

Supplementary Materials: Wing Geometry and Kinematic Parameters Optimization of Flapping Wing Hovering Flight

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S.I. Flapping Wing Morphological Parametrization

Table S1. The morphological parameters of fruit fly wing.

Items	Value	Units	Items	Value	Units
R_{eff}	3.004	mm	ρ_{wing}^a	1.2	mg/mm ³
C_{aver}	0.8854	mm	$m_{wing,orig}^{*,b}$	0.002237	mg
A_w	2.66	mm ²	M_{insect}	1.8	mg
AR	3.4	-	$I_{xx,com,orig}^*$	0.000215	mg·mm ²
x_r	0.3289	mm	$I_{zz,com,orig}^*$	0.001129	mg·mm ²
$x_{com,orig}^*$	1.9202	mm	$z_{com,orig}^*$	-0.1498	mm

* Calculated from the three dimensional CAD model constructed by original wing geometry data of fruit fly after translation operation [1]; ^a Referring to the data reported by Lehmann and Dickinson [2]; ^b This value is approximate to the data from Sun and Tang [3,4].

Table S2. Actual leading-edge profiles ($z_{le}(r)$) and trailing-edge profiles ($z_{tr}(r)$) for fruit fly wing.

Actual Leading-Edge Profiles ($y_{le}(r)$)							
polynomial coefficient	a_0	a_1	a_2	a_3	a_4	a_5	a_6
value	-1.1879	5.674	-10.06	8.872	-4.04	0.9167	-0.08249
$z_{le}(r) = a_0 + a_1r + a_2^*r^2 + a_3^*r^3 + a_4^*r^4 + a_5^*r^5 + a_6^*r^6$							
Actual Trailing-Edge Profiles ($y_{tr}(r)$)							
polynomial coefficient	b_0	b_1	b_2	b_3	b_4	b_5	b_6
value	-0.6467	3.739	-8.769	7.258	-2.795	0.504	-0.0333
$z_{tr}(r) = b_0 + b_1^*r + b_2^*r^2 + b_3^*r^3 + b_4^*r^4 + b_5^*r^5 + b_6^*r^6$							

S.II. Wing Geometry Parameters (WGP) Optimization Results and Sensitivity Analysis

S.A. WGP Optimization Result

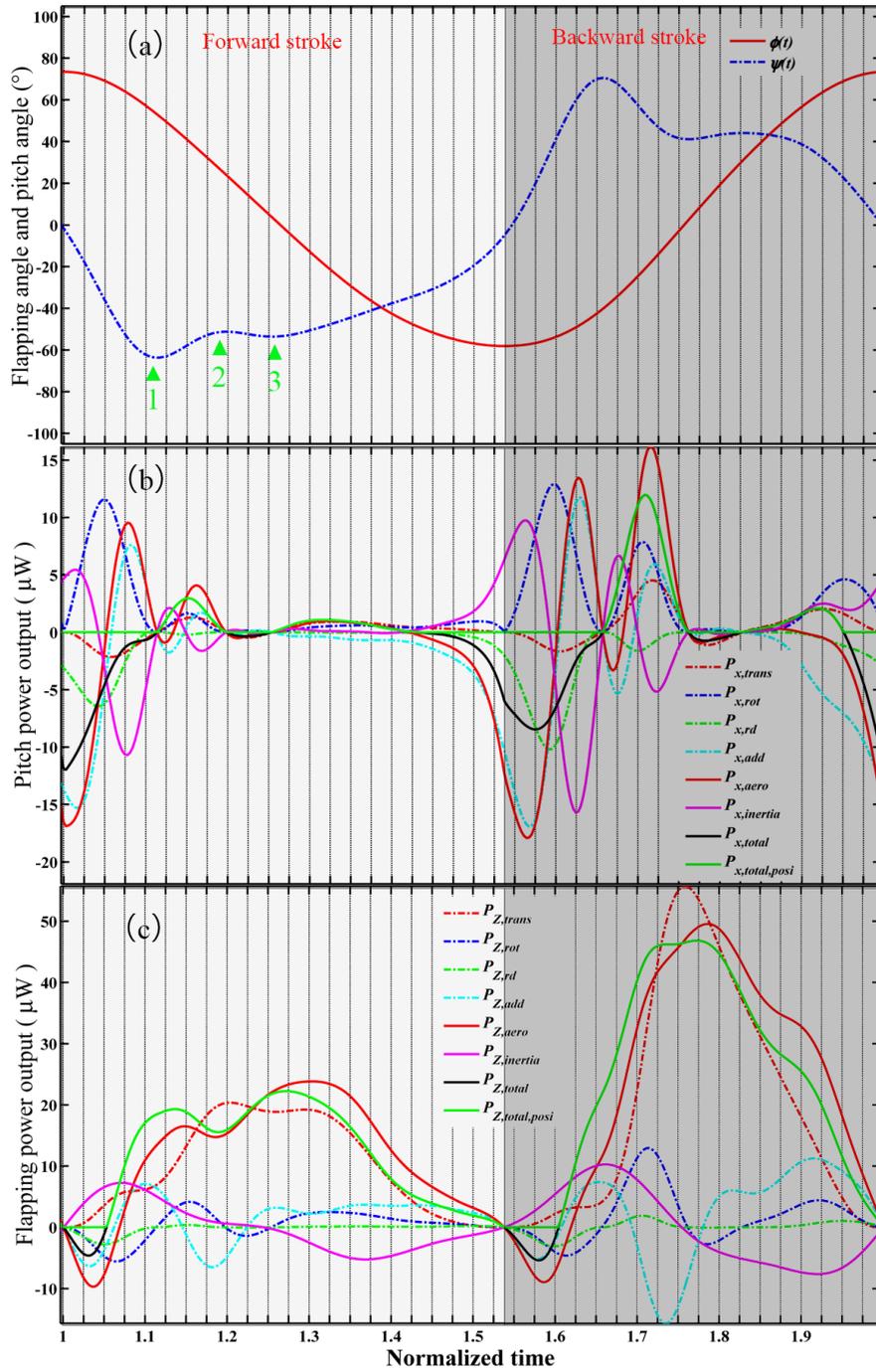


Figure S1. The wingbeat motion (a), pitch and flapping power of single wing output (b,c) for the optimal wing geometry parameters (WGP) with 2D $C_{F,trans}(\alpha)$.

S.B. Sensitivity Analysis for the Optimal WGP

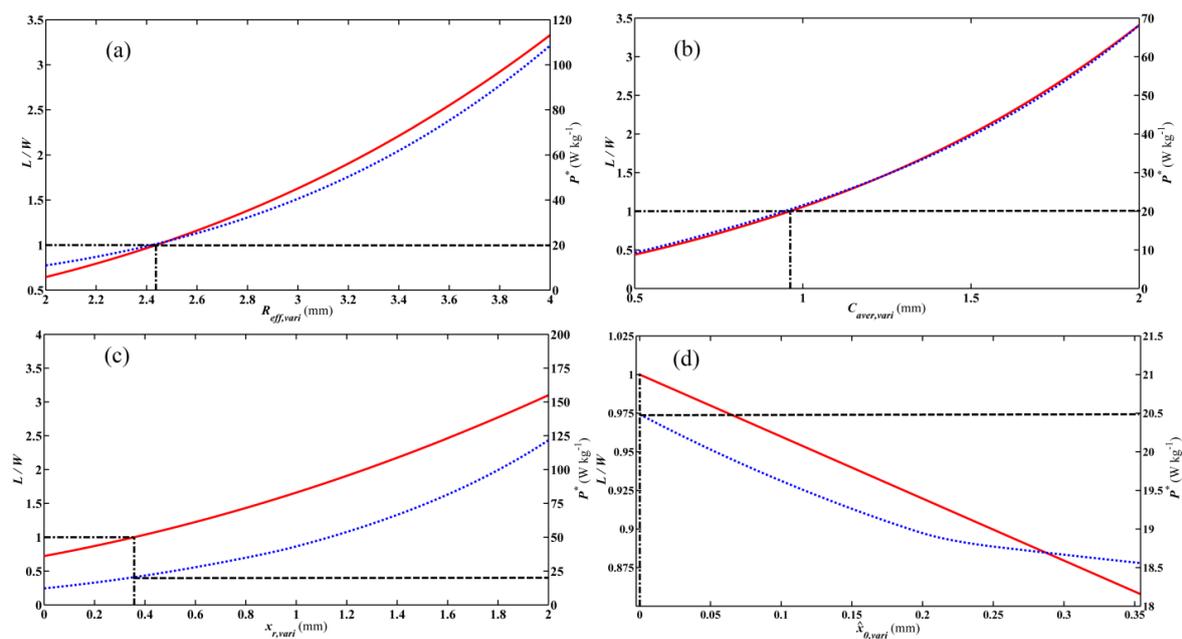


Figure S2. (a–d) Single-parameter sensitivity analyses for optimal WGP with 2D $C_{F,trans}(\alpha)$. The layout is identical to Figure 8.

S.III. Combined Optimization Results for WGP and Wing Kinematics Parameters (WKP) and Sensitivity Analysis

S.A. Combined Optimization Result for WGP and WKP

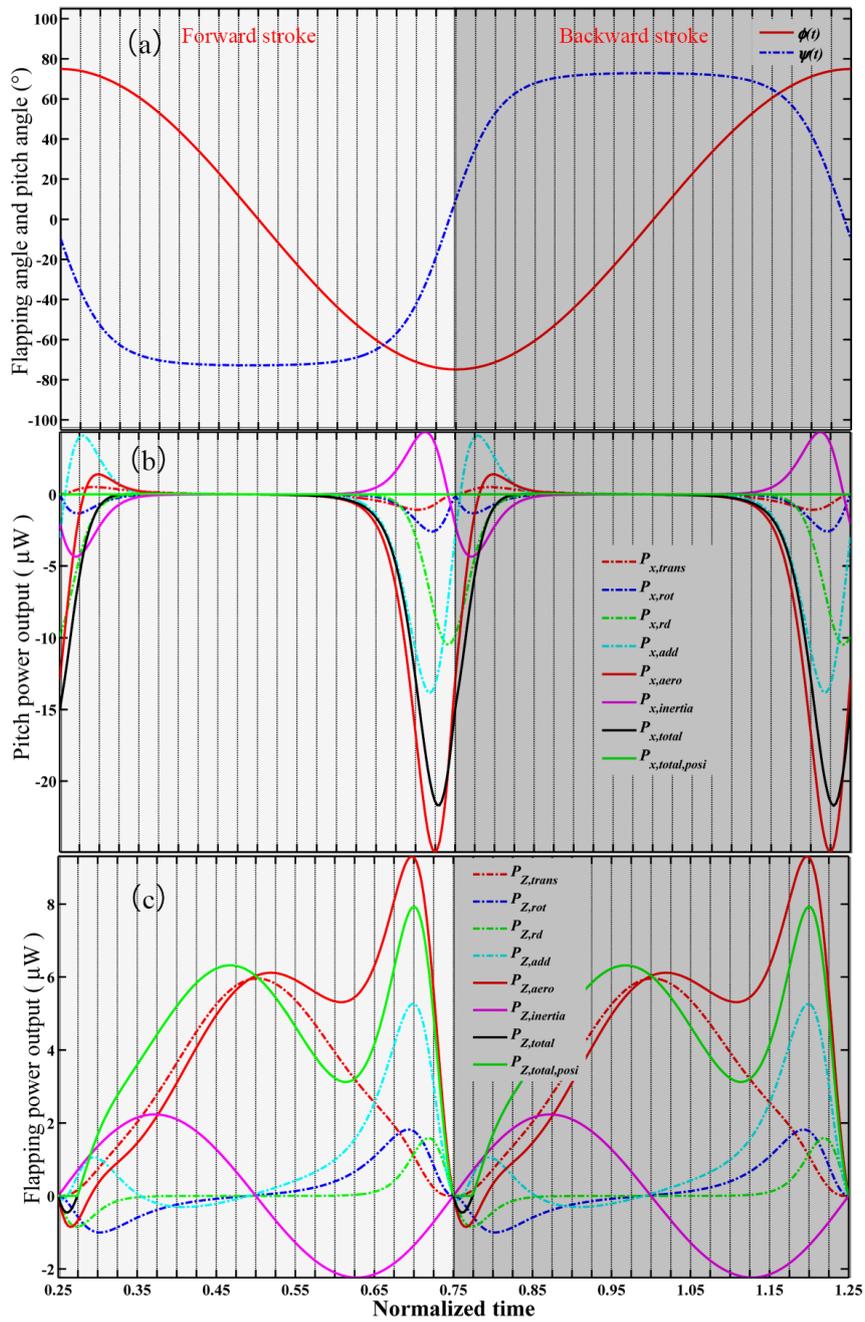


Figure S3. The wingbeat motion (a), pitch and flapping power output of single wing (b,c) for the combined optimal WGP and wing kinematics parameters (WKP) with 2D $C_{F,trans}(\alpha)$.

S.B. Sensitivity Analysis for Combined Optimal WGP and WKP

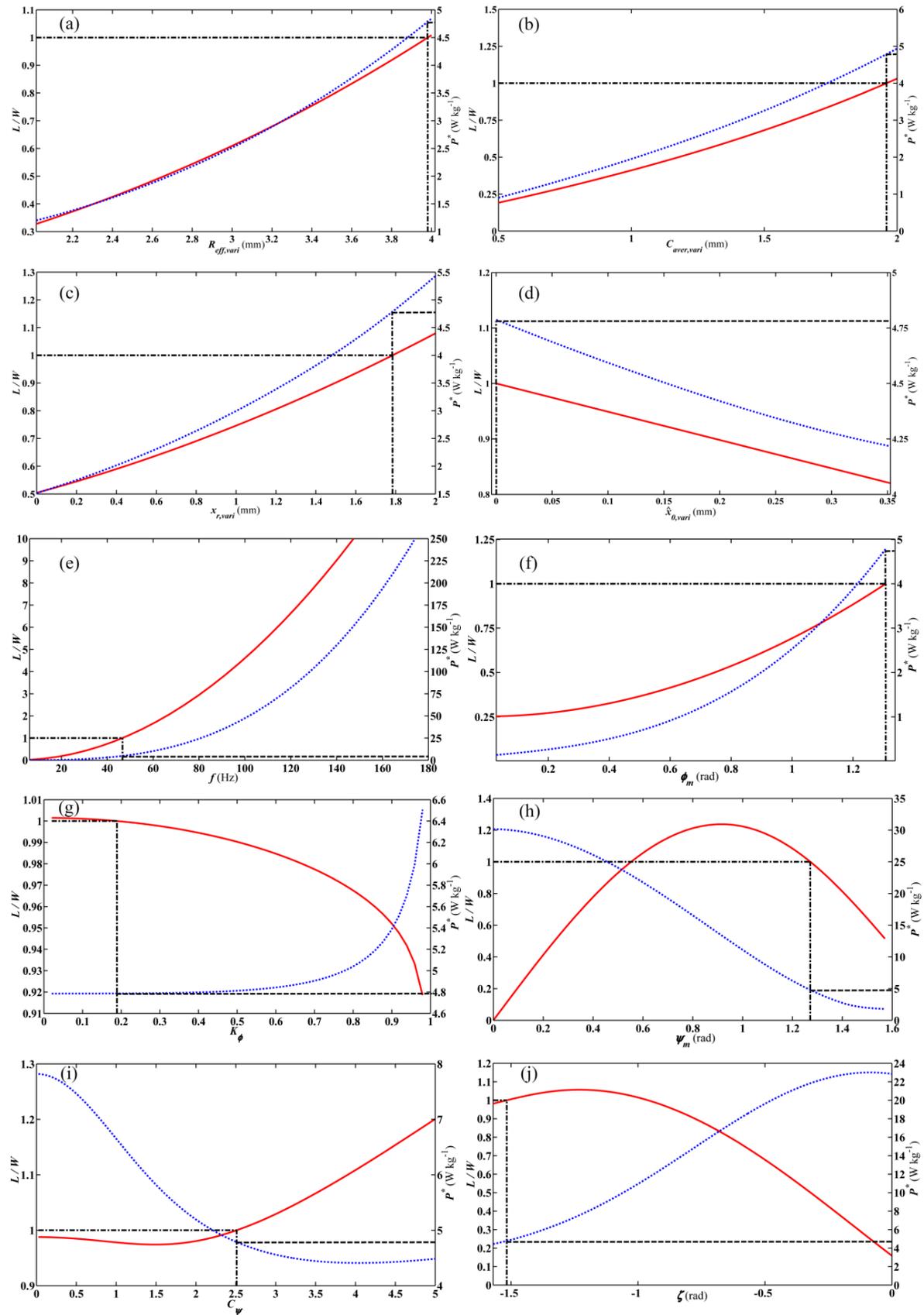


Figure S4. (a–j) Single-parameter sensitivity analyses for the combined optimal WGP and WKP with 2D $C_{F,\text{trans}}(\alpha)$. The layout is identical to Figure 8.

Reference

1. Muijres, F.T.; Elzinga, M.J.; Melis, J.M.; Dickinson, M.H. Flies evade looming targets by executing rapid visually directed banked turns. *Science* **2014**, *344*, 172–177.
2. Lehmann, F.-O.; Dickinson, M.H. The changes in power requirements and muscle efficiency during elevated force production in the fruit fly *drosophila melanogaster*. *J. Exp. Biol.* **1997**, *200*, 1133–1143.
3. Sun, M.; Tang, J. Unsteady aerodynamic force generation by a model fruit fly wing in flapping motion. *J. Exp. Biol.* **2002**, *205*, 55–70.
4. Sun, M.; Tang, J. Lift and power requirements of hovering flight in *drosophila virilis*. *J. Exp. Biol.* **2002**, *205*, 2413–2427.