KITESHIPS, SAILING VESSELS PULLED AND POWERED WITH A KITE

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ABSTRACT

Current windpower technology and future petroleum supply scenarios make it likely that it will become desirable to consider sailing vessels again for the merchant marine. For the wind-powered propulsion it seems possible to use tethered kites, instead of the traditional combination of masts and booms supporting a system of sails. This may be both safer and more cost-effective. We are on boat No 2 in an R&D program aimed at this large scale application, and the present paper represents a progress report. Boat No 1 was used to achieve speed and power, achieving a speed of 33 knots (over 60 km per hour), and sailing speeds at times of twice the wind velocity. Boat No 2 will not be used for speed, but for the development of kite deployment and retrieval techniques, with kites of up to 300 sq ft (28 sq m) in surface area.

1. INTRODUCTION AND BACKGROUND

The 19th century saw most of the large sailing vessels replaced by coal burning steamships. After Winston Churchill changed the British Navy from coal to oil early in the 20th century, shipping came to depend mainly on petroleum.

There were several reasons for these changes. The engines were ready, since steam engines (and later Diesel engines) had become quite dependable. Then there was the "free market," since the "owners" of coal mines and of oil wells found themselves sitting on apparently inexhaustible resources, these resources were of no value to them unless the fossil fuel was priced low enough so that competitors like windmills and sailing vessels were eliminated, and people were so focussed on progress that nobody worried about the externalities or the future. There were also the military strategy needs of warships, since it was possible to build power vessels that were faster and more maneuverable than sailing vessels, and oil provided a greater range than coal.

Future petroleum shortages (1) will provide an incentive to use less oil. It can be useful if wind power can begin to provide some maritime propulsion again.

Wind power, in large windmills and in commercial sailing vessels, had died before humanity really knew what wind power was all about. Humanity still had little or no understanding of aerodynamics and of airplane technology; of electricity generation, transmission, and usage; of gears, mechanical power transmission, and ball and roller bearings; of composite materials and of plastic fibers; of super-alloys or even of good steel or aluminum alloys; or of welding and other modern fabrication techniques.

Things have now changed. It is no wonder that windpower has made almost miraculous advances since it was revived in the mid 1970s, since all the technology that was needed could be taken virtually off the shelf. Windpower can now be produced at a cost of around 4 US cents per kWh. This is about 4 or 5 times cheaper than nuclear power, almost too cheap to meter. It is almost certainly cheaper than any power produced using fossil fuel combustion, particularly if one considers fully the costs of global warming, acid rain, defense costs for the protection of fossil fuel resources and trade routes, and the taxes that should be levied to ensure that our descendants will not inherit a world bereft of resources and blanketed with an unlivable atmosphere. Under EPRI and DOE R&D programs it has been found that the wind resources of the US northern prairies are large enough to provide many times more electrical power than the USA is ever likely to need. Wind power can (and will) become very important.

If large scale wind turbines have become so cost-effective, large scale sailing vessels can not be far behind. As Bernard Smith (Ref. 4, p 45) has written: "Sailing involves no thermodynamic cycle and generates little heat. Sailboats react mechanically to the forces of the wind without any train of energy-losing conversions in the path of action. As a consequence, the theoretical efficiency of transferring the momentum of a moving column of air to the momentum of a boat can be as high as the best windmills, even before windmills perform useful work: close to 60%. Sailing has the highest potential of any means for exploiting the cheap, renewable, clean power of the wind."

Wind power of course does involve a thermodynamic cycle, but nature provides the equipment and the fuel free of charge. Solar energy is the cause of the wind and the weather. The variable solar heating from the poles to the equator produces air circulation currents, with the air rising at the equator and sinking at the poles. The earth's spinning action on these air convection currents produces the "trade winds," with bands of "prevailing westerlies" and "prevailing easterlies" in both southern and northern hemispheres. There are also bands of low wind, the "horse latitudes" and the "doldrums." The wind bands and ocean currents defined the world trade and travel routes of the sailing vessels. Storms (solar energy powered weather instabilities) added danger.

Future sailing vessels are unlikely to be exclusively wind powered. It will be desirable to use power propulsion to move ships across low wind areas between one windy region and another, and to use modern computer, communications, and weather technology (e.g. "weather faxes") to minimize the fuel usage and the travel time involved. In most harbors tugboats will be used, as they are used now. It is likely that much of the marine power propulsion will become electrically powered, with a central generator charging battery installations, and with the propulsion controls being performed electrically and not mechanically.

2. SAILING TECHNOLOGY, THEN AND NOW

Sailing technology improved slowly for many centuries (4, 5, 6, 8, 16, 17, 18, 19). The American clipper ships (17) represented the most highly developed, elegant and efficient commercial sailing vessels, but their development stopped once the world had switched to power vessels. The clipper ships carried as much sail area in their "square rigs" as possible, much more than earlier ships. They also had a faster hull shape. The last clipper ships saw active duty in WW II, but most had been replaced earlier by power boats, since they could not compete with very cheap oil. It is only in some remote areas (e.g. Indonesia), that some shipping still uses sail power.

Traditional sailing vessels, including the clipper ships, were quite primitive. They had no watertight bulkheads, and had none of the electronic communication, computer, control, navigation, depth gage, and radar technology of today. Current sail materials are better than the old canvas. Materials like kevlar have replaced manila and other fibers. Current alloys are much stronger than the old steel and iron, and welding makes stronger joints than riveting. The old boats had no stainless steel, and no composite materials for masts, booms, and structures.

There were other problems with old sailing vessels. The sails were close to sealevel, where the waves slowed down the wind and made it variable. The sails were mounted on masts, and this gave an overturning moment which limited the amount of sails one could carry, and made sailing dangerous. Boats could capsize and sink in less than a minute because of a sudden and unexpected wind change. Some boats sank with all aboard, never to be seen again. Many people took the last rites before any ocean trips.

The old sailing vessels were developed before aerodynamics became a science (4, 5, 6), so that sail shapes and sail trimming involved more feeling than understanding. It was not possible to develop the kiteships (2) that we are working on: a vessel powered by the lift produced by a large controllable kite with a fairly high lift-to-drag ratio. Such kites can be wing-shaped like some modern sport parachutes, with airfoil cross sections inflated with holes in the wing leading edges. One can incorporate internal balloons of helium, hydrogen, or methane to make the kites float in air. One can fly such kites high in the sky in high winds, far from the wave induced surface effects, and in a location which maximizes the driving forces in the direction one wants to sail in. One can sail against the wind (like any modern sailboat). The driving force can be transmitted to the hull directly, with no overturning moment. If the wind speed increases to a dangerous level one need not be "overpowered" by too much kite area for more than an instant: the instant needed to release the kite, which can then perhaps be recovered later. Kiteships can almost certainly be safer, faster, and more cost effective than US clipper ships, and they may become very useful when petroleum runs out, or when stringent controls become necessary to limit the atmospheric carbon dioxide content.

Kite propulsion to date has been used mostly on small devices. There are regular kite buggy events in the USA, like at Mirage Valley dry lake in California just south of the Kramer junction site where the Luz solar thermal power plants are located. Water skiing with kites is becoming very popular, and kite-pulled catamarans have set several speed records. There has however been little work on large kiteships.

3. OUR R&D PROGRAM

This paper is a progress report on our R&D program on kiteships. Our early proa with a 16 foot long main hull, shown in Figure 1, had speed bursts of up to 33 knots with a stack of Flexifoil Power kites of a total area of 200 square feet (18.6 sq.m.). The boat was aimed primarily at achieving high speed, and often sailed at twice the windspeed. A larger proa, shown in Figure 2, has recently been built as the second kiteship (of four) in our program, with the main hull being 24 ft (7.3 m) long and the short (ama) hull being 20 ft (6.1 m) long. The hulls were made from hull sections cut from catamarans that had been damaged. The crew sits on the larger hull, and the kite lines are fastened to a rail mounted on the outer side of the small hull. The small hull can be lifted clear out of the water when the kite is flying high in the sky.

Fig. 1. Our Kiteship Prototype No. 1: A 20 Ft (6.1 m) High Speed Proa

Fig. 2. Our Kiteship Prototype No. 2: A 26 Ft (7.9 m) Proa For Developing Kite Handling Techniques

The proa is symmetrical, reversing direction on each tack when sailing upwind. This is unlike modern sailboats, which can turn into the wind when tacking, or the square-rigged clippers, which have to "wear around" (i.e. make a turn of more than 180 degrees to the outside of the sailpath) every time they want to change a tack.

Two coupled rudders provide steering. The rudder "airfoils" must be turned to face forward each time the boat changes direction, when the fore rudder now becomes the aft rudder and viceversa. It will be sailed with kites of up to 300 sq. ft (27.9 sq. m). It is expected that our top speed will be about 30 knots (56 km/hr), but speed is of secondary importance. The main purpose of this proa will be the development of kite launching and retrieval techniques for the larger boats we will study later.

The prototypes we built already are interesting, but a kite of 28 square meters is still hundreds of times smaller than the kites which will ultimately be required in the merchant marine. We may be able to develop interesting techniques for kite launching and retrieval with our smaller boats, but these techniques will need confirmation with the hardware on larger vessels. It will require two or even three successive (and each time much more expensive) additional steps before one is at the "full-scale" merchant marine level. It may be best to build larger kites like "airships," with helium or hydrogen or methane balloons to provide the buoyancy needed to stay aloft, and perhaps even with a permanent crew on board in the case of merchant marine "kite-tugs." Questions of program financing, technology transfer, and plain old fun may make it desirable to drive our proa number 2 cross-country to Portland, Maine, so as to demonstrate it to the rest of the ASES membership and to the world.

4. CONCLUSIONS

For many centuries sailing vessels used tall masts braced in place with lines or "stays," and used these masts with booms to support a sail system (17, 18). If sail power for the merchant marine can once again become cost-effective, it seems unrealistic to explore only these technologies of the past, when there are now attractive new alternatives. Modern technology and materials makes it possible to use "kites," or remotely tethered wing-like structures, to provide the sailing power in a potentially safer and more cost-effective way. Our program to date has been quite encouraging, but only R&D work and tests on larger vessels will be able to determine the commercial potential of kiteships. Stay tuned!

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