0.137
-2.8	0.25696	0.04058	0.0203	0.1283
-1.8	0.24387	0.0405	0.0202	0.1218
-0.8	0.28836	0.040647	0.02027	0.144
0.2	0.31465	0.04044	0.0202	0.1571
1.2	0.30499	0.0407	0.0203	0.1523
2.2	0.30729	0.04085	0.0204	0.1535
4.2	0.31833	0.04096	0.0205	0.159
9.2	0.30867	0.03986	0.0199	0.1541
14.2	0.32744	0.04095	0.0204	0.1635
19.2	0.32338	0.03981	0.0199	0.1615
24.2	0.32567	0.04028	0.0201	0.1626
29.2	0.3312	0.04101	0.0205	0.1654

yprj31.pro

2100rpm		Rudder No. 2		10 m/s
Angle	Kt	Kq	Cq	Ct
-30.8	0.51909	0.04994	0.0256	0.2663
-25.8	0.50288	0.05007	0.0257	0.258
-20.8	0.51198	0.04974	0.0255	0.2627
-15.8	0.50531	0.04954	0.0254	0.2593
-10.8	0.4882	0.04934	0.0253	0.2505
-5.8	0.47956	0.04932	0.0253	0.2461
-3.8	0.50286	0.04964	0.0255	0.258
-2.8	0.48289	0.04979	0.0255	0.2478
-1.8	0.49155	0.04987	0.0256	0.2522
-0.8	0.48571	0.049503	0.0254	0.2492
1.2	0.48732	0.04901	0.0251	0.25
4.2	0.48979	0.04892	0.0251	0.2513
9.2	0.4813	0.04898	0.0251	0.2469
14.2	0.49066	0.04906	0.0252	0.2517
19.2	0.49529	0.04953	0.0254	0.2541
24.2	0.49576	0.04934	0.0253	0.2544
29.2	0.49665	0.04919	0.0252	0.2548

ypsj019.pro

1460rpm		Skeg-Rudder No. 0		3m/s
Angle	Kt	Kq	Cq	Ct
-35.2	0.48609	0.05143	0.0271	0.256
-30.2	0.48465	0.05137	0.0271	0.2552
-25.2	0.47985	0.0511	0.0269	0.2527
-20.2	0.4741	0.05105	0.0269	0.2496
-15.2	0.46883	0.05094	0.0268	0.2469
-10.2	0.46308	0.0505	0.0266	0.2438
-5.2	0.45924	0.05056	0.0266	0.2418
-2.2	0.45637	0.0498	0.0262	0.2403
-0.2	0.46803	0.05018	0.02643	0.24643
1.8	0.47075	0.05012	0.0264	0.2479
4.8	0.47314	0.05029	0.0265	0.2491
9.8	0.46979	0.05045	0.0266	0.2474
14.8	0.48129	0.0511	0.0269	0.2534
19.8	0.48944	0.05121	0.027	0.2577
24.8	0.48609	0.0511	0.0269	0.256
29.8	0.49184	0.05105	0.0269	0.259
34.8	0.48944	0.05137	0.0271	0.2577

ypsj13.pro

800rpm		Skeg-Rudder No. 0		10m/s
Angle	Kt	Kq	Cq	Ct
-35.2	0.09189	0.02779	0.0124	0.041
-30.2	0.06228	0.02761	0.0123	0.0278
-25.2	0.07632	0.02674	0.0119	0.034
-20.2	0.05756	0.02724	0.0121	0.0257
-15.2	0.02959	0.02657	0.0118	0.0132
-10.2	0.04672	0.02691	0.012	0.0208
-5.2	0.02022	0.02267	0.0101	0.009
-3.2	0.01867	0.022755	0.01015	0.0083

-2.2	0.02956	0.02196	0.0098	0.0132
-1.2	0.00933	0.02177	0.0097	0.0042
-0.2	0.02394	0.022914	0.01024	0.0107
0.8	0.04673	0.0241	0.0107	0.0208
1.8	0.0405	0.0234	0.0104	0.0181
2.8	0.01788	0.02426	0.0108	0.00795
4.8	0.03582	0.02322	0.0104	0.016
9.8	0.03115	0.02269	0.0101	0.0139
14.8	0.03418	0.02246	0.01	0.0153
19.8	0.0529	0.02091	0.0093	0.0236
24.8	0.05763	0.02041	0.0091	0.0257
29.8	0.06698	0.02023	0.009	0.0299
34.8	0.06682	0.01983	0.0088	0.0298
39.8	0.07779	0.01951	0.0087	0.0347

ypsj23.pro

1460rpm **Skeg-Rudder No. 0** **10m/s**

Angle	Kt	Kq	Cq	Ct
-35.2	0.34888	0.03941	0.0197	0.1743
-30.2	0.34035	0.03923	0.0196	0.17
-25.2	0.33528	0.03929	0.0196	0.1675
-20.2	0.33537	0.03936	0.0197	0.1675
-15.2	0.32734	0.03908	0.0195	0.1635
-10.2	0.32052	0.03878	0.0194	0.1601
-5.2	0.31733	0.03901	0.0195	0.1585
-2.2	0.28679	0.03882	0.0194	0.1433
-1.2	0.29285	0.03892	0.0194	0.1463
-0.2	0.31134	0.037887	0.0189	0.15553
1.8	0.304	0.03734	0.0187	0.1518
4.8	0.301	0.03669	0.0183	0.1504
9.8	0.30913	0.03718	0.0186	0.1544
14.8	0.3124	0.03713	0.0185	0.156
19.8	0.33413	0.037	0.0185	0.1669
24.8	0.33296	0.03734	0.0187	0.1663
29.8	0.33482	0.03729	0.0186	0.1672
34.8	0.33574	0.03681	0.0184	0.1677

ypsj33.pro

2100rpm **Skeg-Rudder No. 0** **10m/s**

Angle	Kt	Kq	Cq	Ct
-35.2	0.52061	0.04609	0.0237	0.2671
-30.2	0.51681	0.04605	0.0236	0.2652
-25.2	0.50981	0.04674	0.024	0.2616
-20.2	0.49224	0.04557	0.0234	0.2526
-15.2	0.48563	0.04401	0.0226	0.2492
-10.2	0.49238	0.04424	0.0227	0.2527
-5.2	0.49362	0.0446	0.0229	0.2533
-2.2	0.49558	0.04523	0.0232	0.2543
-0.2	0.49409	0.045347	0.02327	0.25353
1.8	0.49875	0.04465	0.0229	0.2559
4.8	0.49218	0.04457	0.0229	0.2525
9.8	0.49451	0.044565	0.02285	0.25375
14.8	0.49646	0.04482	0.023	0.2547

19.8	0.49692	0.04454	0.0229	0.255
24.8	0.49693	0.04447	0.0228	0.255
29.8	0.49422	0.04444	0.0228	0.2536
34.8	0.49728	0.04417	0.0227	0.2552

ypsy1124.pro **Y/D=+0.25**
800rpm **Skeg-Rudder No. 0 10m/s**

Angle	Kt	Kq	Cq	Ct
-30	0.17139	0.01795	0.008	0.0764
-20	0.14917	0.01724	0.0077	0.0665
-10	0.12378	0.01616	0.0072	0.0552
-5	0.11902	0.01598	0.0071	0.0531
-2	0.10791	0.01616	0.0072	0.0481
0	0.09681	0.01553	0.00695	0.0432
2	0.10157	0.01293	0.0058	0.0453
5	0.0968	0.01436	0.0064	0.0432
10	0.1095	0.01329	0.0059	0.0488
20	0.09522	0.014	0.0062	0.0425
30	0.09522	0.01472	0.0066	0.0425

ypsy1224.pro **Y/D=+0.25**
1460rpm **Skeg-Rudder No. 0 10m/s**

Angle	Kt	Kq	Cq	Ct
-30	0.32259	0.03892	0.0194	0.1611
-20	0.31546	0.03838	0.0192	0.1576
-10	0.30834	0.03763	0.0188	0.154
-5	0.30786	0.03736	0.0187	0.1538
-2	0.29741	0.03725	0.0186	0.1486
0	0.30049	0.03714	0.0186	0.1501
2	0.30739	0.03698	0.0185	0.1536
5	0.30834	0.03671	0.0183	0.154
10	0.30216	0.0365	0.0182	0.1509
20	0.30026	0.03612	0.018	0.15
30	0.30026	0.03644	0.0182	0.15

ypsy1324.pro **Y/D=+0.25**
2100rpm **Skeg-Rudder No. 0 10m/s**

Angle	Kt	Kq	Cq	Ct
-30	0.4923	0.04488	0.023	0.2526
-20	0.47268	0.04459	0.0229	0.2425
-10	0.45836	0.04405	0.0226	0.2352
-5	0.45536	0.04389	0.0225	0.2336
-2	0.45998	0.04384	0.0225	0.236
0	0.46691	0.04377	0.02245	0.2396
2	0.46436	0.04365	0.0224	0.2383
5	0.46667	0.0436	0.0224	0.2394
10	0.46436	0.04329	0.0222	0.2383
20	0.45882	0.04311	0.0221	0.2354
30	0.46575	0.04331	0.0222	0.239

ypsy2225.pro **Y/D=+0.125**
1460rpm **Skeg-Rudder No. 0 10m/s**

Angle	Kt	Kq	Cq	Ct

-30	0.35198	0.04033	0.0201	0.1758
-20	0.33667	0.03909	0.0195	0.1682
-10	0.3295	0.03881	0.0194	0.1646
-5	0.31276	0.0386	0.0193	0.1562
-2	0.31802	0.03854	0.0193	0.1589
0	0.32137	0.038465	0.0192	0.1605
2	0.31802	0.03844	0.0192	0.1589
5	0.31898	0.03844	0.0192	0.1593
10	0.31946	0.03795	0.019	0.1596
20	0.31706	0.03779	0.0189	0.1584
30	0.31754	0.03822	0.0191	0.1586

ypsy2325.pro **Y/D=+0.125**
2100rpm **Skeg-Rudder No. 0 10m/s**

Angle	Kt	Kq	Cq	Ct
-30	0.50411	0.04541	0.0233	0.2587
-20	0.48931	0.04491	0.023	0.2511
-10	0.4826	0.04468	0.0229	0.2476
-5	0.47843	0.04444	0.0228	0.2455
-2	0.48029	0.04449	0.0228	0.2464
0	0.47994	0.044255	0.0227	0.2463
2	0.48052	0.04428	0.0227	0.2466
5	0.47867	0.04415	0.0227	0.2456
10	0.47797	0.04418	0.0227	0.2453
20	0.48167	0.04434	0.0228	0.2472
30	0.48445	0.04434	0.0228	0.2486

ypsy3226.pro **Y/D=-0.125**
1460rpm **Skeg-Rudder No. 0 10m/s**

Angle	Kt	Kq	Cq	Ct
-30	0.32052	0.03796	0.019	0.16
-20	0.32341	0.03768	0.0188	0.1615
-10	0.32293	0.03747	0.0187	0.1613
-5	0.31231	0.03736	0.0187	0.1559
-2	0.31521	0.03703	0.0185	0.1574
0	0.314	0.03725	0.0186	0.15675
2	0.31714	0.03714	0.0185	0.1584
5	0.32148	0.03719	0.0186	0.1605
10	0.31134	0.03703	0.0185	0.1555
20	0.32824	0.03774	0.0188	0.1639
30	0.33065	0.03818	0.0191	0.1651

ypsy3326.pro **Y/D=-0.125**
2100rpm **Skeg-Rudder No. 0 10m/s**

Angle	Kt	Kq	Cq	Ct
-30	0.49392	0.04444	0.0228	0.2534
-20	0.48789	0.0441	0.0226	0.2503
-10	0.4807	0.04342	0.0223	0.2467
-5	0.48418	0.04344	0.0223	0.2484
-2	0.47768	0.04352	0.0223	0.2451
0	0.47896	0.043615	0.0224	0.2458
2	0.48116	0.04373	0.0224	0.2469
5	0.48279	0.04368	0.0224	0.2477

10	0.48163	0.04386	0.0225	0.2471
20	0.48673	0.04412	0.0226	0.2498
30	0.48673	0.04405	0.0226	0.2498

ypsy4227.pro **Y/D=-0.25**
1460rpm **Skeg-Rudder No. 0** **10m/s**

Angle	Kt	Kq	Cq	Ct
-35	0.31833	0.03917	0.0196	0.159
-30	0.31593	0.03901	0.0195	0.1578
-20	0.30777	0.03863	0.0193	0.1537
-10	0.30777	0.03814	0.019	0.1537
-5	0.30345	0.03803	0.019	0.1515
-2	0.30345	0.03792	0.0189	0.1515
0	0.30369	0.03811	0.019	0.15165
2	0.31401	0.03858	0.0193	0.1568
5	0.31353	0.03852	0.0192	0.1566
10	0.31113	0.03803	0.019	0.1554
20	0.3217	0.03858	0.0193	0.1607
30	0.3337	0.03928	0.0196	0.1666
35	0.33994	0.03923	0.0196	0.1698

ypsy4327.pro **Y/D=-0.25**
2100rpm **Skeg-Rudder No. 0** **10m/s**

Angle	Kt	Kq	Cq	Ct
-35	0.4831	0.04495	0.0231	0.2479
-30	0.48078	0.04468	0.0229	0.2467
-20	0.4766	0.04434	0.0228	0.2445
-10	0.47428	0.04429	0.0227	0.2433
-5	0.47335	0.04416	0.0227	0.2429
-2	0.47149	0.04413	0.0226	0.2419
0	0.47382	0.04399	0.02255	0.2431
2	0.47799	0.04405	0.0226	0.2452
5	0.47428	0.04421	0.0227	0.2433
10	0.47265	0.04421	0.0227	0.2425
20	0.48287	0.04471	0.0229	0.2477
30	0.49053	0.04484	0.023	0.2517
35	0.48797	0.04476	0.023	0.2504

ypuj137.pro
800rpm **Hull & Rudder No. 2** **10m/s**

Angle	Kt	Kq	Cq	Ct
-35	0.23728	0.03417	0.0152	0.1057
-30	0.22496	0.03348	0.0149	0.1002
-25	0.22033	0.03244	0.0145	0.0982
-20	0.17411	0.02151	0.0096	0.0776
-15	0.23266	0.0255	0.0114	0.1037
-10	0.18798	0.02359	0.0105	0.0838
-5	0.33589	-0.0111	-0.0049	0.1497
-2	0.18644	0.02706	0.0121	0.0831
0	0.19619	0.02382	0.0106	0.08743
2	0.22187	0.02879	0.0128	0.0989
5	0.21725	0.02706	0.0121	0.0968
10	0.22033	0.02793	0.0124	0.0982

15	0.19568	0.02862	0.0128	0.0872
20	0.19568	0.02793	0.0124	0.0872
25	0.20955	0.0281	0.0125	0.0934
30	0.20647	0.03001	0.0134	0.092
35	0.2003	0.03001	0.0134	0.0893

ypuj237.pro

1460rpm	Hull & Rudder No. 2			10m/s
Angle	Kt	Kq	Cq	Ct
-35	0.40696	0.04076	0.0204	0.2033
-30	0.3978	0.04086	0.0204	0.1987
-25	0.39276	0.04086	0.0204	0.1962
-20	0.39551	0.04076	0.0204	0.1976
-15	0.38588	0.04117	0.0206	0.1928
-10	0.38451	0.04096	0.0205	0.1921
-5	0.38542	0.04194	0.021	0.1925
-2	0.38955	0.04225	0.0211	0.1946
0	0.37595	0.041207	0.0206	0.1878
2	0.37534	0.04102	0.0205	0.1875
5	0.37626	0.0405	0.0202	0.188
10	0.37488	0.04096	0.0205	0.1873
15	0.36709	0.04163	0.0208	0.1834
20	0.36388	0.04133	0.0206	0.1818
25	0.36297	0.04112	0.0205	0.1813
30	0.35838	0.04122	0.0206	0.179
35	0.3538	0.04055	0.0203	0.1767

ypuj337.pro

2100rpm	Hull & Rudder No. 2			10m/s
Angle	Kt	Kq	Cq	Ct
-35	0.52921	0.04825	0.0248	0.2715
-30	0.51985	0.04765	0.0244	0.2667
-25	0.51672	0.04727	0.0243	0.2651
-20	0.51672	0.04685	0.024	0.2651
-15	0.51249	0.04655	0.0239	0.2629
-10	0.50557	0.04637	0.0238	0.2594
-5	0.5058	0.04607	0.0236	0.2595
-2	0.50267	0.04604	0.0236	0.2579
0	0.49851	0.045967	0.02357	0.25577
2	0.49063	0.04584	0.0235	0.2517
5	0.48796	0.04559	0.0234	0.2504
10	0.47993	0.04532	0.0233	0.2462
15	0.47703	0.04501	0.0231	0.2447
20	0.4797	0.04476	0.023	0.2461
25	0.47168	0.04426	0.0227	0.242
30	0.46231	0.04333	0.0222	0.2372
35	0.469	0.04288	0.022	0.2406

yphj036.pro

1460rpm	Hull & Skeg-Rudder No. 0			3m/s
Angle	Kt	Kq	Cq	Ct
-30	0.53098	0.04921	0.0258	0.2782
-20	0.5255	0.04973	0.0261	0.2754

-10	0.5118	0.04988	0.0261	0.2682
0	0.51021	0.049315	0.0258	0.26735
10	0.51363	0.04855	0.0254	0.2691
20	0.52002	0.04788	0.0251	0.2725
30	0.52185	0.04993	0.0262	0.2734

yphj129.pro

800rpm Hull & Skeg-Rudder No. 0 10m/s

Angle	Kt	Kq	Cq	Ct
-35	0.2352	0.02899	0.013	0.1051
-30	0.26133	0.02708	0.0121	0.1167
-25	0.23827	0.02761	0.0123	0.1064
-20	0.2475	0.02587	0.0116	0.1105
-15	0.20753	0.02448	0.0109	0.0927
-10	0.2352	0.0257	0.0115	0.1051
-5	0.19369	0.02465	0.011	0.0865
-2	0.17678	0.02708	0.0121	0.079
0	0.23212	0.02546	0.01137	0.1037
2	0.25672	0.02604	0.0116	0.1147
5	0.2475	0.025	0.0112	0.1105
10	0.2475	0.0257	0.0115	0.1105
15	0.22905	0.02448	0.0109	0.1023
20	0.27978	0.0257	0.0115	0.125
25	0.25365	0.025	0.0112	0.1133
30	0.27056	0.02639	0.0118	0.1208
35	0.26287	0.02708	0.0121	0.1174

yphj229.pro

1460rpm Hull & Skeg-Rudder No. 0 10m/s

Angle	Kt	Kq	Cq	Ct
-35	0.43295	0.04307	0.0215	0.2163
-30	0.419	0.04291	0.0214	0.2093
-25	0.40784	0.04275	0.0214	0.2037
-20	0.40877	0.04228	0.0211	0.2042
-15	0.40552	0.04202	0.021	0.2026
-10	0.39901	0.04186	0.0209	0.1993
-5	0.39575	0.04202	0.021	0.1977
-2	0.3911	0.04197	0.021	0.1954
0	0.39916	0.041703	0.02083	0.19937
2	0.39901	0.04155	0.0208	0.1993
5	0.40319	0.04155	0.0208	0.2014
10	0.40505	0.04134	0.0206	0.2023
15	0.39901	0.04092	0.0204	0.1993
20	0.40598	0.04097	0.0205	0.2028
25	0.39854	0.04113	0.0205	0.1991
30	0.4004	0.04097	0.0205	0.2
35	0.40505	0.04097	0.0205	0.2023

yphj329.pro

2100rpm Hull & Skeg-Rudder No. 0 10m/s

Angle	Kt	Kq	Cq	Ct
-35	0.55793	0.04907	0.0252	0.2863
-30	0.55522	0.04884	0.0251	0.2849

-25	0.55115	0.04841	0.0248	0.2828
-20	0.54866	0.04813	0.0247	0.2815
-15	0.52266	0.04787	0.0246	0.2682
-10	0.51769	0.04757	0.0244	0.2656
-5	0.51679	0.04741	0.0243	0.2651
-2	0.51724	0.04729	0.0243	0.2654
0	0.52312	0.04723	0.0242	0.2684
2	0.52651	0.04713	0.0242	0.2701
5	0.52244	0.04695	0.0241	0.268
10	0.51272	0.04644	0.0238	0.2631
15	0.5152	0.04639	0.0238	0.2643
20	0.51747	0.04632	0.0238	0.2655
25	0.51046	0.04621	0.0237	0.2619
30	0.51136	0.04583	0.0235	0.2624
35	0.5134	0.04573	0.0235	0.2634

ypux2240.pro **X/D=0.64**

1460rpm **Hull & Rudder No. 2** **10m/s**

Angle	Kt	Kq	Cq	Ct
-35	0.35661	0.04387	0.0219	0.1781
-30	0.34956	0.04324	0.0216	0.1746
-25	0.34768	0.04324	0.0216	0.1737
-20	0.34956	0.04313	0.0215	0.1746
-15	0.35379	0.04281	0.0214	0.1767
-10	0.3317	0.04223	0.0211	0.1657
-5	0.34063	0.04223	0.0211	0.1701
-2	0.33311	0.04213	0.021	0.1664
0	0.33758	0.04239	0.0212	0.1686
2	0.34298	0.04244	0.0212	0.1713
5	0.33734	0.04223	0.0211	0.1685
10	0.33593	0.04186	0.0209	0.1678
15	0.33217	0.0416	0.0208	0.1659
20	0.33123	0.04154	0.0208	0.1655
25	0.3209	0.04133	0.0206	0.1603
30	0.32795	0.04128	0.0206	0.1638
35	0.31949	0.04102	0.0205	0.1596

ypux2340.pro **X/D=0.64**

2100rpm **Hull & Rudder No. 2** **10m/s**

Angle	Kt	Kq	Cq	Ct
-35	0.53045	0.04832	0.0248	0.2722
-30	0.52932	0.04811	0.0247	0.2716
-25	0.52863	0.04793	0.0246	0.2712
-20	0.52409	0.04768	0.0245	0.2689
-15	0.51977	0.04729	0.0243	0.2667
-10	0.51817	0.04714	0.0242	0.2659
-5	0.5159	0.04709	0.0242	0.2647
-2	0.51204	0.04681	0.024	0.2627
0	0.50908	0.04678	0.024	0.2612
2	0.51158	0.04671	0.024	0.2625
5	0.50772	0.04648	0.0238	0.2605
10	0.49908	0.04607	0.0236	0.2561
15	0.49521	0.04566	0.0234	0.2541

20	0.49066	0.04566	0.0234	0.2518
25	0.48611	0.0453	0.0232	0.2494
30	0.47497	0.04469	0.0229	0.2437
35	0.46565	0.0442	0.0227	0.2389

yphx1132.pro **X/D=0.52**

800rpm **Hull & Skeg-Rudder No. 0** **10m/s**

Angle	Kt	Kq	Cq	Ct
-35	0.21016	0.02595	0.0116	0.0938
-30	0.21173	0.02577	0.0115	0.0945
-25	0.19291	0.02524	0.0113	0.0861
-20	0.19605	0.02559	0.0114	0.0875
-15	0.17566	0.02471	0.011	0.0784
-10	0.16311	0.024	0.0107	0.0728
-5	0.18664	0.02506	0.0112	0.0833
-2	0.19605	0.02312	0.0103	0.0875
0	0.1767	0.024123	0.01077	0.07887
2	0.15997	0.0233	0.0104	0.0714
5	0.17095	0.02506	0.0112	0.0763
10	0.17879	0.02436	0.0109	0.0798
15	0.1882	0.02365	0.0106	0.084
20	0.18193	0.02471	0.011	0.0812
25	0.218	0.02436	0.0109	0.0973
30	0.22584	0.02471	0.011	0.1008
35	0.21173	0.02647	0.0118	0.0945

yphx1232.pro **X/D=0.52**

1460rpm **Hull & Skeg-Rudder No. 0** **10m/s**

Angle	Kt	Kq	Cq	Ct
-35	0.38795	0.04259	0.0213	0.1937
-30	0.39127	0.04233	0.0211	0.1954
-25	0.38653	0.04211	0.021	0.193
-20	0.37185	0.04174	0.0208	0.1857
-15	0.378	0.04169	0.0208	0.1888
-10	0.36521	0.04131	0.0206	0.1824
-5	0.36995	0.04126	0.0206	0.1847
-2	0.37042	0.04126	0.0206	0.185
0	0.37011	0.041207	0.02057	0.1848
2	0.37327	0.04142	0.0207	0.1864
5	0.3709	0.04094	0.0204	0.1852
10	0.35621	0.04083	0.0204	0.1779
15	0.36095	0.04041	0.0202	0.1803
20	0.35242	0.04025	0.0201	0.176
25	0.34911	0.04014	0.02	0.1743
30	0.36806	0.0403	0.0201	0.1838
35	0.36521	0.04019	0.0201	0.1824

yphx1332.pro **X/D=0.52**

2100rpm **Hull & Skeg-Rudder No. 0** **10m/s**

Angle	Kt	Kq	Cq	Ct
-35	0.53095	0.0479	0.0246	0.2724
-30	0.53255	0.048	0.0246	0.2732
-25	0.51973	0.04767	0.0245	0.2667

-20	0.51927	0.04749	0.0244	0.2664
-15	0.51858	0.0472	0.0242	0.2661
-10	0.50851	0.04689	0.0241	0.2609
-5	0.50668	0.04671	0.024	0.26
-2	0.50553	0.04666	0.0239	0.2594
0	0.50813	0.046453	0.02383	0.2607
2	0.50416	0.0463	0.0238	0.2587
5	0.50324	0.04615	0.0237	0.2582
10	0.50851	0.04573	0.0235	0.2609
15	0.49706	0.0454	0.0233	0.255
20	0.50324	0.0454	0.0233	0.2582
25	0.49775	0.0454	0.0233	0.2554
30	0.49821	0.04527	0.0232	0.2556
35	0.49867	0.04496	0.0231	0.2558

yphx2134.pro **X/D=0.64**

800rpm **Hull & Skeg-Rudder No. 0** **10m/s**

Angle	Kt	Kq	Cq	Ct
-35	0.26513	0.03053	0.0136	0.1182
-30	0.25388	0.02945	0.0131	0.1131
-25	0.25549	0.02873	0.0128	0.1139
-20	0.26513	0.02855	0.0127	0.1182
-15	0.27155	0.02837	0.0126	0.121
-10	0.21692	0.02782	0.0124	0.0967
-5	0.24424	0.02764	0.0123	0.1088
-2	0.2105	0.02855	0.0127	0.0938
0	0.24317	0.028367	0.0126	0.10837
2	0.22978	0.02855	0.0127	0.1024
5	0.25709	0.02873	0.0128	0.1146
10	0.25227	0.02873	0.0128	0.1124
15	0.24906	0.02909	0.013	0.111
20	0.24585	0.02855	0.0127	0.1096
25	0.24263	0.02855	0.0127	0.1081
30	0.23942	0.02891	0.0129	0.1067
35	0.22496	0.02927	0.013	0.1003

yphx2234.pro **X/D=0.64**

1460rpm **Hull & Skeg-Rudder No. 0** **10m/s**

Angle	Kt	Kq	Cq	Ct
-35	0.38937	0.04416	0.0221	0.1944
-30	0.38166	0.04383	0.0219	0.1906
-25	0.38311	0.04373	0.0218	0.1913
-20	0.36913	0.04351	0.0217	0.1843
-15	0.3725	0.04318	0.0216	0.186
-10	0.36431	0.04308	0.0215	0.1819
-5	0.36287	0.04297	0.0215	0.1812
-2	0.36528	0.04297	0.0215	0.1824
0	0.36319	0.042837	0.0214	0.18137
2	0.36383	0.04264	0.0213	0.1817
5	0.36576	0.04264	0.0213	0.1826
10	0.35853	0.04259	0.0213	0.179
15	0.35998	0.04194	0.0209	0.1798
20	0.35275	0.04188	0.0209	0.1761

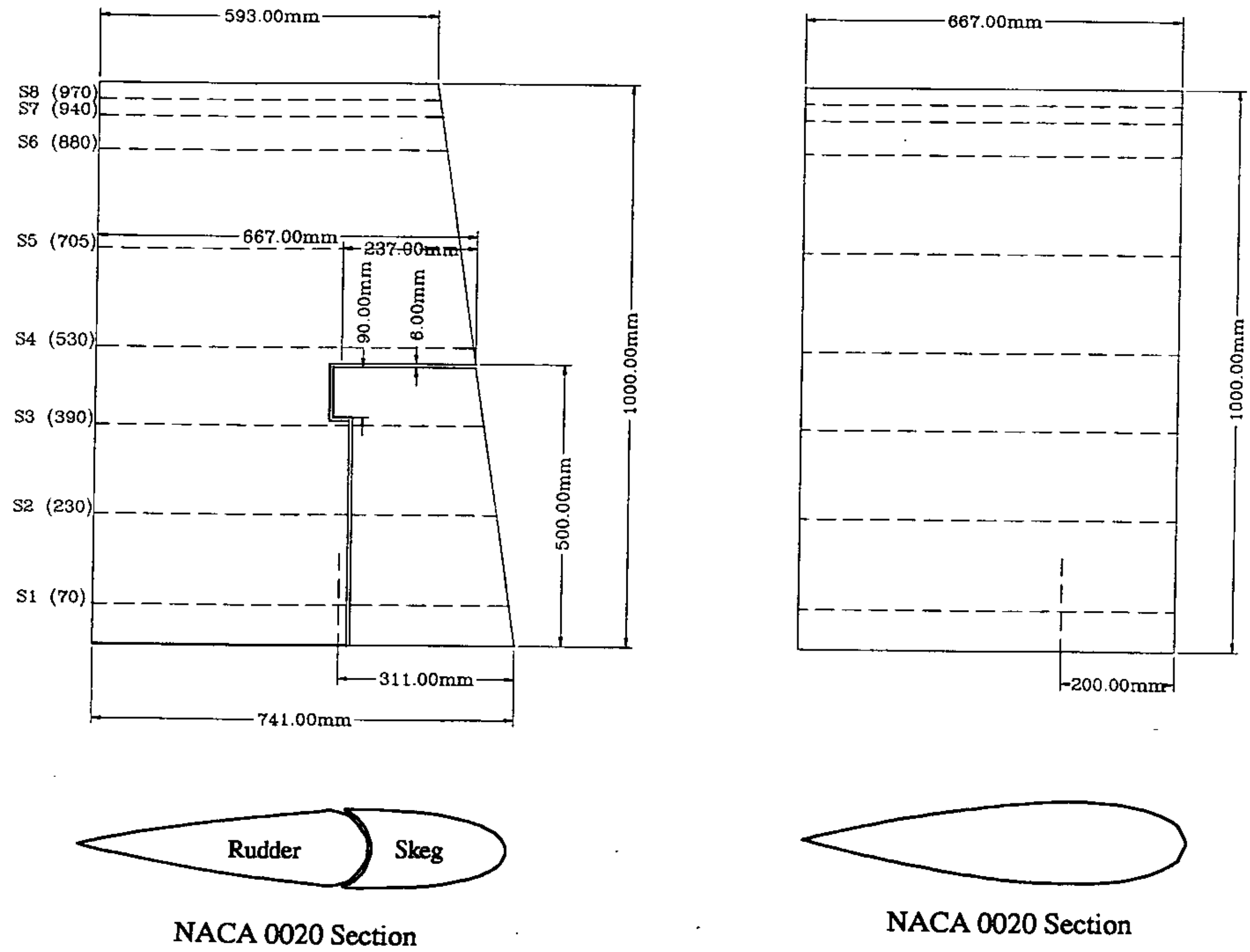
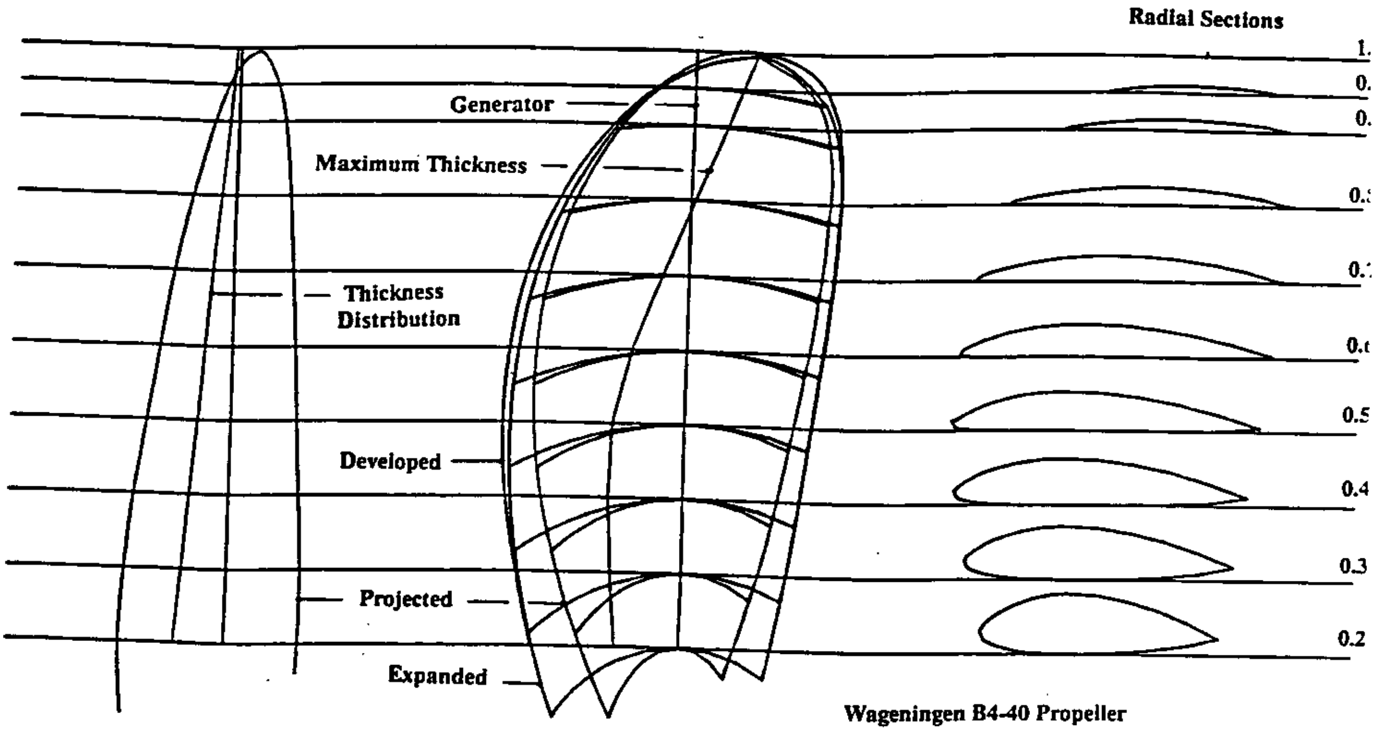


Fig. 1 Dimensions of two rudder models



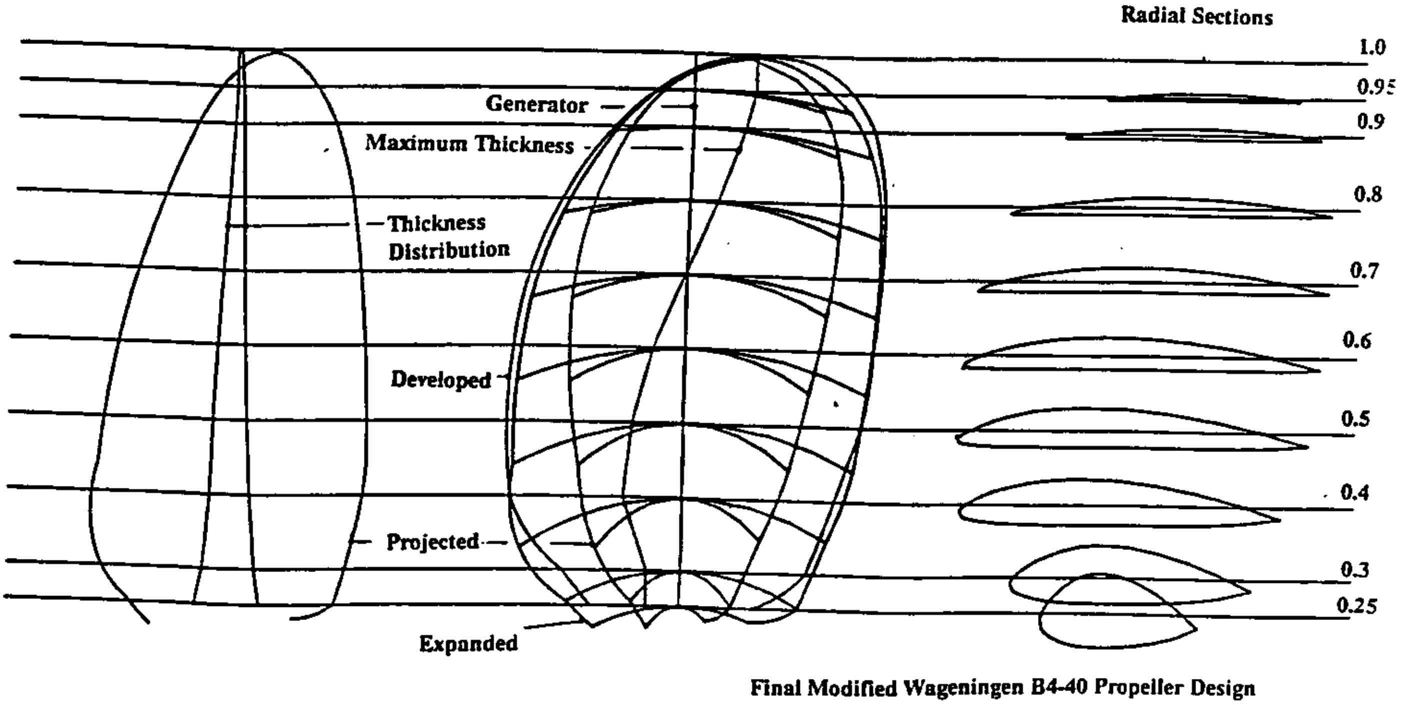


Fig. 2 Comparison of basis and modified Wageningen B.4.40 Propeller

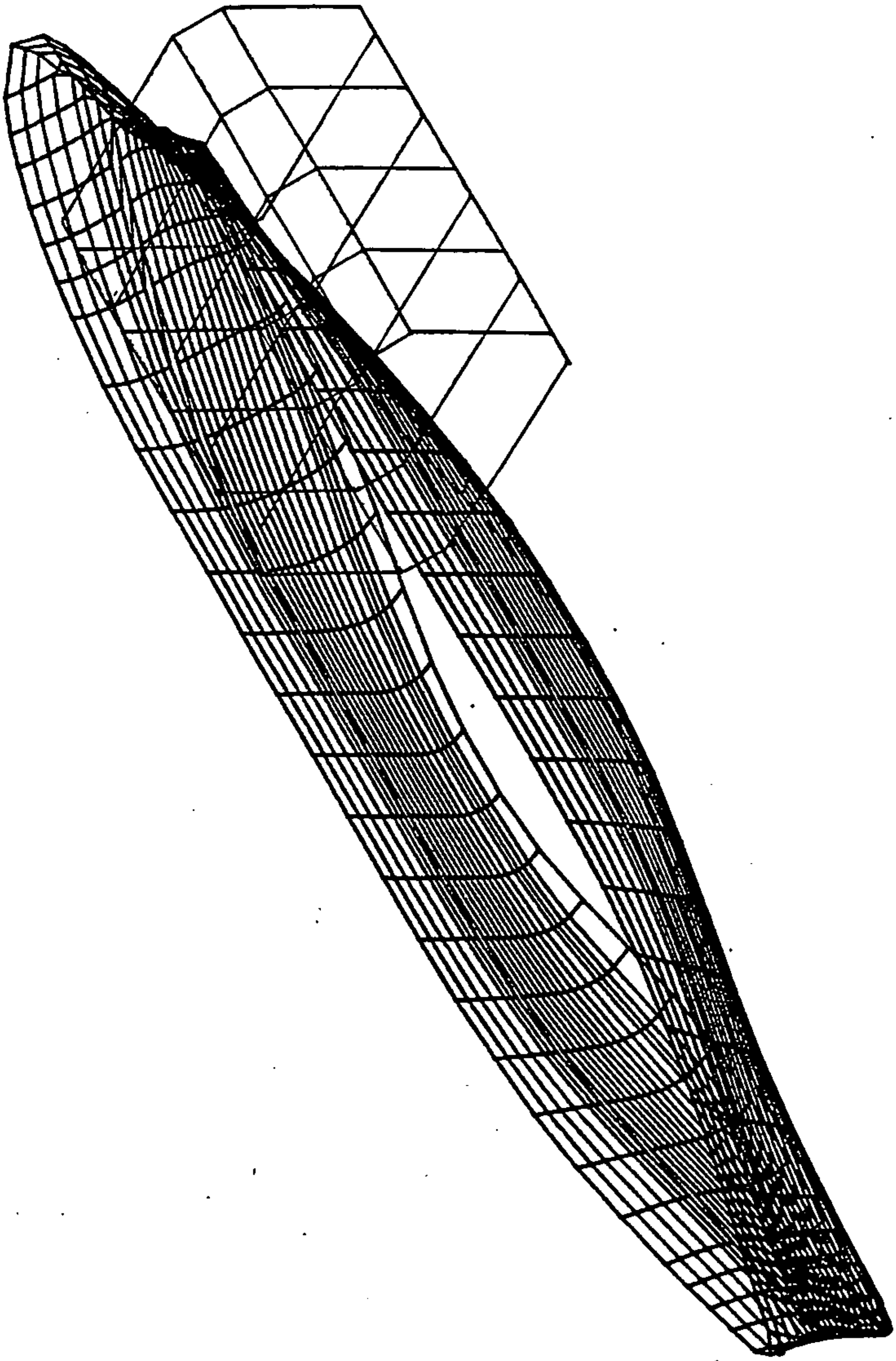


Fig. 3 Schematic showing tunnel working section and scaled Mariner Hull.

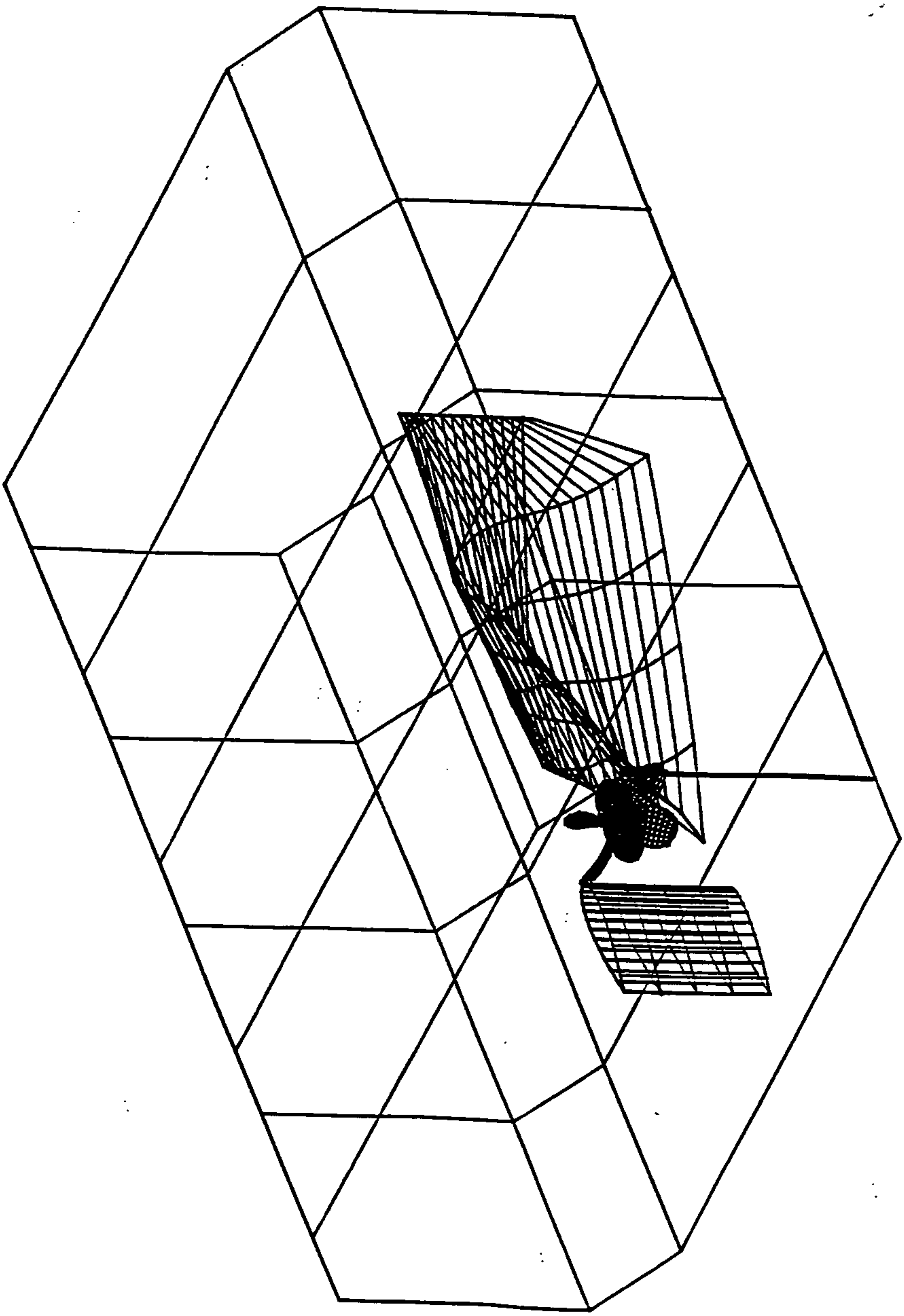


Fig. 4 Isometric view of rig and wind tunnel working section.

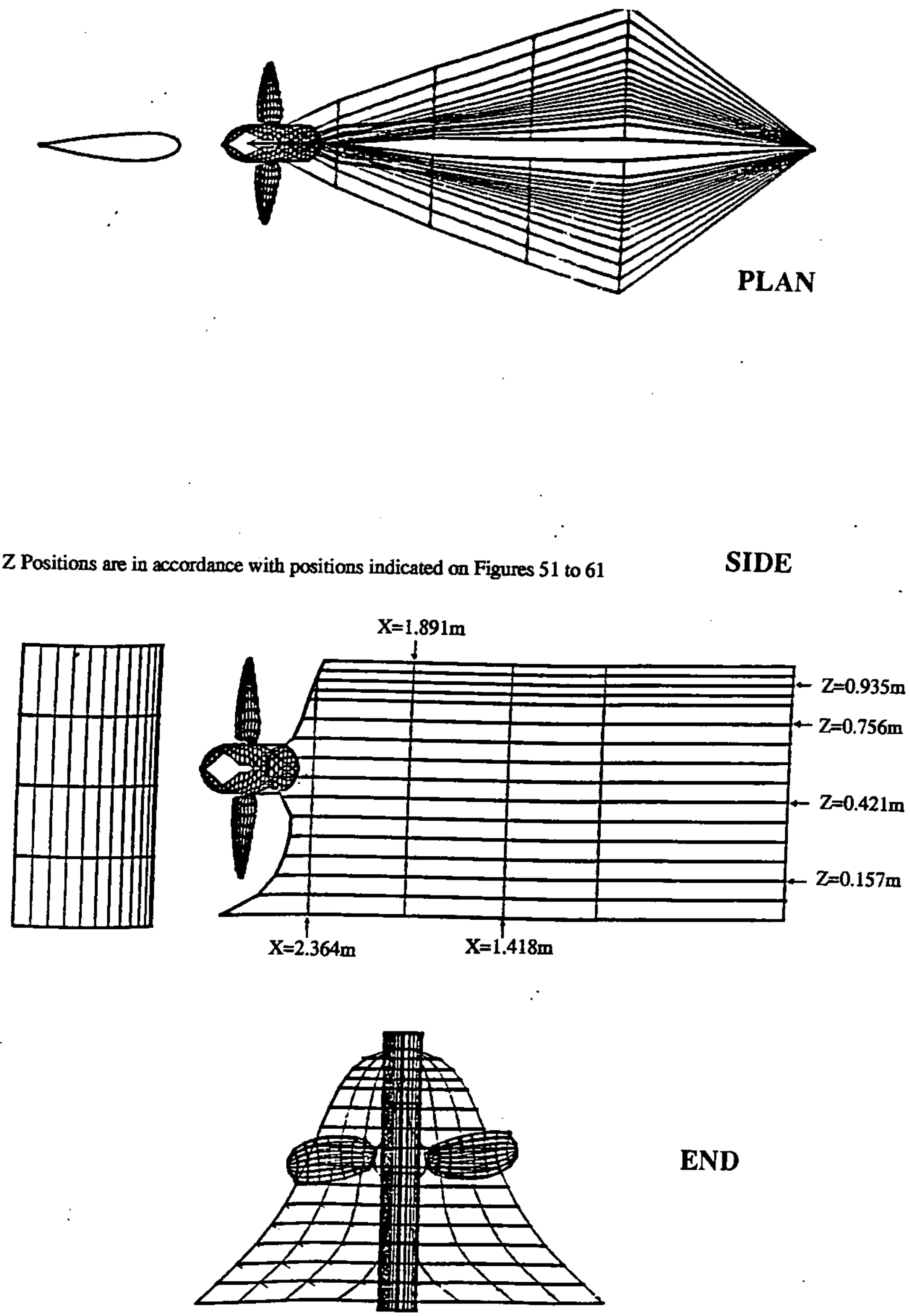


Fig. 5 Plan, side and end elevations of mariner stern form hull.

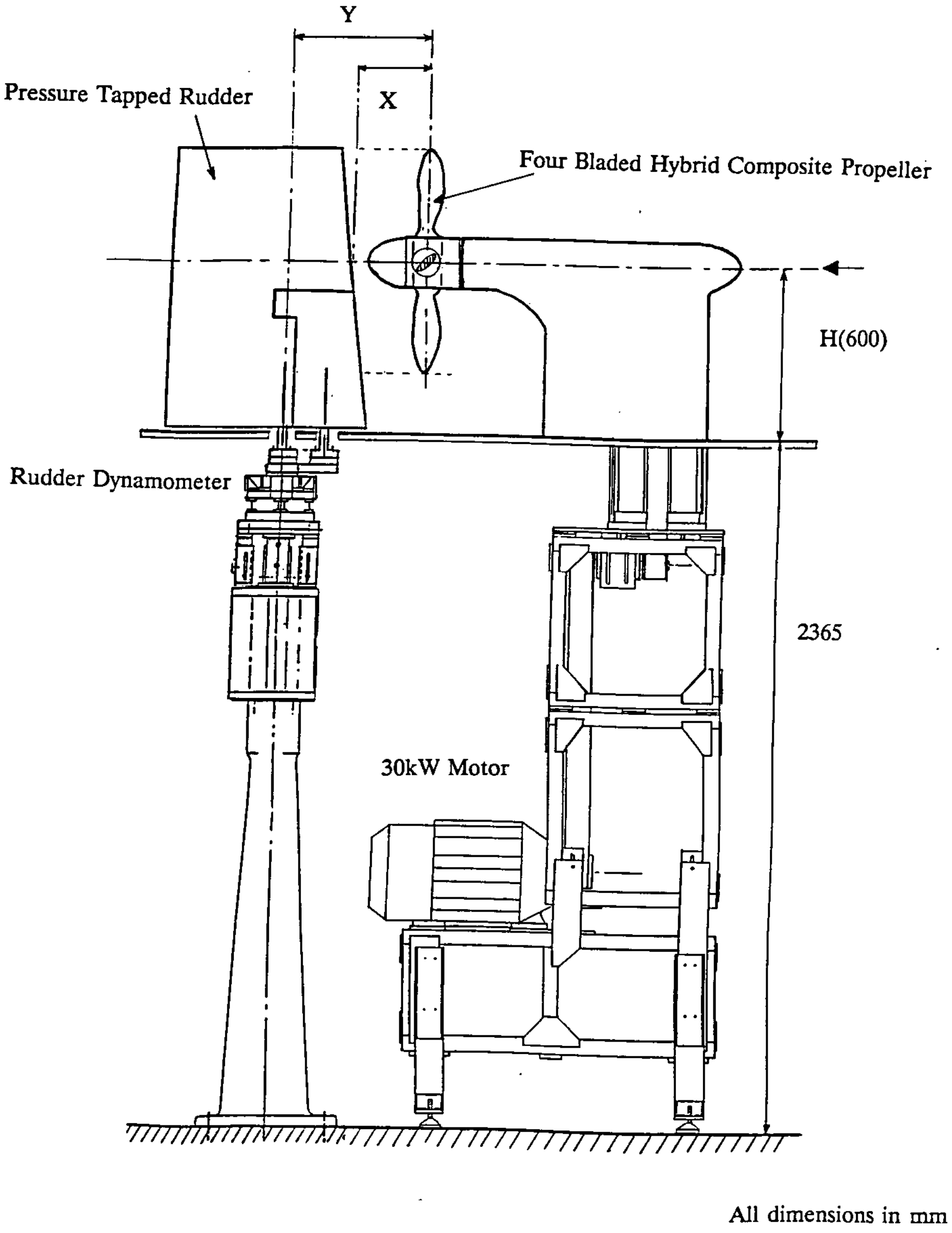


Fig. 6 Overall test rig for investigation of rudder propeller interaction.

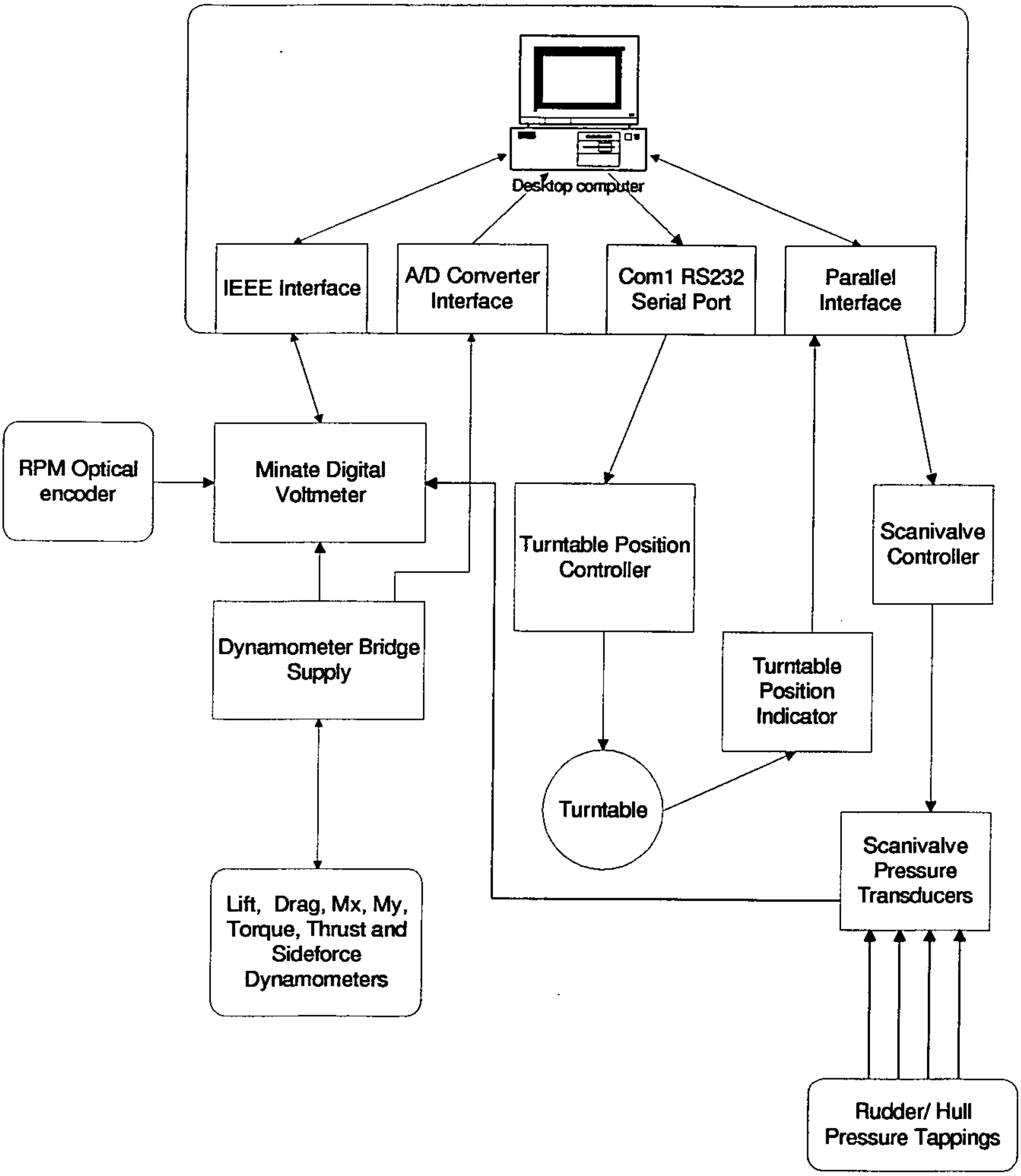


Fig. 7 Rudder and Propeller Control System Schematic

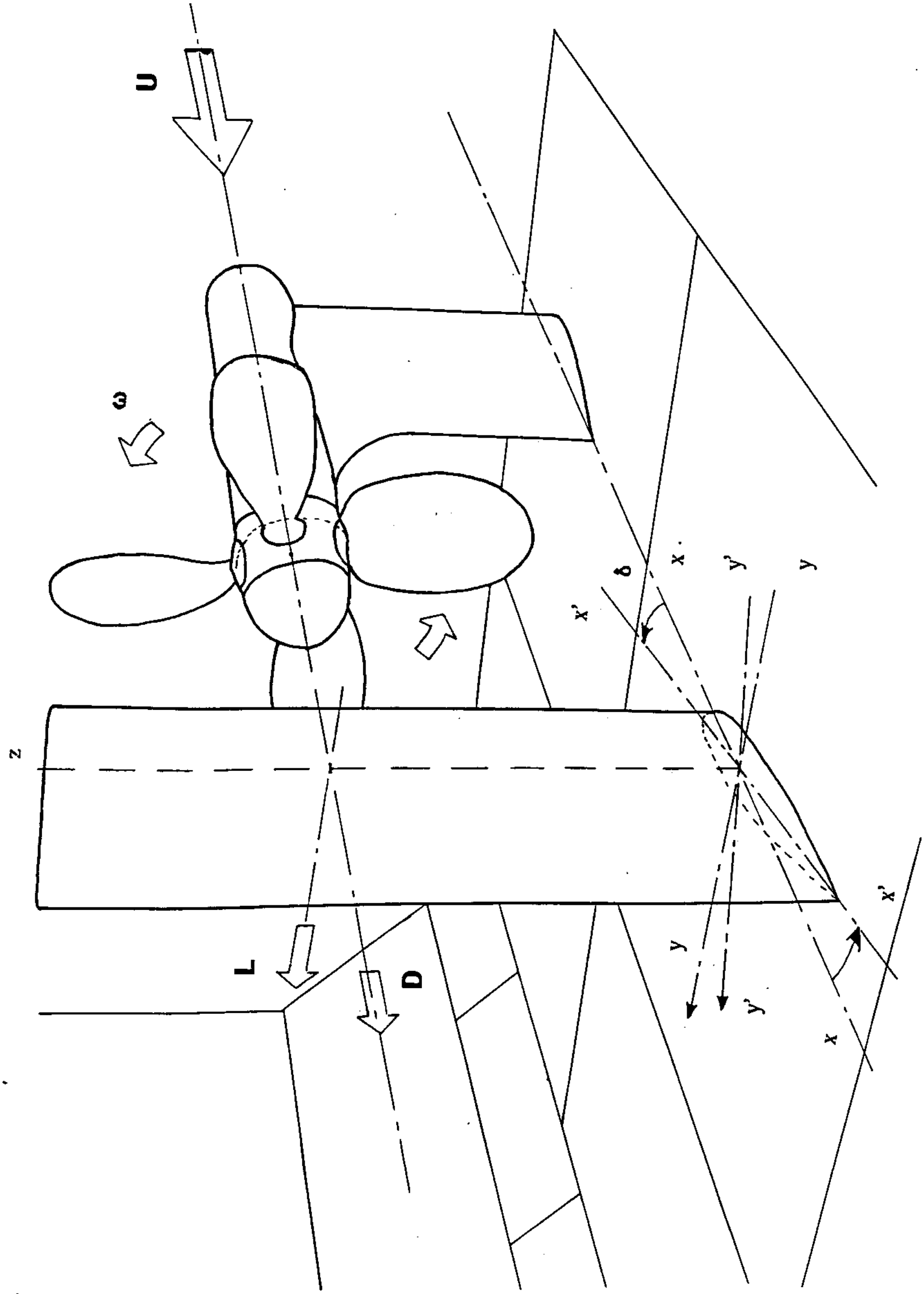


Fig. 8 Rudder and propeller test definition.

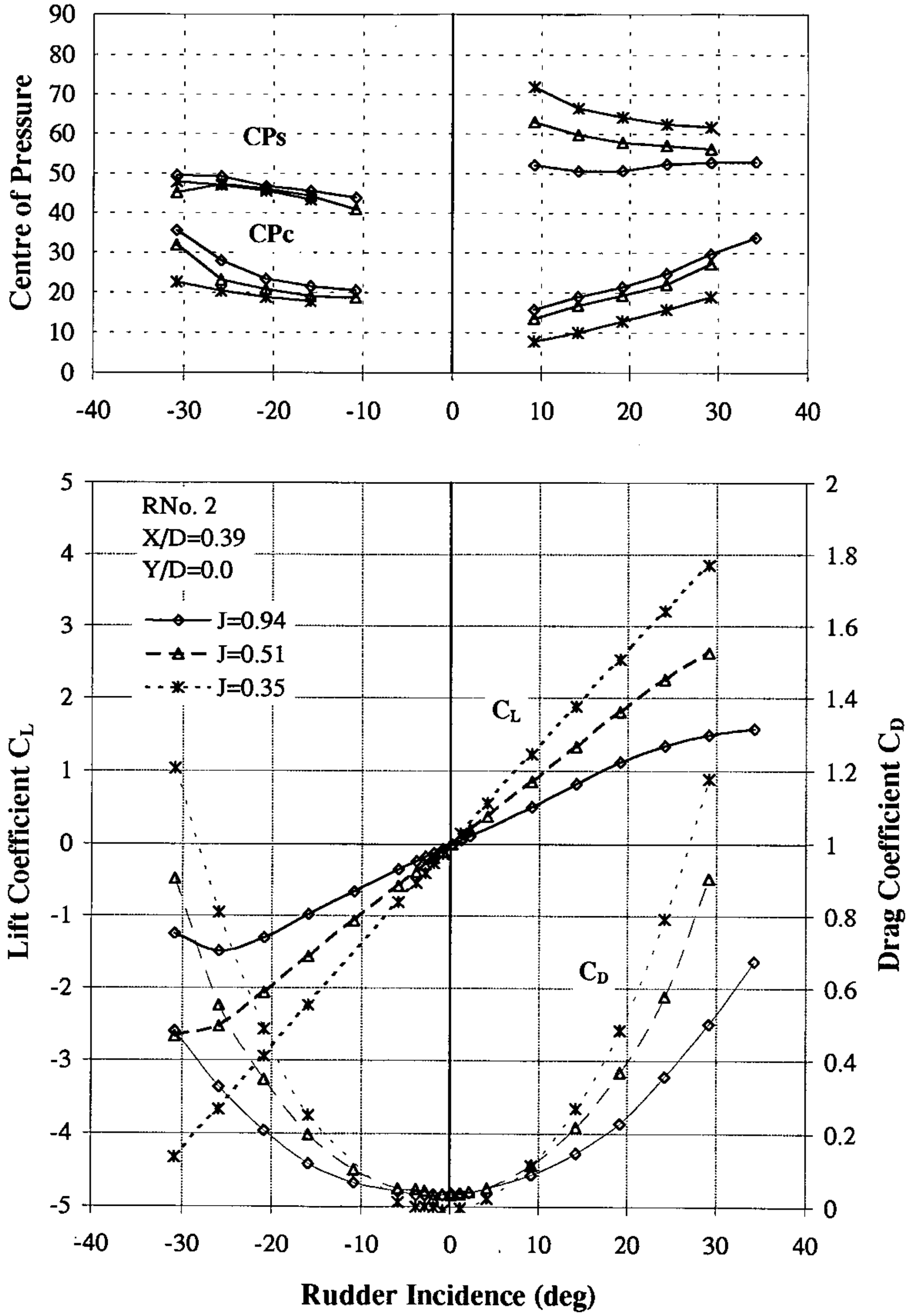


Fig. 9 Influence of Propeller Thrust Loading on the Performance of Rudder No. 2

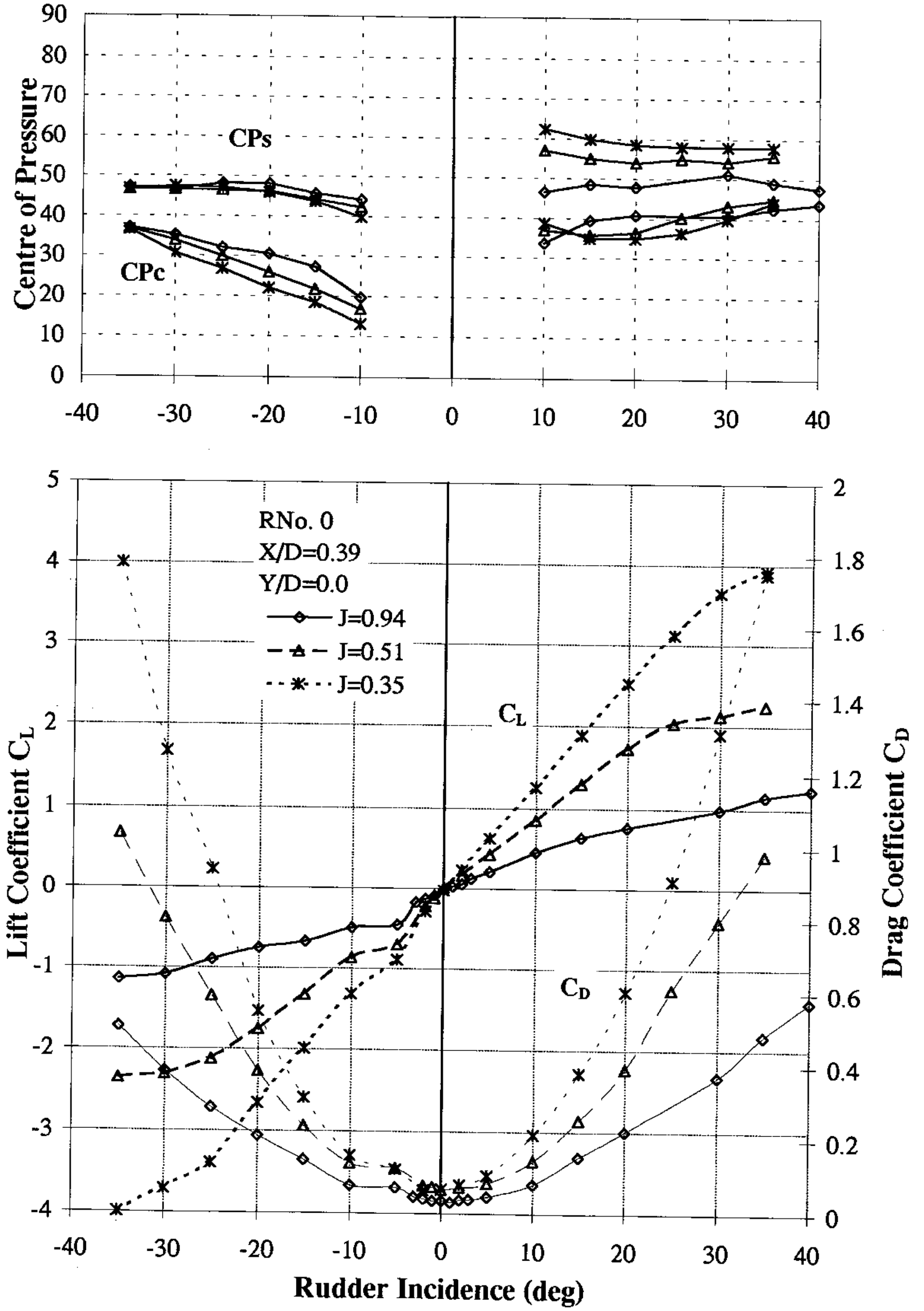


Fig. 10 Influence of Propeller Thrust Loading on the Performance of Skeg-Rudder No. 0 (rudder plus skeg forces), skeg angle β=0 degrees.

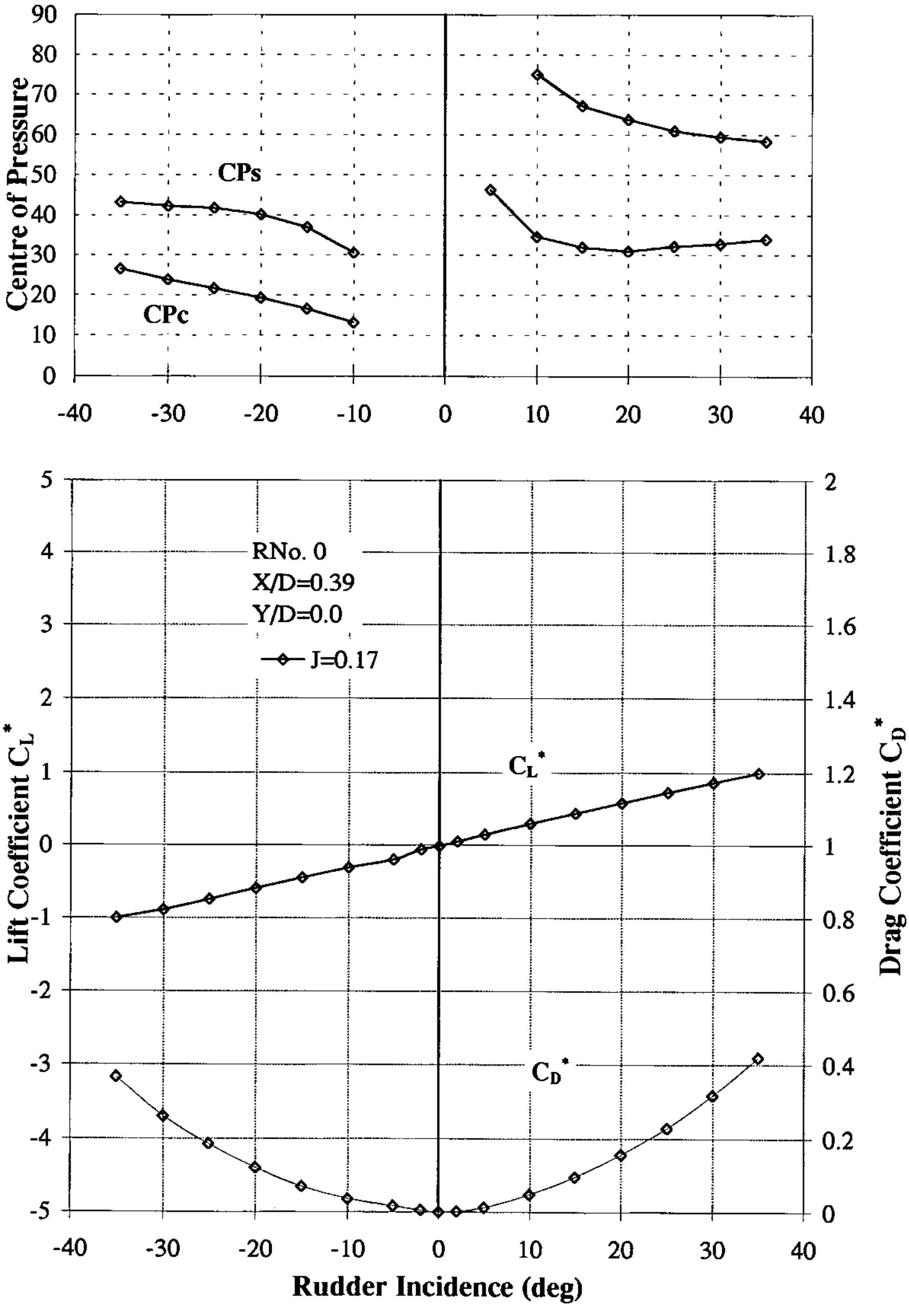


Fig. 11 Skeg-Rudder No. 0 Performance at a Propeller Advance Ratio of J=0.17 (rudder plus skeg forces), skeg angle β=0 degrees.

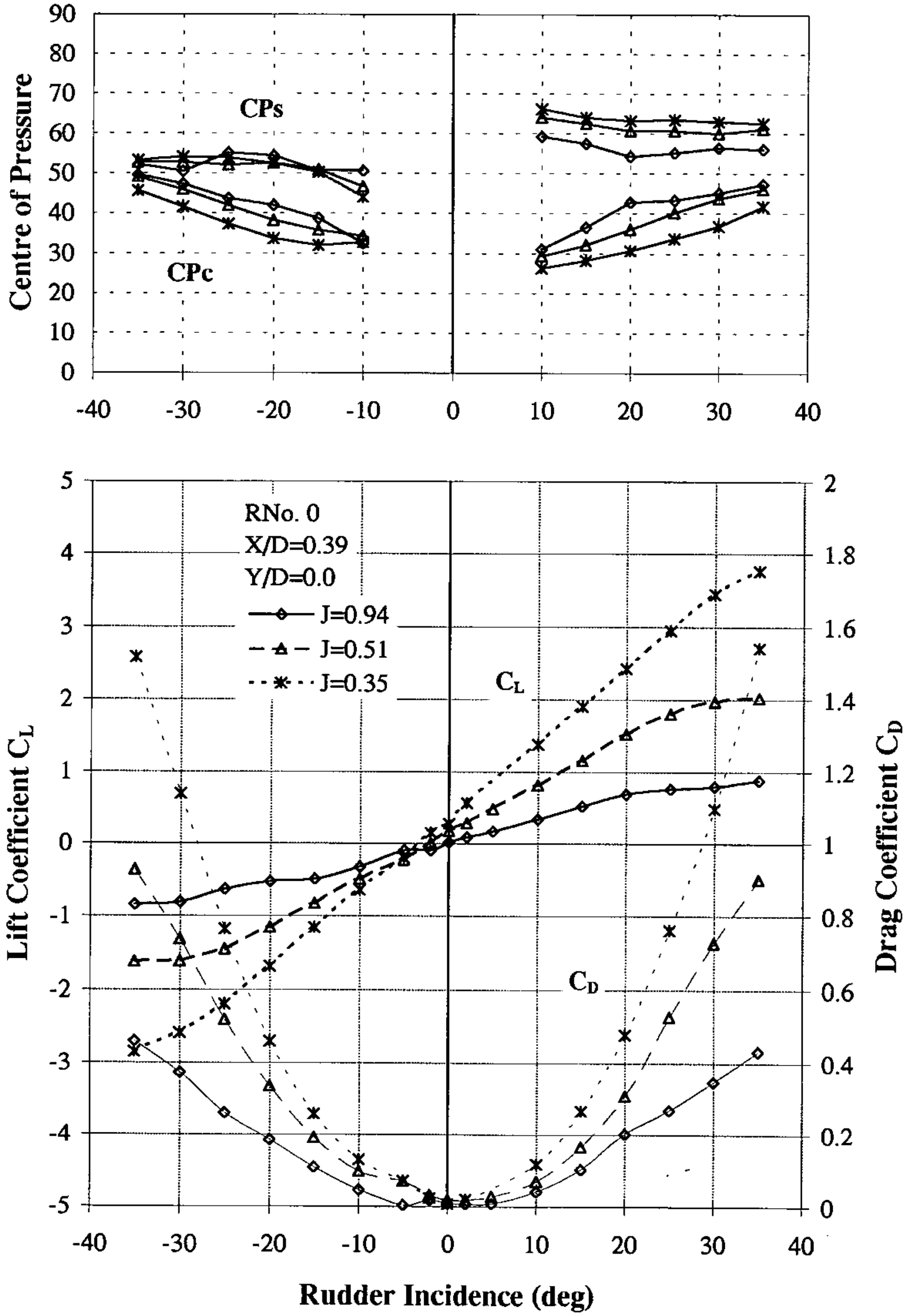


Fig. 12 Influence of Propeller Thrust Loading on the Performance of Skeg-Rudder No. 0 (rudder alone forces), skeg angle β=0 degrees.

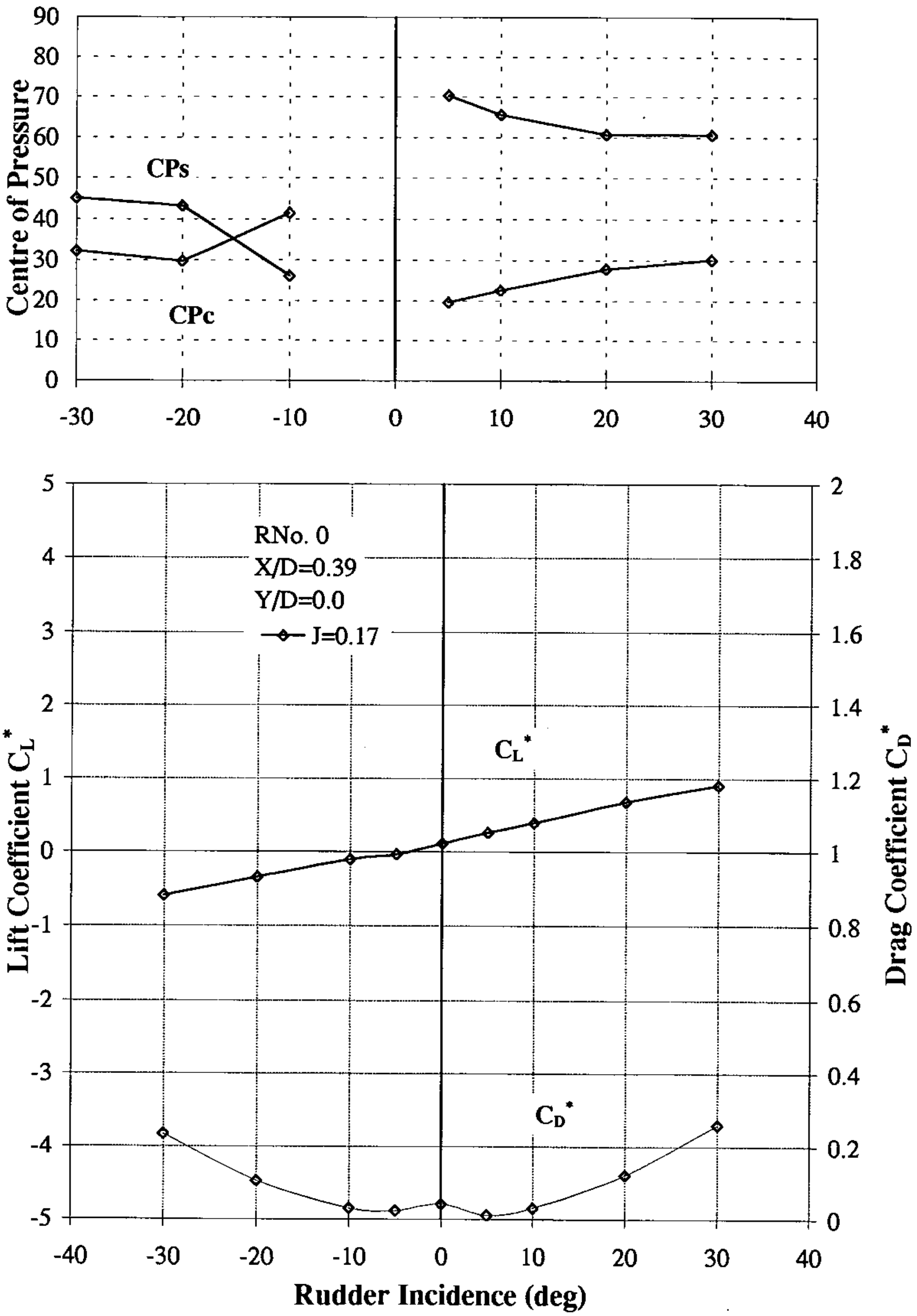


Fig. 13 Skeg-Rudder No. 0 Performance at a Propeller Advance Ratio of J=0.17 (rudder alone forces), skeg angle β=0 degrees.

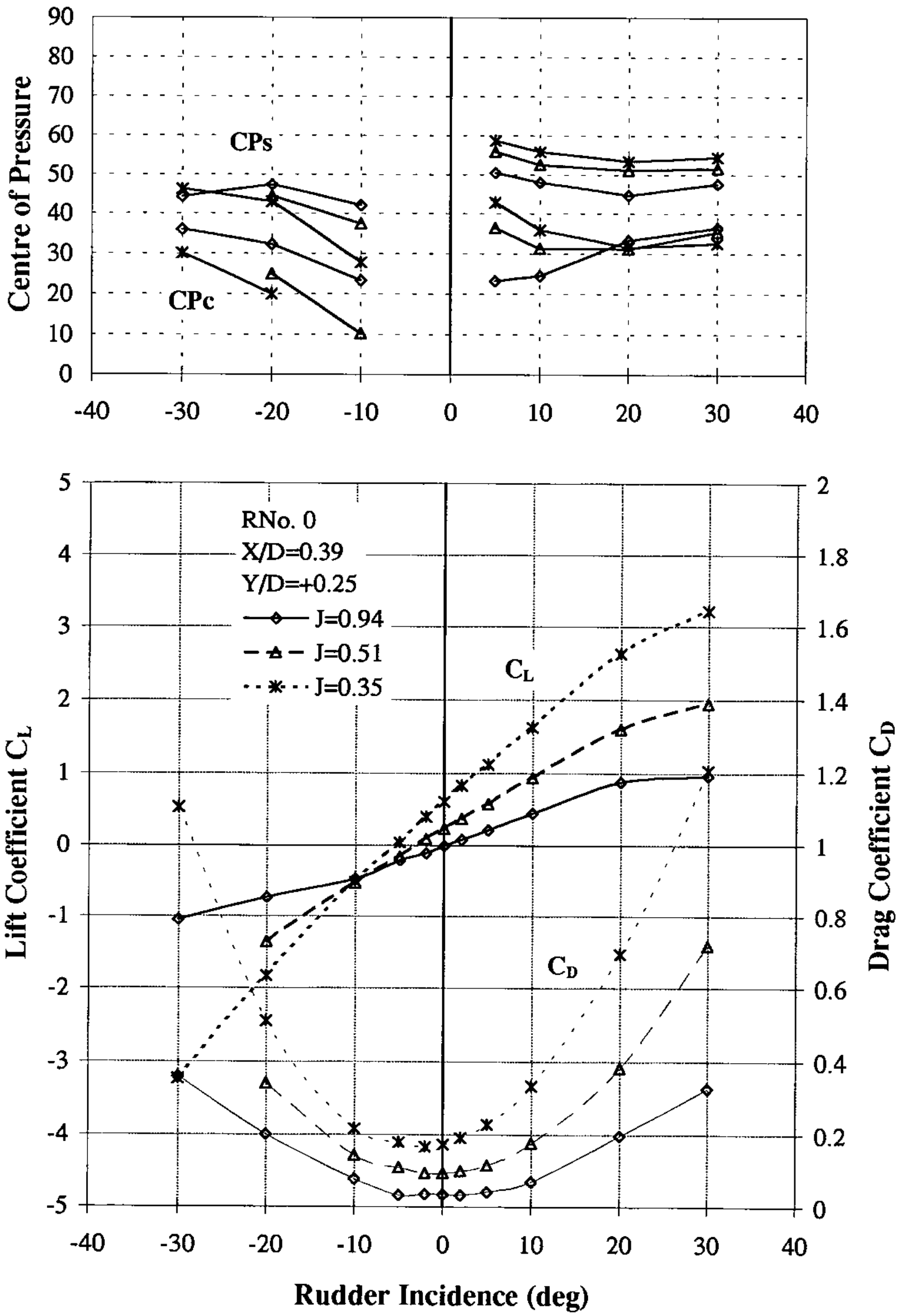


Fig. 14 Influence of Propeller Thrust Loading on the Performance of Skeg-Rudder No. 0 at a Lateral Separation of Y/D=+0.25 (rudder plus skeg forces), skeg angle β=0 degrees.

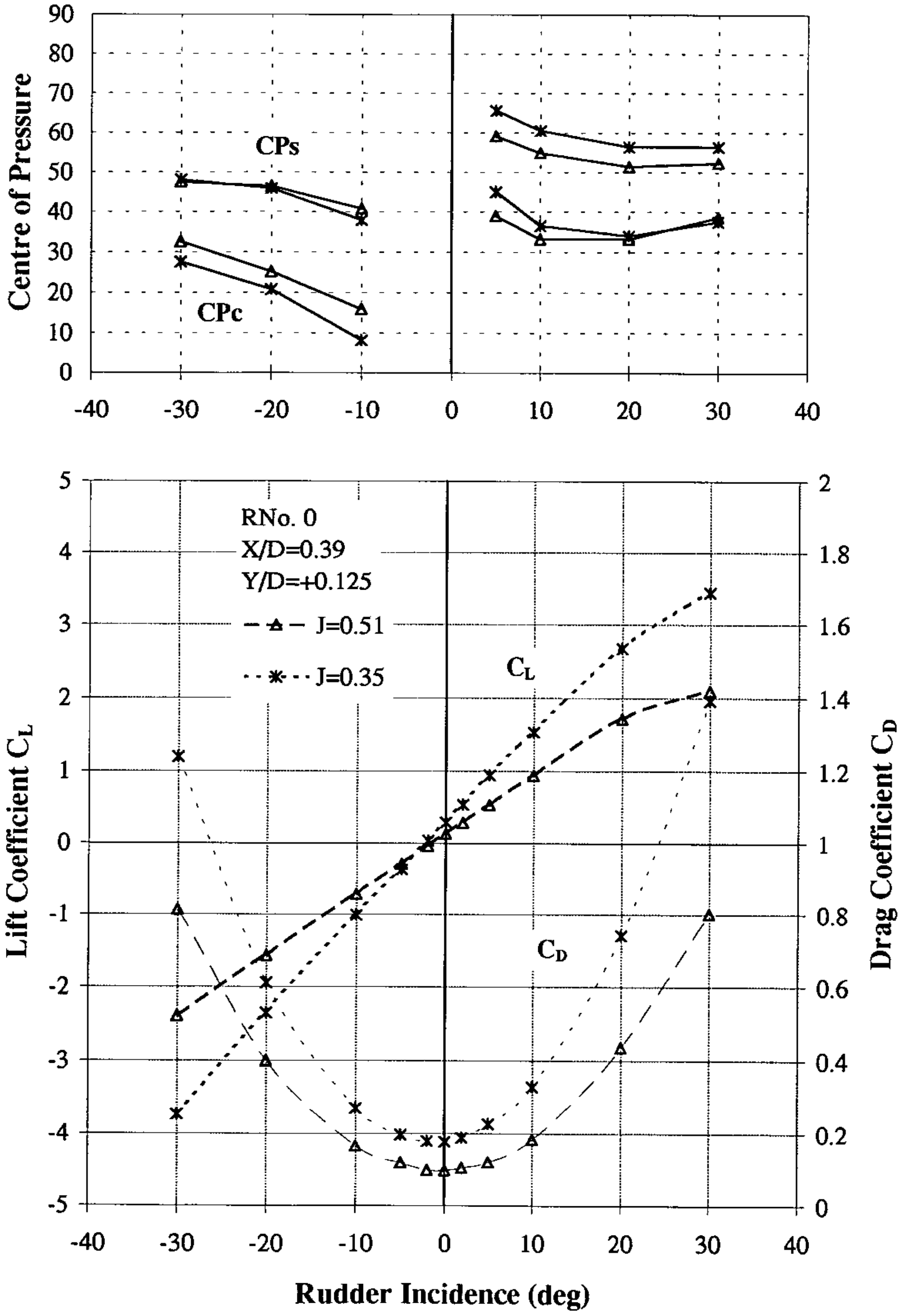


Fig. 15 Influence of Propeller Thrust Loading on the Performance of Skeg-Rudder No. 0 at a Lateral Separation of Y/D=+0.125 (rudder plus skeg forces), skeg angle β=0 degrees.

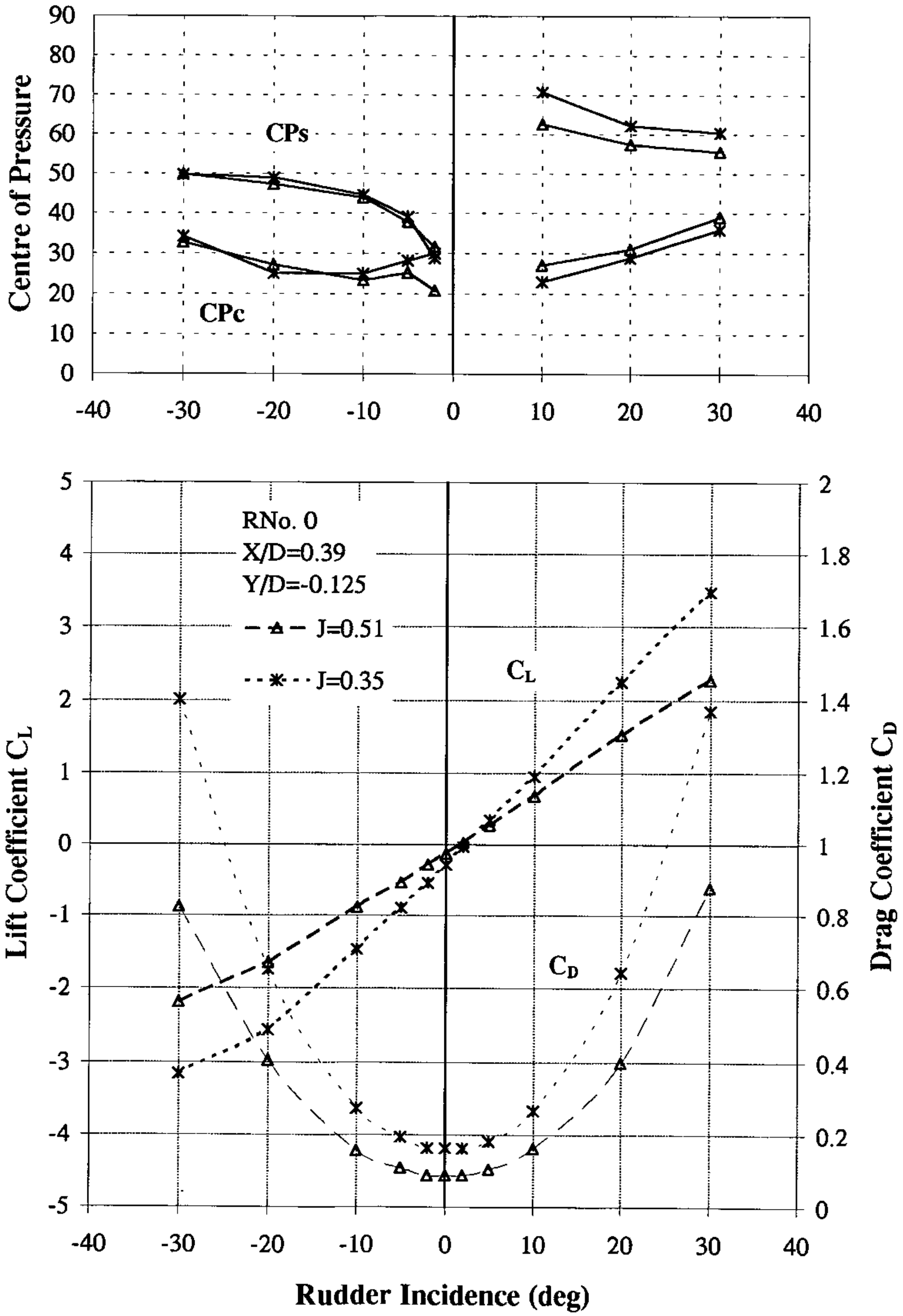


Fig. 16 Influence of Propeller Thrust Loading on the Performance of Skeg-Rudder No. 0 at a Lateral Separation of Y/D=-0.125 (rudder plus skeg forces), skeg angle β=0 degrees.

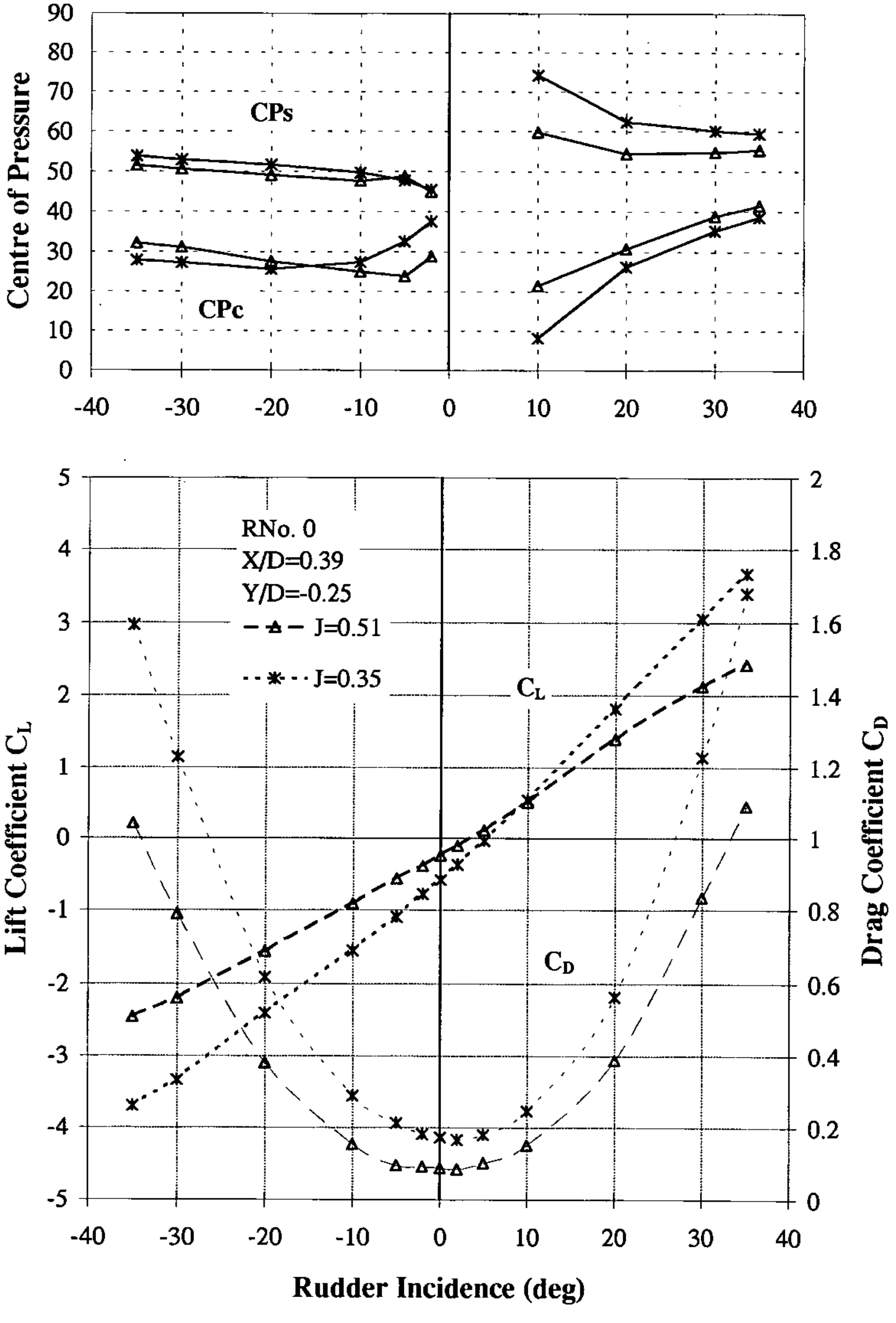


Fig. 17 Influence of Propeller Thrust Loading on the Performance of Skeg-Rudder No. 0 at a Lateral Separation of Y/D=-0.25 (rudder plus skeg forces), skeg angle β=0 degrees.

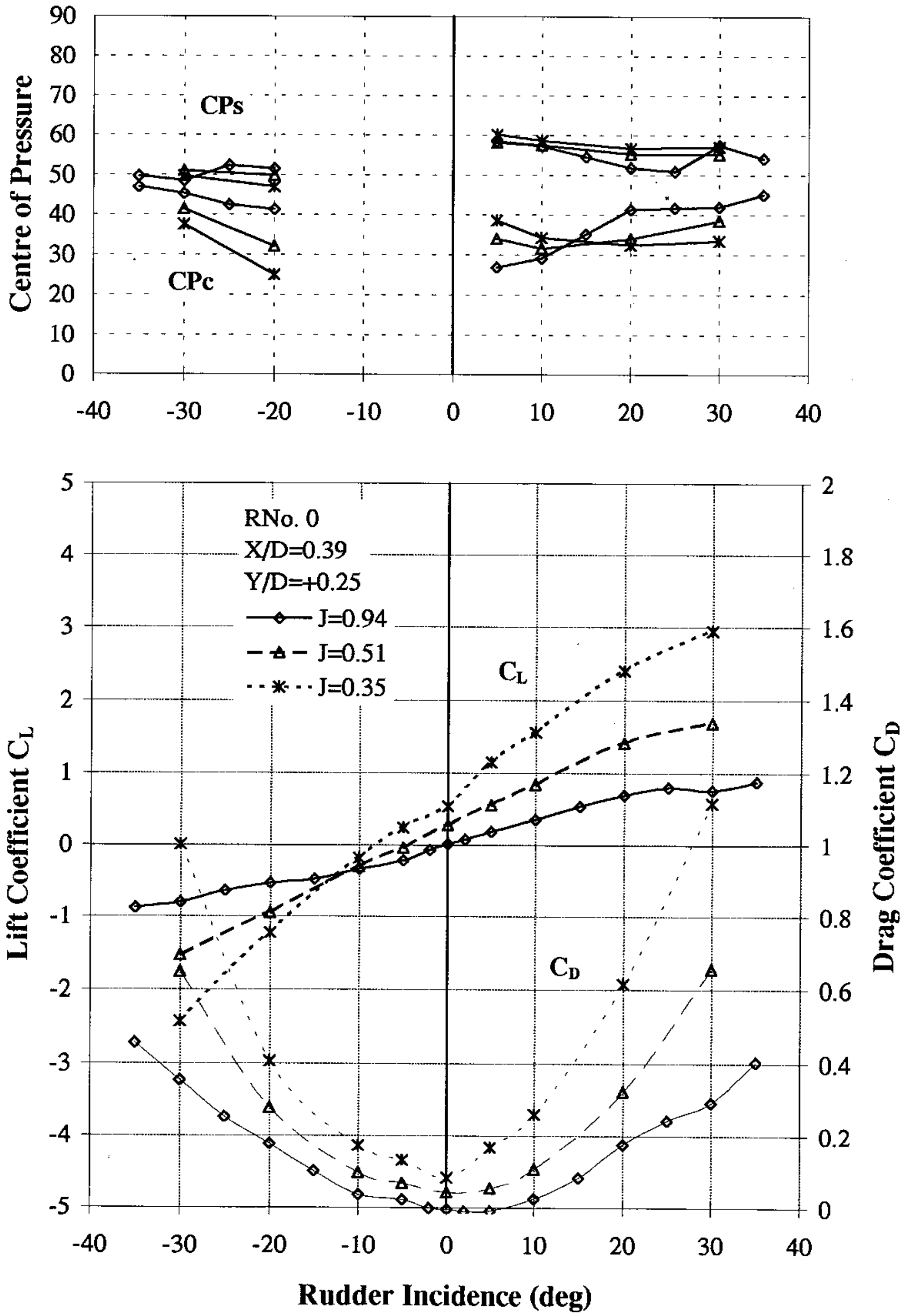


Fig. 18 Influence of Propeller Thrust Loading on the Performance of Skeg-Rudder No. 0 at a Lateral Separation of Y/D=+0.25 (rudder alone forces), skeg angle β=0 degrees.

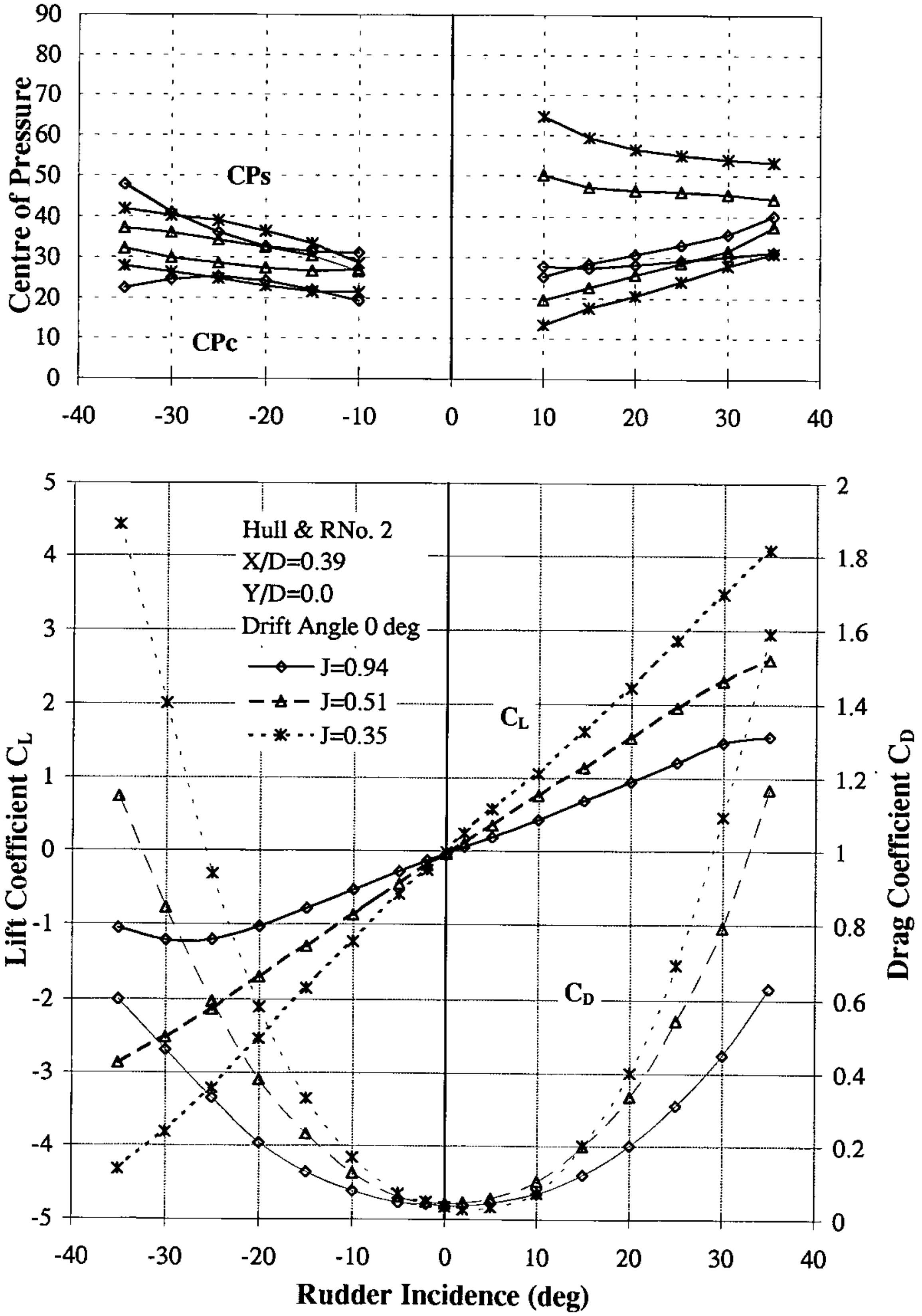


Fig. 19 Influence of Propeller Thrust Loading on the Performance of Rudder No. 2 Behind the Hull.

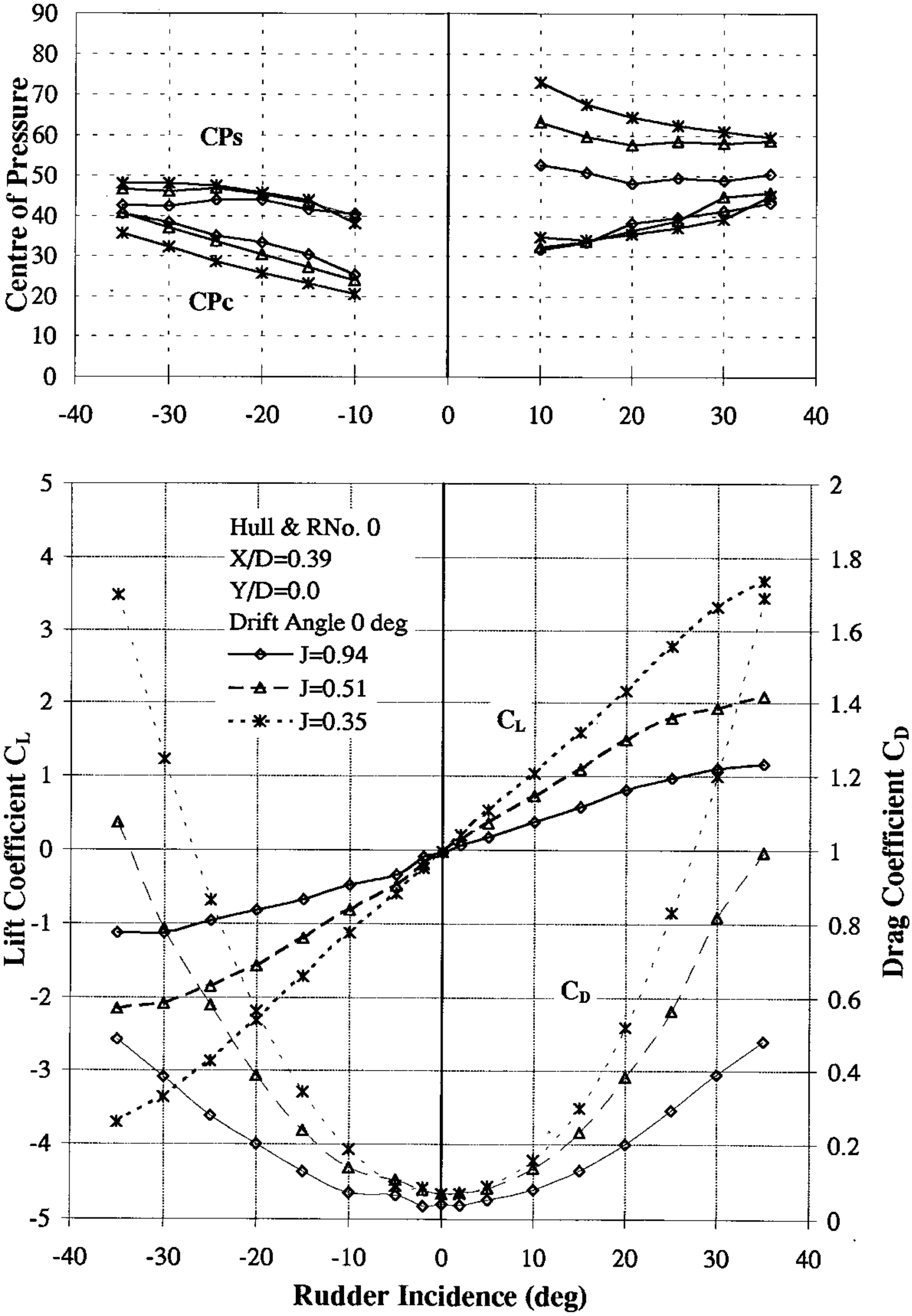


Fig. 20 Influence of Propeller Thrust Loading on the Performance of Skeg-Rudder No. 0 Behind the Hull (rudder plus skeg forces), skeg angle β=0 degrees.

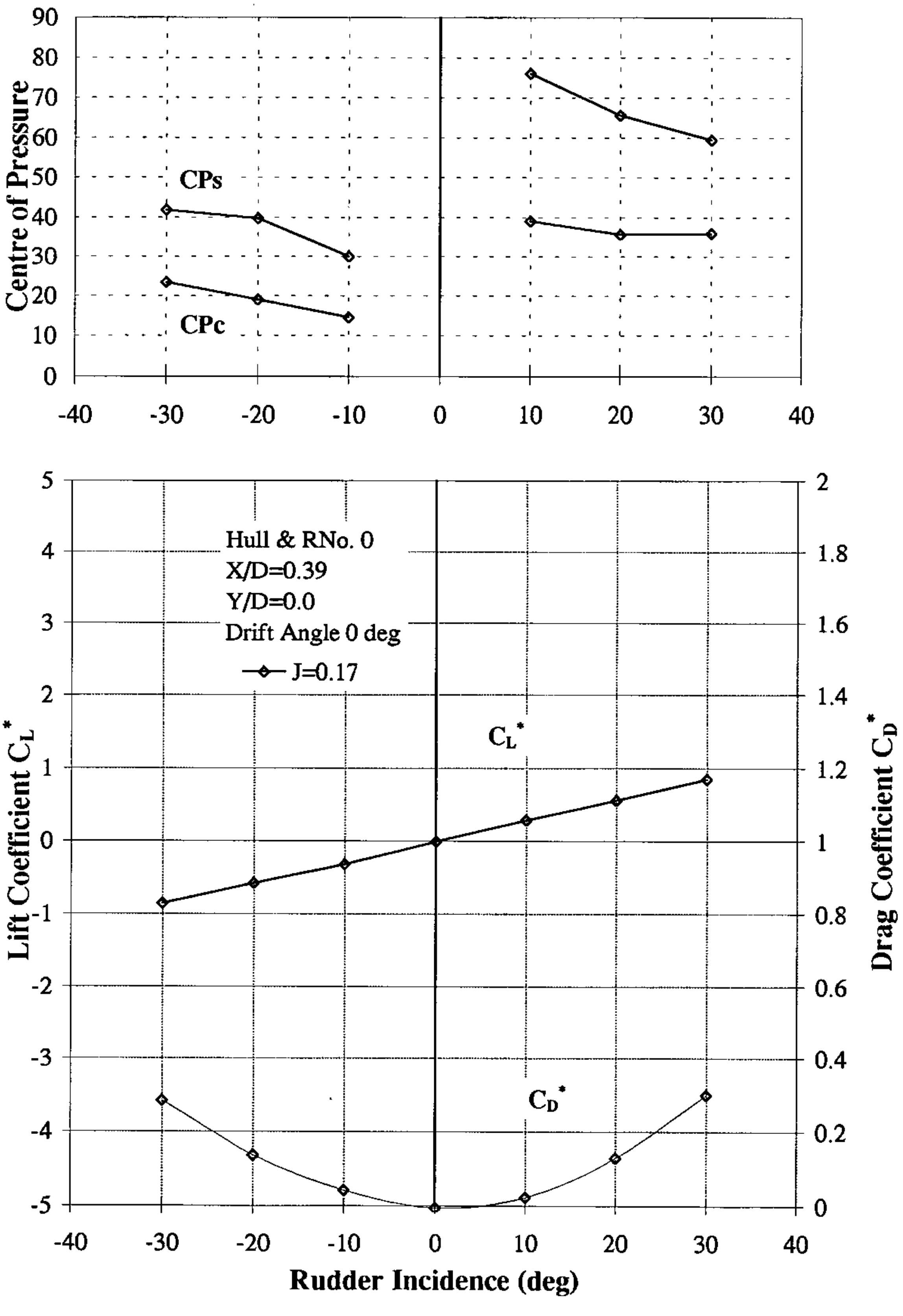


Fig. 21 Skeg-Rudder No. 0 Performance at a Propeller Advance Ratio of J=0.17 and Behind the Hull (rudder plus skeg forces), skeg angle β=0 degrees .

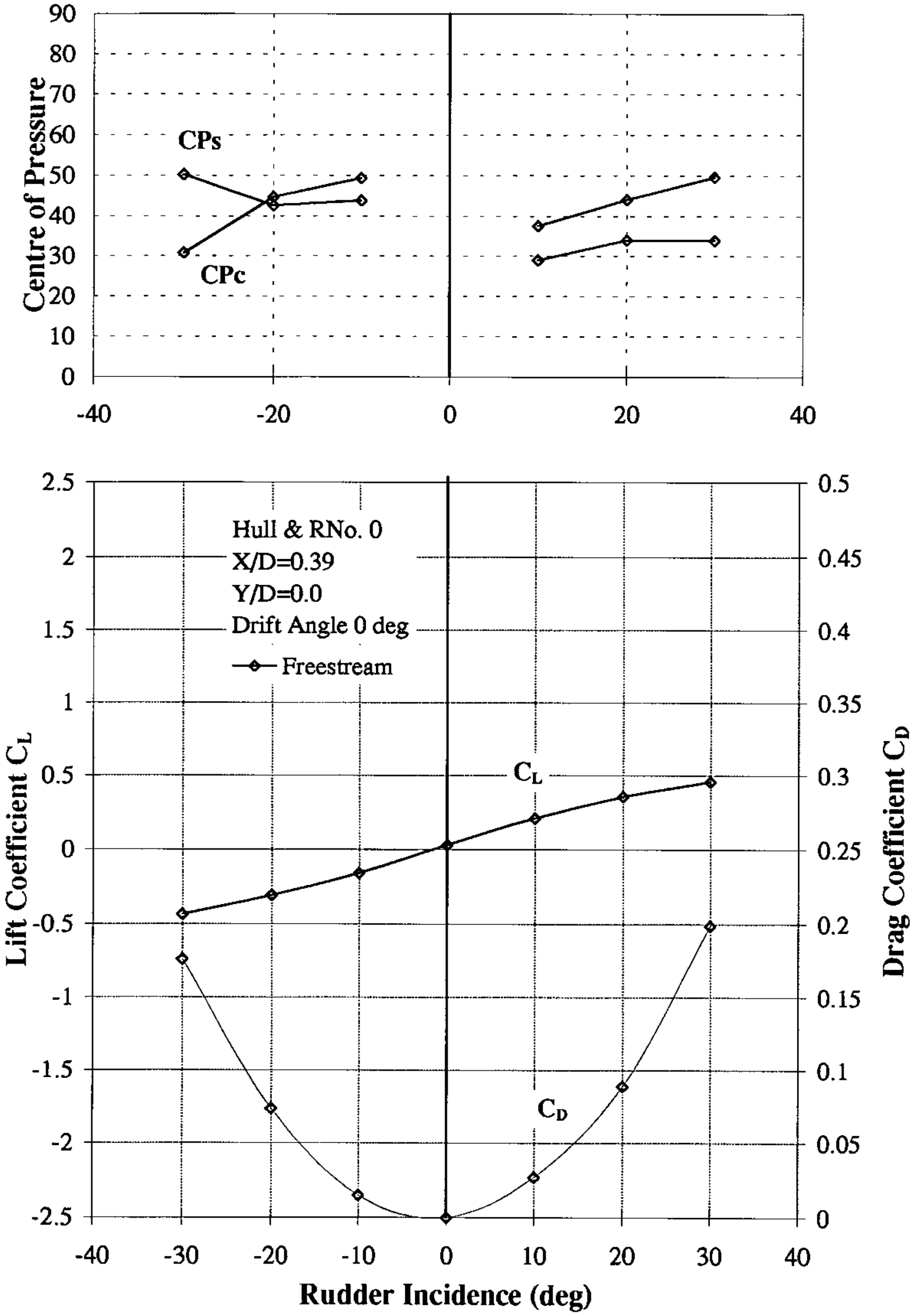
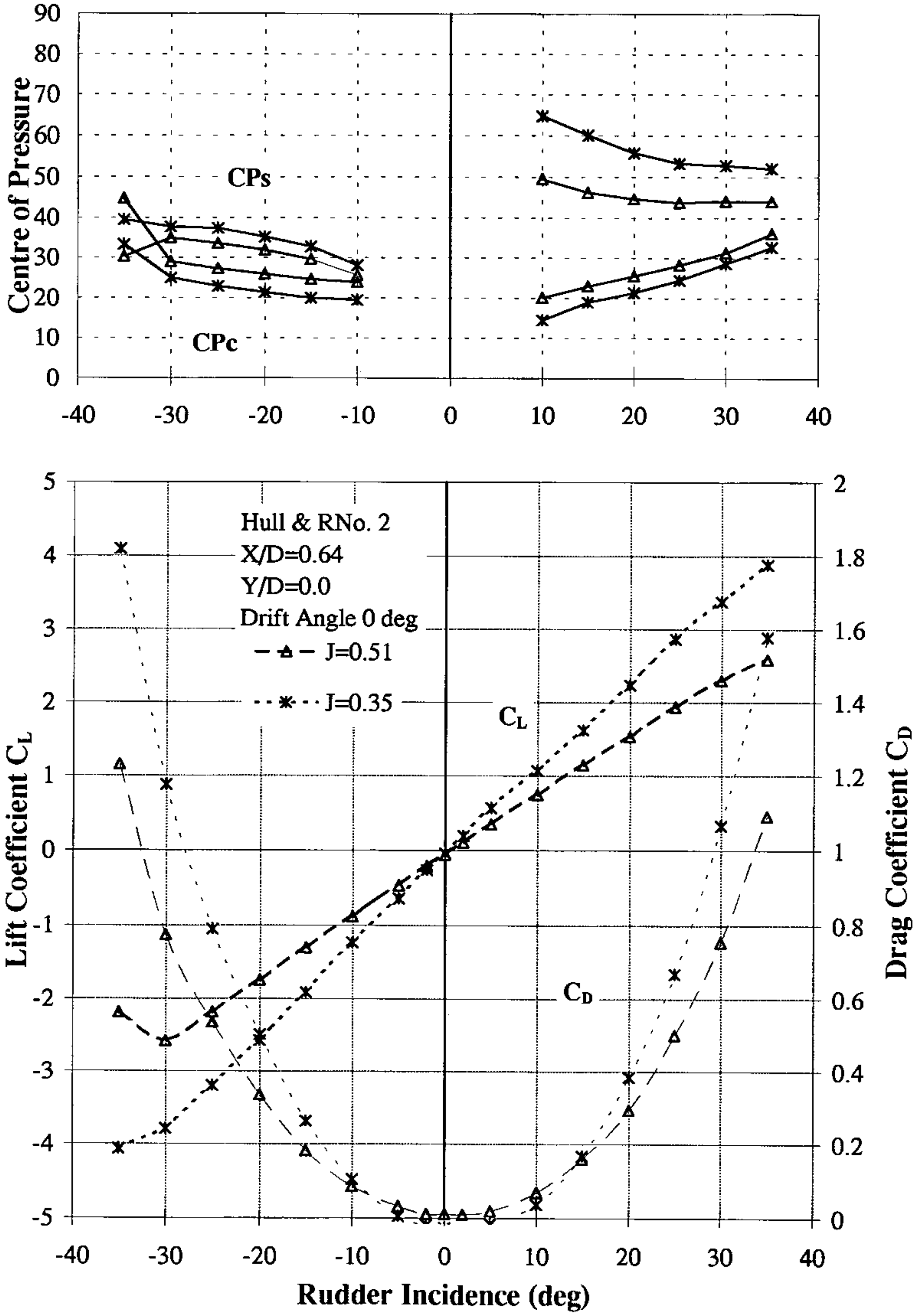


Fig. 22 Skeg-Rudder No. 0 Performance in Freestream Behin the Hull and Stationary Propeller (rudder plus skeg forces), skeg angle β=0 deg.



Fig, 23 Influence of Propeller Thrust Loading on the Performance of Rudder No. 2 Behind the Hull and at a longitudinal Separation of X/D=0.64.

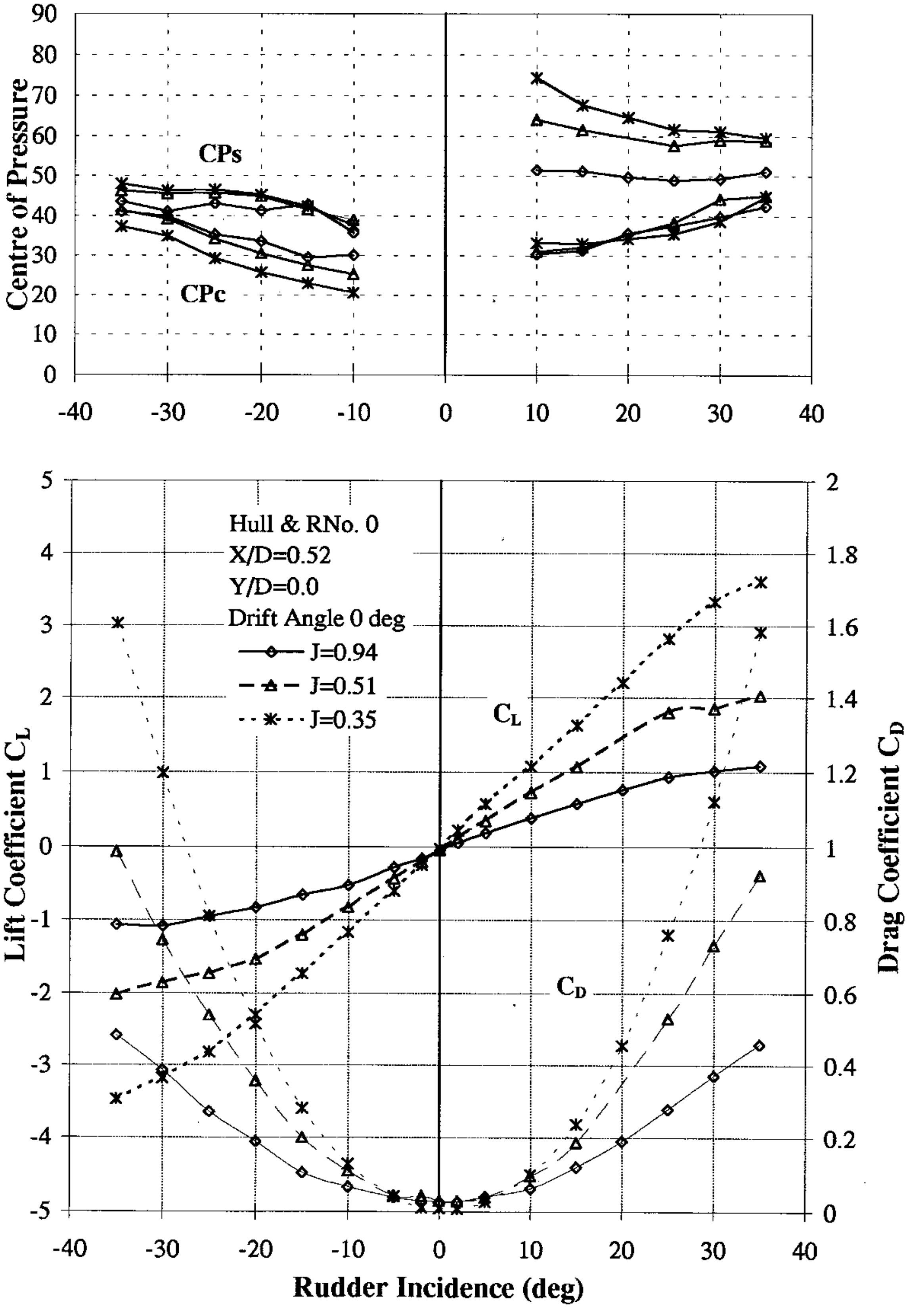


Fig. 24 Influence of Propeller Thrust Loading on the Performance of Skeg-Rudder No. 0 Behind the Hull and at a Longitudinal Separation of X/D=0.52 (rudder plus Skeg forces), skeg angle β=0 degrees.

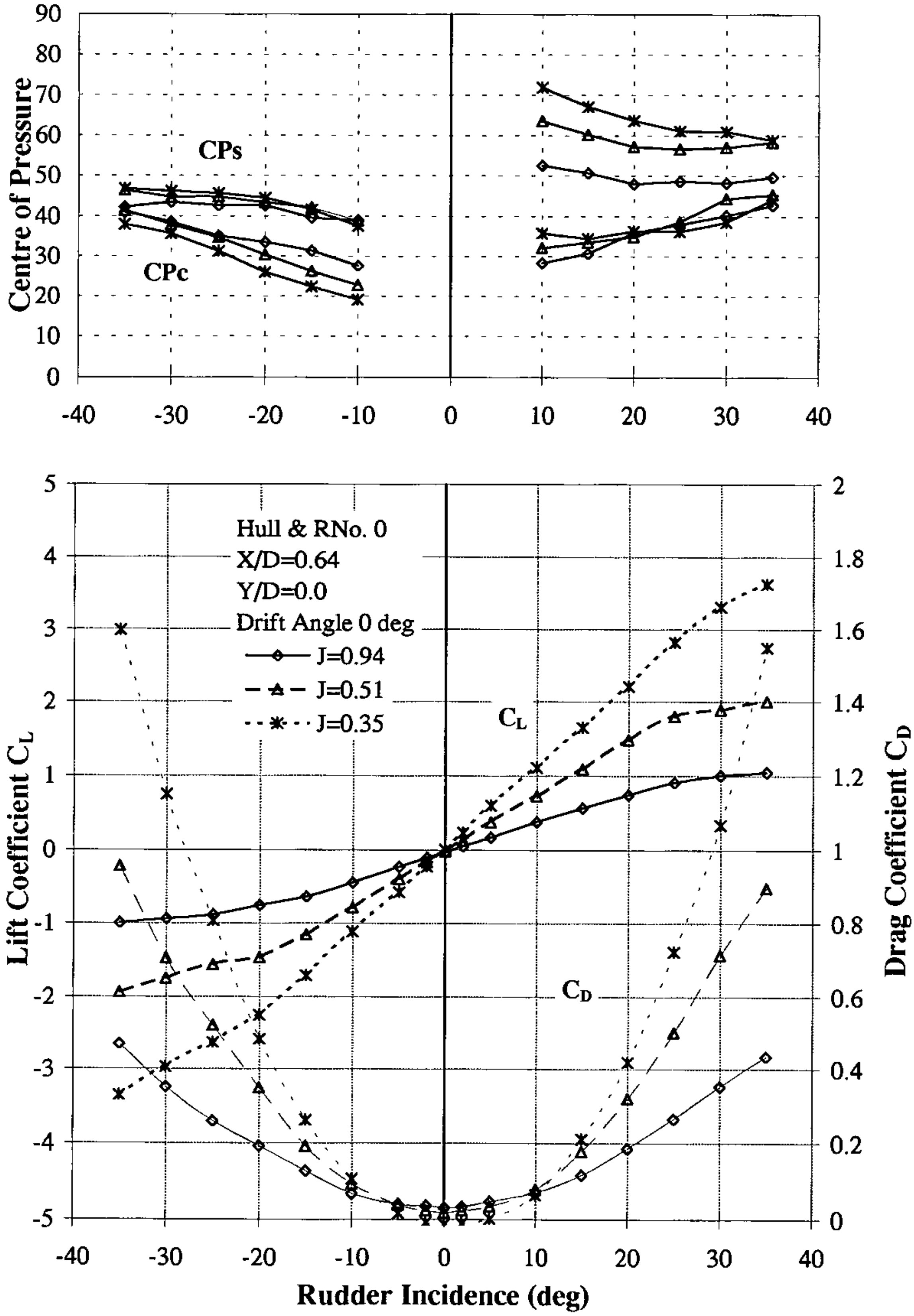


Fig. 25 Influence of Propeller Thrust Loading on the Performance of Skeg-Rudder No. 0 Behind the Hull and at a Longitudinal Separation of X/D=0.64 (rudder plus Skeg forces), skeg angle β=0 degrees.

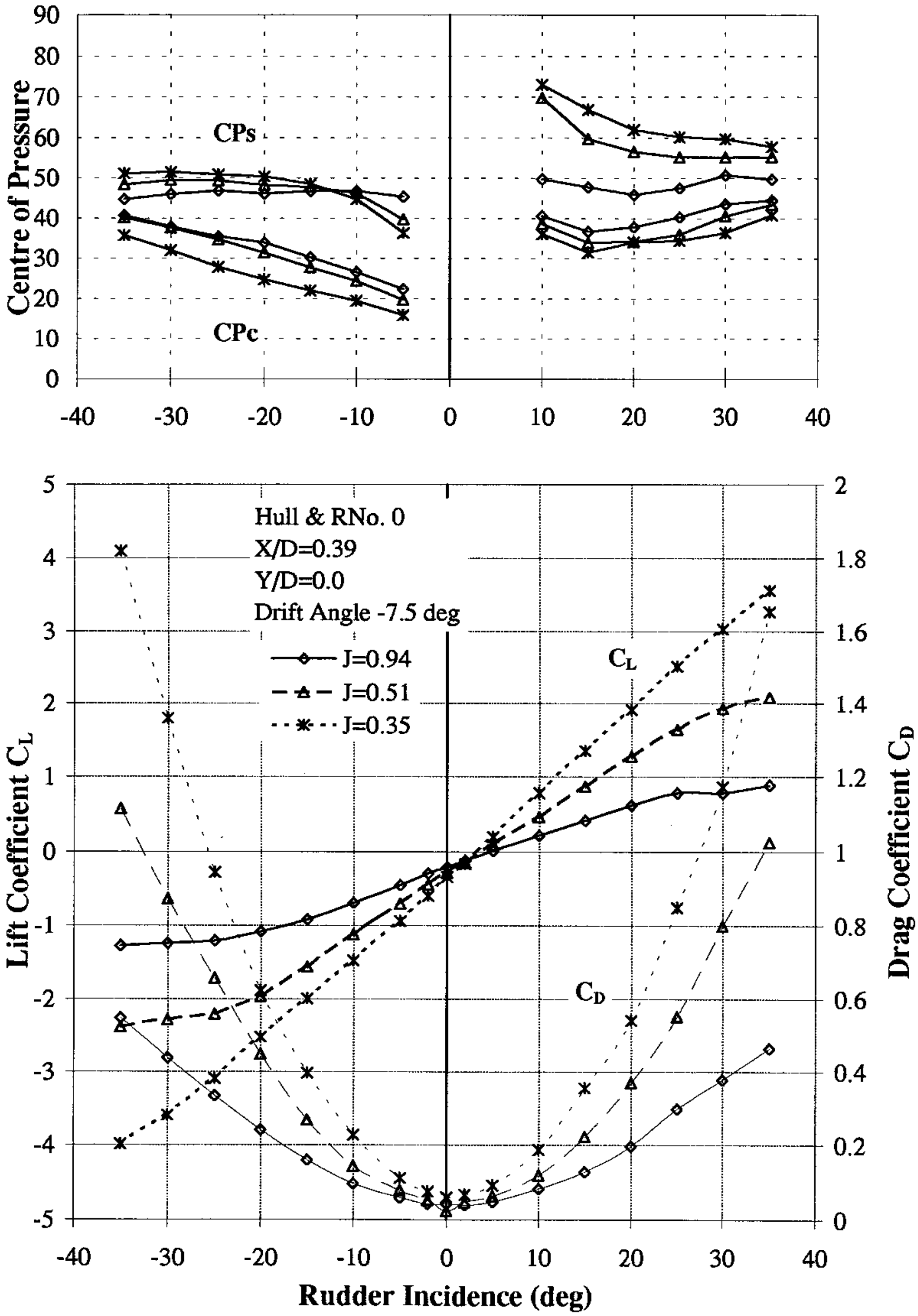


Fig. 26 Influence of Thrust Loading on the Performance of Skeg-Rudder No. 0
Behind the Hull and at a Yaw Angle of -7.5 degrees (rudder plus skeg forces),
skeg angle β=-7.5 degrees

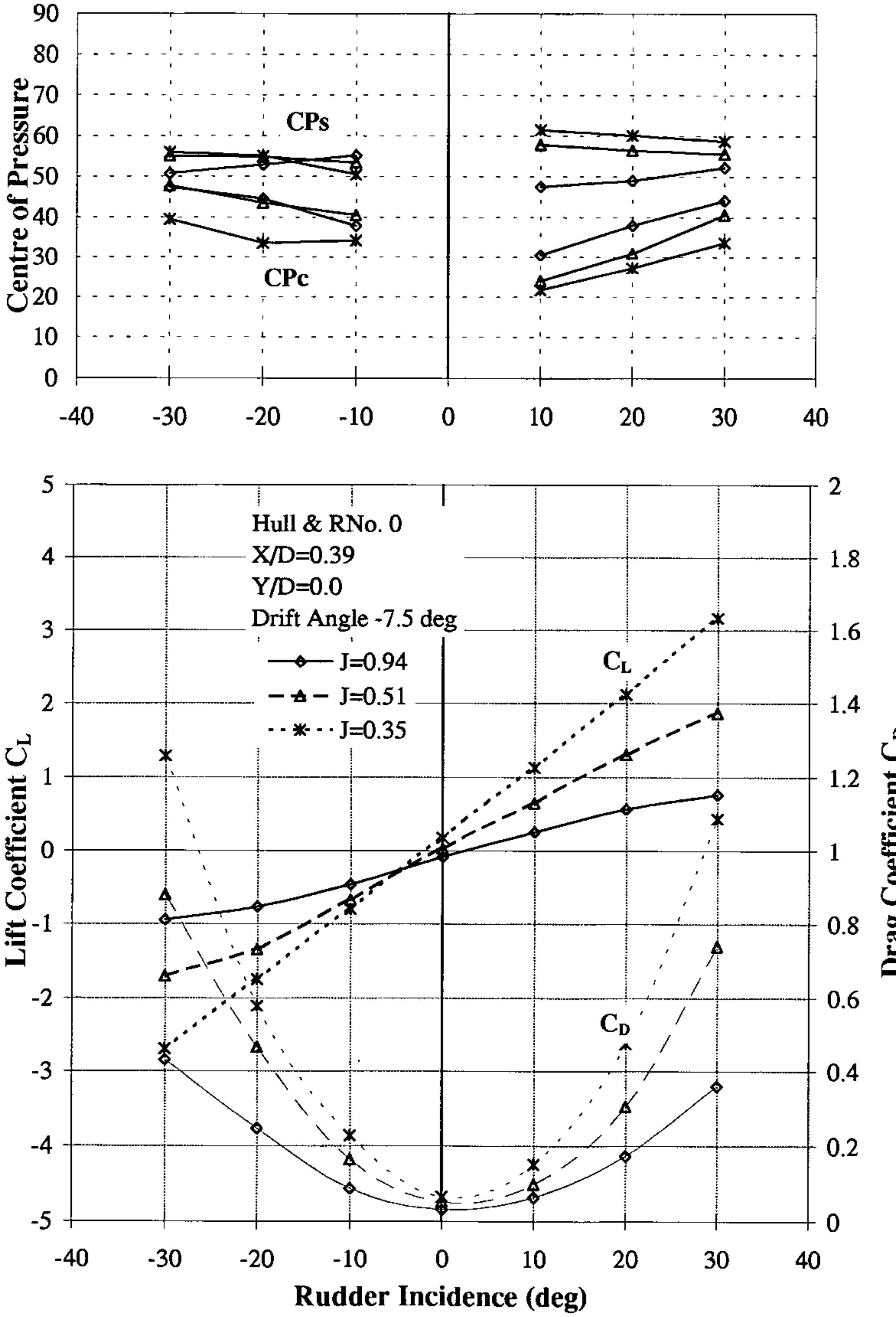


Fig. 27 Influence of Thrust Loading on the Performance of Skeg-Rudder No. 0 Behind the Hull and at a Yaw Angle of -7.5 degrees (rudder alone forces), skeg angle β=-7.5 degrees.

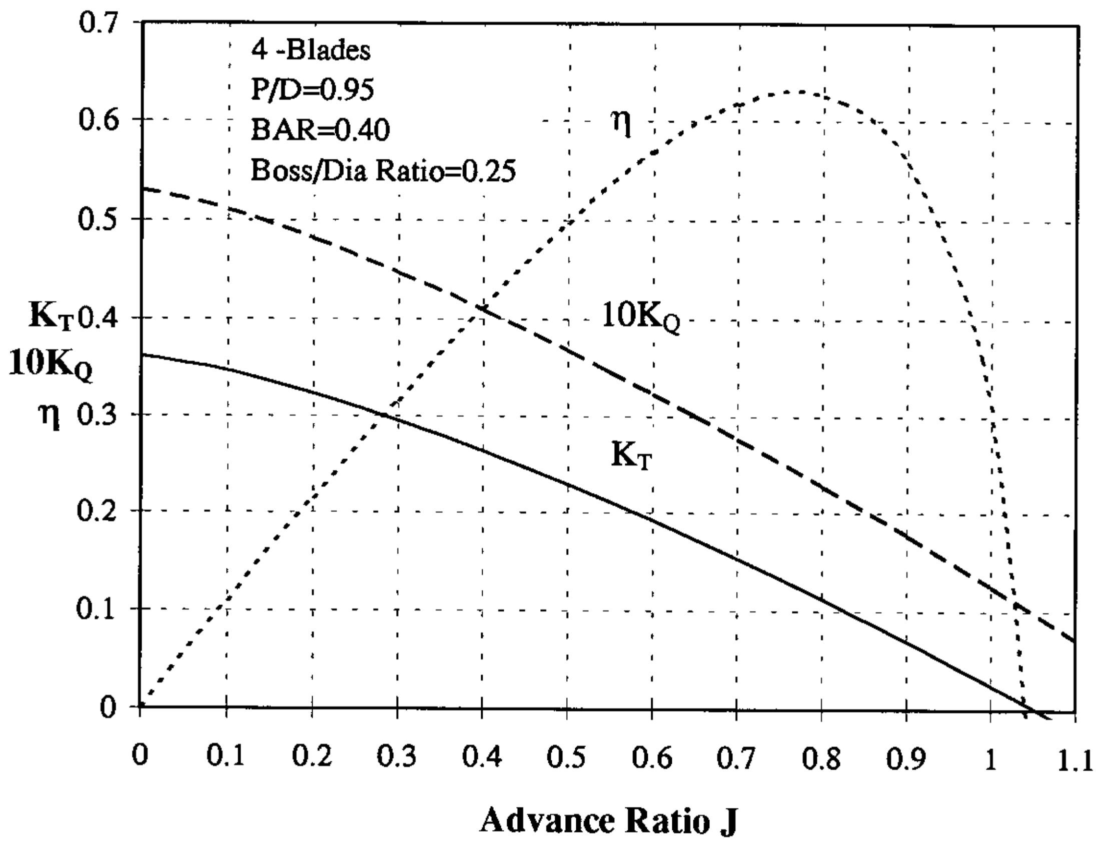


Fig. 28 Freestream (Open Water) Propeller Characteristics of Modified Wageningen B.4.40 at a mean Pitch Ratio of 0.95.

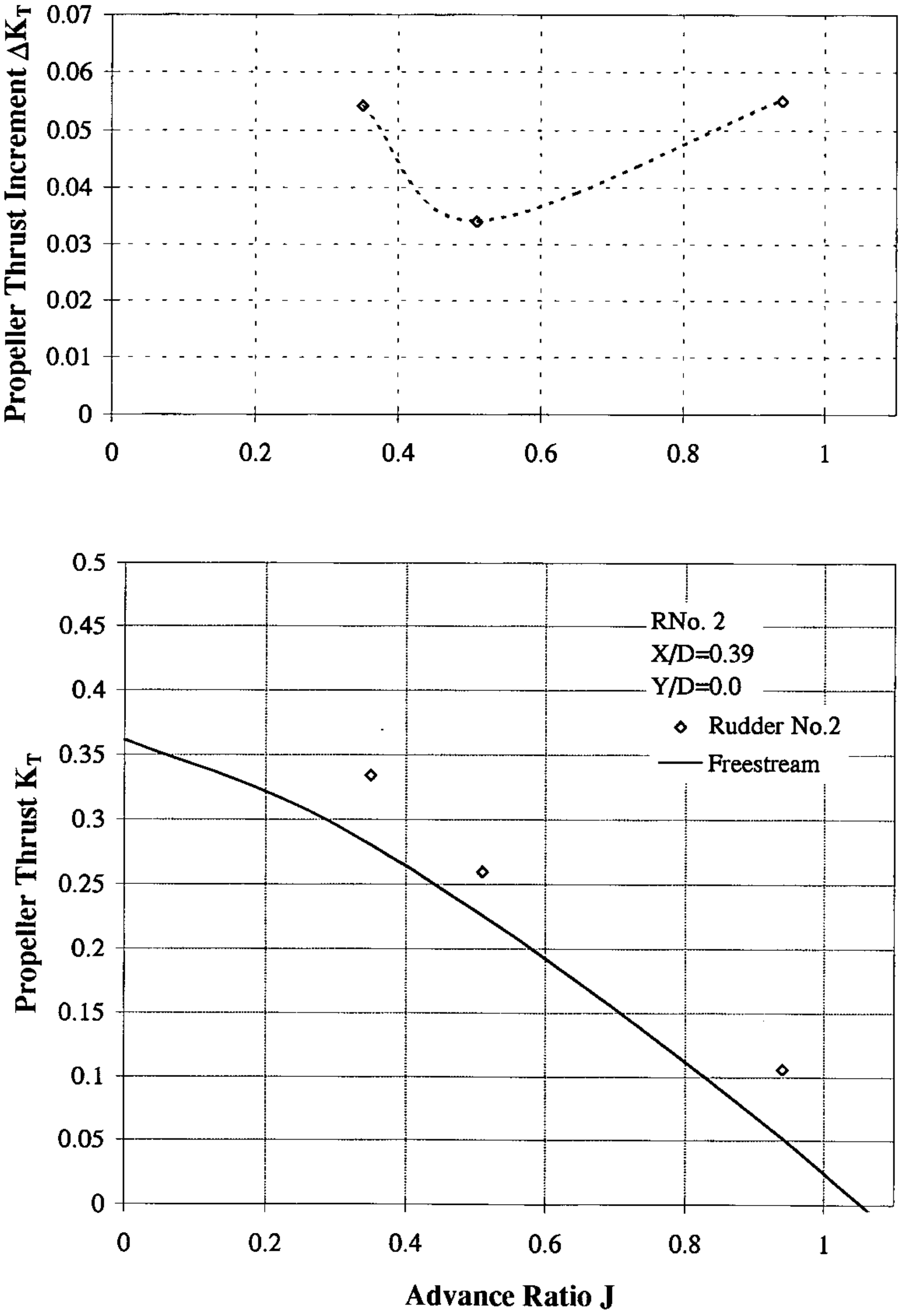


Fig. 29 Propeller Thrust and Thrust Increment Against Advance Ratio for Rudder No. 2

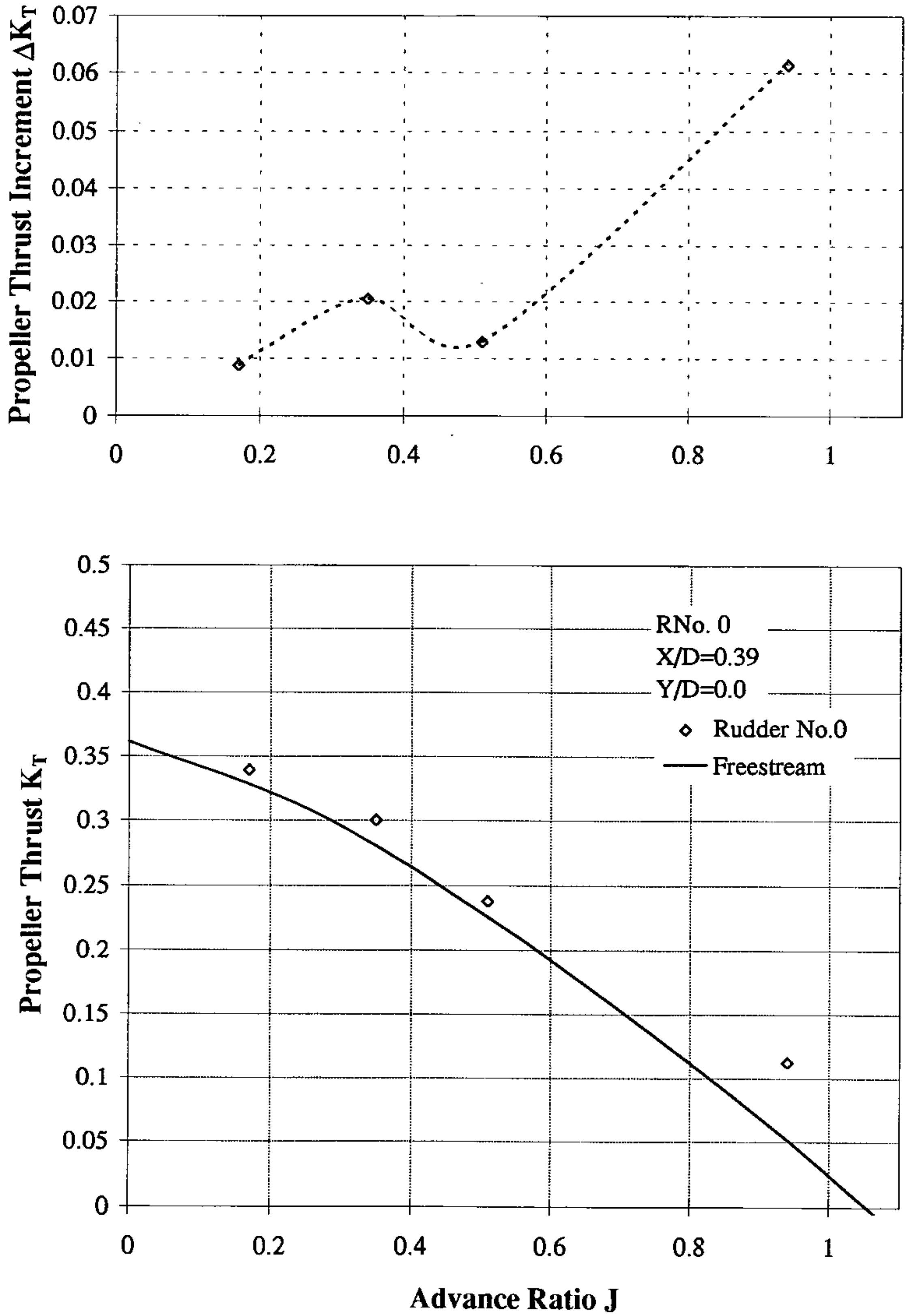


Fig. 30 Propeller Thrust and Thrust Increment Against Advance Ratio for Skeg-Rudder No. 0

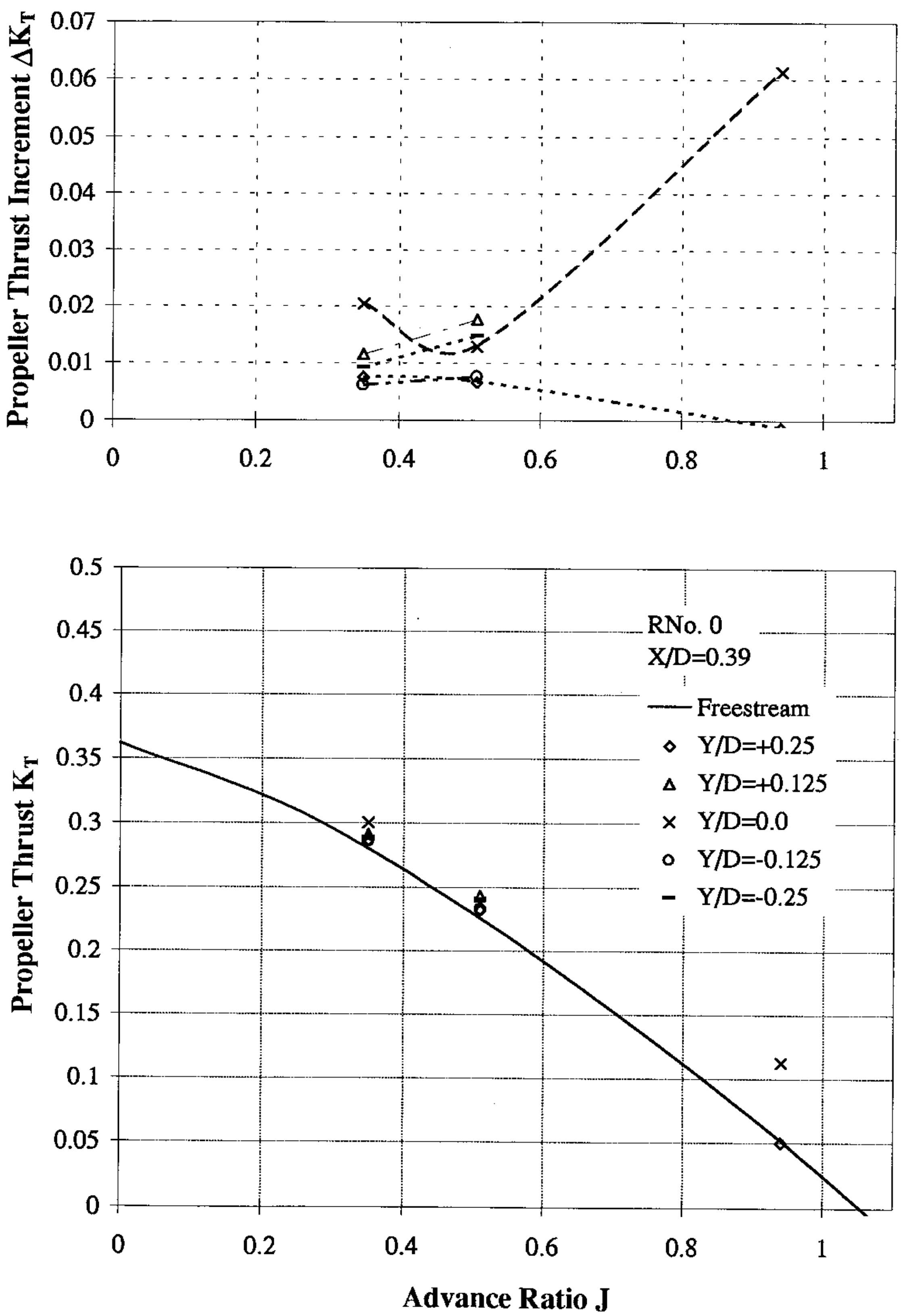


Fig. 31 Comparison of Propeller Thrust and Thrust and Thrust Increment Against Advance Ratio for a Lateral Separation of Skeg-Rudder No. 0 and Propeller of Y/D=+0.25, +0.125, 0.0, -0.125, -0.25.

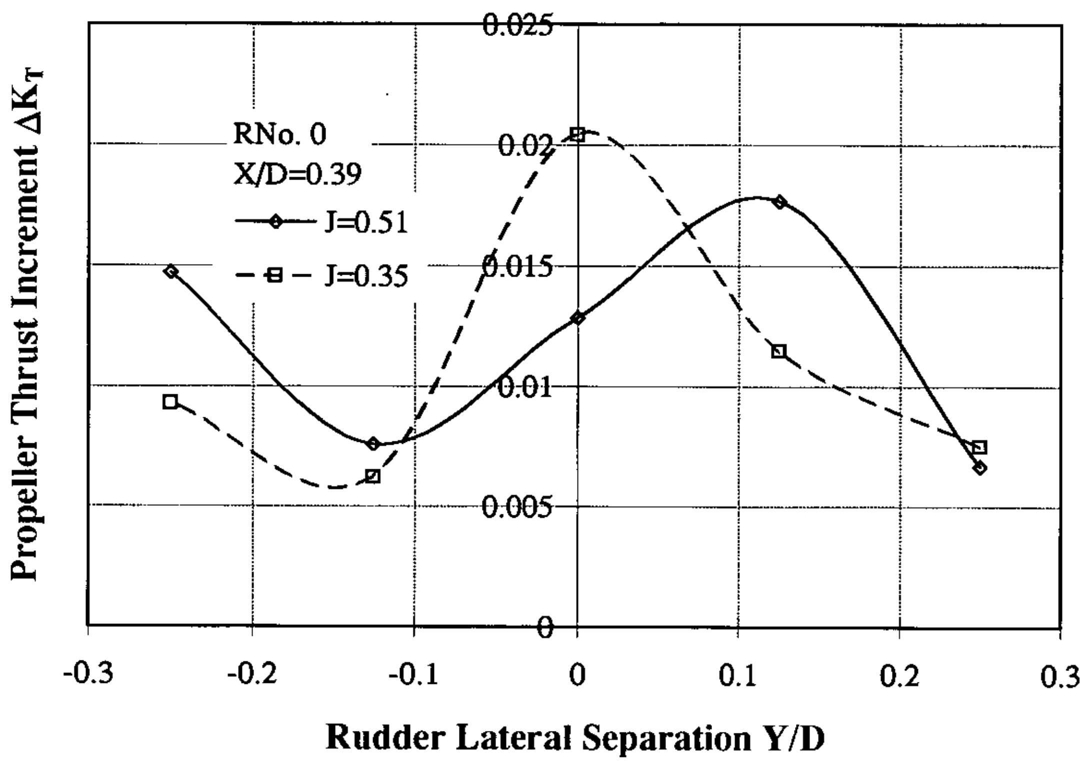


Fig. 32 Thrust Increment Against Rudder/Propeller Lateral Separation Y/D of Skeg-Rudder No. 0 for Two Advance Ratios of J=0.51 and 0.35.

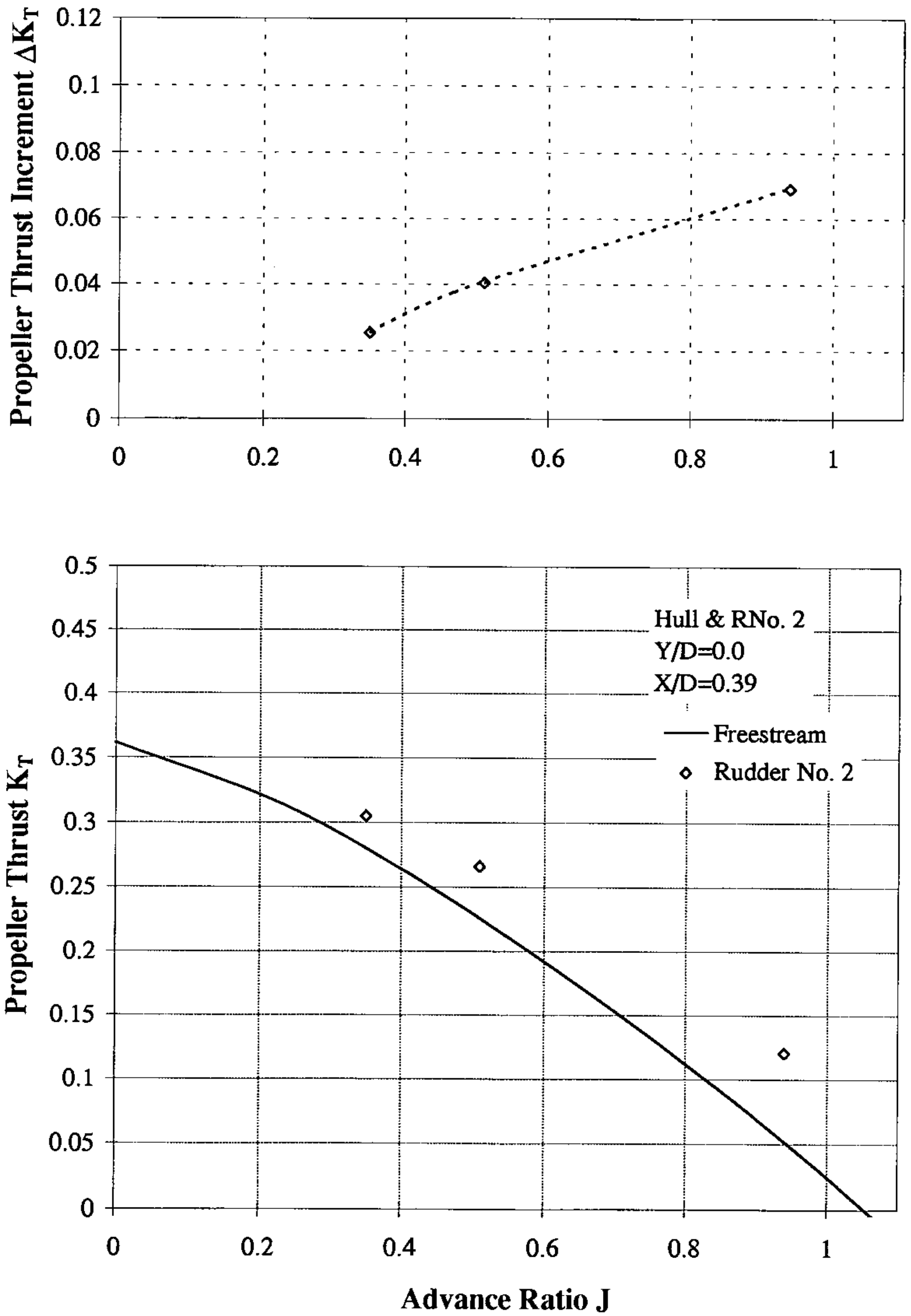


Fig. 33 Propeller Thrust and Thrust Increment Against Advance Ratio for Rudder No. 2 and Hull

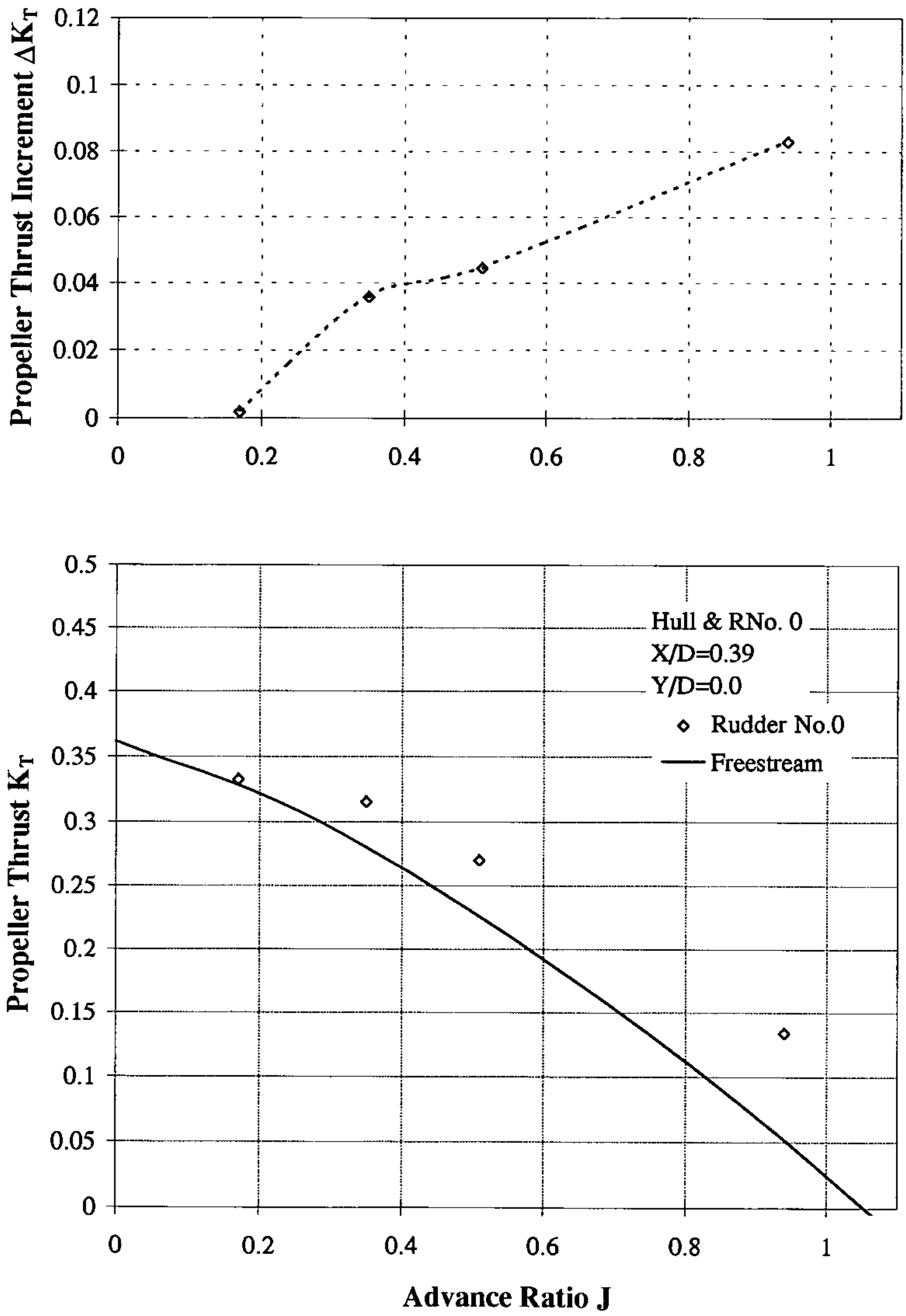


Fig. 34 Propeller Thrust and Thrust Increment Against Advance Ratio for Skeg-Rudder No. 0 and Hull.

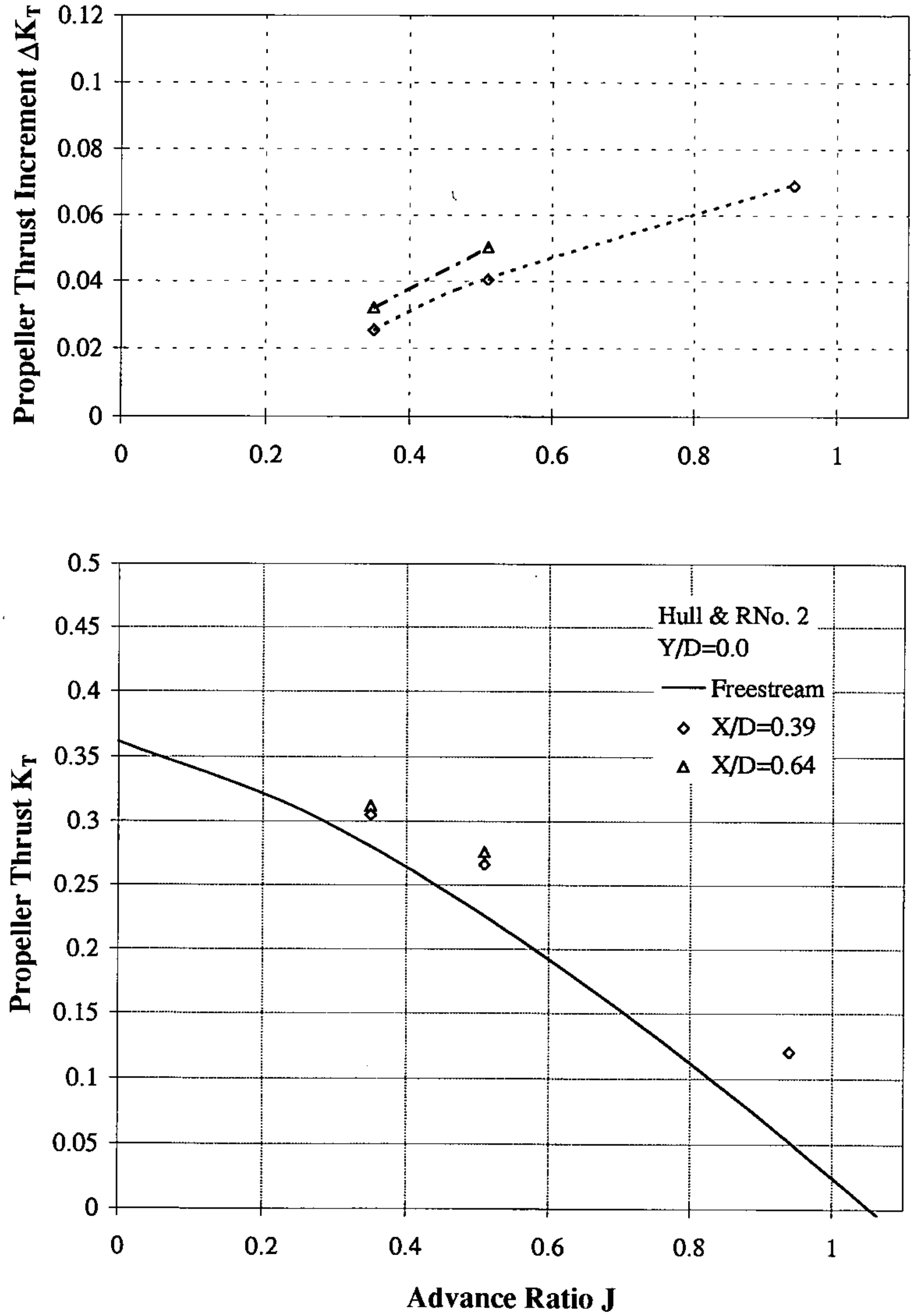


Fig. 35 Comparison of Propeller Thrust and Thrust Increment Against Advance Ratio for a Longitudinal Separation of Rudder No. 2 and Propeller of X/D=0.39 and 0.64

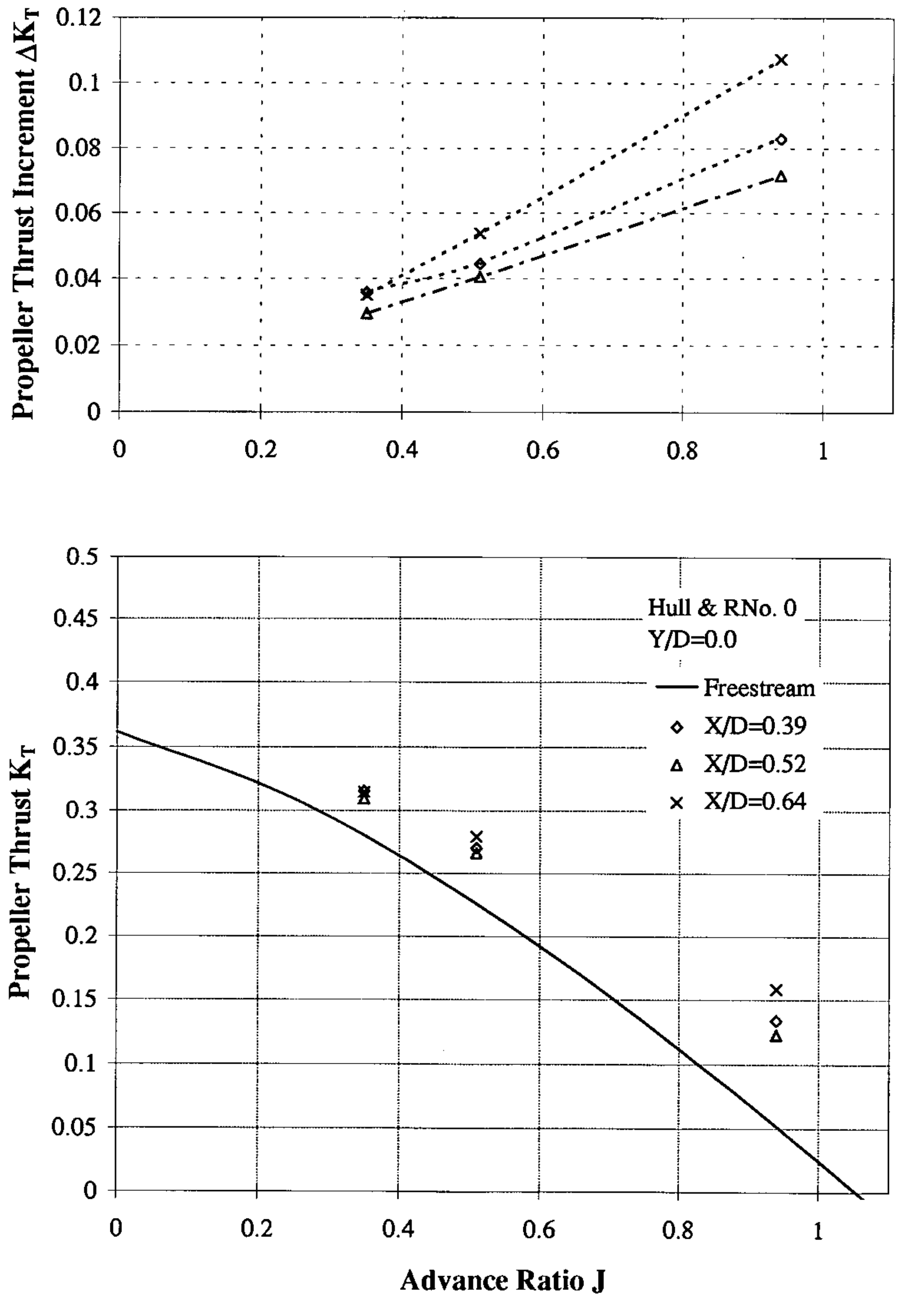


Fig. 36 Comparison of Propeller Thrust and Thrust Increment Against Advance Ratio for a Longitudinal Separation of Skeg-Rudder No. 0 and Hull of X/D=0.39, 0.52 and 0.64.

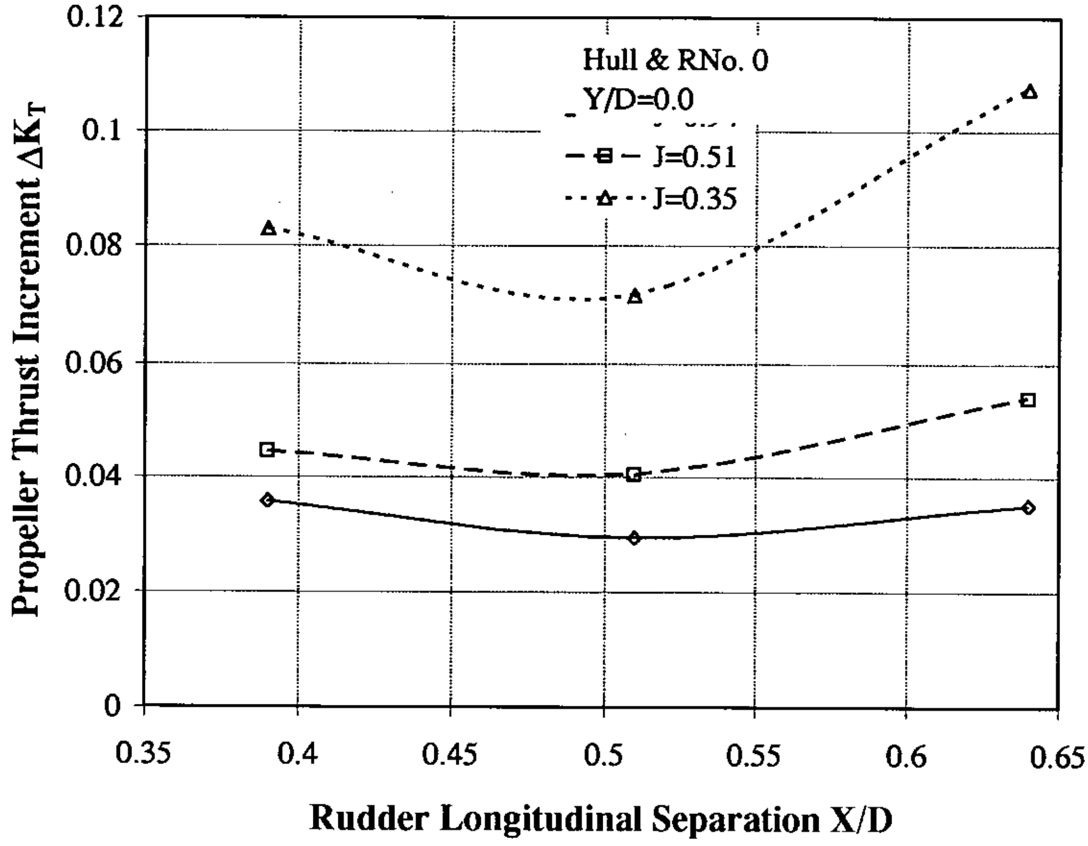


Fig. 37 Thrust Increment Against Rudder/Propeller Longitudinal Separation X/D of Skeg-Rudder No. 0 and Hull for Threee Advance Ratios of J=0.94, 0.51 and 0.35.

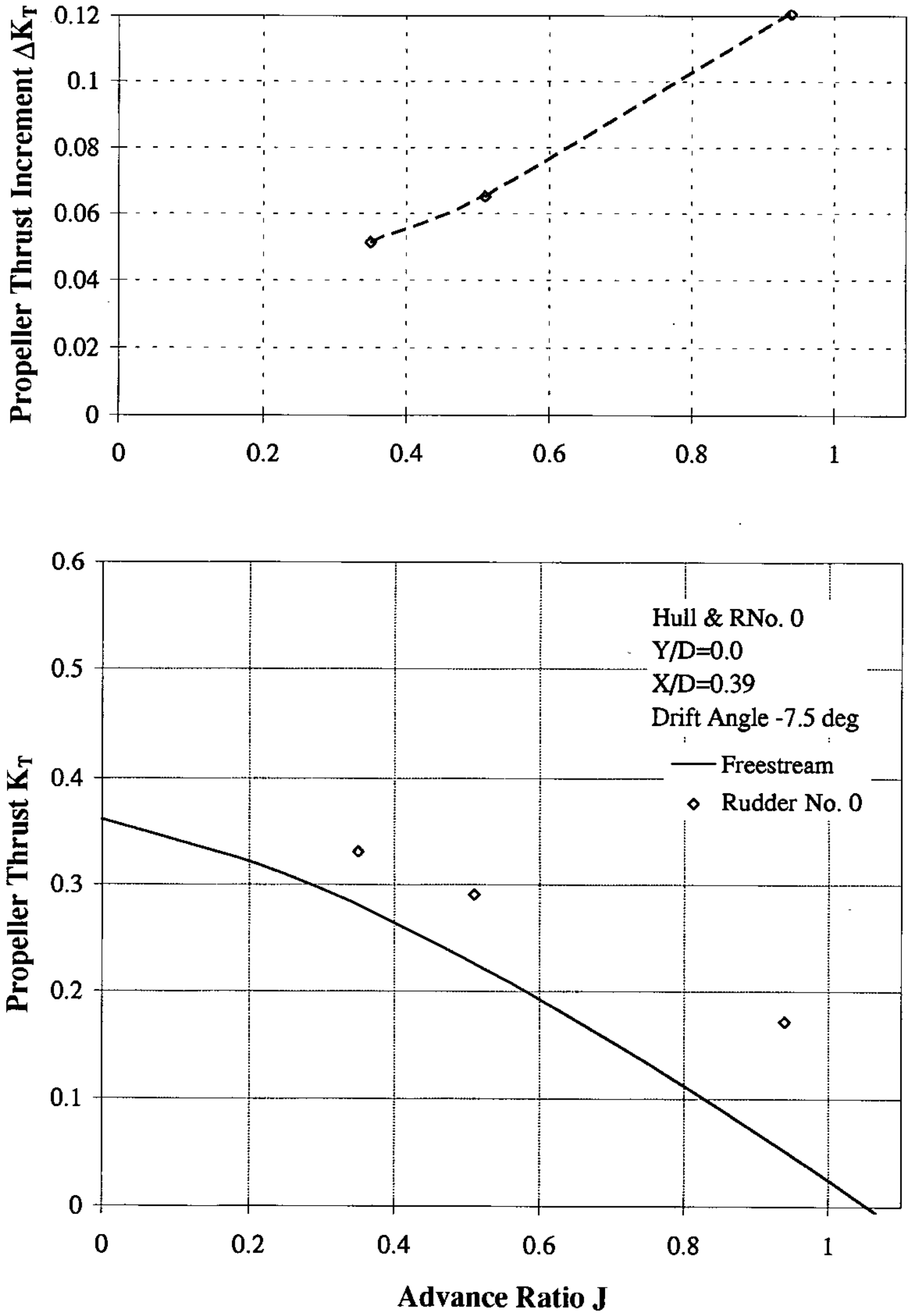


Fig. 38 Propeller Thrust and Thrust Increment Against Advance Ratio for Skeg_rudder No. 0 and Hull at a Drift Angle of -7.5 degrees.

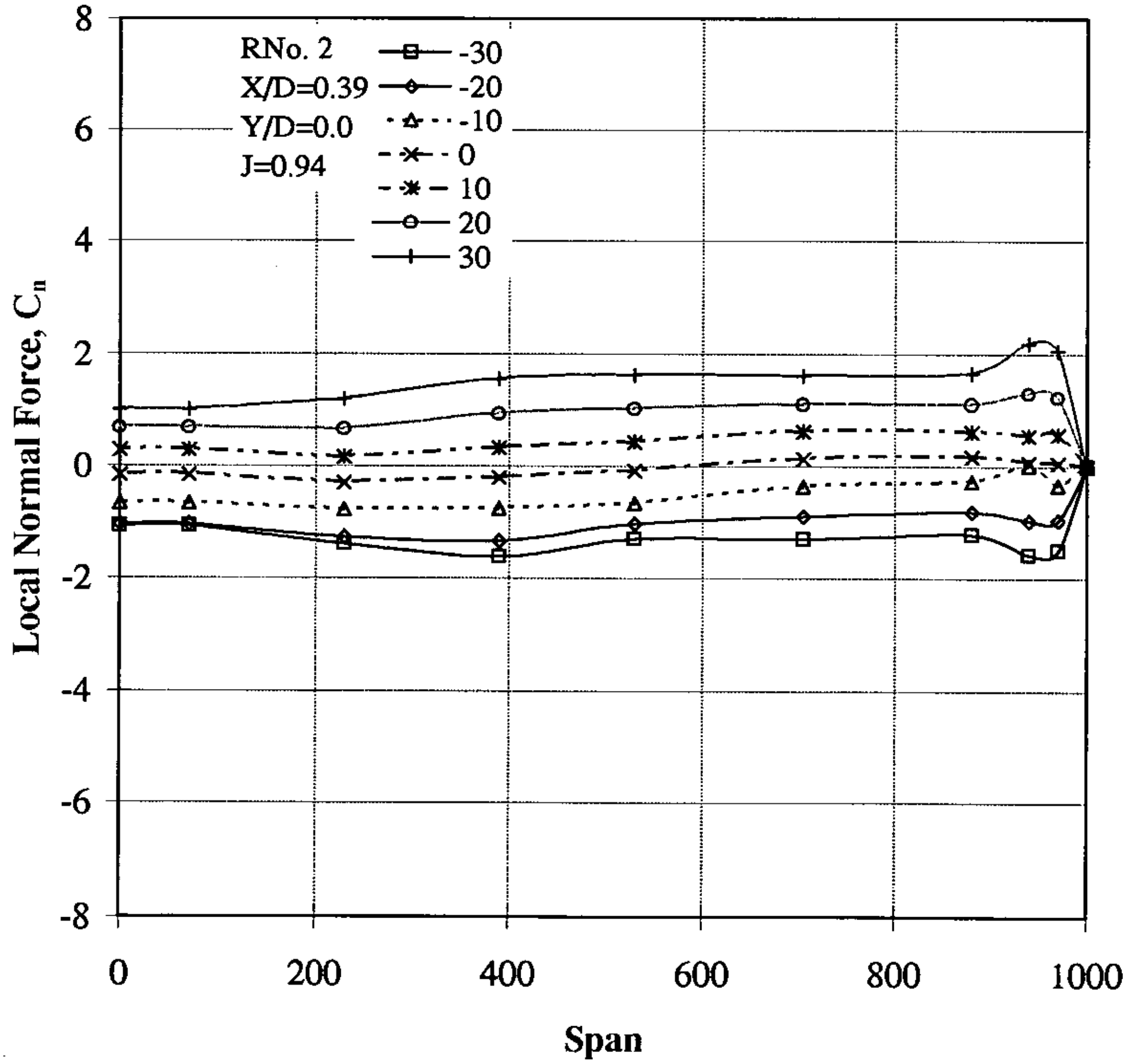


Fig 39. Variation of Spanwise Distribution of Local Section Cn with incidence for Rudder No. 2 at a propeller advance ratio of J=0.94.

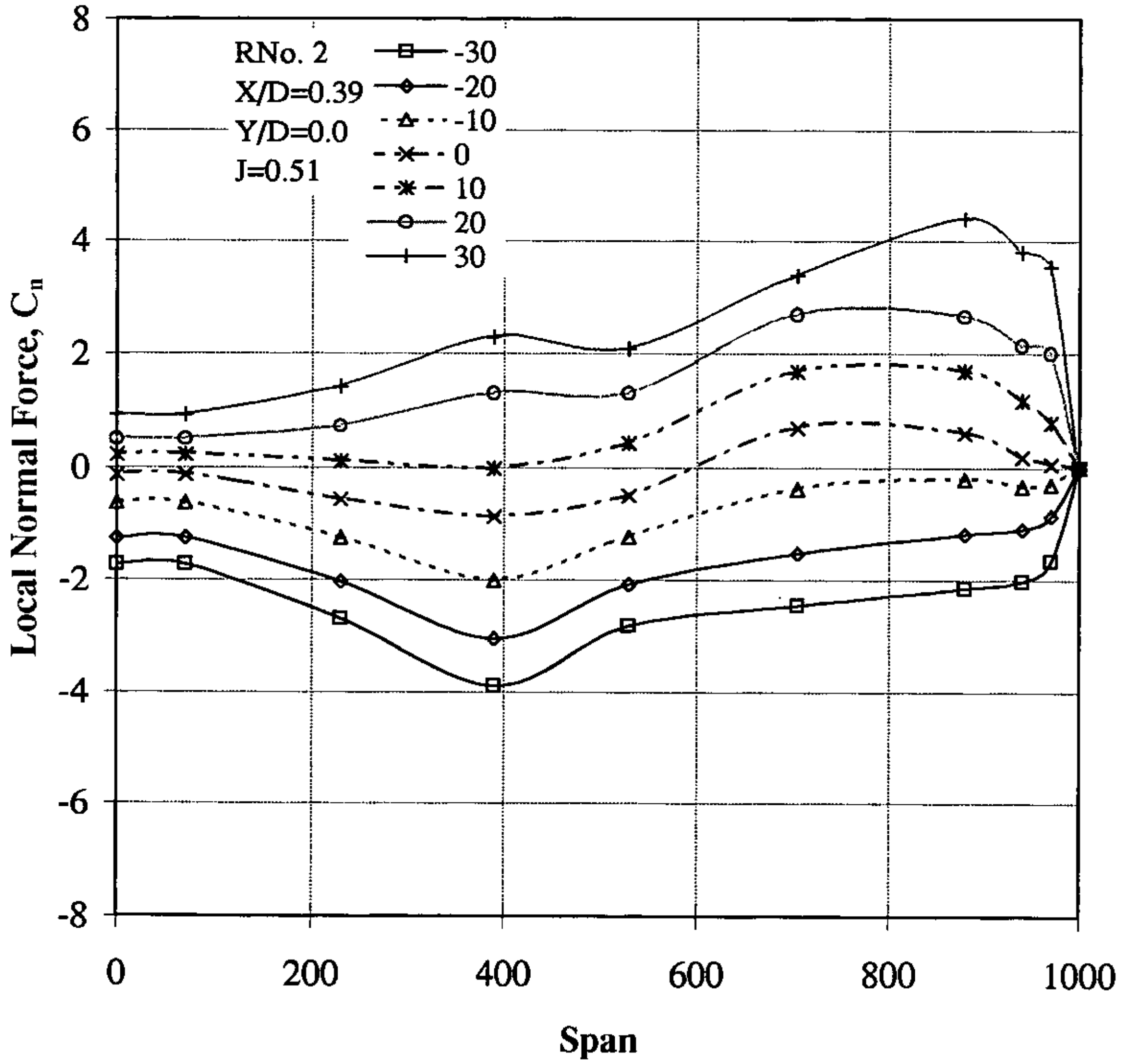


Fig. 40 Variation of Spanwise Distribution of Local Section Cn with incidence for Rudder No. 2 at a propeller advance ratio of J=0.51.

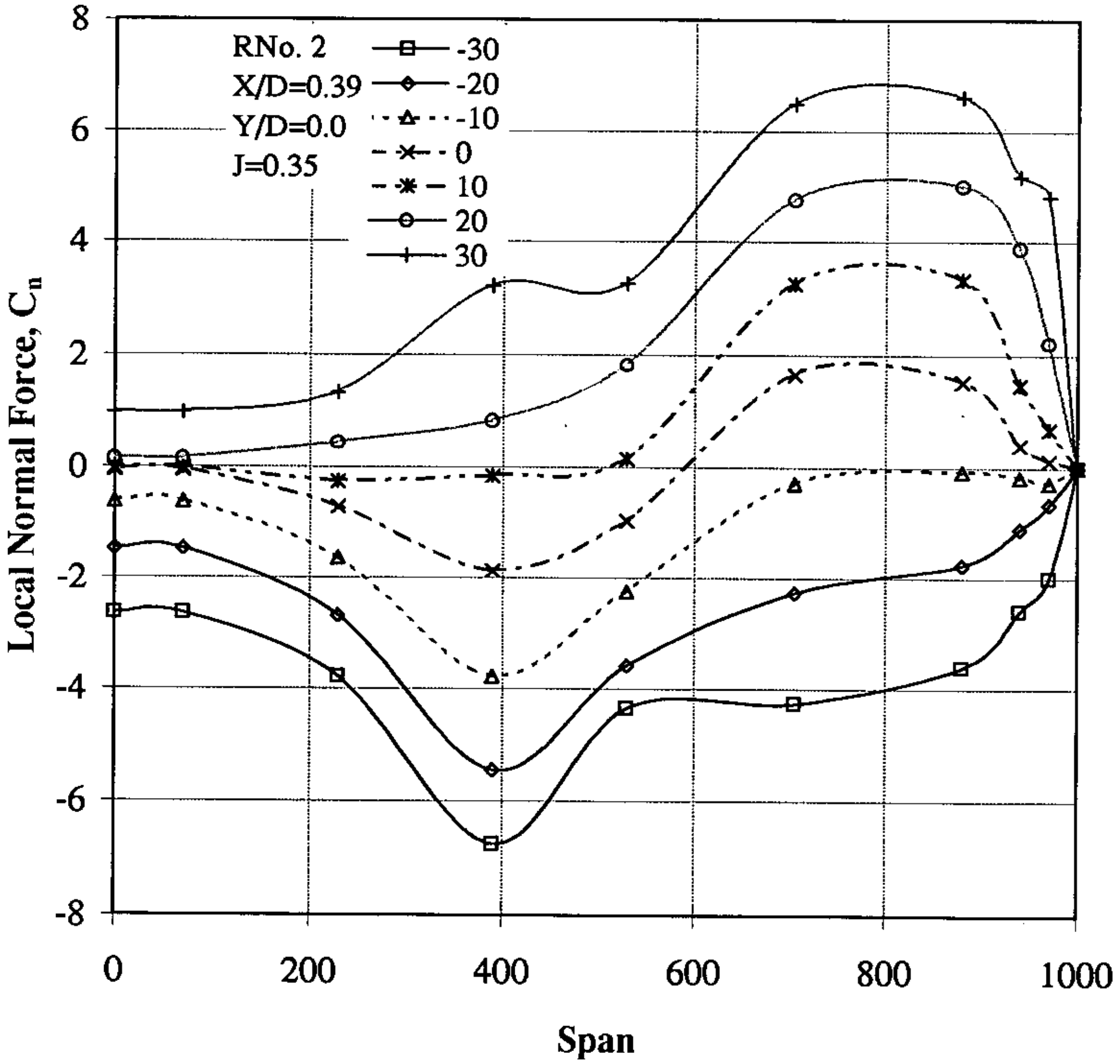


Fig. 41 Variation of Spanwise Distribution of Local Section Cn with incidence for Rudder No. 2 at a propeller advance ratio of J=0.35.

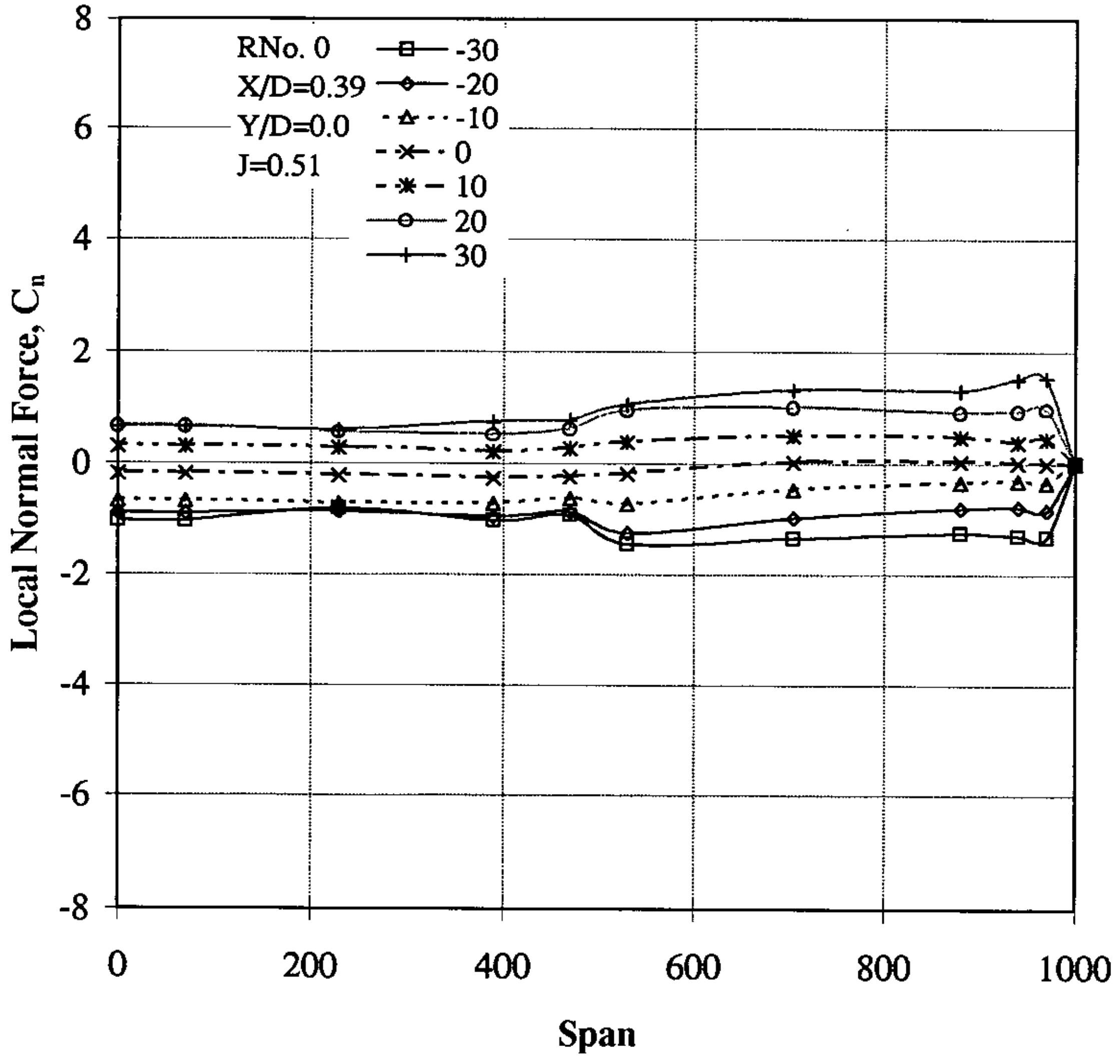


Fig. 42 Variation of Spanwise Distribution of Local Section Cn with incidence for Skeg-Rudder No. 0 at a propeller advance ratio of J=0.94.

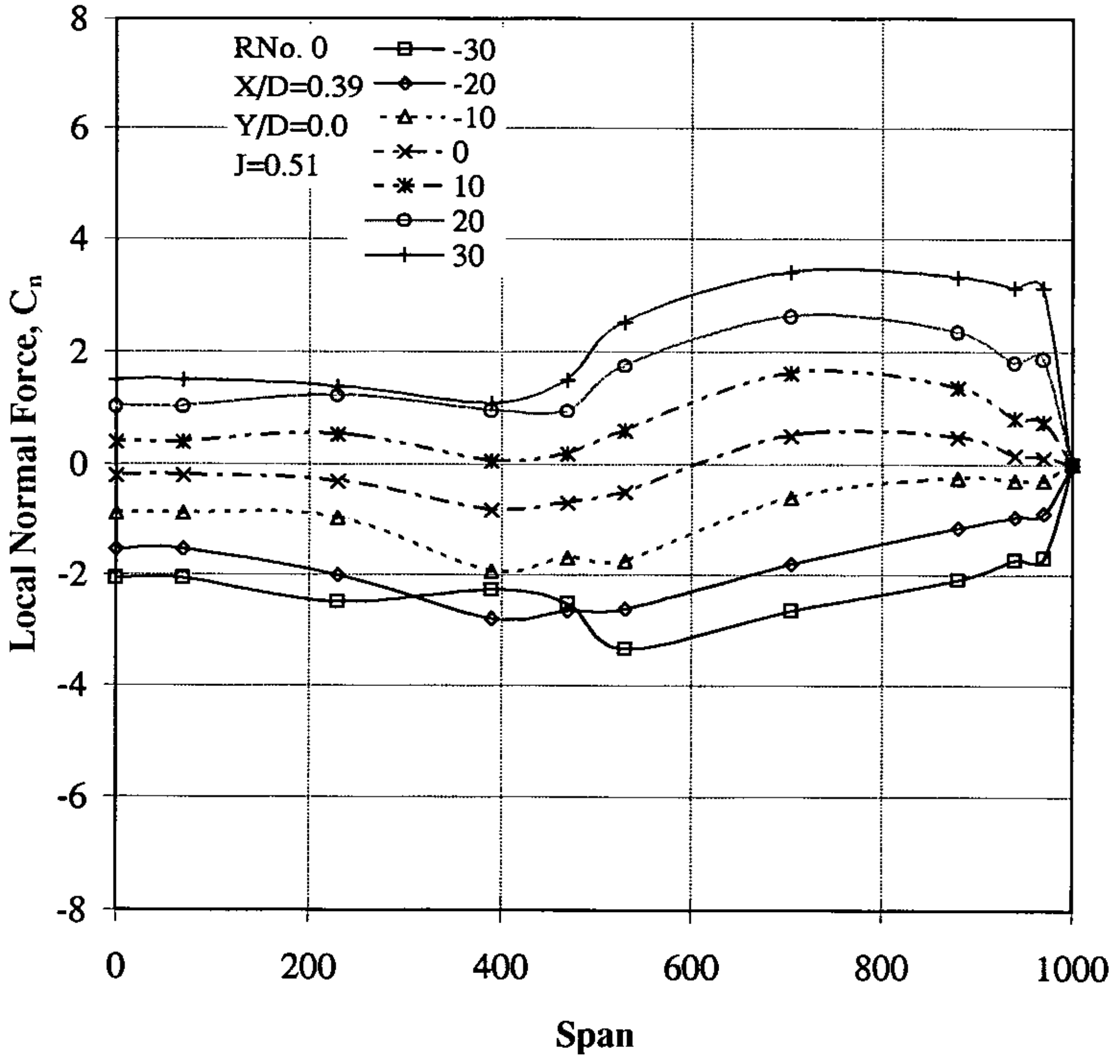


Fig. 43 Variation of Spanwise Distribution of Local Section Cn with incidence for Skeg-Rudder No. 0 at a propeller advance ratio of J=0.51.

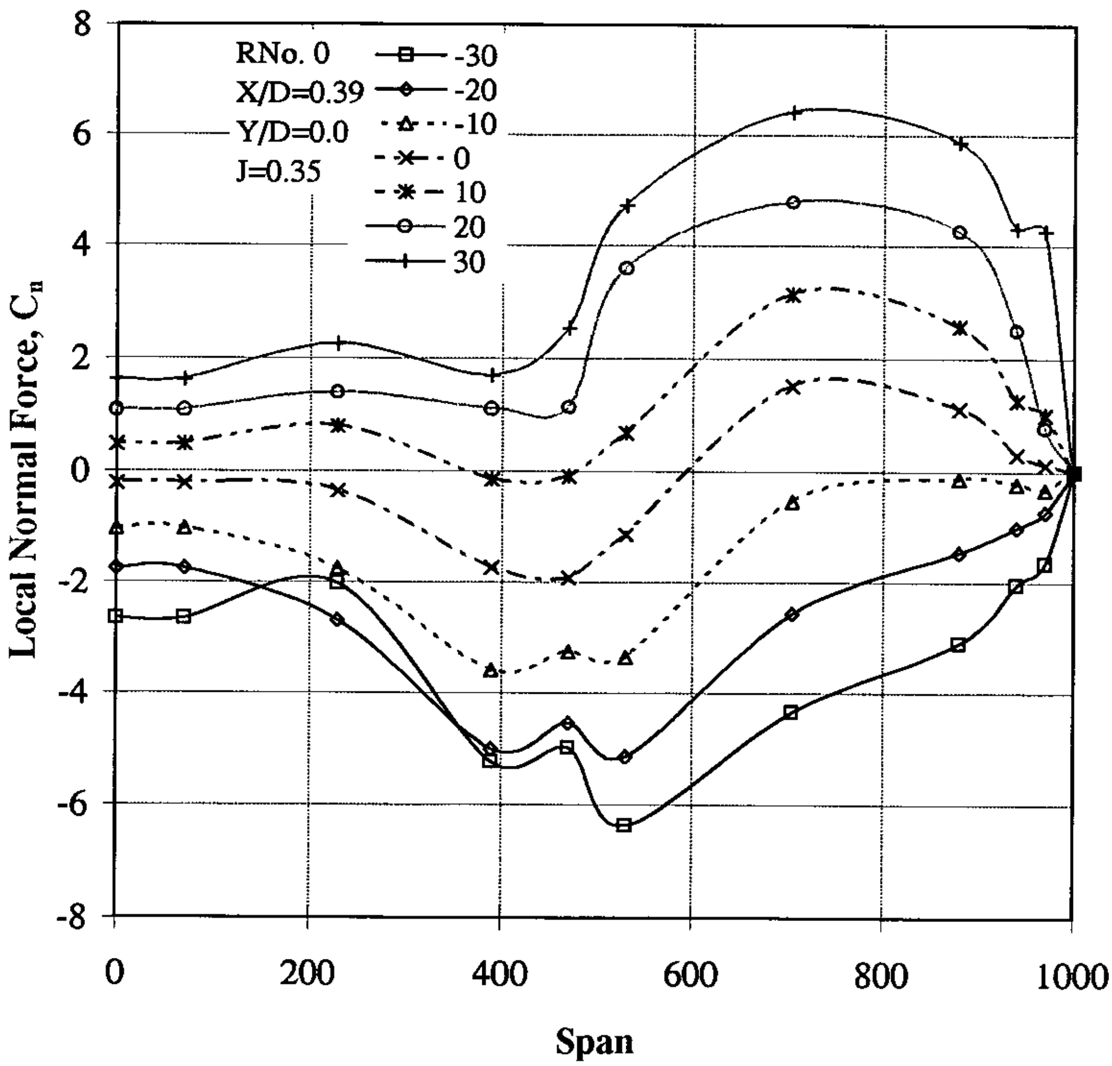


Fig. 44 Variation of Spanwise Distribution of Local Section Cn with incidence for Skeg-Rudder No. 0 at a propeller advance ratio of J=0.35.

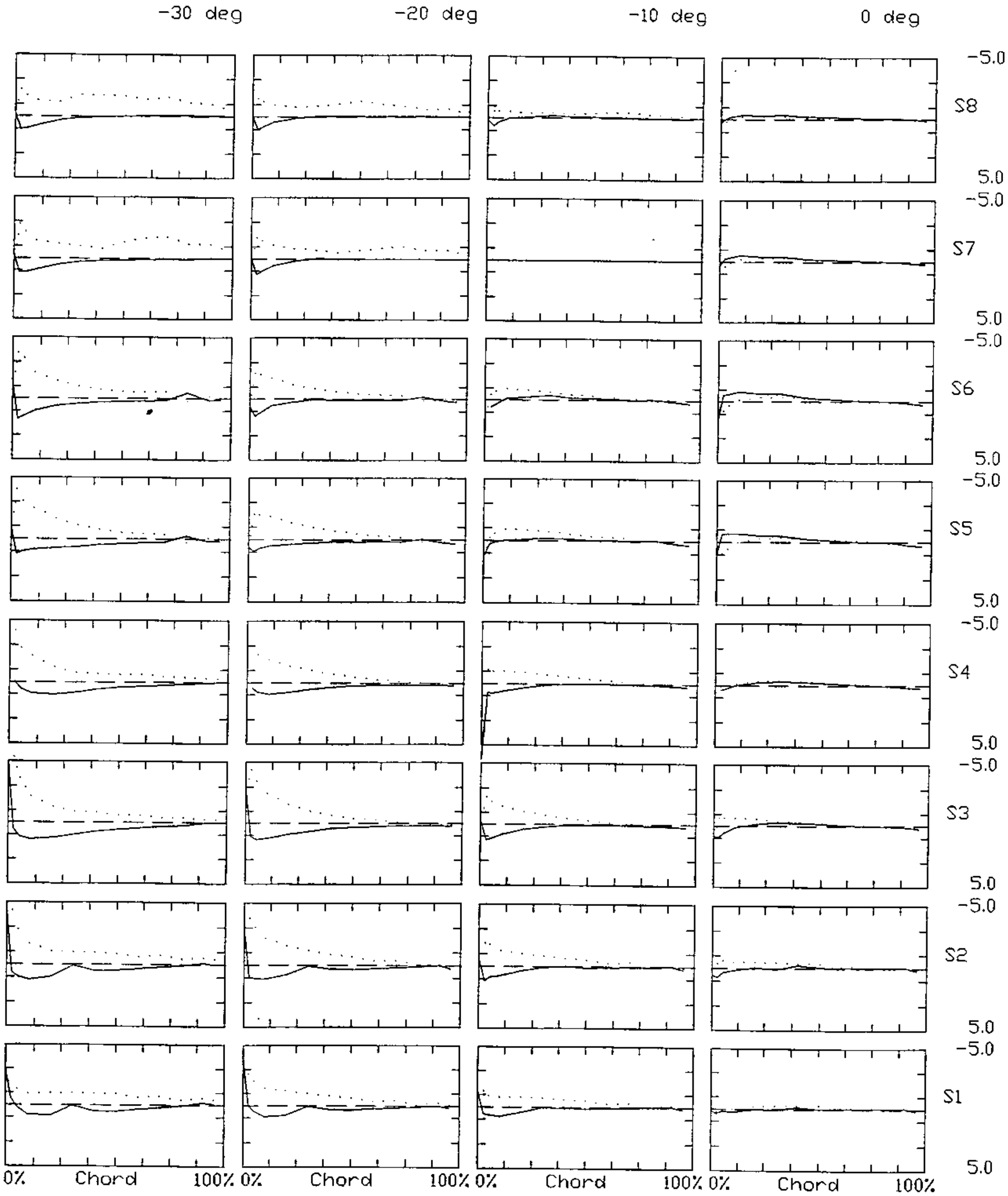


Figure 45 Chordwise pressure distributions at 8 spanwise positions for Rudder No. 2 at J=0.94 for incidence of -30°, -20°, -10°, 0°.

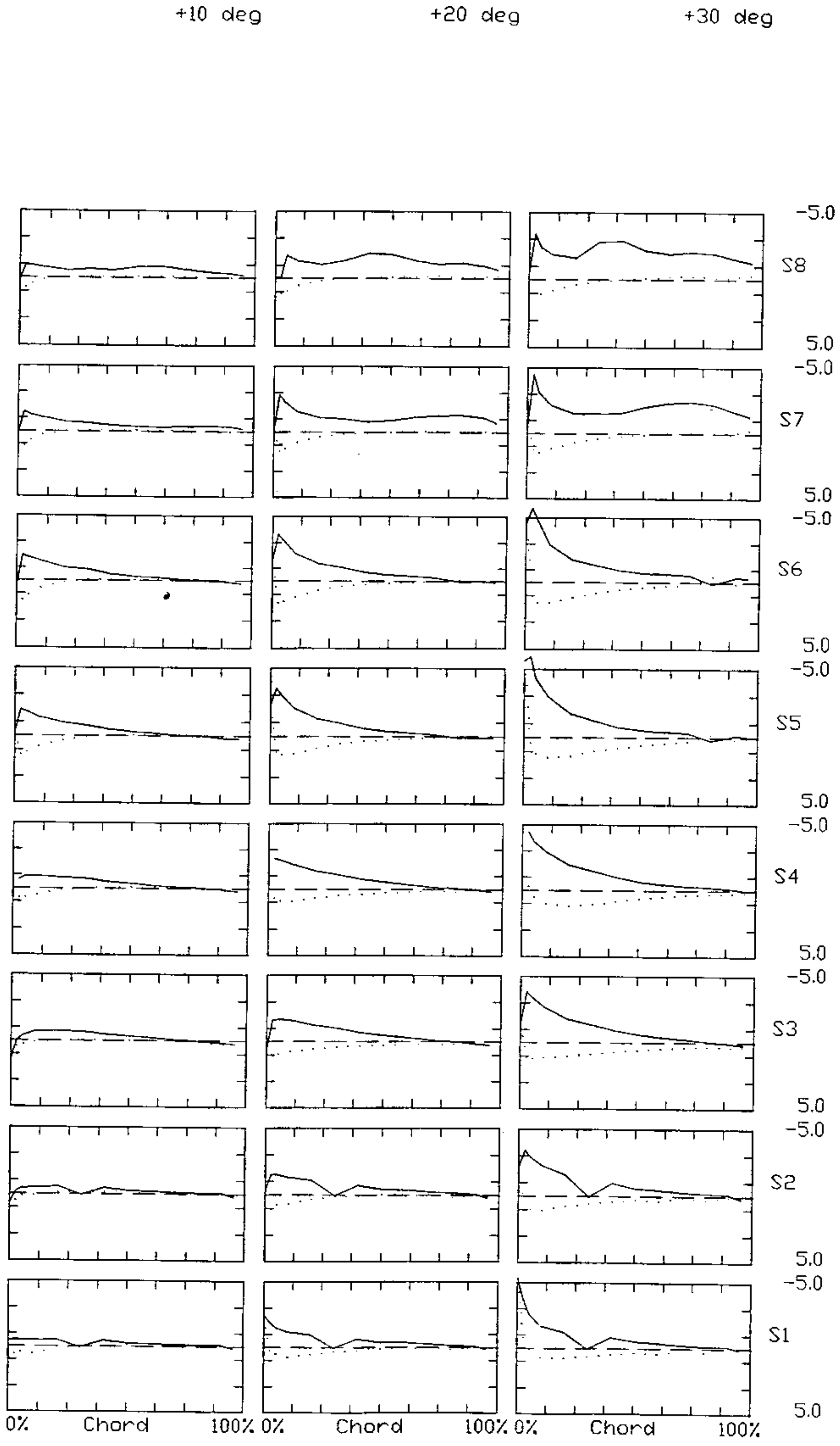


Figure 45 Chordwise pressure distributions at 8 spanwise positions for Rudder No. 2 at J=0.94 for incidence of 10° ,20°, 30°.

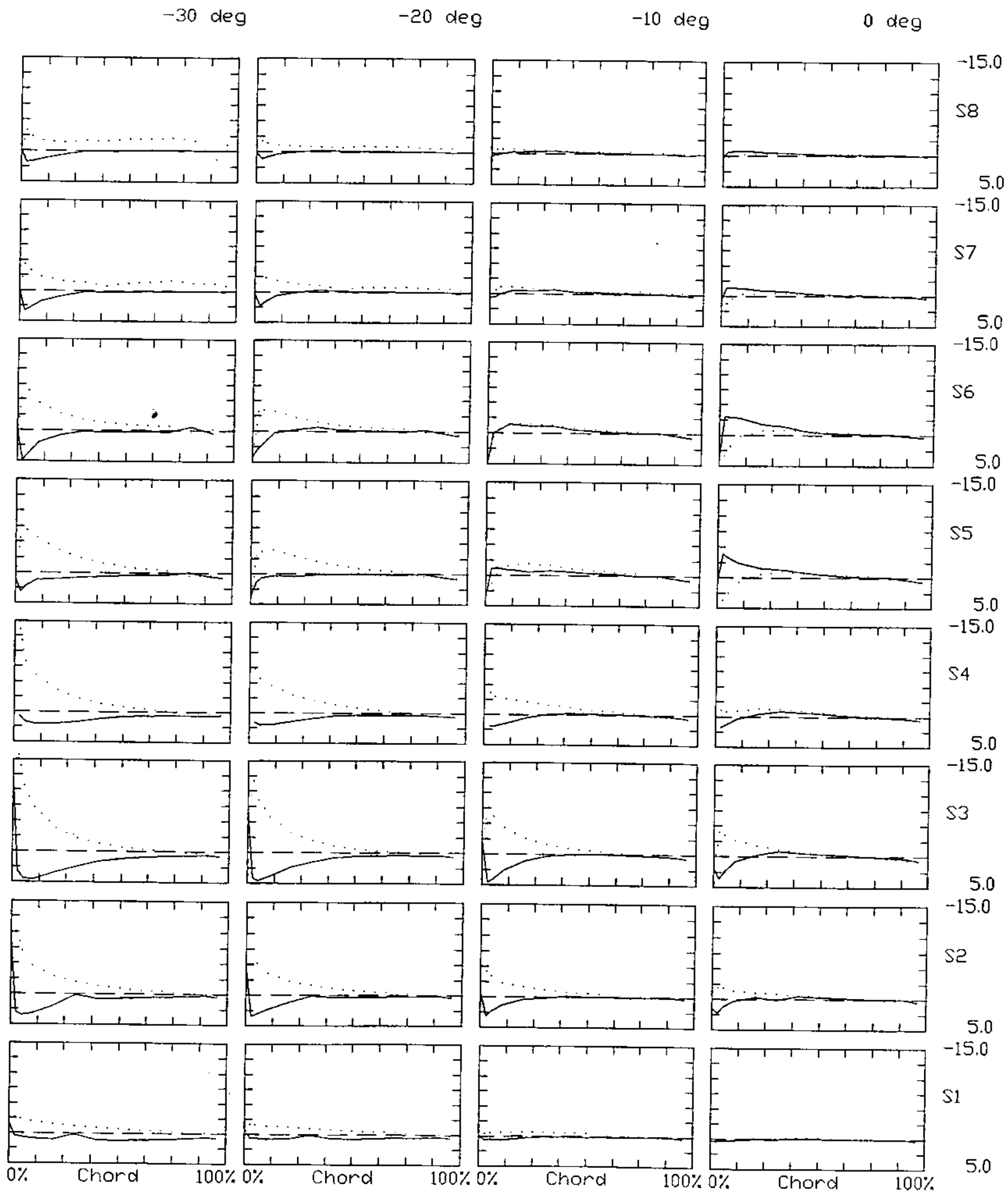


Figure 46 Chordwise pressure distributions at 8 spanwise positions for Rudder No. 2 at J=0.51 for incidence of -30°, -20°, -10°, 0°.

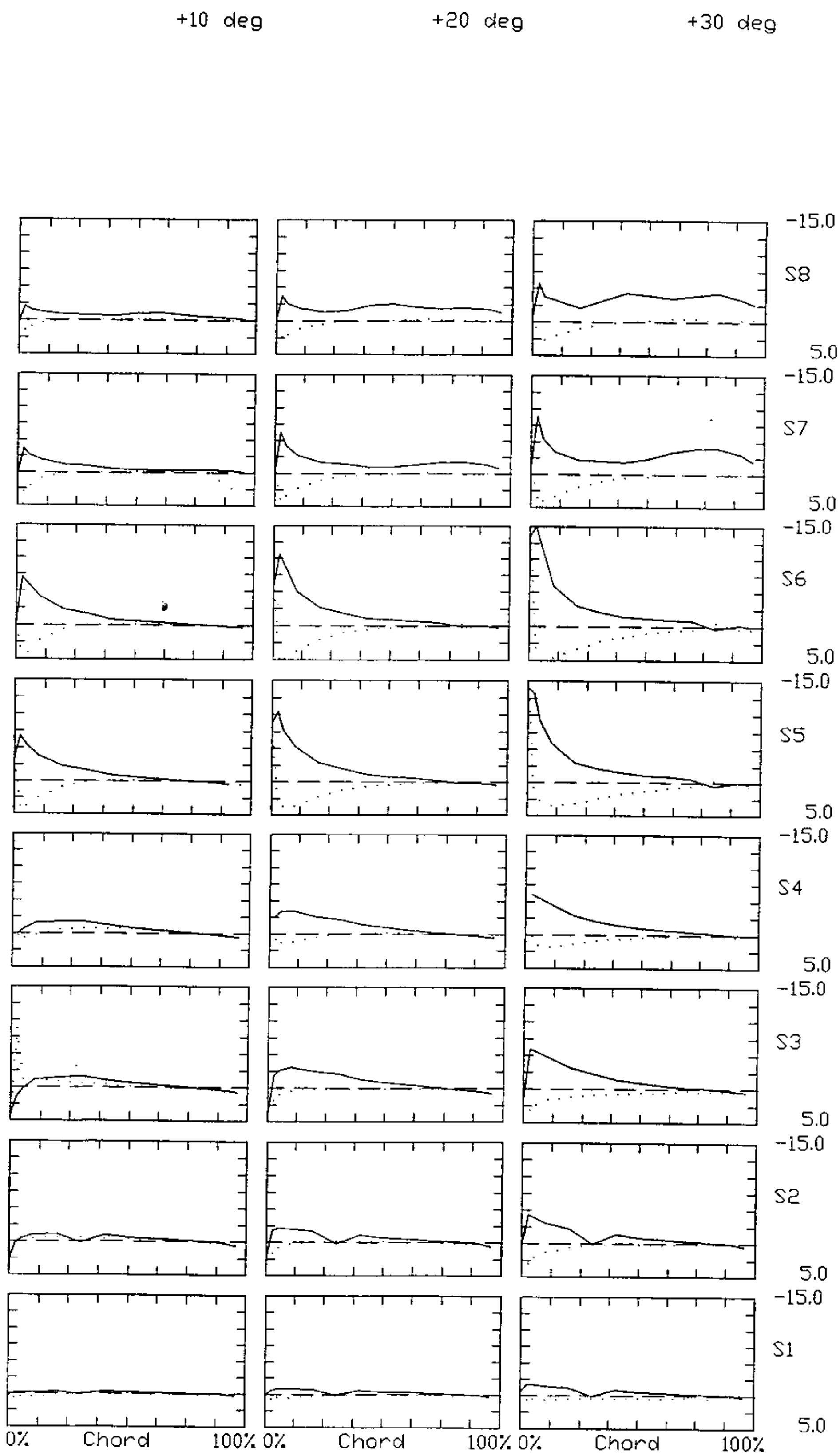


Figure 46 Chordwise pressure distributions at 8 spanwise positions for Rudder No. 2 at J=0.51 for incidence of 10° ,20°, 30°.

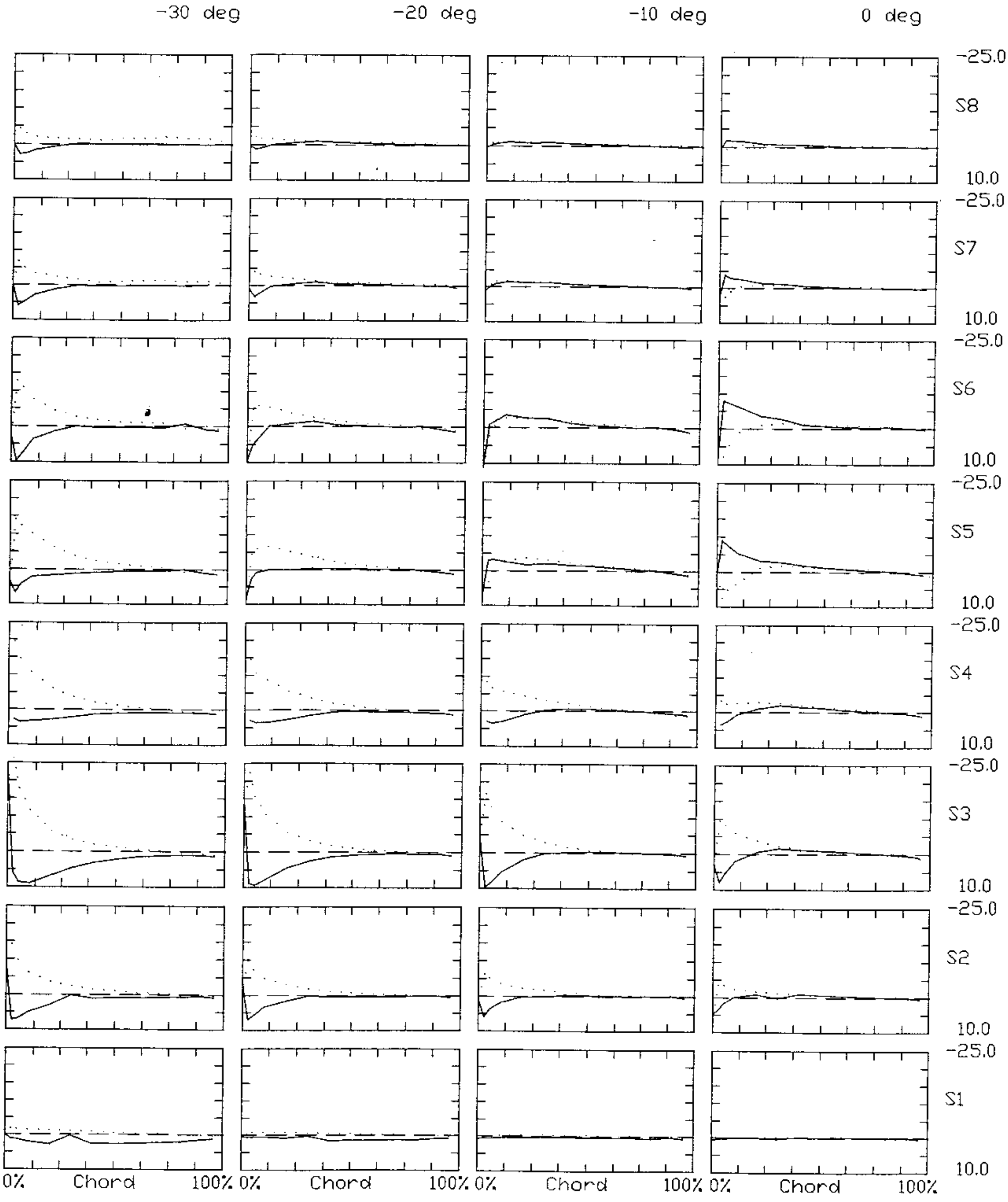


Figure 47 Chordwise pressure distributions at 8 spanwise positions for Rudder No. 2 at J=0.35 for incidence of -30°, -20°, -10°, 0°.

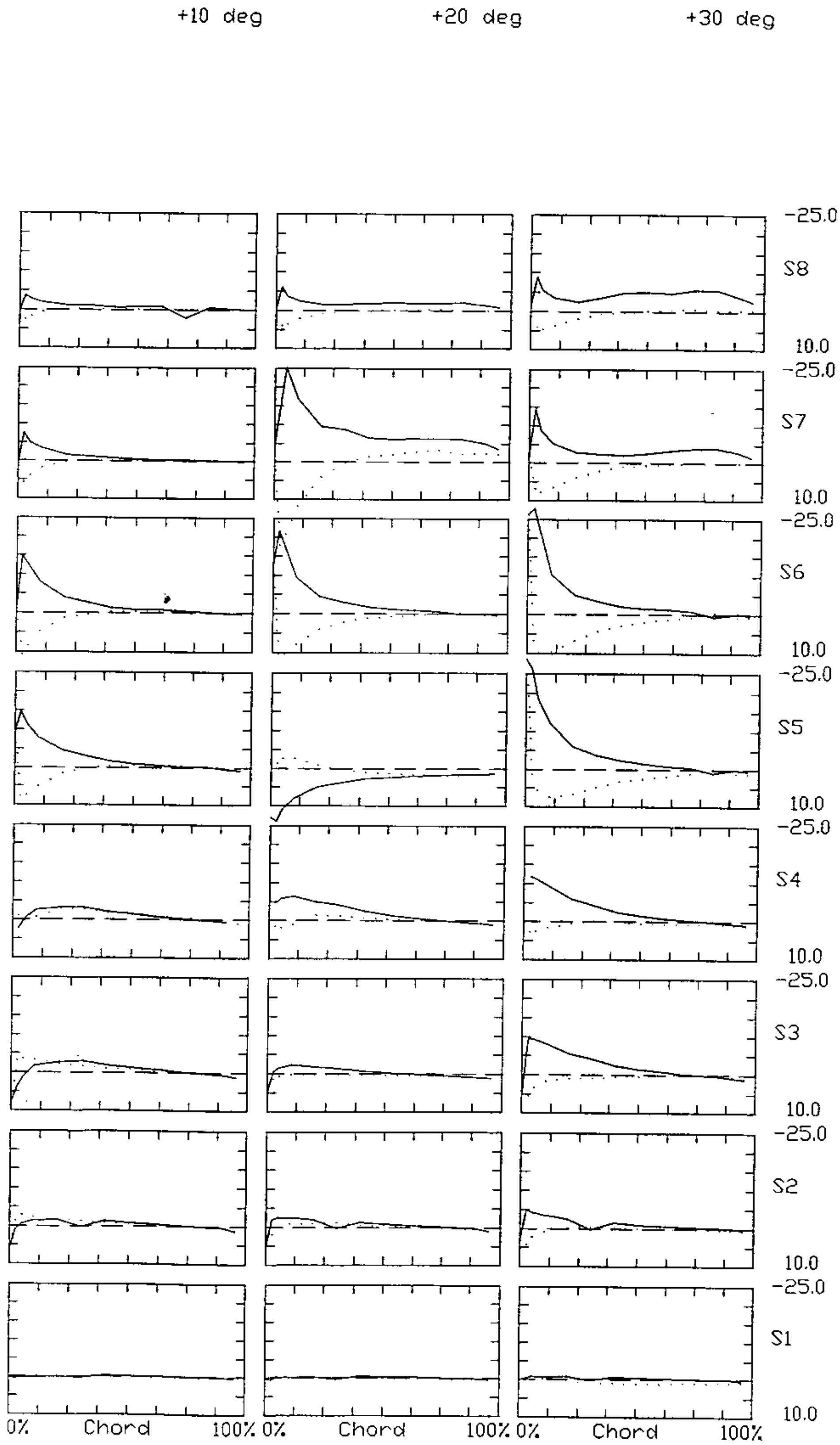


Figure 47 Chordwise pressure distributions at 8 spanwise positions for Rudder No. 2 at J=0.35 for incidence of 10° ,20°, 30°.

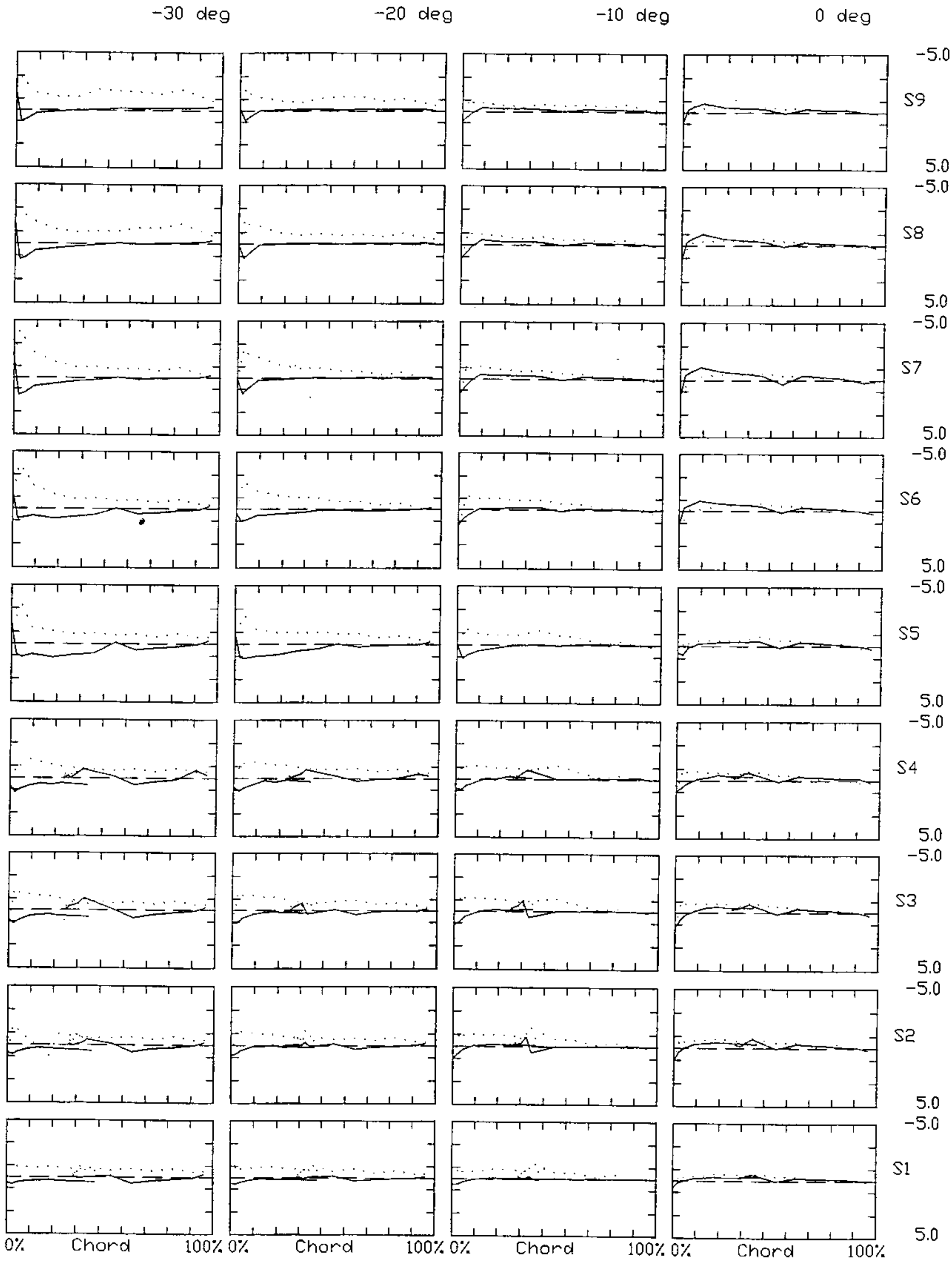


Figure 48 Chordwise pressure distributions at 9 spanwise positions for Skeg-Rudder No. 0 at J=0.94 for incidence of -30°, -20°, -10°, 0°.

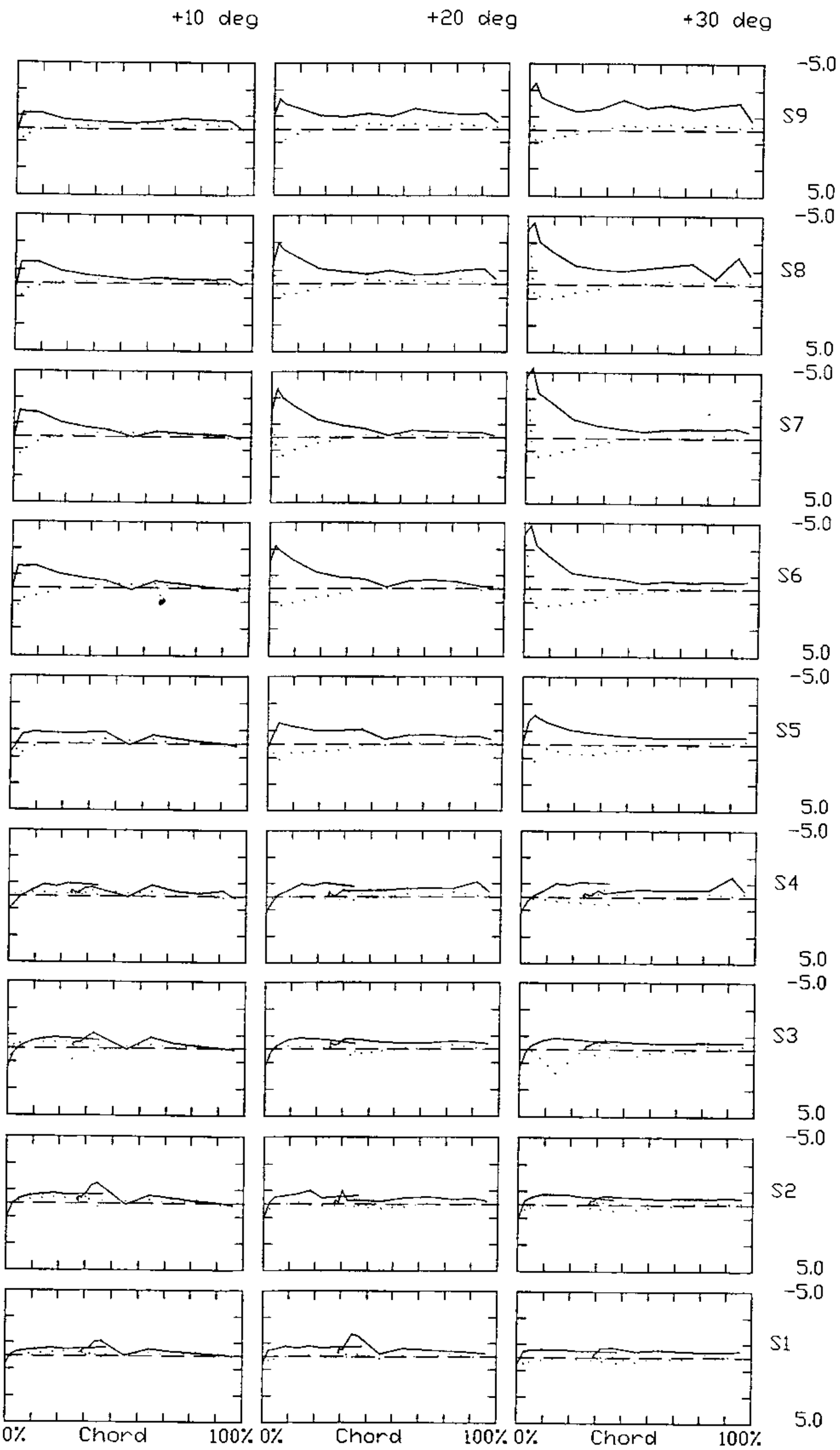


Figure 48 Chordwise pressure distributions at 9 spanwise positions for Skeg-Rudder No. 0 at J=0.94 for incidence of 10° ,20°, 30°.

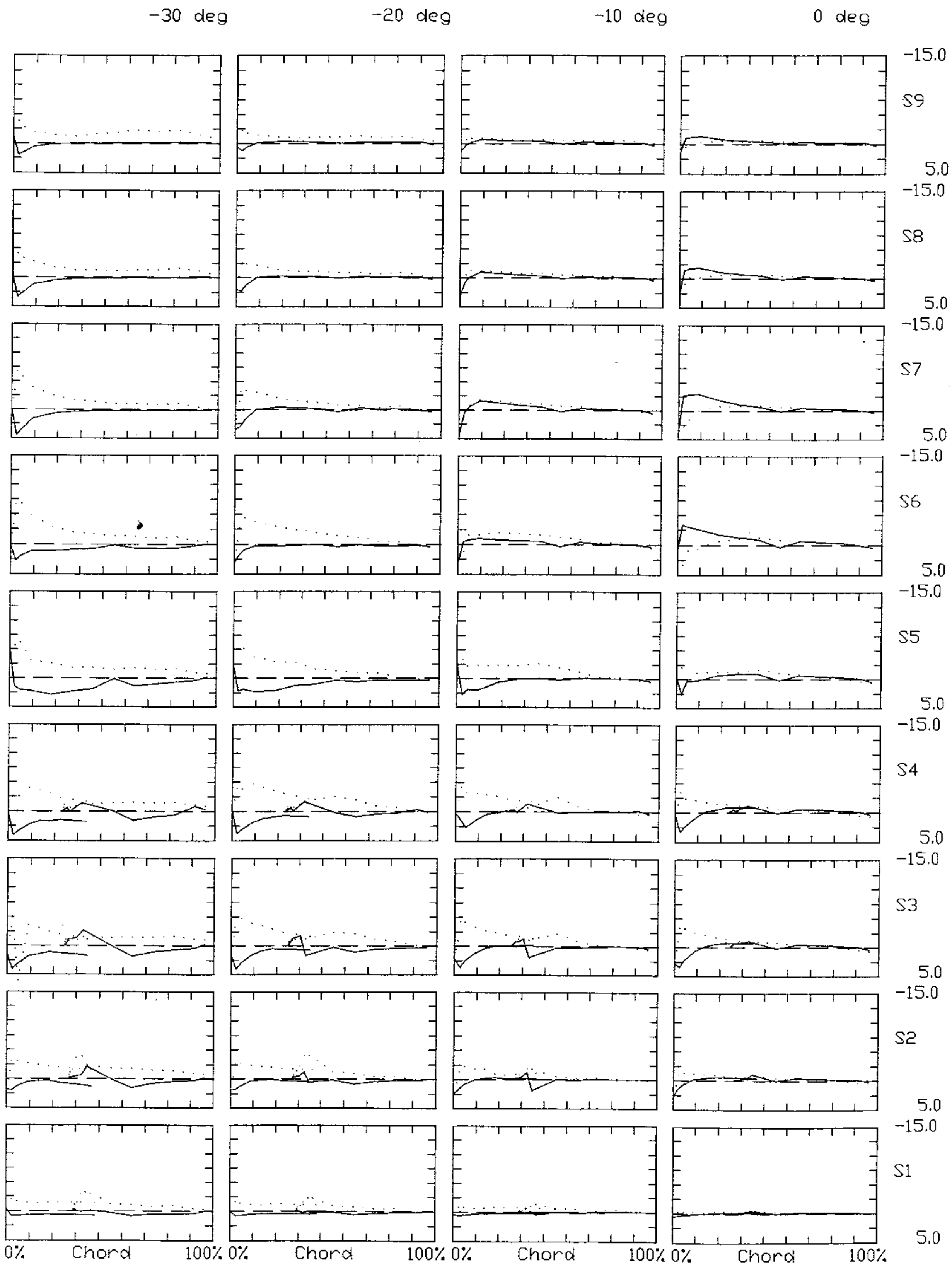


Figure 49 Chordwise pressure distributions at 9 spanwise positions for Skeg-Rudder No. 0 at J=0.51 for incidence of -30°, -20°, -10°, 0°.

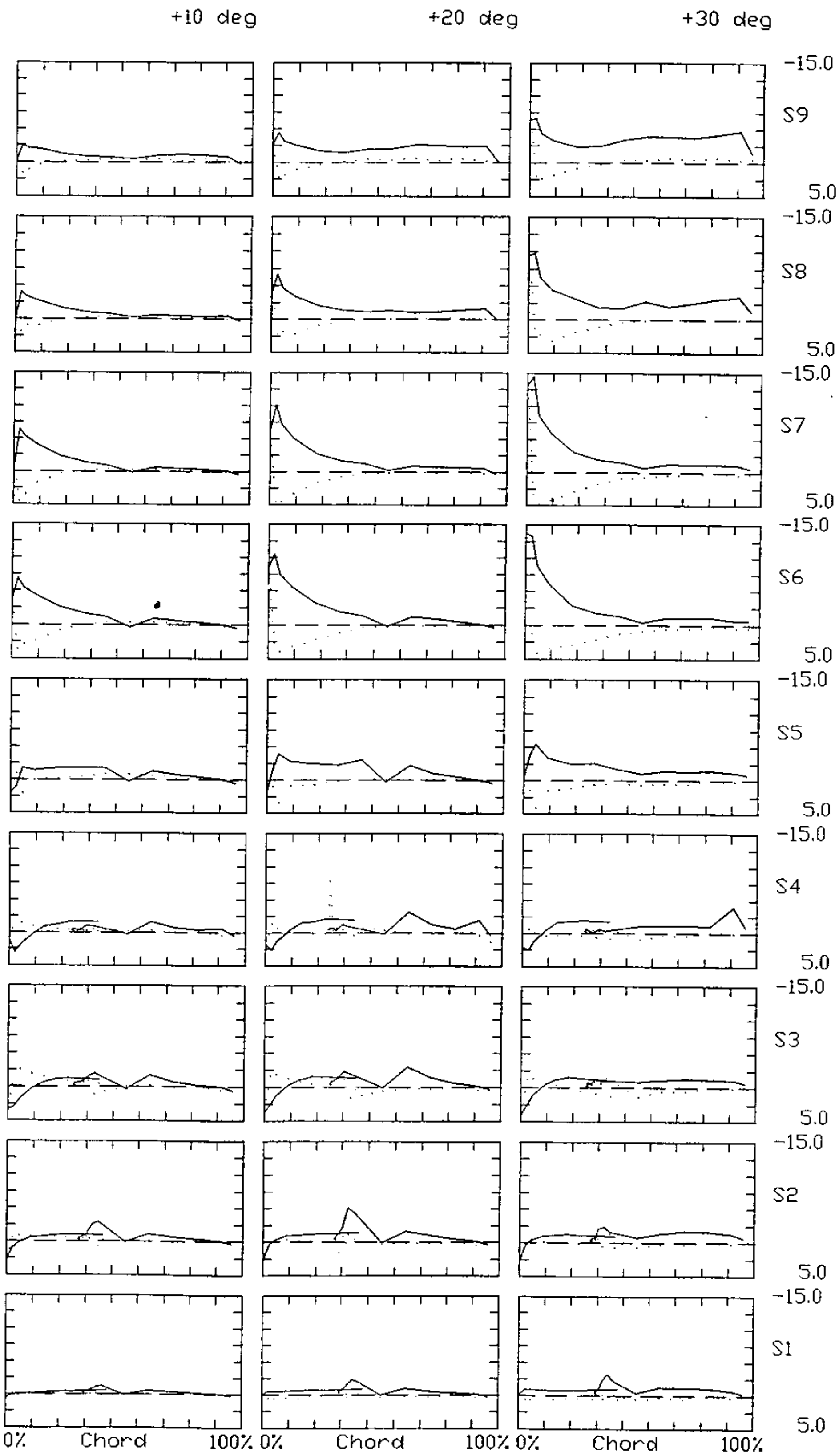


Figure 49 Chordwise pressure distributions at 9 spanwise positions for Skeg-Rudder No. 0 at J=0.51 for incidence of 10° ,20°, 30°.

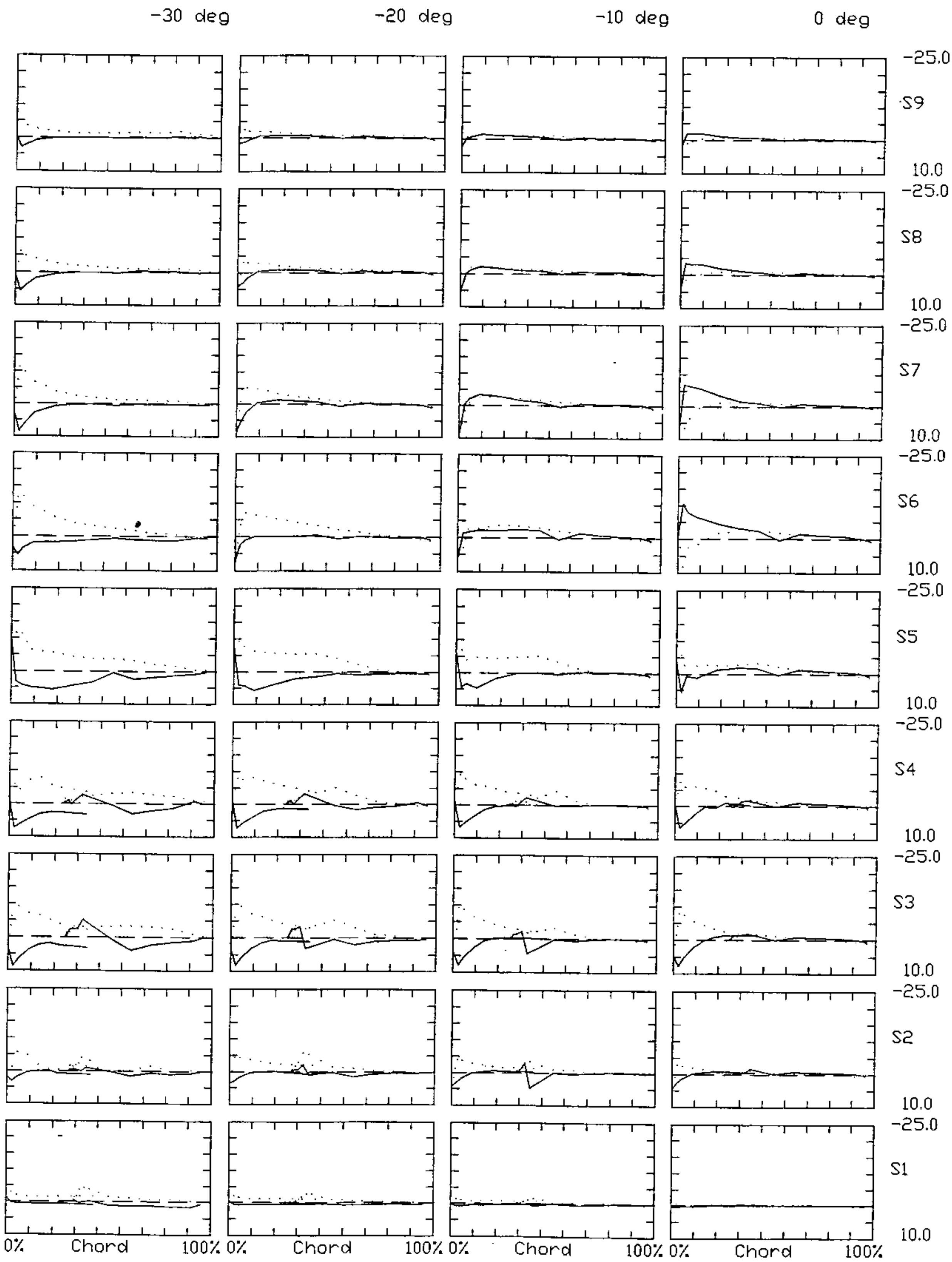


Figure 50 Chordwise pressure distributions at 9 spanwise positions for Skeg-Rudder No. 0 at J=0.35 for incidence of -30°, -20°, -10°, 0°.

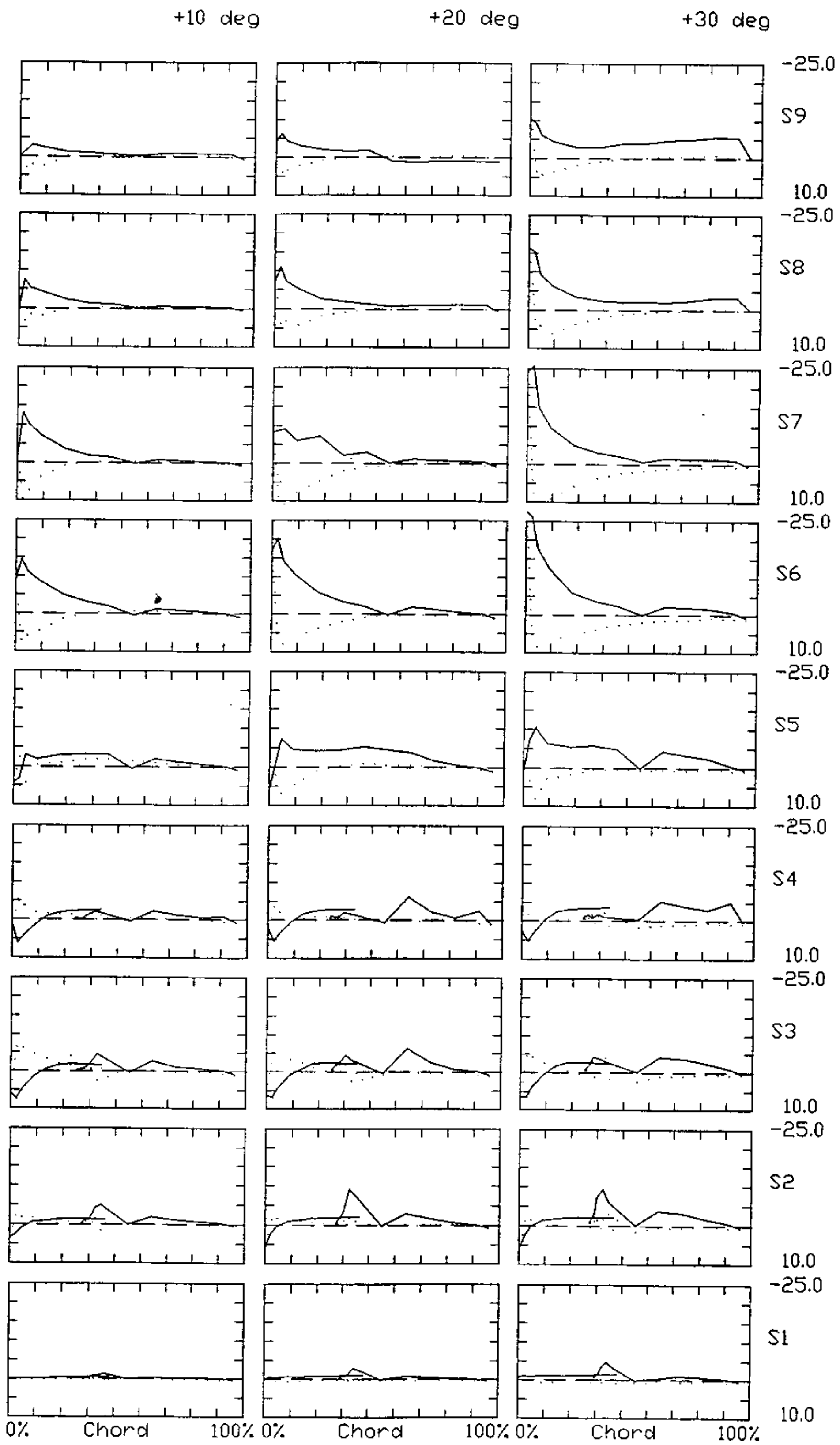


Figure 50 **Chordwise pressure distributions at 9 spanwise positions for Skeg-Rudder No. 0 at J=0.35 for incidence of 10° ,20°, 30°.**

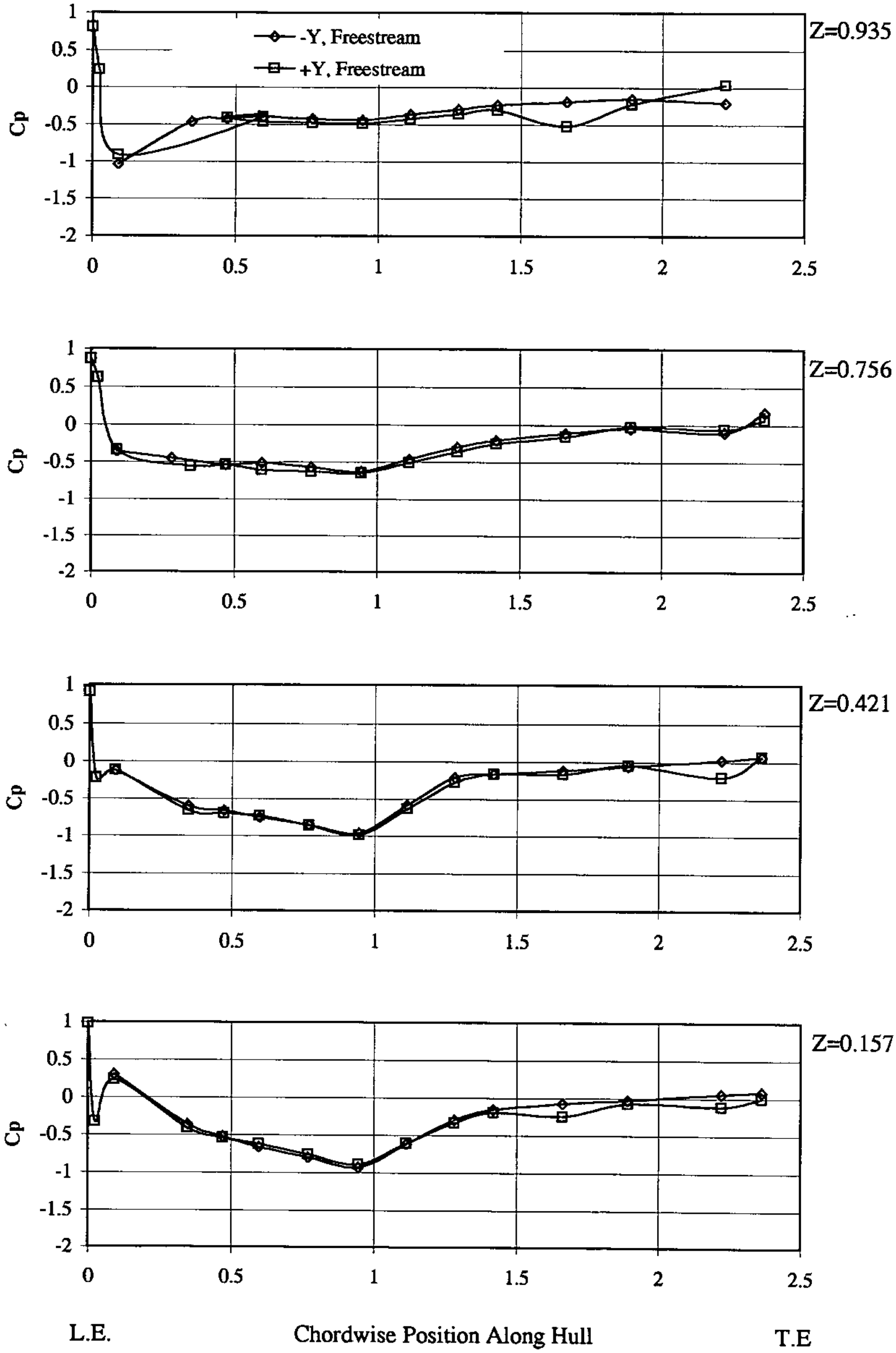


Fig. 51 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.39 in freestream at a skeg rudder angle of -30 degrees

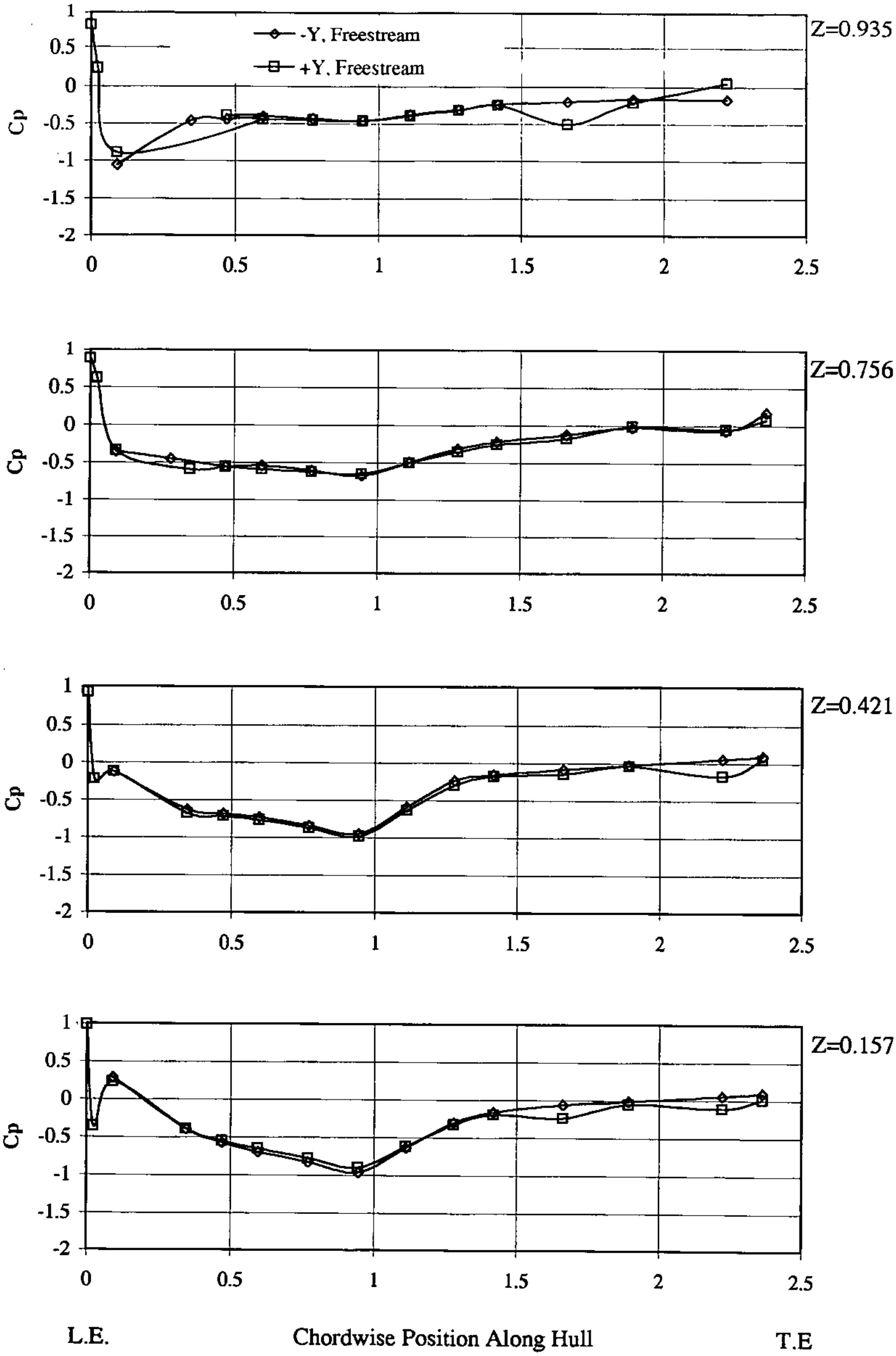


Fig. 51 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.39 in freestream at a skeg rudder angle of -20 degrees

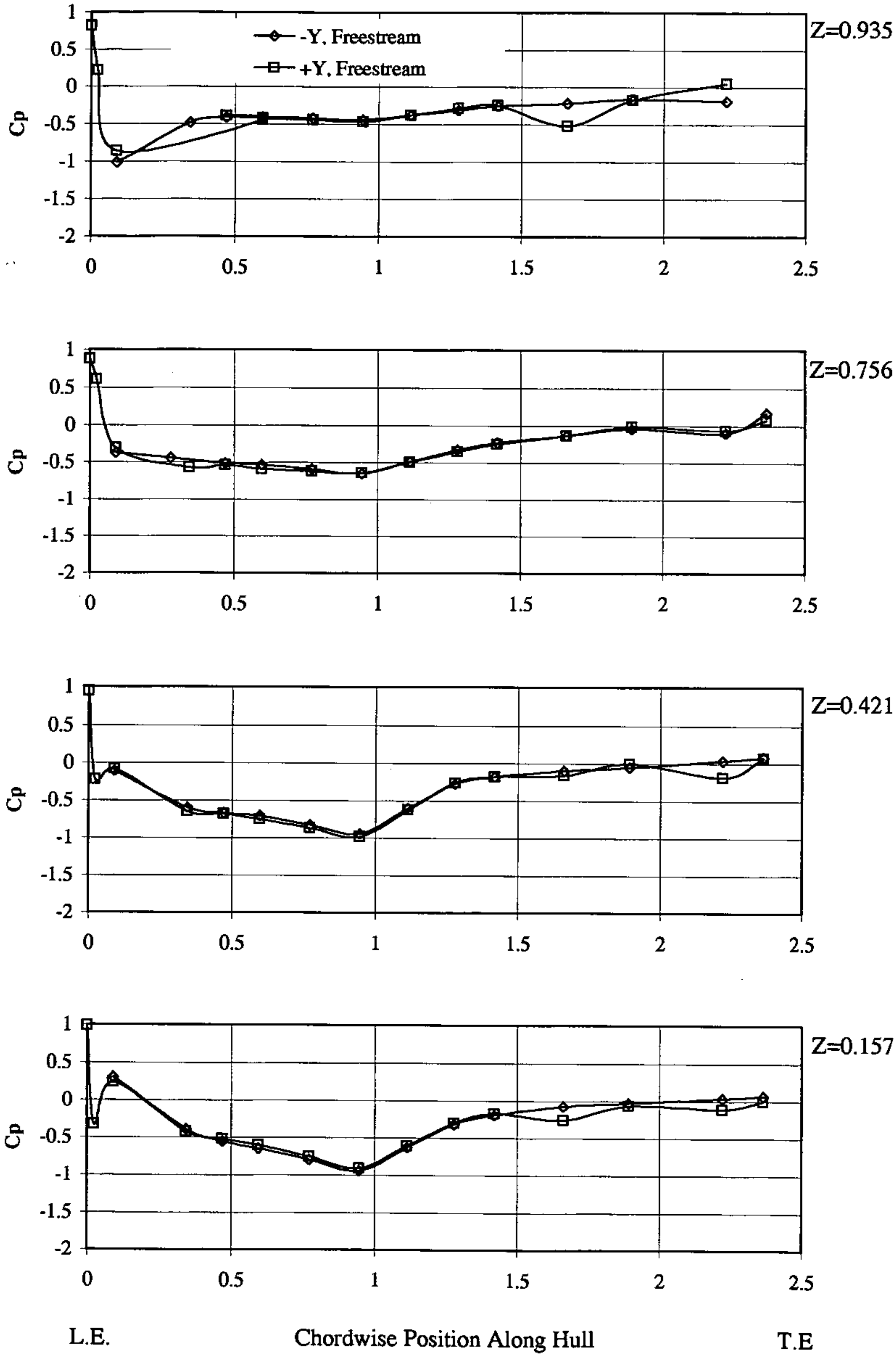


Fig. 51 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.39 in freestream at a skeg rudder angle of -10 degrees

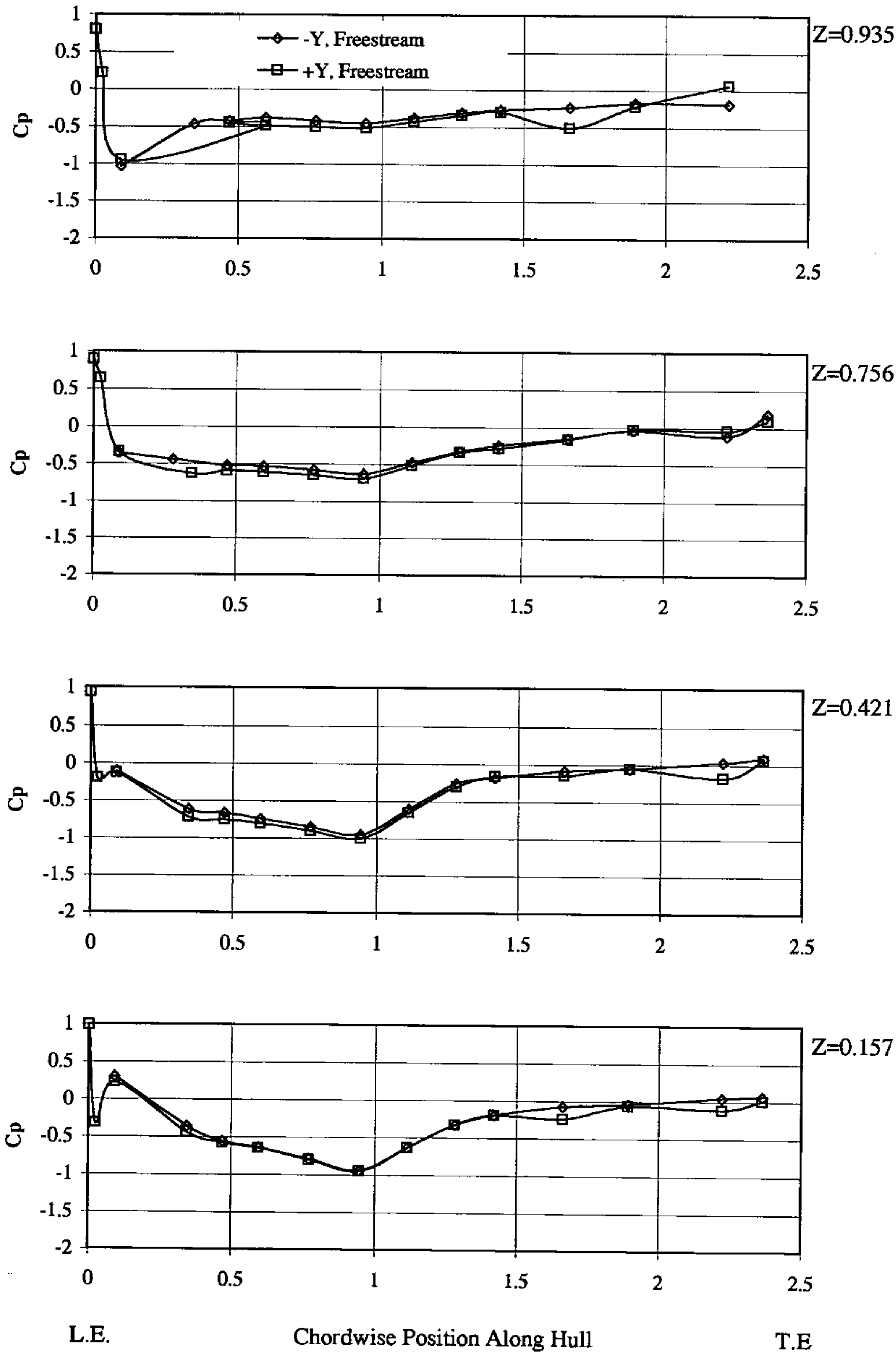


Fig. 51 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.39 in freestream at a skeg rudder angle of 0 degrees

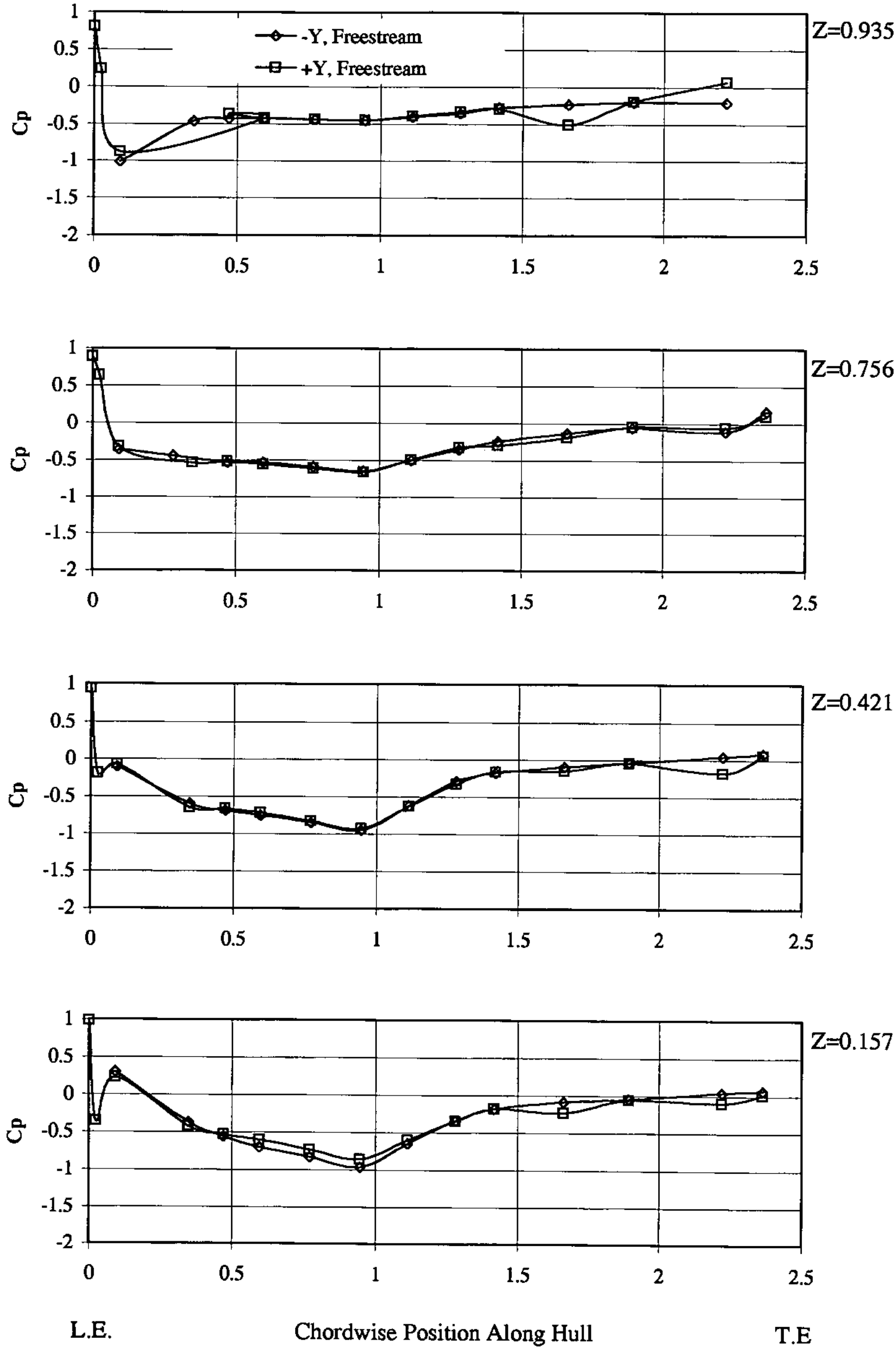


Fig. 51 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.39 in freestream at a skeg rudder angle of +10 degrees

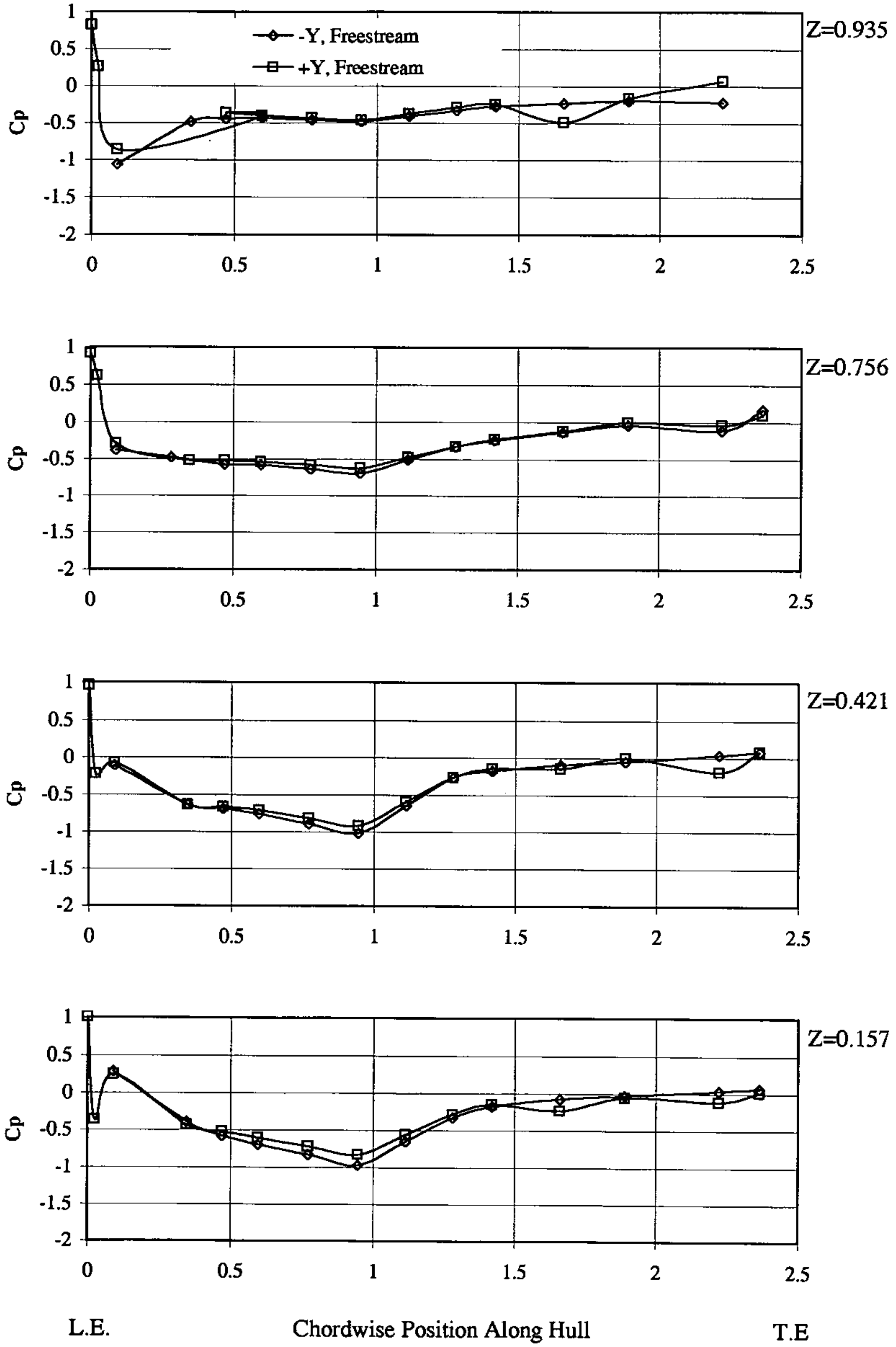


Fig. 51 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.39 in freestream at a skeg rudder angle of +20 degrees

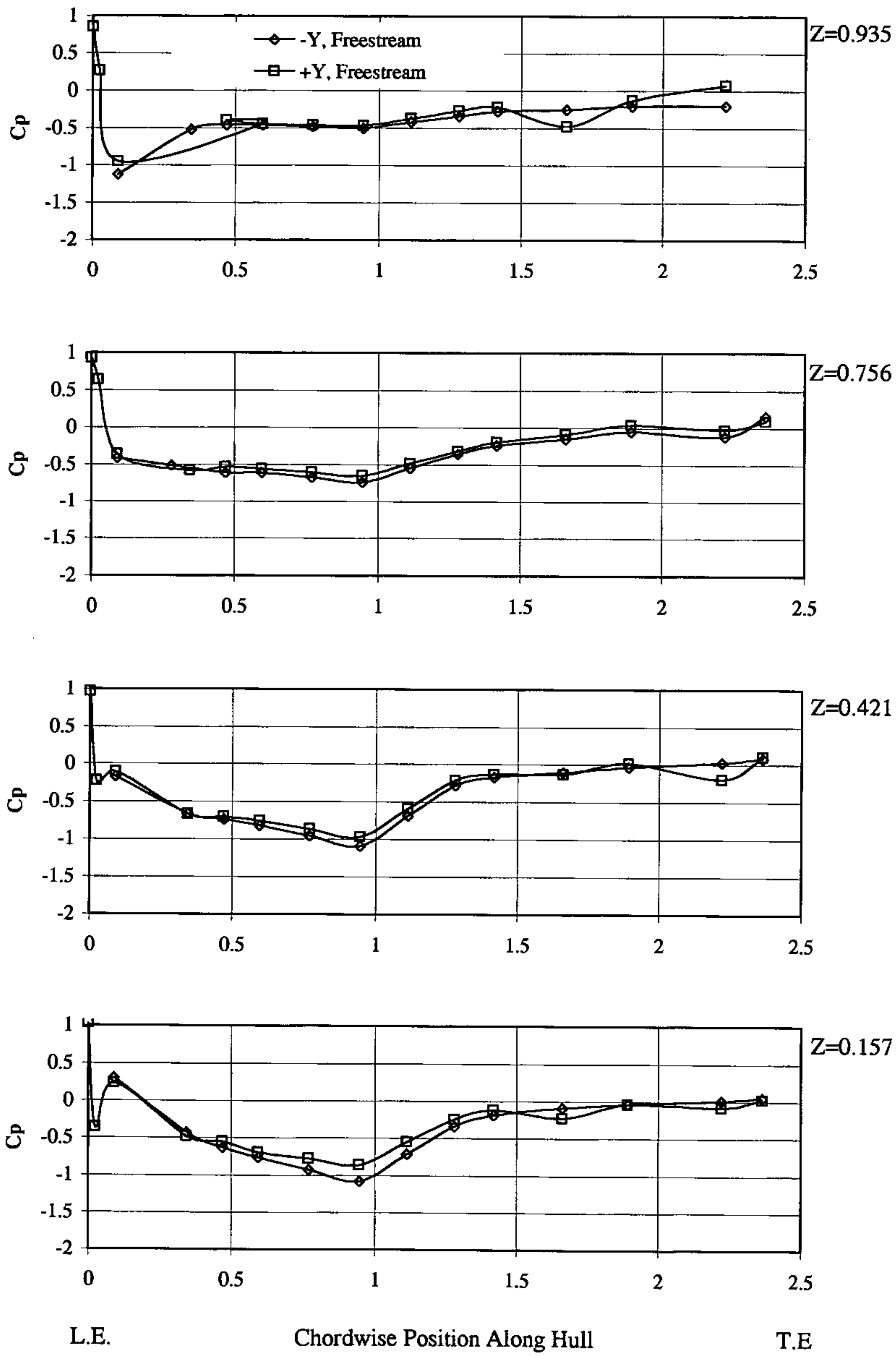


Fig. 51 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.39 in freestream at a skeg rudder angle of +30 degrees

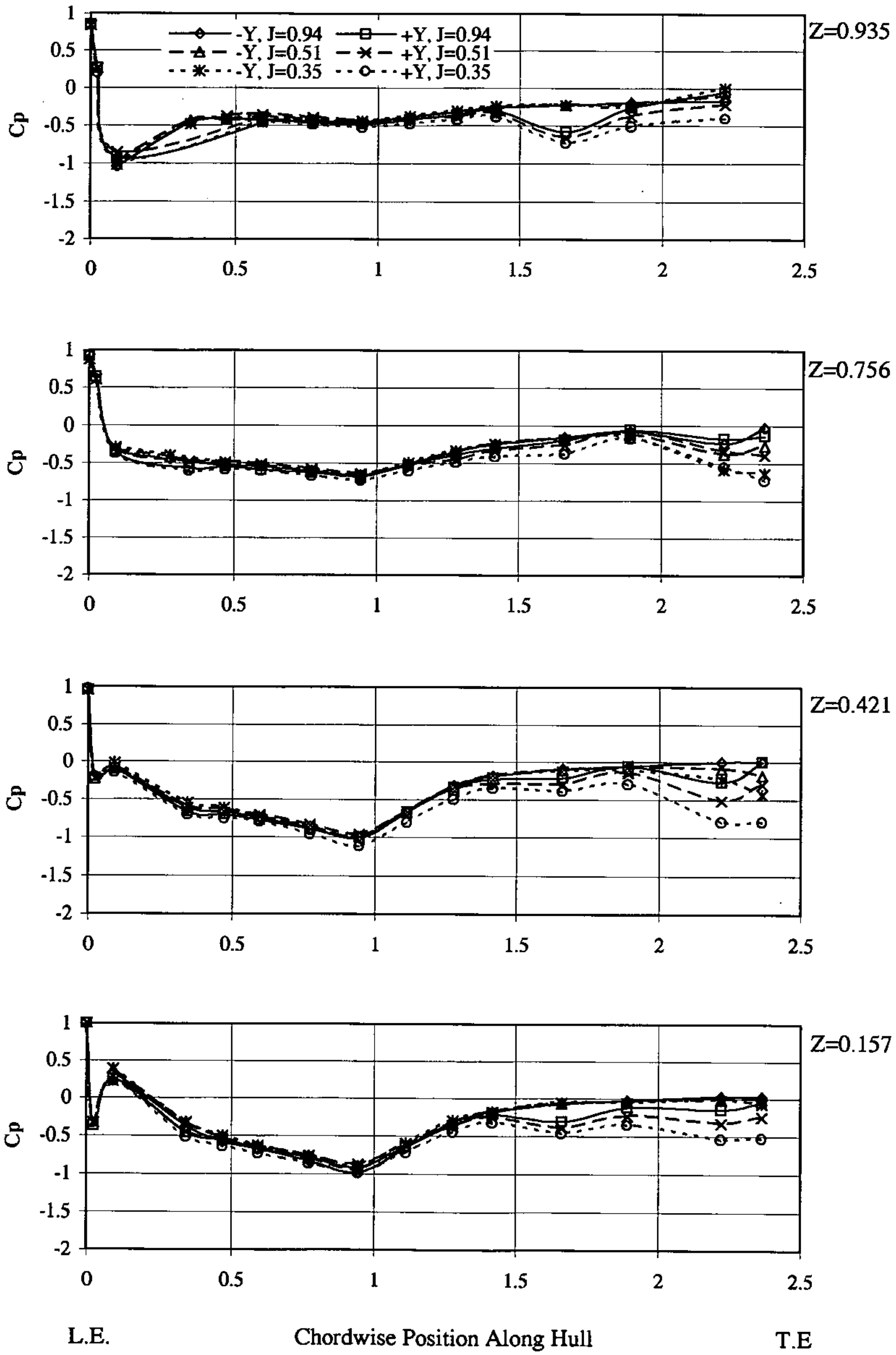


Fig. 52 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.39 for varying J at a skeg rudder angle of -30 degrees

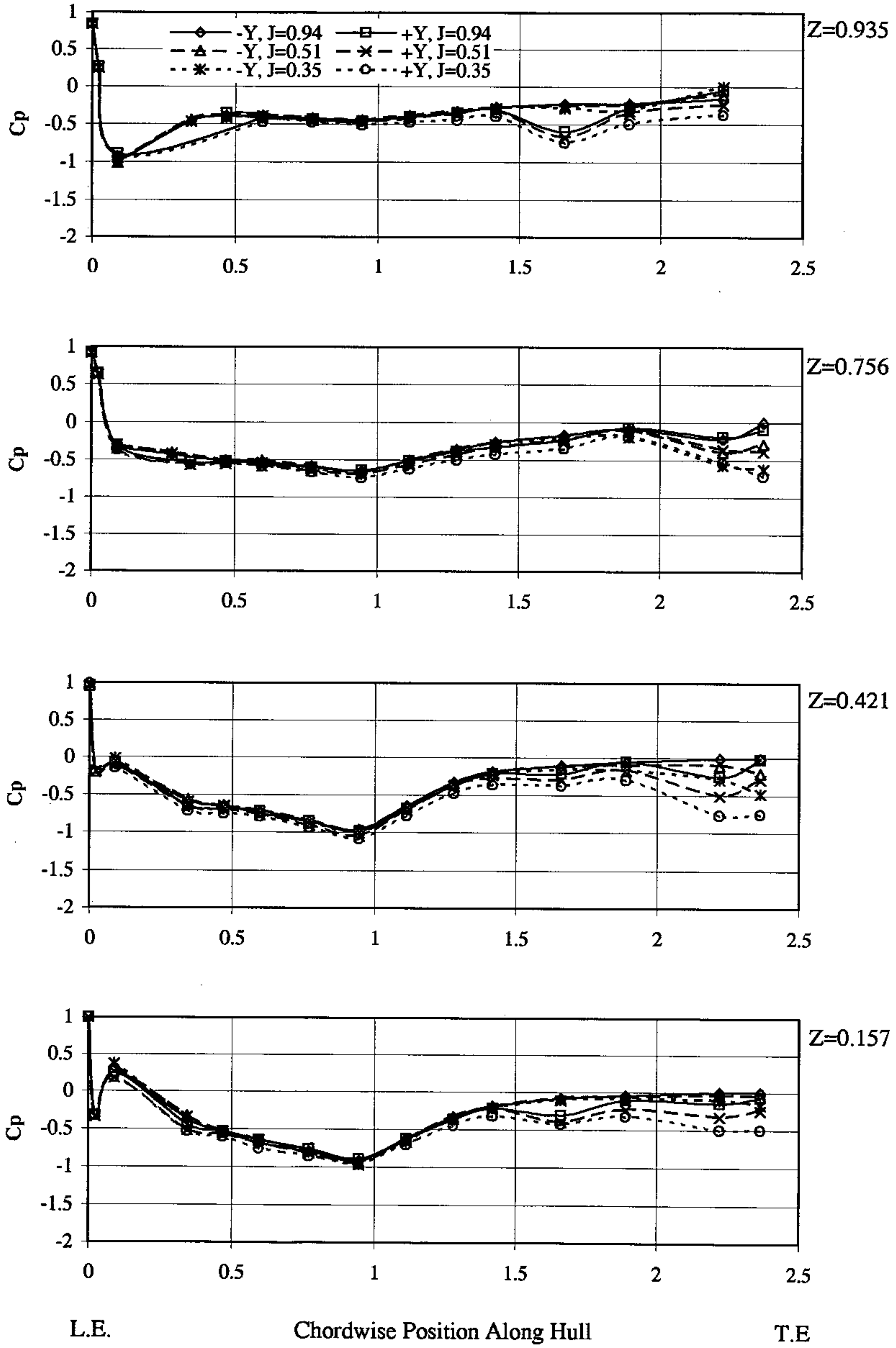


Fig. 52 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.39 for varying J at a skeg rudder angle of -20 degrees

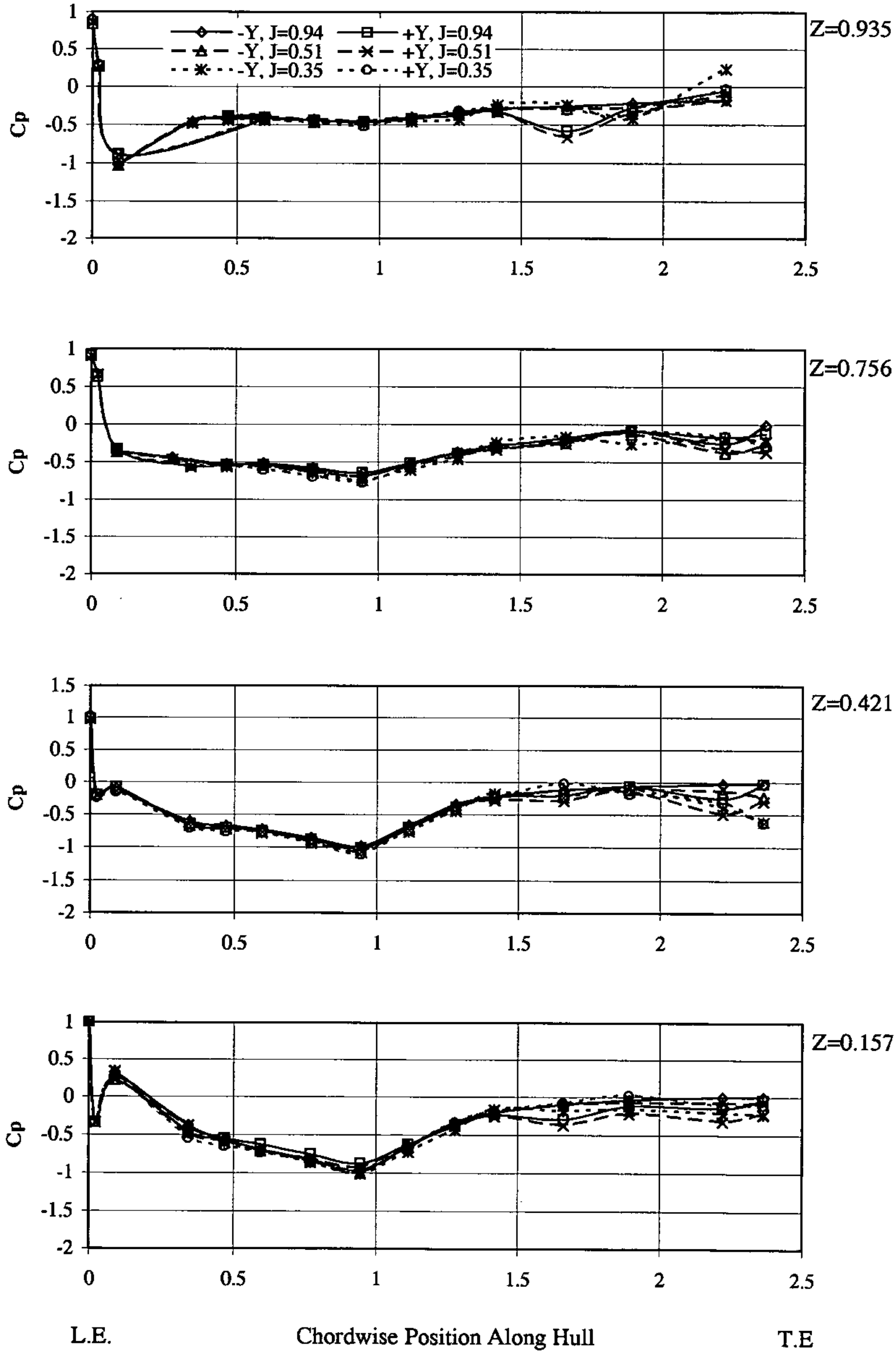


Fig. 52 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.39 for varying J at a skeg rudder angle of -10 degrees

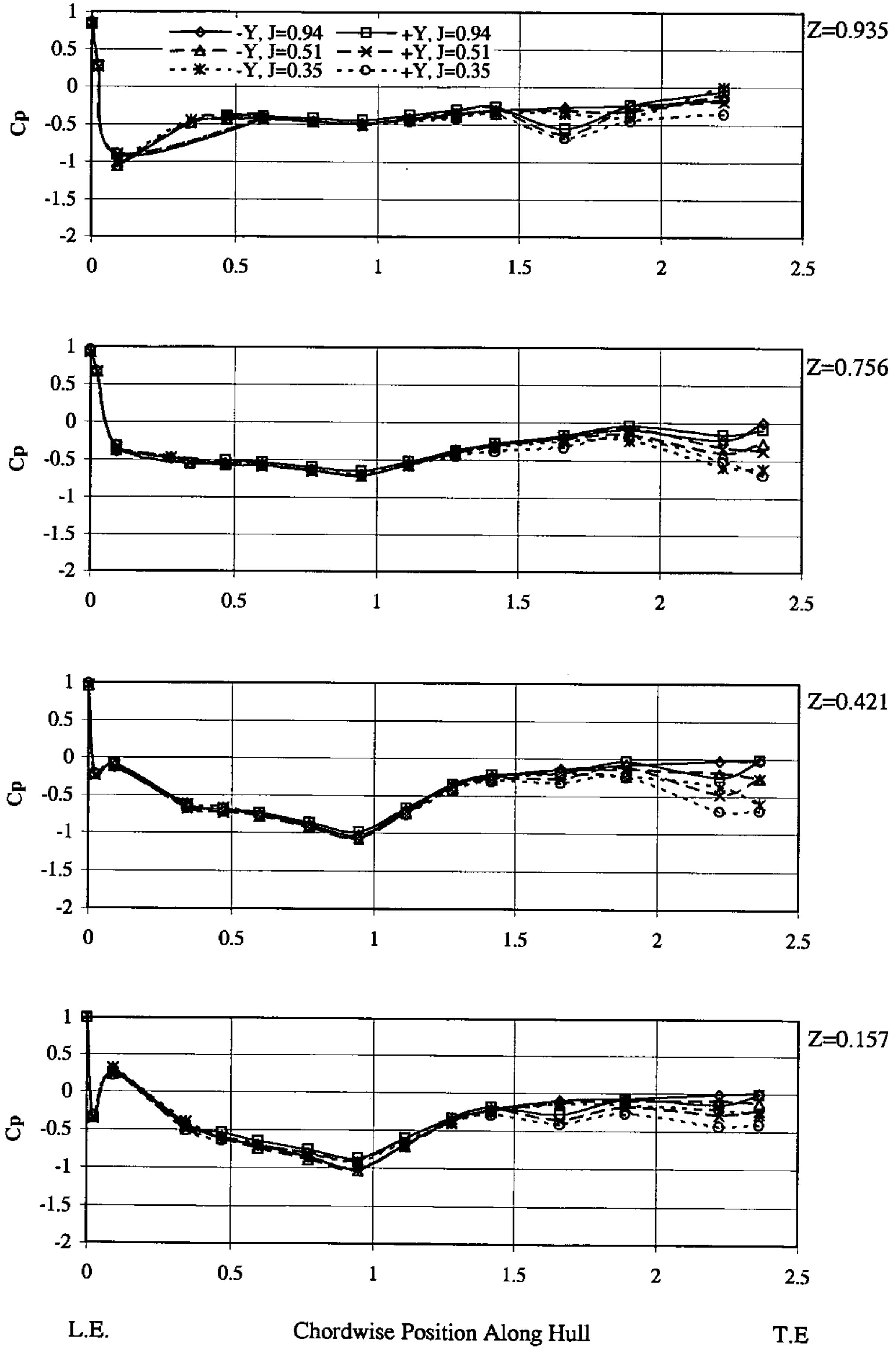


Fig. 52 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.39 for varying J at a skeg rudder angle of 0 degrees

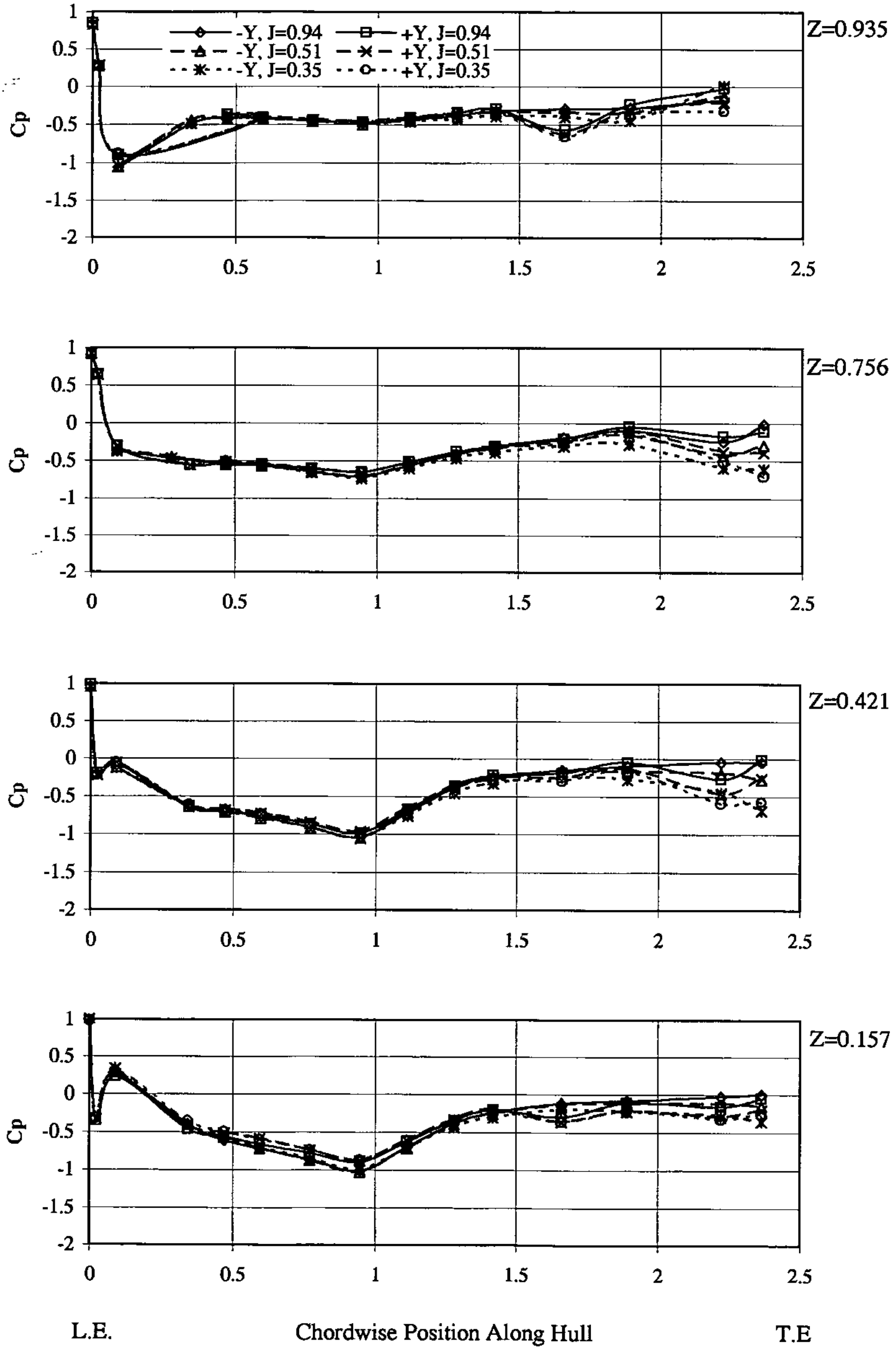


Fig. 52 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.39 for varying J at a skeg rudder angle of +10 degrees

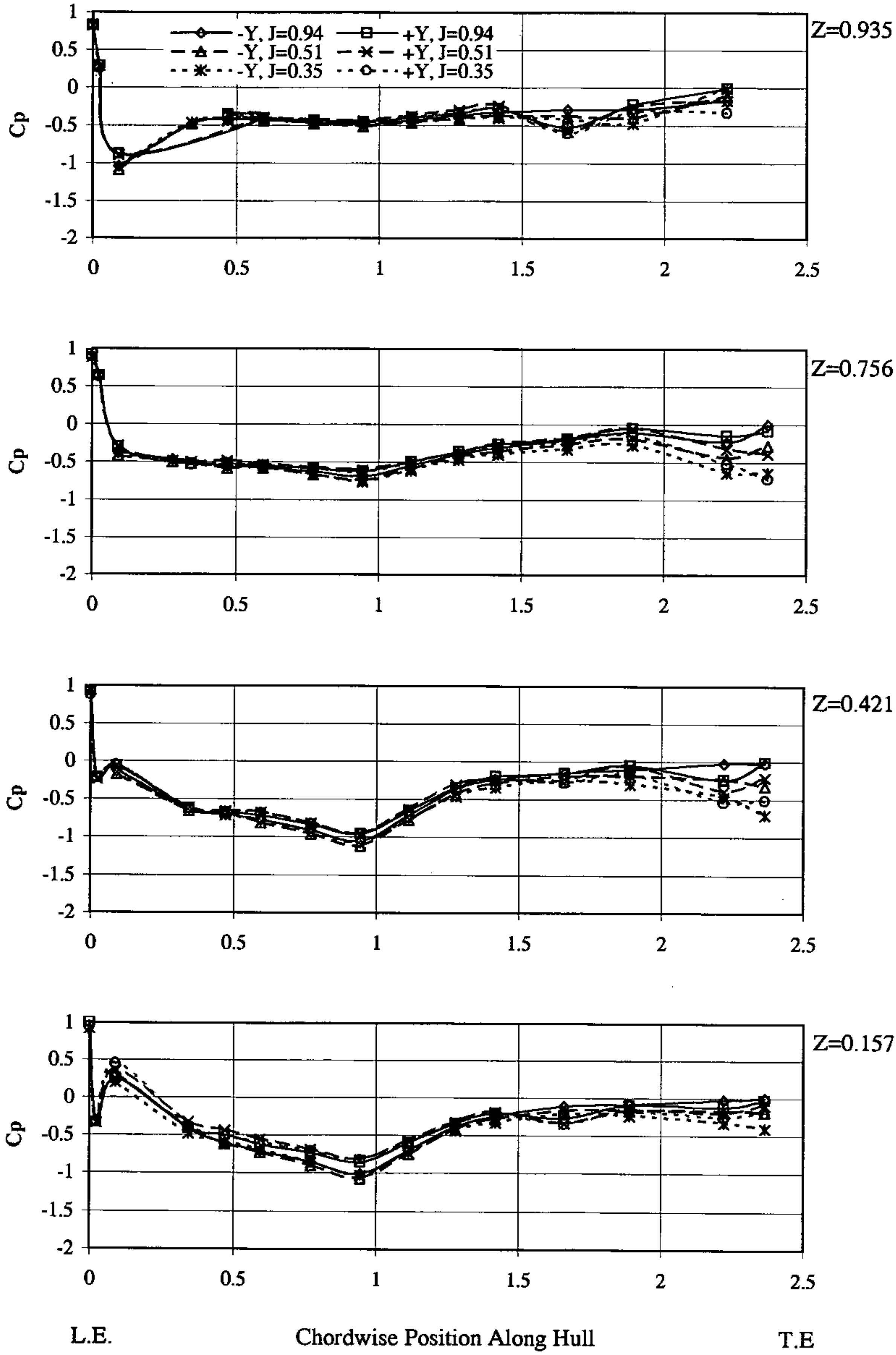


Fig. 52 . Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.39 for varying J at a skeg rudder angle of +20 degrees

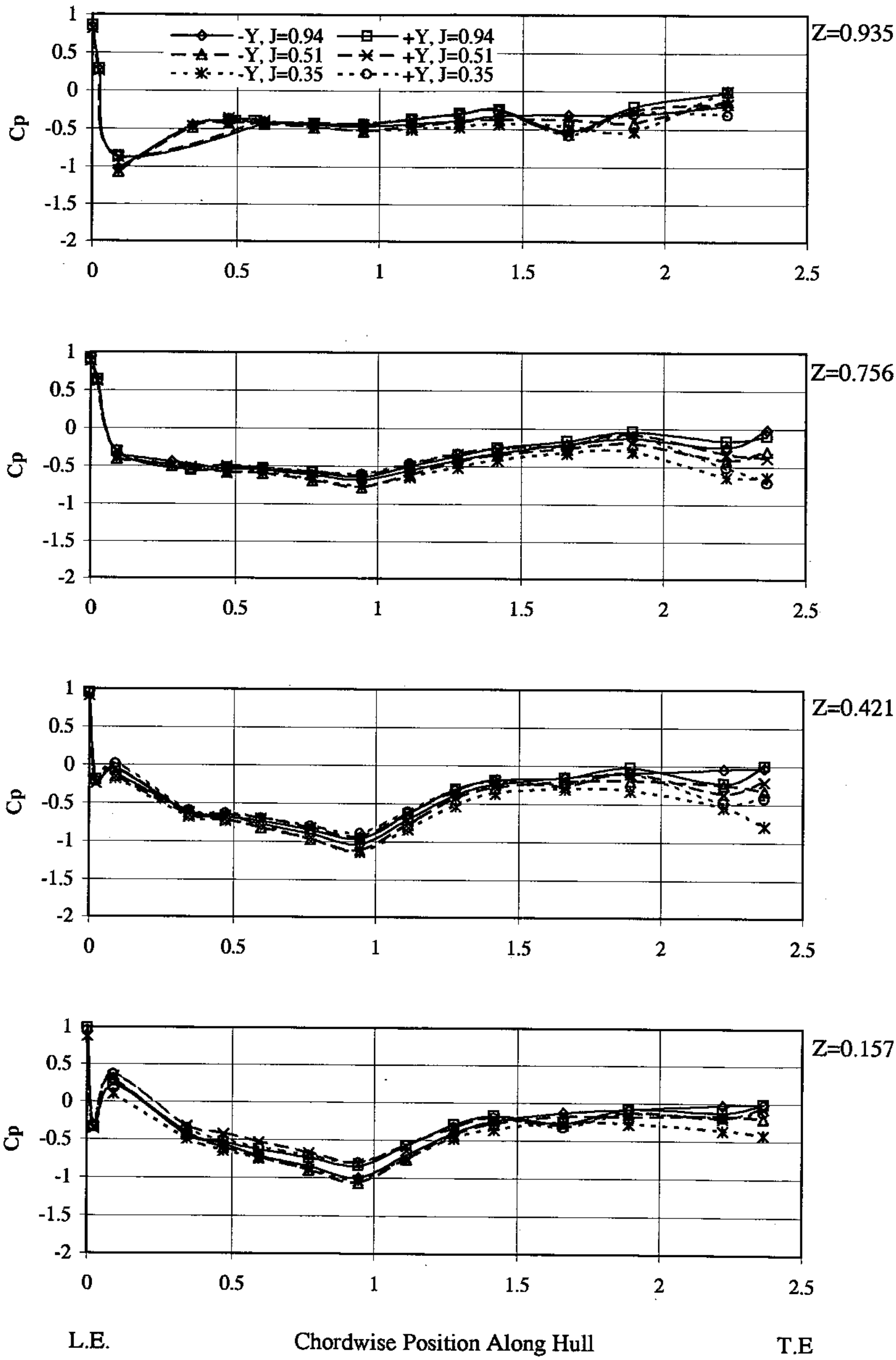


Fig. 52 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.39 for varying J at a skeg rudder angle of +30 degrees

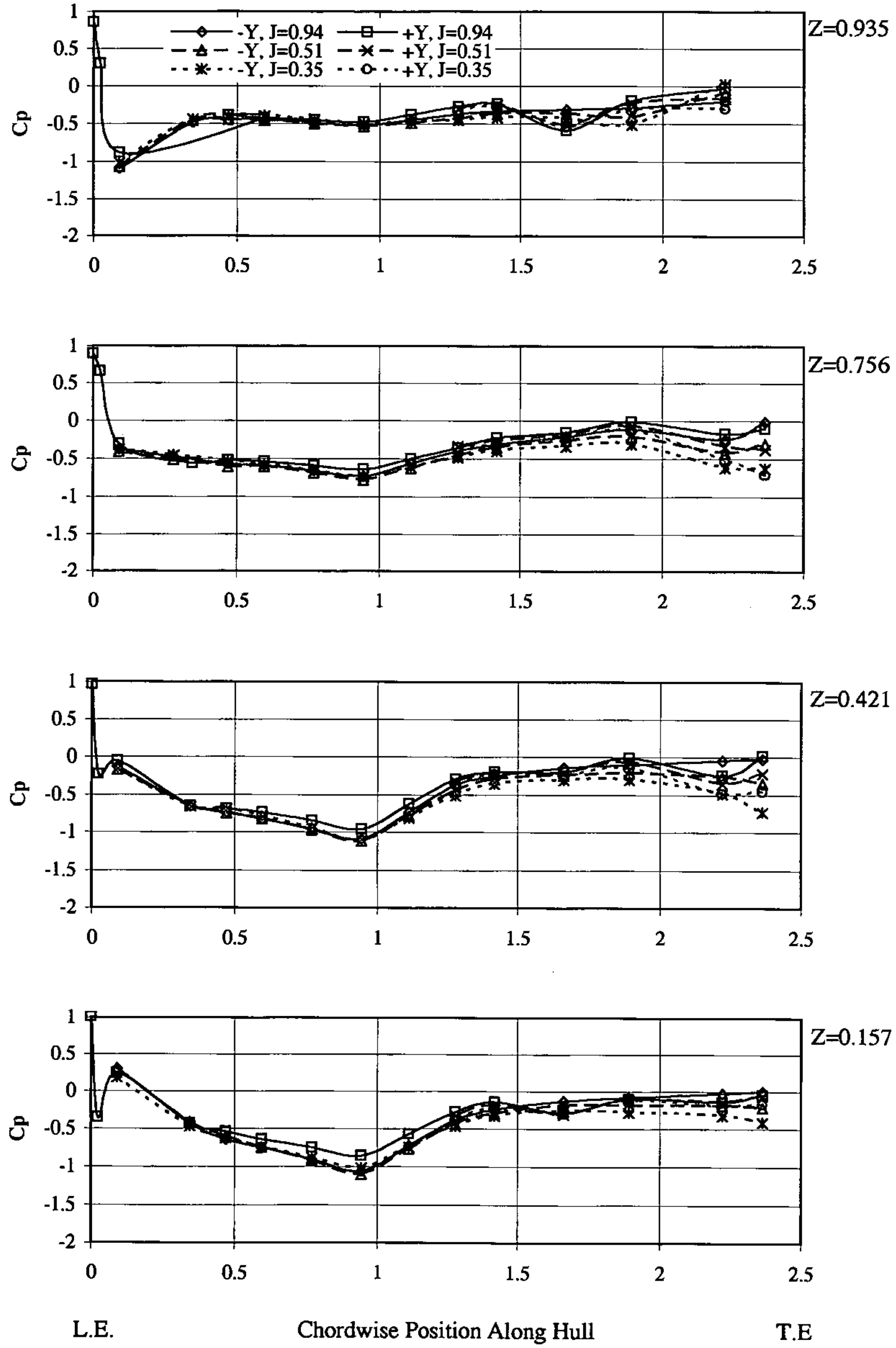


Fig. 53 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.52 for varying J at a skeg rudder angle of +30 degrees

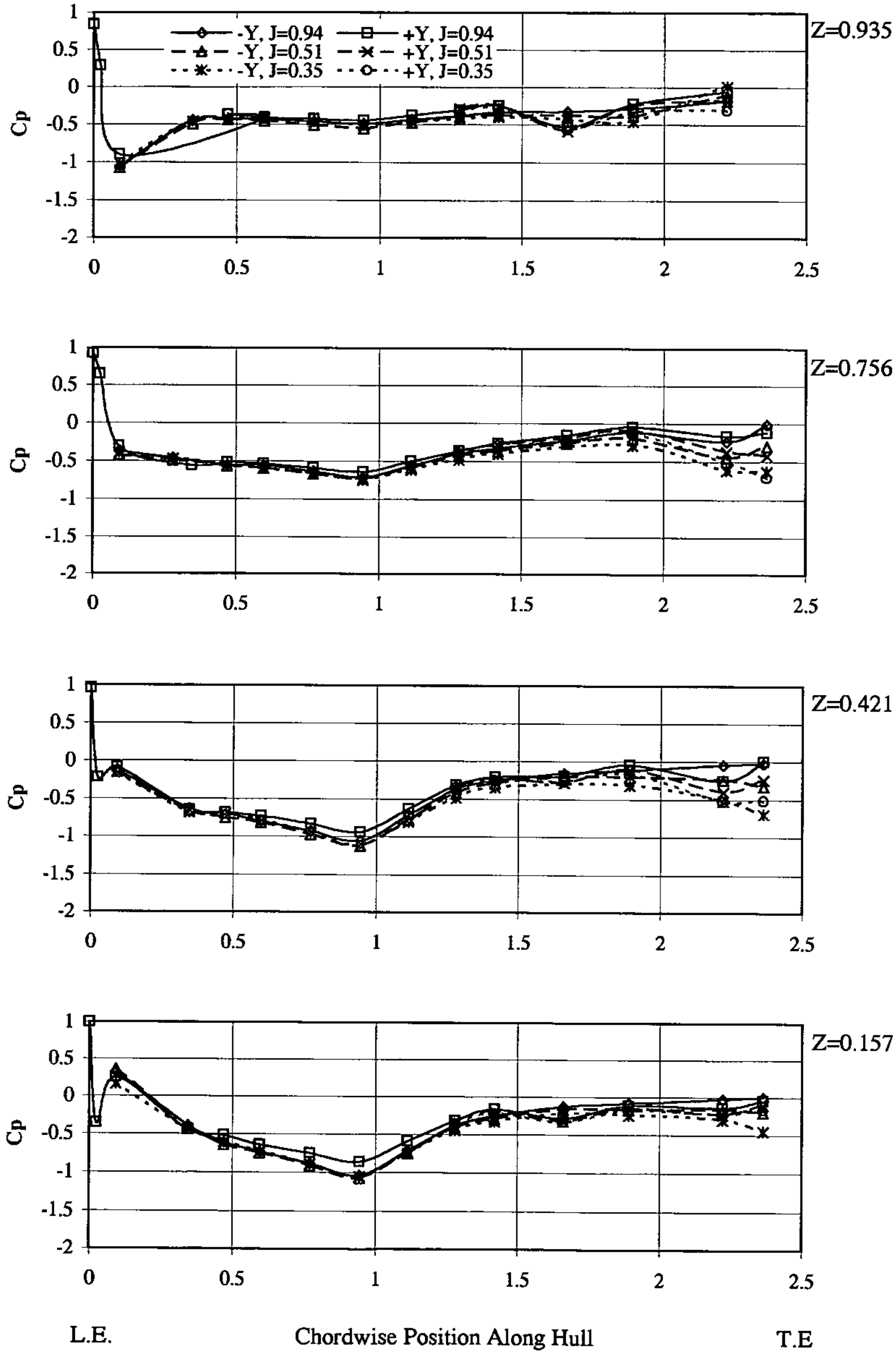


Fig. 53 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.52 for varying J at a skeg rudder angle of +20 degrees

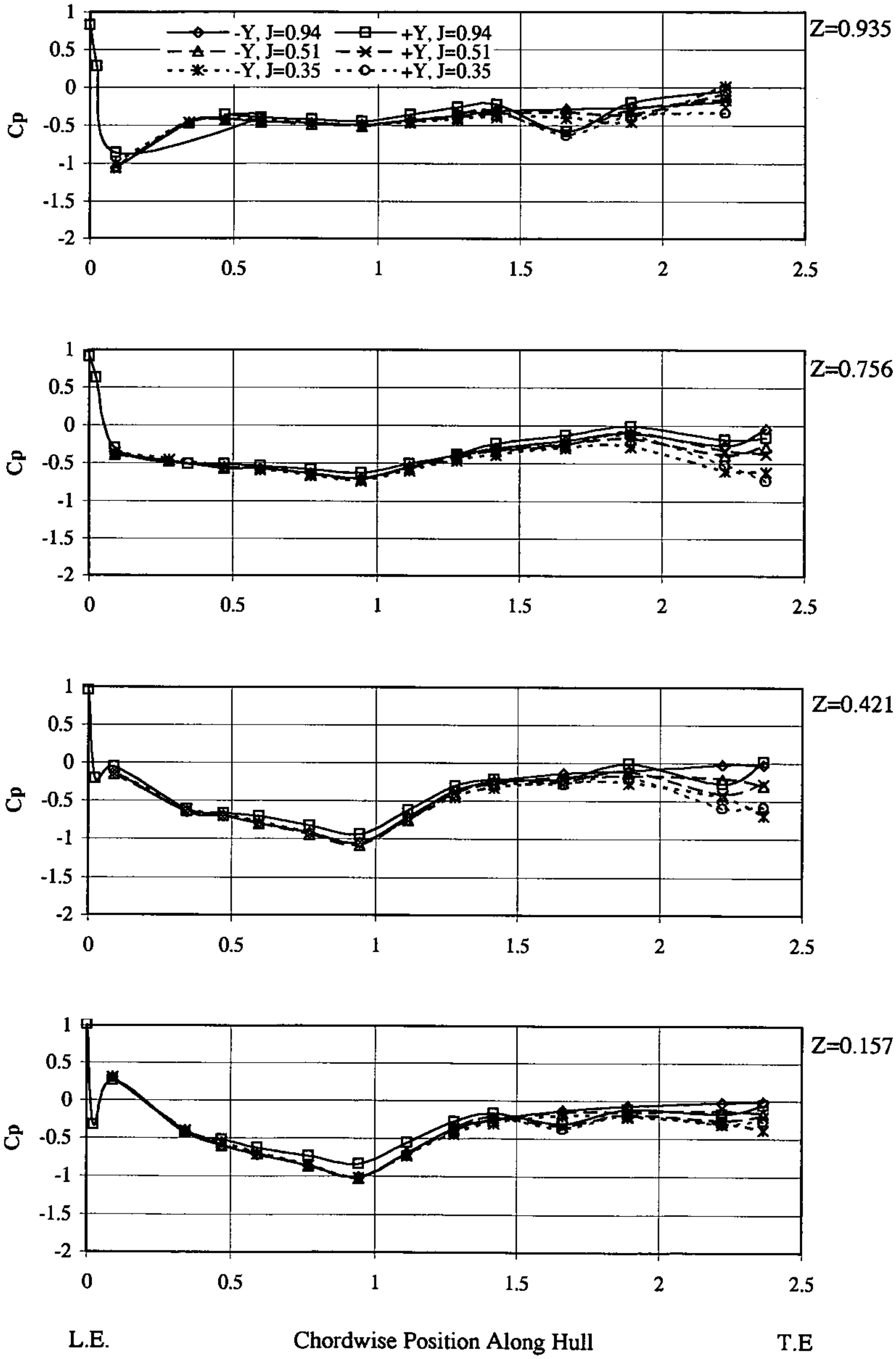


Fig. 53 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.52 for varying J at a skeg rudder angle of +10 degrees

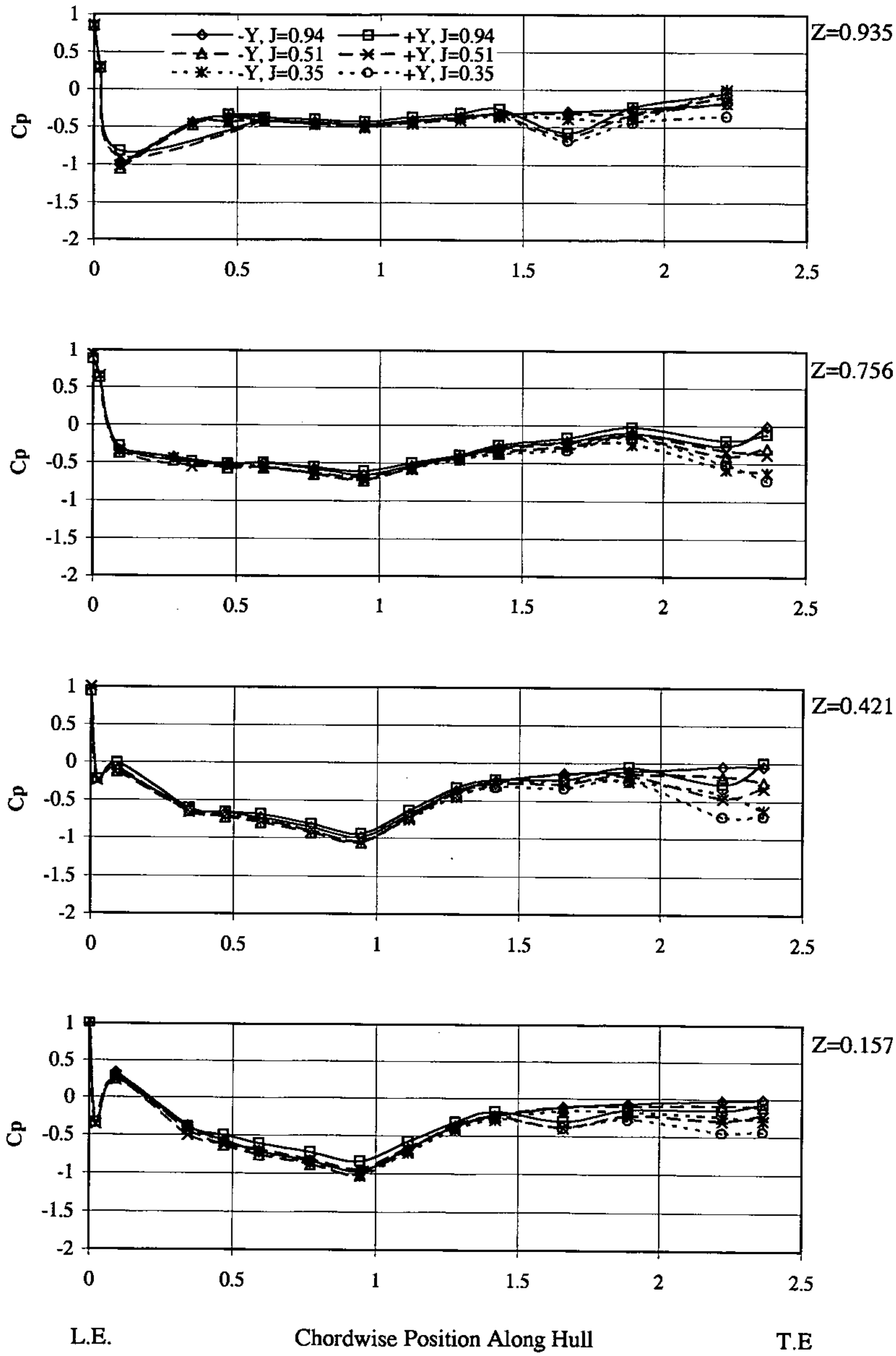


Fig. 53 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.52 for varying J at a skeg rudder angle of 0 degrees

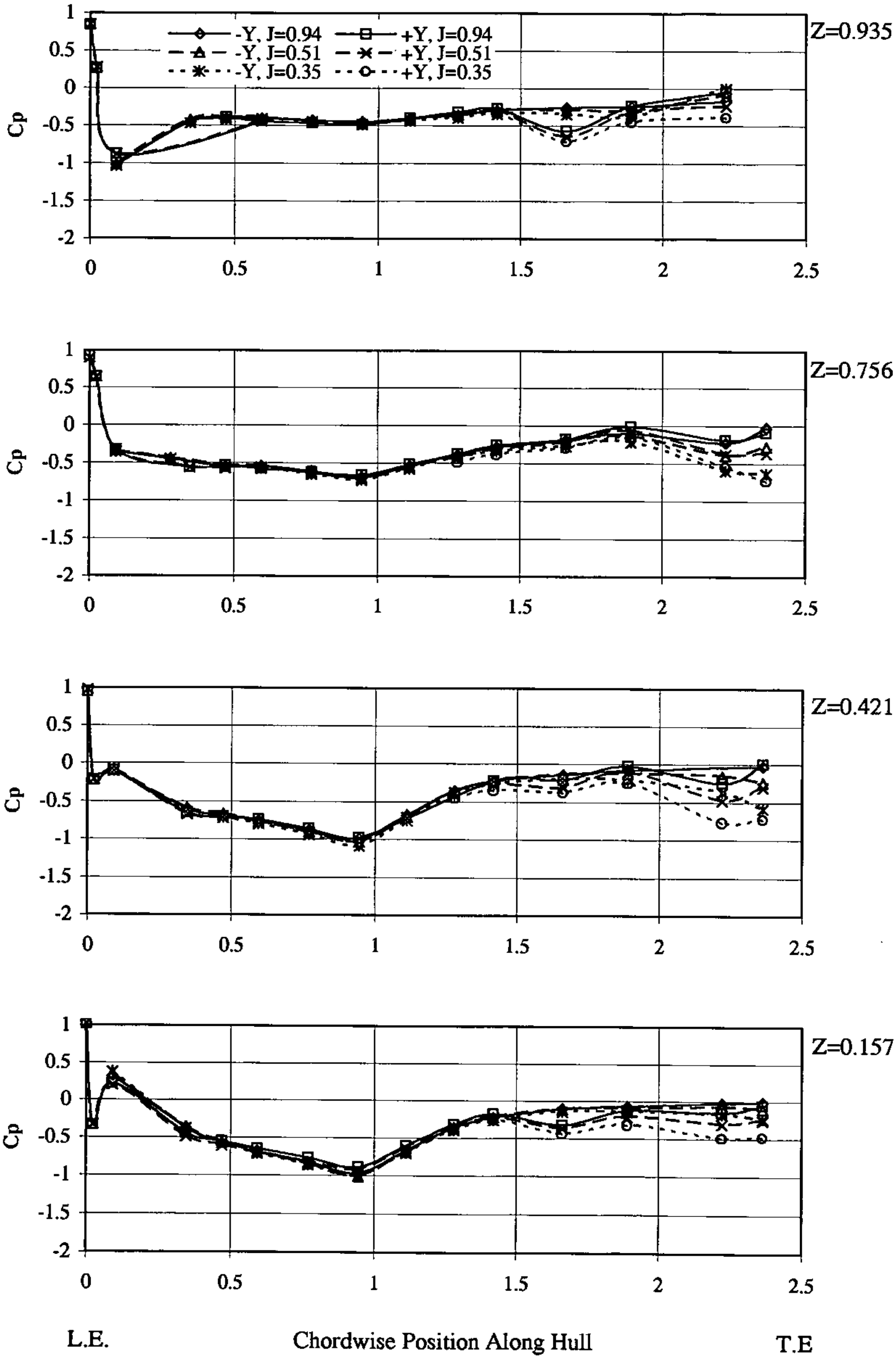


Fig. 53 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.52 for varying J at a skeg rudder angle of -10 degrees

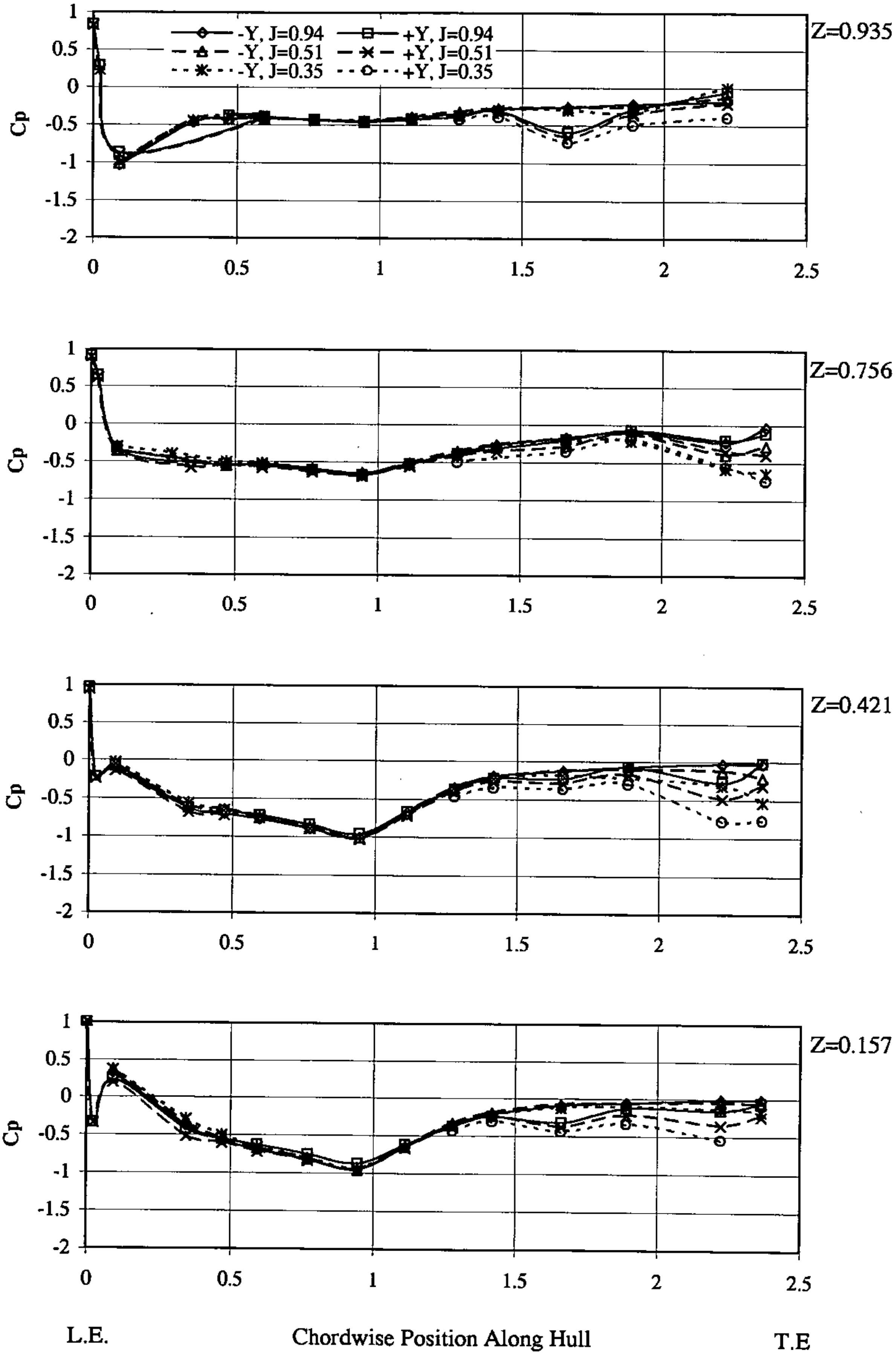


Fig. 53 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.52 for varying J at a skeg rudder angle of -20 degrees

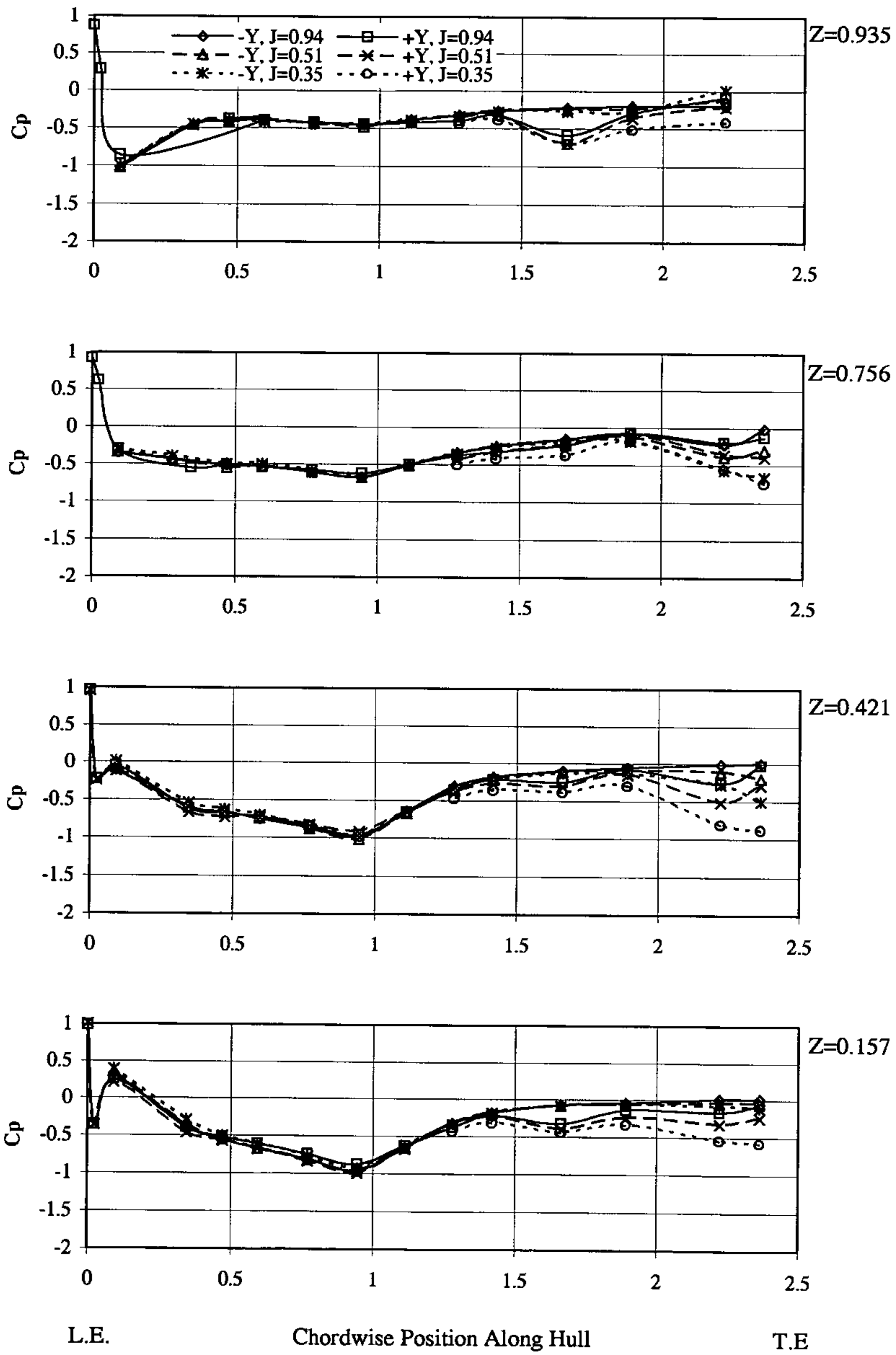


Fig. 53 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.52 for varying J at a skeg rudder angle of -30 degrees

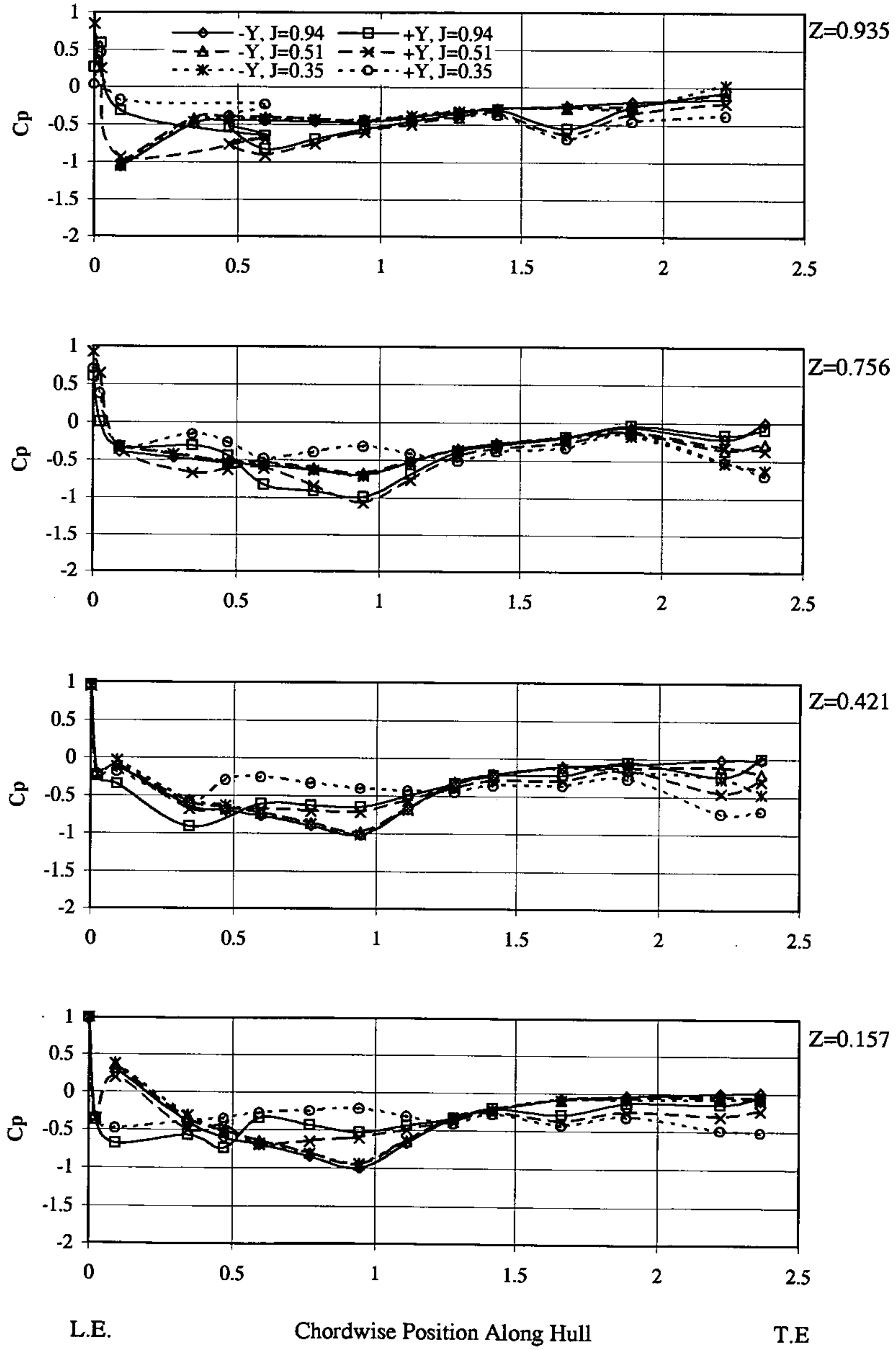


Fig. 54 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.64 for varying J at a skeg rudder angle of -30 degrees

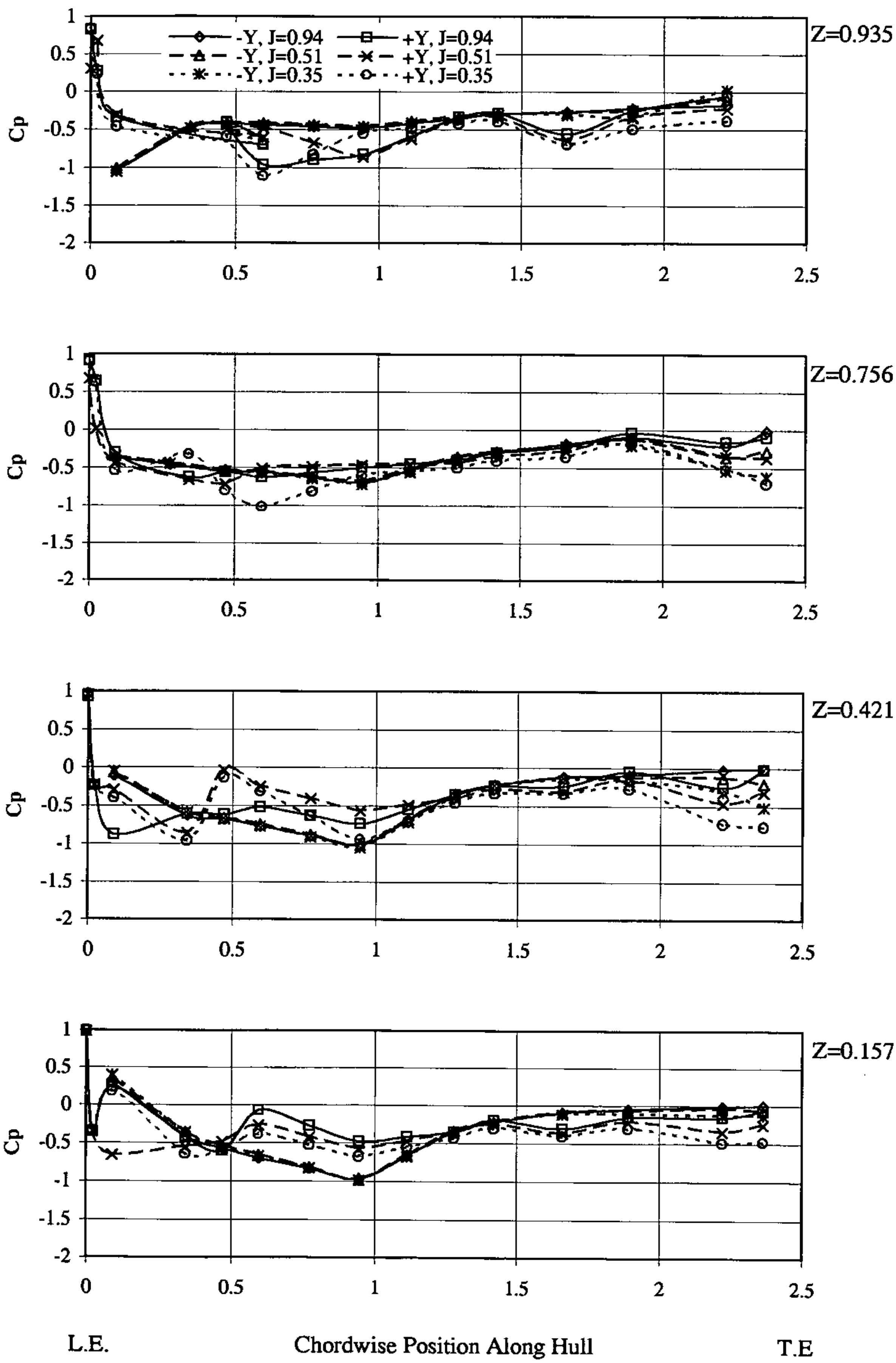


Fig. 54 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.64 for varying J at a skeg rudder angle of -20 degrees

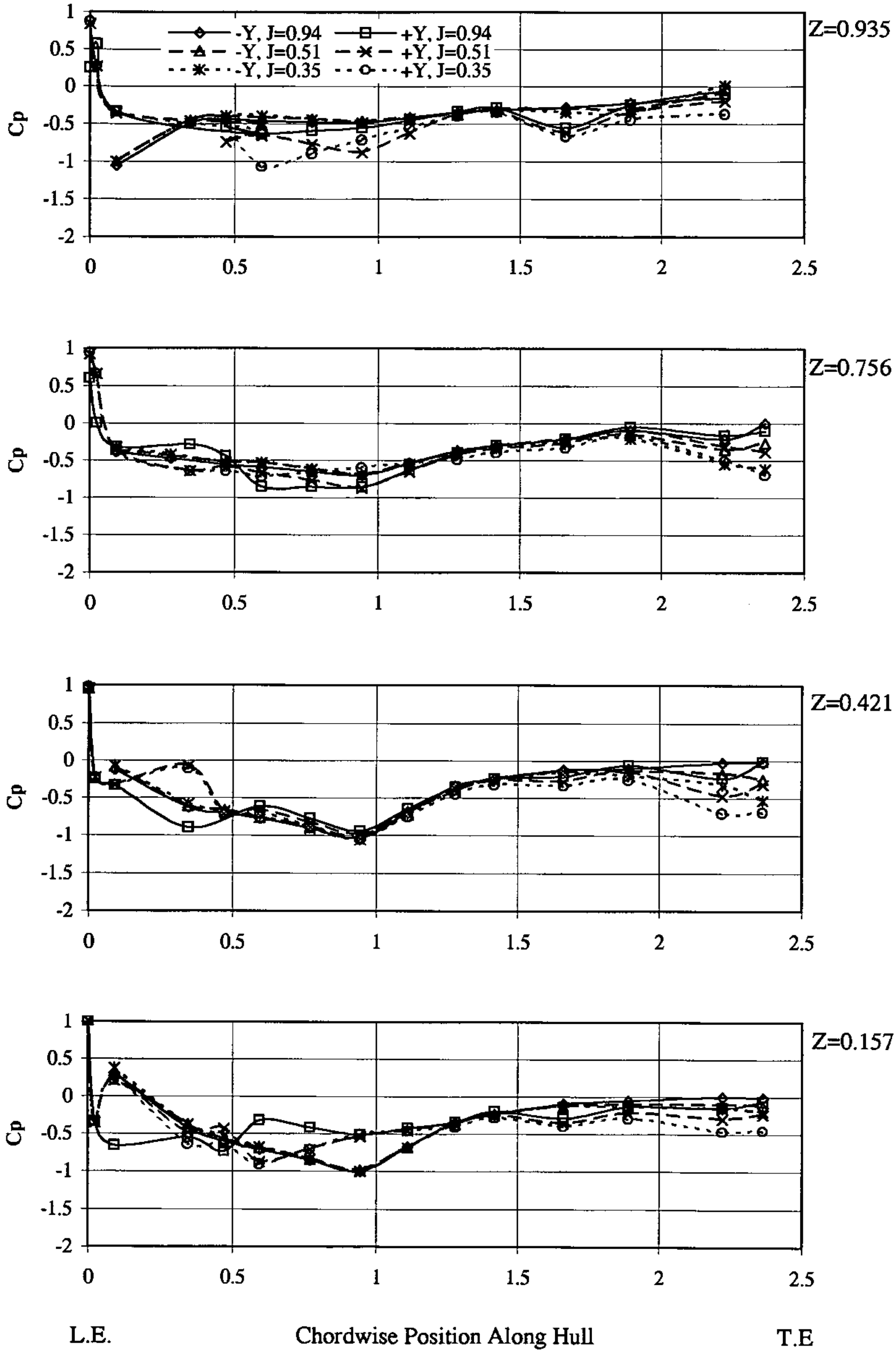


Fig. 54 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.64 for varying J at a skeg rudder angle of -10 degrees

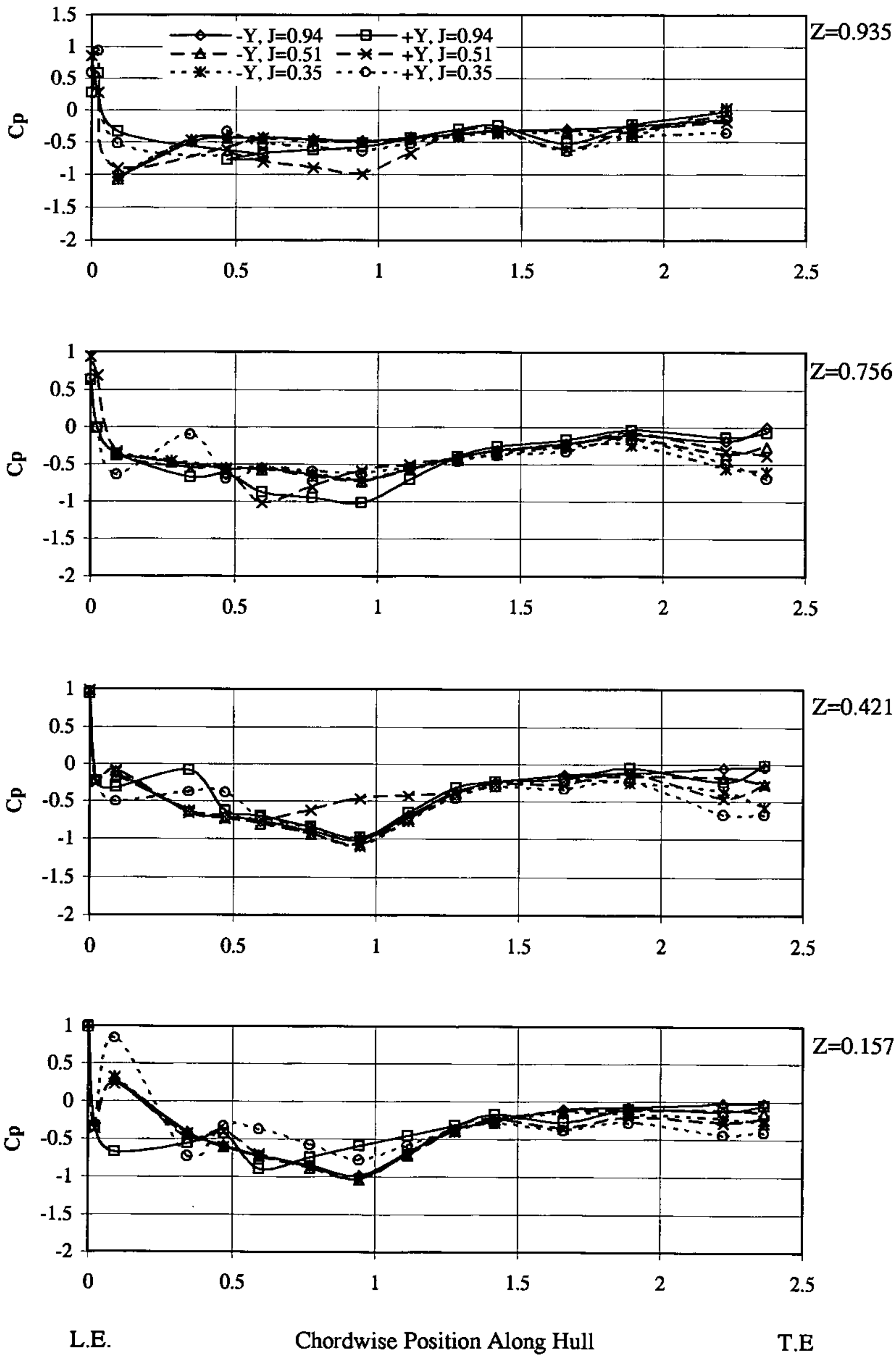


Fig. 54 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.64 for varying J at a skeg rudder angle of 0 degrees

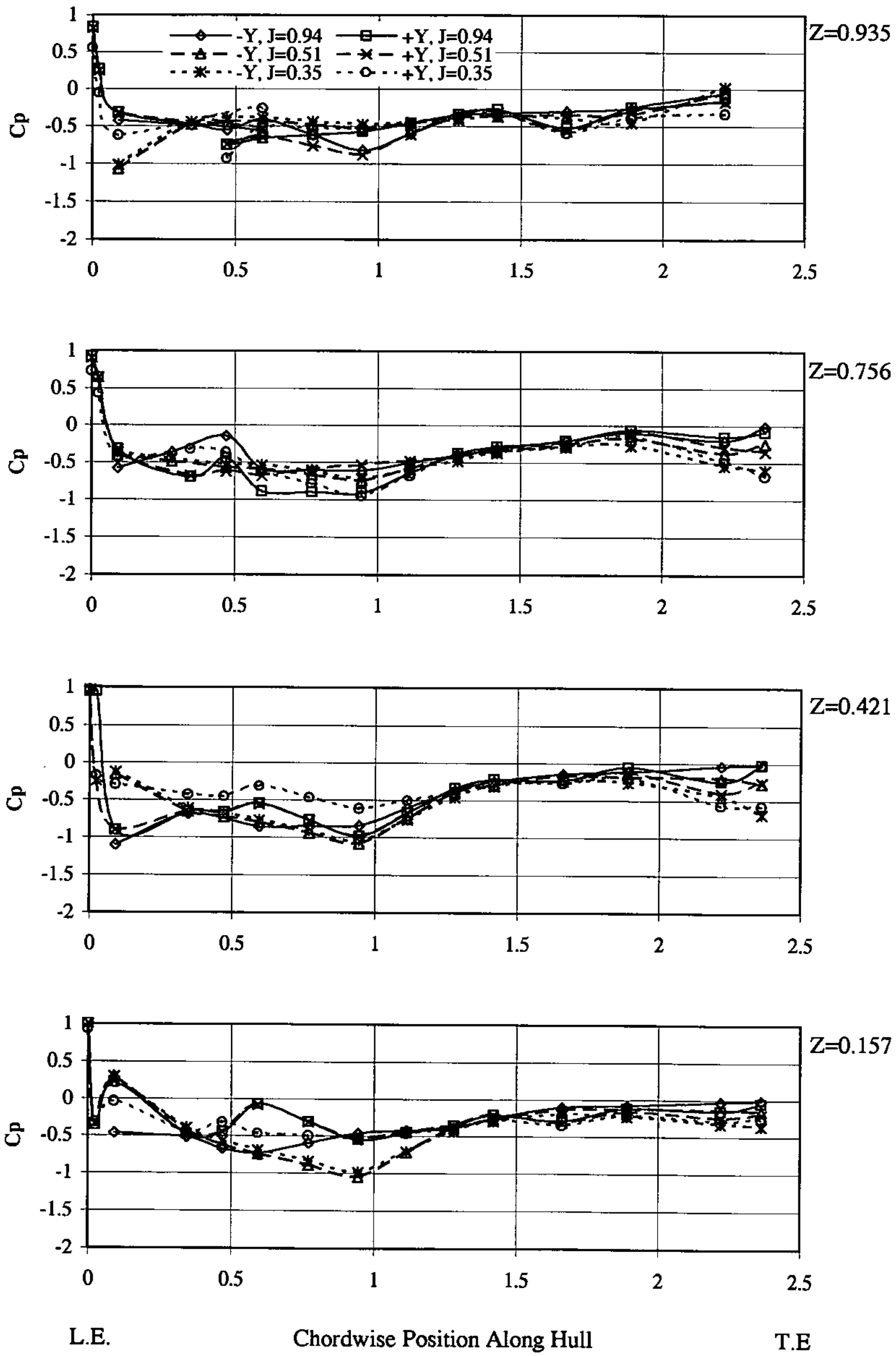


Fig. 54 . Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.64 for varying J at a skeg rudder angle of +10 degrees

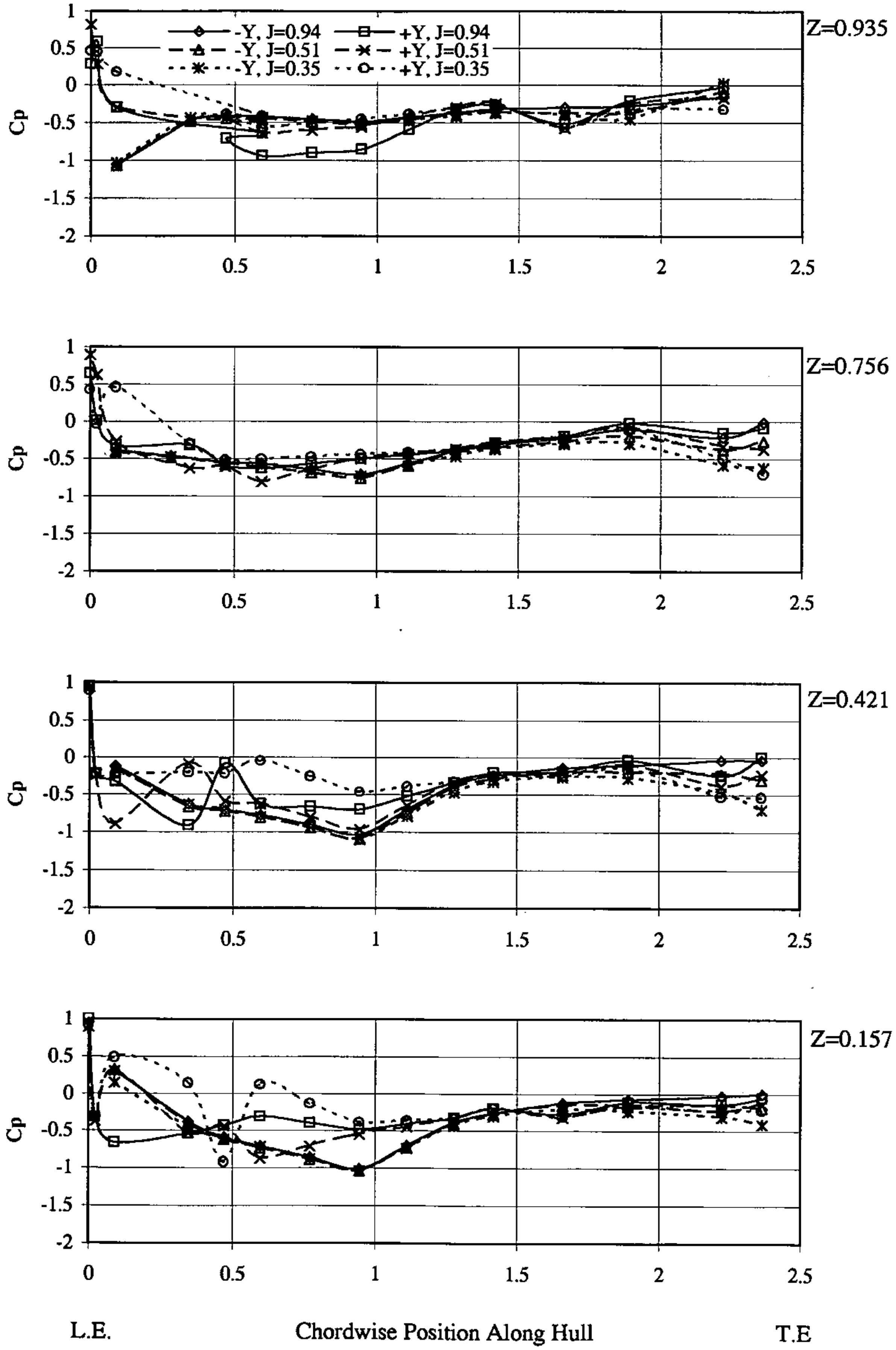


Fig. 54 - Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.64 for varying J at a skeg rudder angle of +20 degrees

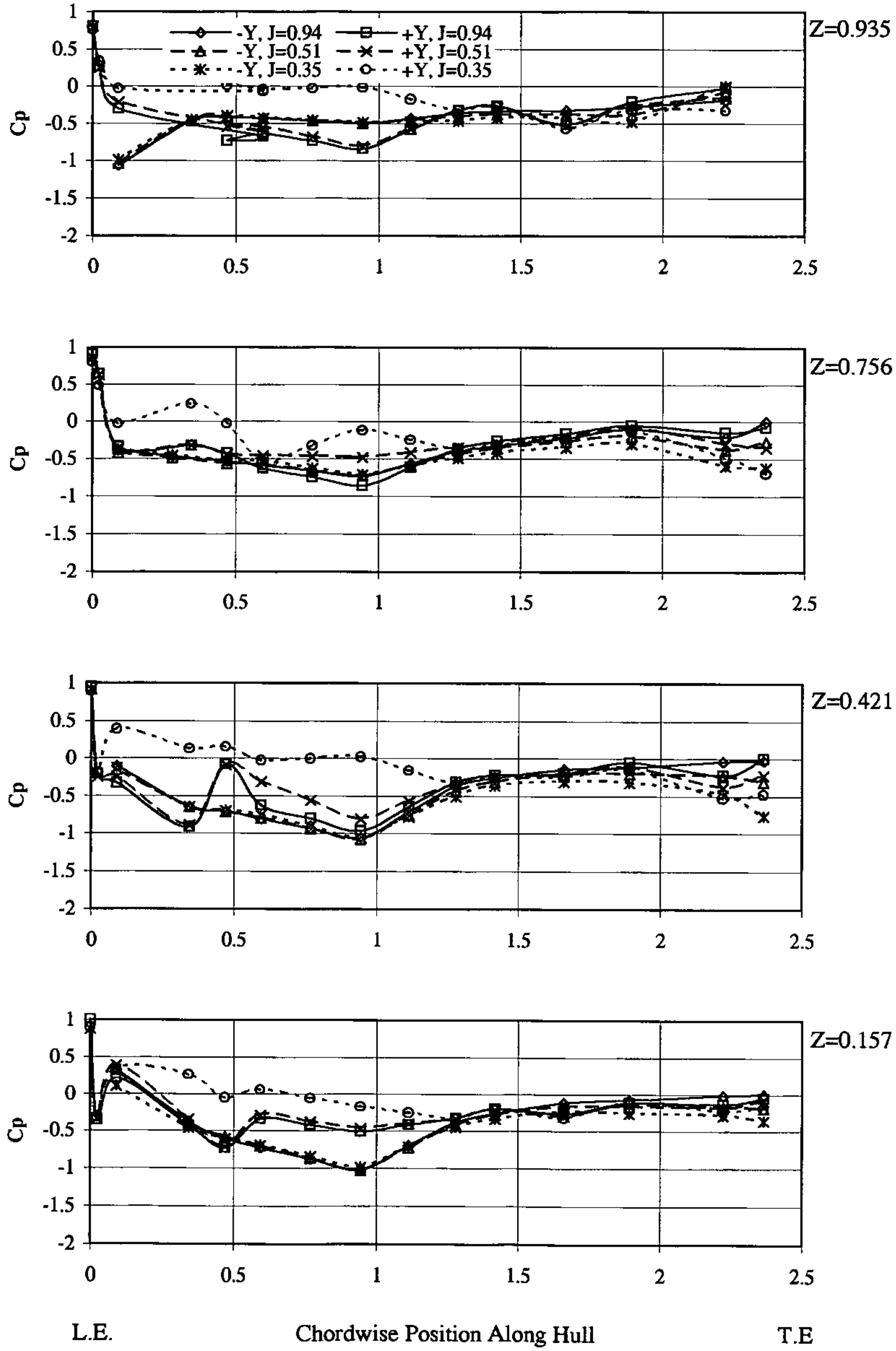


Fig. 54 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.64 for varying J at a skeg rudder angle of +30 degrees

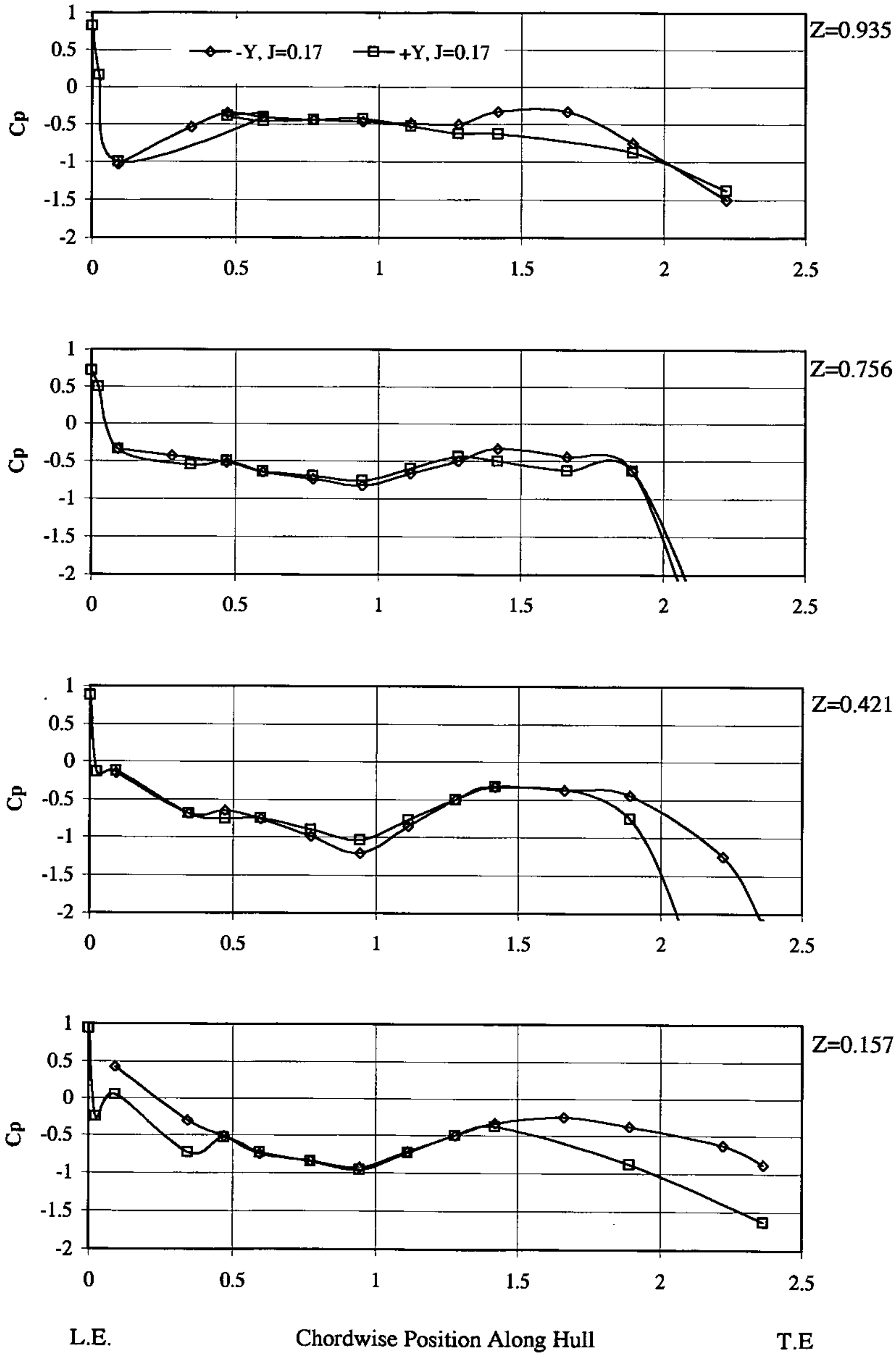


Fig. 55 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.64 at J=0.17 at a skeg rudder angle of -30 degrees

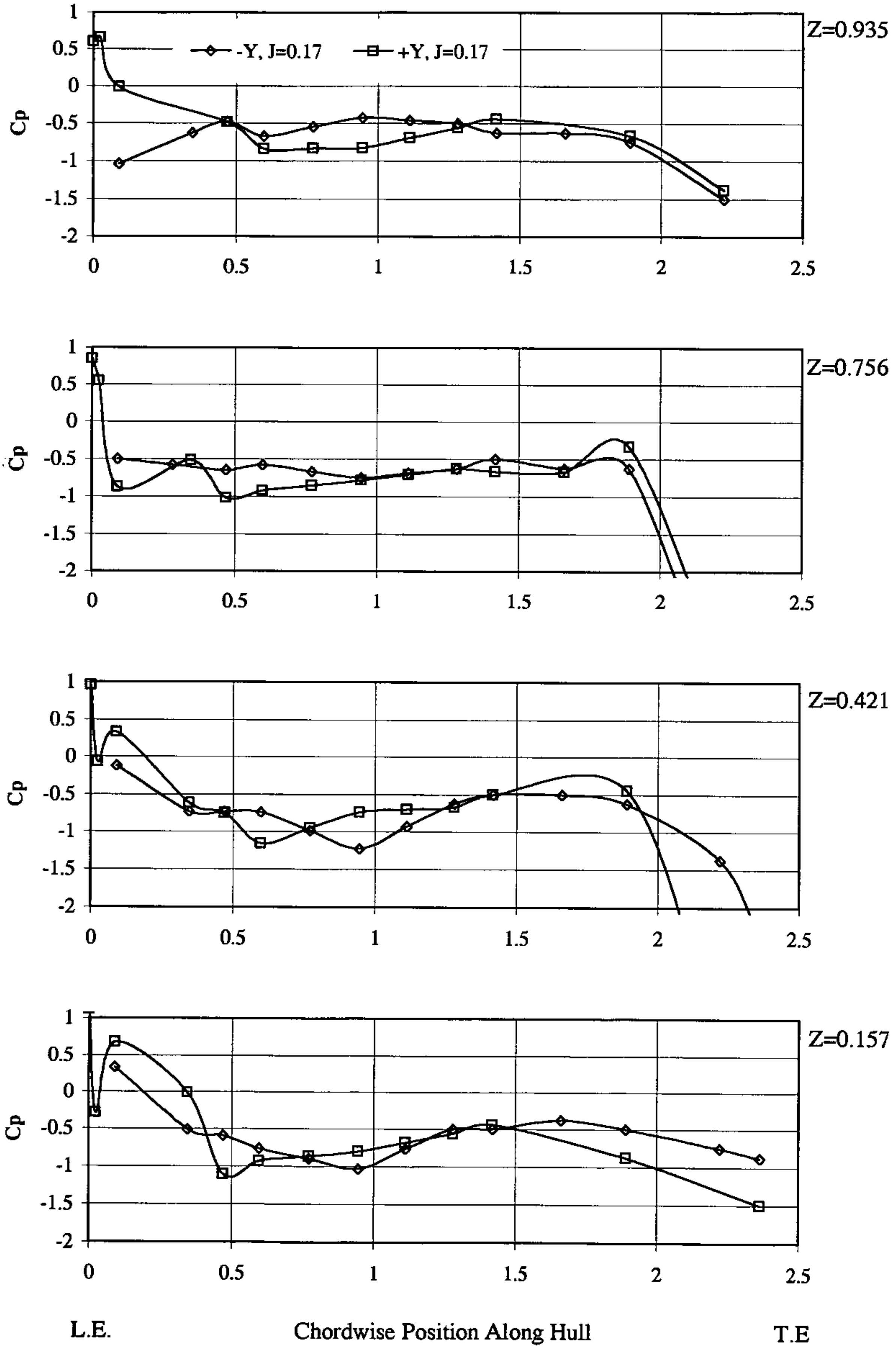


Fig. 55 . Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.64 at J=0.17 at a skeg rudder angle of -20 degrees

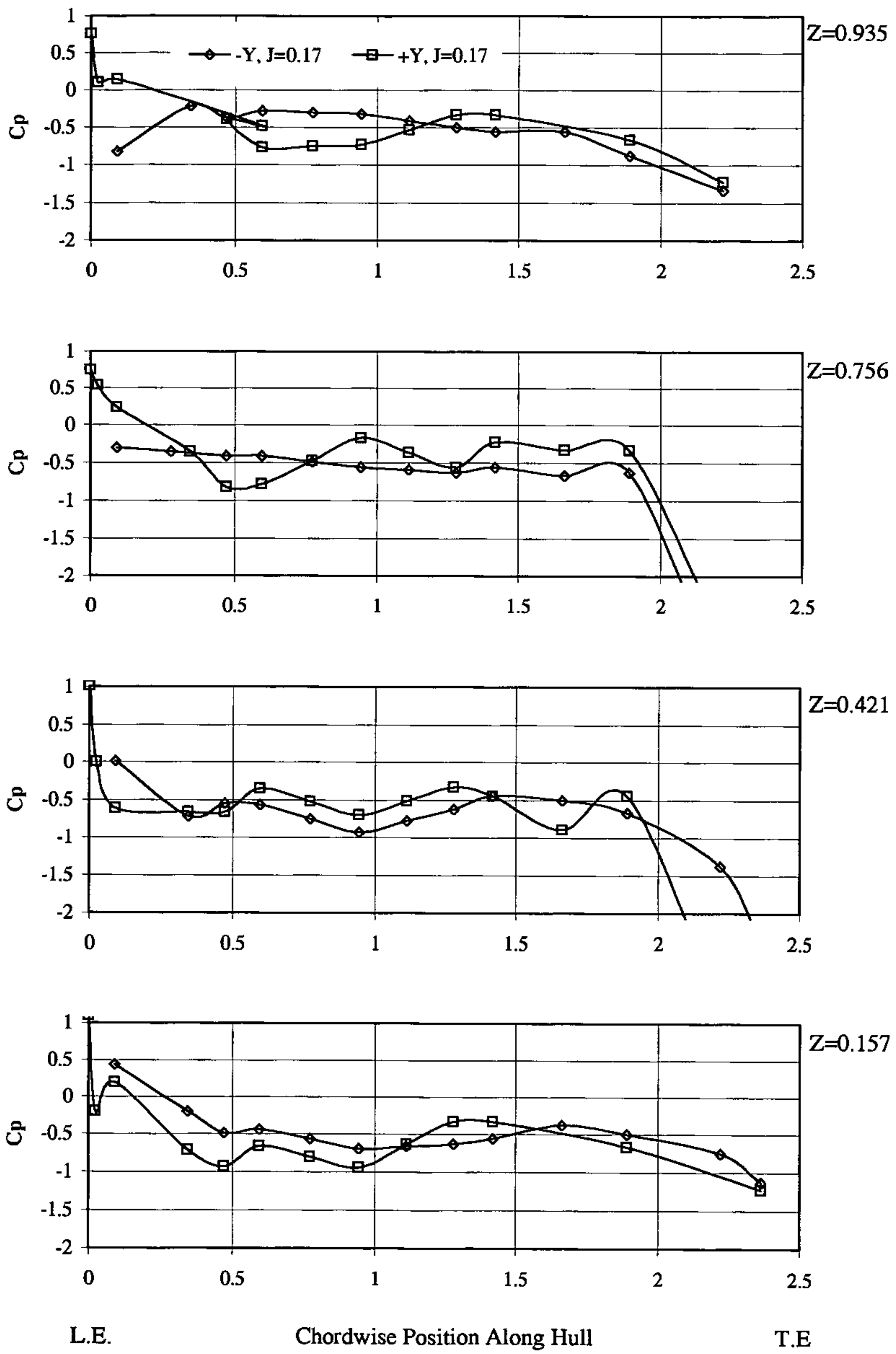


Fig. 55 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.64 at J=0.17 at a skeg rudder angle of -10 degrees

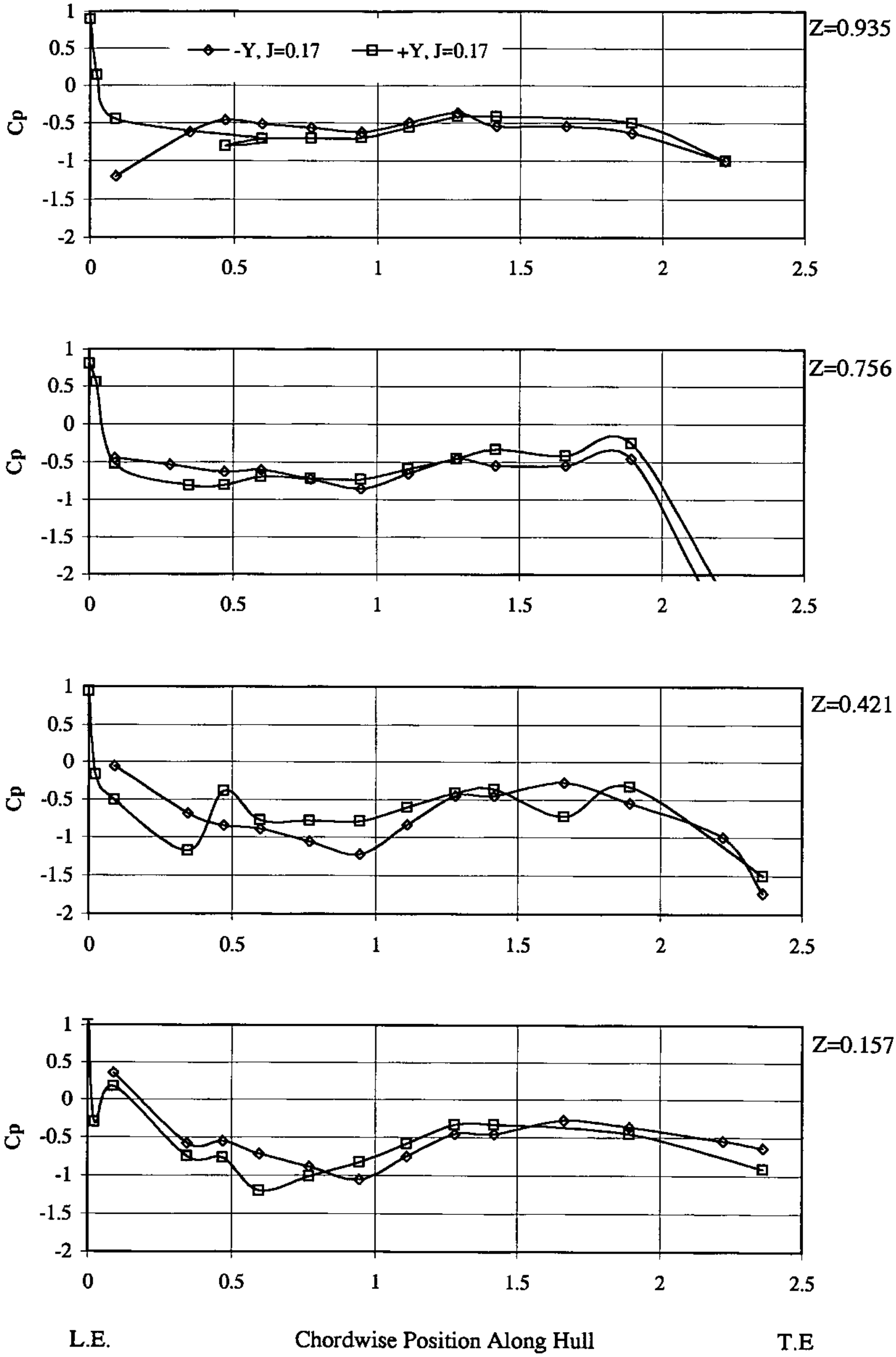


Fig. 55 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.64 at J=0.17 at a skeg rudder angle of 0 degrees

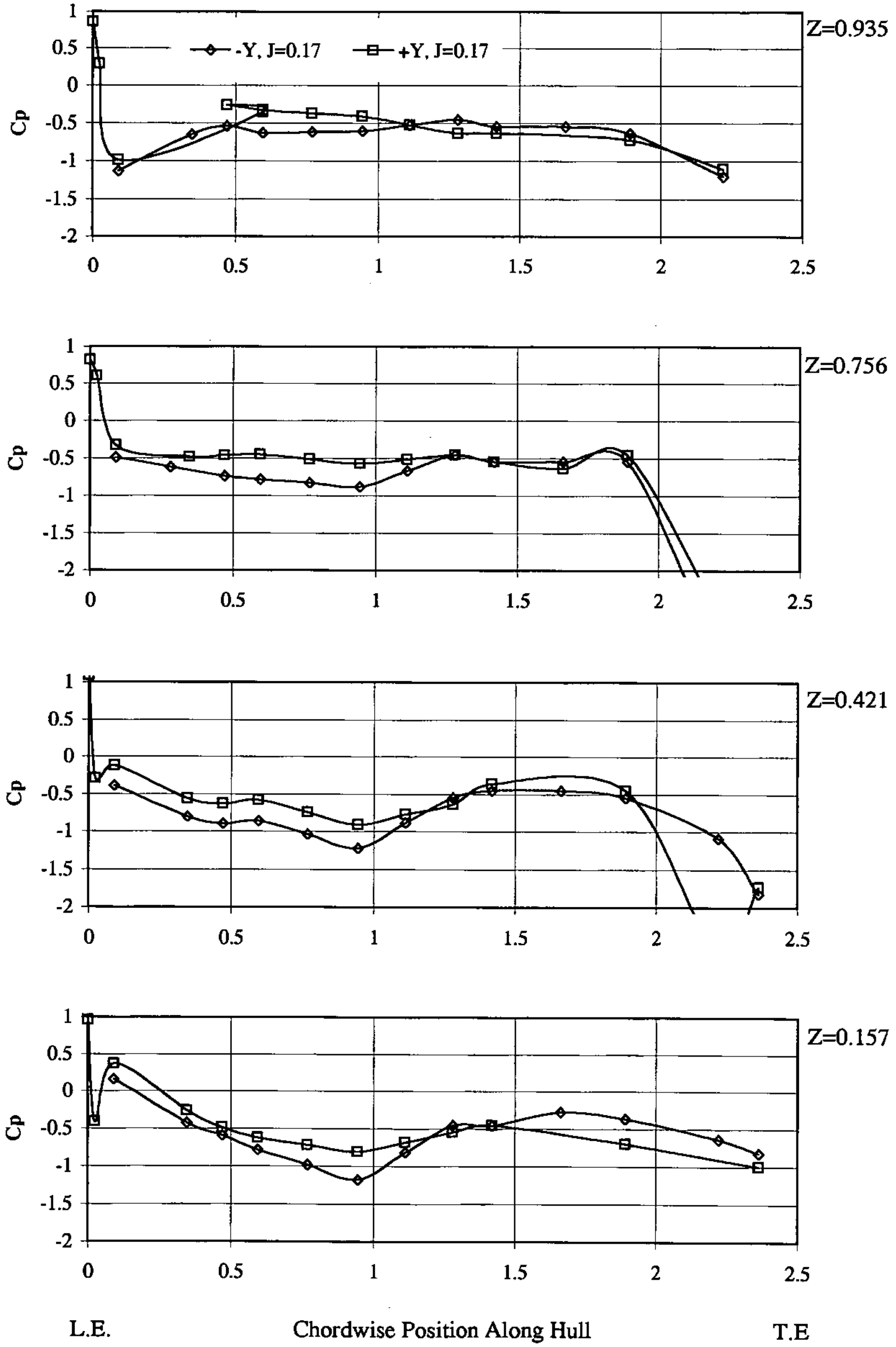


Fig. 55 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.64 at J=0.17 at a skeg rudder angle of +10 degrees

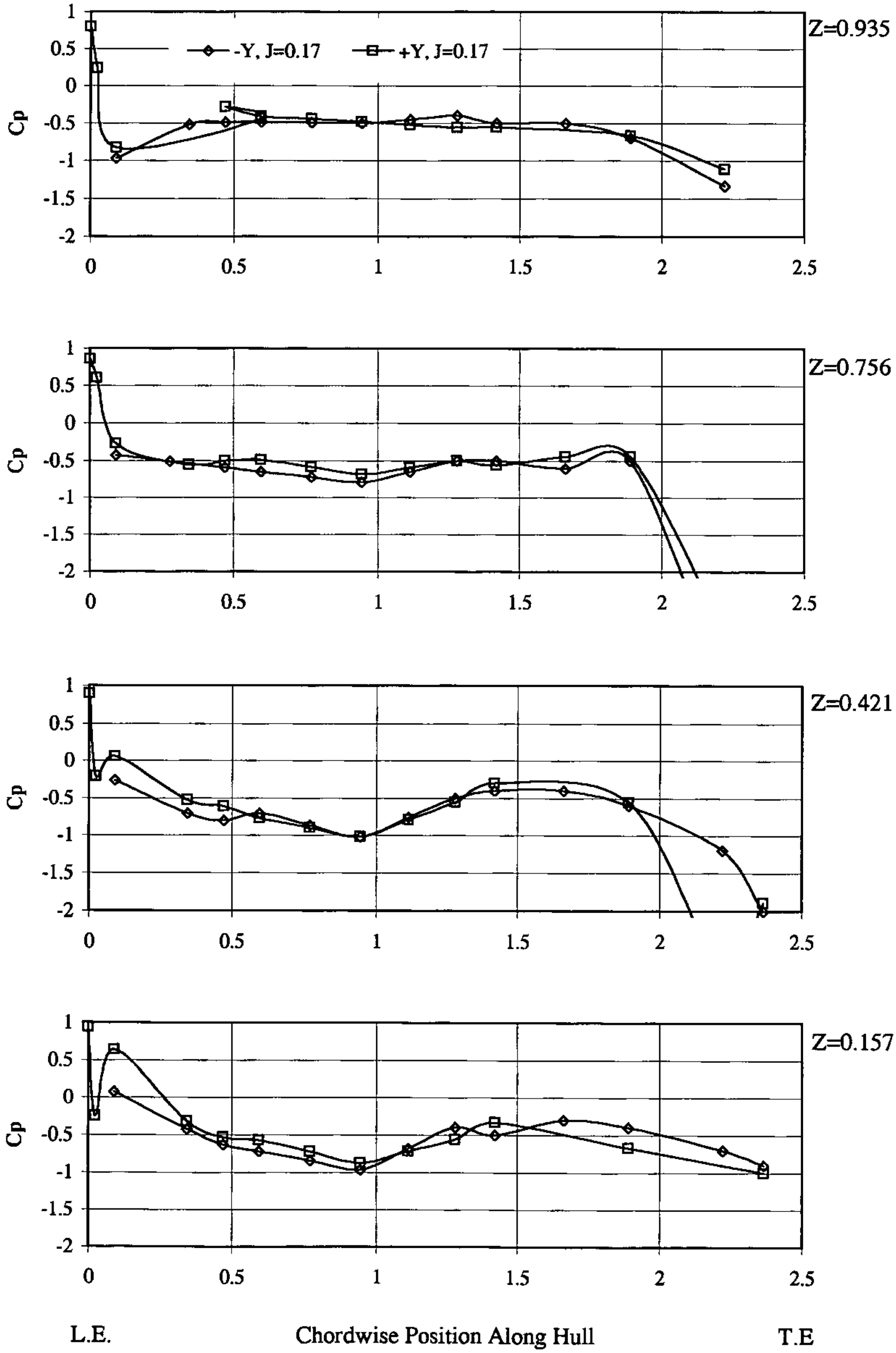


Fig. 55 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.64 at J=0.17 at a skeg rudder angle of +20 degrees

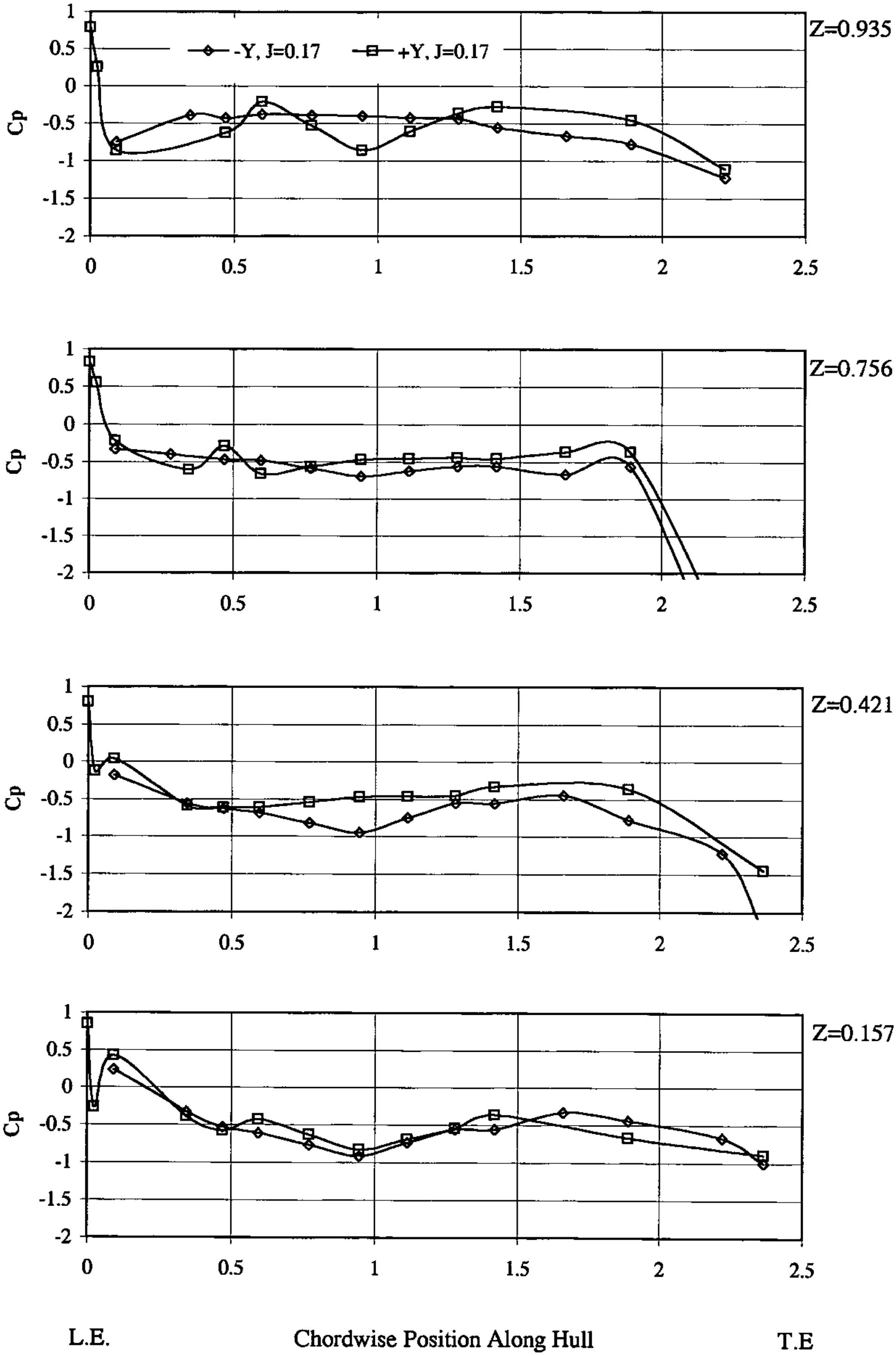


Fig. 55 Chordwise pressure distributions at 4 spanwise positions for the hull for X/D=0.64 at J=0.17 at a skeg rudder angle of +30 degrees

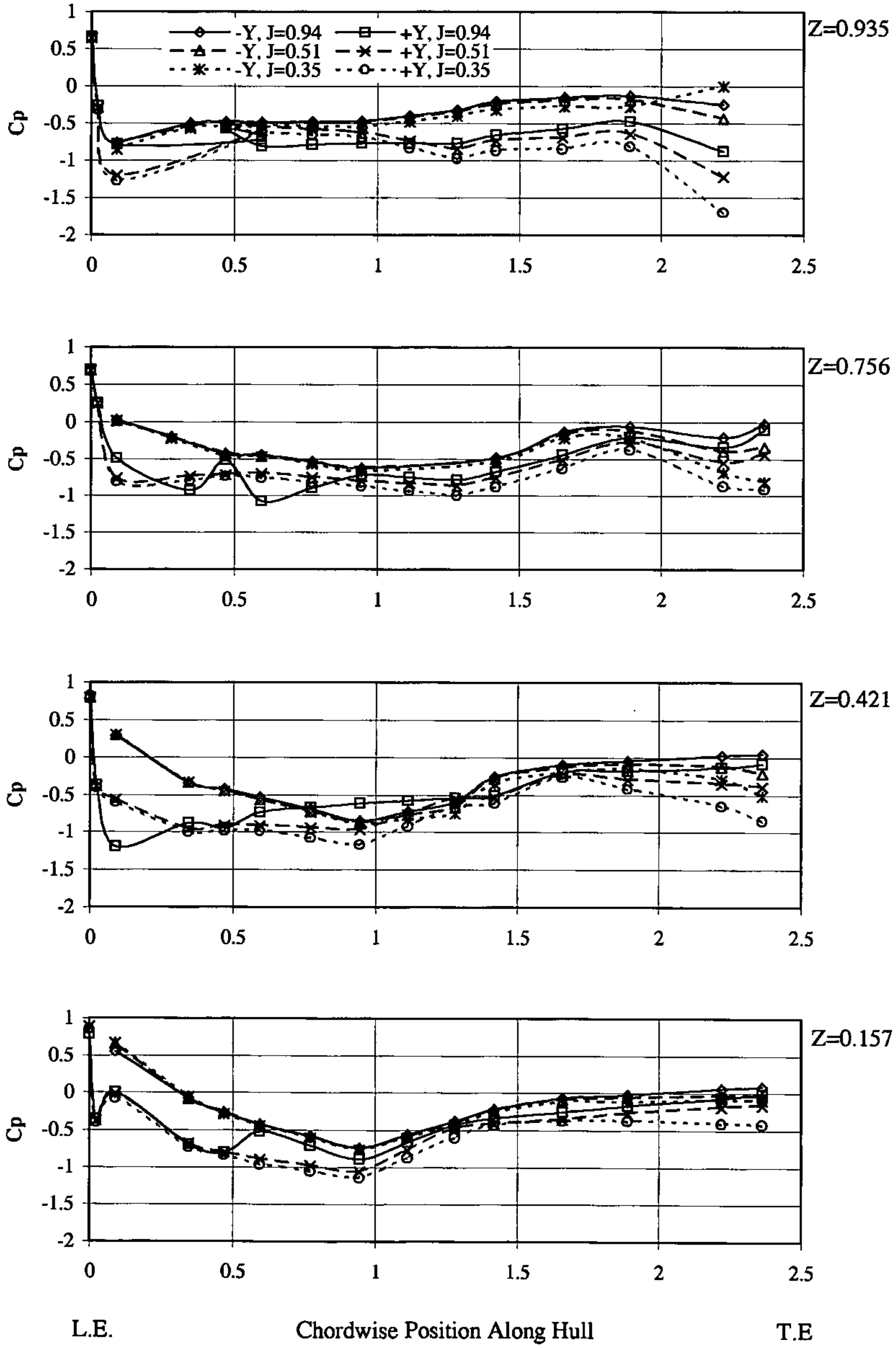


Fig. 56 Chordwise pressure distributions at 4 spanwise positions for the hull at a yaw angle of -7.5 degrees for X/D=0.39 and varying J at a skeg rudder angle of -30 degrees.

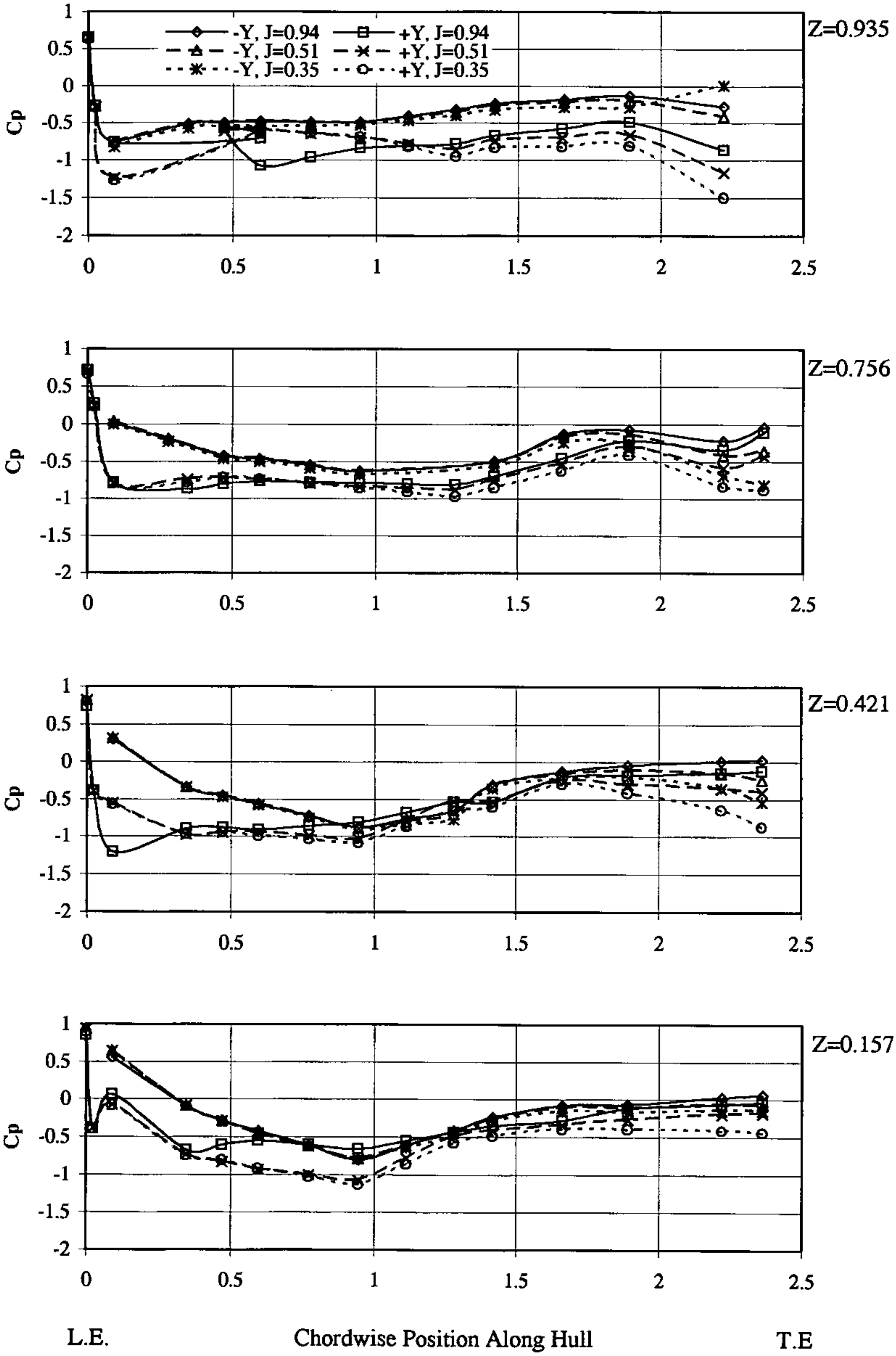


Fig. 56 Chordwise pressure distributions at 4 spanwise positions for the hull at a yaw angle of -7.5 degrees for X/D=0.39 and varying J at a skeg rudder angle of -20 degrees.

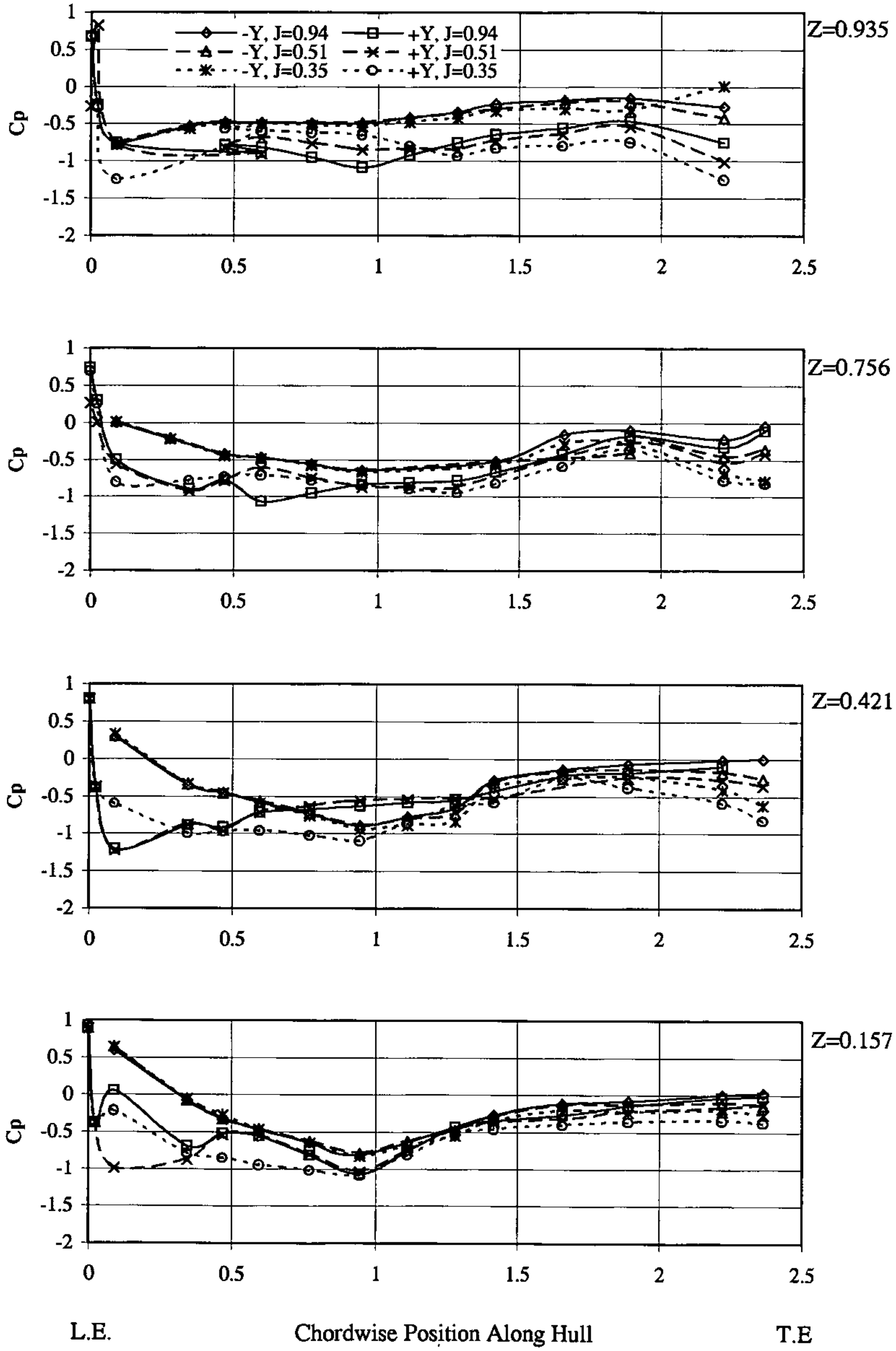


Fig. 56 Chordwise pressure distributions at 4 spanwise positions for the hull at a yaw angle of -7.5 degrees for X/D=0.39 and varying J at a skeg rudder angle of -10 degrees.

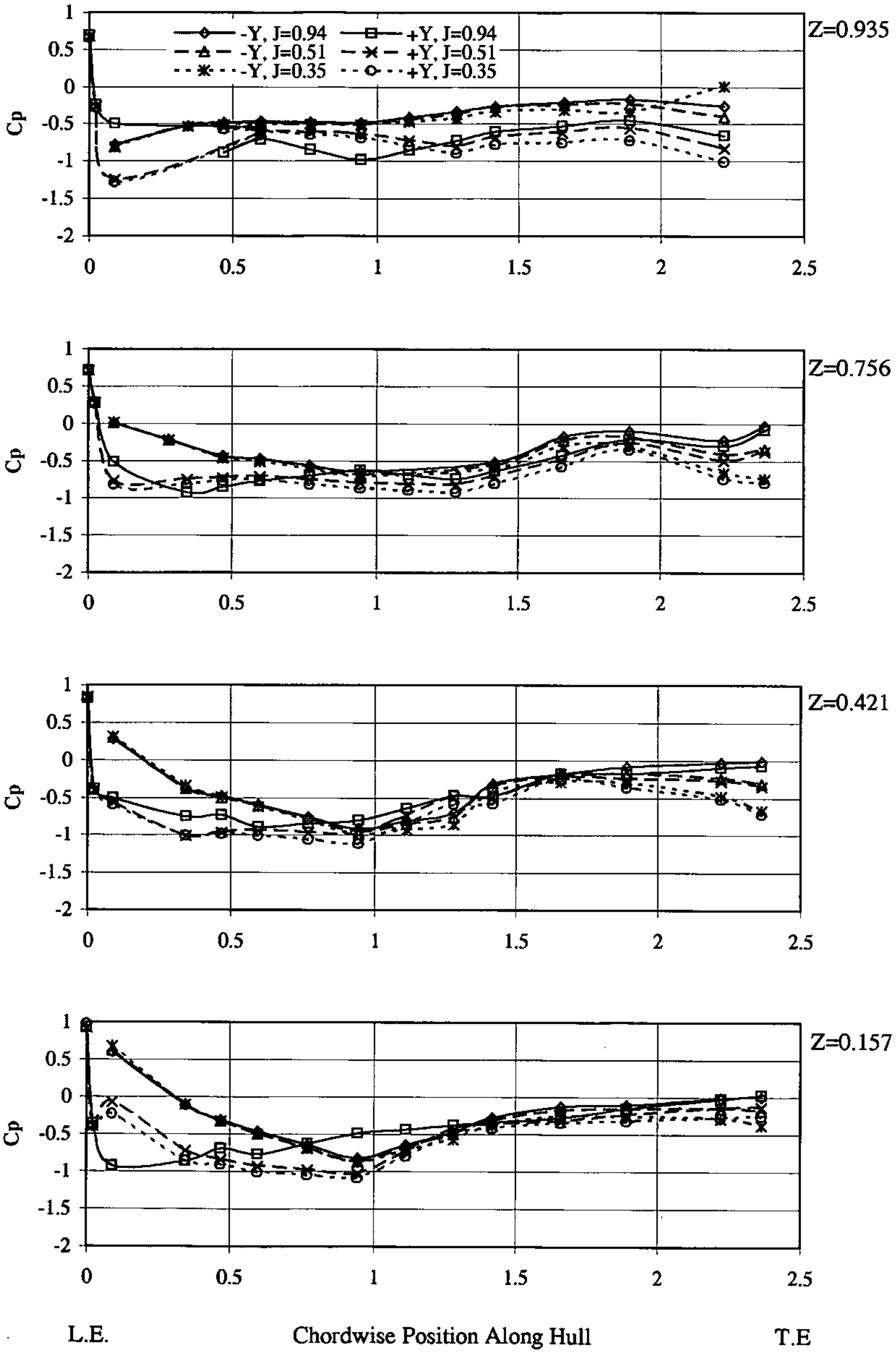


Fig. 56 Chordwise pressure distributions at 4 spanwise positions for the hull at a yaw angle of -7.5 degrees for X/D=0.39 and varying J at a skeg rudder angle of 0 degrees.

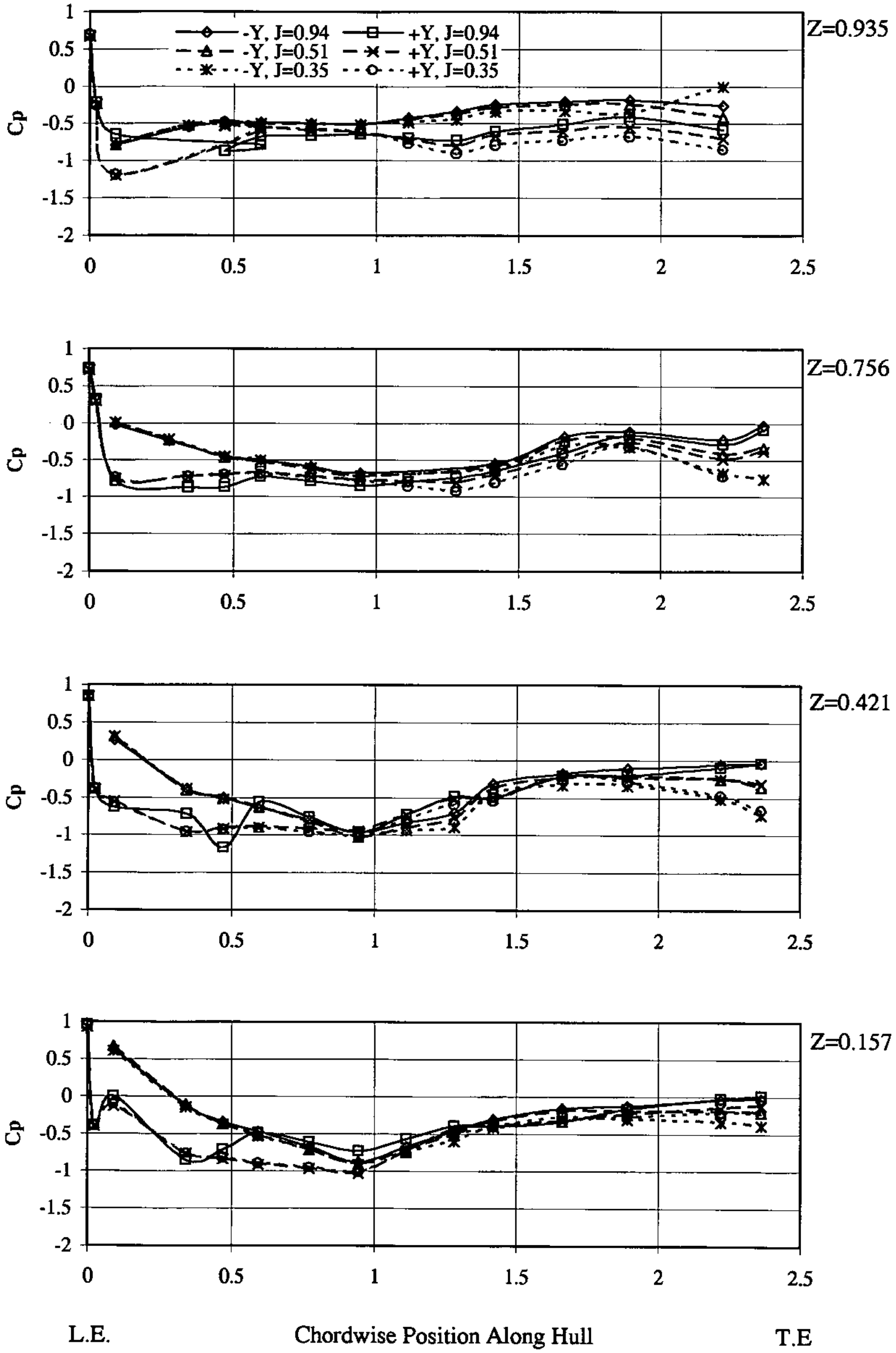


Fig. 56 Chordwise pressure distributions at 4 spanwise positions for the hull at a yaw angle of -7.5 degrees for X/D=0.39 and varying J at a skeg rudder angle of +10 degrees.

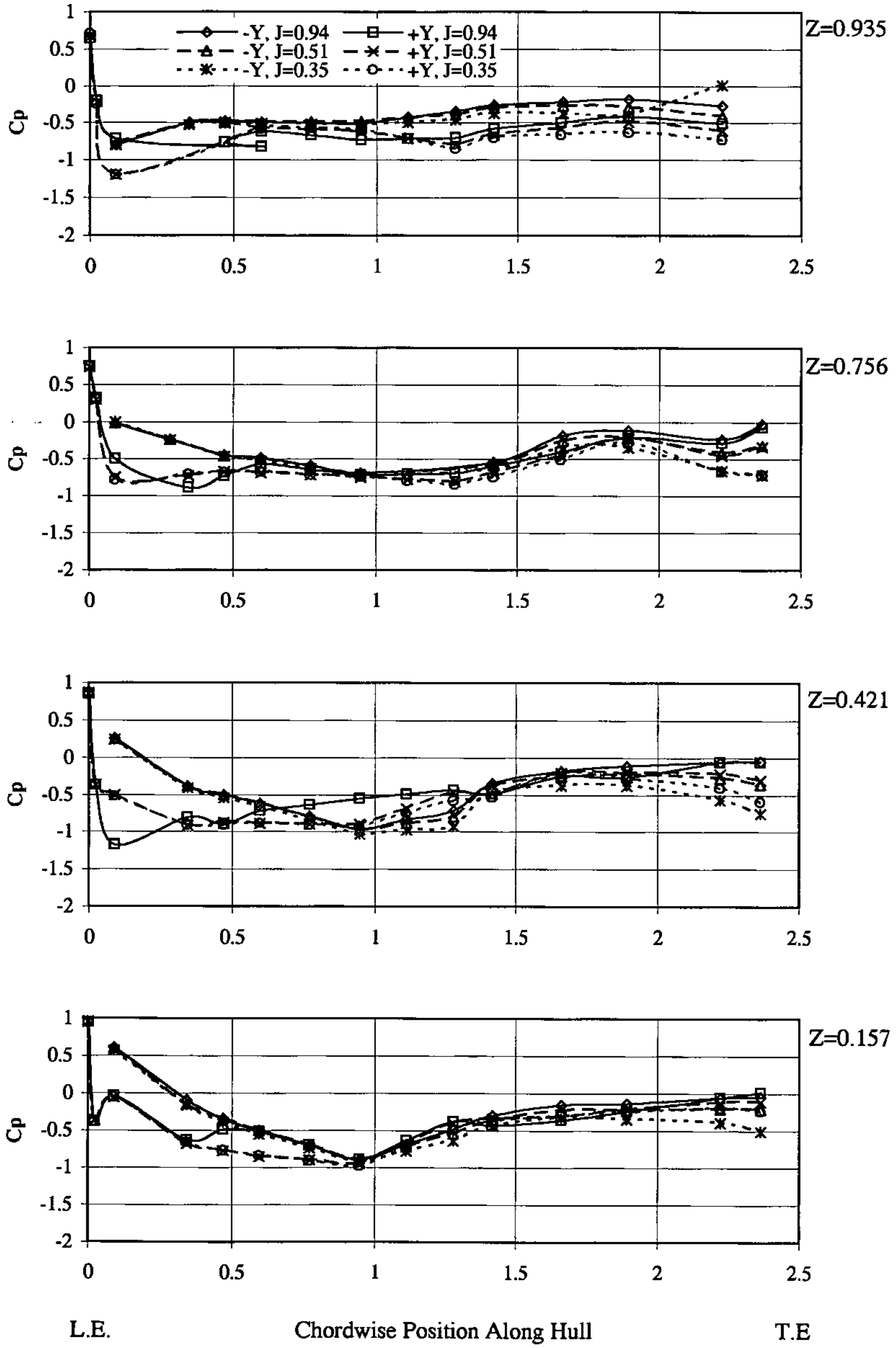


Fig. 56 . Chordwise pressure distributions at 4 spanwise positions for the hull at a yaw angle of -7.5 degrees for X/D=0.39 and varying J at a skeg rudder angle of +20 degrees.

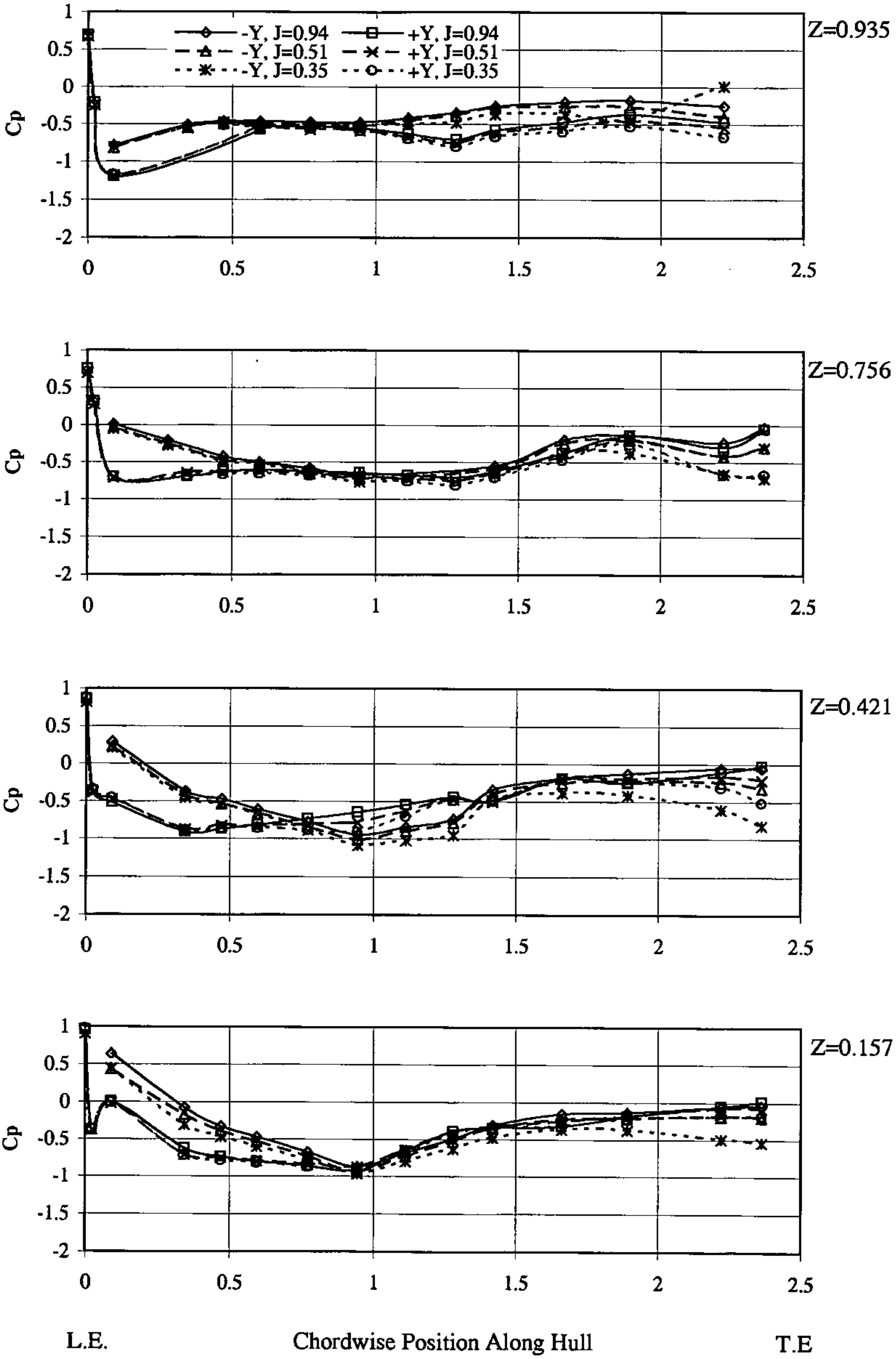


Fig. 56 Chordwise pressure distributions at 4 spanwise positions for the hull at a yaw angle of -7.5 degrees for X/D=0.39 and varying J at a skeg rudder angle of +30 degrees.

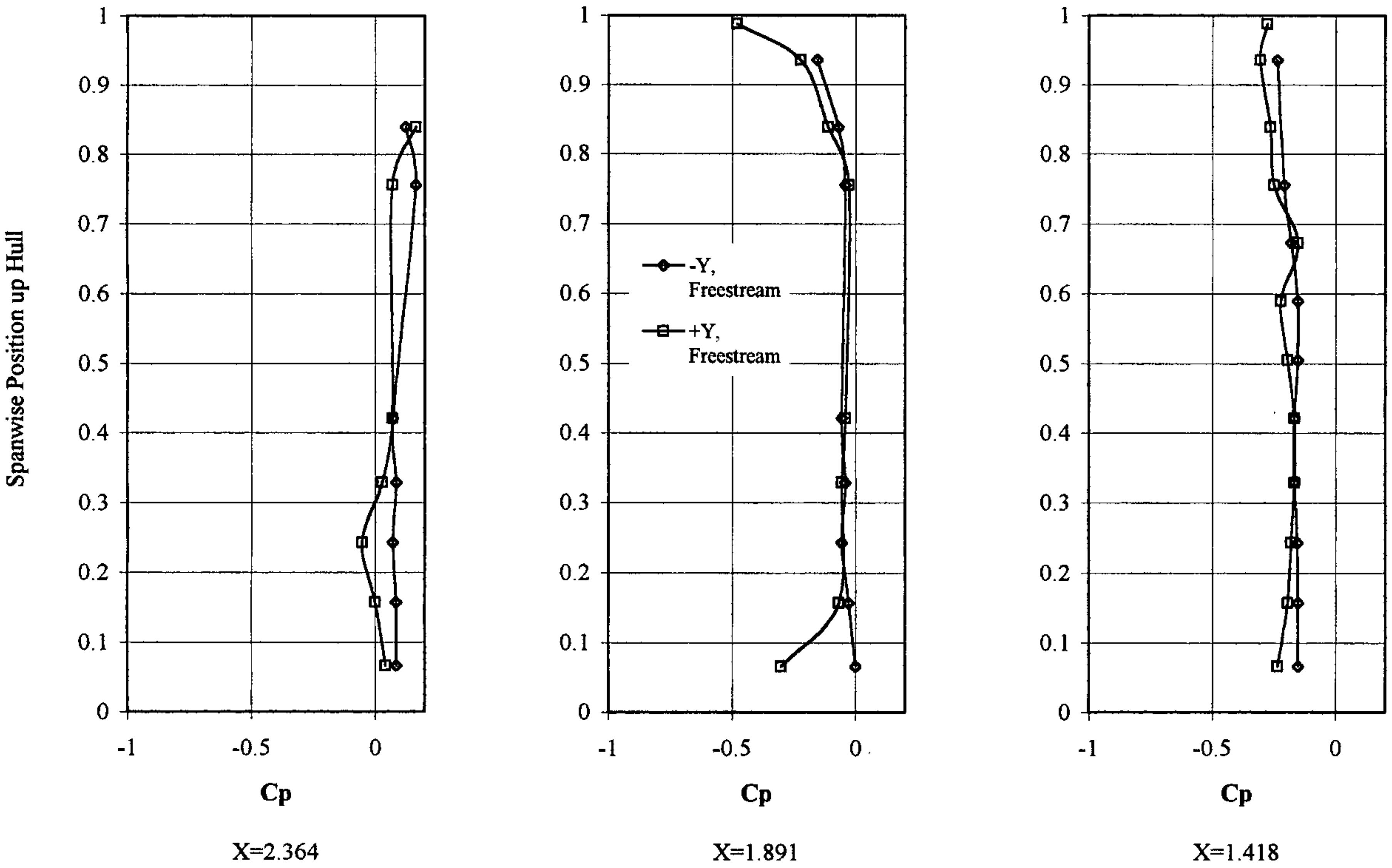


Fig. 57 Spanwise pressure distributions at 3 aft chordwise positions of the hull for X/D=0.39 in freestream at a skeg rudder angle of -30 degrees

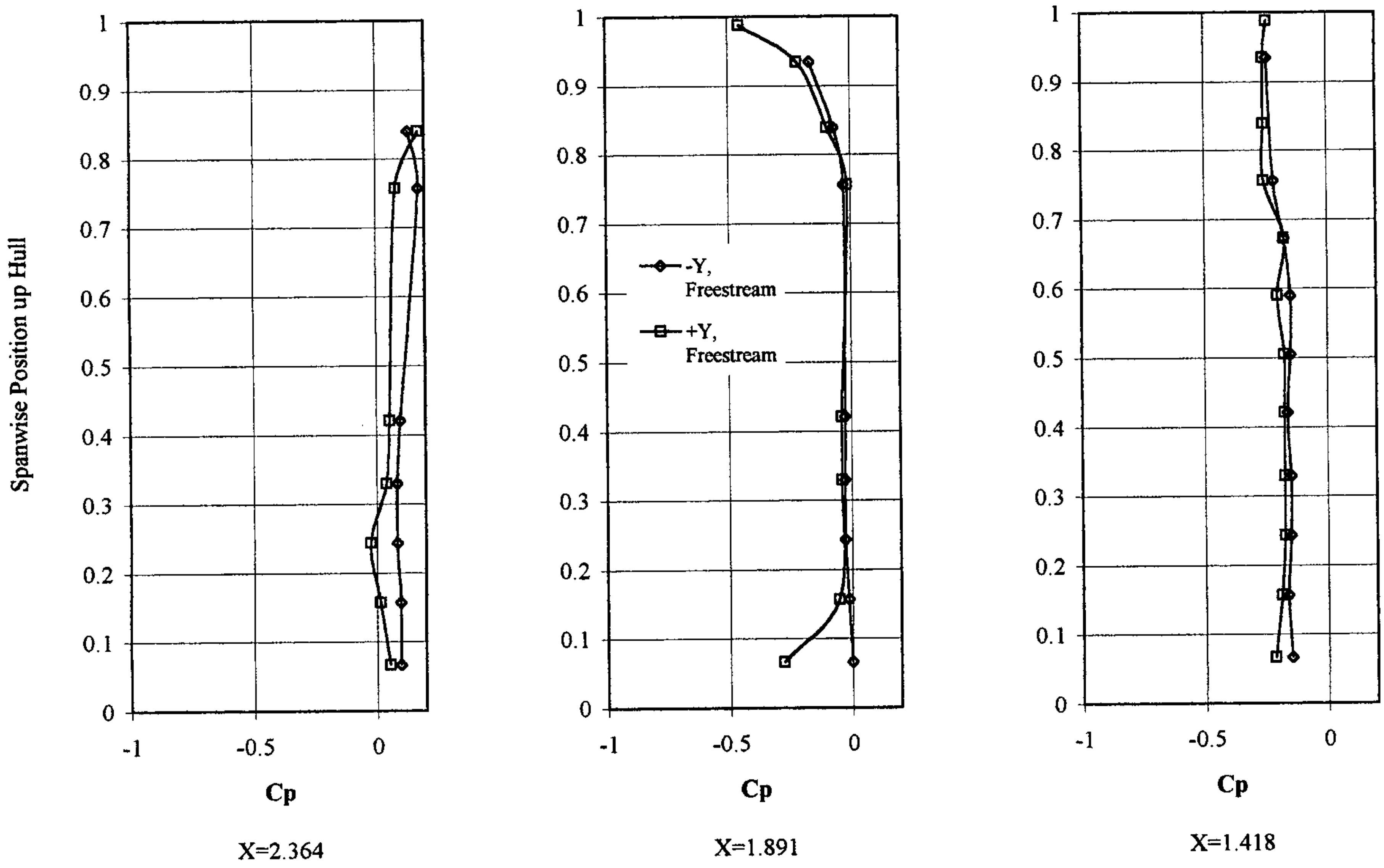


Fig. 57 Spanwise pressure distributions at 3 aft chordwise positions of the hull for X/D=0.39 in freestream at a skeg rudder angle of -20 degrees

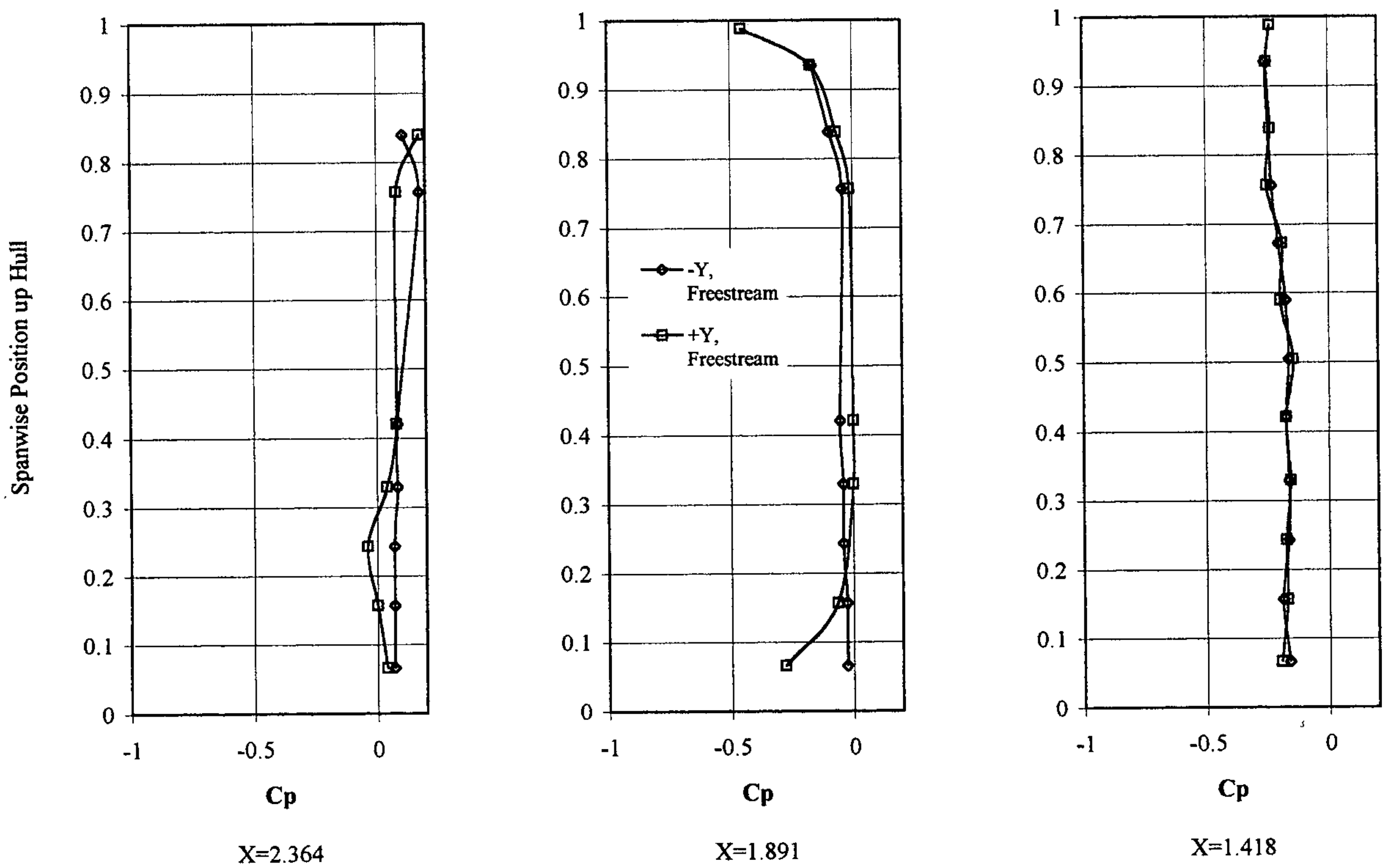


Fig. 57 Spanwise pressure distributions at 3 aft chordwise positions of the hull for X/D=0.39 in freestream at a skeg rudder angle of -10 degrees

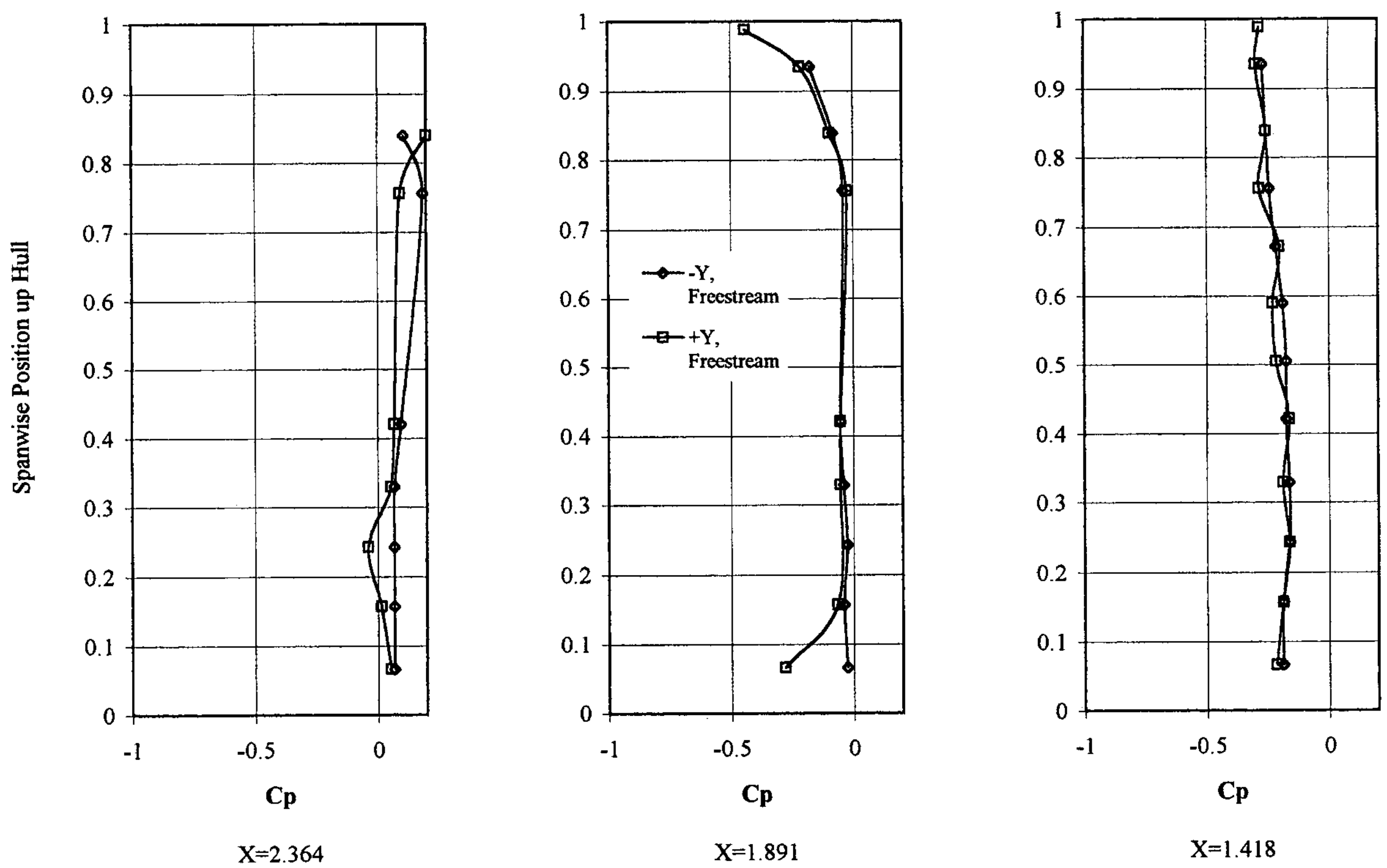


Fig. 57 Spanwise pressure distributions at 3 aft chordwise positions of the hull for X/D=0.39 in freestream at a skeg rudder angle of 0 degrees

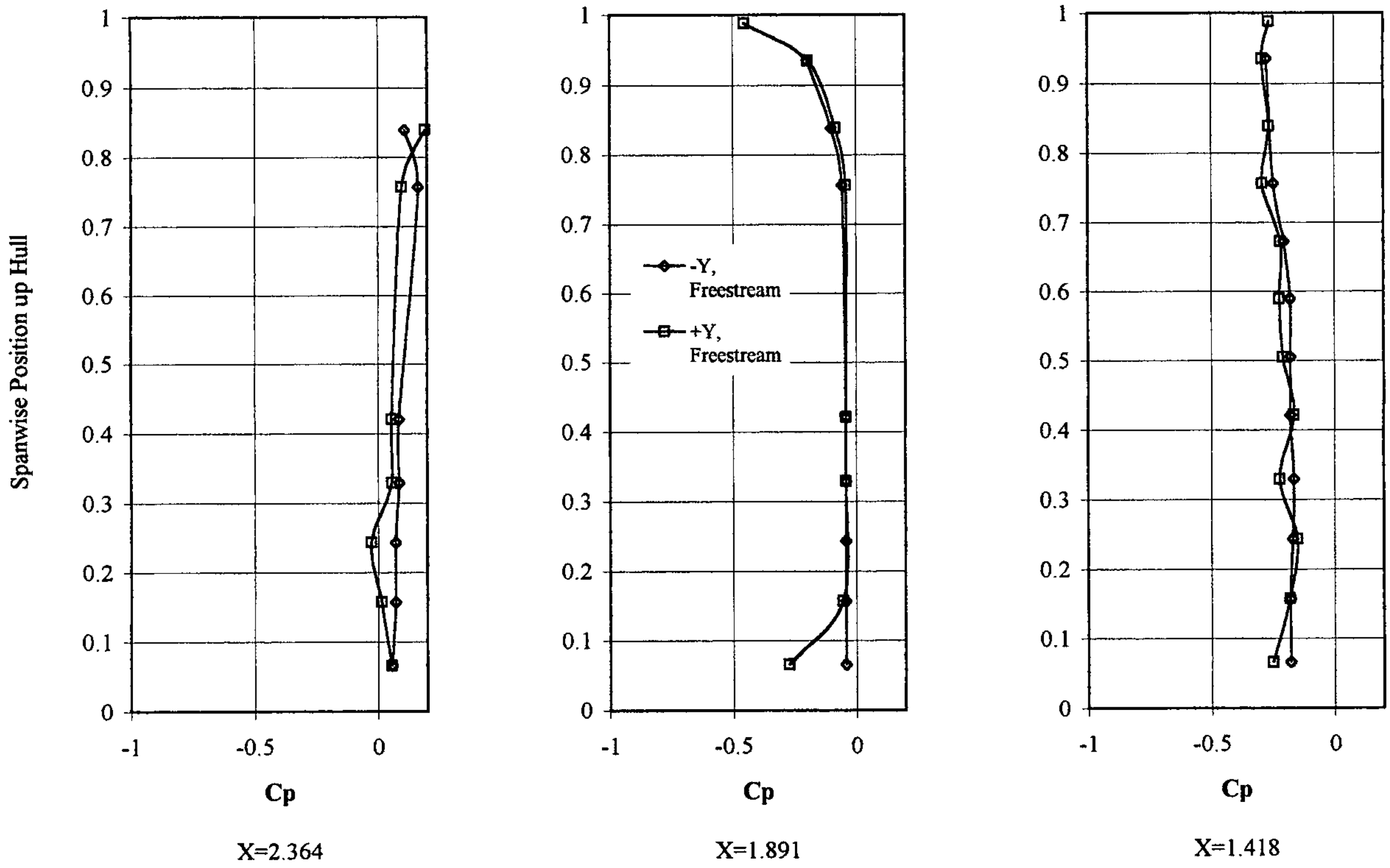


Fig. 57 Spanwise pressure distributions at 3 aft chordwise positions of the hull for X/D=0.39 in freestream at a skeg rudder angle of +10 degrees

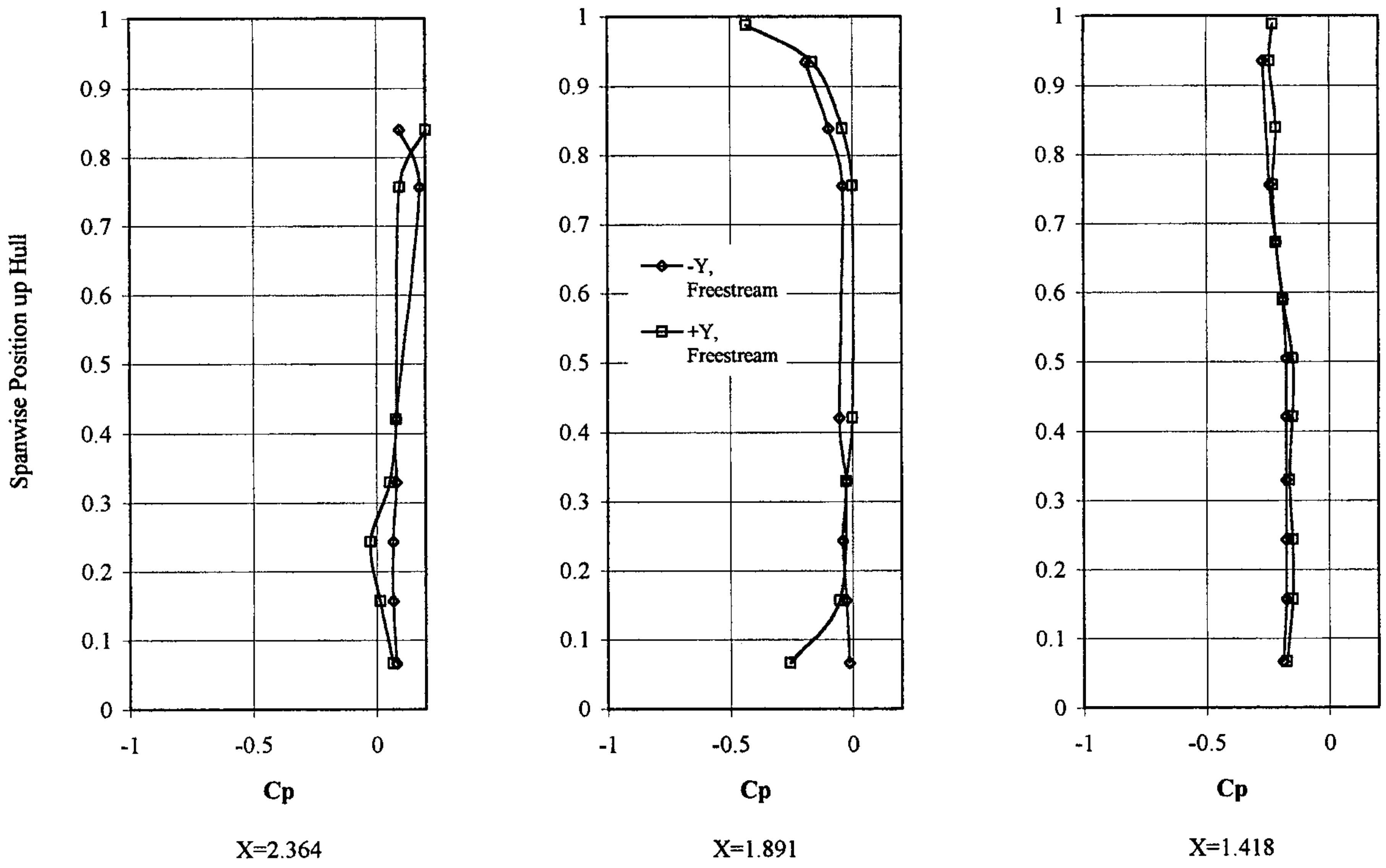


Fig. 57 Spanwise pressure distributions at 3 aft chordwise positions of the hull for X/D=0.39 in freestream at a skeg rudder angle of +20 degrees

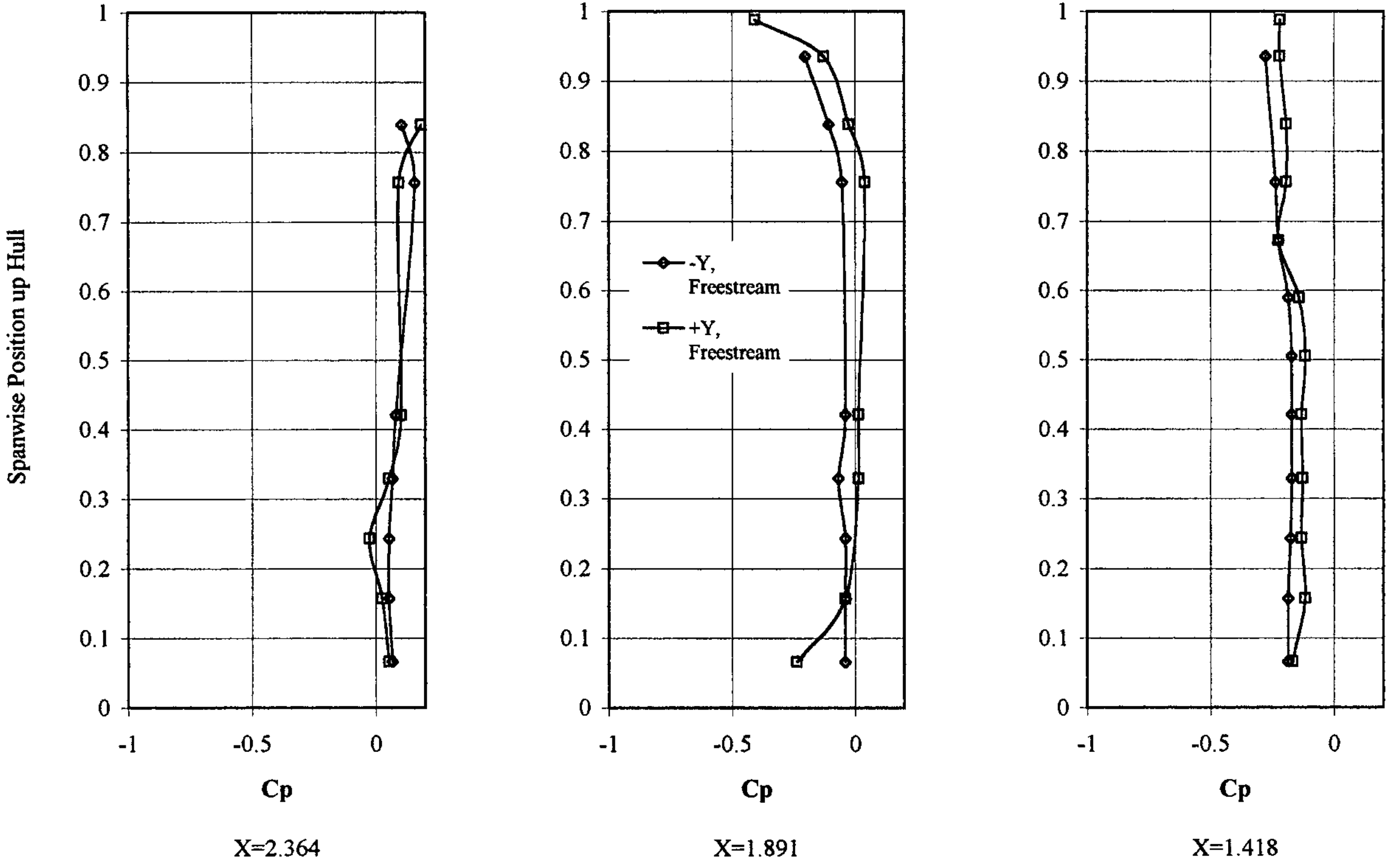


Fig. 57 Spanwise pressure distributions at 3 aft chordwise positions of the hull for X/D=0.39 in freestream at a skeg rudder angle of +30 degrees

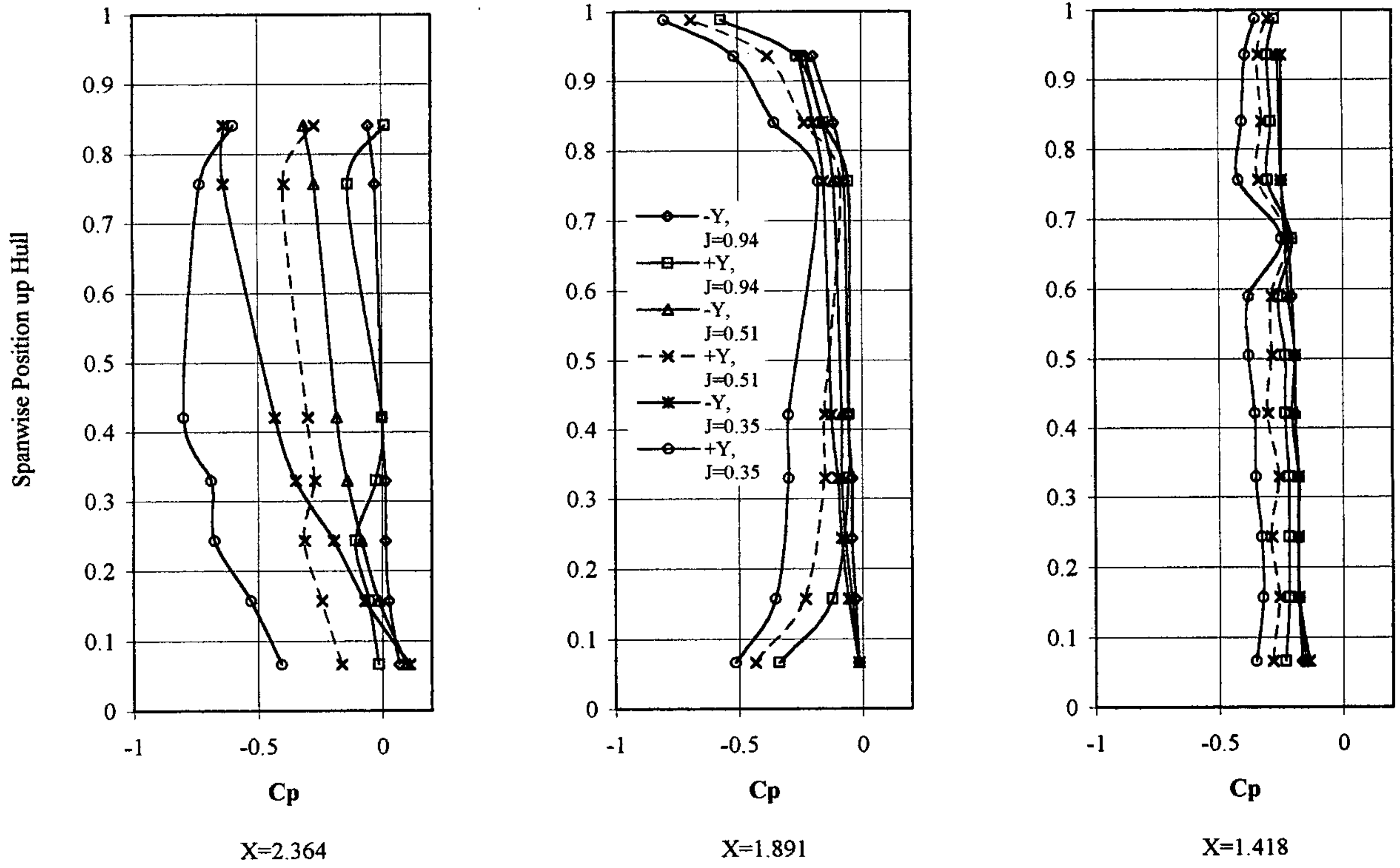


Fig. 58 Spanwise Pressure distributions at 3 aft chordwise positions of the hull for X/D=0.39 for varying J at a skeg rudder angle of -30 degrees

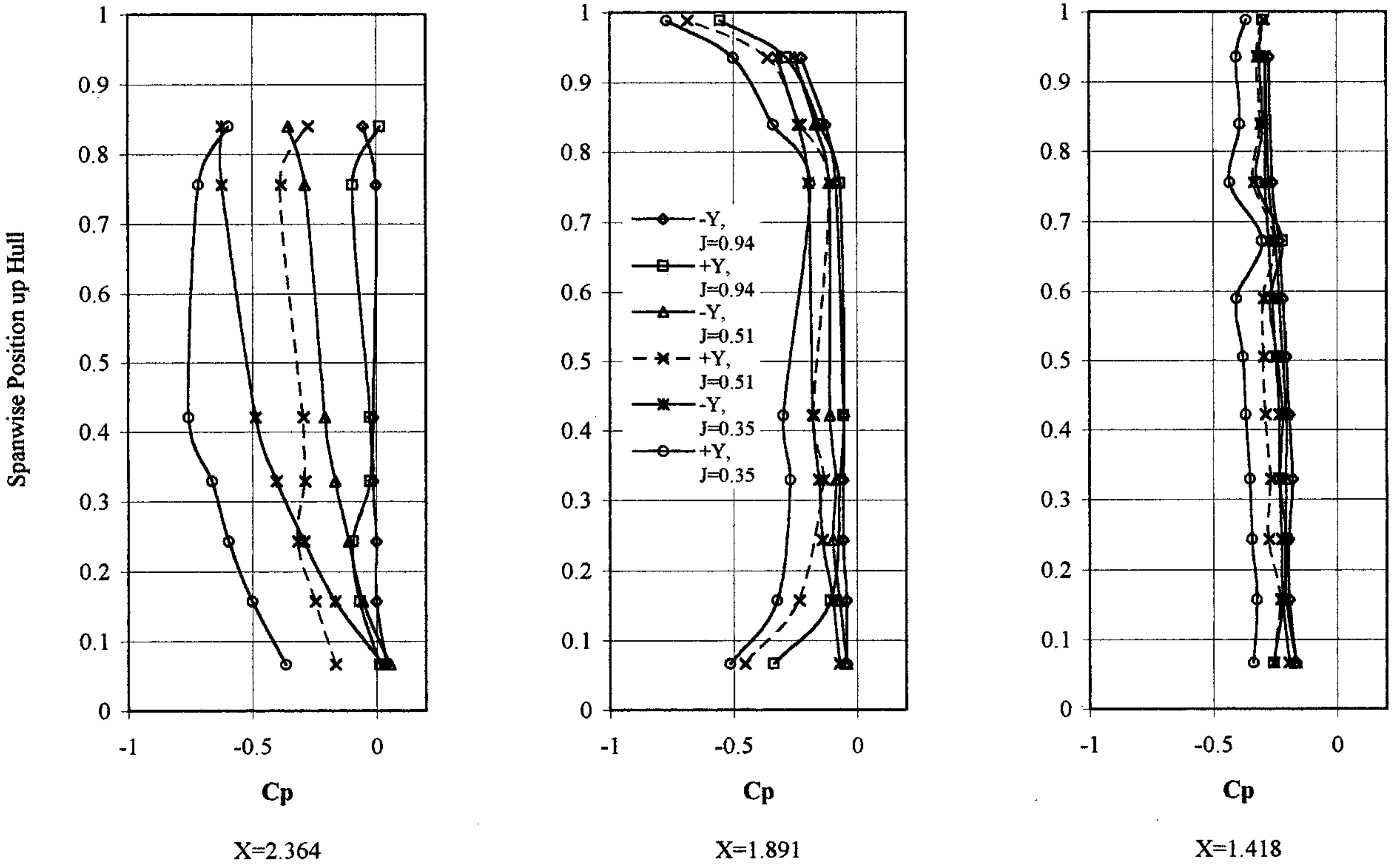


Fig. 58 Spanwise Pressure distributions at 3 aft chordwise positions of the hull for X/D=0.39 for varying J at a skeg rudder angle of -20 degrees

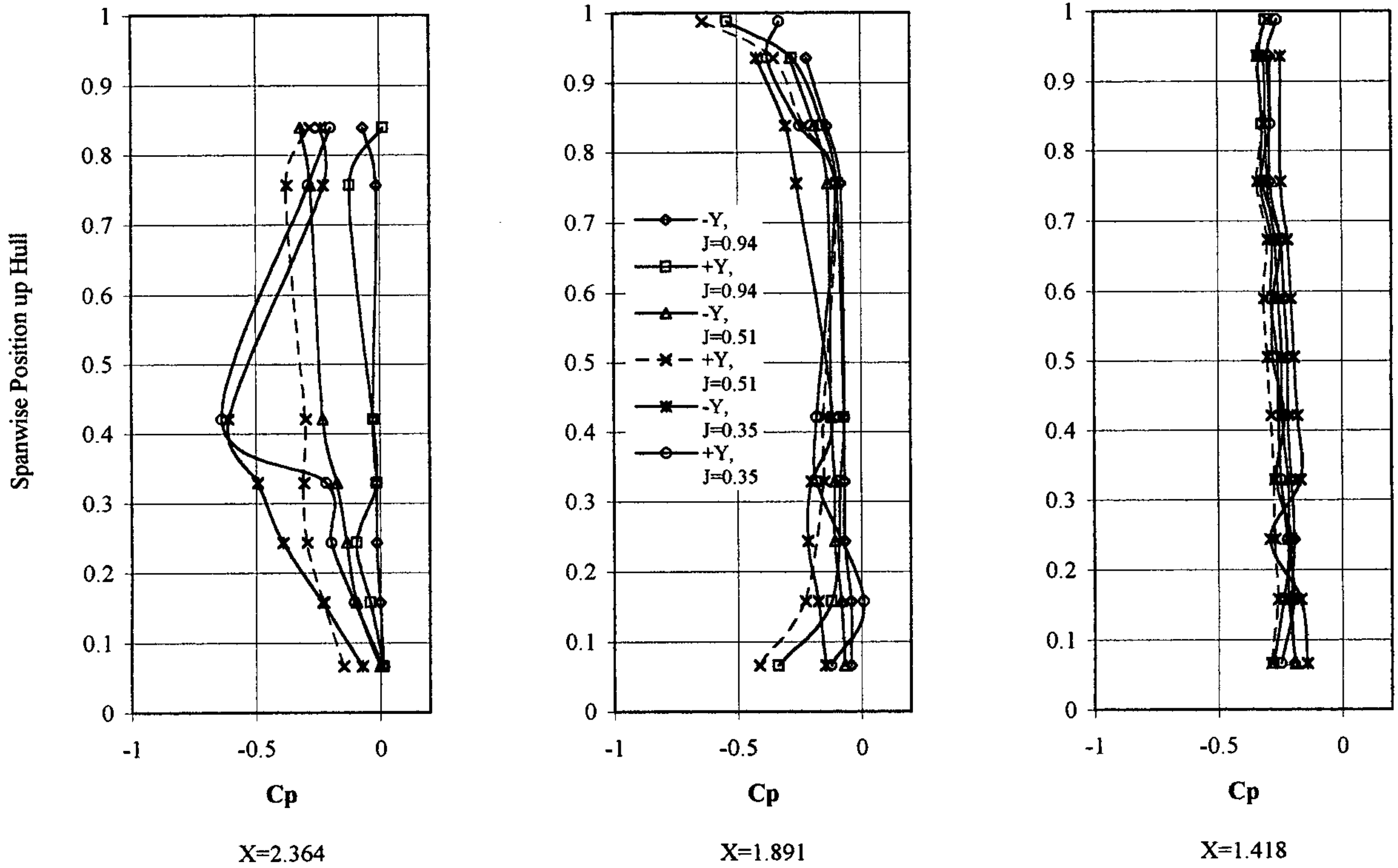


Fig. 58 Spanwise pressure distributions at 3 aft chordwise positions of the hull for X/D=0.39 for varying J at a skeg rudder angle of -10 degrees

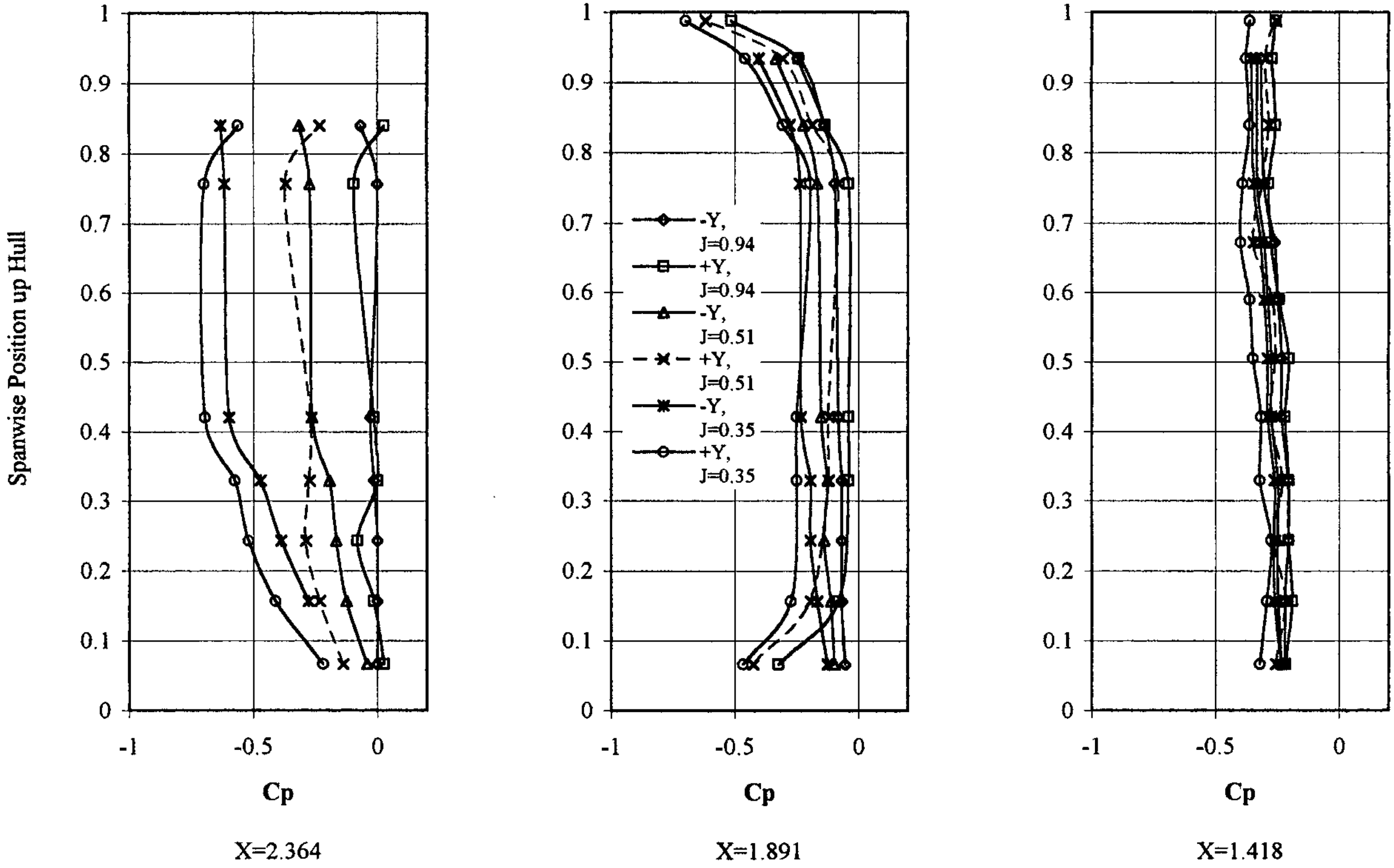


Fig. 58 Spanwise pressure distributions at 3 aft chordwise positions of the hull for X/D=0.39 for varying J at a skeg rudder angle of 0 degrees

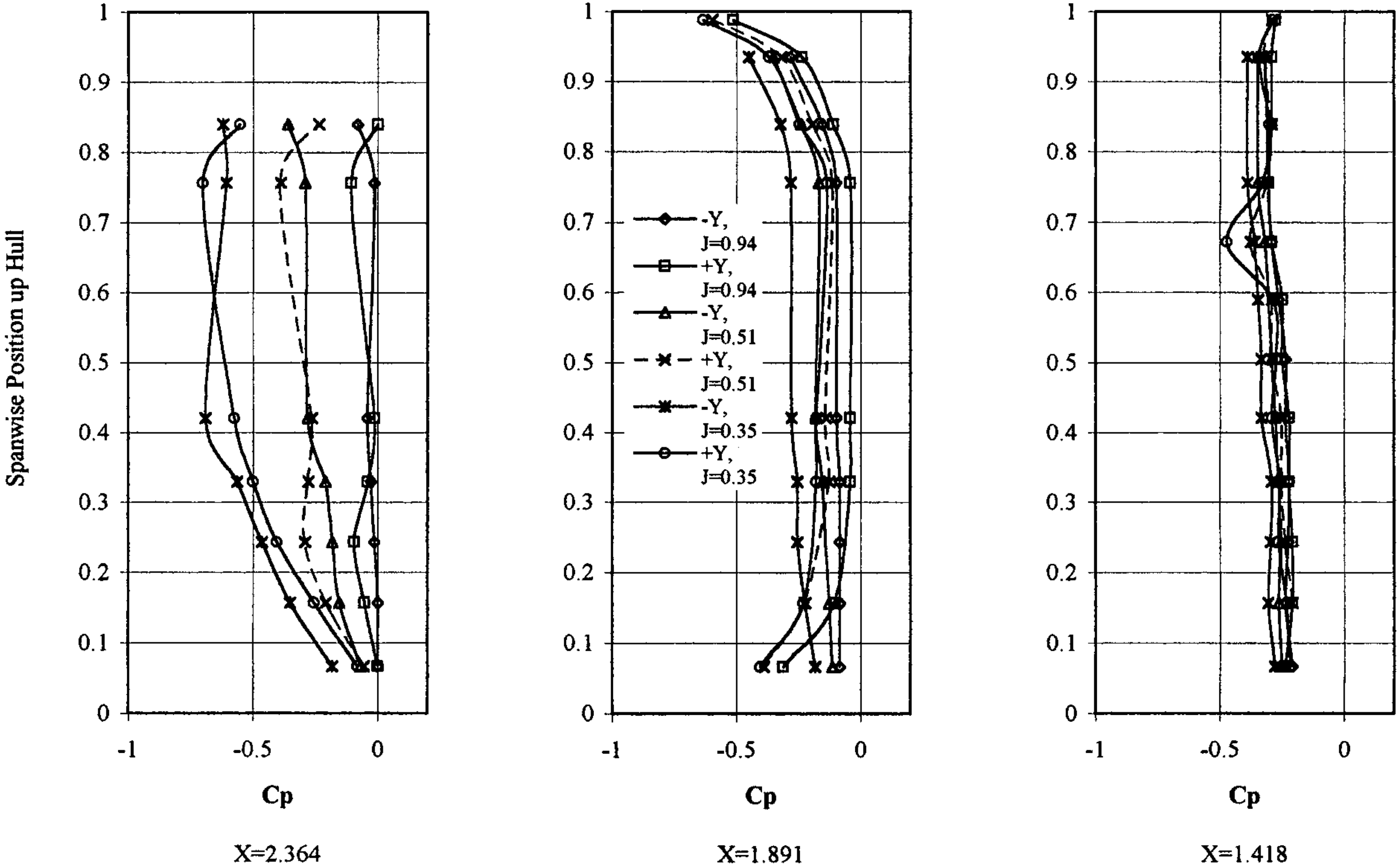


Fig. 58 Spanwise pressure distributions at 3 aft chordwise positions of the hull for X/D=0.39 for varying J at a skeg rudder angle of +10 degrees

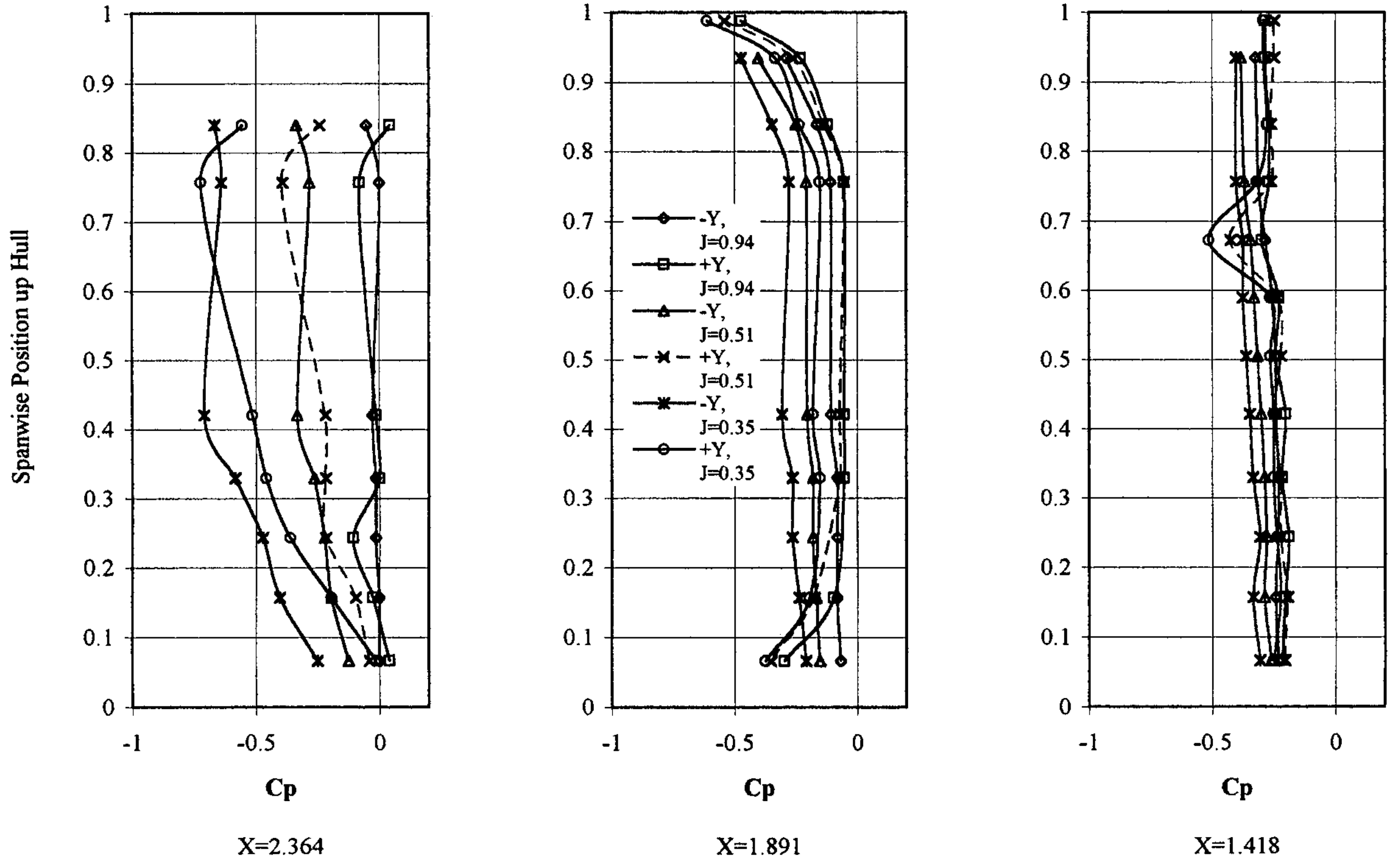


Fig. 58 Spanwise pressure distributions at 3 aft chordwise positions of the hull for X/D=0.39 for varying J at a skeg rudder angle of +20 degrees

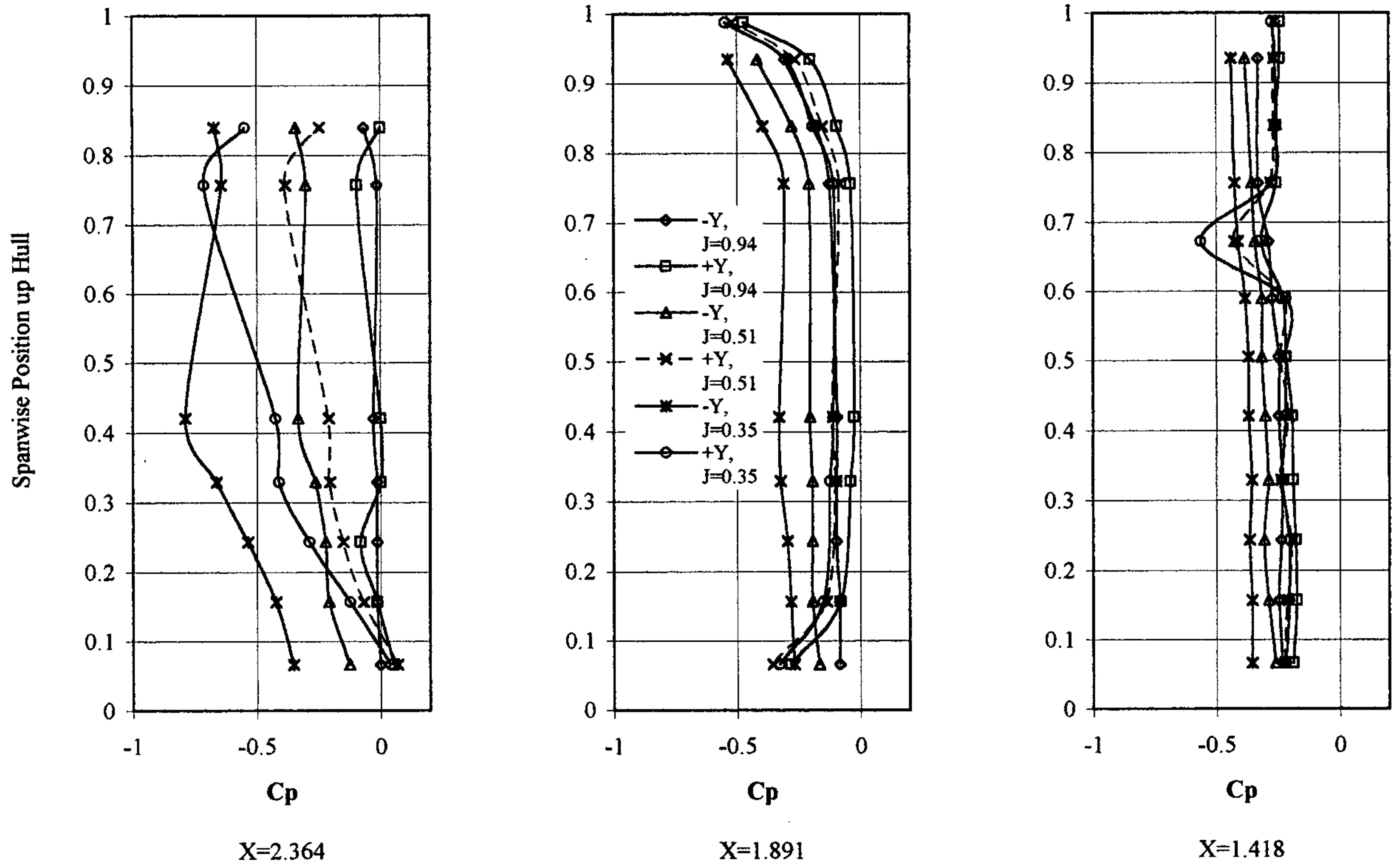


Fig. 58 Spanwise pressure distributions at 3 aft chordwise positions of the hull for X/D=0.39 for varying J at a skeg rudder angle of +30 degrees

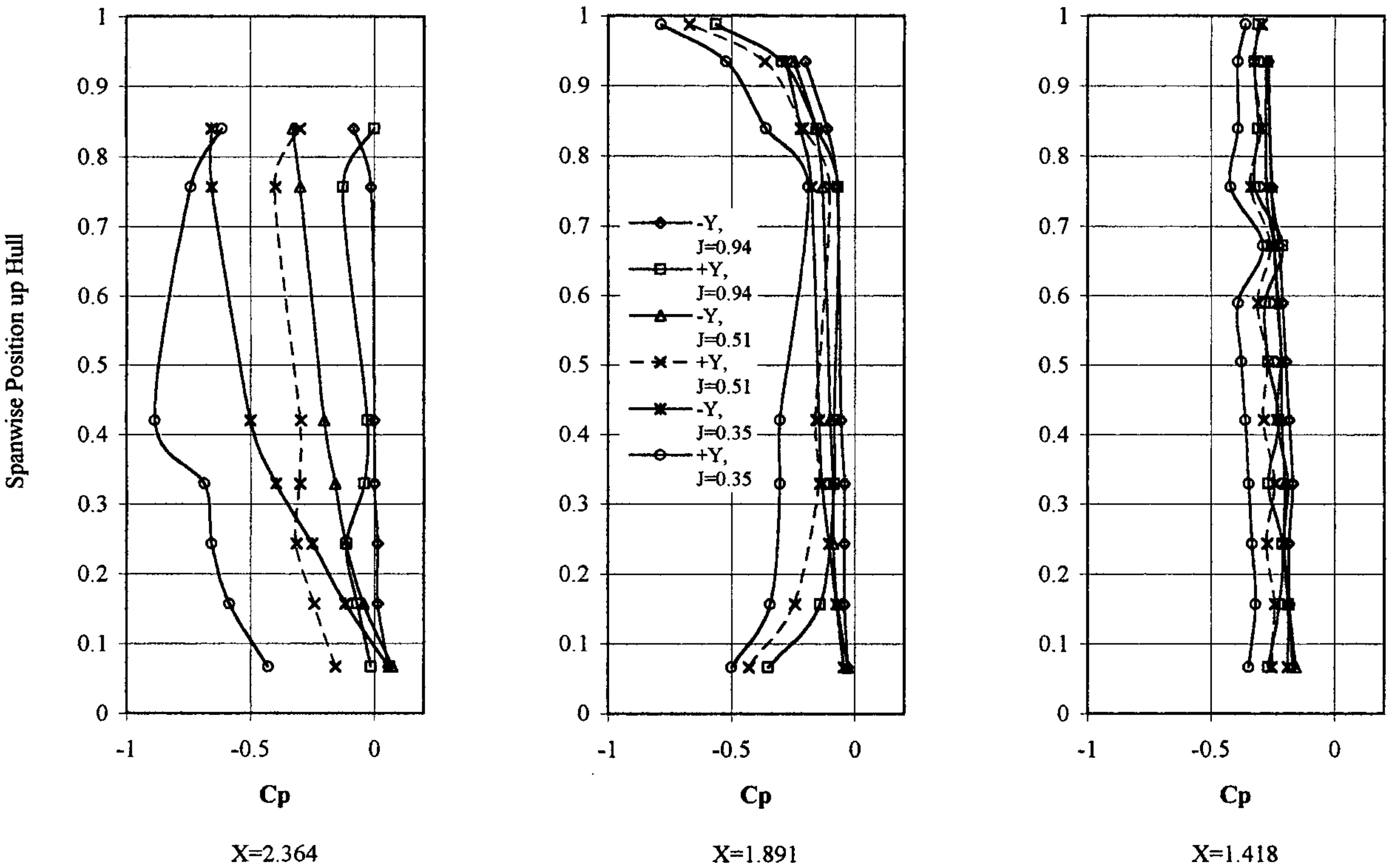


Fig. 59 Spanwise pressure distributions at 3 aft chordwise positions of the hull for X/D=0.52 for varying J at a skeg rudder angle of -30 degrees

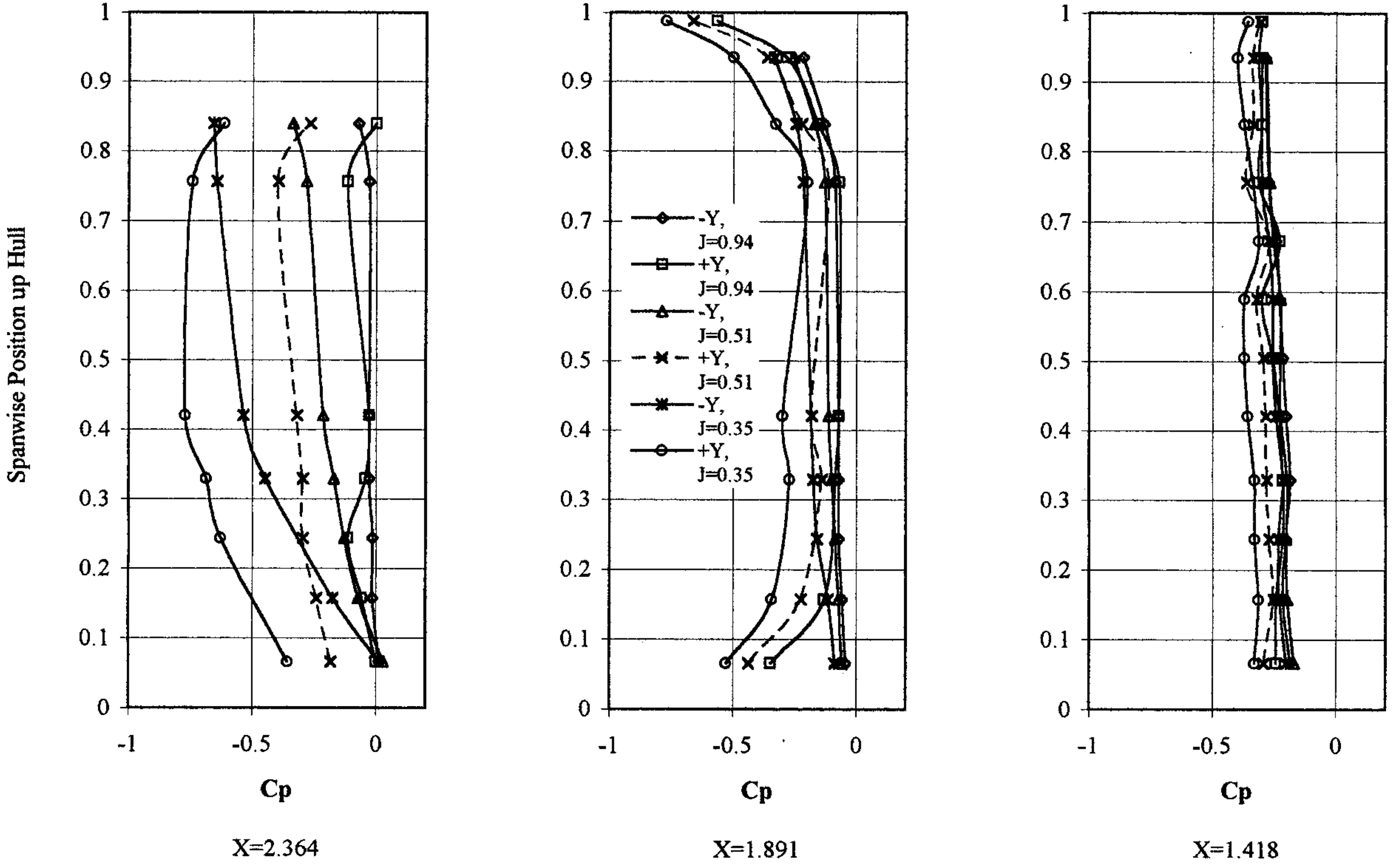


Fig. 59 Spanwise pressure distributions at 3 aft chordwise positions of the hull for X/D=0.52 for varying J at a skeg rudder angle of -20 degrees

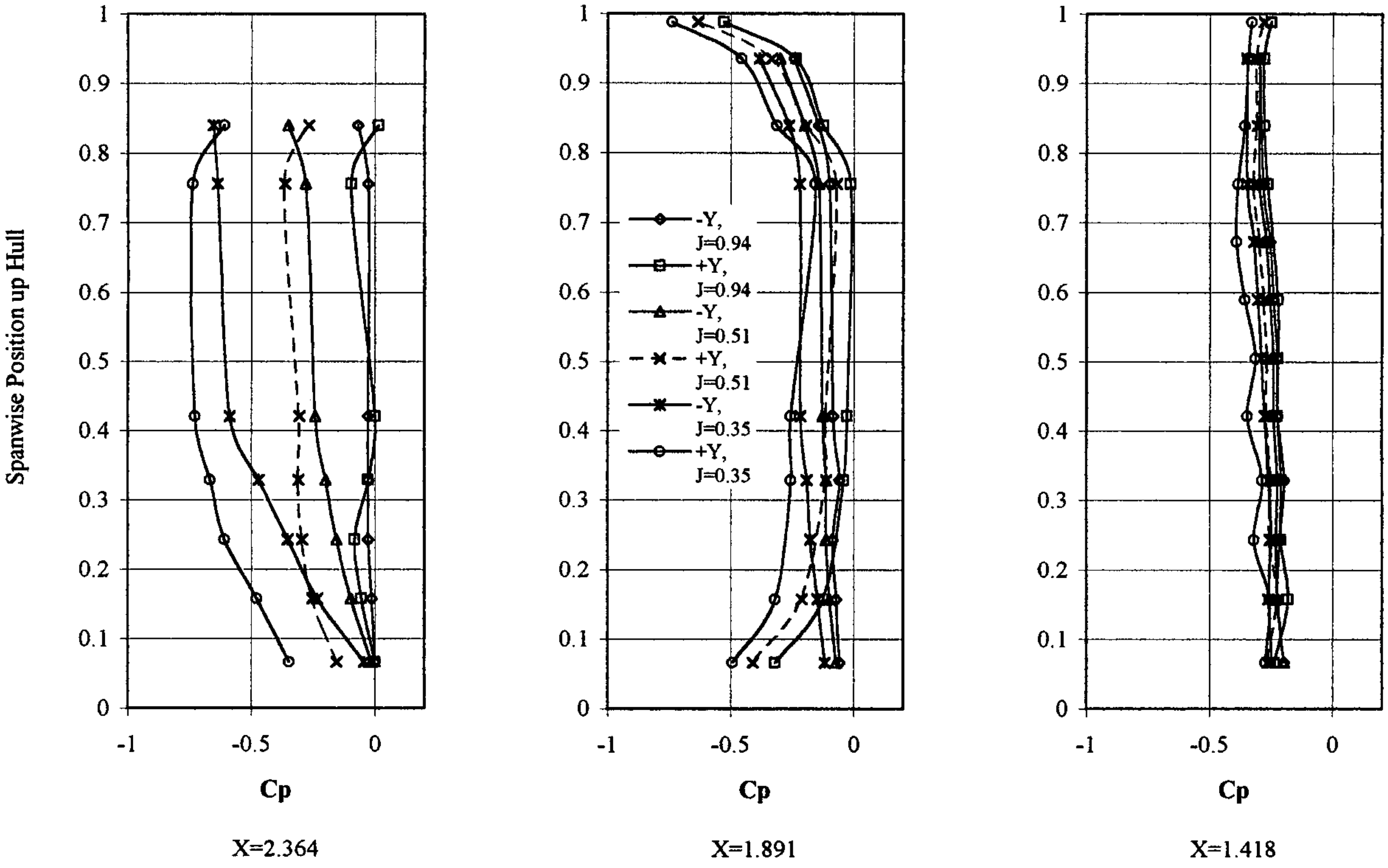


Fig. 59 Spanwise pressure distributions at 3 aft chordwise positions of the hull for X/D=0.52 for varying J at a skeg rudder angle of -10 degrees

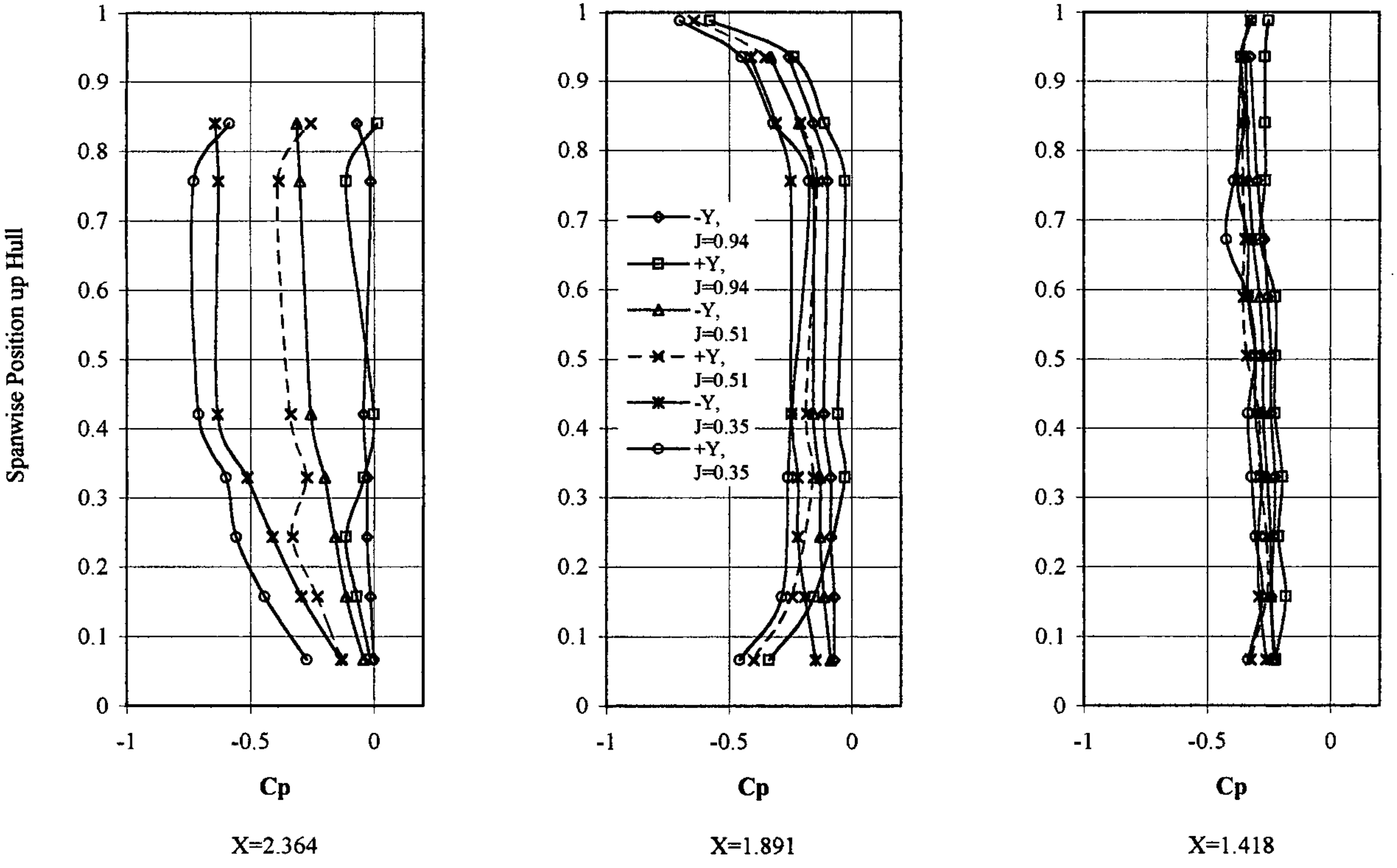


Fig. 59 Spanwise pressure distributions at 3 aft chordwise positions of the hull for X/D=0.52 for varying J at a skeg rudder angle of 0 degrees

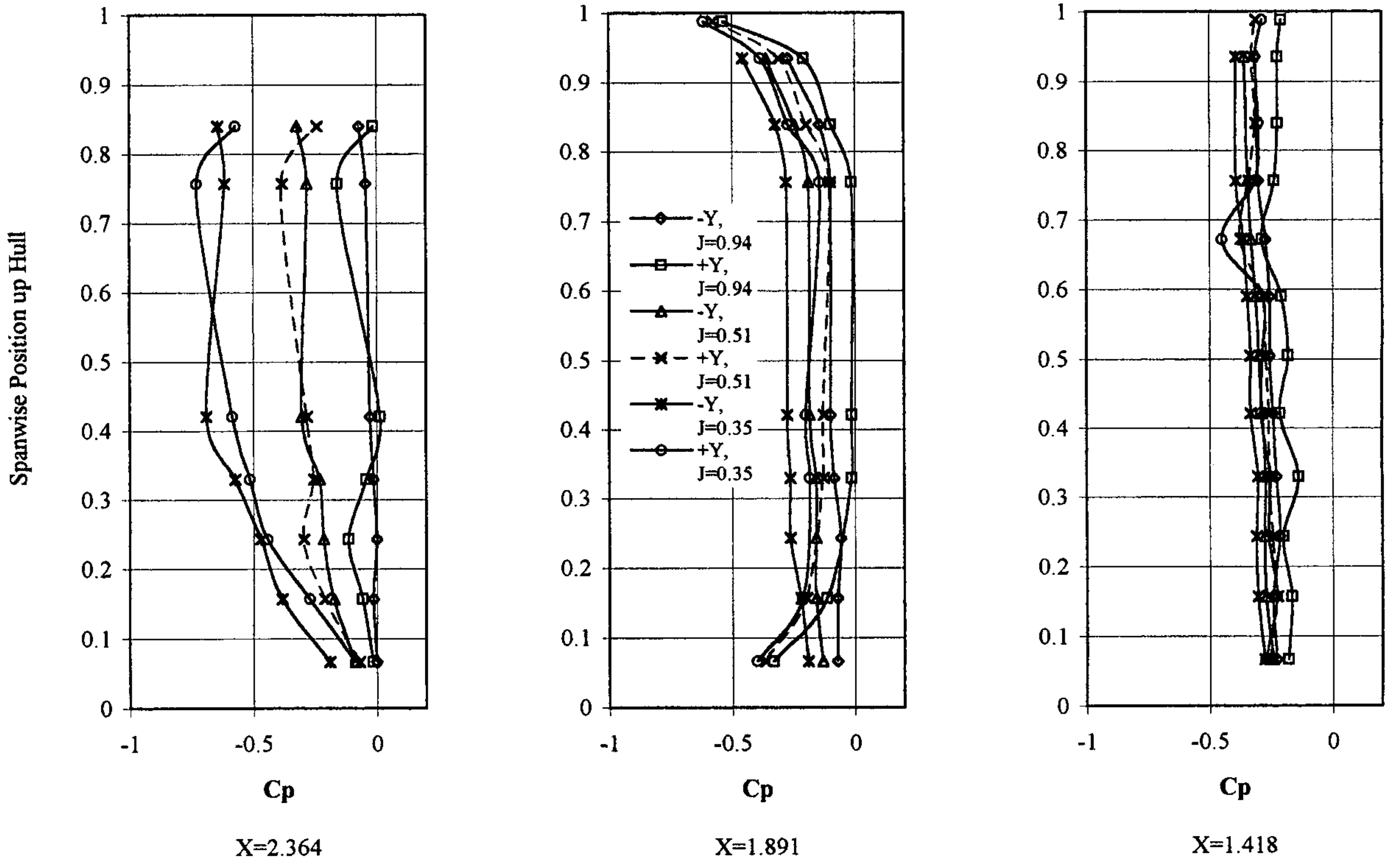


Fig. 59 Spanwise pressure distributions at 3 aft chordwise positions of the hull for X/D=0.52 for varying J at a skeg rudder angle of +10 degrees

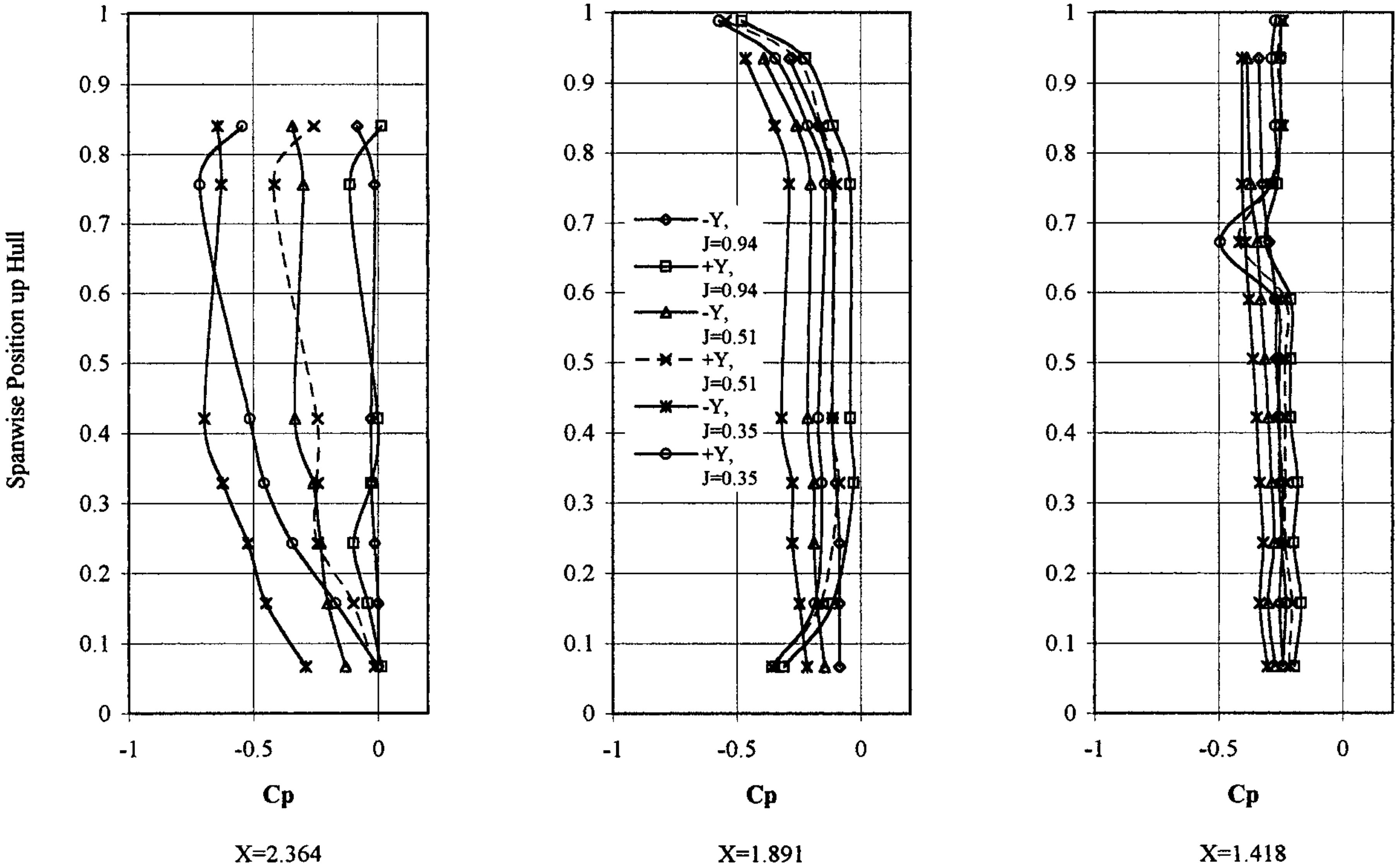


Fig. 59 Spanwise pressure distributions at 3 aft chordwise positions of the hull for X/D=0.52 for varying J at a skeg rudder angle of +20 degrees

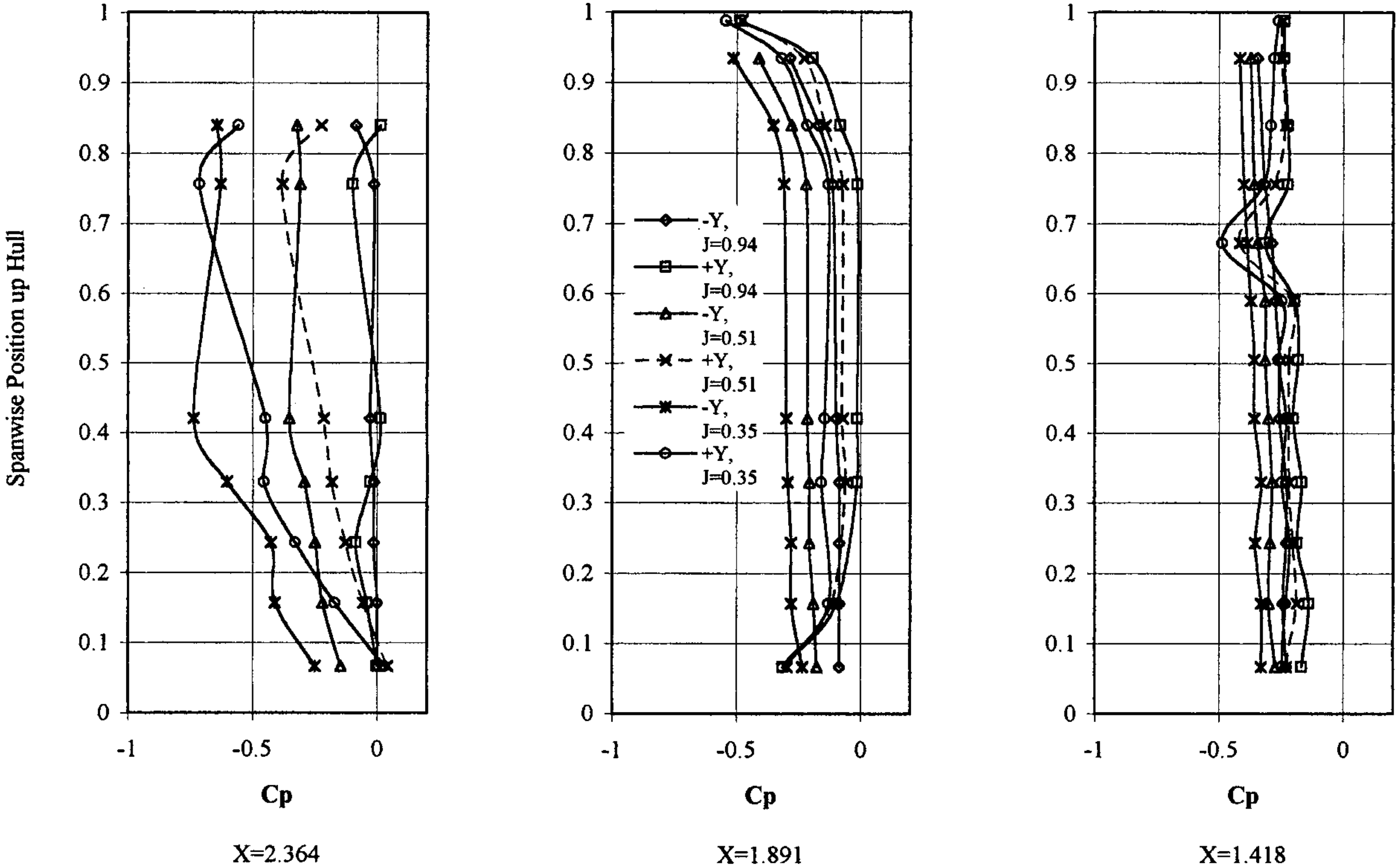


Fig. 59 Spanwise pressure distributions at 3 aft chordwise positions of the hull for X/D=0.52 for varying J at a skeg rudder angle of +30 degrees

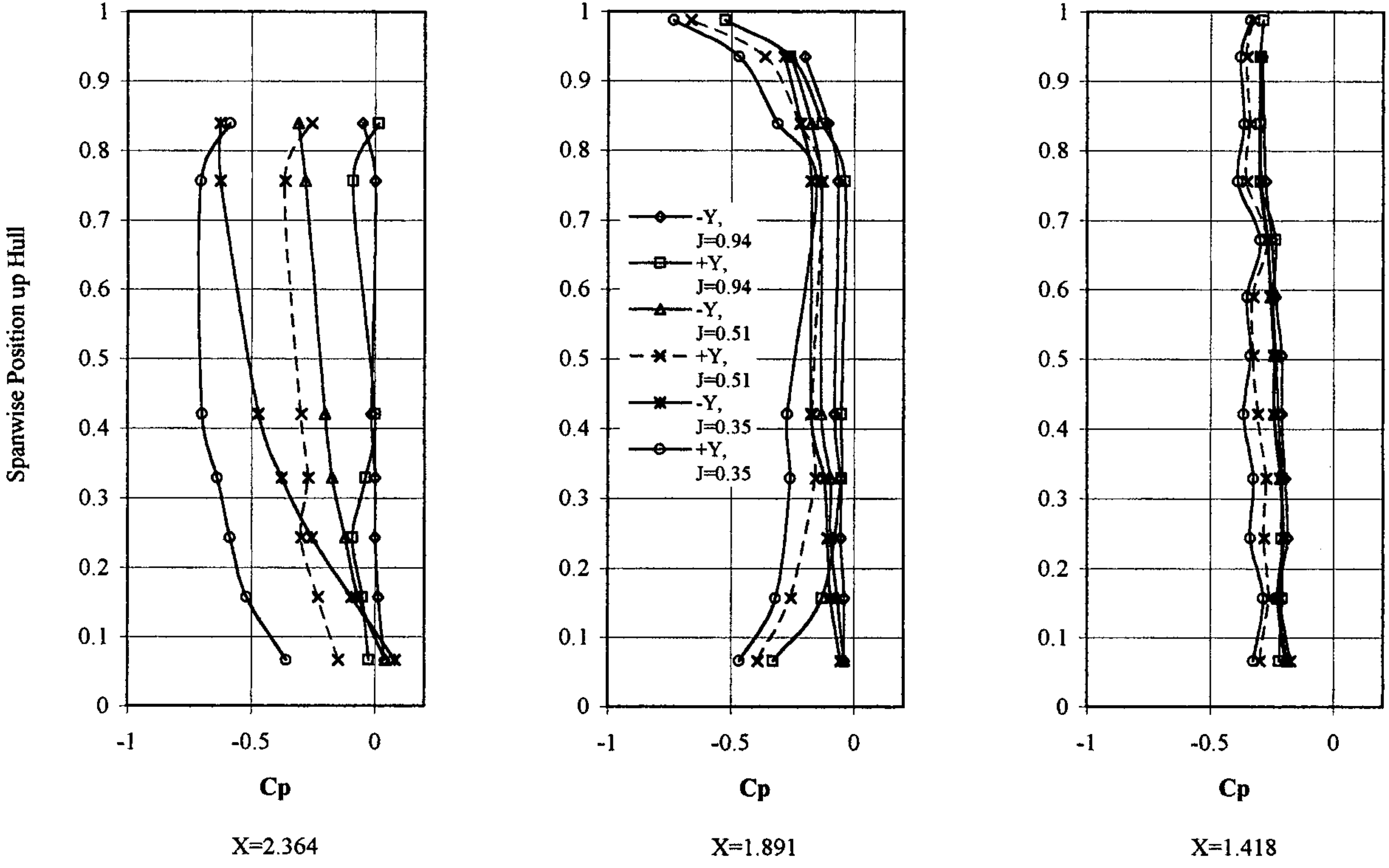


Fig. 60 Spanwise pressure distributions at 3 aft chordwise positions of the hull for X/D=0.64 for varying J at a skeg rudder angle of -30 degrees

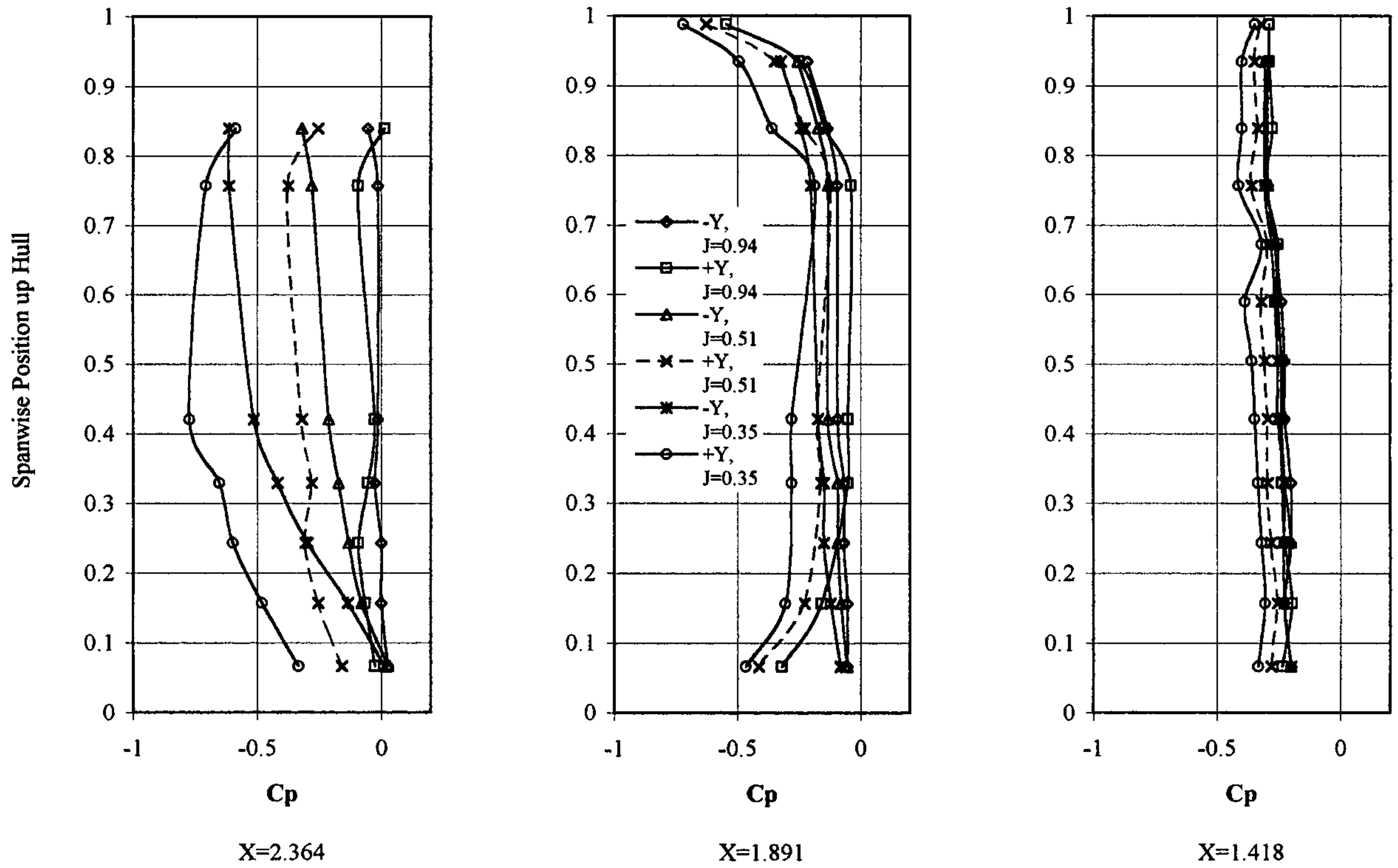


Fig. 60 Spanwise pressure distributions at 3 aft chordwise positions of the hull for X/D=0.64 for varying J at a skeg rudder angle of -20 degrees

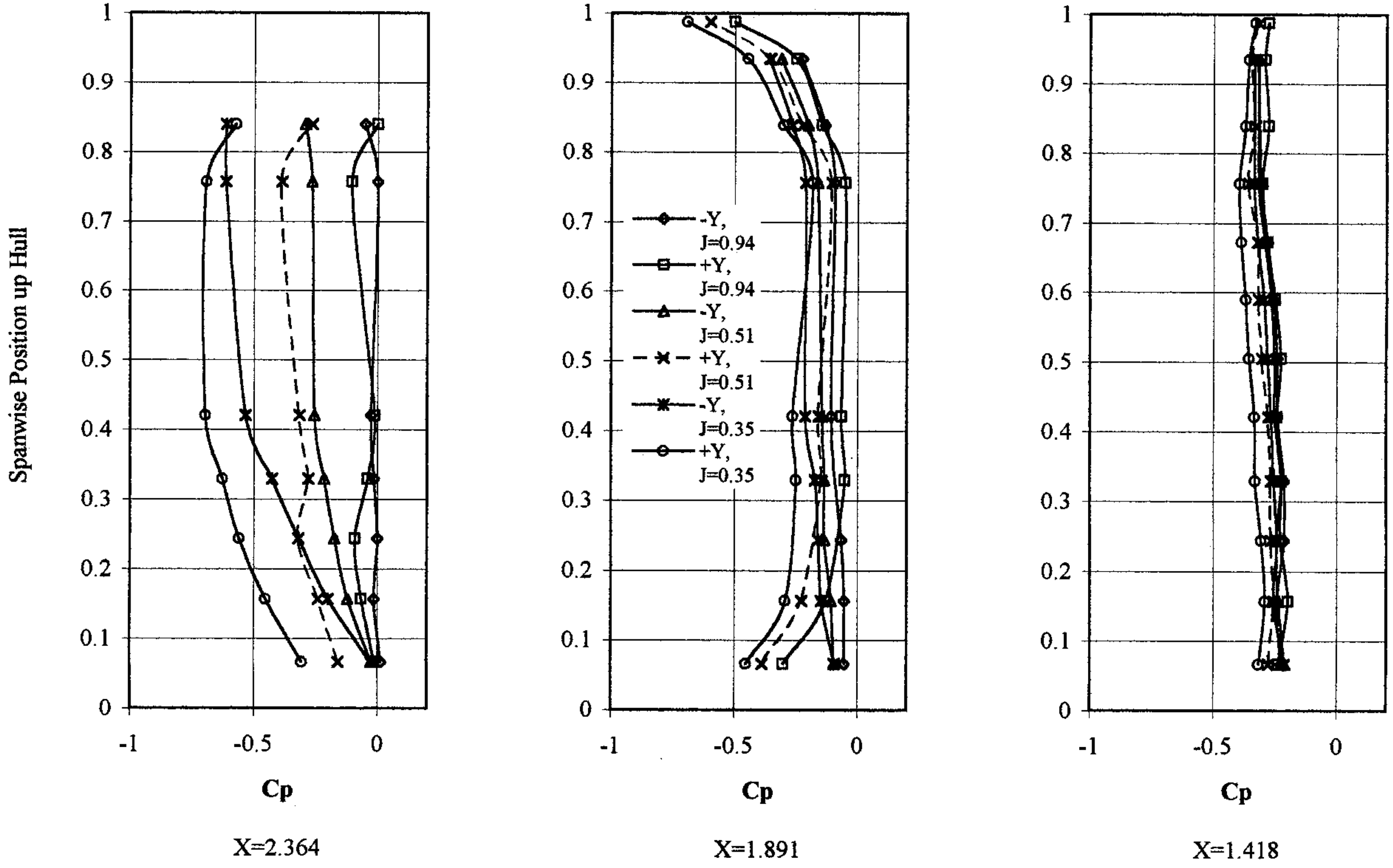


Fig. 60 Spanwise pressure distributions at 3 aft chordwise positions of the hull for X/D=0.64 for varying J at a skeg rudder angle of -10 degrees

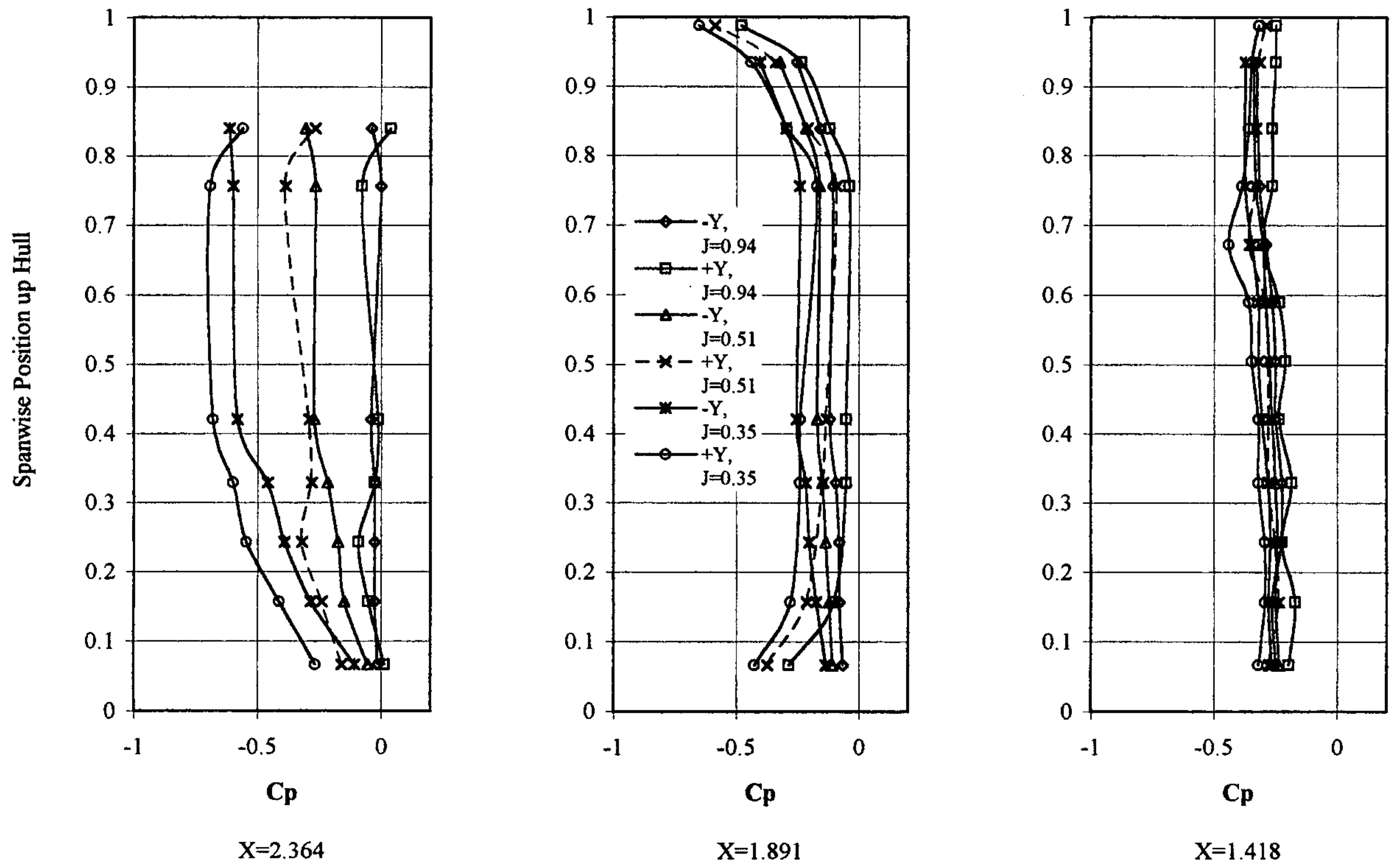


Fig. 60 Spanwise pressure distributions at 3 aft chordwise positions of the hull for X/D=0.64 for varying J at a skeg rudder angle of 0 degrees

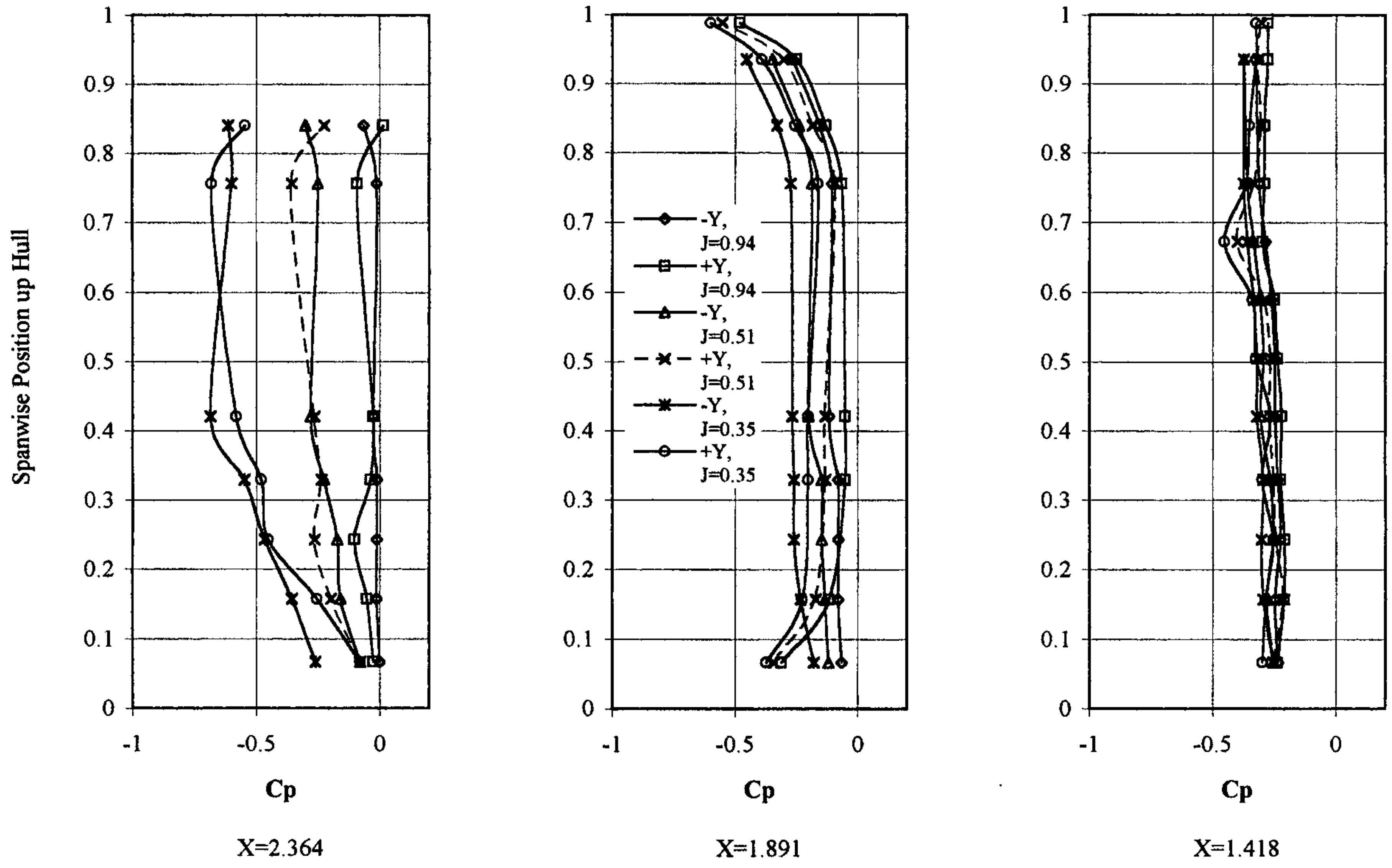


Fig. 60 Spanwise pressure distributions at 3 aft chordwise positions of the hull for X/D=0.64 for varying J at a skeg rudder angle of +10 degrees

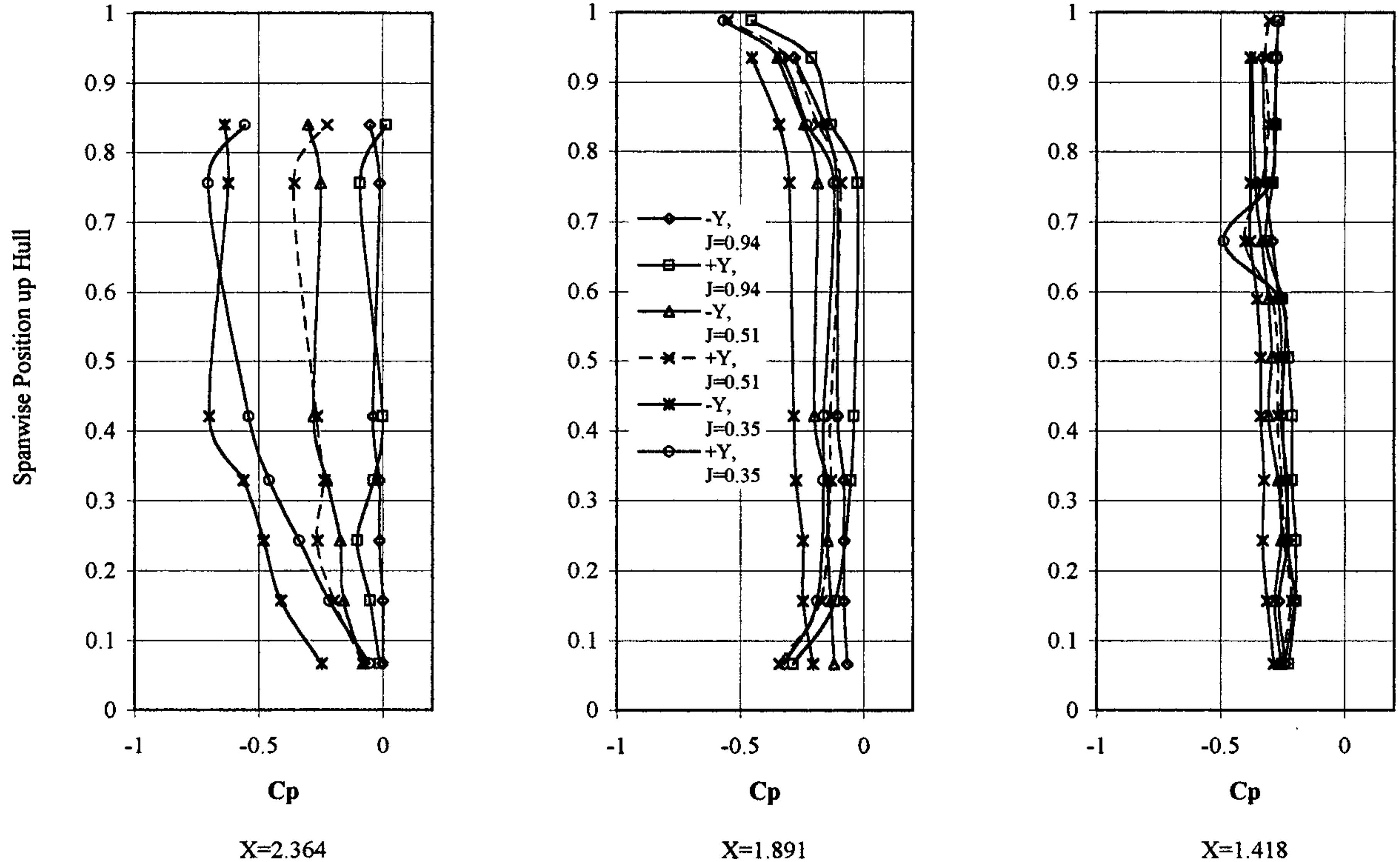


Fig. 60 Spanwise pressure distributions at 3 aft chordwise positions of the hull for X/D=0.64 for varying J at a skeg rudder angle of +20 degrees

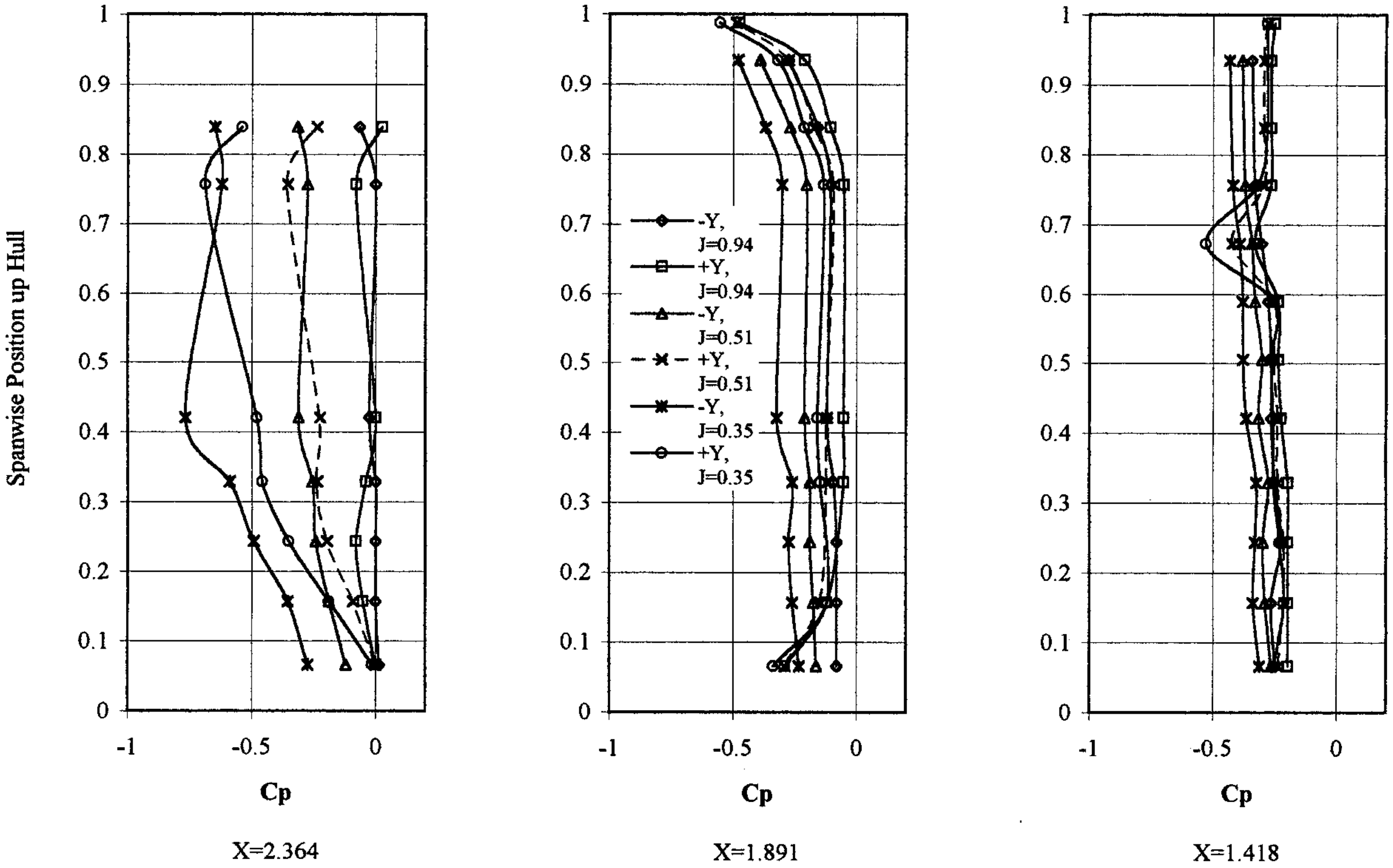


Fig. 60 Spanwise pressure distributions at 3 aft chordwise positions of the hull for X/D=0.64 for varying J at a skeg rudder angle of +30 degrees

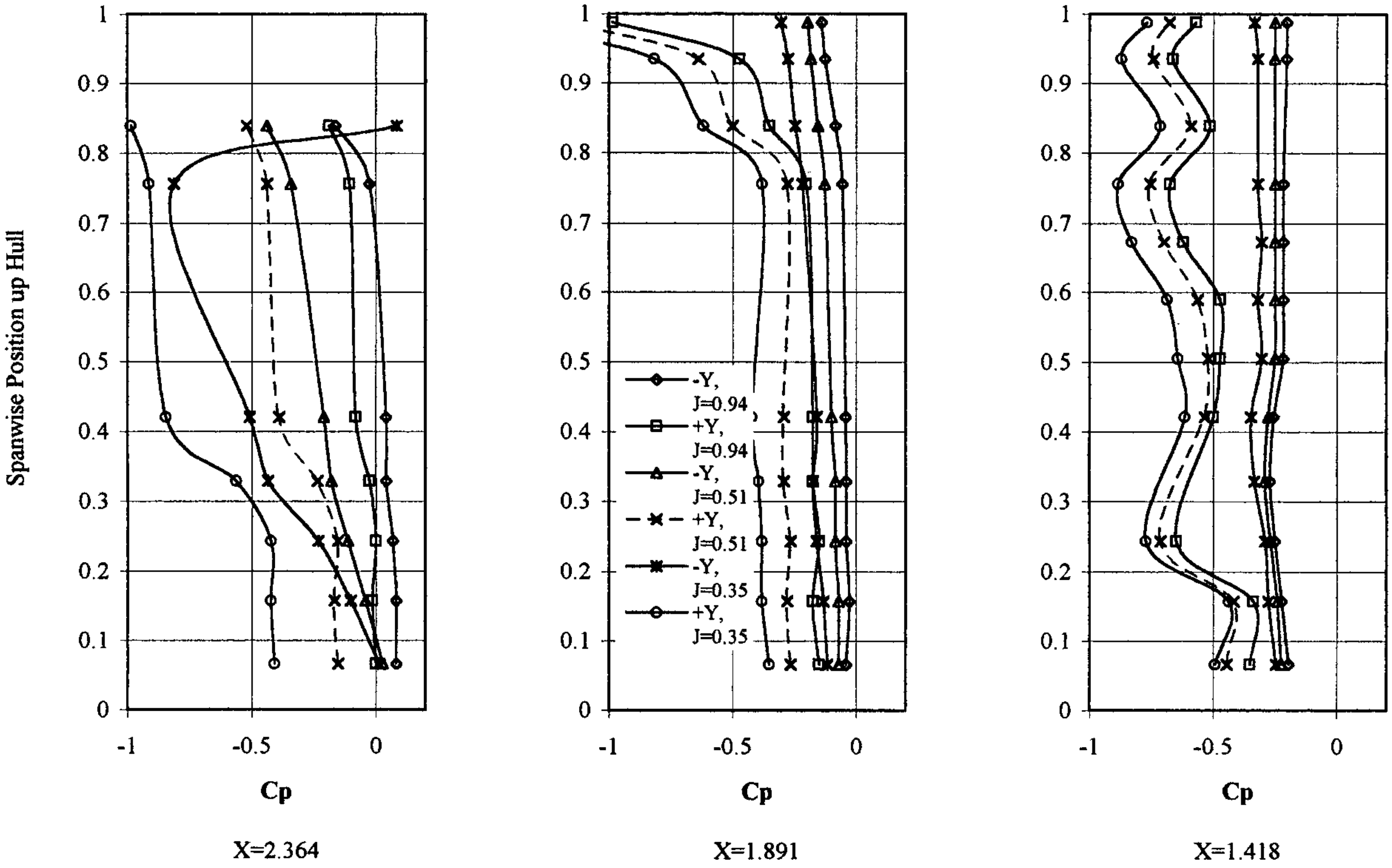


Fig. 61 Spanwise pressure distributions at 3 aft chordwise positions of the hull at a yaw angle of -7.5 degrees for X/D=0.39 and varying J at a skeg rudder angle of -30 degrees

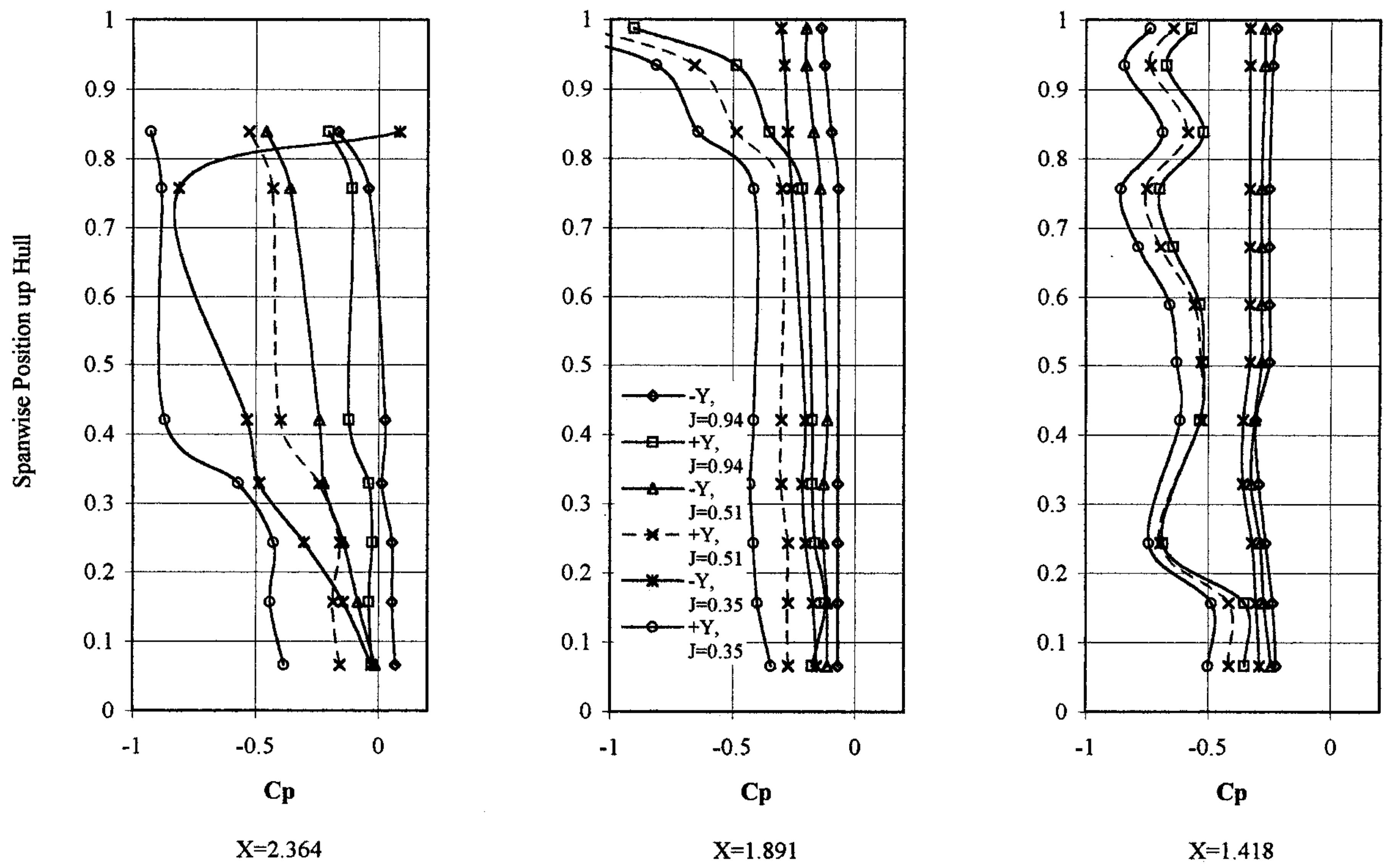


Fig. 61 Spanwise pressure distributions at 3 aft chordwise positions of the hull at a yaw angle of -7.5 degrees for X/D=0.39 and varying J at a skeg rudder angle of -20 degrees

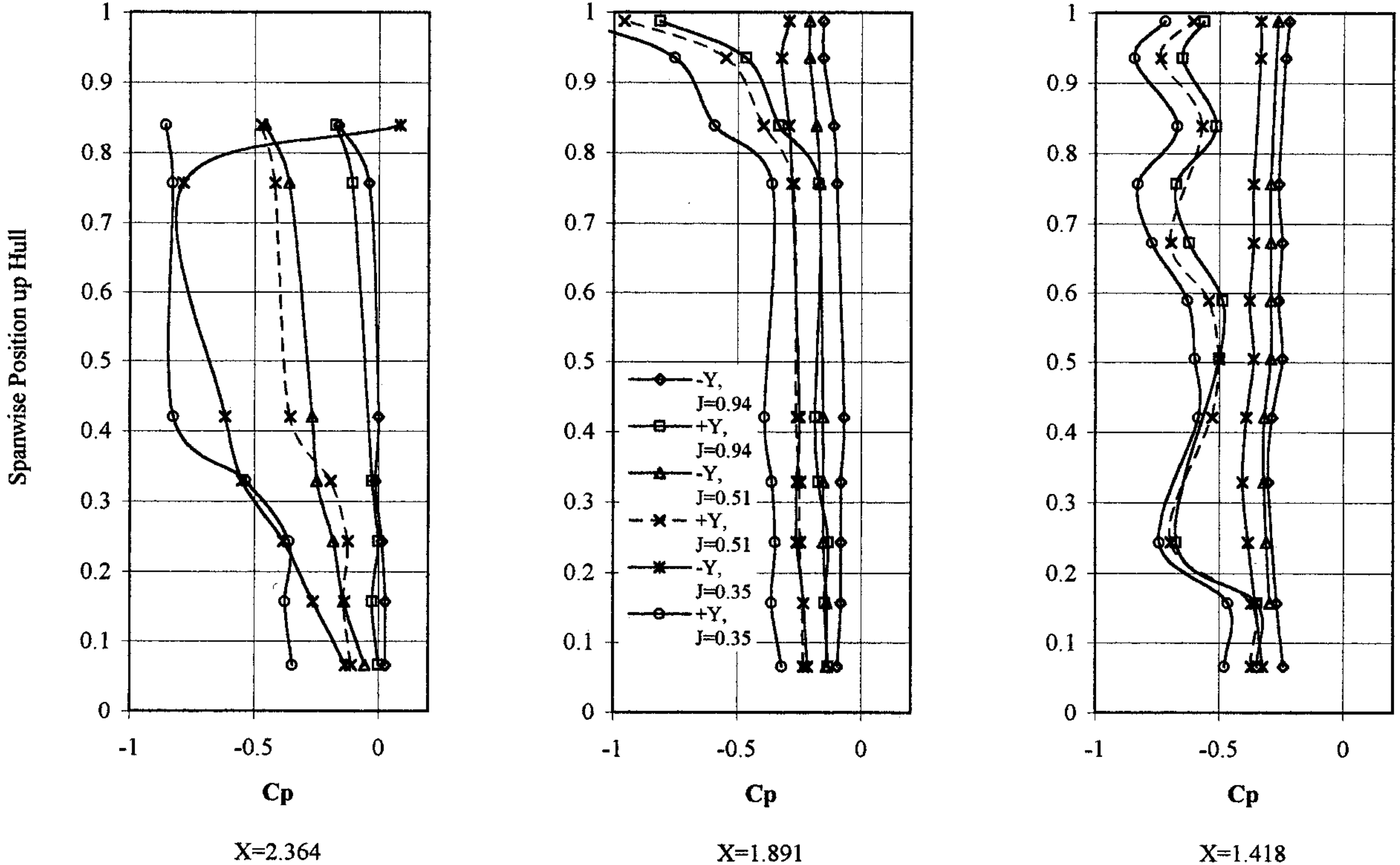


Fig. 61 Spanwise pressure distributions at 3 aft chordwise positions of the hull at a yaw angle of -7.5 degrees for X/D=0.39 and varying J at a skeg rudder angle of -10 degrees

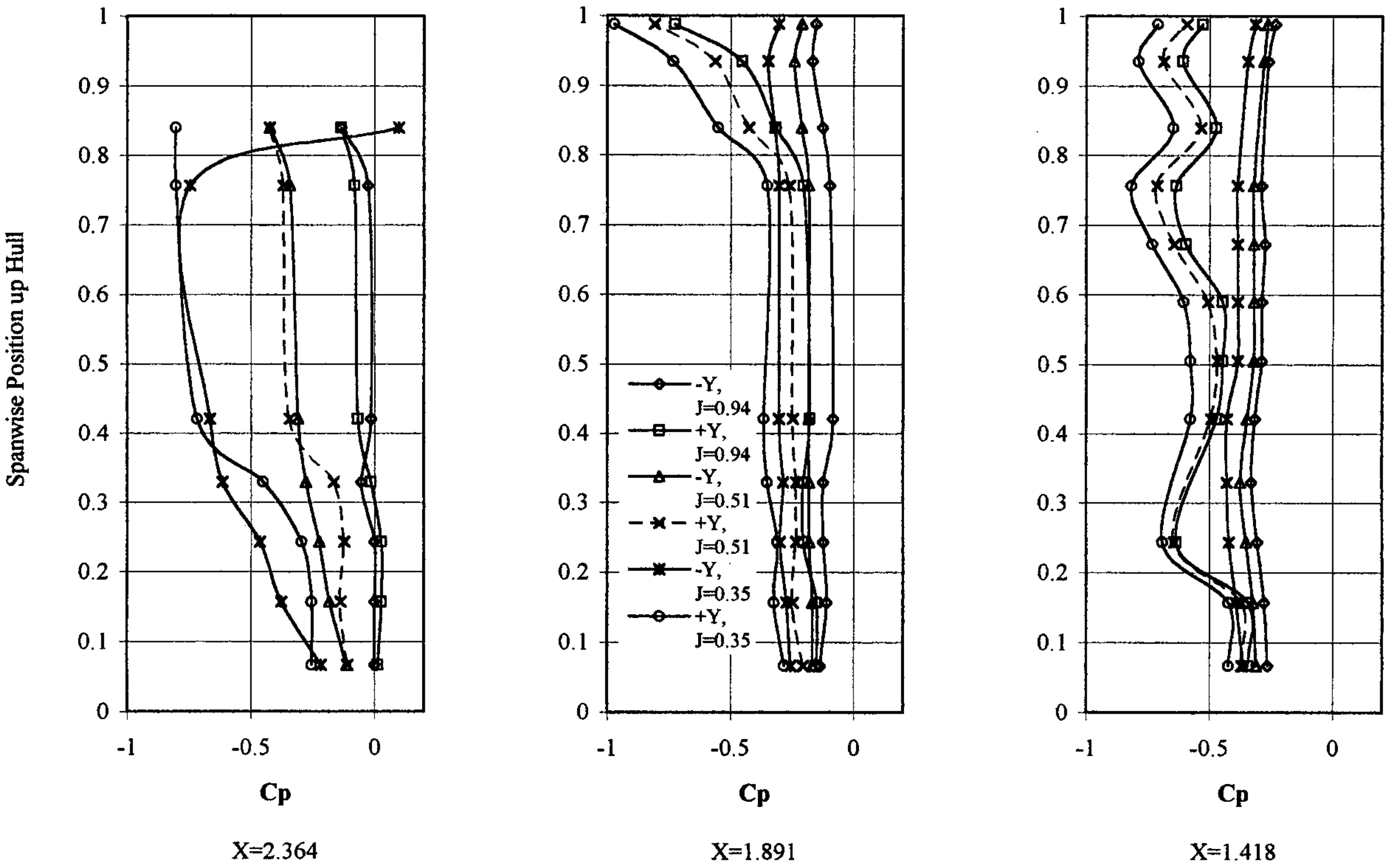


Fig. 61 Spanwise pressure distributions at 3 aft chordwise positions of the hull at a yaw angle of -7.5 degrees for X/D=0.39 and varying J at a skeg rudder angle of 0 degrees

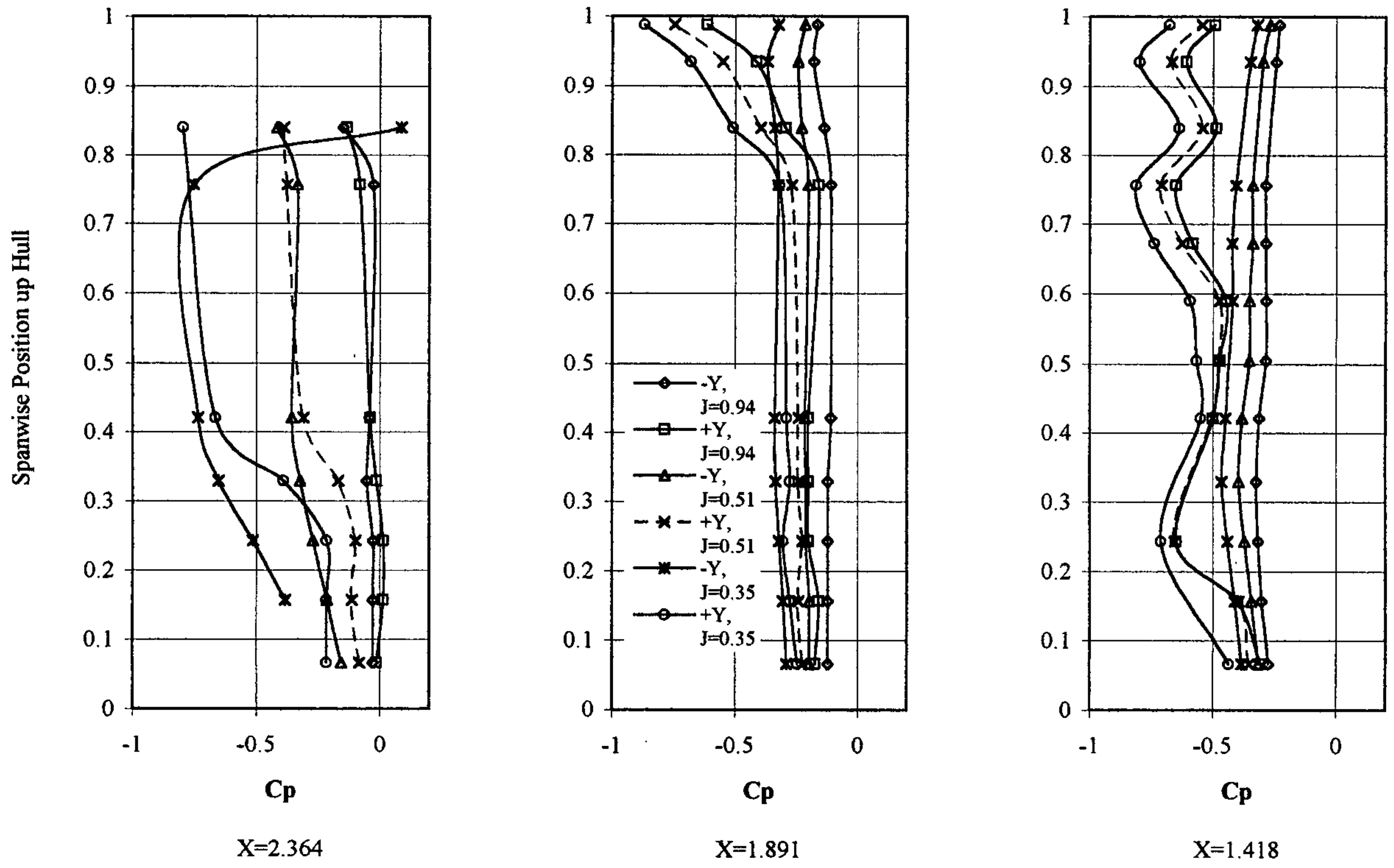


Fig. 61 Spanwise pressure distributions at 3 aft chordwise positions of the hull at a yaw angle of -7.5 degrees for X/D=0.39 and varying J at a skeg rudder angle of +10 degrees

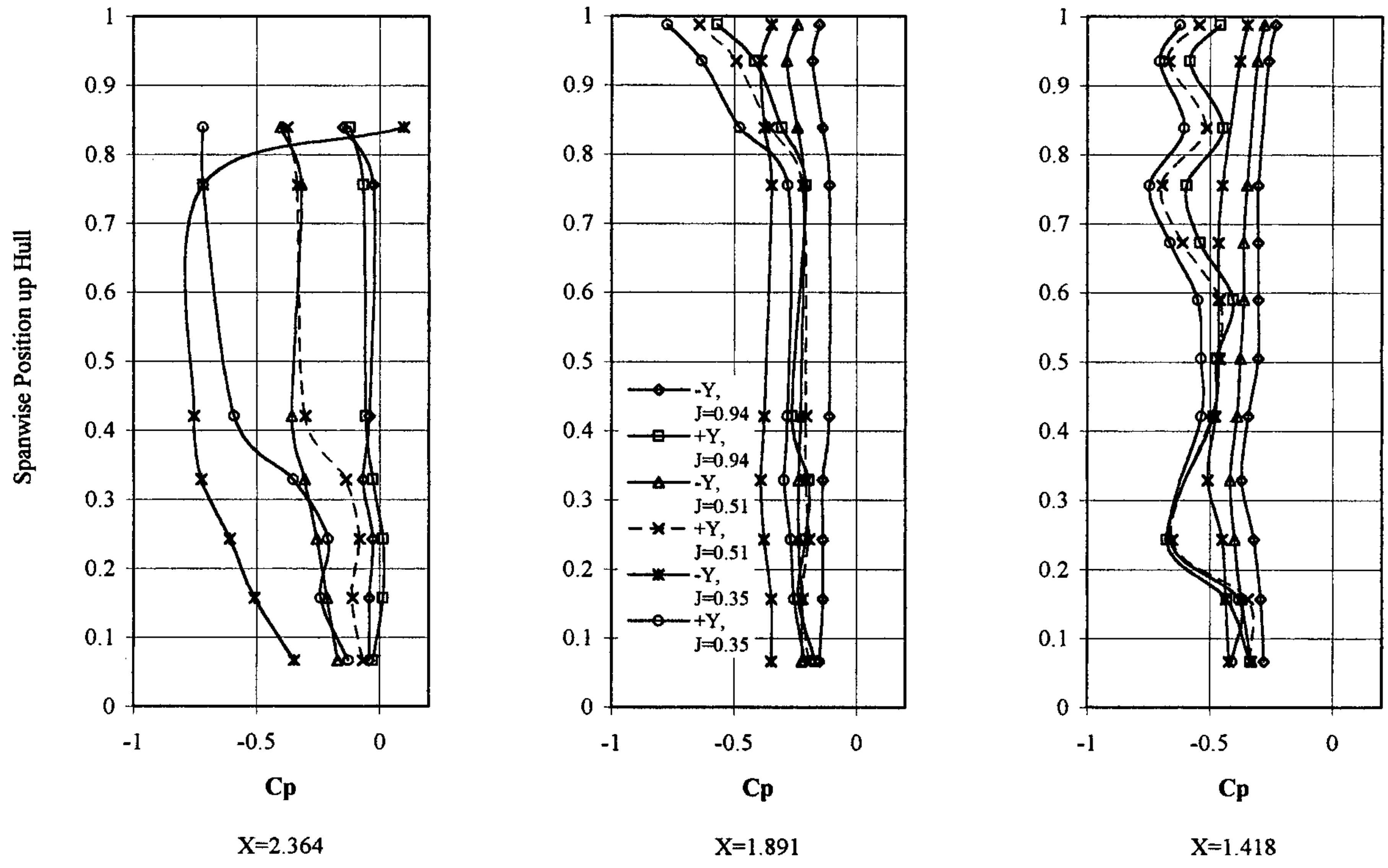


Fig. 61 Spanwise pressure distributions at 3 aft chordwise positions of the hull at a yaw angle of -7.5 degrees for X/D=0.39 and varying J at a skeg rudder angle of +20 degrees

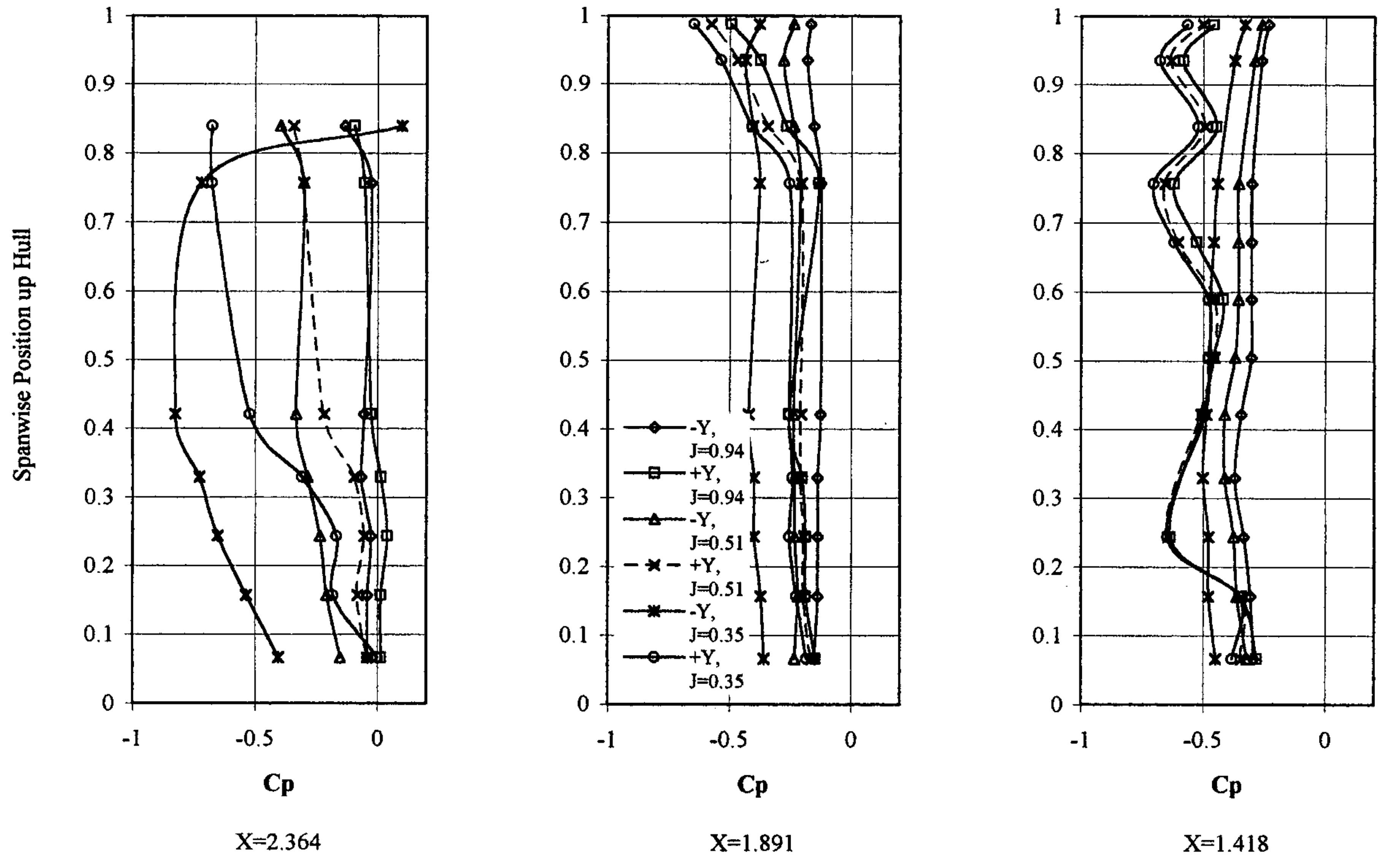


Fig. 61 Spanwise pressure distributions at 3 aft chordwise positions of the hull at a yaw angle of -7.5 degrees for X/D=0.39 and varying J at a skeg rudder angle of +30 degrees

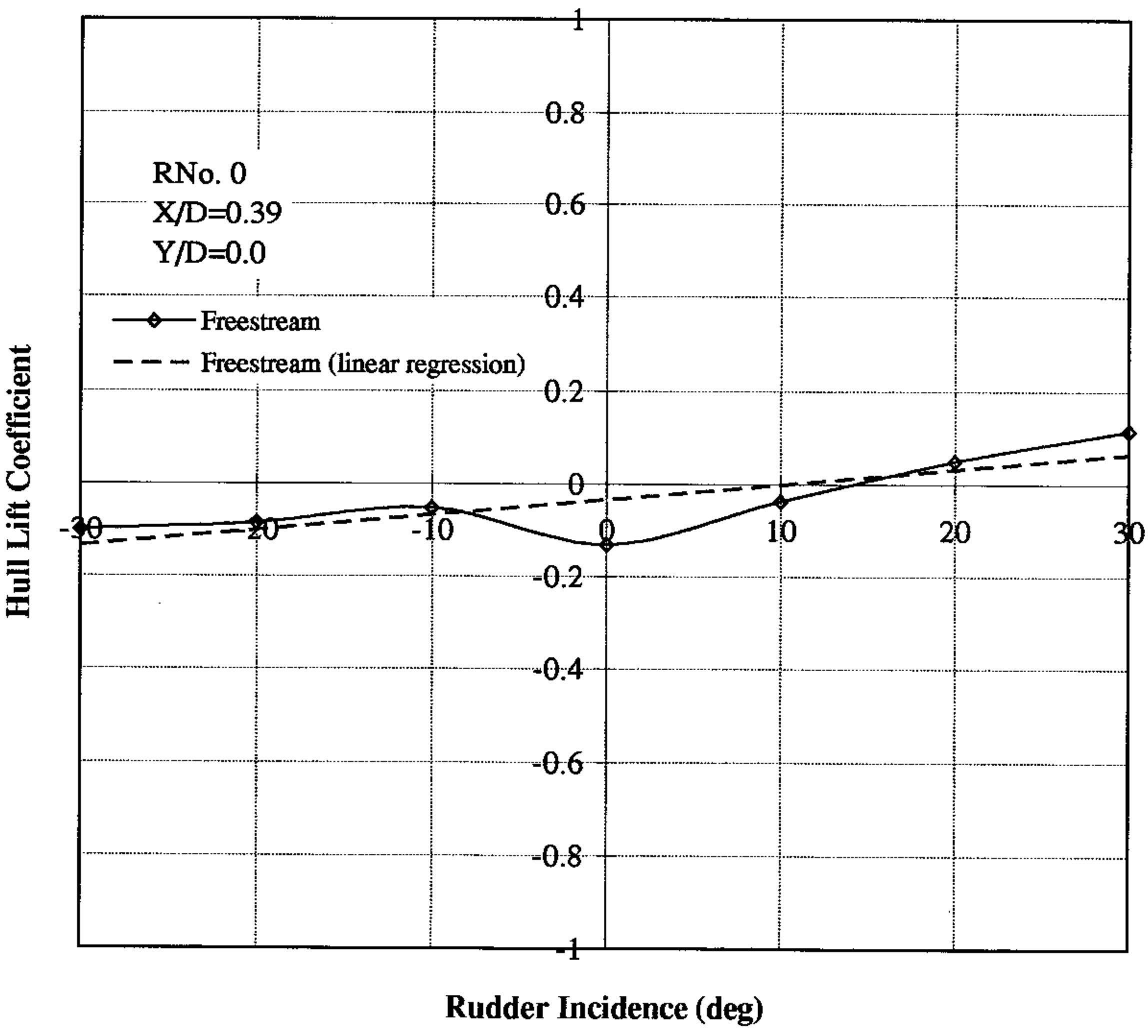


Fig. 62 Hull lift performance in freestream with skeg rudder and stationary propeller.

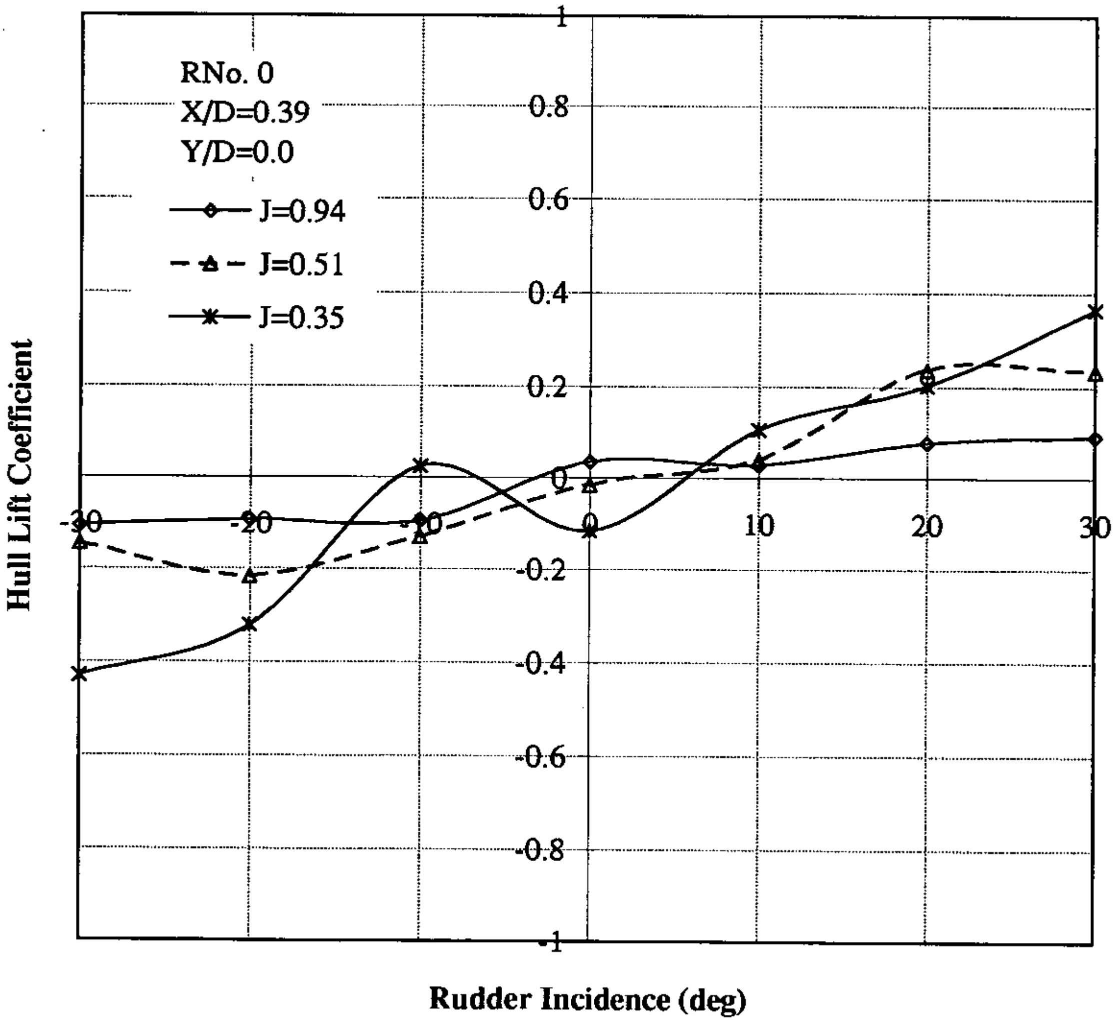


Fig. 63 Influence of propeller thrust loading on hull lift performance at a longitudinal separation of X/D=0.39

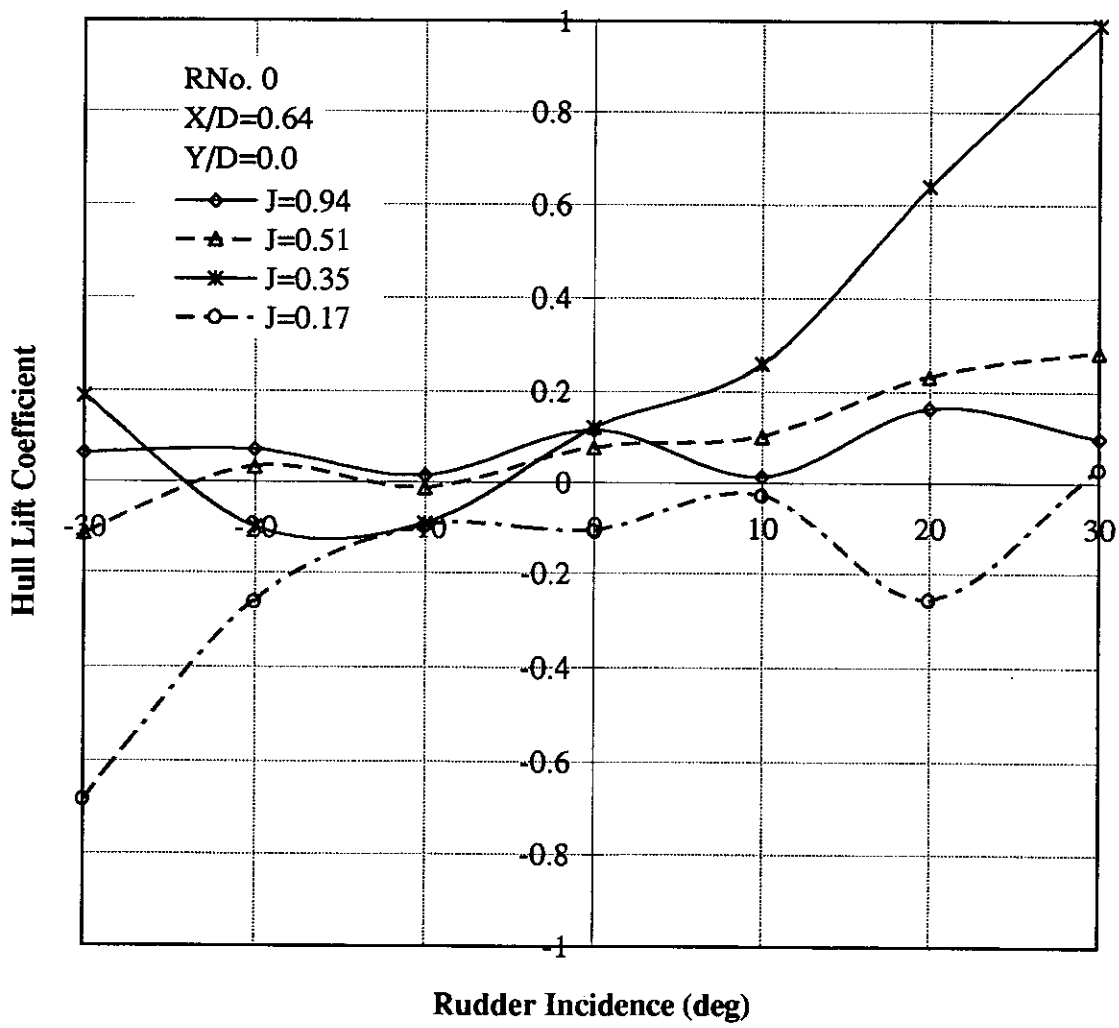


Fig. 64 Influence of propeller,thrust loading on hull lift performance at longitudinal separation of X/D=0.64.

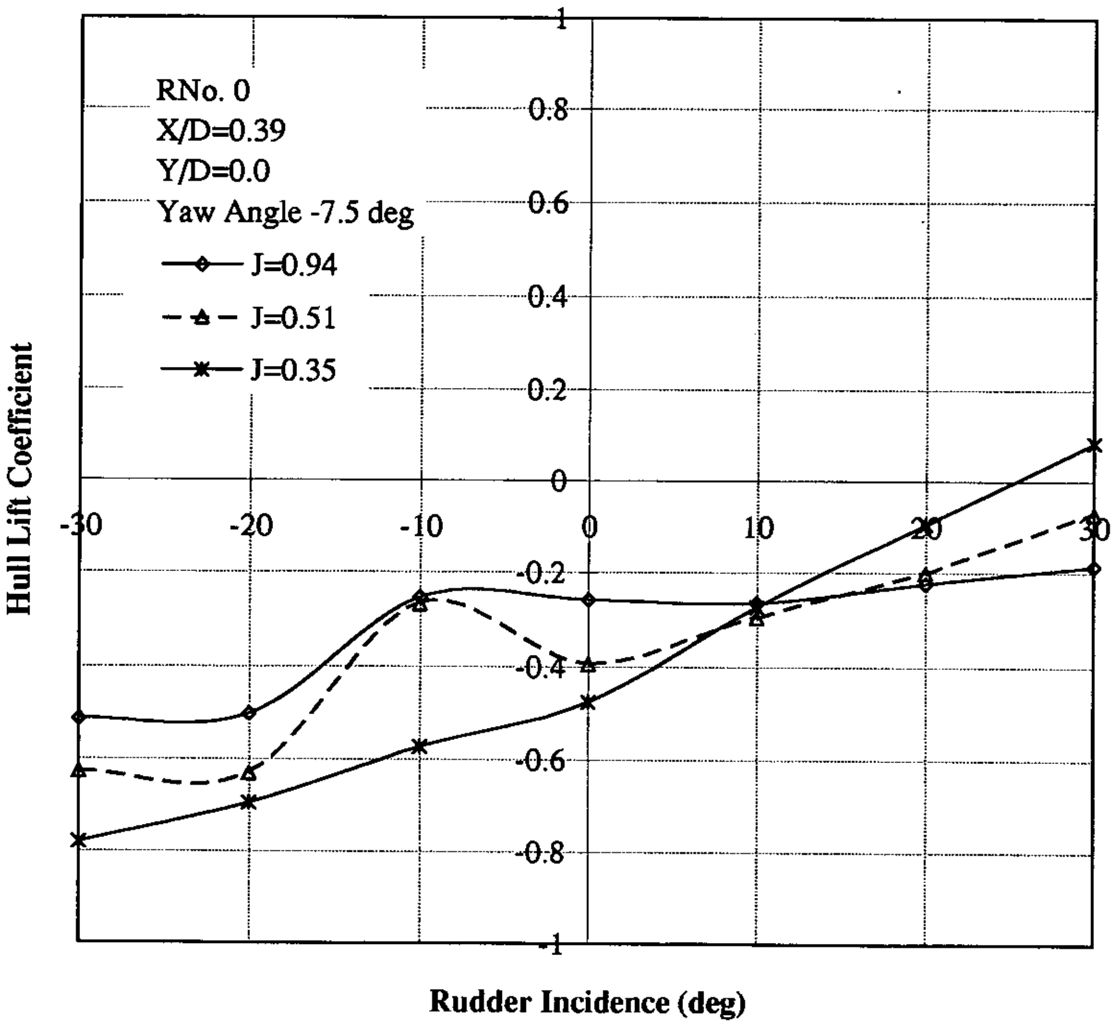


Fig. 65 Influence of propeller thrust loading on hull lift performance at a longitudinal separation of X/D=0.39 and at a yaw angle of -7.5 degrees