Wing Shape and Wing Pitching Kinematics Optimization for Effective Roll of a FWMAV

Hugo Peters, Hans Goosen and Fred van Keulen

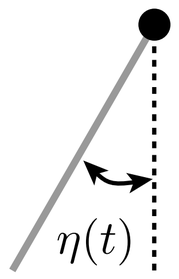
Structural Optimization & Mechanics, Delft University of Technology, Mekelweg 2, 2628 CD Delft, The Netherlands
DevLab, Development Laboratories, Horsten 1, MMP 0.10, 5612 AX Eindhoven, The Netherlands

☎ +31 (0)15 27 85 737, ✉ h.j.peters-1@tudelft.nl

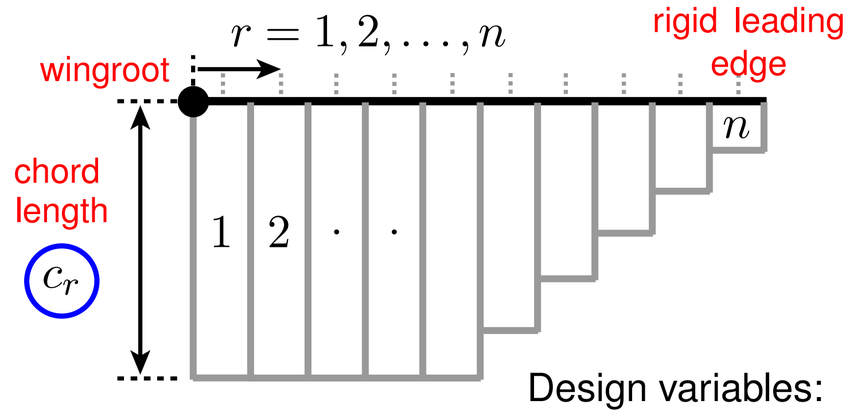
Introduction

- High interest in energy-effective ways to control the roll of (resonating) FWMAVs using asymmetric wing kinematics.
- A semi-empirical quasi-steady aerodynamic model[1] is used to determine the aerodynamic loads on the wing during the flapping motion.
- Chord lengths, c_r, and pitch amplitudes, η_m, of the individual, separated wing strips are the design varables ⇒ potentially warped wings.

Wing pitching angle:



Typical FWMAV wing planform:



Design variables: c_r & η_m

Flapping kinematics

Sweeping angle: $\phi(t) = \phi_m \sin(2\pi f t)$

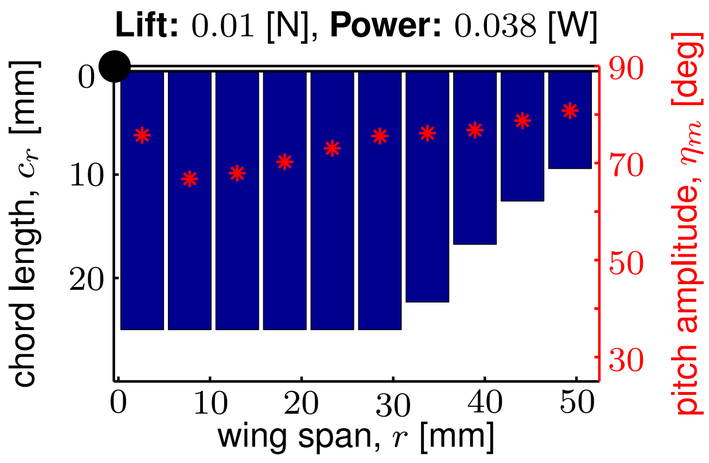
Pitching angle: $\eta(t) = \eta_m \sin(2\pi f t + \Phi_\eta) + \eta_0$

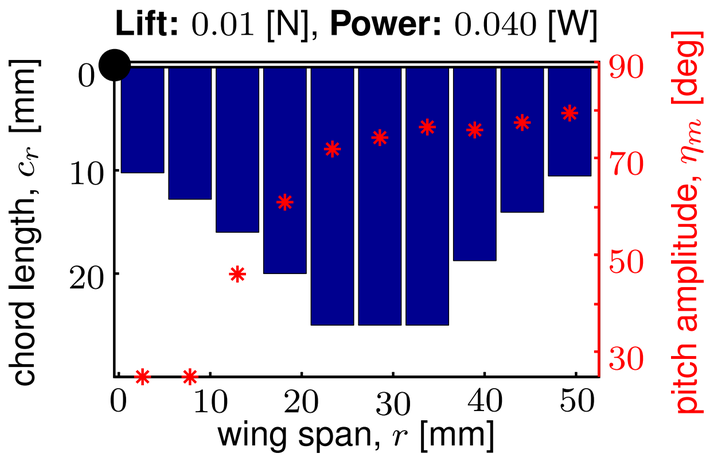
Power effective hovering flight[2]

$= 0$

***Power: Power**$_{aero}$ + **Power**$_{inertia}$*

Different wing designs, similar performance!



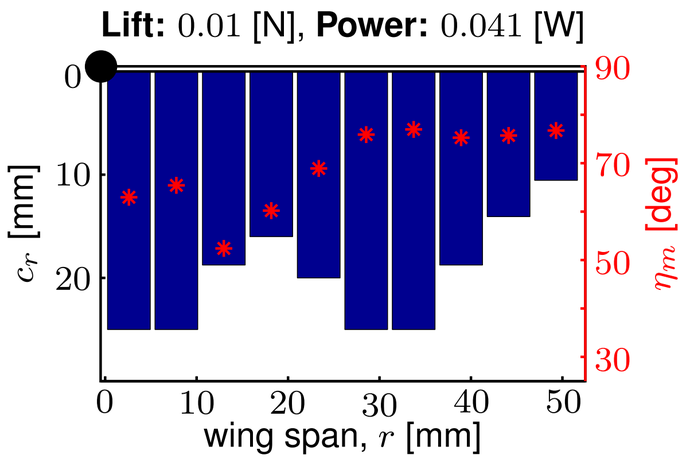


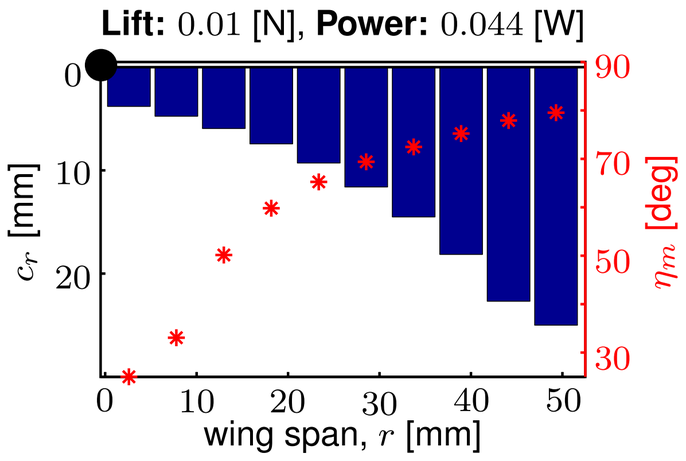
Effective roll using asymmetric kinematics

In the wing designs below:

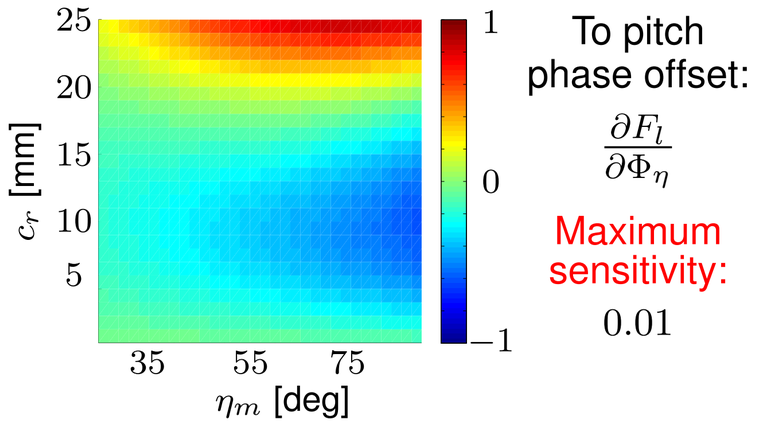
$\Delta P \approx 7,0\%$

$\Delta \ddot{\theta} \approx 22,6\%$ Roll acceleration improvement





Sensitivity of lift force to kinematical parameters



To sweep amplitude: $\frac{\partial F_l}{\partial \phi_m}$ Maximum sensitivity: 0.035

To pitch amplitude: $\frac{\partial F_l}{\partial \eta_m}$ Maximum sensitivity: -0.027

To pitch phase offset: $\frac{\partial F_l}{\partial \Phi_\eta}$ Maximum sensitivity: 0.01

Results & Conclusions

- Multiple designs, similar performance: freedom.
- The improvement of the roll effectiveness goes with an increase in power consumption.
- Wing design depend on FWMAV control options.

References

[1] G.J. Berman and Z.J. Wang (2007)

[2] H.J. Peters, J.F.L. Goosen and F. van Keulen (2012)