

# The Study on Maneuverability of Electric Propulsion All-Direction Vector Thrusting Ship Using Rudder Propeller

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**Abstract:** This paper studied the maneuverability of the pure electric propulsion all-direction vector thrusting ship called “Century myth”, which also is the first one of its kind in inland rivers in China. Abilities such as turning, stop, changing of course and course keeping are studied. The main research method is by test and comparison, the result shows that the maneuverability of this kind of ship is much better than traditional ships running in inland rivers currently due to its all-direction vector thrusting, and are more comfortable due to its electric propulsion. This kind of ship becomes the new trend of developing environmentally friendly green ships on inland rivers both for its excellent maneuverability and reduced emissions. At the same time, the result of this trial test also provides reliable and objective data for revision and evolution of the specification for inland river ships.

**Keywords:** Electric propulsion, All-direction propeller, Maneuverability, Trial test.

## 1. INTRODUCTION

With the progressive application of China’s sustainable economic development strategy and the booming of Chang Jiang river communication, vessels navigating in Chang Jiang are becoming faster, larger and more specialized than ever before. At the same time, more rules and standards relating to energy saving, emission reduction, vibration and noise reduction are proposed. Green energy saving and environment friend vessels, such as electric propulsion ships like “Century myth”, becomes the new standard of ship development in Chang Jiang. “Century myth”, is the first electric propulsion all-direction vector thrusting and “steering oar one” propulsion vessel in Chang Jiang, its excellent maneuverability and reliability has been studied in this paper.

During the past decades, a lot of work has been done around ship maneuverability, such as researches done by XU Mingcai, etc. [1-6], ZOU Zaojian etc. reviewed the latest work that has been done in this filed [7]. Researches related to electric propulsion are also focused by many researchers, DUAN Xuxu studied the matching of main engine and rudder of electric propulsion ships [8]. SHAN Tiebing etc. researched the hydrodynamic performance of ships with four propellers and two rudders [9, 10].

However, researches related to ships such as “Century myth” of electric propulsion, and with vector thrusting all-direction rudder are less-known. For this reason, this paper mainly focus on the study of this kind of ships.

## 2. THE TRIAL TEST OF CENTURY MYTH

According to Chapter 9 Claus 9.1.1, Section 5 of the "Inland river ship inspection rules" (2011), the inland river ships during the operation shall be equipped with maneuverability handbook, which mainly contains maneuvering data from the vessel's trial test, the whole trial testing process must be monitored by the water traffic monitoring systems as illustrated in Fig. (1).

### 2.1. The Main Parameters of the Ship

The dimension and main parameters of the electric propulsion ship “Century myth” are listed in Table 1. Installation of all-direction rudder propeller is shown in Fig. (2).

**Table 1.** Typical parameters of “Century myth”.

Length	141.8m
Length between perpendiculars	132.0m
molded breadth	19.0m
designed draft	2.90m
design speed	24km/h
Main propulsion motor model and the Numbers	4
rated power	680kW
rated speed	1000rpm
Propeller type	Rudder Propeller
Rudder propeller diameter	1680mm
Rudder propeller blade number	4



Fig. (1). Trial test result of the "Century myth".

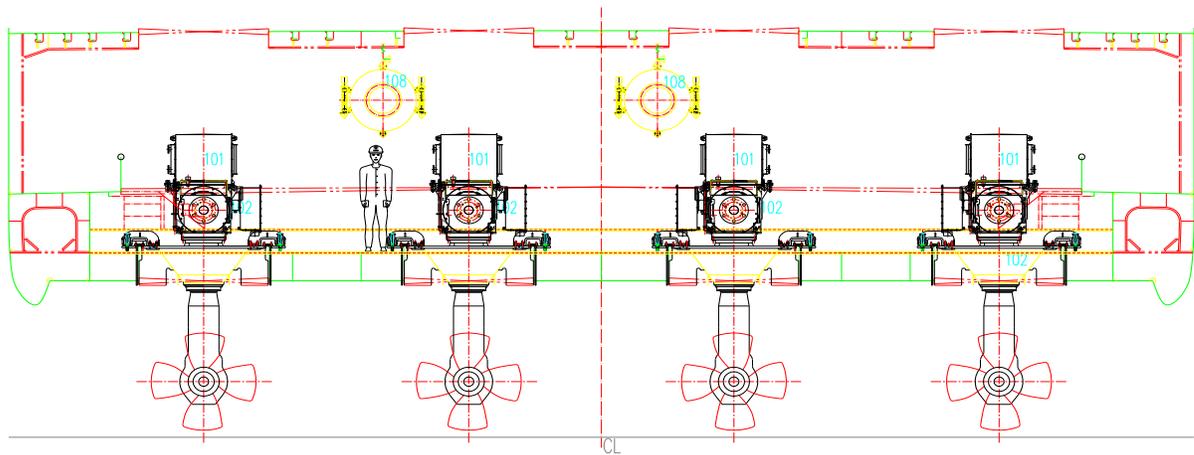


Fig. (2). Rudder propeller.

**2.2. Turing Ability Test**

The turning test is recorded by DGPS system, and the test is carried out in open water area with current speed of 1.2 km/h. The ship keeps constant speed and the rotation speed of the main engine is 955 RPM during turning. Turning test is carried out with left and right rudder angle of 90 respectively, each turning test stopped when the ship completed a circular turning with course turned up to 360°. Parameters such as transverse distance, longitudinal distance, the radius of gyration, diameter and maximum heeling angle are recorded for each turning test. Detailed results are shown in Table 2.

**2.3 Stop Ability Test**

Conditions for stopping test are the same as turning test. When the ship moves straight with full speed, changing the engine form "full ahead" to "stop", results in gradual speed reduction due to inertial force, which are recorded. Test results are shown in Table 3, the track of the test is illustrated in Fig. (3).

**2.4. Course Changing Test**

The test is started when the vessel is moving in the straight direction, with main engine at 955 RPM, then the ruder is turned to port/starboard for 15° quickly and held at the new course until the course deviates to 15° left (right) compared to the initial course. Then the rudder is turned in the opposite direction for 15° (starboard / port 15°) and held there till the course deviates from the initial course to left ( right) 15°. The course is changed once again back to the left ( right ) 15°. The process is repeated three times. When the course coincides with the initial course, then the rudder is turned to 0°, while continuously recording the time, speed, course and rudder angle. The test results are plotted in Fig. (4).

**2.5. Course Stability Test**

The initial state is that the ship moves in straight with constant speed, with main engine at 955 RPM. Course stability test is done by keeping the rudder angle unchanged and maintaining course. The test time lasted 3 minutes for each case. The result is shown in Table 4 and Fig. (5).

**Table 2. Turning test results.**

Item	Turning by Hard a Port Rudder	Turning by Hard a Right Rudder
engine speed (r/min)	955	955
rudder Angle(Deg.)	90°	90°
initial speed(km/h)	15.2	12.3
initial course(Deg.)	235	0
transverse distance(m)	0	0
longitudinal distance(m)	0	0
maximum heeling angle(Deg.)	1	1
Steady turning diameter(m)	0	0
Tactical turning diameter(m)	0	0
The ratio of tuning diameter to length (D./L)	0	0
The ratio of tactical turning diameter to length(DT/L)	0	0
The time needed for rotary Time needed for turning to course(S)	90o	80
	180o	142
	270o	180
	360o	219

**Table 3. Stop test results.**

Item	Full Speed Ahead-stop	
	1000	0
Main Engine Speed(r/min)		
The initial course(Deg.)	314.7	
Initial Speed(km/h)	24	
The final course(Deg.)	261.4	
Final Speed(km/h)	2.3	
Test time(s)	594	
Trail distance(m)	1112	
Ratio of track length to the vessel's length	7.92	
Experimental stopping distance(m)	1089	
cc(m)	143	

**Table 4. Test results of course stability.**

Item	Keep Rudder Unchanged (Maintain the Rudder Angle)	Keep Course Unchanged (Maintain the Course)
Main javascript:void(0);engine speed(r/min)	1000	1000
Initial course (Deg.)	27	27

Table 4. contd...

Item	Keep Rudder Unchanged (Maintain the Rudder Angle)	Keep Course Unchanged (Maintain the Course)
Initial Speed (km/h)	24.6	24.2
The final course (Deg.)	21.6	23.2
Final speed (km/h)	24.8	24.6
Test time(s)	180	180
Times of steering(n)	---	2
Steering frequency(c/m)	---	1
Maximum Angle of steering(Deg.)	---	2
Experimental stroke(m)	1030	1085
The track's offset(m)	23.5	19.8

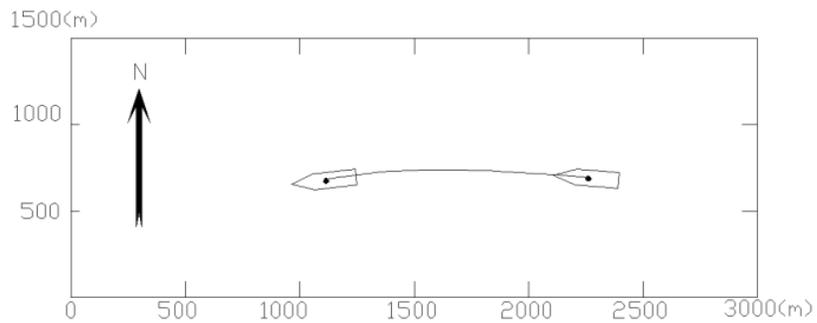


Fig. (3). Stop test track.

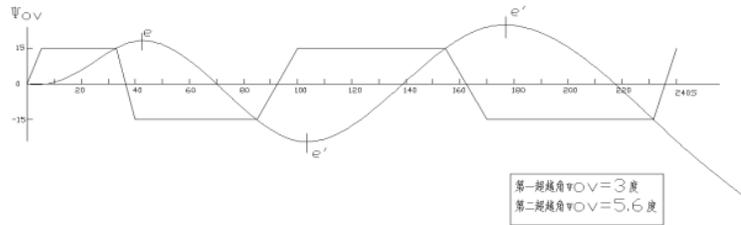


Fig. (4). 15° / 15° Zig-Zag test.

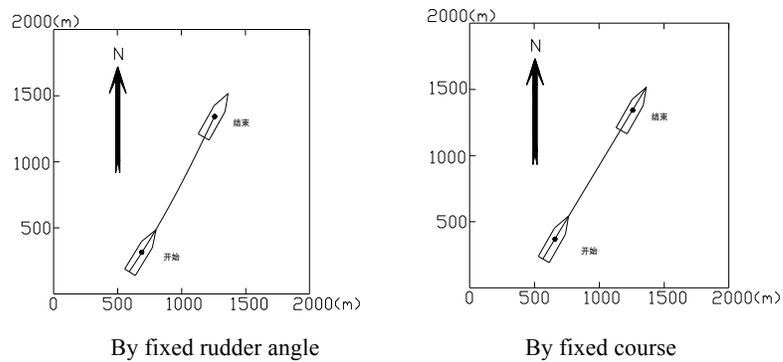


Fig. (5). Track of course stability test.

**Table 5. The approximate value of various types' minimum relative diameter of turning.**

Type	The Minimum Relative Turning Diameter	Type	The Minimum Relative Turning Diameter
Destroyer	5.0-7.0	Large passenger ship	5.0-7.0
Large cargo ships	5.0-6.5	Medium-sized passenger ship	4.0-5.0
Medium-sized vessels	4.0-5.0	Tanker	3.5-7.5
General small boat	2.0-3.0		

**Table 6. Test result of several typical ships.**

Type	Main Engine RPM	Test Time (S)	Gliding Distance (m)	Glide Ratio of the Distance and the Captain
Zheng fen (20000t bulk carrier)	ahead 150-0-astern 150	240	814	5.29
Jiang shen (passenger Ship)	ahead 280-0-astern 205	276	800	7.63
An ping (35000t bulk carrier)	ahead 105-0-astern 85	365	1392.7	7.26
Lu ban (16000t multipurpose ship)	Ahead 137-0-astern 90	490	2408	16.61

### 3. ANALYSIS OF MANEUVERABILITY TEST RESULT

#### 3.1. Analysis of Turning Ability Test Result

In specifications related to ship designation, turning diameter of various types of ship is specified. For traditional propulsion and goodturning ability vessels, the relative smallest diameter is about 3m, meanwhile for poor tuning vessels, it is about 10m. Commonly for most vessels this figure falls into the range of 5 to 7m. The minimum relative turning diameters of most types of vessels are shown in Table 5.

In Table 2, it shows that the longitudinal distance of "Century myth" is 0, the horizontal distance is 0, and initial turning diameter, tactical turning diameter, the ratio of tuning diameter to length all are 0. All the parameters are not within those of traditional propulsion vessels, indicating that this vessel can turn in place without any positional movement, thus its turning ability is much better than that of traditional ships.

#### 3.2. Analysis of Stopping Ability Test Results

The test results in Table 3 shows that the stopping ability of "Century myth" ship is much better than those of other similar ships such as "Lu ban" and "An Ping", etc. Table 6 listed some ships and their stopping abilities. The result shows that the stopping distance of "Century myth" is slightly larger than other similar ships, and shorter than those of "Lu ban" and "An Ping", the track offset after stop is about 13% of the stopping distance.

#### 3.3. Analysis of Changing Course Ability Test Results

Simple analysis of the zigzag test result can be done by analyzing the characteristics of the zigzag curve. Some typical parameters, such as overshoot angle and overshoot time (see Fig. 4) were considered for this work, and resulted in finding out K and T indices. This process is shown in Fig. (6).

The result of calculation shows that the turning ability index K and turning lag index T of "Century myth" ship are 0.435 and 0.135 respectively. It can be concluded that both turning ability and turning lag are satisfying. At the same time, the conformability, fast reaction to rudder, small turning circle are all better than traditional ships.

#### 3.4. Analysis of Course Keeping Ability Test Results

To ensure the course keeping ability of "century myth", tuck plates were settled at the rear of the ship's keel. As shown in Table 4, the course stability test of "century myth" was conducted at full speed. And the result shows that after forward 1030m at a constant rudder angle the track offset is 23.5m, track offset accounted for 2.3% to forward distance, track offset is 19.8m after moving forward by 1085m when the course is kept constant. Track offset accounts to about 1.8% of the forward distance, which means better course stability of this vessel.

### CONCLUSION

Comparing the "century myth" electric propulsion trial tests and analysis, stop performance, course changing ability

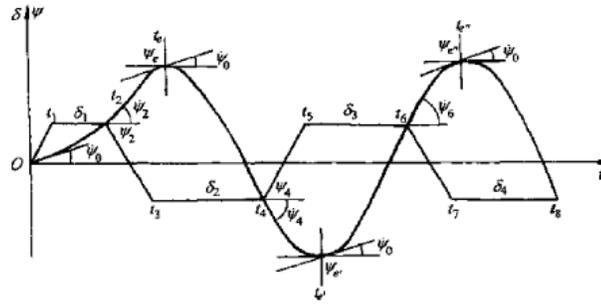


Fig. (6). Zigzag test analysis.

and course keeping ability with the traditional propulsion vessels, the result shows that the maneuverability of "century myth" is much better than that of traditional propulsion vessels. The "century myth" is energy efficient, has less vibrations and noise, it shall become the new trend of inland vessels.

### CONFLICT OF INTEREST

The author confirms that this article content has no conflict of interest.

### ACKNOWLEDGEMENTS

This paper is supported by Chongqing Science & Technology Committee (cstc2012gg-yyjsB70002), and also thanks to Chongqing Dong Gang Ship building corporation for providing us the test environment and test result of "Century myth".

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Received: November 26, 2014

Revised: January 08, 2015

Accepted: January 21, 2015

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