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Author(s)	Yoshimura, Yasuo
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# A Prospect of Sail-Assisted Fishing Boats

YASUO YOSHIMURA

*Graduate School of Fishery Sciences, Hokkaido University, Hakodate, Hokkaido 041-8611, Japan*

**SUMMARY:** Ships are potentially suitable for using wind energy. Almost every ship before the 19th century had been using only the wind power by classic sails, and supporting the worldwide trades and logistics in those days. In 1980's after the last oil crises, many kind of modern sail-assisted ships were developed. Now, they will be hoped to become one of the best solution against the increasing  $CO_2$  discharge. In this paper, the author tries to review the past sail assisted-ships, and investigate into the prospect of the sail-assisted ships especially focusing to the fishing boat in future.

**KEYWORDS:** wind-energy, sail, fishing boat, power gain, fuel saving

## INTRODUCTION

Recent huge amount of  $CO_2$  discharge and the diffusion of detrimental substances by the excessive use of petroleum resources have brought the serious problem of an earth scale such as the global-warming. It has been the world common subject for every work of the future to take account of the preserving natural environments and the reduction of the  $CO_2$  discharge.

There are several solutions for taking place the petroleum energy. One of them is obviously the use of the clean energy such as wind, solar, wave, tidal and ocean current. Among them, the wind energy is the most powerful and efficient to obtain, and recently the wind-power plant in land is great developed. It will be hoped to shire the important part of the whole electric-power supplies in future.

As for the energy to propel the vessels, human or wind-power was the main propulsion power before the 19th century. In particular, almost every ship has been depending on the wind power using classic type of sailing rigs. They used only clean energy and supported the worldwide transportation and logistics in those days. However, as the increase of economical situation and the invention of thermal on-board plant, almost all ships shifted their power plant from sailing rigs to powerful steam turbine or diesel engine, which began to discharge a lot of  $CO_2$ . Now, sail equipped ships had been limited to the sail training or sports field.

In 1980's when the petroleum price jumped with the twice oil crises, the use of wind power was reevaluated. Many kind of modern sailing rigs and new concepts of sail-equipped ships were proposed. These researches are summarized in the international symposiums by RINA in 1980<sup>1)</sup> and 1985<sup>2)</sup>. Most of them were just ideas or experimental trials and not constructed the actual ships, but the sail-equipped cruising ships are one of the most successful projects

among them, and those ships are now operated as the luxury cruising passenger ships. Also in Japan, JAMDA (Japan Marine Machinery Development Association) was the center of the research as well as the construction support of sail- equipped ships in those days. It developed the world first sail-assisted 1,600 DWT tanker "Shin-Aitoku-Maru"<sup>3)</sup>, 26,000 DWT bulk carrier "Usuki-Pioner" and many sail-assisted ships. The principal concept of those ships were not pure-sailing or motor-sailing ships but sail is just used for assist the prime mover to get the power saving. So, the sail area is not larger than the above-mentioned European cruising ships. As for the fishing boat, simple soft sails were installed to the boat deck. These sail-assisted fishing boats were constructed well from 1984 to 1986 in Japan. JAMDA's rigid sail was also applied to fishing boats.

However, after settled the oil crises, these efforts were folded as the fall of the petroleum price, and most of the sail-equipped ships removed their rigs. The first reason was obviously the decrease of the merit by the fall of petroleum price, and the second is the maintenance costs of the sail. However, these experiences and techniques from the past sail-assisted ships suggest one of the solutions against the global warming. In this paper, the author reviews the past sail assisted- ships at first, and then investigates into some prospects of the sail-assisted ships based on the numerical simulations.

## REVIEW OF SAILING DEVICES

In order to get the wind energy, lift force or drag force induced by wind is used to propel the ship. Peoples have been developing the lift or drag generating devices seeking for the more effective and easy-handling systems. As the results, many kinds of devices have been proposed up to now. They are shown in Fig.1 arranging by their mechanisms.

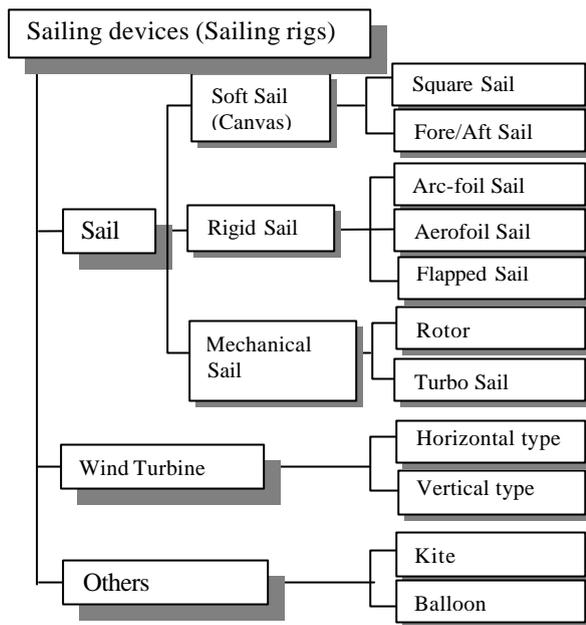


Fig.1 Type of sailing devices

**Soft Sail**

This device is the most popular and has been used for the classic tall ships. In 1955, the project of “Dynaship”<sup>4)</sup> in Germany began to develop the semi-rigid square sail as shown in Fig.2 This sail however, was not realized at all, but this concept might be succeeded to JAMDA’s rigid sail.

As for the fore and aft sail, traditional gaff sail has been well used for topsail schooners. Bermuda sail that is more simplified loose-foot sail is still used for a sailing yacht and dinghy. Wartsila Ab. developed the automatic sail handling system<sup>5)</sup> and designed the modern sail cruising ships “Wind Star”, “Wind Song” and “Wind Sprits” from 1986 to 1988 with as shown in Fig.3. Furthermore, the larger sail-equipped cruising ship “Club Med 1” and “Club Med 2” were constructed from 1990 to 1992.

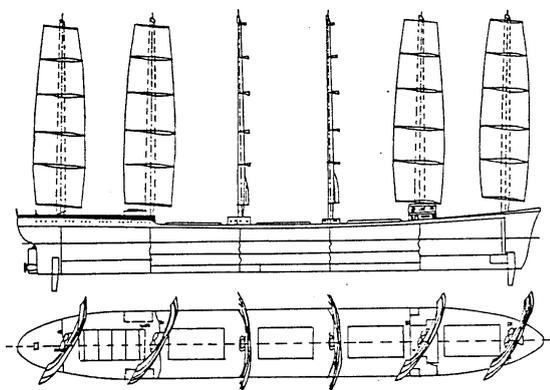


Fig.2 General Plan of “Dynaship”



Fig.3 Modern sail-equipped cruising ship “Wind Star” (GT:5703, Sail area:2005m<sup>2</sup>)

Such simple sail is also applied to the fishing boat in Japan. Aburatsubo Port Service Co. developed the sail system, and many sail-assisted fishing boats were constructed around 1985’s. Fig.4 shows the example.



Fig.4 Sail-equipped fishing boat “Enoshima-Maru” (GT: 160, Sail area: 73m<sup>2</sup>)

**Rigid Sail**

JAMDA and NKK developed the rigid type square sail<sup>6)</sup>. The expansion of the sail and the setting of sail angle were automatically driven by hydraulic units as shown in Fig.5. In 1980, the world first modern sail equipped ship “Shin-Aitoku-Maru” was constructed as shown in Fig.6, utilizing the above sail. After that, 17 ships equipped the JAMADA’s sail in Japan.

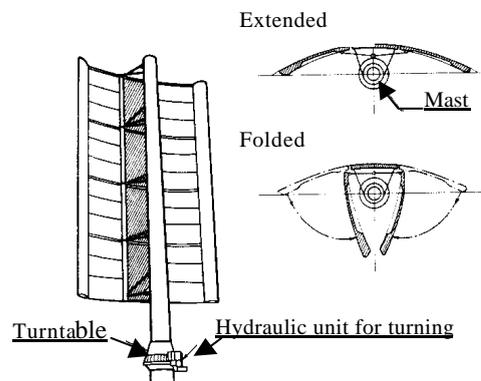


Fig.5 Arrangement of JAMADA’s sail



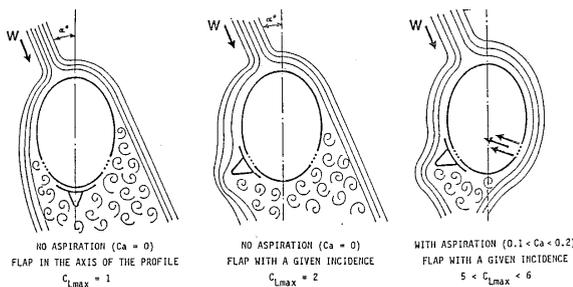
**Fig.6** Sail-assisted tanker “Shin-Aitoku-Maru” (DWT: 1600, Sail area: 200m<sup>2</sup>)

Another rigid sails such as aerofoil sail, flapped sail were proposed in 1980’s. However, they were just tested by experimental small boat and not developed well in actual use.

**Mechanical Sail**

Mechanical sail can produce the higher lift coefficient than the conventional sail. However, the sail weight generally becomes heavier. The rotor system was developed by Flettner<sup>7)</sup> in Germany. This principle is that the rotating cylinder in wind produces the lift force by Magnus effect. Equipping these rotors, 455GT cargo ship “Buchau” and 2,077GT cargo ship “Barbara” were really constructed in 1924 and 1926 respectively. However, the rotor ship has never come out after those days, as the merit was small.

Turbo Sail<sup>8)</sup> is unique as shown in Fig.7, where the stalled air is drawn behind the sail-body by a strong electric fan. It was hopped as a high-lift sail, but not used in actual ship except experimental small boats.



**Fig.7** Mechanism of turbo sail.

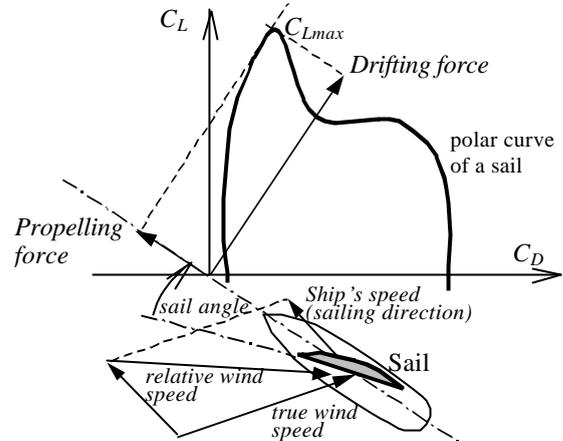
**Wind turbine and another devices**

Many types of wind turbine, wind propeller, kite and balloon systems<sup>1), 2)</sup> were proposed and tried in 1980’s, but they could not be applied to an actual ship.

**INVESTIGATION INTO THE SAIL SYSTEM**

**Maximum lift coefficient:  $C_{Lmax}$**

The propulsion force is derived from the lift force of sail. The mechanism is described as Fig.8.



**Fig.8** Schematic diagram of the propelling force by a sail

Lift force of sail is described as the following form, which depends on the lift coefficient:  $C_L$  as well as sail area:  $A$  and the square of relative wind velocity:  $U$ .

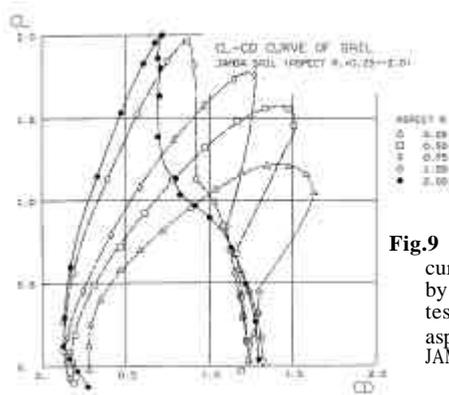
$$L = (\pi/2) C_L A U^2$$

As the higher  $C_{Lmax}$  promises the large propelling force, most of the designers in 1980’s were seeking after the higher  $C_{Lmax}$  of sail. Indeed the rotor and turbo-sail produces high  $C_{Lmax}$ , but these sails were not used in actual ships. One reason is the high cost, and the other is the weight of the sail. If the heavy sail is installed on deck, the center of gravity: CG of ship becomes higher, which causes the poor stability. In order to avoid this, the large ballast weight shall be installed to cancel the rise of CG. This arrangement makes the ship heavier, the payload smaller and the construction cost higher. Then, the merit of the sail is lost. Consequently, it is clear that the weight and cost of sail are most important than the higher  $C_{Lmax}$ , particularly for a small ship like a fishing boat.

**Effect of sail aspect ratio on power gain**

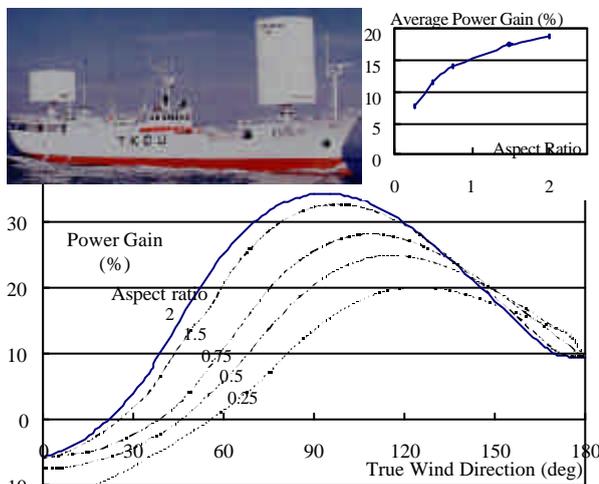
$C_L$  becomes larger as the aspect ratio is higher. Fig.9 shows the result of wind tunnel test for various aspect ratio of a sail. The section of the sail is JAMDA .

Using this result, the power gain corresponding to these sails is numerically predicted with the sail-assisted fishing boat “No.1 Yachiyo-Maru” that has 78m<sup>2</sup> of JAMDA sail. The sail area and location are the same in each other. Calculated results are shown in Fig.10. Although the higher sail aspect ratio makes the large power gain, the derivative of the power gain becomes small over 1.0 of the aspect ratio.



**Fig.9**  $C_L$ - $C_D$  polar curves measured by wind tunnel test for various aspect ratios of JAMDA sail

Since the higher aspect sail is taller and makes the C.G of ship higher, the optimum ratio is assumed 1.0 or 1.5. This tendency is more or less the same with the conventional soft sail.

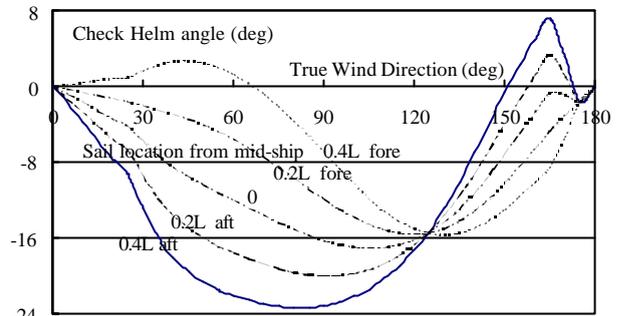


**Fig.10** Simulated power gain for various aspect ratio (“No.1 Yachiyo-Maru” with 11.5 knots running under 15m/s of wind speed)

### Effect of sail Location

As mentioned above, a sail produces the significant drifting force as well as the propelling force. This affects the lateral balance of a ship. In order to cancel the unbalance moment, a rudder is steered. This unbalance moment strongly depend on the location of the sail. Fig.11 shows the necessary check helm angles to keep the course at 6 knots that is slow speed running. Those are simulated with the above fishing boat for various sail location. In this figure, when the sail is located aft-ward, the check helm becomes larger to the bow-lee-side direction. This tendency decreases as the sail location shifts to the fore-ward. Obviously, it is better that the check helm is smaller in the straight running, as the large helm causes the loss of power. However, the characteristics that automati-

cally turn to the weather or wind side without helm is sometimes convenient and safe particularly for a small fishing boat.



**Fig.11** Simulated check helm for various sail location (“No.1 Yachiyo-Maru” with 6 knots running under 15m/s of wind speed)

### CONCLUDING REMARKS

Conclusions are summarized as the followings.

- 1) The experiences and techniques from the past sail-equipped ships are useful for the fuel saving of ships.
- 2) The weight and cost of sail are most important than the higher maximum lift coefficient of sail:  $C_{Lmax}$
- 3) As the larger aspect sail becomes tall and makes the gravity center of ship higher, the optimum aspect ratio is limited to be 1.0 or 1.5.
- 4) Aft-sail is sometimes convenient and safe for the operation of a small fishing boat, as it automatically turns the ship’s heading to the weather side.

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