KINEMATIC ARCHITECTURE OF A TWO-DOF MECHANISM FOR THE CONTROL OF AN OSCILLATIONG WING

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Abstract

This work is part of a project which aims at the development of underwater generators using oscillating wings. One of the important challenges in the design of a system collecting the kinetic energy of a fluid is the transformation of this energy into electric power. Since it is not possible to pass directly from the movement of a fluid to electric power, it is necessary to conceive an intermediate mechanical system. Its function is to convert the kinetic energy of the fluid into kinetic energy of a mechanism capable of converting kinetic energy into electric power. In this work, the mechanical system also has an additional function, i.e., to guide the orientation of the blades (wings) throughout the cycle of movement in order to maximize the efficiency.

Keywords: mechanism, synthesis, kinetic energy, kinematics, dynamics

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ARCHITECTURE CINÉMATIQUE D'UN MÉCANISME À DEUX DDL POUR LE CONTRÔLE D'UNE AILE OSCILLANTE

Résumé

Ce travail s'inscrit dans un projet plus global impliquant des chercheurs en mécanique des fluides, en mécanismes et en électrotechnique et qui vise le développement de génératrices hydroliennes à ailes oscillantes. Dans ce contexte, un des enjeux importants dans la conception d'un système permettant de capter l'énergie cinétique d'un fluide est la transformation de cette énergie en énergie électrique. Étant donné qu'il n'est pas possible de passer directement du mouvement d'un fluide à une énergie électrique, il est nécessaire de concevoir un système mécanique intermédiaire dont la fonction est de convertir l'énergie cinétique du fluide en énergie cinétique d'un mécanisme capable de convertir celle-ci en énergie électrique. Dans le projet proposé ici, le système mécanique a aussi une fonction supplémentaire, soit de guider l'orientation des pales (ailes) tout au long du cycle de mouvement afin de maximiser l'efficacité.

Mots clés : mécanisme, synthèse, énergie cinétique, cinématique, dynamique

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1 INTRODUCTION

In order to produce more green energy, a steadily increasing number of wind turbines are being installed. Unfortunately, they radically change the landscape and are quite noisy. One promising concept could change the situation since it relies on the use of oscillating wings simultaneously heaving and pitching below water as power extraction devices [1].

2 DESCRIPTION OF THE OSCILLATING WING

We define an oscillating wing as an airfoil experiencing simultaneous pitching $\theta(t)$ and heaving $h(t)$ motions as shown in Figure 1.

Referring to a pitching axis located on the chord line at position x_p from the leading edge, the airfoil motion may be expressed as in equations (1) and (2).

$$\theta(t) = \theta_0 \sin(\gamma t) \quad (1)$$

$$h(t) = H_0 \sin(\gamma t + \phi) \quad (2)$$

where θ_0 and H_0 are respectively the pitching and heaving amplitudes, γ the angular frequency and ϕ the phase difference between the two motions. The direction of the free stream velocity far upstream of the oscillating airfoil, U_∞, is also illustrated in Figure 1.

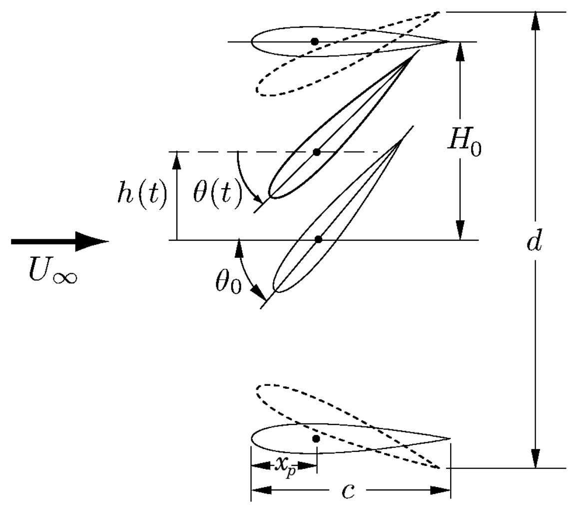

Figure 1: Imposed heaving and pitching motion.

The latest results have shown that the highest efficiency is reached for a pitch amplitude, θ_0, of $75°$ and for a heaving amplitude of one chord, $H_0 = c$, where c stands for the length of the airfoil (Figure 1). As seen in Figure 1, only symmetric airfoils are considered and ϕ is kept constant at $90°$, since the piching is null for the maximum amplitudes in heaving and the greater pitch is reached at the mean position in heaving. It is now important to find a mechanism that can produce this kind of motion while, at the same time, transmit the kinetic energy of the wing to an alternator with the highest efficiency.

3 PROPOSED ARCHITECTURE

Since the mechanism will be built to become an electrical generator, the electrical engines will be massive and must therefore be attached to the ground. A parallel manipulator is consequently the best solution. Also, in order to obtain a better control of the oscillating wing and to allow the possibility to modify its trajectory, it has been proposed that two inputs be used : one to regulate the heaving and the other to direct the pitching. Hence, a two-dof mechanism is required. The resulting mechanism, named Valkyrie 2, is shown in Figure 2. A simplified but equivalent architecture may then be sketched, like in Figure 3, for the purposes of obtaining the kinematic equations. Indeed, the equations relating the prescribed motions $h(t)$ and $\theta(t)$ with the input-output θ_1 and θ_2 are the same for these two architectures, since the oscillating wing in Valkyrie 2 is only stilted above the main mechanism by the use of parallelograms. It is now obvious that we have obtained a mechanism similar to those of the Assur group, which are well documented in the literature [2]. A schematic containing all the variables used in equations (3) and (4) is shown in Figure 4. From now on, φ is used instead of $h(t)$ for simplicity, where we have $h(t) = c_1 \sin\varphi$.

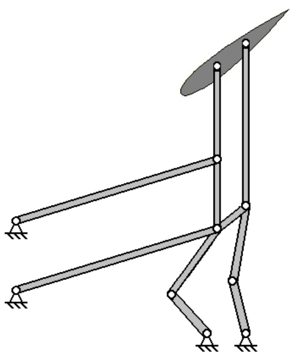

Figure 2: Valkyrie 2.

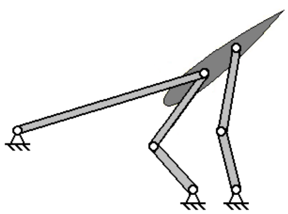

Figure 3: Valkyrie 2 simplified.

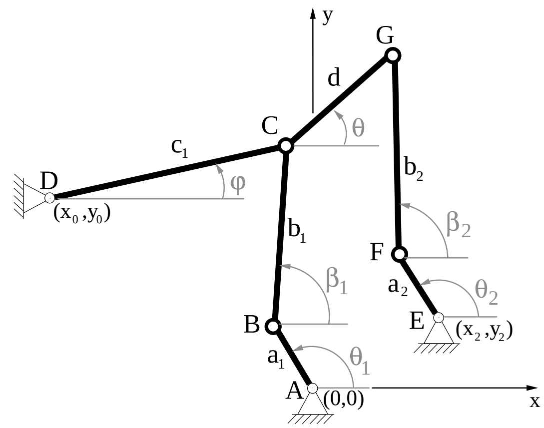

Figure 4: Schematic of Valkyrie 2.

One obtains the following input-output equations :

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\begin{aligned}
&x_0^2 + y_0^2 + a_1^2 - b_1^2 + c_1^2 + 2\,c_1\,(x_0\,\cos\varphi + y_0\,\sin\varphi) = \\
&\qquad 2\,a_1\,(x_0 + c_1\,\cos\varphi)\cos\theta_1 + 2\,a_1\,(y_0 + c_1\,\sin\varphi)\,\sin\theta_1
\end{aligned} \tag{3}
$$

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\begin{aligned}
&(x_0 - x_2)^2 + (y_0 - y_2)^2 + a_2^2 - b_2^2 + c_1^2 + d^2 + 2\,c_1\,((x_0 - x_2)\,\cos\varphi + (y_0 - y_2)\,\sin\varphi) \\
&+2\,d\,((x_0 - x_2 + c_1\,\cos\varphi)\,\cos\theta + (y_0 - y_2 + c_1\,\sin\varphi)\,\sin\theta) = \\
&\qquad 2\,a_2\,(x_0 - x_2 + c_1\,\cos\varphi + d\,\cos\theta)\,\cos\theta_2 + 2\,a_2\,(y_0 - y_2 + c_1\,\sin\varphi + d\,\sin\theta)\,\sin\theta_2
\end{aligned} \tag{4}
$$

4 Conclusion

The ongoing investigation of mechanisms capable of directing an oscillating wing led us to propose a two-dof Parallel Manipulator. We presented its simplified model from which the kinematic equations were obtained. A dynamic model was also obtained using the approach proposed by Wang and Gosselin [3]. The energy transmission characteristics of the device can therefore be obtained.

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