PADDLE WHEEL DESIGN METHODOLOGY[1]

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Abstract

A design methodology for articulated paddle wheel design is reviewed. A design calculation for the paddle wheel is presented.

1. Introduction

Amidst the tourist sights in New Orleans is a marker across from Jackson Square indicating that in 1810 the paddle wheel steamer New Orleans arrived. This marked an epoch of paddle wheel transport on the Mississippi River. One of the first articles in the Institution of Naval Architects Proceedings present a description of a Mississippi River paddle wheel steamer [1]. Taggert's book on propulsion devices [2] showed that higher paddle wheel efficiency is realized when the paddle wheel vanes are articulated.

With efficiency of 40-45% an initial question should be asked if the owner/operator can afford the higher expense of a paddle wheel drive compared to a conventional prop with a free wheeling stern wheel.

In this paper a scheme developed for paddle wheel design developed in the Soviet Union [3] is presented. It allows the horsepower, thrust, and efficiency to be estimated for articulated paddle wheels.

2. Paddle Wheel Geometry and Design Calculation Scheme.

Fig. 1 shows the geometry of the articulated paddle wheel which will be used in the present example. Here we define:

$$C_p = T/\rho\, F_p\, D^2 n^2 \quad \text{P.W. Thrust Coeff.} \qquad (1)$$

$$C_m = M/\rho\, F_p\, D^3 n^2 \quad \text{P.W. Torque Coeff.} \qquad (2)$$

$$\eta_p = \frac{C_p}{C_m}\frac{J_p}{2} \quad \text{P.W. Efficiency} \qquad (3)$$

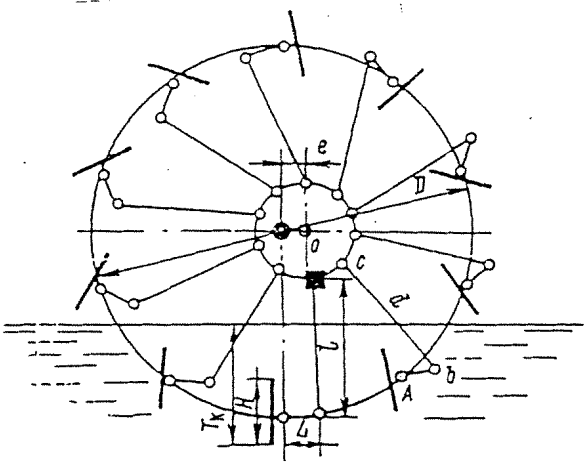

FIG.1

$$J_p = \frac{V_p}{\pi\, nD} \quad \text{P.W. Advance Ratio} \qquad (4)$$

$$F_p = 2\, B_p\, T_k\, m^2 \quad \text{P.W. Area} \qquad (5)$$

$$K_F = V_p \sqrt{\frac{\rho\, F_p V_p}{A\ 11.93\ HP}} \qquad (6)$$

$$\frac{V_p}{\sqrt{D}} = J_p\, \pi\, n \sqrt{D} \qquad (7)$$

$$\text{The horsepower } HP = \frac{75\ TB\ \eta_p}{V_p} \qquad (8)$$

$$A = 1/(a_m \cdot a_2, a_\theta, a_\beta, a_e) \qquad (9)$$

$$\text{where } B = b_p\, b_\theta\, b_\beta\, b_e \qquad (10)$$

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Speed	V	m/s	3.31
Speed	V_p	m/s	3.41*
Draft	T	m	1.61
Dia	D	m	3.89
Width	β_p	m	6.8
Depth	T_K	m	1.41
Paddle Height	H	m	0.95
Paddle No	Z	-	8
Hub	h_B	m	2.62
offset ratio	e	-	0.667
rps	n	sec	0.427
a_m	a_m	-	0.91
b_p	b_p	-	1.03

Note: * $V_p = V(b_p)$

Table 1. Stern Wheel Paddle Wheel

3. Example of Design Calculation

Evolution of design in Table 1 is done based on Soviet Design Graph [3]. This articulated paddle wheel design data is summarized in Table 1.

Using the data in Table 1

Calculate:

a) $\beta_p = H/D = 0.244$

b) $\theta_1 = (2h_B - 2T_K)/D = 0.519$

c) $F_p = 2B_p T_K = 19.2\ m^2$

d) $n\sqrt{D} = 0.427\ \sqrt{3.89} = 0.844$

e) $\dfrac{V_p}{\sqrt{D}} = \dfrac{1.03\ (3.31)}{\sqrt{3.9}} = 1.72$

f) $J_p = \dfrac{1.03\ (3.31)}{(3.14)(3.89)(0.427)} = 0.65$

Using the diagram for $n\sqrt{D}$ and J_p (Fig. 2)

Read $\sqrt{Cm} = 1.135$ or $Cm = 1.285$

$K_p = 7.57$ or $K_p^2 = 6.6$

$\eta_p = 0.57$

for A and B the facilities in the upper part of the diagram are

$a_2 = 1.1$ for $Z = 8$

$a_\theta = 1.024$ for $\theta = 0.519$

$a_\beta = 0.988$ for $\beta_p = 0.244$

$a_e = 1.02$ for $e = 0.667$

giving $A = 1/(0.91 \times 1.1 \times 1.024 \times 0.988 \times 1.02) = 0.91$

From the same diagrams

$b_\theta = 0.992$ for $\theta_1 = 0.519$

$b_\beta = 1.00$ for $\beta_p = 0.244$

$b_e = 0.982$ for $e = 0.667$

giving

$B = 1.03 \times 0.992 \times 1.00 \times 0.982 = 1.01$

The horsepower HP, thrust, and efficiency of the articulated wheel is then calculated

$$HP = \frac{C_m \rho F_p D^3 n^3}{11.93} =$$

$$\frac{1.285 \times 1.02 \times 19.2 \times 59 \times 0.078}{11.93} = 1070\ HP$$

$\eta = B\eta_p = 1.01 \times 0.57 = 0.575$

$$T = \frac{75\ N_p\ \eta}{V_p} = \frac{7.5 \times 1075\ .\ 0.575}{3.4} =$$

$= 13{,}600$ Kg

4. Concluding Remarks

The articulated paddle wheel design has been presented. It is possible using the methodology outlined to estimate the articulated paddle wheel horsepower, thrust, and paddle wheel offering.

Acknowledgments

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References

1. Transactions Institution of Naval Architects, Vol. 1, 1861.

2. Taggert, R., Marine Propulsion, Principles and Evolution, Gulf Publishing Co., Houston, Texas, 1969, pp. 47-89.

3. Voznesansky, Y. E. (ed.),HANDBOOK OF SHIP THEORY, SHIP PROPULSION, AND CONTROL, Sudostroyeniye, Leningrad, 1973, pp. 225-229 (In Russian).

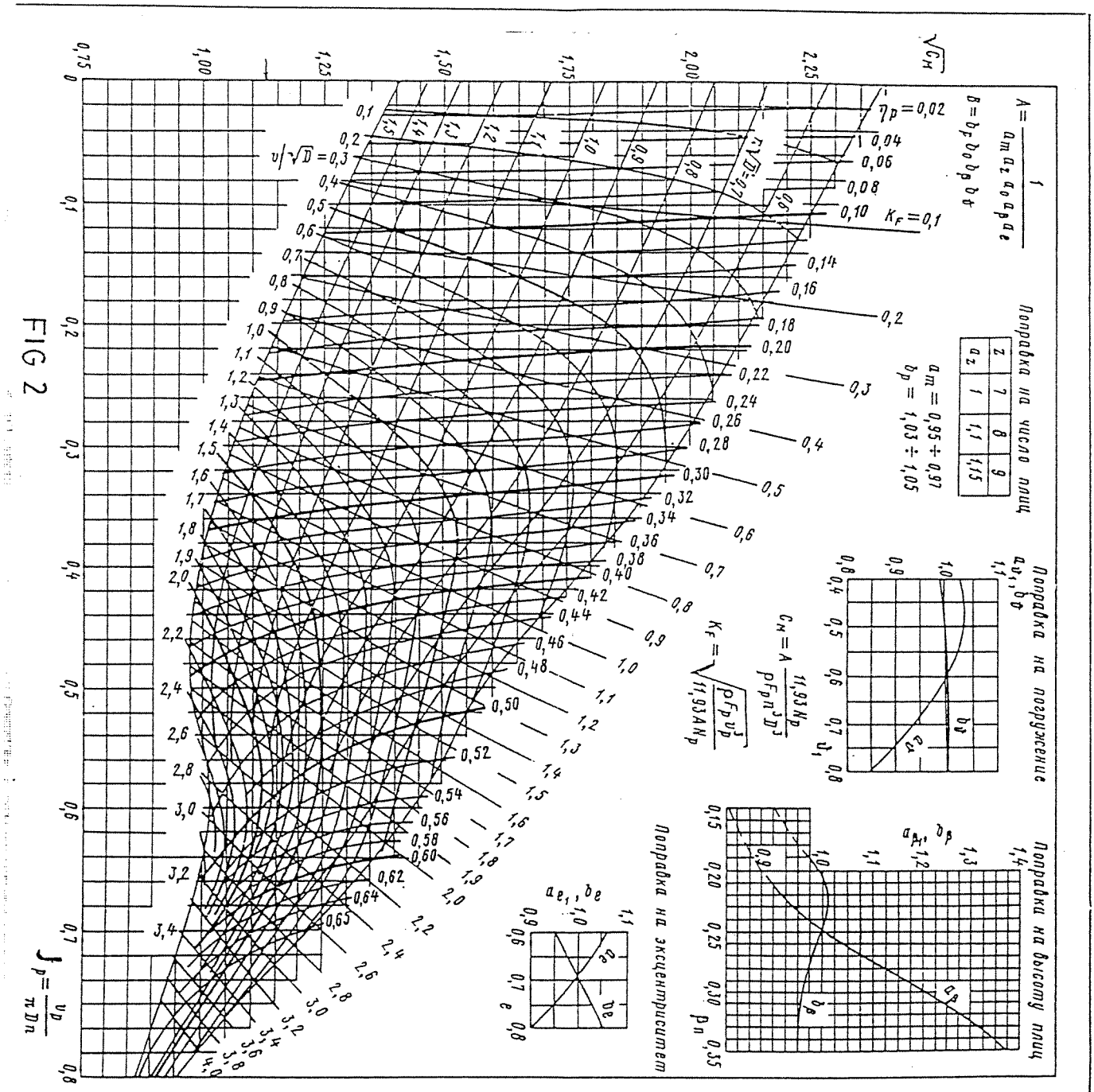
$A = \frac{1}{a_m a_z a_0 a_p a_e}$
$B = b_z b_0 b_p b_e$
$\sqrt{G_H}$
$\eta_p = 0{,}02$
$v/\sqrt{D} = 0{,}3$
$K_F = 0{,}1$
$K_F = \sqrt{\frac{\rho F_p v_p^3}{11{,}93 A N_p}}$
$C_H = A \frac{11{,}93 N_p}{\rho F_p n^3 D^3}$
$J_p = \frac{v_p}{\pi D n}$
Поправка на число плиц
$a_m = 0{,}95 \div 0{,}97$
$b_p = 1{,}03 \div 1{,}05$
Поправка на погружение
Поправка на высоту плиц
Поправка на эксцентриситет

FIG 2