Open Water Test Series with Modern Five-Bladed Propeller Models

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Abstract

The paper records the result of experiments with a systematic series of five-bladed aerofoil propeller models, designed in accordance with present-day practice.

Charts of series are shown by so called $\sqrt{B_p}-\delta$ design diagrams.

I. Introduction

Nowadays, five bladed propellers are widely equipped to many ships. However, design diagrams based on open water test series with five-bladed propeller models are hitherto unpublished except Prof. Ir. L. Troost's papers. In this report, authors write the result of experiments with a systematic series of five-bladed AU-series propeller models carried out in the Experiment Tank of Ship Propulsion Division, Transportation Technical Research Institute of Transportation Ministry.

II. Propeller Models

Forms of AU-series propeller models used in the experiments are shown in Fig. 1, and

原稿受付. 7 月 15 日

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TABLE 1
PARTICULARS OF AU-SERIES PROPELLER MODELS

	AU5-50	AU5-65
DIAMETER(M)	0.250	0.250
BOSS RATIO	0.180	0.180
EXP. AREA RATIO	0.500	0.650
MAX. BLADE WIDTH RATIO	0.226	0.294
BLADE THICKNESS RATIO	0.050	0.050
ANGLE OF RAKE	10° 0'	10° 0'
NUMBER OF BLADES	5	5

particulars in Table 1. Considering the ever-increasing speed and power of modern ships, the form of blade section, contour of blade, disc area, blade thickness, boss ratio etc. are preferred.

Experiments have been done in two series of expanded-area ratio namely 0.50 and 0.65, in order to provide means of interpolation and extrapolation, and as to pitch ratio, have been investigated in 0.4, 0.6, 0.8, 1.0 and 1.2. Pitch distribution is constant from

the boss to the tip.

All propeller models of AU-series have a diameter of 250 mm.

Particulars and ordinates of propeller forms and blade sections of AU-series are given in Tables 2 A and 2 B

TABLE 2 A

WIDTHS OF BLADE AS PERCENTAGE OF MAX BLADE WIDTH	r/R	0.2	0.3	0.4	0.5	0.6	0.66	0.7	0.8	0.9	1.0	MAX. BLADE WIDTH AT $0.66r/R=0.2260$ FOR $P/R=0.50$
	FROM GENERATOR-LINE TO TRAILING EDGE	27.96	33.45	38.76	43.54	47.96	49.74	51.33	52.39	48.49	17.29	
	FROM GENERATOR-LINE TO LEADING EDGE	38.58	44.25	48.32	50.80	51.15	50.26	48.31	40.53	25.13		
	TOTAL BLADE WIDTH	66.54	77.70	87.08	94.34	99.11	100.00	99.64	92.92	73.62		
BLADE THICKNESS AS PERCENTAGE OF D		4.06	3.60	3.13	2.66	2.19	1.91	1.72	1.26	0.79	0.32	MAX. BLADE THICKNESS AT PROPELLER AXIS=0.05D
DISTANCE OF THE POINT OF MAX THICKNESS FROM THE LEADING EDGE AS PERCENTAGE OF BLADE WIDTH		32.0	32.0	32.0	32.5	34.9	37.9	40.2	45.4	48.9		

TABLE 2 B

(1) ORDINATES OF X VALUE ARE GIVEN AS PERCENTAGE OF BLADE WIDTH B.																			
(2) ORDINATES OF Y VALUE ARE GIVEN AS PERCENTAGE OF Y_{max} .																			
r/R	X	0	2.00	4.00	6.00	10.00	15.00	20.00	30.00	32.00	40.00	50.00	60.00	70.00	80.00	90.00	95.00	100.00	
0.20	Y_0	35.00	51.85	59.75	66.15	76.05	85.25	92.20	99.80	100.00	97.75	89.95	78.15	63.15	45.25	25.30	15.00	4.50	
	Y_0	24.25	19.05	15.00	10.00	5.40	2.35												
0.30	X	0	2.00	4.00	6.00	10.00	15.00	20.00	30.00	32.00	40.00	50.00	60.00	70.00	80.00	90.00	95.00	100.00	
	Y_0	35.00	51.85	59.75	66.15	76.05	85.25	92.20	99.80	100.00	97.75	89.95	78.15	63.15	45.25	25.30	15.00	4.50	
0.40	Y_0	24.25	19.05	15.00	10.00	5.40	2.35												
	X	0	2.03	4.06	6.09	10.16	15.23	20.31	30.47	32.50	40.44	50.37	60.29	70.22	80.15	90.07	95.04	100.00	
0.50	Y_0	35.00	51.85	59.75	66.15	76.05	85.25	92.20	99.80	100.00	97.75	89.95	79.15	63.15	45.25	25.30	15.00	4.50	
	Y_0	24.25	19.05	15.00	10.00	5.40	2.35												
0.60	X	0	2.18	4.36	6.54	10.91	16.36	21.81	32.72	34.90	42.56	52.13	61.70	71.28	80.85	90.43	95.21	100.00	
	Y_0	35.00	51.85	59.75	66.15	76.05	85.25	92.20	99.80	100.00	97.75	89.95	78.15	63.15	45.25	25.30	15.00	4.50	
0.70	Y_0	24.25	19.05	15.00	10.00	5.40	2.35												
	X	0	2.51	5.03	7.54	12.56	18.84	25.12	37.69	40.20	47.23	56.03	64.82	73.62	82.41	91.21	95.60	100.00	
0.80	Y_0	35.00	51.85	59.75	66.15	76.05	85.25	92.20	99.80	100.00	97.75	89.95	78.15	63.15	45.25	25.30	15.00	4.50	
	Y_0	24.25	19.05	15.00	10.00	5.40	2.35												
0.90	X	0	3.06	6.11	9.17	15.26	22.92	30.56	45.85	48.90	54.91	62.42	69.94	77.46	84.97	92.48	96.24	100.00	
	Y_0	35.00	51.85	59.75	66.15	76.05	85.25	92.20	99.80	100.00	97.75	89.95	78.15	63.15	45.25	25.30	15.00	4.50	
0.95	X	0	3.13	6.25	9.38	15.63	23.44	31.25	46.87	50.00	55.88	63.23	70.59	77.94	85.30	92.65	96.32	100.00	
	Y_0	35.00	51.85	59.75	66.15	76.05	85.25	92.20	99.80	100.00	97.75	89.95	78.15	63.15	45.25	25.30	15.00	4.50

III. Open Water Tests

The tests were carried out by means of a propeller open water test dynamometer, according to the scheme of the Experiment Tank of Ship Propulsion Division. The arrangement of the test instruments is shown in Fig. 2. All propeller models have been tested over a 100% slip range at an immersion to the centre of propeller shaft equal to the screw diameter, and the number of revolutions was kept constant, namely 11 revolutions per seconds, and the speed of advance varied from zero to above the speed for zero thrust.

For fixing the net thrust, the correction for the resistance of the screw hub at various speeds of advance were applied. Mean temperature of water among these tests is 7°C., and the Reynolds numbers according to the following formulars are as in Table 3. So, it is considered scale effect is negligible.

FIG. 2

$$R = \frac{nD^2}{\nu} \quad (1)$$

$$R = \frac{a_e}{z} \frac{nD^2}{\nu} \quad (2)$$

$$R = \frac{nD^2}{\nu} b_{mn} \quad (3)$$

n = Revolutions per sec. D = Diameter of screw a_e = Expanded area ratio
 z = Number of blades b_{mn} = Mean blade width ratio ν = Kinematic viscosity coefficient
 R = Reynolds numbers

TABLE 3
LIST OF REYNOLDS NUMBERS

TYPE	FORMULA (1)	FORMULA (2)	FORMULA (3)
AU5-50	4.84×10^5	4.84×10^4	9.27×10^4
AU5-65	4.84×10^5	6.29×10^4	12.06×10^4

IV. Diagrams

(a) Curves of K_t , K_q , and η_p on a based of J .

These curves are given in Figs 3. and 4. The meaning of symbols is as follows : -

K_t = Thrust constant = $T/\rho n^2 D^4$

K_q = Torque constant

$\eta_p = Q/\rho n^2 D^5$ η_p = Propeller efficiency in open water = $\frac{K_t J}{2\pi K_q}$ $J = v_e/nD$

T = Measured thrust Q = Measured torque ρ = Density of tank water

(b) $\sqrt{B_p} - \delta$ diagrams

In these diagrams, we used metric units, and density of sea water is assumed as 104.51 Kg m⁻⁴sec⁻². $\sqrt{B_p} - \delta$ diagrams are given in Figs. 5 and 6.

The meaning of symbols as follows : -

B_p =Power coefficient= $NP^{0.5}/Va^{2.5}$

δ =Diameter constant= ND/Va

H/D =Pitch ratio

N =Revolutions per minute for ship

P =Delivered horse power in sea water

V_a =Speed of advance through the wake water in knots

D =Screw diameter in meter

1 HP=75 kg msec⁻¹

V. Comparison of AU 5-50 and AU 5-65

Optimum values of η_p of AU 5-50 is better than that of AU 5-65 for all range of J , and its superiority is greater in low pitch ratio. This shows the gap effect is larger in low pitch ratio than in high pitch ratio. Effective pitch ratio is about 4% smaller in AU 5-65 than in AU 5-50.

Table 4 gives optimum values of η_p , diameter constant and pitch ratio for various power constant. From this table, optimum values of η_p of AU 5-65 is lower, diameter constant is smaller, and pitch ratio is greater than those of AU 5-50. In the case of same power and revolutions of ships, therefore, optimum diameter of the propeller of great disc area is small, and pitch ratio is great as comparison with the propeller of small disc area.

TABLE 4
OPTIMUM VALUES OF η_p , DIAMETER CONSTANT δ
AND PITCH RATIO H/D FOR VARIOUS $\sqrt{B_p}$.

$\sqrt{B_p}$	AU 5-50			AU 5-65		
	η_p	δ	H/D	η_p	δ	H/D
4.0	0.672	46.7	0.888	0.664	46.0	0.928
6.0	0.564	67.0	0.720	0.556	65.3	0.770
8.0	0.483	86.0	0.635	0.475	84.0	0.689
10.0	0.425	104.0	0.583	0.414	101.8	0.635
12.0	0.380	121.8	0.550	0.368	119.0	0.598
14.0	0.343	138.9	0.525	0.334	136.0	0.570

VI. Acknowledgement

Authors wish to thank Mr. Shiro Kan (Vice-President of Transportation Technical Research Institute), Mr. late Nobutsune Masaki (Amagasaki Iron and Steel Mfg. Co. Ltd.), Mr. Tadao Kondō (Kure Shipbuilding and Engineering Co. Ltd.) and the staff of the Experiment Tank, especially Mr. Yoshiro Kawakami and Mr. Akiyoshi Okumoto, for their valuable assistance in the evaluation of the experiments and the preparation of the propeller charts.