Trials of a semi-Kaplan towboat propeller

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IN the 1950-1960's ducted propellers and higher powered diesel towboats began to operate on U.S. inland waterways. This was the standard until the past decade when the high cost of fuel resulted in towboats fitted with heavy fuel engines.

Actual towboat performance is difficult to quantify using scale model tests. Consequently, many developments in river towboats evolve from operational feedback, analysis of logbooks and designer intuition in addition to preliminary tow tank studies. This is the main reason for making extended measurements of the towboat fuel consumption.

Recently the authors developed a semi-Kaplan ducted propeller for repowering a 700 hp towboat. The semi-Kaplan propeller is shown in Fig. 1.

This new propeller design resulted from the necessity of repowering a triple screw towboat with 3 × 2400 bhp 600 rpm heavy fuel diesel engines. The original towboat engines turned 5 bladed ducted propellers which absorbed 2800 shp at 215 rpm. Since the 3:156 to 1 reduction gears were to be retained, the new propellers would be turning at a slower 190 rpm. This design requirement is summarized in Table 1.

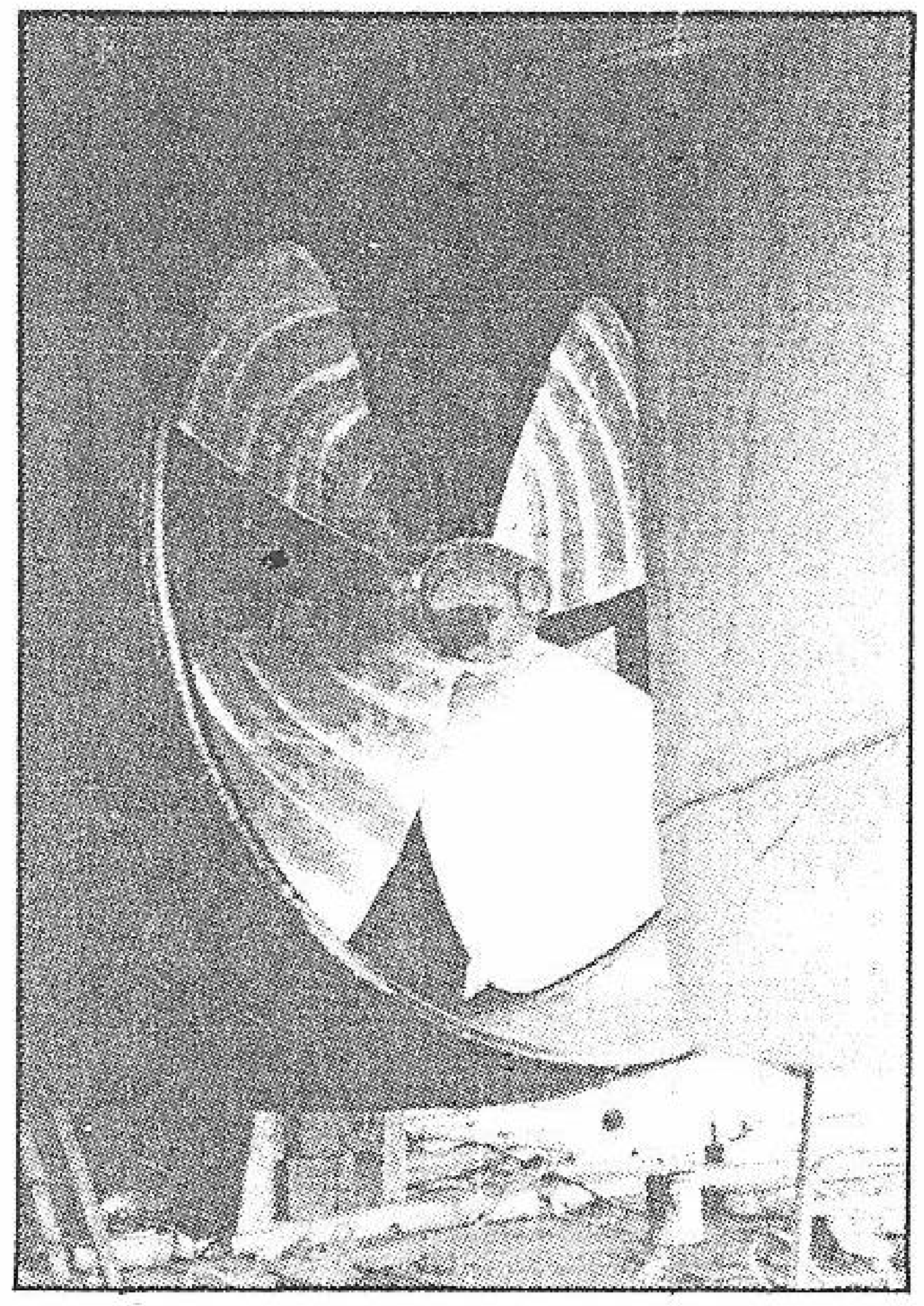
Towboat propeller design

The towboat propeller design is based on the methods developed in Ref [1] [2]. The propellers were matched for 7000 hp towboat pushing a 5 × 6 barge tow in deep water. In order to insure the correct thrust, an unconventional pitch distribution was adopted which loaded the blade tips of the semi-Kaplan propellers.

Trial results

To verify the performance improvements extended towboat trials were conducted over 10-15 trips to establish towboat speed and fuel consumption. The initial tests were done with the semi Kaplan propellers installed. The towboat was docked and 5 bladed propellers of conventional design were fitted. These tests provided the basis for the present comparison.

To identify the advantages a readily



The semi-Kaplan towboat propeller installed.

calculated index Equivalent Barge Mile per gallon of fuel was adopted.

$$EBM/g = \frac{(n + 0.6\ m)R}{g}$$

where

n = number of loaded barges
m = number of empty barges
R = trip distance in miles
g = gallons of fuel consumed

Table 2 summarizes a comparison for 15 towboat trips going north bound against the river current. Taking 1/(EBM/g) we obtained 2.7 gallons/EBM for the semi-Kaplan propellers. The corresponding value is 3.125 gallons/EBM was obtained for the conventional 5 bladed propeller. This indicates a 13.5% improvement from fitting the semi-Kaplan propeller.

The higher speed when the towboat is fitted with the semi-Kaplan propellers translates into 3 additional trips (Cairo, Illinois to Baton Rouge, Louisiana) corresponding to an increased yearly revenue of US$ 100,000. The reduced (2.7 versus 3.125 gallons) engine fuel costs represents a savings of $200,000/year. Consequently, fitting the semi-Kaplan propellers generates a total from fuel savings and increased revenue of $300,000/year.

Vibration levels

In order to document the vibration levels, vibration signature analysis was performed in the engine room. The measurements with the semi-Kaplan propellers were made on two trips with different tow arrangements and differing barge numbers.

Experience with propellers with different blade numbers has shown that the blade number affects the unsteady force levels. In several cases it has been demonstrated that increasing the blade number from 4 to 5 reduced the measured hull vibration levels. It was expected that the four bladed design with large blade area and no skew would encounter the abrupt axial wake changes and transmit high vibration loads into

Table 1. 7000 hp towboat design specifications

Towboat	
Length	44.2 m
Beam	14.93 m
Draft	2.74 m
Operating Speed V	8.5 mph
Towboat Push	617,833 N
Thrust Shaft	205,961 N
Propeller Diameter	2.79 m
Ahead rpm	190 rpm
Astern rpm	193 rpm

Table 2. Comparison of towboat trip data with semi-Kaplan and conventional propellers. Northbound against river current

	Towboat Fitted with with Semi-Kaplan Design 4-Blade Propeller (11/83 - 9/84)			Towboat Fitted with Conventional 5-Blade Propeller (9/84 - 2/85)		
Trip	EBM Barge-Mile	EBM/g Barge-Mile Gal.	Speed V mph	EBM Barge-Mile	EBM/g Barge-Mile Gal.	Speed V mph
1	15.0[1]	0.299[1]	4.96[1]	19.0	0.320	3.88
2	26.0	0.407	4.27	22.8	0.319	3.85
3	15.4	0.365	5.83	24.0	0.357	4.02
4	15.0	0.347	5.83	24.0[1]	0.228[1]	2.83[1]
5	21.6[2]	0.530[2]	5.92[2]	22.8	0.305	3.46
6	20.4	0.343	4.55	18.4	0.338	4.29
7	27.0	0.341	3.25	22.0	0.253	3.79
8	20.0	0.383	4.67	20.8	0.302	2.56
9	20.0	0.344	5.44	22.0	0.369	4.04
10	26.6	0.505	4.54	16.6	0.312	5.29
11	22.0	0.415	9.06	20.4	0.325	4.60
12	26.8	0.394	3.50	18.2	0.288	4.58
13	27.6	0.337	2.86	18.4	0.341	4.60
14	21.0	0.303	3.90	25.6[2]	0.395[2]	3.65[2]
15	20.0	0.325	4.71	24.2	0.345	3.50
Avg[3]	22.13	0.370	4.49	20.7	0.320	4.04
% Gain	6.8%	13.5%	10%	BASE	BASE	BASE

Notes:
[1] Disregarded as low value of EBM/g
[2] Disregarded as high value of EBM/g
[3] Avg. of remaining 13 trips
[4] $\frac{\text{Value-Base}}{\text{BASE}} \times 100\%$

the propulsion system. It was quite pleasant to find that the engine room measurements showed the 4-bladed semi-Kaplan vibration levels were equivalent or slightly higher than those measured when the 5-bladed conventional propellers were fitted [3].

Since these vibration levels are quite sensitive to small changes in the propeller pitch especially at the tip, there is a possibility to "tune" the semi-Kaplan propeller design by slight adjustment to the pitch distribution. This was outside the scope of the repowering project, but should be considered when using a semi-Kaplan towboat propeller.

Discussion and conclusions

The extended trials of the semi-Kaplan propeller shown in Table 2 indicate improvements in both speed and efficiency. This is equivalent to a 10% improvement, when compared with conventional towboat propellers. The semi-Kaplan design is also simpler to manufacture.

This project demonstrated a possible economic gain from careful propeller design. It is anticipated there will be future developments using this semi-Kaplan design in river towboats.

Acknowledgements

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