Wind engines for land transport

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Abstract

The article examines the use of new propeller wind engines for ground transport (small cars, bicycles, sailboats on skates, catamarans, sea vessels). It is shown that using rotary wind screw installations, it is possible to significantly improve the traction characteristics of wind engines and reduce their dependence on the wind direction. In particular, allow the vehicle to move along the highway strictly against the wind (which is impossible for sailing vehicles).

Keywords: wind engines, non - fuel engines, transport wind installations.

Introduction

Wind engines (sails for sea transport) have been used since ancient times. Its main advantage is that it does not require fuel. But the sail engine has significant drawbacks: the thrust force strictly depends on the presence, direction and speed of the wind. In particular, sailing vessels cannot sail strictly against the wind. With the creation of mechanical engines, the low-speed sailing fleet almost ceased to exist. However, stationary wind installations for generating electricity have been greatly developed.

This paper explores the possibilities of a new rotary propeller wind engine. These features are much wider than the sail.

Advantages over a sail:

1) The power of the proposed wind engine does not depend on the wind direction; the propeller always turns strictly against the wind.

2) A Propeller converts wind energy into thrust more efficiently than a sail, especially a headwind. A normal sail is not able to move the ship strictly against the wind. Wind speed-the engine is most effective when driving against the wind and is able to move the vehicle at a speed several times higher than the wind speed.

3) The Propeller can convert (regardless of the vehicle's movement) wind energy into mechanical or electrical energy and store it in the flywheel or battery, i.e. it turns the vehicle into a fuel-free vehicle even when the wind is temporarily absent or weak.

4) The Propeller can withstand higher wind speeds than a normal sail, which, if the wind speed exceeds a certain limit, can break or capsize the transport. This is because the propeller has a lower height and less air resistance.

5) The Propeller has a lower height than the vertical triangular sail, which allows transport to pass under bridges.

In the work given to the evaluation of the data small cars, bicycles, sailing on skates, catamaran, ships. It is also essential that the proposed device does not require the design of new vehicles. It can be created in the form of attachment to the existing small cars, bikes, river or sea-going vessels (Fig.2).

Theory

A diagram of the forces acting on a ground vehicle with a wind engine is shown in Fig.1. Here the wind blows in the direction and at the speed of V_w, and the movement of the device in the direction and at the speed of V. T_o – ground thrust of the propeller wind engine; V_w – wind direction and speed; α – the angle between the vectors V , -Vw ; F – the friction force of the device on the surface.

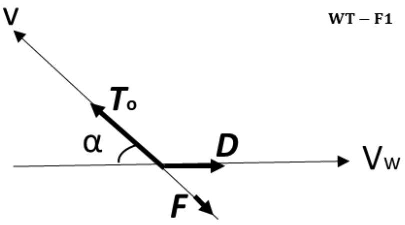

Fig.1. Diagram of forces acting on a vehicle with a propeller wind engine. *Designations*: ***V*** – direction of movement (*V*-speed of the device), *D* – aerodynamic resistance of the propeller to the wind, T_o – ground thrust of the wind engine, $\boldsymbol{V_w}$ – direction and V_w wind speed, α – angle between the vectors ***V*** , -$\boldsymbol{V_w}$; *F* – friction force of the device on the surface.

Projecting these forces on the direction of motion, we obtain the thrust equation of a propeller wind engine:

$$T = T_o - D{\cdot}\cos\alpha - F, \qquad (1)$$

where T – useful thrust apparatus, N; T_o– engine propeller thrust, N; D – wind resistance of the propeller, N; F is the frictional resistance of the apparatus, N.

Power, traction and wind resistance of the engine is equal to:

$$P = 0.5\eta\rho S(V_w+V)^3, \quad T_o = P/V = 0.5\eta\rho S(\rho V_w+V)^3/V,\ D = P/(V_w+V) = 0.5\eta\rho S(V_w+V)^2,\ F = Mgf. \quad (2)$$

Where P is power of wind engine, W; $\eta \approx 0.5$ is coefficient efficiency of wind engine; ρ=1.225 is air density, kg/m^3; S is propeller area, m^2; M is mass of apparatus, kg; g = 9.81 m/s^2 ≈ 10 m/s^2, gravity; f is a friction coefficient of apparatus about Earth surface.

Substitute (2) into (1) we reserve the useful trust:

$$T = 0.5\eta\rho S(V_w+V\cos\alpha)^2(V_w/V) - Mgf, \qquad (3)$$

or

$$T = A(V_w+V\cos\alpha)^2(V_w/V) - Mgf. \qquad (3')$$

where $A = 0.5\eta\rho S$ is the parameter of the wind installation.

When moving strictly against the wind, α=0, cosα=1, and equation (3) takes the form

$$T = 0.5\eta\rho S(V_w+V)^2(V_w/V) - Mgf. \qquad (4)$$

When moving strictly with a crosswind α=90°, cosα=0, and equation (3) takes the form

$$T = 0.5\eta\rho SV_w^3/V - Mgf. \qquad (5)$$

The wind resistance of the propeller *D* (2) creates a tipping moment, but it is usually less than the tipping moment from the sail perpendicular to the flow, because the propeller has a smaller area, height, and less drag on the flow than the sail.

From equation (5) at $T = 0$, you can find the speed of the vehicle in a crosswind:

$$V = 0.5\eta\rho S V_w^3/Mgf = AV_w^3/Mgf\,. \qquad (6)$$

The air resistance *X* to the movement of the apparatus is approximately equal to

$$X = 0.5C_x\rho V^2 S_a\,, \qquad (7)$$

where $C_x = 0.03 \div 0.15$ coefficient of air resistance, S_a – cross-section in water of the device, m^2. If the speed of the device is < 20 m/s, air resistance can be ignored.

The main resistance to a sea vessel is provided by water. Water resistance X_w can be estimated by the formula similar to formula (7).

$$X_w = 0.5C_w\rho_w V^2 S_a/\eta_w\,, \qquad (8)$$

where $C_w = 0.1 \div 0.2$ coefficient of resistance of water, S_a is the cross section of a ship in water, m^2; $\rho_w = 1000$ kg/m^3 is the density of water; $\eta_w \approx 0.8$ is the efficiency of the water screw.

Sustainability, management, and design issues.

A wind turbine for transport is useful when fuel costs are high in areas where winds are constantly blowing. For convenience, it is desirable to have a battery of energy (mechanical or chemical) for a few hours of economical running in case of calm or weak or tailwind. The unit will automatically be charged with energy during Parking or strong winds. With the help of a simple rudder, the propelltr will always automatically be installed strictly against the wind. It must be universal, i.e. it can be installed on any ground vehicle. In case of a storm and for ease of transportation, the unit must have a folding propeller. For efficiency, it is desirable to use a propeller with automatic pitch adjustment, as is customary on conventional wind turbines.

Examples of installing a wind turbine on ground transport devices.

Recall that the installation of the proposed wind engine eliminates fuel consumption.

Below are estimates of the traction and speed of some vehicles (Fig.2) from the installation of the proposed wind turbine on them. The average wind speed is assumed to be the standard $V_w = 10$ m/sec.

1. Passenger car weighing 1 ton, with a screw area $S = 10$ m^2 (screw diameter $D = 3.67$ m), $f = 0.02$. Then $A = 0.5 \cdot 0.5 \cdot 1.225 \cdot 10 = 3.06 \approx 3$. Fig. 2A.

When moving against the wind at a speed of $V = 20$ m/s, the excess thrust (3') will be

$$T = 3.06(30)^2(10/20) - 1000 \cdot 10 \cdot 0.02 = 1377 - 200 = 1177 \text{ N}$$

The air resistance is equal to

$$X = 0.5 \cdot 0.1 \cdot 1.225 \cdot 30^2 \cdot 3 = 165 \text{ N}\,. \quad T = 1177 - 165 = 1012 \text{ N}\,.$$

The excess thrust is about 100 kgf, which means that the speed against the wind can be greater than $V = 20$ m/s = 72 km/h.

In a crosswind, the vehicle speed according to (6) can reach

$$V = AV_w^3/Mgf = 3.06{\cdot}10^3/(10^3 10{\cdot}0.015) = 20 \text{ m/s} = 72 \text{ km/час}.$$

In General, a wind turbine for a car is the most difficult case and can be used for light cars and strollers.

2. **Bicycle** or wheelchair. Let's assume that the bike together with the cyclist weighs 100 kg., swept by a screw with an area of S = 3 m^2 (screw diameter D = 2 m), f = 0.015. Then $A = 0.5{\cdot}0.5{\cdot}1.225{\cdot}3 = 0.92 \approx 1$. Fig. 2B.

When moving against the wind at a speed of V = 10 m/s, the excess thrust (3') will be

$$T = 1{\cdot}(20)^2(10/10) - 100{\cdot}10{\cdot}0.015 = 400 - 15 = 385 \text{ N}$$

The air resistance is equal to

$$X = 0.5{\cdot}0.2{\cdot}1.225{\cdot}20^2{\cdot}1 \approx 50 \text{ N}. \quad T = 385 - 50 = 335 \text{ N}.$$

The excess thrust is about 33.5 kgf, which means that the speed against the wind can be greater than V = 10 m/s = 36 km/h.

In a crosswind, the cyclist's speed according to (6) can reach

$$V = AV_w^3/Mgf = 0.92{\cdot}10^3/(10^2 10{\cdot}0.02) = 46 \text{ m/s} = 165 \text{ km/час}.$$

Without taking into account air resistance. Taking into account the air resistance, the speed can reach 70 km/h.

3. Sand yachting on skates. Weight 200 kg., with a screw area S = 10 m^2 (screw diameter D = 3.67 m), f = 0.02. Then $A = 0.5{\cdot}0.5{\cdot}1.225{\cdot}10 = 3.06 \approx 3$. Fig. 2C.

When moving against the wind at a speed of V = 20 m/s, the excess thrust (3') will be

$$T = 3.06(30)^2(10/20) - 200{\cdot}10{\cdot}0.025 = 1377 - 400 = 977 \text{ N}.$$

The air resistance is equal to

$$X = 0.5{\cdot}0.2{\cdot}1.225{\cdot}30^2{\cdot}2 = 220 \text{ N}. \quad T = 977 - 200 = 777 \text{ N}.$$

The excess thrust is about 78 kgf, which means that the speed against the wind can be greater than V = 20 m/s = 72 km/h.

In a crosswind, the speed of the Sand yachting on skates according to (6) can reach

$$V = AV_w^3/Mgf = 3{\cdot}10^3/(200{\cdot}10{\cdot}0.025) = 60 \text{ m/s} = 216 \text{ km/h.},$$

excluding air resistance. Taking into account the air resistance, the speed can reach 100 km/h.

4. **Marine cargo ship**. Displacement 14000 m^3, with 4 propellers (n = 4) each with an area of S = 800 m^2 (screw diameter D = 32 m). Then $A = 0.5{\cdot}0.5{\cdot}1.225{\cdot}800 \approx 245$. Fig. 2D. $S_w \approx 100$ m^2.

When moving against the wind at a speed of V = 10 m/s, the excess thrust of one wind crew (3') will be

$$T = 245{\cdot}(20)^2(10/10) - X_w = 98000 - X_w \quad \text{N}$$

The water resistance is (8)

$$X_w = 0.5{\cdot}0.15{\cdot}1000{\cdot}10^2{\cdot}100/0.8 = 9.4{\cdot}10^4 \text{ N}, \quad T_1 = 9.8{\cdot}10^4 - 9.4{\cdot}10^4 = 400 \text{ N}.$$

The excess thrust of one wind turbine is about 40 kgf, which means that the speed against the wind will be V = 10 m/s = 36 km/h. When moving strictly against the wind at a speed of 10 m/s, one wind turbine is sufficient.

In a crosswind, the speed of the vessel according to (6) can only be reached with 4 wind engines:

$$V = nAV_w^3/X = 4{\cdot}245{\cdot}10^3/X_w = 10.4 \text{ м/s} \approx 36 \text{ km/h}.$$

In practice, such a vessel has a power plant of 8,100 kW and at a speed of about 18 knots (29 km/h) in a few days' sails from the Western ports of the United States (across the Pacific Ocean) to the Eastern ports of Asia, spending 1,300 tons of liquid fuel.

The reader can calculate the savings. Conclusion: the use of the proposed wind engines in marine shipbuilding is the most appropriate.

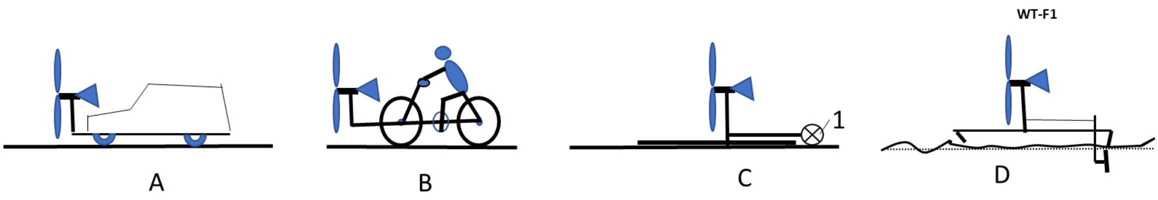

Fig.2. A ground vehicle that uses a propeller to wind the engine. Designations: A – passenger car, B – Bicycle, C – horse – drawn platform (on ice, 1-wheel with hooks), river or sea vessel (in particular, catamaran).

The author also evaluated the use of wind engines in **railway transport**. I will only give the result.

Let's assume that three propellers with a diameter of 5 m (A = 6.12) are placed on the railway platform and the train should move at a speed of V = 20 m/s with a coefficient of friction f = 0.005. Then, according to (5), with a crosswind of V_w = 10 m/s, the maximum mass of the train cannot exceed

$$M = nAV_w^3/(Vgf) = 3{\cdot}6.12{\cdot}10^3/(20{\cdot}10{\cdot}0.005) = 18360 \text{ kg} = 18.36 \text{ тонн}.$$

This is the mass of a small locomotive and 3 – 4 light passenger cars of 3 – 4 tons. This train can be used on small tourist routes or as a tram on urban routes.

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