INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN: 2278 – 0211 (Online)

Kite Technology (Pull Shipping To Greener Future)

J. Sidhartha
Mercantile Marine Department, Chennai
M. Satya Phani Kumar
Marine Engineer

Abstract:
This paper describes a study on the research and development by skysails and BBC chartering on kite technology towards improvement in energy efficiency and emission reduction by harnessing renewable wind energy. Case studies on same analysed and results projected.

1. Introduction

Cargo ships are the most efficient means of transportation worldwide. Over 90% of world trade is being transported by sea. Thus shipping not only plays a key role with regard to global logistics of goods, but also concerning the consumption of energy resources and the emission of climate damaging gases and consequently contributes significantly to the pollution of our environment.

From a climate policy perspective, maritime operations have so far been overlooked. Thus shipping, like aviation, is not yet included in the Kyoto Protocol. Maritime shipping, with its output of over 1 billion tons of carbon dioxide (CO_2) per year, is responsible for over 3% of worldwide CO_2 emissions (ca. 31 billion tons in 2007). Shipping thus emits more CO_2 than the country of Germany as shown in the **Figure 1.**

1.1. CO_2 emissions from shipping in comparison

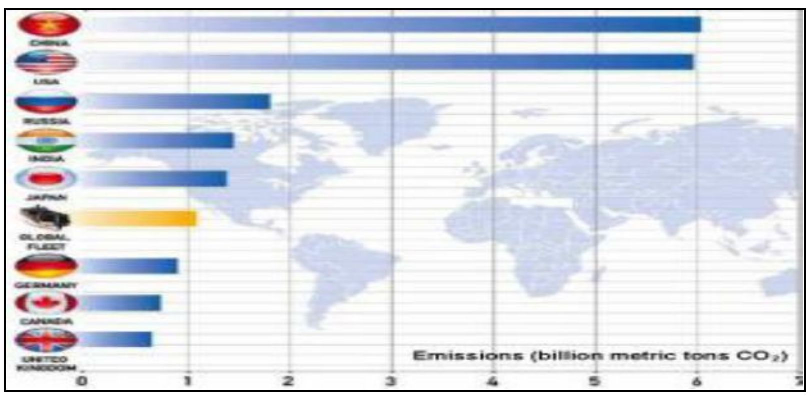


Figure 1

Source: Oceana, "Shipping Solutions – Technological and Operational Methods Available to Reduce CO_2", 2010

In April 2008, the International Maritime Organization (IMO) approved a reduction in sulphur emissions for the shipping industry. From the year 2020 shipping companies either have to use distilled fuels with a limited sulphur content of 0.5% instead of heavy fuel oil or have to use scrubbing technology to clean their exhaust gases.

For shipping companies using distillate fuels means a doubling of fuel costs in the future, since refined products such as Marine Gas Oil (MGO) and Marine Diesel Oil (MDO) are considerably more expensive than highly sulphurous heavy fuel oil which is predominantly being used as ship fuel at present.

Already today shipping companies must use “clean” fuel with a maximum sulphur content of 1.0% when operating their fleets in what are called ECA (Emission Control Areas) on the North Sea and Baltic Sea. This is nothing less than a MDO/MGO obligation since it is not possible to reduce the sulphur content of heavy fuel oil to this level. The result will be higher fuel costs from having to convert from heavy fuel to diesel, and from price increases in combination with a greater demand for MGO and MDO. Starting in 2015 the maximum allowable sulphur content in marine fuels within these regions will be reduced once more to 0.1%, which will set off another rise in prices.

Scrubbing as the end of pipe alternative leads to high investments in cleaning technology and an increase in fuel consumption of about 2% due to the higher resistance in the exhaust gas stream. It remains to be seen whether scrubbing will be allowed in the long term as it is counterproductive in view of international climate politics. When discharging sulphur oxides into the sea, large quantities of CO_2 are being released.

In addition to the regulations already passed and in response to global political pressure, the IMO is currently preparing a regulation on the reduction of CO_2 emissions from shipping in the form of a CO_2 indexing scheme (EEDI, Energy Efficiency Design Index). Experts assume that corresponding regulations will be implemented in a timely manner. Thus, shipping companies will also be burdened with emissions based levies in the future. CO_2 emissions can only be effectively reduced by burning less fuel.

2. The Limited Refining Capacity

Experts believe that fuel prices will go up once more by enacting the ban on heavy fuel oil. The reason is that refinery capacities are too limited to cover the demand. And when it comes to the demand for fuel it is important to keep in mind that ships will be competing with cars, trucks, heating oil and all other onshore oil consumers in the future. Modern refineries are designed to produce less heavy fuel oil and more high quality and high priced refined products. As a result of this, trade associations believe that refineries are not able to cover the additional demand. And for the shipping industry, the situation is already making a turn for the worse clean over the short term. Since refineries are producing less heavy oil, the prices for heavy ship fuels are rising disproportionately even today.

2.1. Triplication Of Fuel Costs For Shipping Companies

All in all these developments imply that fuel costs for shipping companies will triple in the future compared to today's level. Thus ship operating costs will predominantly be determined by the cost of fuel in the future.

2.2. Projection Of Fuel Price Development Within The Shipping Industry

Possible Scenarios for the development of fuel costs including environmentally relevant surcharges (based on SO_x and CO_2) in the future, low emission drives will pay off more and more. **Figure 2,** below shows how the internationally renowned classification society Germanischer Lloyd projects fuel prices will develop within the shipping industry (prices given exclude any increases due to inflation). Cost increases stemming from CO_2 emission based levies from the year 2013 on, as well as the mandatory use of more expensive diesel fuels (MGO) beginning in 2020, are clearly recognizable. Shipping industry customer's freight owners, such as major commodities companies, as well as logistics service providers are working hard to reduce their CO_2 emissions in response to rising pressures on the part of their own customers. For many companies, logistics are a major contributor to their overall corporate emissions levels.

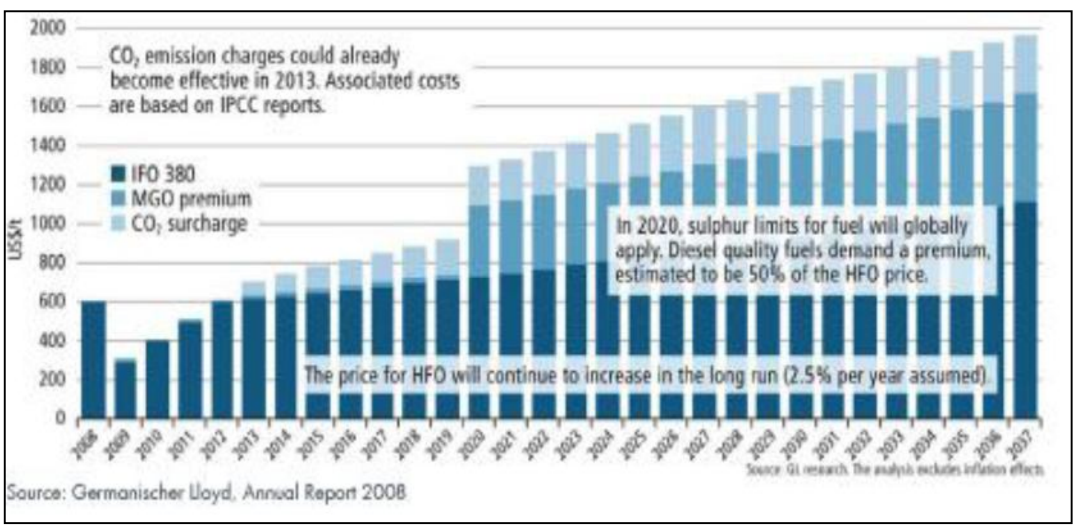


Figure 2:Germanischer Lloyd projection fuel prices

3. Green Shipping – Wind Power As Economic Alternative

Wind is cheaper than oil and the most economic and environmentally sound source of energy on the high seas. It was little more than a century ago that wind was the sole source of power for the world's merchant fleet. The ready availability of cheap oil at the beginning of the 20th century led to the steady replacement of sails with diesel power. The introduction of the diesel engine changed the face of shipping. Classic sail propulsion can no longer be used in today's world of cargo shipping. Conventional sail systems simply cannot generate the propulsion power required for modern ships. Also, those tall masts would severely restrict the cargo capacity on deck and make loading and unloading in port extremely difficult. The tilt caused by the large lever arms of sails secured to masts would pose a serious safety risk. In addition, high investment costs for mast supported sail systems lower their profitability significantly.

Ships are long lasting capital goods which are in operation for 25 years and more. The shipping industry's greatest challenge will be to quickly and efficiently retrofit the existing cargo fleet in order to rapidly reduce the emission of climate damaging greenhouse gases. This will not be possible with mast supported sails as it would require considerable modifications of the ship's structures which in turn would be too expensive.

The towing kite system which allow modern cargo ships to use the wind as source of power in order to save fuel and therefore to save costs and reduce emissions. Starting the development with kites of 6–10m^2 size the latest product generation with a nominal size of 320m^2 can replace up to 2MW of the main engine's propulsion power. Among the marine applications of kites there is a strongly increasing activity in using automatically controlled kites and rigid wings in order to generate power from high altitude wind.

4. Advantages Of Kite Technology

- The amount of space that the Kite System occupies on the ship is negligible from an economic stand point. This is because the system's deck components are installed in the area of the forecastle, which is not used for cargo anyway.
- The textile towing kite is easy to stow when folded and requires very little space on board ship. A folded 160m^2 Skysails for example is only the size of a telephone booth.

- There are no superstructures which may obstruct loading and unloading at harbours or navigating under bridges, since the towing kite is recovered when approaching land.
- The heeling caused by the kite technology is minimal and virtually negligible in terms of ship safety and operation. The forces of the towing kite are transmitted to the ship at deck level. The lever arm which causes the inclined position (heeling) of conventional sailing ships is thus shortened. The towing kite is controlled by an autopilot during flight.
- The ship's regular crew is adequate for operating the system and no additional personnel costs will arise.
- Depending on the prevailing wind conditions, a ship's average annual fuel consumption and emissions can be reduced by 10 to 35% by using the kite technology. The latest kite technology produces propulsion power of more than 2 MW (approx. 2,700 horse powers; equivalent ship engine) and can save up to 10 tons of oil per day.
- Kite technology is the only wind propulsion system that cannot only be installed on new buildings, but easily retrofitted onto most existing cargo ships as well. Kite technology thus offers a solution that can make a major and quick environmental impact by reducing the carbon emissions of the existing "old" ships in the world's merchant fleet.

The UN body IMO (International Maritime Organisation) attaches great importance to Kite technology with regard to climate protection: in its latest GHG Emissions study, the IMO states that the Kite technology has the potential to save approx. 100 million tons of CO_2 per year when applied broadly on ships of the world's merchant fleet.

5. Ship propulsion using the kite

5.1. Forces on a kite

The kite, which is considered to be an aerodynamic surface found in an air current, is under the action of three main forces: the weight force ($\overline{W}$), the total aerodynamic force ($\overline{T_{af}}$) and the cable tension $\overline{C_t}$.

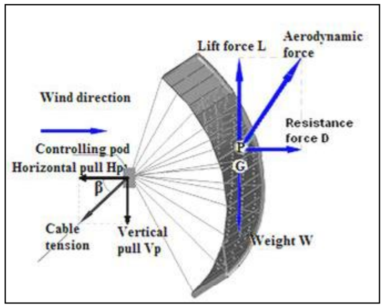


Figure 3:Forces on a kite

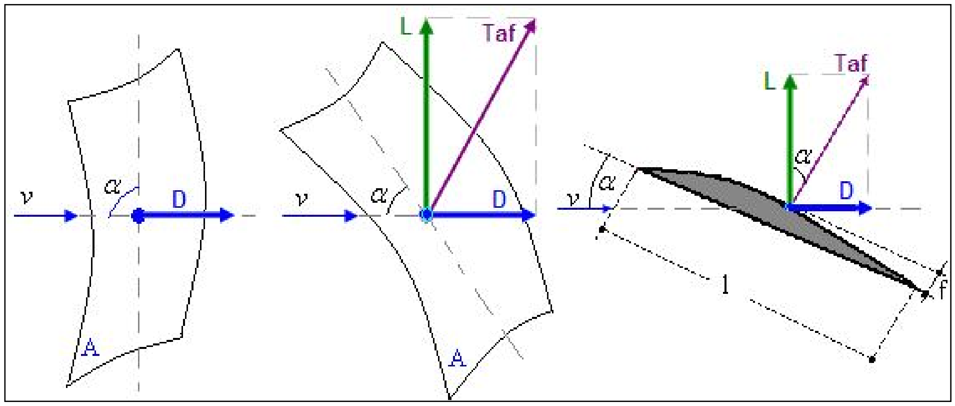
As shown in Figure 3, the forces which act upon hydrodynamic or aerodynamic profiles give a resultant force $\overline{T_{af}}$ (aerodynamic force) which decomposes by the direction of velocity in infinite and by a direction which is perpendicular on it. The weight force $\overline{W}$ always acts in the kite's centre of gravity, "G", and it's oriented towards the centre of the earth. The total aerodynamic force $\overline{T_{af}}$ is the resultant of two other forces: the lift force $\overline{L}$, which is perpendicular on the air flow's direction (wind direction), and the drag force $\overline{D}$ which acts in the direction of the air current. The two forces are applied in "P", called the kite's centre of pressure. The third force, the cable tension $\overline{C_t}$ is applied in the connexion point of the link cable with the kite's stays, "C".

5.2. General considerations regarding wind effect on sails

Given that the propulsion using the kite is strongly related to the one using classical sails, and that often the two sails are compared, considered that some general considerations on sail propulsion are necessary.

The resultant of the pressure forces $\overline{D}$(Figure 4a and 4b) acts in the centre of pressure of the surface, which can be considered most of the time its geometrical centre, and is oriented in the direction of the air flow and its size depends on the total surface of the sail, it's form and the speed of the air current.

In order to do an exact calculation of the values of the forces $\overline{L}$ and $\overline{D}$ respectively $\overline{T_{af}}$, then, when the sail is oriented in different directions from the wind we use the diagram called "The sail's polar".



(a) (b)

Figure 4: Cross wind *Figure 4: Transverse wind*

5.3. The Kite forces and moments

As presented in Figure 5, there are several forces acting upon the kite: lift force ($\overline{L}$), drag force ($\overline{D}$), weight force ($\overline{W}$), cable tension ($\overline{T_c}$).

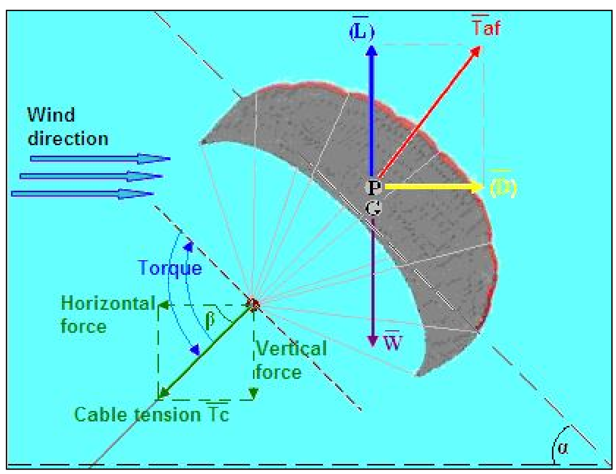


Figure 5: Kite forces and moments

The total aerodynamic force, $\overline{T_{af}}$, is decomposed on the direction of the speed tending to infinity $\overline{D}$ (drag force), and on a direction perpendicular on it $\overline{L}$ (lift force). The two forces are calculated using the formulas:

$D = C_D*P*V_\infty^2/2*A_k$

$L = C_L*P*V_\infty^2/2*A_k$

Where:

C_D : drag coefficient of the towing kite

C_L : lift coefficient of the towing kite

P : density of air

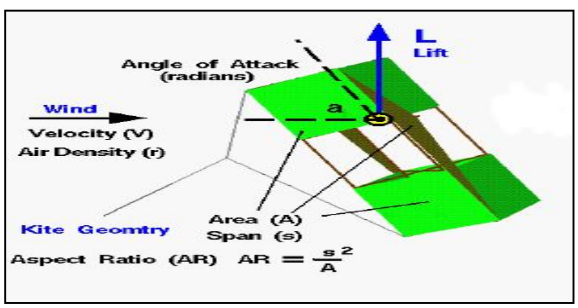
A_k : the total surface of the kite.

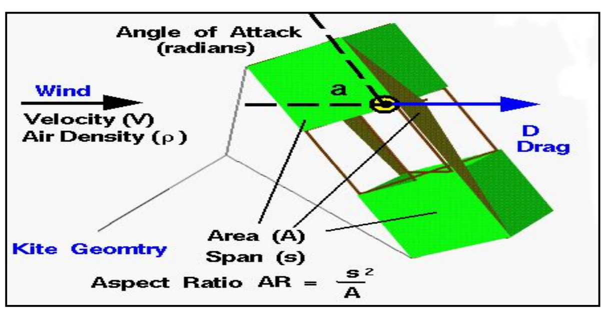
By calculating the values of $\overline{D}$ and $\overline{L}$ from above equations we can determine the value of the total aerodynamic force using the formula:

$$T_{af} = \sqrt{L^2 + D^2}\,.$$

5.4.Theoretical Lift Coefficient and Drag Coefficient

Calculating the theoretical values of the coefficients of lift (Figure 6a) and drag (Figure 6b) was important to test the results that were produced in the lab. The theoretical value for the lift coefficient of a kite is given by the following equation:





$$C_l = \frac{C_{l0}}{1 + \frac{C_{l0}}{\pi * AR}}$$

Where

C_l : Lift Coefficient of a kite

C_{l0} : Coefficient of Lift for a flat plate = 2*π*aoa (angle of attack in radians)

AR : Aspect ratio of the kite (wingspan^2/surface area)

C_{l0} is the lift coefficient for a flat plate at a given angle of attack. Since a kite can be mostly modelled by several flat plates at different angles of attack, this value is just a starting value for the coefficient of lift for the entire kite.

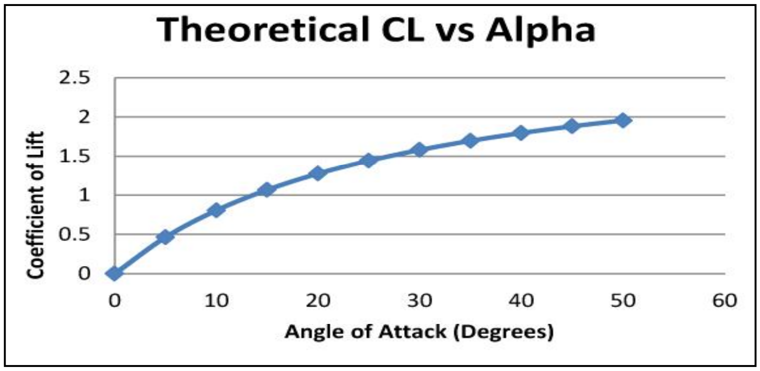


Figure 6a: Theoretical Coefficient of Lift versus angle of attack

For the calculation of coefficient of drag for the kite, the following equation was used:

$$C_d = C_{d0} + \frac{C_l^2}{.7 * \pi * AR}$$

Where

C_d : Drag Coefficient of a Kite

C_{do}: Form Drag for the kite = 1.28*sin aoa (angle of attack)

C_l : Lift Coefficient of a Kite

AR: Aspect ratio of the kite (wingspan^2/ surface area)

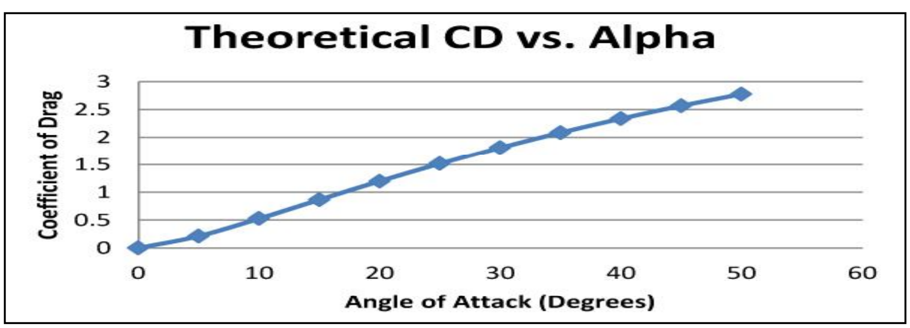


Figure 6b: Theoretical coefficient of drag versus angle of attack

6. Case study on 1) calculation of the forces developed by the kite at different angles 2) using kite at higher altitude and 3) high propulsion power

6.1. Calculations of the forces developed by the kite at different angles

The following values were taken into consideration for the calculations:

A_k : 200 m^2 (total surface of the kite)

α : 15°

C_L : 0.9250

C_D : 0.2421

P : 1.2047 Kg/ m^3 (air density at a temperature of 20°C)

W : 10 m/s.

The kite dimensions: length 28.57 m, width 7 m, profile thickness 0.7 m.

By applying the formulas for the lift and drag for an attack angle of 15° as shown below Table 1, we obtain:

$L = ½ *P*C_L*W^2*A_k$= 11143,475 N

$D = ½*P*C_D*W^2*A_k$ = 2916,579 N

$T_{af} = \sqrt{L^2 + D^2}$ = 11519,830 N.

α (°)	***5°***	***8°***	***12°***	***14°***	***15°***
P(kg/m^3)	1.2047	1.2047	1.2047	1.2047	1.2047
W(m/s)	10	10	10	10	10
C_D	0.0565	0.0804	0.1400	0.2172	0.2421
C_L	0.6605	0.8780	1.054	0.9750	0.9250
L (N)	**7957.043**	**10577,265**	**12697,602**	**11745,824**	**11143,474**
D (N)	**680,768**	**968,578**	**1686,580**	**2616,608**	**2916,578**
T_{af} (N)	**7986,101**	**10581,72**	**12809,043**	**12033,768**	**11518,830**

Table 1: The values of the kite's forces for different attack angles

From the results the following conclusions can be drawn.

For the chosen profile, the optimum angle of incidence is about 12°, angle at which the high value of the lift raises the total aerodynamic force, although the drag is not large. It should be noticed the progressive grow of the forces up to α = 12°, after which the lift and the total aerodynamic force start to drop together with the drag. At angles of more than 15°-20°, the lift value decreases a lot and the drag increases.

6.2.Greater power from using kite at high altitude winds

Towing kites for ships operate at altitudes between 100 and 500 m where stronger and more stable winds prevail.

E.g. In the Figure 7, down below shows that towing kites easily generate 5 to 25 times more power per square meter sail area than conventional sails. Thus, it is possible to gain significant savings by using comparatively small sail areas.

For comparison: the 109 m four mast bark "Sea Cloud" has a total sail area of 3,000m². A towing kite of only 150m² is all this ship would need in order to have the same amount of propulsive power.

"At 2,000 feet (610 m), there is two to three times the wind velocity compared to ground level. The power goes up with the cube of that wind velocity, so it is 8 to 27 times the power production just by getting 2,000 feet (610 m) up, and the wind velocity is more consistent."

Because these winds are at such a high altitude, airborne devices, such as kites, are needed to capture and use their energy. Spurred by the development of kite technology, the drive to harness the vast potential of high-altitude wind power has already become a major global trend in research and development particularly in the United States. Experts consider towing and power kites to be the next generation in utilizing wind power.

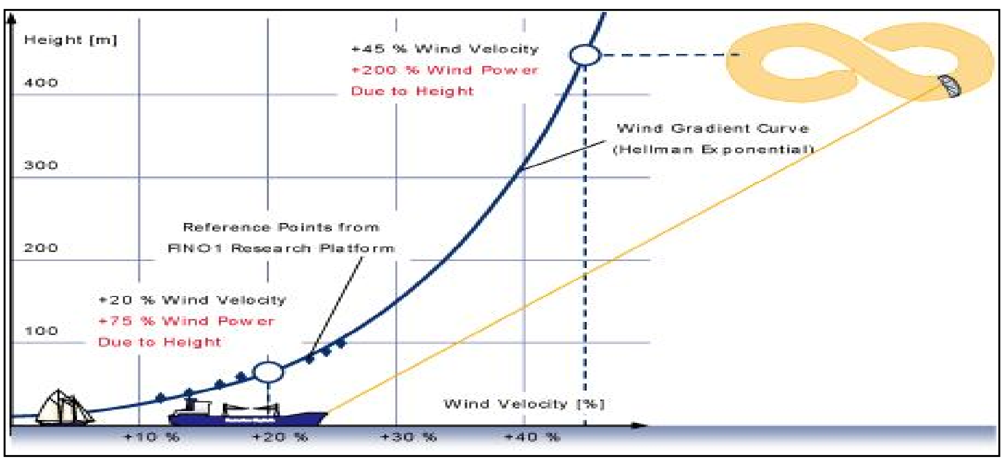


Figure 7: Shows using kites at high altitude winds

6.3. High Propulsion Power

The technical possibilities resulting from the spatial separation of the ship and the sail or towing kite gives sky sails an entirely new performance spectrum. Skysails easily generate five times more propulsion power per square metre sail area than conventional sail propulsions. The towing kite of the sky sails propulsion can be navigated dynamically this means that the autopilot can perform flight manoeuvres with the towing kite such as the figure 8 in front of the ship.

The high air speed of the towing kite is particularly relevant since the air flow velocity at the kites aerodynamic profile is the key to performance. For the calculation of the tractive force of towing kites the air flow velocity is squared.

$L = C_L * P/2 * V_\infty^2 * A_k$

Where

L : Lifting force of the towing kite

C_L: Lift coefficient of the towing kite

P : Density of the air

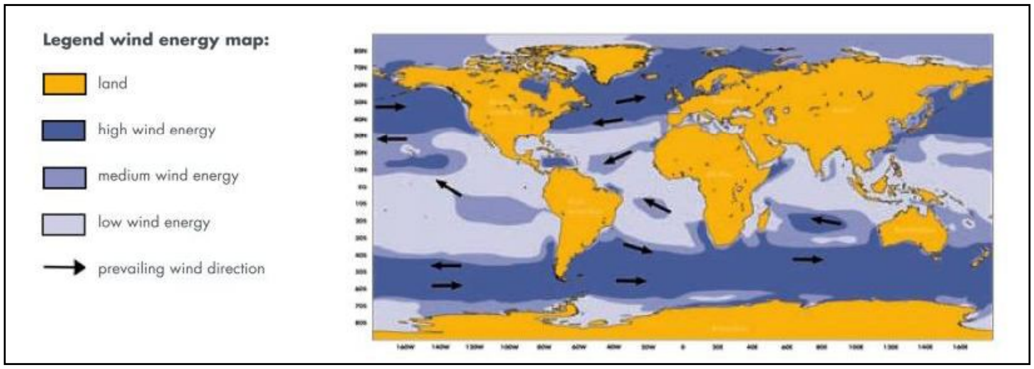
V_∞: Air flow velocity at the towing kite

A_k : Surface area of the towing kite

If the air flow velocity is doubled, the tractive force of the system quadruples. In practice, the towing kite can easily reach speeds three times that of the present true wind and more.

A further significant technological advantage of the system is that at an altitude of 150m the average wind speed is approx 25% higher than at an altitude of 10m, due to the absence of friction with the earth and the water surface. As the kinetic energy of an air mass increases to the power of three with the wind speed, more than twice the amount of energy can be available at the operating altitude of the towing kite than at 10m depending on the weather conditions. Since the system generates a significantly higher propulsion power per square meter sail area than conventional sail propulsions, it is possible to gain significant savings by using comparatively small sail areas.

7. World Wise Average Wind Energy

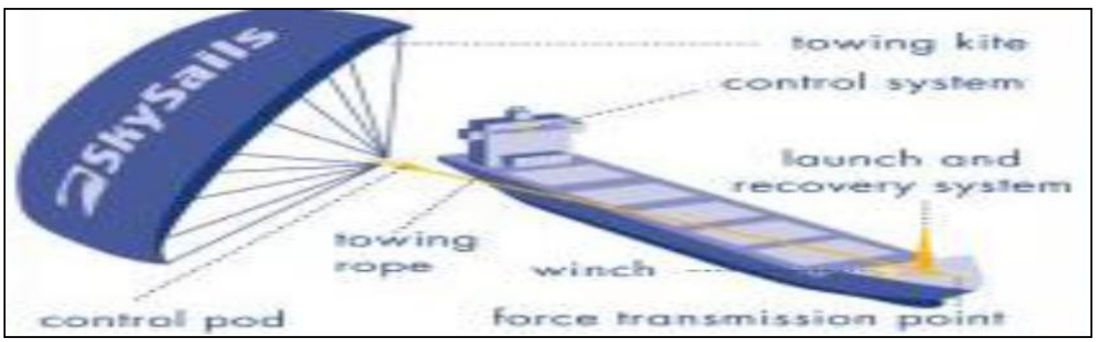


World Wise Average Wind Energy

8. Components In Kite Technology

The Kite technology consists of three main components:

- A towing kite with rope (flying system)
- A control system for automatic operation
- A launch and recovery system



Components In Kite Technology

8.1. Towing Kite

Instead of a traditional sail fitted to a mast, kite technology uses large towing kites for the propulsion of the ship their shape is comparable to that of a paraglide as shown in Figure 8. The towing kite is made of high-strength and weather proof textiles. It is double walled and fitted with chambers along its entire length as well as ports at the front end. A line tree defines the requested kite shape by spanning lines of different lengths between the pod and the towing kite. The profile of the towing kite is designed in such a way that optimal aero dynamic efficiency can be achieved. Their double wall profile gives the towing kites aerodynamic properties similar to the wing of an aircraft. In case of strong winds, the power of the towing kite is reduced by changing its position in the wind window, without having to minimize the towing kite area. Presently kites for cargo ships with kite areas of app. 150 to 600m^2.

Figure 8: Towing kite

8.1.1. Force Transmission

The specially designed for transmission system of the skysails propulsion transmits the tractive forces of the towing kite to the ship. The system is customized for each ship.

The force transmission system comprises the following components:

- Towing rope
- Force transmission point
- Winch

8.1.1.1. Towing Rope

The tractive forces are transmitted to the ship via a highly tear proof, synthetic rope as shown in Figure 9. The energy supply of the control pod is ensured by means of a patented special cable integrated in the towing rope.

Figure 9: Towing rope

Figure 10: Force transmission point

8.1.1.2. Force Transmission Point (Tow Point)

The force transmission point also called as tow point (as shown in **Figure 10**) is the point at which the towing rope of the kite is connected to the ship. The tow point guarantees the optimal alignment of the kite power for every course and wind direction. The tractive force of the kite system is directed to the bow area over the force transmission point mounted on the foredeck. Generally the existing ships structures are sufficiently dimensioned, since that is where the anchor windlass is also housed. The power transmitted by the kite system is comparable to that of an ocean going tug. An appropriate stability computation is made for each vessel prior to the installation of a kite propulsion system.

8.1.1.3. Winch

The towing kite is recovered and launched using a dynamically operating winch, which also serves as rope storage as shown in **Figure 11**. The tractive force measurement is pre installed in the winch. The winch speed is chosen so that the towing kite can be stabilized at any time when wind conditions are unstable. During heavy swell the winch assures safe operation during the launch and recovery procedure by means of dynamic sea state compensation.

Figure 11:Winch

8.1.2.Steering System

The steering system of kite technology operates automatically. The towing kite is aligned relative to wind direction, wind force, ship course and ship speed in order to achieve optimal propulsion power. The steering system consists of the control pod and the control system

8.1.2.1. Control pod

The functionality of the control pod is comparable to the pilot of a paraglider as shown in Figure 12. It pulls to the left and right of the control lines, thereby modifying the aerodynamic profile of the towing kite and thus controlling its flight path. Both the mechanical control actuators as well as the electronics and autopilot software for the control of the kite are installed in the control pod.

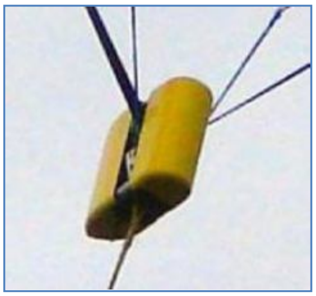


Figure 12: Control pod

Towing kite with control pod

8.2. Control System

The function of the control system as shown in Figure 13, is to steer the towing kite automatically. It is similar to the autopilot of an airplane in that data is collected via sensors and processed by the autopilot software. Subsequently, the software sends control commands to actuators in the system e.g control pod.

Figure 13: Control system on bridge

The control system comprises of the following components:

8.2.1.<u>On-board computer</u>

The entire towing kite system is managed using the on-board computer as shown in Figure 14. A graphic user interface on the bridge informs those commanding the ship about the systems status and allows the system to be operated by inputting commands (launch, recovery).

8.2.2. Control pod computer

A computer in the control pod takes over the tasks of sensor signals processing, motor control data communications and backup functions for the autopilot

8.2.3. Autopilot program

The towing kite is controlled automatically at all times. The autopilot as shown in Figure 15, lets the towing kite fly defines depending on the wind direction. This is performed by autopilot software like those used in aerospace applications. The autopilot is integrated in the onboard computer. Data and control commands are transmitted to the control pod by means of a special cable integrated in the towing rope.

Figure 14: On-board computer

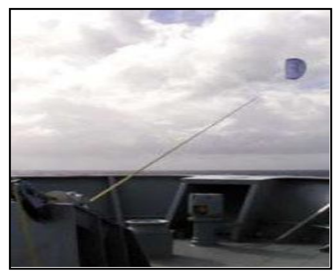


Figure 15: Auto pilot

8.3. Launch And Recovery Process Control

Managing the launch and recovery process consists of controlling the launch and recovery mast, winch and mast adapter. This semi automatic mechanism in the form of a programmable logic controller manages the entire launch and recovery process. The winch control is also handled by this device. The device is operated using a control panel installed on the foredeck when the launch and recover process is to be controlled manually.

As a minimum the following sensors must be installed on the ship for the towing kite technology

- GPS
- Wind direction gauge
- Anemometer

- Rudder position
- Course

Sky sails provides the following supplementary sensors together with the system

- Kite adapter sensor
- Tow point sensor
- Winch sensor
- Consumption sensor

8.3.1. Skysails Arrangement Module (SAM)

The launch and recovery system manages the deployment and lowering of the towing kite. It is installed on the forecastle and consists of a telescopic mast with reefing system as shown in Figure 16, which unfurls and reefs the kite respectively during the launch and recovery system.

A coupling mechanism connects the towing kite with the mast adapter attached to the launch and recovery mast. The towing kite is stored in the kite storage on the forecastle.

Force transmission point, launch and recovery system as well as the kite storage are all included in a single component the Skysails Arrangement Module (SAM) that is integrated on the forecastle.

Figure 16: Skysails Arrangement Module

During launch as shown in the Figure 17, the telescopic mast raises the towing kite which is folded like a accorden from the kite storage. Subsequently, the telescopic mast extends to its maximum height. The towing kite then unfolds to its full size and can be launched. The winch releases the towing rope until operating altitude has been reached.

The recovery process is performed in the reverse order of the launch. The winch retracts the towing rope and the towing kite docks on the launch and recovery mast. The towing kite is then reefed. The telescopic mast retracts and the towing kite is stowed in the storage along with the control pod. The entire launch and recovery procedure is carried out automatically and approx about 10 – 20 mins each.

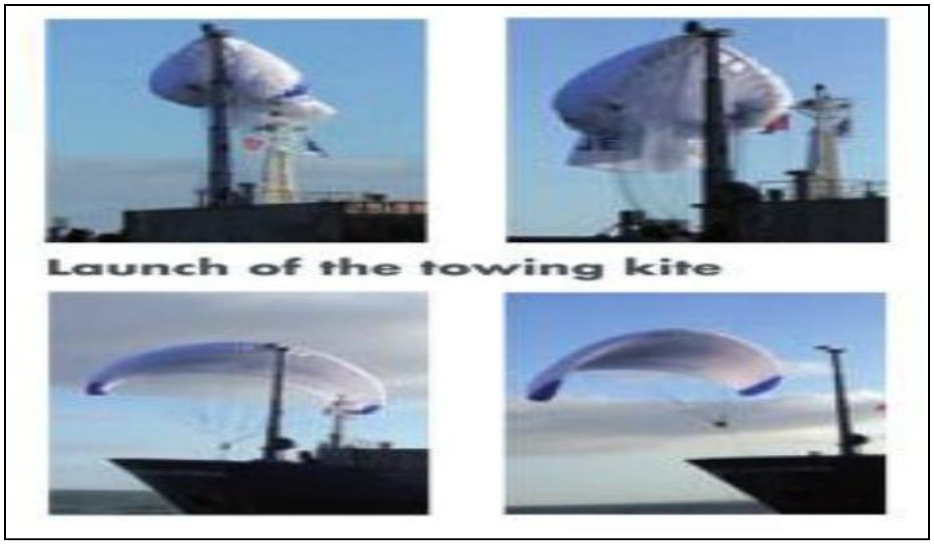


Figure 17:Launch of the towing kite

9. Operating Conditions

The towing kite system supplements the existing propulsion of a vessel and is used offshore, outside the 3 mile zone and traffic separation areas. The towing kite system is designed for operation in predominantly prevailing wind forces of 3 to 8 Beaufort at sea. The system can be recovered, but not launched at wind forces below 3.

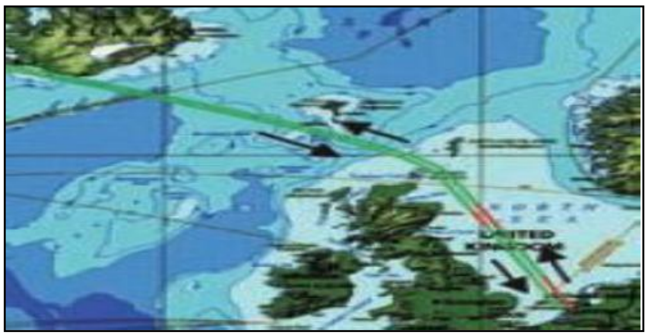
10. Routing System And Route Optimization

The optional weather routing system provides shipping companies with a means to guide their ships to their destinations on the most cost effective routes and according to schedule

Experienced meteorologists do the weather routing in four steps

- Weather forecast: First they determine what kind of performance can be generated with towing kite propulsion under the forecast weather conditions. Potential routes and speeds are then calculated.

- Decision model: Included in the decision model are the requirements set forth by the shipping company, such as the desired arrival time.
- Performance calculation: The data from the weather forecast and the decision model flow into the performance calculation. The optimal route is then computed based on the projected performance.
- Recommended route: Finally the recommended route is translated into way points and sent to the shipmaster.



Route optimization

Modern meteorological methods make precise three to five day weather forecasting possible. Major weather systems and weather trends can be forecast for even longer periods. The routing system hence contributes significantly to system safety by means of projecting and preventing risk.

11. Installation And Commissioning

Virtually all existing cargo vessels and new builds can be retro or outfitted with the towing kite system. Installation can be made in the shipyard of choice or in a port that has an adequate crane system. The ship can remain the water during installation.

The components are installed in three steps:

- Preparation of the mounts and foundations for winch and SAM, cutting of openings for the wiring and hydraulic lines as shown in Figure 18. Reinforcement of the foredeck may be required. Commonly, the ships structure in this area is however already designed with adequate stability due to the reinforcements for the anchor windlass.
- Installation of the components winch and SAM on the foredeck mounts as shown in Figure 19, installation of the workstation on the bridge.

- Laying of the electrical and hydraulic lines and connection of the system components. Winding of the towing rope onto the winch. Stowing the towing kite and control pod in the kite storage.

As desired or needed, each of the individual installation steps can be performed independently, at different times and at different locations. This, for example allows using extended docking times for loading and offloading to install the system.

Figure 18: Installation winch

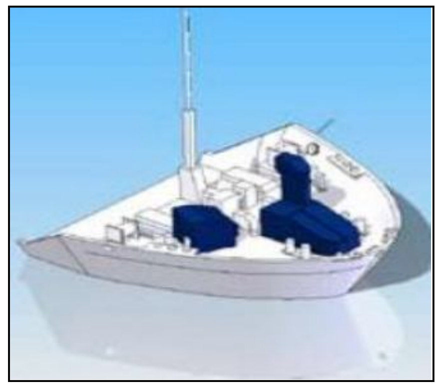


Figure 19: Arrangements of foredeck components

12. Future research

It is possible to produce electrical energy using a kite moving up or down, or using a series of kites.

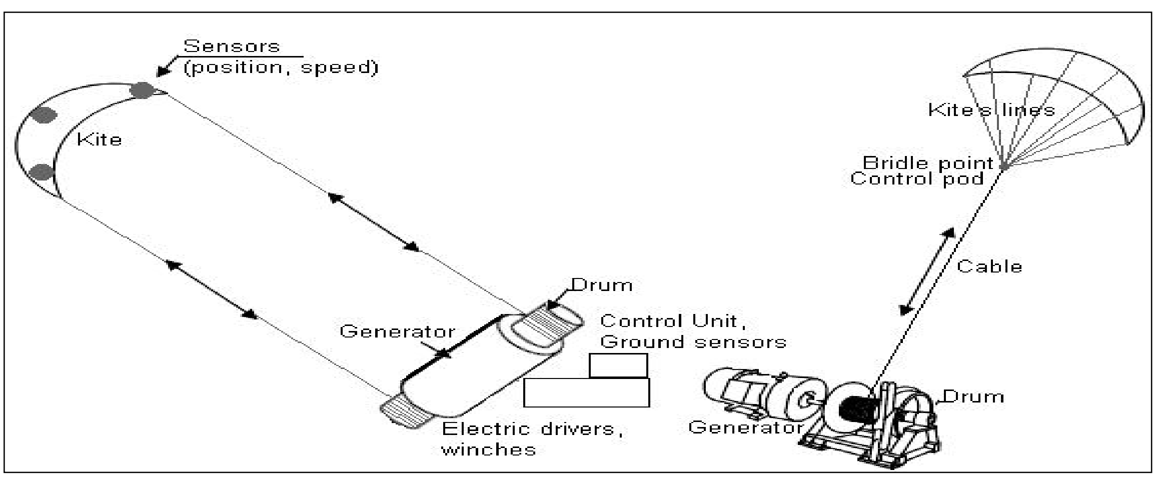


Figure 20: Shows Kite Energy Generator

Research can be extended, and these kites can be mounted on board ships, experimenting in a primary phase the way the ship moves at slow speed or is a drift and the energy produced by the auxiliary engines (current generators) is replaced by the energy supplied by the kites as shown above in Figure 20.

13. Conclusion

Using renewable energy is the ultimate aim for sustainable transportation. Olden days wind energy (sails) was used for transporting people and goods over the oceans, the current developing kite technology proves old techniques can be future proof and catalyse the innovation in the shipping industry. A fuel saving of 35% can be obtained by the new kite technology. The latest kite technology produces propulsion power of more than 2 MW (approx. 2,700 horse powers; equivalent ship engine) and can save up to 10 tons of oil per day. Through this paper it is understood that besides fuel savings and a quick return of investment, the system will lower cost for emission system and emission disposal costs.

14. Reference

1. www.bsr.org/consulting/working-groups/clean-cargo.cfm
2. Control of towing kites for sea going vessels report by Michael Erhard and Hams Strauch
3. Second IMO (International Maritime Organization) GHG Study 2009; International Maritime Organization London, UK
4. www.bbcchartering.com
5. SkySails brochure "Technology Information",
6. www.awtdata.webs.com/
7. www.skysails.com
8. www.dsm.com
9. www.nasa.gov/topics/technology/features/capturingwind.html
10. http://www.imo.org/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Air-Pollution.aspx
11. http://www.imo.org/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Sulphur-oxides-
12. %28SOx%29%E2%80%93-Regulation-14.aspx
13. www.skysails-technology.com
14. http://www.grc.nasa.gov/www/k-12/VirtualAero/BottleRocket/airplane/Images/liftco.gif
15. http://www.grc.nasa.gov/www/k12/VirtualAero/BottleRocket/airplane/Images/kitelift.gif
16. http://www.grc.nasa.gov/www/k12/VirtualAero/BottleRocket/airplane/Images/dragco.gif
17. http://www.ptrivedi.com/projects/kite_aerodynamics.pdf
18. http://www.grc.nasa.gov/www/k-12/airplane/Images/kitedrag.gif