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Open Water Test Series with Modified AU-Type Four-Bladed Propeller Models

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Summary

The paper records the result of experiments with a systematic series of modified AU-type four-bladed propeller models.

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

I. Introduction

Further to the work on AU-type five-bladed propellers, a paper read in the Society of Naval Architects of Japan (Vol.106), on the effect of propeller blades (Vol.103), and on AU and AU_w-type six-bladed propellers (Vol.106), a systematic testing work with modified AU-type four-bladed propeller models for the solid-type propellers has been carried out in the Experiment Tank of Ship Propulsion Division.

In this report, authors write the result of this work, and give the design diagrams for the four-bladed propellers.

II. Propeller Models

List of the model propellers are given in Table 1.

Constructional diagrams and tables, stating all particulars of the blade sections of the modified AU-type series, are given in Fig.1 and in the Tables 2 and 3.

Table 1 Particulars of Propeller Models

	Modified AU4-40	Modified AU4-55
M. P. NO.	1305~1309	1310~1314
Diameter (mm)	250	250
Boss Ratio	0.180	0.180
Exp. Area Ratio	0.40	0.55
Max. Blade Width Ratio	0.226	0.311
Mean Blade Width Ratio	0.192	0.263
Blade Thickness Ratio	0.050	0.050
Angle of Rake	10°—0'	10°—0'

Fig.1 General Plan of Modified AU4 Series Propeller Models

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Table 2 Dimensions of Modified AU-4 Series Prop.

r/R	0.2	0.3	0.4	0.5	0.6	0.66	0.7	0.8	0.9	0.95	1.00	Max. Blade Width at 0.66R =0.226 D for $F_E/F=0.40$ Max Blade Thickness at Prop. Axis =0.050 D
From Generator Line to Trailing Edge	27.96	33.45	38.76	43.54	47.96	49.74	51.33	52.39	48.49	42.07	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	13.55		
Total Blade Width	66.54	77.70	87.08	94.34	99.11	100.00	99.64	92.92	73.62	55.62		
Blade Thickness as % of D	4.06	3.59	3.12	2.65	2.18	1.90	1.71	1.24	0.77	0.54	0.30	
Distance of the Point of Max. Thickness From the Leading Edge as % of Blade Width	32.0	32.0	32.0	32.5	34.9	37.9	40.2	45.4	48.9	50.0		

Table 3 Offsets of Modified AU Type Prop.

1) Ordinates of X Value are Given as % of Blade Width.

2) Ordinates of Y Value are Given as % 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_U		24.25	19.05	15.00	10.00	5.40	2.35										
0.30	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_U		24.25	19.05	15.00	10.00	5.40	2.35										
0.40	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_U		24.25	19.05	15.00	10.00	5.40	2.35										
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	78.15	63.15	45.25	25.30	15.00	4.50
	Y_U		24.25	19.05	15.00	10.00	5.40	2.35										
0.60	Y_0	34.00	49.60	58.00	64.75	75.20	84.80	91.80	99.80	100.00	97.75	89.95	78.15	63.15	45.25	25.30	15.00	4.50
	Y_U		23.60	18.10	14.25	9.45	5.00	2.25										
0.70	Y_0	30.00	42.90	52.20	59.90	71.65	82.35	90.60	99.80	100.00	97.75	89.95	78.15	63.15	45.25	25.30	15.00	4.50
	Y_U		20.50	15.45	11.95	7.70	4.10	1.75										
0.80	Y_0	21.00	32.45	41.70	50.10	64.60	78.45	88.90	99.80	100.00	97.75	89.95	78.15	63.15	45.25	25.30	15.00	4.50
	Y_U		14.00	10.45	8.05	5.05	2.70	1.15										
0.90	Y_0	8.30	21.10	31.50	40.90	57.45	74.70	87.45	99.70	100.00	98.65	92.75	83.05	69.35	51.85	30.80	19.40	6.85
	X_U		4.00	2.70	2.05	1.20	0.70	0.30										
0.95	Y_0	6.00	19.65	30.00	39.60	56.75	74.30	87.30	99.65	100.00	99.00	93.85	84.65	71.65	54.30	33.50	21.50	8.00
	Y_U																	

The shape of profiles for modified AU-type series were improved from the AU-type series on accounting of a prevention from cavitation of the back side and face side of the blade sections¹⁾. Experiments have been done in two modified AU-type series of expanded-area ratio, namely 0.40 and 0.55, in order to provide means of interpolation and extrapolation. As to pitch ratio, 0.5, 0.6, 0.8, 1.0 and 1.2 are tested. Pitch distribution is constant from the hub to the tip. All ten propeller models have a diameter of 250mm, and are made of aluminium alloy.

III. Open Water Tests

The tests were carried out by means of a propeller open water test dynamometer (Mitsubishi-type), according to the scheme of the Experiment Tank of Ship Propulsion Division. The arrangement of the test instruments is shown in Fig. 2.

- 1) H. Takahashi ; A. Prevention from Face Cavitation by varying the Form of Blade Sections of a Screw Propeller, Report of T.T.R.I. No.38, 1959.

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 11.5 revolutions per second, 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 speed of advance was applied.

Mean temperature of water among these tests in 8.0°C, and the Reynolds number according to the following formulas are as in Table 4. So, it is considered scale effect is negligible.

$$R_{n1} = nD^2/\nu \quad (1)$$

$$R_{n2} = nD^2/\nu \cdot a_E/z \quad (2)$$

$$R_{n3} = b_{mn} \cdot nD^2/\nu \quad (3)$$

n = Revolutions per second, D = Diameter of screw,

a_E = Expanded-area ratio, z = Number of blades,

b_{mn} = Mean blade width ratio,

Fig. 2 Arrangement of the Test Instruments

ν = Kinematic viscosity coefficient,

R_n = Reynolds number.

Table 4 Reynolds number

	Formula (1)	Formula (2)	Formula (3)
Modified AU 4-40	5.21×10^5	5.21×10^4	1.00×10^5
Modified AU 4-55	5.21×10^5	7.16×10^4	1.37×10^5

IV. Diagrams

Fig. 3 J - K_T - K_Q Diagram (Modified AU 4-40)

Fig. 4 J - K_T - K_Q Diagram (Midified AU 4-55)

Fig.5 $\sqrt{B_p} \sim \delta$ Design Diagram (Modified AU 4-55)

Fig. 6 $\sqrt{B_p} \sim \delta$ Design Diagram (Modified AU 4-40)

(a) Curves of K_T, K_Q and η_0 on a base of J ;

These curves are given in Figs. 3 and 4.

The meaning of symbols is as follows :—

$$K_T = \text{Thrust coefficient} = T / \rho n^2 D^4$$

$$K_Q = \text{Torque coefficient} = Q / \rho n^2 D^5$$

$$\eta_0 = \text{Propeller efficiency in open water} = J \cdot K_T / 2\pi K_Q$$

$$J = \text{Advance coefficient} = v_A / nD$$

$$T = \text{Measured thrust, } Q = \text{Measured torque}$$

$$v_A = \text{Speed of advance, } \rho = \text{Density of tank water}$$

(b) $\sqrt{B_p} \sim \delta$ design diagrams ;

In these diagrams, we used metric units, and density of sea water is assumed as $101., 51 \text{ kg} \cdot \text{m}^{-4} \cdot \text{sec}^{-2}$.

$\sqrt{B_p} \sim \delta$ design diagrams are given in Fig. 5 and 6.

The meaning of symbols is as follows :—

$$B_p = \text{Power coefficient} = NP^{0.5} / V_A^{2.5}$$

$$\delta = \text{Diameter constant} = ND / V_A$$

$$H/D = \text{Pitch ratio, } N = \text{Revolutions per minute for ship,}$$

$$P = \text{Delivered horse power in sea water,}$$

$$V_A = \text{Speed of advance through the wake water in knots, } D = \text{Screw diameter in meter.}$$

$$1 \text{ PS} = 75 \text{ kg} \cdot \text{m} \cdot \text{sec}^{-1}$$

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