Journal of Applied Mechanics

Fluid–~~-~~Structure Interaction Effects on the Propulsion of a~~n~~ Flexible Composite Monofin

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Do not hesitate to contact me if you require any clarifications or have some questions. My best wishes for your success with the manuscript.

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ABSTRACT

~~Finite element method has been used to analyze the propulsive efficiency of a swimming fin.~~ Fluid~~-~~–structure interaction models can be used to study the effects of an added mass on the natural frequencies of a multilayer anisotropic fin oscillating in a compressible fluid. In this study, the finite element method was used to analyze the propulsive efficiency of a swimming fin. Water ~~by neglecting viscidity effects has~~

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[1] Corresponding author information can be added as a footnote.

~~been~~ was considered as the~~a~~ surrounding fluid, and the viscidity effects were neglected. ~~and~~ T~~t~~he frequency response of the fin in such conditions ~~has been~~ was compared with that ~~of~~ in vacuum ~~conditions~~. ~~It has been shown that~~ The results show that because of the added mass effects in water ~~environment~~, the natural frequencies of the fin decrease.

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INTRODUCTION

Multilayer anisotropic structures have~~s~~ ~~wide~~ applications in ~~areas~~ various fields, ~~such as~~including modern construction engineering, biomechanical engineering, aerospace ~~industries~~engineering, aircraft construction, and ~~the components of~~ nuclear-power~~-~~plant component design~~s~~. ~~It is~~ Therefore, ~~therefore~~ it is very important that the modal and dynamic ~~analysis~~ properties of multilayer anisotropic structures ~~when subjected to~~ under different loading conditions ~~be~~ be clearly understood ~~so that they may be safely used in these~~ for safe industrial applications.

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~~It is well known that the~~The natural frequencies of structures in contact with fluids are known to be different from the natural frequencies of those in vacuum. Therefore, ~~the prediction of~~predicting the change in the natural frequency changes ~~due to~~owing to the presence of ~~the~~ a fluid is important for designing structures ~~which~~ that are in contact with or immersed in fluids. In general, the effect of the fluid force on the structure is represented as an added mass, which lowers the natural frequency of the structure from that ~~which would be~~ measured in ~~a~~ vacuum. This decrease ~~in the natural frequency of the fluid-structure system~~ is caused by ~~increasing~~ an increase in the kinetic energy of the coupled system without a corresponding increase in the strain energy.

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~~In this paper the propulsive efficiency of a swimming fin has been studied. D~~The dynamic analysis of aquatic locomotion is a ~~a ~~fundamental requirement ~~parameter ~~in ~~the ~~performance ~~search~~analysis. In the case of swimming ~~with ~~fins, the propulsive efficiency depends on several factors. Most previous models ~~suggested ~~aimed at~~to~~ evaluating~~e~~ the dynamic performance~~s~~, including the drag and lift, which are the two relevant parameters ~~relevant to quantifing~~associated with the propulsive efficiency of a fin. Some previous studies have proposed ~~-~~models that are essentially discrete ~~are essentially of discrete type ~~[1, 2], while others~~s , by being inspired by organs of propulsion of marine cetaceans, use ~~have used continuous models based on the organs of propulsion in marine cetaceans [3, 4]. Most of these ~~authors ~~studies did~~o~~ not account for the highly coupled nature of the ~~problem~~system (fin and fluid). ~~In fact~~For ~~, for ~~the rate of stress~~es~~ observed in actual swimming, the coupling between the fluid and ~~the ~~fin becomes stronger.

In this study, the propulsive efficiency of a swimming fin has been investigated.

GOVERNING EQUATIONS

The numerical formulations used in the dynamic analysis of aquatic locomotion include the displacement formulation [5], ~~the ~~potential formulation [6], ~~the ~~pressure formulation [7], and ~~the combination of some of~~combination of multiple formulations~~them~~ [8]. The f~~F~~inite element method is used to ~~extract ~~obtain the natural frequencies and modal shapes. To compute only the natural vibration modes of ~~a ~~the

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Commented [A14]: Please provide citations for these models.

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“the coupling between the fluid and fin is highly significant”

Commented [A17]: Please provide citations for these statements.

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If there are, briefly discuss the studies and their limitations. Then state how your study addresses this limitation.

Here, please also further elaborate on the objective of the study and outline the methodology employed.

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Commented [A20]: Repeated article error refers to the unnecessary repetition of the same article in a series or list. The unnecessary repetition of the same article in a series tends to cause wordiness. Identify the repeated words and eliminate them.

For example
Original: We verified the samples using the source, the original, and the final images.
Revised: We verified the samples using the source, original, and final images.

It is fine to place the article before the first item in the list only.

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fluid~~ alone~~, the fluid is typically described either by pressure or ~~by ~~displacement potential variables. When the fluid is coupled with a solid, standard methods ~~to solve (1) and (2) consist in~~involve eliminating either the pressure or ~~the ~~displacement potential [9]. However, in both cases, non-symmetric eigenvalues~~ problems~~ are obtained ~~(see, e.g., ~~[10]~~)~~. To ~~avoid ~~overcome this ~~drawback~~limitation, Morand and Ohayon ~~introduce in~~ [6] introduced an alternative ~~procedure ~~approach ~~which consists in~~that simultaneously solved for ~~using ~~pressure and displacement potentials~~ simultaneously~~. In this section, we summarize their approach; further details ~~and discussions can be found~~on this approach can be found in their book [11].

In this study~~work~~, we ~~assume ~~consider an amateur swimmer, ~~where the scale of~~whose velocity U_0 is ~~supposed to be~~assumed to be ~~very small~~negligible compared ~~to ~~with the compression wave velocities c_L in the fin.~~ Indeed, ~~S~~s~~ome amateur swimmers have noted that~~,~~ when making foot movements at low frequencies~~y~~, ~~the ~~resonance ~~phenomenon ~~and buckling phenomena ~~appear~~are observed. ~~And we cannot~~However, this ~~explain why these phenomena tend to occur~~cannot be explained, because the natural frequencies of the fin, ~~which would be~~as measured in ~~the ~~vacuum, are higher than the~~of the~~ beat frequency of an ankle~~, for example~~. In this study, we assume that the swimmer does not disturb the free surface of the fluid domain. ~~This leads to~~Therefore, ~~neglect the gravity effects~~the effects of gravity can be neglected.

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~~D~~The dimensional analysis of coupled equations (Navier–Stokes ~~equations ~~and the governing equations of nonlinear elasticity) of a fluid~~-~~–structure interaction model [12] ~~reveals ~~yields several dimensionless parameters. One of its dimensionless parameters,

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$\alpha=U_0/c_L$, is called the displacement parameter. The displacement parameter α allows the ~~characterizing~~ characterization of the ~~the~~ nature of the coupling problem considered in this study~~work~~. In the case of the amateur swimmer, ~~hypothesis~~ where $U_0 \ll c_L$, we can set the parameter α ~~to~~ at a very low value and ~~we can~~ show that the convective ~~terms~~ and viscosity terms can be neglected ~~for~~ in the fluid model [12]. We can also assume that~~e~~ ~~assumption of small deformations for the~~the deformations in the fin are sufficiently small. The resulting model is called an inertial coupling model [13]. The real shape of the fin is ~~given~~ presented in Figure 1.~~,~~ ~~but~~ However, for ~~the sake of the~~ simplicity, the problem is considered bidimensional (Figure 2), and the fin is immersed in a large pool. The fin is modeled ~~by~~ as a multilayer linear elastic transverse anisotropic material. The different layers constituting the fin are denoted by Ω_i and have the density ρ_i. We denote ~~by u_i~~ the displacement field in the fin as u_i and ~~p~~ the pressure field in the fluid as p. The sound celerity and density of the fluid are denoted by c_0 and ρ_0, ~~denote the sound celerity and density of the fluid,~~ respectively. The longitudinal axis of the fin is denoted by *x*. The force F, as expressed in ~~given in~~ Eq. (1), is used to describe the motion of the fin. The orientation of the layers relative to the longitudinal axis *x* on the fin is denoted by θ_i~~,~~, ~~denotes the orientation of fibers relative to the longitudinal axis x on the fin and takes~~which assumes the values 0°~~°~~ or 90°~~90°~~. Here, each layer is made of either fiberglass or carbon fiber.

The use of the ALE method is not essential in this study because the material is assumed to be linear. In the frame attached to the fin, solutions to ~~the problem is to find~~ ($\mathbf{u}_i$, p) ~~solutions~~can be determined using the following formulations:

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An abbreviation should be spelled out at its first occurrence in each standalone section of text, i.e., the title, abstract, main text, and each figure/table legend, followed by the abbreviation in parentheses. (Exception: If the abbreviation is on the journal's list of permitted abbreviations, this need not be done. Moreover, an abbreviation need not be introduced in a section if there is no subsequent mention of the term in that section; only the full term should be used in such cases.) Thereafter, only the abbreviation may be used.

In addition, this is the first mention of the method. Please provide background information and the necessary citations.

(i) solid domain (Ω_i):

$$\rho_i \frac{\partial^2 \mathbf{u}_i}{\partial t^2} = \nabla \cdot \sigma(\mathbf{u}_i) + \rho_i \mathbf{F}, \\ \sigma(\mathbf{u}_i) = \mathbb{K}(\theta_i)\,\varepsilon(\mathbf{u}_i); \tag{1}$$

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(ii) fluid domain (Ω_f):

$$\frac{1}{\rho_0 c_0^2}\frac{\partial^2 p}{\partial t^2} = \nabla \cdot \left[\frac{1}{\rho_0}(\nabla p - \rho_0 \mathbf{F})\right]; \tag{2}$$

(iii) fluid–~~-~~solid interaction (Γ):

$$\sigma(\mathbf{u})\,\mathbf{n} = -p\mathbf{n}, \\ [\nabla p - \rho_0 \mathbf{F}] \cdot \mathbf{n} = -\rho_0 \frac{\partial^2 \mathbf{u}}{\partial t^2} \cdot \mathbf{n}; \tag{3}$$

(iv) other boundary conditions:

$$\mathbf{u} = \mathbf{0} \quad (\Gamma_0), \\ [\nabla p - \rho_0 \mathbf{F}] \cdot \mathbf{n} = 0 \quad (\Gamma_f), \\ p = 0 \quad (\Gamma_e \cup \Gamma_g \cup \Gamma_s). \tag{4}$$

MODAL ANALYSIS OF COMPOSITE MONOFIN

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~~M~~The modal analysis of elastic submerged structures is ~~needed~~ required in ~~every~~ all modern constructions and has wide ~~engineering~~ applications in engineering fields, especially in ocean engineering. In this study, modal analysis ~~is~~ was ~~important to~~performed to predict the dynamic behavior of the submerged fin. ~~It is well known that~~ T~~t~~he natural frequencies of the submerged elastic structures are ~~different~~ lower ~~from~~ than those in vacuum. ~~The effect of fluid forces on the submerged fin is represented as~~

~~added mass, which decreases the natural frequencies of the submerged fin from those which would be measured in the vacuum. This decrease in the natural frequencies of the submerged structures is caused by the increase of the kinetic energy of the fluid-fin system without a corresponding increase in strain energy.~~ This ~~step seems~~is an important ~~to~~ consideration when calculating ~~calculate~~ the variations ~~of~~ in the natural frequencies of the fin ~~for~~ under different ~~situations~~conditions. ~~For~~ To this end, we ~~looked at~~determined the modes of the fin in ~~the~~ vacuum and water.

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~~Indeed,~~In general, ~~to test~~ the quality of a fin is tested~~n~~ by examining~~, it is usual to search~~ its quasi-static deformed shape and dynamic response in air. Here, we ~~The~~ aim ~~is~~ to ~~check~~ determine ~~if~~ whether the results of the tests ~~carried out of the~~conducted in water are strongly influenced by the presence of the surrounding fluid. In addition, frequencies can ~~have~~ contain accurate information ~~in~~ on the dynamic behavior of the system. ~~By~~ Upon introducing the ~~spaces of~~ test function spaces~~s~~ $V = \{k \in H^1(\Omega_s), k = 0\ (\Gamma 0)\}$ and $\phi \in Q = H^1(\Omega_f)$, the ~~weak~~ formulations ~~of~~ presented in Eqs. (1) and (2) ~~holds~~can be expressed as follows:

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$$\begin{aligned}
&\int_{\Omega_s} \sigma(\mathbf{u}) : \varepsilon(\mathbf{v})\,dx - \omega^2 \int_{\Omega_s} \rho \mathbf{u} \cdot \mathbf{v}\,dx \\
&\quad + \int_{\Gamma} p\mathbf{v} \cdot \mathbf{n}\,d\Gamma = 0, \\
&\int_{\Omega_f} \frac{1}{\rho_0} \nabla p \cdot \nabla \phi\,dx - \omega^2 \int_{\Omega_f} \frac{p\phi}{\rho_0 c_0^2}\,dx \\
&\quad - \omega^2 \int_{\Gamma} \mathbf{u} \cdot \mathbf{n} \phi\,d\Gamma = 0,
\end{aligned} \tag{5}$$

w~~W~~here

$$\begin{aligned}\int_{\Omega_s} \sigma(\mathbf{u}) : \varepsilon(\mathbf{v})\,dx &= \sum_{i=1}^{N_L} \int_{\Omega_i} \sigma(\mathbf{u}_i) : \varepsilon(\mathbf{v}_i)\,dx,\\ \int_{\Omega_s} \rho\mathbf{u}\cdot\mathbf{v}\,dx &= \sum_{i=1}^{N_L} \int_{\Omega_i} \rho_i\mathbf{u}_i\cdot\mathbf{v}_i\,dx.\end{aligned} \qquad (6)$$

In the above equations, N_L is the~~a~~ number of layers. Upon u~~U~~sing the Lagrange finite element~~s~~, where $u_h \in P_2 \times P_2$ and $p_h \in P_1$, the discretization of the weak formulation in Eq. (5) ~~induces~~ yields a non-symmetrical system:

$$\begin{bmatrix} \mathbb{K}_s & \mathbb{B} \\ \mathbb{O} & \mathbb{K}_p \end{bmatrix} \begin{bmatrix} \mathbf{U} \\ \mathbf{P} \end{bmatrix} = \omega^2 \begin{bmatrix} \mathbb{M}_s & \mathbb{O} \\ \mathbb{M}_a & \mathbb{M}_p \end{bmatrix} \begin{bmatrix} \mathbf{U} \\ \mathbf{P} \end{bmatrix}, \qquad (7)$$

where U and P are the vectors of the nodal values for u and p, respectively. The submatrices of the matrices presented in Eq. (7) are defined ~~by~~as

$$\begin{aligned}
\mathbf{V}^T\mathbb{K}_s\mathbf{U} &= \int_{\Omega_s} \sigma(\mathbf{u}) : \varepsilon(\mathbf{v})\,dx,\\
\Phi^T\mathbb{K}_p\mathbf{P} &= \int_{\Omega_f} \frac{p\phi}{c_0^2}\,dx,\\
\mathbf{V}^T\mathbb{M}_s\mathbf{U} &= \int_{\Omega_s} \rho\mathbf{u}\cdot\mathbf{v}\,dx,\\
\mathbf{V}^T\mathbb{B}\mathbf{P} &= \int_{\Gamma} p\mathbf{v}\cdot\mathbf{n}\,d\Gamma,\\
\Phi^T\mathbb{M}_p\mathbf{P} &= \int_{\Omega_f} \nabla p\cdot\nabla\phi\,dx,\\
\Phi^T\mathbb{M}_a\mathbf{U} &= \int_{\Gamma} \rho_0\mathbf{u}\cdot\mathbf{n}\phi\,d\Gamma,
\end{aligned} \qquad (8)$$

where V and Φ are the vectors of the nodal values for k and ϕ, respectively, and~~.~~ M_a is the added mass matrix (symmetric and positive definite~~ [11]~~) [11]. The non-symmetric system (Eq. (7)) was solved using the commercial software COMSOL~~omsol~~ Multiphysics (COMSOL, Inc.).

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Two types of calculations were ~~carried out~~performed.~~.~~ The first ~~is~~ corresponds to when the palm is plunged into ~~the~~ vacuum, and the second corresponds to when it is plunged into water. We ~~give below~~present the results ~~for~~ of a model ~~of~~ for up to ~~up to~~ five layers ($N_L = 5$) and the natural frequencies in vacuum and water. The fibers of each layer are arranged alternately along the two directions represented by the orthogonal axes *x* and *y* of the mean plane of the fin. The parameters presented in Tables 2 and 4 ~~show~~ demonstrate that the arrangement of layers has a strong influence on the natural frequencies~~,~~ and that the added mass decreases the natural frequencies. Figures 3 and 4 ~~show~~ demonstrate that the arrangement of layers has no influence on the coupled modal shapes (Tables 1 and 3).

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DYNAMIC ANALYSIS OF COMPOSITE MONOFIN

The dynamic ~~problem~~ analysis of the composite monofin was ~~conducted~~ performed using the data ~~proposed in~~published in a previous study [14]. For this analysis, the fin is subjected to combined translational and rotation motions. In this case, the quantity F introduced in the model problem represented by Eq. (1) ~~has the expression~~can be expressed as follows:

$$\mathbf{F} = \begin{Bmatrix} x\dot{\omega}^2(t) + y\ddot{\omega}(t) - \ddot{h}(t)\sin[\omega(t)] \\ y\dot{\omega}^2(t) - x\ddot{\omega}(t) - \ddot{h}(t)\cos[\omega(t)] \end{Bmatrix}, \qquad (9)$$

w~~W~~here

$$\omega(t) = \theta_0 \sin(2\pi f t),$$
$$h(t) = h_0 \sin(2\pi f t - \psi), \qquad (10)$$

Here, θ_0 = 40°~~°~~, $\psi = \pi/2$, $h_0 = 1c$, f = 0.225 ~~[~~Hz~~]~~, and c = 0.7; c is the chord of the profile, that is, ~~to say,~~ the length of the fin. The phase ψ is introduced to model the muscle dissymmetry.

To avoid a resonant frequency, the excitation frequency is ~~taken far enough from the~~considered to be considerably different from the first natural frequency of the coupled system. The most relevant hydrodynamic parameter~~s that seem most relevant are~~is the total force R (= ∫Γ σ(u)n dΓ) exerted on the fin during the movement phase. The two components of R are~~,~~ ~~respectively,~~ the drag (D) and lift (L) of the fin. The quantity $T = -D$ is called thrust. Different types of ~~types of~~materials are used in the manufacture of the layers of ~~exist in the manufacture of~~the fins. Throughout the model, the thickness of the fin is fixed in advance. We use the same physical characteristics as in the case of the modal analysis.

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"Respectively" is an adverb that means "for each separately and in turn, and in the order mentioned." The correct use of respectively requires two parallel lists of corresponding items.

For example, these sentences are correct:
The values of x and y are 3.5 and 18.2, respectively.
The samples containing mouse serum, fly serum, and control solution were labeled M, D, and C, respectively.
RNA and protein were digested with RNase A and Proteinase K, respectively.

~~U~~By using the same notation as before, the weak formulation of the boundary value problem as expressed in Eqs. (1) and (2) is ~~then written~~depicted as~~:~~

$$\begin{aligned} &\frac{d^2}{dt^2}\int_{\Omega_s}\rho\mathbf{u}\cdot\mathbf{v}\,dx+\int_{\Omega_s}\sigma(\mathbf{u}):\varepsilon(\mathbf{v})\,dx \\ &\qquad+\int_{\Gamma}p\mathbf{v}\cdot\mathbf{n}\,d\Gamma=-\int_{\Omega_s}\rho\mathbf{F}\cdot\mathbf{v}\,dx, \\ &\frac{d^2}{dt^2}\left(\int_{\Omega_f}\frac{p\phi}{c_0^2}dx+\int_{\Gamma}\rho_0\mathbf{u}\cdot\mathbf{n}\phi\,d\Gamma\right) \\ &\qquad+\int_{\Omega_f}\nabla p\cdot\nabla\phi\,dx=\int_{\Omega_f}\rho_0\mathbf{F}\cdot\nabla\phi\,dx. \end{aligned} \tag{11}$$

In this section, we use ~~a particular~~ the kinematics proposed ~~in~~ previously [14, 15], even ~~if~~ though our models are not exactly similar. ~~Indeed, the~~The kinematics ~~will allow us~~may allow us ~~in the future~~ to develop a new experimental protocol for measuring various hydrodynamic parameters of a fin. As the ~~model problem~~model problem formulated in Eqs. (1) and ~~-~~(2) is linear, it is ~~interesting~~ noteworthy to ~~see~~ consider the different contributions of each elementary movement in the dynamic response of the fin.

Commented [A34]: The authors must justify why they have used a model which is not the same as in Refs 14 and 15. The difference between the two model must be discussed. Also, discuss how the difference may not impact the results of this current study. The new model developed must be validated. Therefore, the authors must present the validation results.

Dynamic Response in the Case of Translational Motion

The rotation $\omega(t)$ is ~~canceled~~ ignored, which renders ~~and the~~ movement ~~is then~~ sinusoidal along the direction y. ~~Figure 5 shows that~~ T~~t~~he two-layer model ~~seems~~ appears to ~~give~~ produce a greater thrust than the other models, as shown in Figure 5. This is consistent with the results of the modal analysis, where ~~this is the first~~the two-layer model ~~that~~ has the lowest frequency. This type of movement ~~is not interesting for the propulsive efficiency. Indeed, it~~ leads to ~~a zero mean~~a propulsive efficiency of zero mean. ~~On the other hand~~However, ~~we see~~ a greater amplitude ~~for thrust, compared to~~is observed for thrust than that for ~~the~~ lift.

Commented [A35]: Please explain why this is ignored.

Dynamic Response in the Case of Rotation Motion

The function $h(t)$ is ~~canceled~~ ignored, which induces a ~~and the movement will be a~~ sinusoidal rotation to the movement around the foot. ~~According to Figure 7, the~~The two-layer model ~~always gives~~produces a greater thrust than the other models, as shown in Figure 7. ~~But by eliminating~~However, upon eliminating the results of this model in the response curves, we can see that the five-layer model ~~gives~~ achieves the best performance. The three-layer model ~~gives~~ produces a better lift ~~compared to~~ than other models. Thus, this type of movement provides a noteworthy propulsive efficiency ~~rather interesting~~. This phenomenon is also ~~well~~ observed in the movement of marine mammals. ~~On the other hand~~Furthermore, ~~such~~ this movement can be ~~interesting if you~~ significant ~~want to stay stationary at one position~~for a stationary position.

Dynamic Response in the Case of Combined Rotational~~-~~–Translational Motion.

~~In order to~~ To ~~have~~ obtain a reasonable performance of the system, ~~we must combine both~~the translational and rotation motions must be combined and ~~take the full expression of~~ the excitation force F must be expressed in its entirety. In this case,~~According to Figure 9,~~ t~~t~~he two-layer model ~~always gives~~produces a greater thrust than the other models. In general, the three-layer model ~~seems~~ appears to ~~give~~ achieve a better ~~compromise~~balance between thrust and lift. ~~Indeed, its~~The thrust remains positive all the time, while its lift ~~is of~~attains a negative value, which renders it less important ~~and has less importance~~ than the other models. It is possible that by varying some physical parameters, we can significantly reduce certain hydrodynamic quantities, such as ~~the~~ moment and lift.

CONCLUSION~~S~~

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Finally, ~~the above results allow us to~~we draw ~~some ~~the following conclusions from the results above.~~.~~

(i) The presence of layers provides some flexibility as indicated by the results of modal analysis. The first mode is flexural type, which justifies the use of the models proposed in a previous study [1].

(ii) Fins ~~with ~~made of anisotropic materials ~~structures ~~allow ~~implementing~~ implementation of ~~a technique of layers~~layer parameterization, which~~ to~~ can improve the performance of the fin. ~~It is quite possible now to bring special attention~~This study highlights the significance ~~ to~~ of the structure of the layers and types of constituent materials thereof.

(iii) The sensitivity of the dynamic behavior of the model with respect to the materials used and ~~the ~~boundary conditions for the fluid domain should be noted. ~~Indeed, the~~The presence or absence of rigid walls ~~alters ~~significantly alters the natural modes of the coupled system. Thus, the dynamic behavior of a swimmer depends on the localization in the pool where it is at the given moment. To obtain a better thrust, the fin ~~has to be~~must be elastic and ~~has to be sought at least~~moved in rotation. The amplitude of the vertical translation must be controlled to avoid a~~ too~~n exceptionally high lift~~,~~ ~~in ~~and to ~~order to remain at~~maintain a constant depth. The use of multilayer fins ~~allows ~~enables the control of~~ling~~ ~~an ~~excessive variations of the lift (Figures 6, 8, and 10).

Commented [A37]: Did you perhaps mean “location of the swimmer in the pool at any given time”?

(iv) Most experiment~~tal~~s~~ results we know~~ [16,17] are ~~mainly interested~~ ~~in~~primarily focused on the kinematic aspect of the mechanical ~~problem~~dynamics of fins. Nevertheless, the results obtained ~~in the case of~~ ~~a~~for a rigid fin [14] allow~~ed~~ us to have a basis for comparison. We found that the dynamic responses curves ~~are~~ were similar for different models but with different amplitudes. These differences in the results ~~obtained~~ can be explained by the type of model~~s~~ used (rigid fin and flexible composite fin).

In this ~~paper~~ study, ~~the~~ a modal and dynamic analysis is ~~proposed~~ performed to accurately understand the behavior of a flexible composite fin ~~with a good accuracy~~. ~~The publications in the literatures deal with the behavior of fins~~Many studies have been conducted on the behavior of fins; however, ~~few authors have not studied the~~few studies ~~case of~~have investigated the case of coupled boundary conditions [18]. ~~It is for this~~Hence, ~~reason~~ this study was conducted ~~on~~ upon the request of a company specializing in the design of fins ~~in order~~ to determine ways of ~~improve~~ improving the propulsion of a flexible composite fin.

References

1. J. C. Mollendorf, J. D. Felske, S. Samimy, and D. R. Pendergast, "A fluid/solid model for predicting slender body deflection in a moving fluid," *Journal of Applied Mechanics, Transactions ASME*, vol. 70, no. 3, pp. 346–350, 2003.
2. M. A. Luersen, R. Le Riche, D. Lemosse, and O. Le Maître, "A computationally efficient approach to swimming monofin optimization," *Structural and Multidisciplinary Optimization*, vol. 31, no. 6, pp. 488–496, 2006.

Commented [A38]: Statements referring to previous studies should be included in the Introduction and Results and Discussion. The conclusion should focus on the inferences drawn from the results of the study and the larger significance of the study. I recommend shifting these statements to the Introduction of this paper.

Commented [A39]: I recommend presenting this line at the start of the conclusion. The results can then logically follow from this sentence.

Commented [A40]: As mentioned before, this statement highlights the gaps in research related to the contents of this study and should be placed in the introductory part of the paper.

Commented [A41]: Please add a section after conclusions with heading "**ACKNOWLEDGMENT**" for acknowledgments. Specific company names should be provided in this section and not in the body of the manuscript.

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