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Flight control mechanisms of a comet

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Abstract. The growth of technology and the demand for the use of renewable resources has unleashed the interest of researchers to generate knowledge to obtain resources of this type. For this, they have built different proposals; one of them is the generation of energy through wind resources. In this article, a search is carried out in publications that relate renewable energies to air vehicles, proposals for flight control mechanisms in an aerodynamic system and the different control designs used by researchers in this area

Keywords: Aerodynamics, control design, angle of attack, renewable energy.

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1 Introduction

Energy is the potential capacity of bodies to produce work or heat, it is a physical property that is not created or destroyed, is transformed into another type of energy; For example, when a person is pedalling on a bicycle a job is being done, the energy of a man is produced with sugar and fat can be used to do a job, such as pedalling a bicycle, with this analogy Merino verifies that energy is not It is created or destroyed, it only transforms to a job [1].

In his article Santamarta mentions that renewable energies solve environmental problems, including climate change, radioactive waste, acid rain and air pollution, energy consumption was exceeded in 2003 with 10,500 (millions of tons equivalent in Mtep oil), 2,400 Mtep of coal, 3,600 Mtep of oil, 2,300 Mtep of natural gas, 610 Mtep of nuclear, 590 Mtep of hydroelectric and about 950 Mtep of biomass, mainly firewood, and still small amounts of geothermal, solar and wind. Environmental degradation is mainly caused by the production, transformation and consumption of energy. OECD countries, with 15% of the world's population, consume 60% of energy [2].

Renewable energies, alternative or soft, represent a set of energy sources in some cases are not new, such as firewood or hydroelectric plants, although it does not mean that these are soft, their environmental impact can be significant. All renewable energies come directly or indirectly from solar energy. Those produced by light and heat produced by solar radiation are direct and the energies that come from wind, water, tides, waves and biomass, among others, are indirect. In the nineteenth century, renewable energies came into force, and since then, they have almost completely met the needs of man in matters of energy [2].

According to André, De Castro & Cerdá, the evolution and current situation of renewable energies at an international level, are studied to understand how technology has been transformed to obtain clean energy and how depending on the there are considerable variations in the country both for the use and obtaining of these energies. The situation of renewable resource obtained from wind resource in different countries is analyzed, being the best Germany, China and the United States [3].

Production of renewable wind energy through kite

Of all the different energy sources, renewable energy sources are those that are produced continuously and are inexhaustible, renewable energy sources can be wind, hydraulic, solar, geothermal, tidal, biomass and Biogas. In this section, we talk about the production of wind energy through a comet.

The research on comets began in 1987 where Loyd conducts a study on the power generated in watts, there are different classifications of the system: fixed land station, mobile land station, crosswind, no crosswind. [4]

Lorenz and Scheidt in their article mention, that comets are not only used to generate energy, but they can also be used in some sports, research, observations, on operations transporting cameras that are lifted by a comet, for geomorphological study. In dunes demonstrating two scientific applications the detection of changes in dunes and the generation of a model for topographic parameterization [5].

Fritz mentions that pilot vessels operate propulsion kites to reduce fuel costs. The generation of clean energy through kite technology is considerable for cost reduction, the main components of the comet are: control, rope, launch and recovery system. A comet uses the principles of power generation and propulsion. In the air the forces of the comet are used to pull the rope from a drum, so it feeds the generator, when it reaches the maximum length of the rope, the comet is rolled again this is how the motor becomes the generator to this, he calls it pumping mode [6].

Not all applications of a comet are autonomous or should be, but for the generation of energy they should be, different types of control are implemented by researchers mentioned in the section of state of the art.

2 Description of the Problem

The use of large-scale energy has generated significant wear of fossil fuels to planet Earth, due to this, it is intended to use renewable resources to generate clean energy. To obtain clean energy, different technological mechanisms are being developed that can be generated directly from the air, from the sun and the water. Some of the devices that have been created to generate energy are: the solar panel, conventional wind turbines and comets, to name just a few. Some researchers have carried out experiments with kites to generate renewable energy since this type of wind energy is commonly obtained with wind turbines, nowadays we are looking for ways to generate more energy at a lower price.

3 State of the art

3.1 Clean energies

There are different types of clean energy, wind, hydraulic, solar, geothermal, tidal, biomass and Biogas. Clean energies are those that produce energy and are inexhaustible. Next, in figure 1, each of the clean energies is presented graphically.

Figure 1. Renewable energy [7].

A brief description of some renewable energies is presented.

- Solar energy: Known by the name photovoltaic effect, electricity is obtained directly by sunlight, physicist Antoine Becquerel proposed this in 1839. To obtain it, a material that fulfils the function of absorbing light is needed. From the sun and be able to transform the radiant energy into electrical, photovoltaic cells capable of achieving the objective [8].

Figure 2 shows the devices that perform the cycle to produce energy.

Figure 2. Solar Panel [9].

- Hydraulic energy: this energy has as its principle the water of the rivers and currents in return to the seas and oceans, this is part of the hydrological cycle, this could be the oldest way to use energy for the development of the human energy needs, the basis is the conversion of kinetic and potential energy, for activities such as grinding grains, sawmills or mechanical force, kinetic energy has been used, potential energy is added in reservoirs and transformed into usable energy. Electricity is produced with an electric generator, and a hydraulic turbine are implemented at the end of the 19th century utilizing hydraulic power [10]. Figure 3 shows how hydraulic energy can be produced.

Figure 3. Hydraulic energy [11].

- Geothermal energy: refers to the energy that comes from the natural heat inside the earth, this heat comes mostly from the material called magma. This accumulates at depths between 5 and 10 km, large heat parts of rock or confined fluids, geothermal energy is called to the study and application of thermal energy that is made through rocks and/or fluids from inside the crust. Terrestrial to the surface of it, it manifests as fumaroles, thermal springs and volcanoes to name a few [12]. Figure 4 shows the force that a geyser can have, making it an efficient geothermal energy resource.

Figure 4. Geiser [13].

- Wind energy: it is the one that is generated by the moving air masses, a system that generates this energy is the wind turbines these generate kinetic energy in mechanical energy by means of a propeller, there is also the system utilizing a comet these have been considered as a potential means to generate energy from high altitude winds, to achieve the generation of energy through comets a control is needed that can make a trajectory, because the flexibility of comets makes modelling a problem. [14]

Converting wind energy into electricity is a key source for changing the energy model, cleaner and more sustainable. At this time, wind turbines produce energy, although at this time there is a new technology through kites to be able to produce more energy with lower costs, this depends on control, with a flight path that must be controlled [15]. Figure 5 and 6 shows the systems that can produce this type of energy.

Figure 5. Conventional wind turbines [16].

Figure 6. Awes [17].

There are different types of kites with which wind energy can be generated in the next section the different types are shown.

3.2 Kite types

These have advantages over each other highlighting the LEI SLE type with the following characteristics: it has flanges in the central part causing its angle of attack is in the central part thus increasing aerodynamic efficiency also highlighting the Foild Kites pore studios have a better efficiency Aerodynamic flanges are increased according to size. All this must be taken into account so that these kites can make a trajectory and thus generate energy, so that they make the trajectory a control must be implemented. Figure 7 shows the different types of aircraft. Just as there are different types of kites, there are also two types of

configuration for wind power generation, which are Yo-Yo and Carousel in Table 1 shows a comparison of these two configurations.

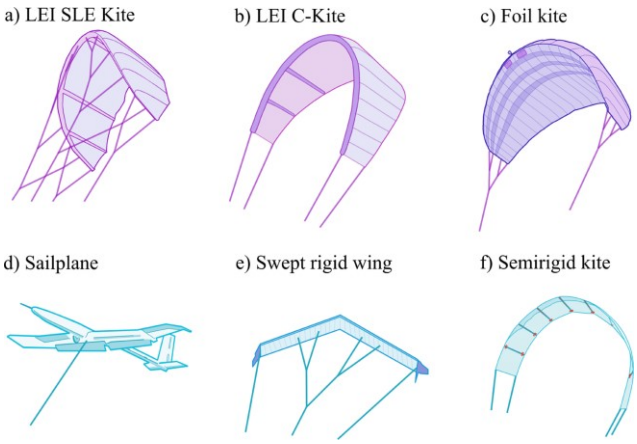

Figure 7. Renewable energy [18].

Table 1. Configuration for wind power generation.

Yo-Yo	Carousel
It is fixed with respect to the ground, the energy is obtained with a two-phase cycle that of traction the kite exploits the wind energy to unwind the ropes, and the electric drives act as generators, driven by the rotation of the drums, when the maximum length of the rope, the second phase that is the passive begins and the drives act like motors and thus spending a minimum amount of the previously generated energy. It is considered a very simple model that does not take into account the weight of the rope, the drag and the variable aerodynamic coefficients of the comet, including those derived from the rolling angle of the comet, the elevation coefficient and the wind speed of the cable [19].	The vehicles are placed on a circular road, the speeds are constant by means of electric generators that act on wheels, it is considered a simple kite model in the same way with a two-phase cycle in the first the comet pulls the carousel, generating energy, while in the second the comet is dragged against the wind and driven to a position such that the energy loss is less than that produced [19].

Figure 8. Aerogenerador tipo Yo-Yo [20].

Figure 9. Aerogenerador tipo carrusel [21].

Different types of control can be used in the generation of wind energy by a comet, just as different models can contribute more to the control or simple models that only represent the system that is easier to understand, but with limitations.

3.2 Control types and models.

Pastor-Rodríguez et al. shown a simple model that restricts the tilt movement of a comet, to include the movement of the tilt of the comment, inertia, flexibility, wind face and elasticity of the rope. The models are shown in small sets of differential equations without algebraic restrictions, where they are eliminated with the use of Lagrangian mechanics, each physical mechanism instability is analyzed separately. The rope is a key component to stabilize the comet [22].

Goela et al. mention that the effects of wind on a static profile and the transmission of force from a rope tied to an aerodynamic body like a comet. Two important parameters are obtained that characterize how the ropes that are the weight behave, the relationship between the weight and the tension, and the wind load, results with five different models (straight line, catenary, constant speed, variable speed and effort maximum) are compared to determine the application regions of each model [23].

Salord Losantos et al. show that the dynamics and stability of a comet are variables depending on the wind whether it is stable or unstable. In non-stationary wind speed conditions, there is no balance, the comet's stability can be understood with a numerical method that is based on Floquet theory [24].

Adomaitis suggest the observation of the dynamics of a comet in flight, the possibility of multiple equilibrium states. With the application of the bifurcation theory to a simplified flight model, it is confirmed by demonstrating the existence of a bifurcation of the limit point in the plane of wind speed and the rope angle of the comet [25].

Alexander explains the important behaviour of comets, predicting where they will settle during the flight. The analysis is limited to a vertical plane where the comet's rope is contained, the basic forces of the comet of one or two ropes are examined and shows how the angle or angles and the equilibrium points can be derived from the aerodynamic properties, although they predict several equilibrium points, not all are stable equilibrium points [26].

Hand et al. related the movement of a comet, it must be simulated by a numerical code where aerodynamics and flight dynamics, this study examines aerodynamic forces, altitude and stability. It is verified that this method is effective by the response that the comet has [27].

Sanchez analysis a comet with a single string and two degrees of freedom. The states of equilibrium of the system and stability, proper values with linear theory are studied. The system must go through a Hopf fork where constant solutions appear. Consider the comet's responses against gusts and develop an open-loop control to maintain an invariant flight altitude in changing atmospheric conditions [28].

There are different types of control designs that can be implemented to these systems, a control design that is shown is that of monitoring.

Jehle and Schmehl applied a kinematic framework and tracking control applicable to flying objects such as kites for power generation, where definitions and terminology of aerospace engineering are used, these are used for the model and the control,

based on the measurement data, is an empirical correlation of the steering law that tells us that the details that maintain a pattern or direction that tend to be grouped together as part of a model and the speed of yaw of the kite , this provides a fundamental part of the cascade controller, the path that the object must perform is projected onto a unitary sphere centered on the anchoring point of the strings must be based on geometric considerations on curves, a control law is derived from Follow this with the objective of reducing the spatial displacement of the comet gently to zero [29].

Groot et al. have a successful deployment of wind power at high altitude on a comet, automatic control is needed, the design of the control law is based on a dynamic model of real-time flight, it is an analysis of a multi-body representation of an inflatable kite in the form of a bow attached to straight ropes without mass with movable fixing point, the reduction of this system to a rigid body approach, the process is divided into two: 1) state reduction: decreases the degrees of freedom, 2) model identification: establishes the aerodynamic and structural characteristics of the rigid body model; The flexibility of the comet must be taken into account using variable aerodynamics and a quasi-static structural model. With the help of the error criterion, the state reduction can be performed [30].

Erhard and Strauch show the configuration of the system, equations of movement, the problems that can occur during the cycle that it performs for the generation of energy, with a navigation algorithm that is used for the control, this is illustrated by experimental flight data, after modifications to improve control [31].

Erhard and Strauch generate energy when moving away from the base at high clamping forces during the crosswind after it is rolled up in a stationary position, so there is a net amount of energy generated, this document presents a control of direction that allows a flight with a pattern of eight where they take into account the details of each element such as pressures, altitude, etc [32].

Sánchez presents a dynamic analysis of a comet of a line with two degrees of freedom. To write the equations of motion, the Lagrangian formulation is used. The stability and equilibrium states of the system are studied, for linear values a linear theory is used. The comet's response against the gusts is considered, and an open-loop control system is developed where invariant flight altitude is maintained in changing atmospheric conditions [33].

Alonso-Pardo and Sánchez-Arriaga have shown for the dynamic analysis a parallel flight simulator, with the use of the Lagrangian method used a rigid system. The simulator is used to calculate periodic paths in the form of eight with an open-loop law, an unstable equilibrium state can be stabilized with closed-loop control [34].

Novara et al. show that high-altitude wind energy technologies have emerged this in order to occupy the force of the wind that blows up to 1000 m above the ground, Automatic control is an important aspect of comets since the system is unstable in closed-loop, In this document, he proposes a control technique that is based on direct-reverse control, this directly calculates a controller through the data thus avoiding the need to derive the system model. This controller is designed by scattered identification [35].

Fechner & Schmehl say that there is a great solution at low cost for wind energy is based on converting the traction power of kites into electricity, controlling a flight path that projects into spherical coordinates It is what is presented in this document, the proposed algorithm is easy to implement since LPV and PID components are used, this allows defining limits for the speed of rotation and thus avoiding sensor failures, allows using a low gain in the feedback cycle against cycle delay. During the generation of eights, the advance control is mainly used, thus reducing instability, the second part of the cycle is used the feedback control in combination are the non-linear dynamic inversion (NDI) this is used to compensate for the effect of gravity on the speed of rotation, the changes in the direction sensitivity, the apparent wind speed and the angle of attack. To validate the performance of the control uses a dynamic 4-point model of the comet, to model the turbulence the Mann model is used [36].

Podgaets, & Ockels say that to use the energy of high altitude winds is to launch a series of kites on a long rope, let themselves be pulled by the rope and drive the generator. A mathematical model of the system is developed, consisting of the model of the comet and the cable that joins them, this is described and then investigated to determine the stability with respect to various wind conditions, this includes random wind gusts [37].

Fagiano et al. investigate technology for the generation of wind power at high altitude, exploiting the tensile forces exerted by the kites that can be controlled automatically, flying fast in a crosswind condition, a mathematical model of the system and a predictive control law of a nonlinear model. It is considered in the design of NMPC is the predicted force of attraction exerted on the strings of the comet [38].

Wood et al. show an orientation strategy for a kite's flight control. The trajectory is controlled with the cascade approach through the orientation of the velocity vector. It is considered a model oriented to control entry delay this to be able to follow a reference route. In order to measure the delay, a predictor is designed, the predictions are used to calculate a reference for a lower level tracking controller. In the route, planning reference is made to a figure in the form of eight for the comet to follow. The route design considers the model parameters used in the tracking controller so that the limits that are induced by the delay are taken into account [39].

Wood et al. propose a design of a controller for an autonomous kite system to generate wind energy, a tracking controller for the orientation of the velocity vector. By empirical data, we model the behaviour of the comet's handling as a delayed dynamic system, the model information is used for the controller design. The parameters involved are identified and extracted by experimental data, this in order to have control through a real-time flight [40].

Podgaets & Ockels present that comets tend to simulate as rigid bodies and rope as a thin elastic line. Euler's angles and rope speed will be controls. The flight control is written as a fusion between this are the design of experiments and optimization. This merger ensures finding a reasonable number of parameters in a reasonable time while collecting information. The system is very constant despite variations in wind speed. The resulting optimal path can be used as the first iteration for closed-loop control algorithms [41].

Erhard & Strauch present the characteristics of the kite system's flight control. After understanding coordinate definitions and system dynamics. It presents a new model used for controller design to justify the main dynamics with the system identification results, present the controller design, for operational flights and explain the flight patterns. [42]

Fechner et al. say that the control of the trajectory and the winding of the ropes is important. A modelling framework is proposed that represents the dynamic behaviour of the system components, the comet, the flange, the air and the rope are represented as a particle system that uses spring dampers to represent their properties two models are proposed: a spot mass model and a four-point model. The winding of the rope is modelled by varying the lengths. Dynamic bra behaviour is included. The frame is validated by combining the automatic control system. The results show that the point mass model can be adjusted to match the behaviour through the first part of the cycle, the four-point model can predict the influence of gravity and inertia on the direction response. The proposed framework is more precise and robust while allowing real-time simulations. [43]

Lozano et al. show a wind energy system based on a comet joins a rope, the aerodynamic equations that model the system are presented, with a control strategy to stabilize the flight angle and the length of the rope. The objective is to maintain the angle of the rope at the desired value during an energy production cycle in which the length of the rope continues on a path [44].

Gohl & Luchsinger say that with the simulation tool, it contains a detailed aerodynamic model and a string model. Two different kites are analyzed with respect to their efficiency, determined with a study of parameters that show the trends of the most important geometric. The power cycles of a pumping system are simulated and controlled automatically [45].

Alonso-Pardo & Sánchez-Arriaga development of a compact dynamic model of a comet where the Lagrangian formulation is used. The lengths of the flange and rope strings depend on time and are used to implement an open-loop control scheme for the comet system, when implementing simple periodic time control laws, two pumping strategies are investigated for wind power generation. Continuous system paths and stability properties are calculated numerically. When the amplitudes of the routes are increased in the form of eight, the system becomes more efficient but less stable. A cyclic fold fork is found for lateral displacement of the comet. The impact of the parameters of the control law on the power generated, including the period and amplitude, is sought [46].

The following section cites patents on air vehicles that can be implemented in awes systems, taking into account that when they are implemented, the main objective that is to generate more energy than is consumed is not modified.

3.3 Patents

Milanese Milanese & Novara describe a system for automatic flight control of at least one kite that is controlled and driven by ropes that contains at least one drive motor that is adapted for exerting an unwind-rewind action of said strings adapted to perform a differential control action of the strings [47].

Vander Lind writes that a comet can operate with strong winds in a crosswind. The system can operate with reduced efficiency in strong winds to adjust the load on the system during strong winds. To reduce the elevation of the aerodynamic profiles, multi-element aerodynamic profiles can be used in order to adjust the load in strong wind conditions. They can control other aspects of flight, such as flying the crosswind in side slip this to include drag that reduces the load on the system [48].

Stewart says that the comet is inflatable and the wings flexible with sheet material that extends to a tail of it. An inflatable tube is provided in the rear of each wing, this can be variable to change the characteristics of the comet this in order to adapt to different circumstances. [49]

Benze show a device to control the flight of a comet, the device contains support that has a handle adapted to be held in an operator's hand, the control ropes are guided to and from a common reel slot where it is rolled on the support. The reel is maintained in a releasable manner on the support by resistant elastic elements. The reel is positioned so that the operator while taking the handle, can extend a finger forward to engage and slow the rotation of the reel this when required [50].

Bevirt et al. show an aerial vehicle for vertical take-off and landing only using the same engines for its two functions, as well as for forwarding flight. Air vehicles are adapted to take off with wings at a vertical flight altitude instead of horizontal that takes off at this vertical altitude and then passes to a horizontal flight path. The vehicle that controls the altitude during takeoff and landing by altering the thrust of the engines, which are separated by two minimum dimensions with respect to the horizontal while it is taking off and which can also control the regular flight of some aspects during the use of differential thrust of the motors [51].

Rundle & Hooten present a wind-powered flight device, known as a broken-kite, allows the flight in the mild wind and strong wind conditions. This has a stabilizing keel with an adjustable position on the axis of the main body and the swivel wings articulated to the axis this to allow flapping to relieve stress from forces when they are unbalanced during rotation. A rope is attached to an arm in the keel so that when the rope causes the keel to turn in the wind, the comet changes direction [52].

Barber shows an invention that relates to devices for controlling the flight of comets and particularly to improved devices for controlling comets that are adapted to provide better manoeuvrability and ease of control. Such comets are controlled by the control that is attached to the comet to generate stability in a single flight attitude. Comet control is limited by some control devices [53].

Young provide an improved rotary type aerial device to have said device captive, it has an inherently improved stability to work on the aerial device so that its balance is not disturbed, to avoid instability caused by external forces such as those of the wind, this invention may be applicable to motor-driven helicopters or for rotating-wing kites, relative winds for lifting and sustaining forces. Kites should be characteristic such as pulling and releasing the rope that holds the comet alternately [54].

Labrador, G. A. Shows a new device that harnesses the energy of high altitude winds to produce usable and storable energy without using fuel. The device can be in the form of a comet that serves as a transporting sail that is connected to a land device or in water as an anchor, the comet can transport a person by air, this can be driven to the left and to the right, the device that acts as an anchor has a control of several types including a control rope that is wound around the central section, or a straight bar that extends past both sides through the ends on which the rope is wound control, to avoid overturning the bar is shaped like a rail to push the inferred end of the rope away from the leeward sides of the comet [55].

4 Discussion and future research

In the literature search, it can be seen that different proposals are being worked on to generate clean energy, specifically in regards to wind energy generated by kites. There are different types of kite control, in most of the articles consulted it is emphasized that awes systems are not stable, so this is difficult to analyze, but the system can be controlled so that the path of eight can be performed for the generation of energy, they also present with disadvantages since the source of energy that in this case is the air is not controllable, an example of them is that there may be gusts of wind, to the conclusion that is reached by this type of problems are that there are many disturbances that can intervene with the control that is applied to the system.

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