COMPARATIVE BENDING MOMENT TESTS WITH T2-SE-A1 TANKER MODELS.

Ir J.Ch. de Does.

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Since Lewis paper "Ship Model Tests to Determine Bending Moments in Waves" presented at the 1954 meeting of the "Society of Naval Architects and Marine Engineers" a great number of tests has been carried out by several towing tanks. With some exceptions all have adopted the method described in this paper by which the model is divided by a number of cuts. Bending moment and shear force can be measured at these cuts for instance by connecting the several parts by a flexure beam provided with strain gauges. Another method, first applied by Sato, makes use of undivided models and in this case stresses can be measured and converted into bending moments. Part C of the list of references gives a review of recent publications in which tests of the above mentioned kind are described.

For his tests Lewis used the model of a T2-SE-A1 tanker. As some other investigators have also chosen this ship for the measurement of bending moments, it was recommended at the September 1960 meeting of the "Committee on Wave Loads" to use the T2-hull form for comparative bending moment tests.

For completeness the lines of this ship are given in fig. 1.

At this moment the results of tests with T2-tanker models in 6 towing tanks, are available and this gives the opportunity to compare the measurements of pitch, heave, shear force and bending moment as obtained in different tanks and by using different dynamometers and recording instruments. Table 1 gives a review of the main particulars of the tests from which results are available.

Christensen (C 1) used a wooden model with 3 cuts. The methods of measuring were those developed at the Davidson Laboratory. For the measurement of bending moment and shear forces the four parts were connected by means of a flexure beam provided with inductive pick-ups. The freeboard of the model was increased to prevent the shipping of water.

From the motion measurements only the recorded pitching is given. Heave and phase angles will appear in a later report.

The model tested by Dalzell (C 2) was cut at the midship section. The free-board corresponded with the real ship.

Motions, although measured, were not published. Only for wave length = ship length pitch and heave are given in a paper by Jacobs (B 35)

A plastic model without cuts was tested by De Does. The bending moment was obtained from strain gauges, fitted at the shear strake after a dynamic calibration of the model.

Fukuda (C 4) tested a wooden model with one cut at the midship section. Unlike the other tests mentioned in this report the model was not free to surge. Fukuda studied two weight conditions with the same displacement but different radii of gyration.

Pitching and heaving motions, bending moments and phase angles are all published in his report.

Taniguchi's model (C 13) had five cuts and the necessary strength was obtained by providing the ship with a light alloy longitudinal girder to which the six parts of the ship were fastened. Complete results of motion, phase angle and bending moment measurements were published. The test programme included 2 variations of the weight distribution in which the displacement and the radii of gyration were kept at the original value.

Akita also tested a model with 5 cuts and a central girder to connect the blocks, in which the ship was divided. His dynamometers were designed in such a way that also vertical hydrodynamical forces acting on each block could be measured. Akita studied two weight distributions with the same displacement but different radii of gyration. All the results of bending moment, motions and phase lag measurement were published.

Comparison of results.

Fig. 2 ÷ 7 show the results of the motion measurements as given in the above mentioned reports. It is a pity that the differences are rather large, even if the difference in gyratio of the models is kept in mind, and that at lower Froude numbers, results may be affected by wall influence.

Fig. 9 ÷ 13 show the results of bending moment measurements. In long waves there is excellent agreement between the results of Christensen and De Does. However, in waves with λ/L = 1,00, 1,25 and 1,50 the differences, obtained by the different authors, are remarkable and even the trend of the curves differs considerable. As the bending moment is very affective to variations in weight distribution this may be the cause of the differences. Perhaps it will be worthwhile to determine the "hydrodynamic" part of the bending moment by subtracting the moment caused by the mass inertia forces of the ship's weight from the measured value. However this is only possible when all phase anglesof motions and moments are published. Moreover it looks advisable to repeat some of the tests, in which special care should be devoted to obtain exactly the same weight distribution. Furthermore the published oscillograph records show in some cases differences in wave height with time which also may have affected the results.

TABEL 1

COMPARITIVE BENDING MOMENT TESTS WITH T2-SE-A1 TANKER MODELS

● PUBLISHED
○ UNPUBLISHED

AUTHOR AND LABORATORY	SCALE OF REDUCTION	TYPE OF MODEL	MAIN MODEL DIMENSIONS L×B×d (m)	VARIATIONS	NUMBER OF CUTS e.g. STRAIN DYNAMOMETERS	TYPE OF BENDING MOMENT DYNAMOMETER	RADIUS OF GYRATION i	DISPLACEMENT KG	PARTICULARS OF REGULAR WAVES 2ζ/L	λ/L	IRREGULAR SEAS	FOLLOWING SEAS	MAX. SPEED IN REGULAR HEAD SEAS	MEASUREMENTS: PITCH	HEAVE	BENDING MOMENT	SHEAR FORCE	ACCELERATION: FORE	AFT	BOTTOM PRESSURE	REF.	REMARKS
CHRISTENSEN S.M.T. TRONDHEIM	50	JOINTED WOOD	3.066×0.415×0.183	WEIGHT DISTRIBUTION DRAUGHT BOW SHAPE (PLANNED)	1/4 L FORE MIDSHIP SECTION 1/4 L AFT	INDUCTNE PICK-UP	0.23	172.5	1/40	0.60 0.75÷2.25			0.30	●	○	●	●	○			(C7)	
DALZELL DAVIDSON HOBOKEN	105	JOINTED WOOD	1.463×0.197×0.087		MIDSHIP SECTION	INDUCTIVE PICK-UP	0.23	18.6	1/30 - 1/51	1.00	●	●	0.25	○	○	●					(C2)	WIDE TANK NARROW TANK
DE DOES DELFT TOWING TANK	62.88	PLASTIC	2.438×0.330×0.146		0.3 L FORE 0.2 L " 0.1 L " MIDSHIP SECTION 0.1 L AFT 0.2 L " 0.3 L "	STRAIN GAUGES	0.24	86.6	1/50	0.75÷2.25			0.30	○	○	○		○	○			
FUKUDA KYUSHU UNIVERSITY	85.17	JOINTED WOOD	1.800×0.243×0.107	WEIGHT DISTRIBUTION	MIDSHIP SECTION	STRAIN GAUGES	0.231	34.3	1/45	0.75÷1.50			0.35	●	●	●					(C4)	
TANIGUCHI MITSUBISHI TANK NAGASAKI	30.662	JOINTED WOOD	5.000×0.676×0.298	WEIGHT DISTRIBUTION	1/4 L FORE 1/8 L " MIDSHIP SECTION 1/8 L AFT 1/4 L "	STRAIN GAUGES	0.22	745.3	1/30 - 1/50	0.75÷1.50		●	0.30	●	●	●		●	●		(C13)	SELF PROPELLED
AKITA T.T.R.I. TOKYO	34.07	JOINTED WOOD	4.500×0.608×0.268	WEIGHT DISTRIBUTION	0.30 L FORE 0.13 L " MIDSHIP SECTION 0.13 L AFT 0.30 L "	STRAIN GAUGES	0.25 0.272	530	1/30 - 1/50 1/30	0.75÷1.50 1.00 - 1.25			0.30 0.30	● ●	● ●	● ●		○ ○	○ ○	○ ○	(C16)	SELF PROPELLED

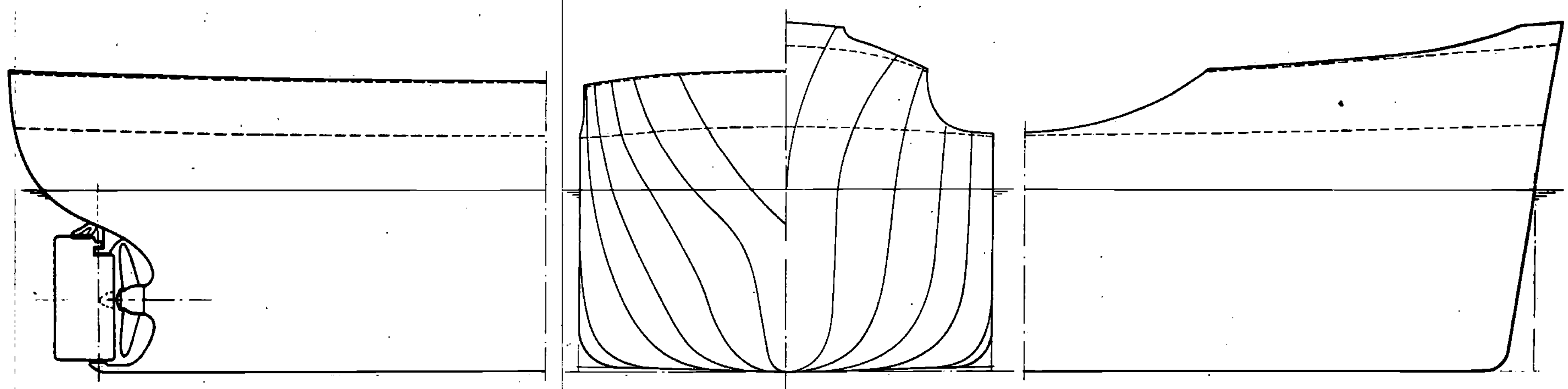


FIG. 1 BODY PLAN

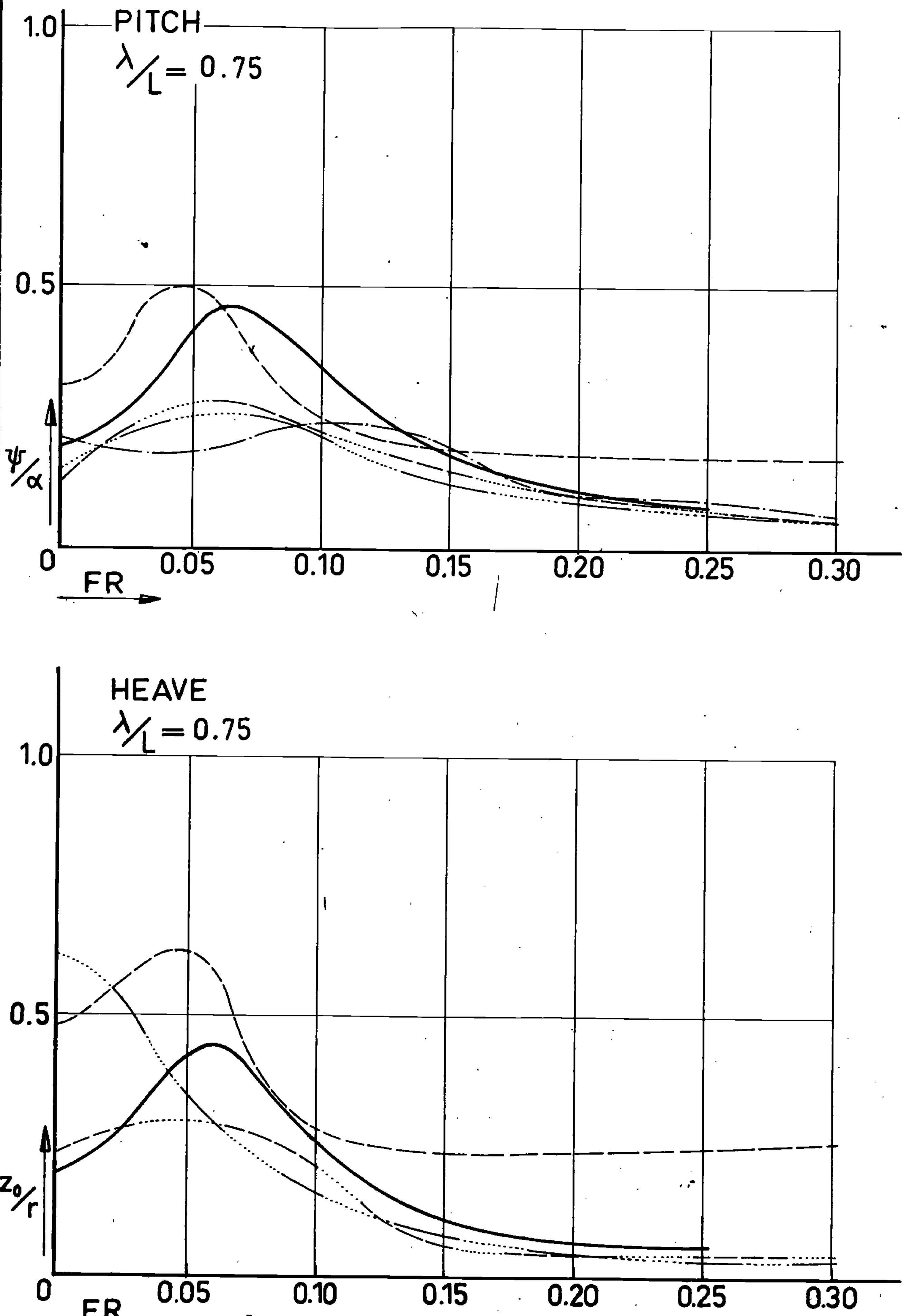

PITCH
λ/L = 0.75
1.0
0.5
0
ψ/α
0.05
0.10
0.15
0.20
0.25
0.30
FR
HEAVE
λ/L = 0.75
1.0
0.5
0
z₀/r
0.05
0.10
0.15
0.20
0.25
0.30
FR

FIG.2

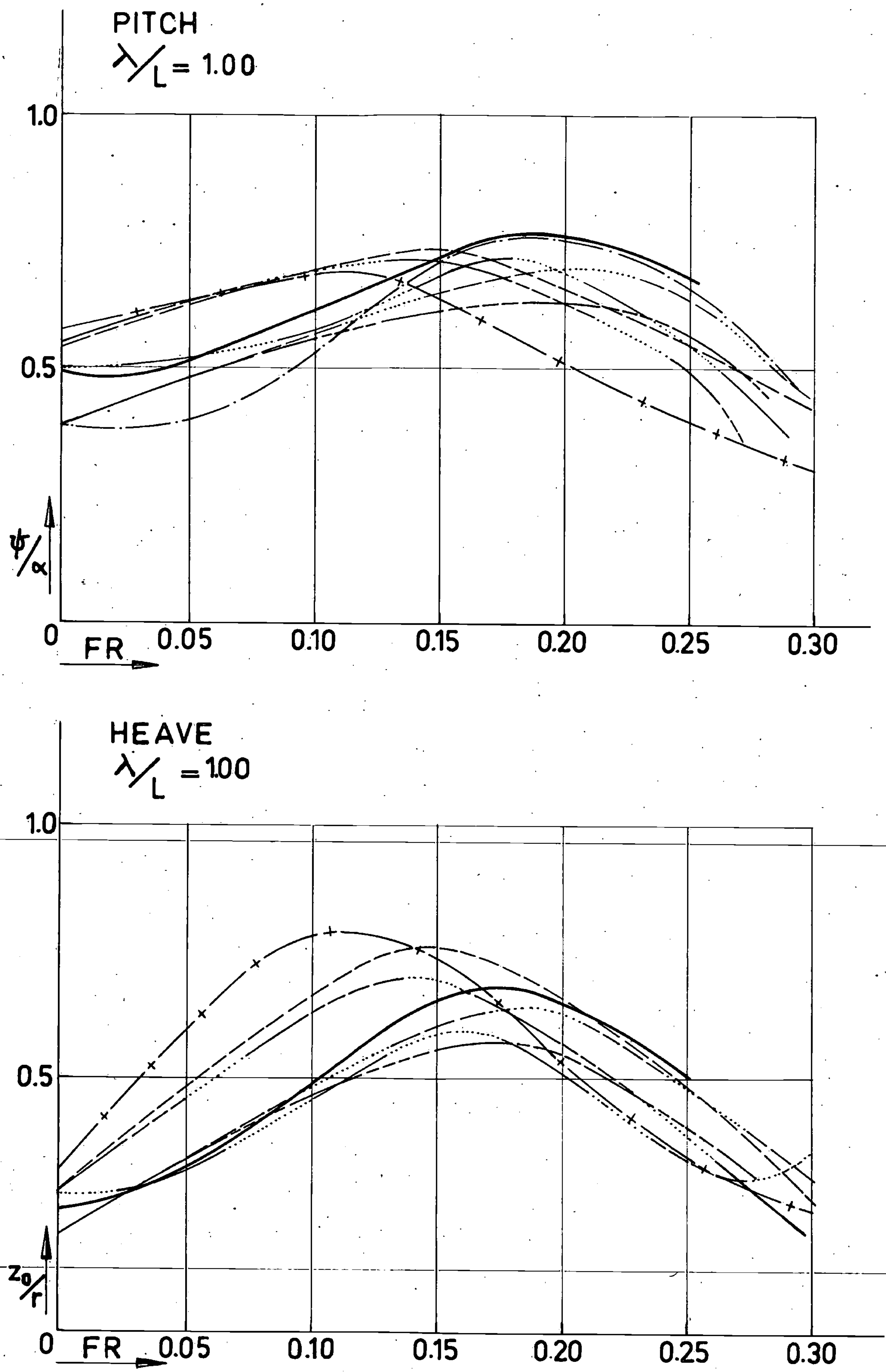
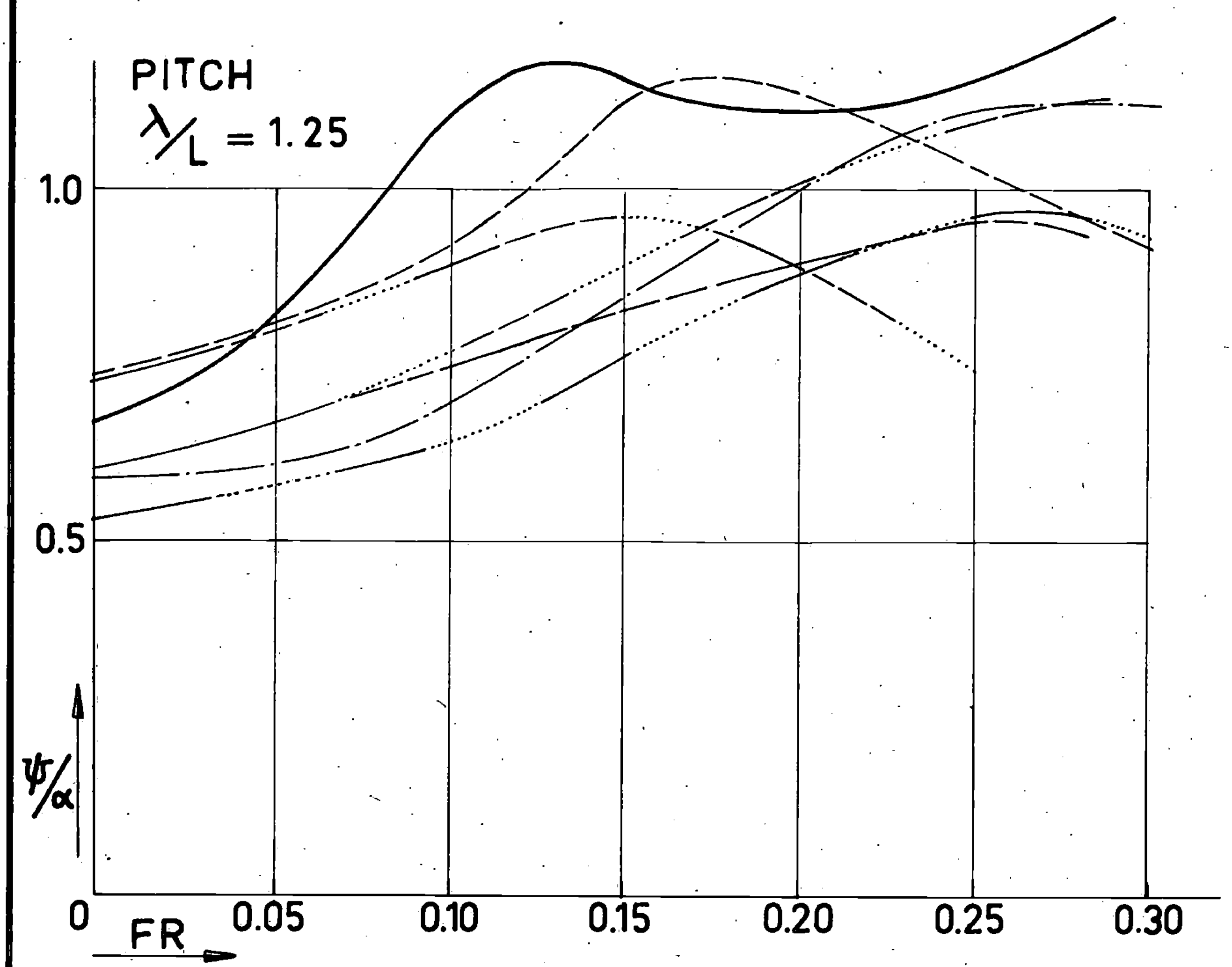

PITCH
λ/L = 1.00
1.0
0.5
ψ/α
0
FR
0.05
0.10
0.15
0.20
0.25
0.30
HEAVE
λ/L = 1.00
1.0
0.5
z₀/r
0
FR
0.05
0.10
0.15
0.20
0.25
0.30

FIG.3


PITCH
λ/L = 1.25
1.0
0.5
0
ψ/α
FR
0.05
0.10
0.15
0.20
0.25
0.30

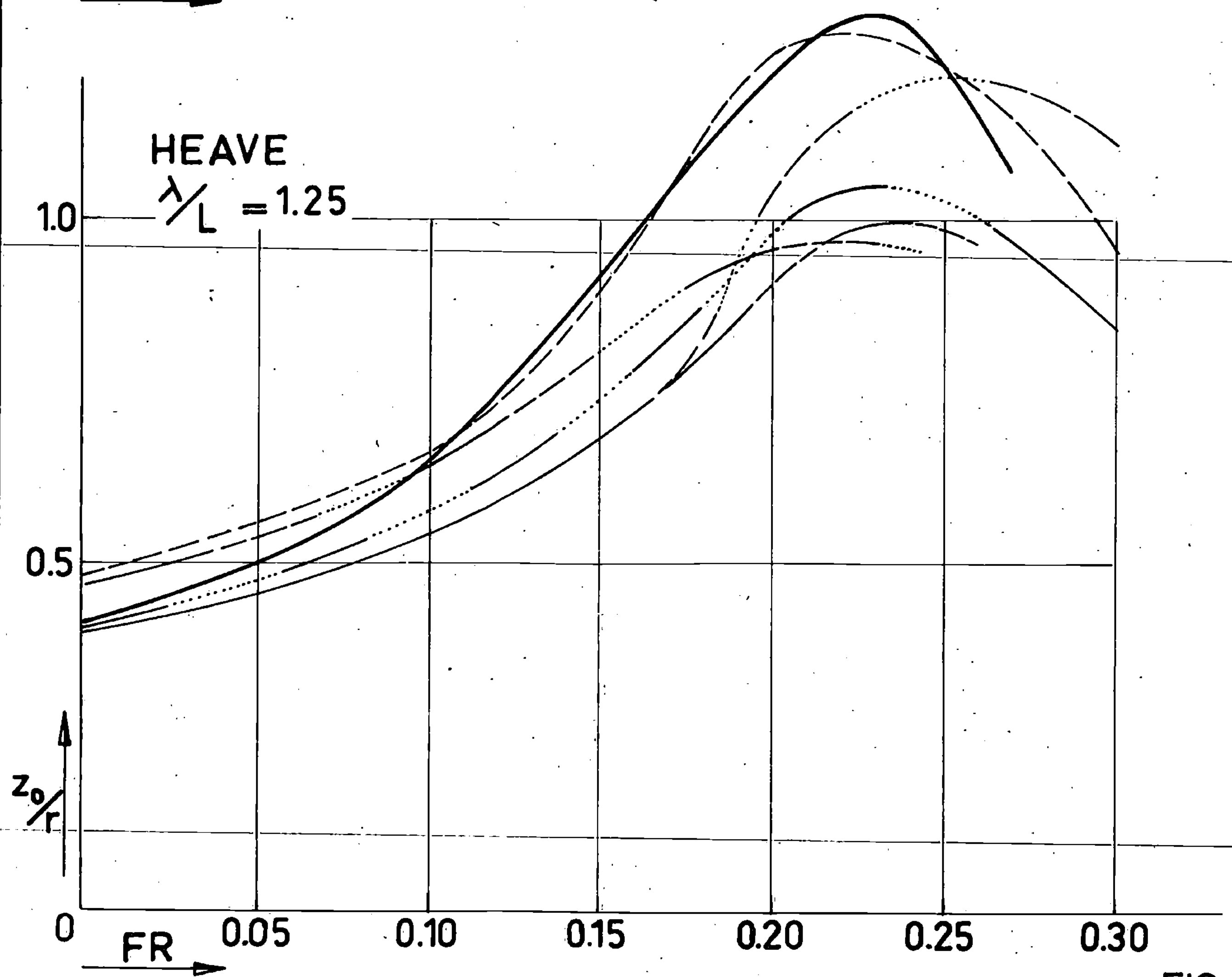
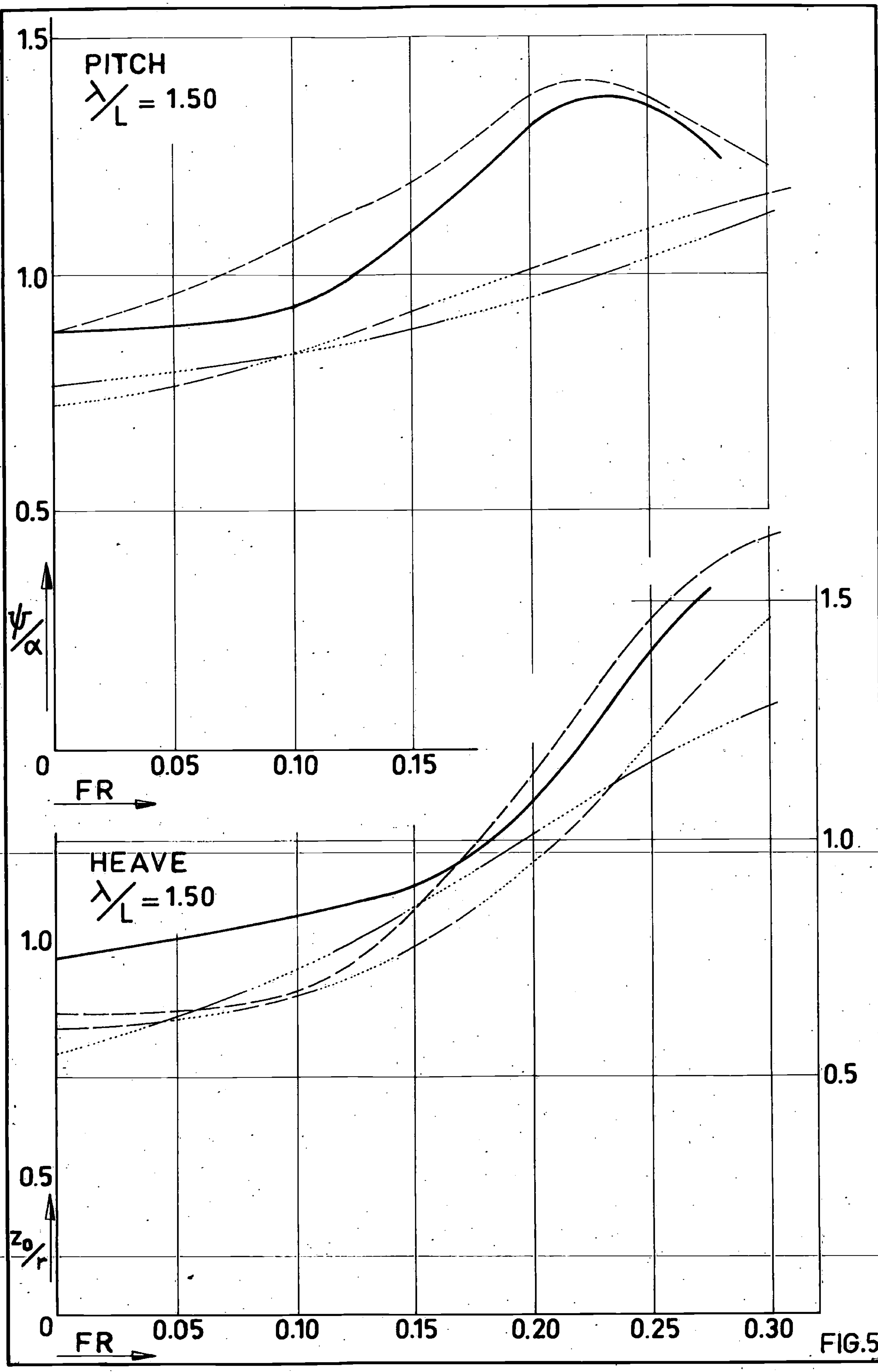

HEAVE
λ/L = 1.25
1.0
0.5
0
z₀/r
FR
0.05
0.10
0.15
0.20
0.25
0.30

FIG. 4



PITCH
λ/L = 1.50
1.5
1.0
0.5
ψ/α
0
0.05
0.10
0.15
FR
HEAVE
λ/L = 1.50
1.0
0.5
z0/r
0
0.05
0.10
0.15
0.20
0.25
0.30
FR
1.5
1.0
0.5

FIG.5

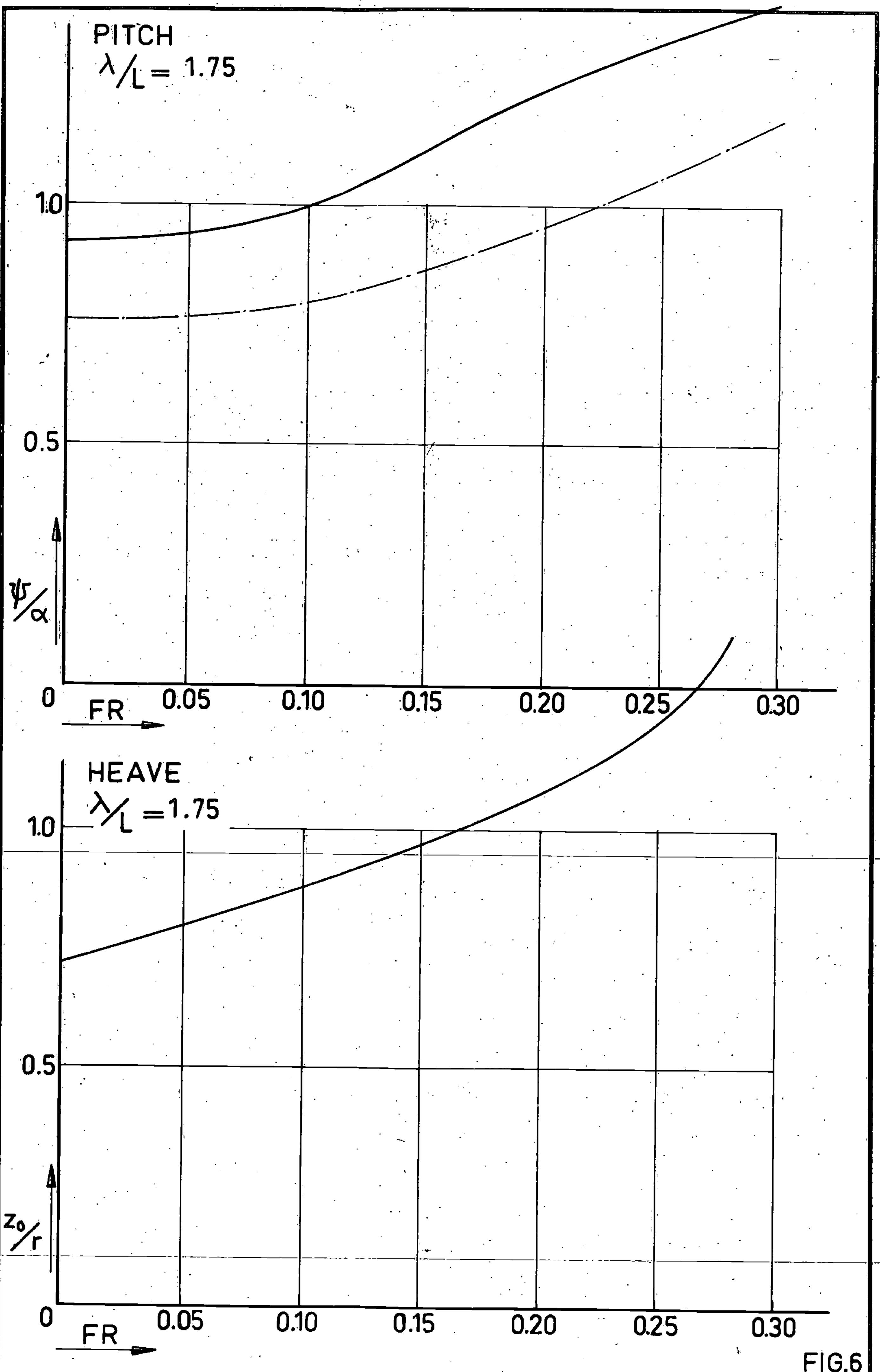

PITCH
λ/L = 1.75
1.0
0.5
ψ/α
0
FR
0.05
0.10
0.15
0.20
0.25
0.30
HEAVE
λ/L = 1.75
1.0
0.5
z₀/r
0
FR
0.05
0.10
0.15
0.20
0.25
0.30

FIG.6

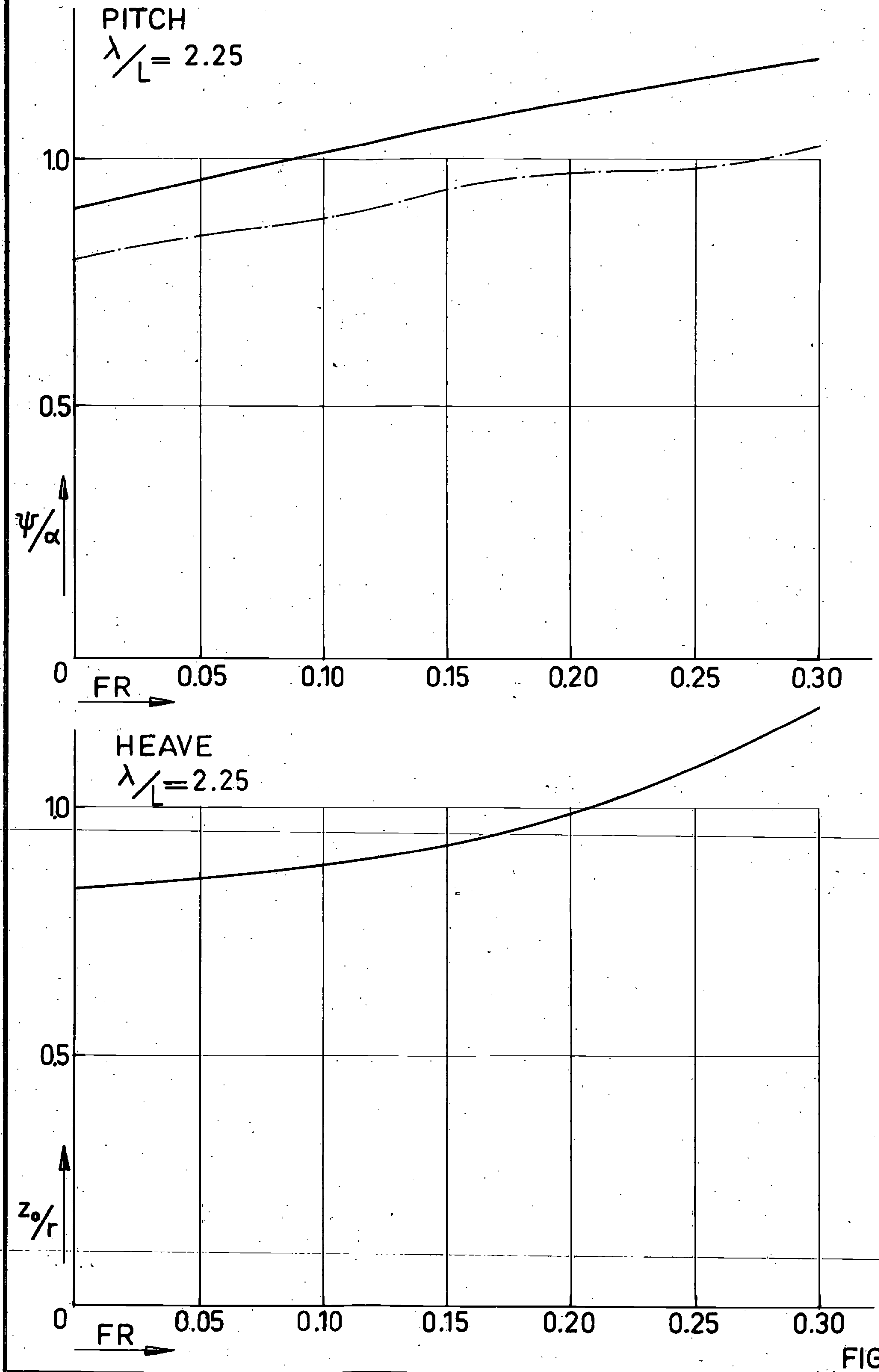

PITCH
λ/L = 2.25
1.0
0.5
ψ/α
0
FR
0.05
0.10
0.15
0.20
0.25
0.30
HEAVE
λ/L = 2.25
1.0
0.5
z₀/r
0
FR
0.05
0.10
0.15
0.20
0.25
0.30

FIG.7

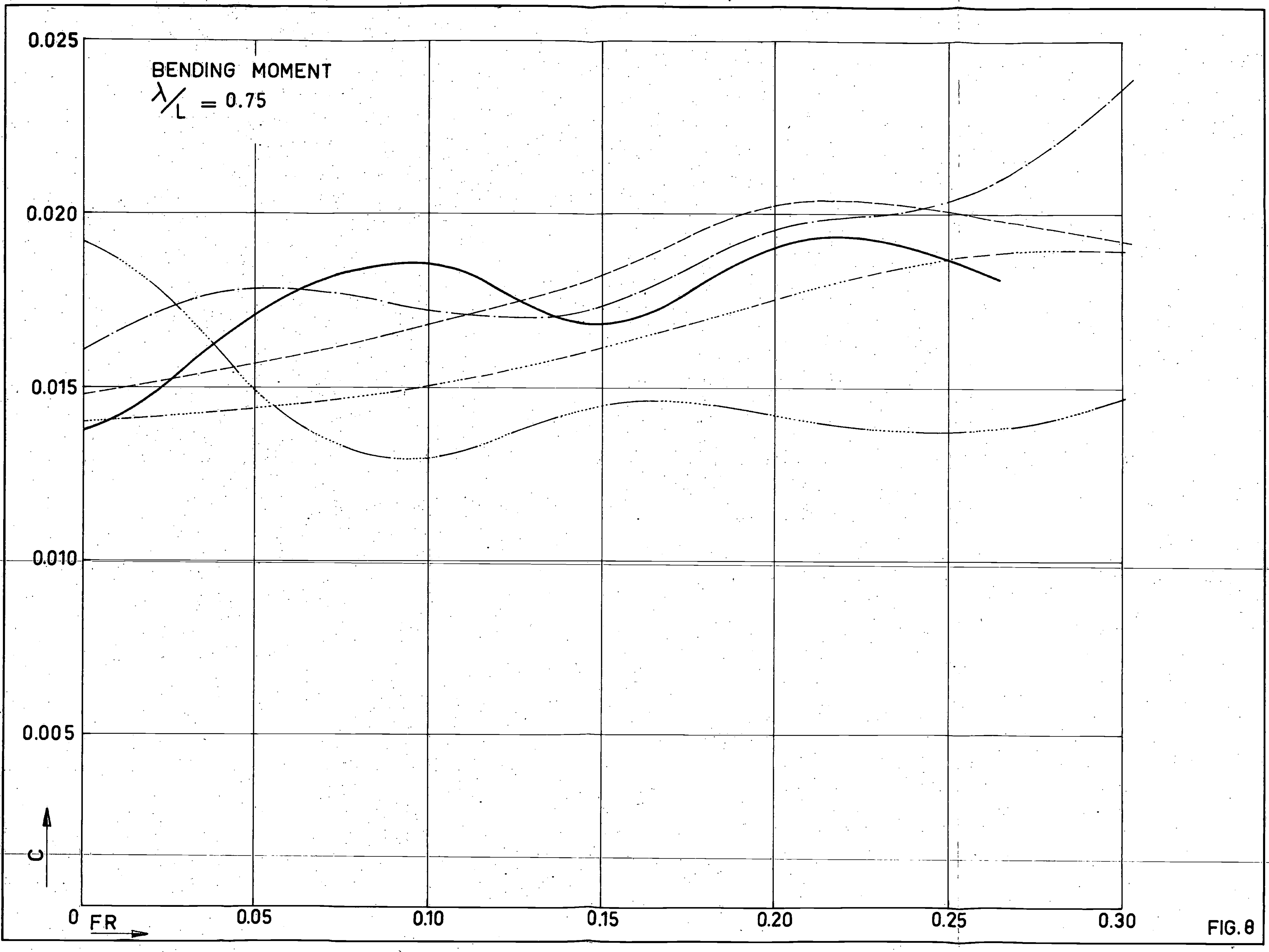
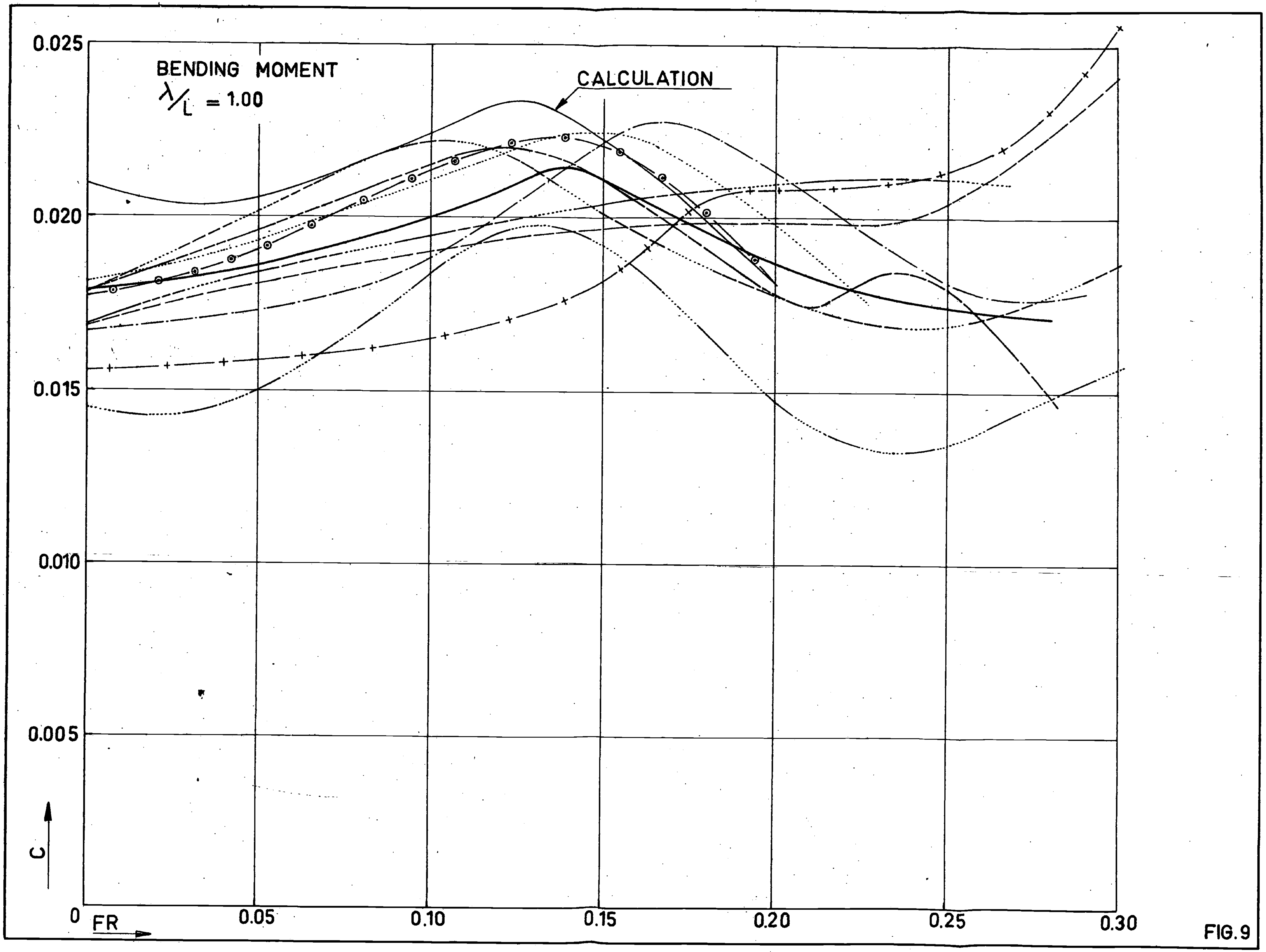

BENDING MOMENT
λ/L = 0.75
0.025
0.020
0.015
0.010
0.005
C
0
FR
0.05
0.10
0.15
0.20
0.25
0.30

FIG. 8


BENDING MOMENT
λ/L = 1.00
CALCULATION
0.025
0.020
0.015
0.010
0.005
0
C
FR
0.05
0.10
0.15
0.20
0.25
0.30
FIG. 9

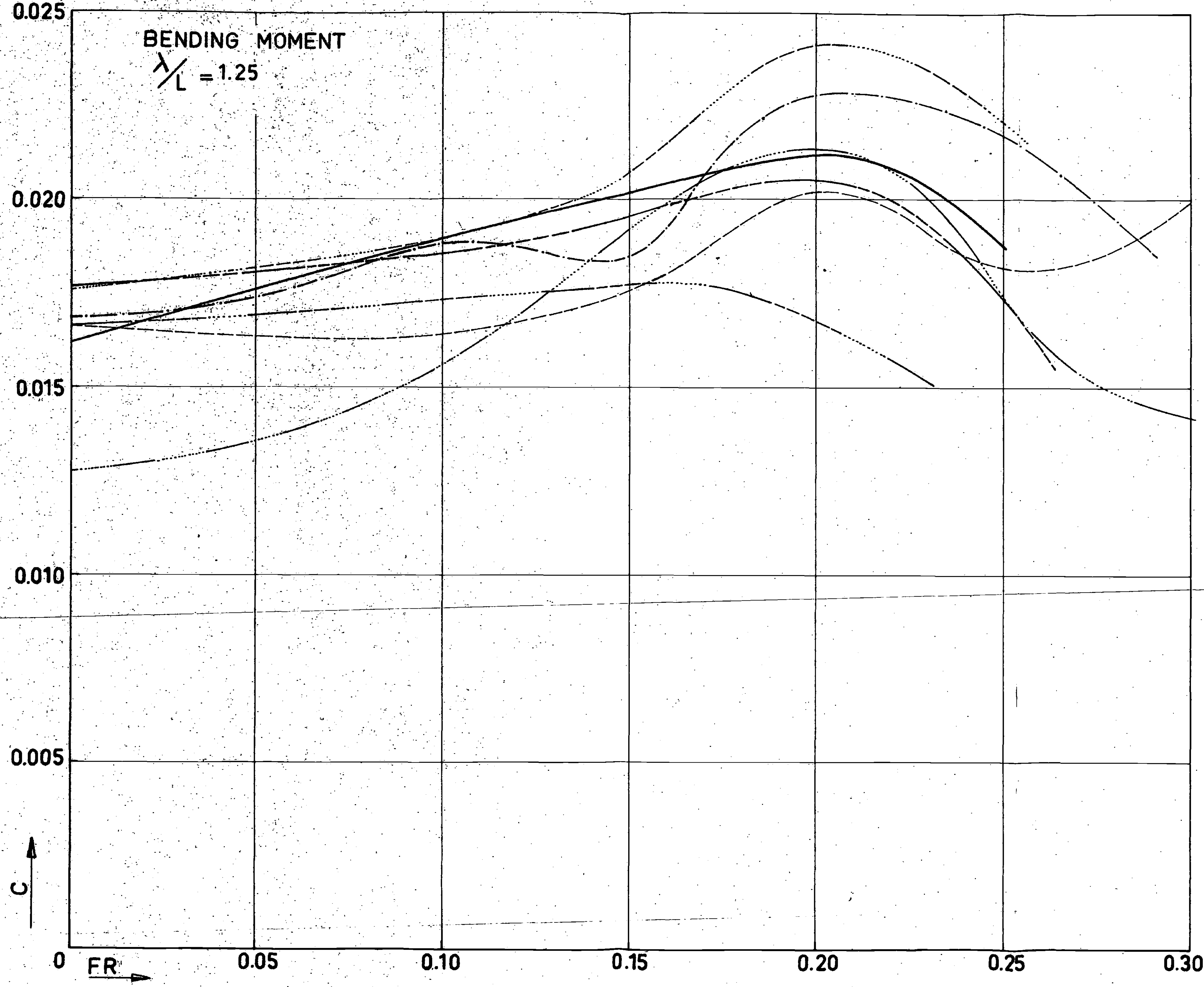
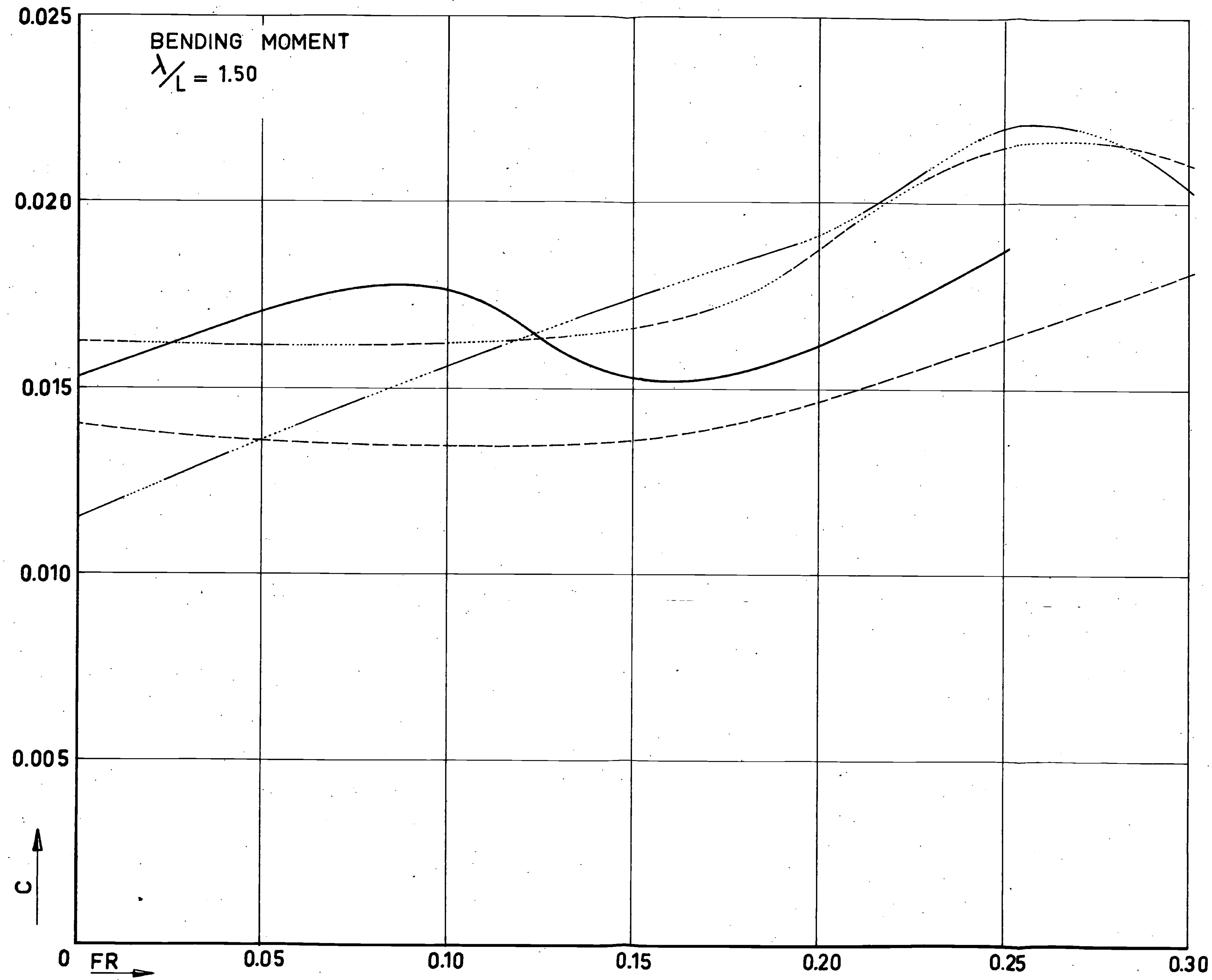
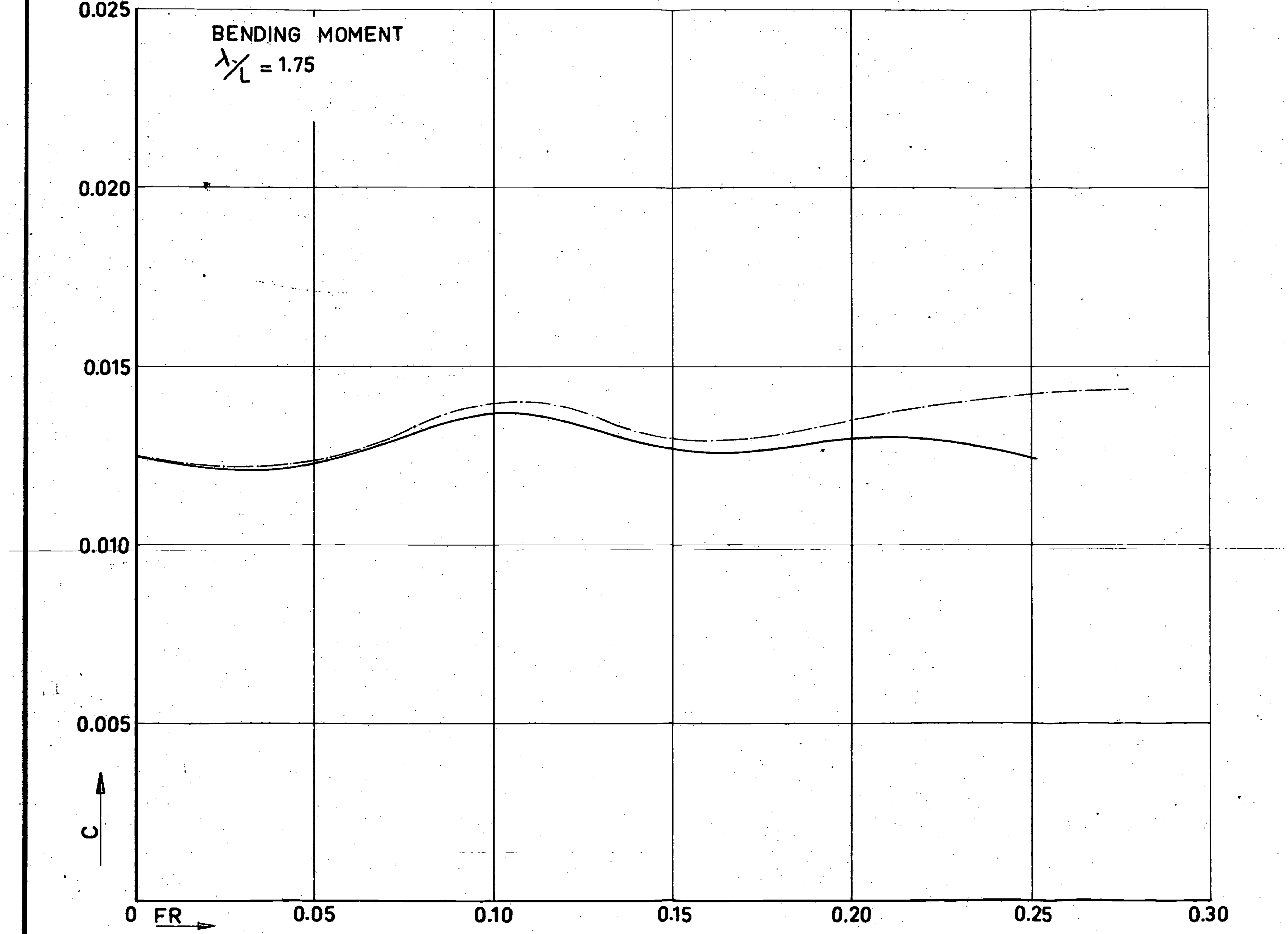

BENDING MOMENT
λ/L = 1.25
0.025
0.020
0.015
0.010
0.005
C
0
FR
0.05
0.10
0.15
0.20
0.25
0.30

FIG.10



BENDING MOMENT
$\lambda/L = 1.50$
0.025
0.020
0.015
0.010
0.005
C
0
FR
0.05
0.10
0.15
0.20
0.25
0.30

FIG.11


BENDING MOMENT
λ/L = 1.75
0.025
0.020
0.015
0.010
0.005
C
0
FR
0.05
0.10
0.15
0.20
0.25
0.30
FIG.12

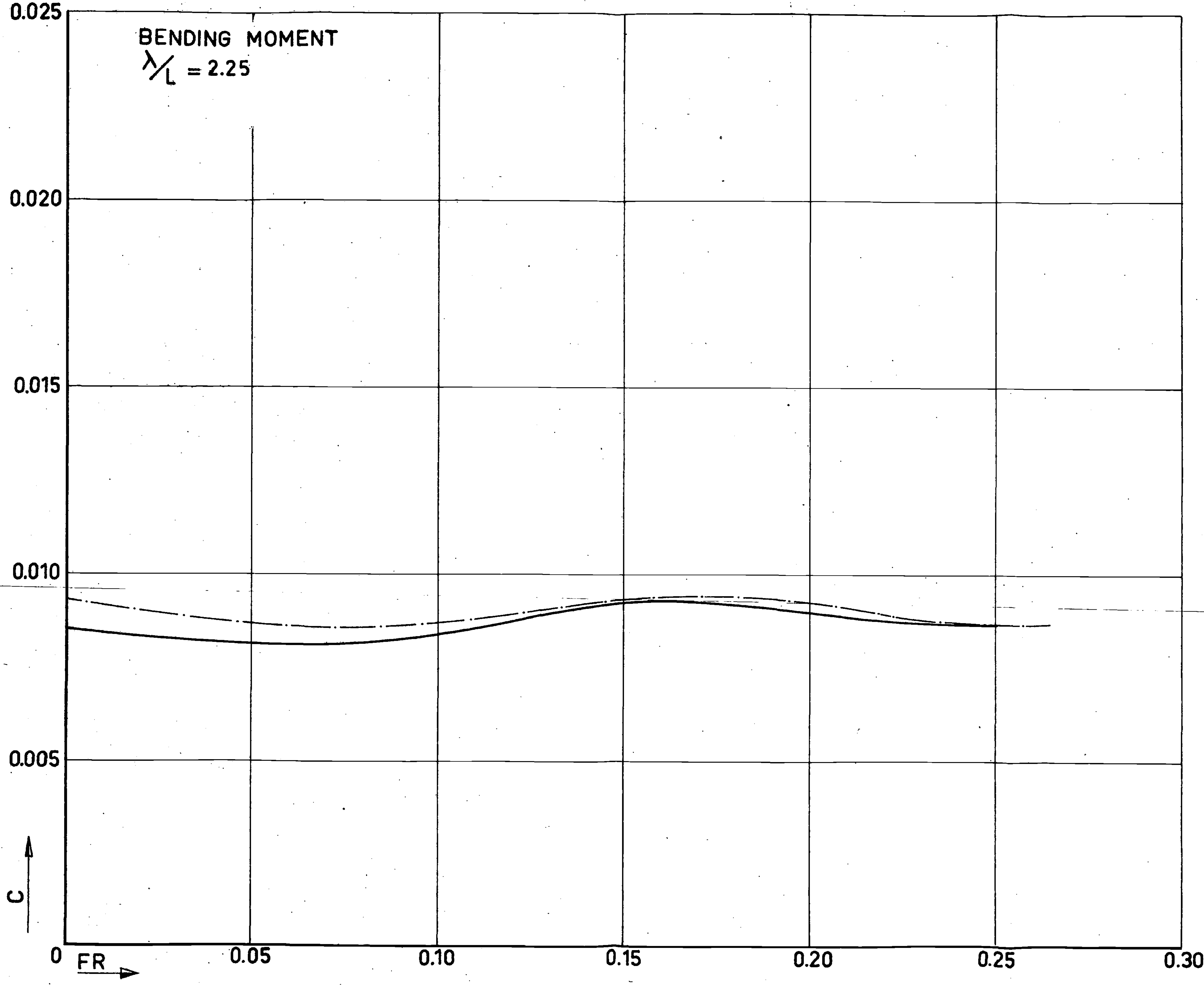

BENDING MOMENT
λ/L = 2.25
0.025
0.020
0.015
0.010
0.005
C
0
FR
0.05
0.10
0.15
0.20
0.25
0.30

FIG.13

AUTHORS		i	$2r/L$	
CHRISTENSEN		0.23	$\frac{1}{40}$	
DALZELL	WIDE TANK	0.23	$\frac{1}{51}$	
DALZELL	NARROW TANK	0.23	$\frac{1}{51}$	
de DOES		0.24	$\frac{1}{50}$	
FUKUDA		0.231	$\frac{1}{45}$	
TANIGUCHI		0.22	$\frac{1}{30}$	
TANIGUCHI		0.22	$\frac{1}{50}$	
AKITA		0.25	$\frac{1}{50}$	
AKITA		0.25	$\frac{1}{30}$	
AKITA		0.272	$\frac{1}{50}$	