Active aerodynamic control of a bluff body based on machine learning control

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1. Background

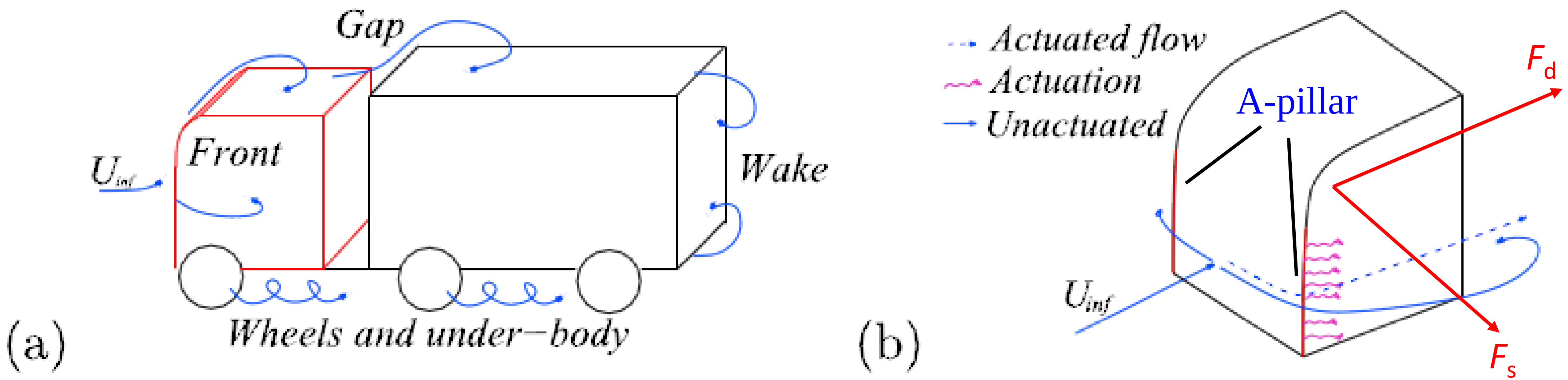
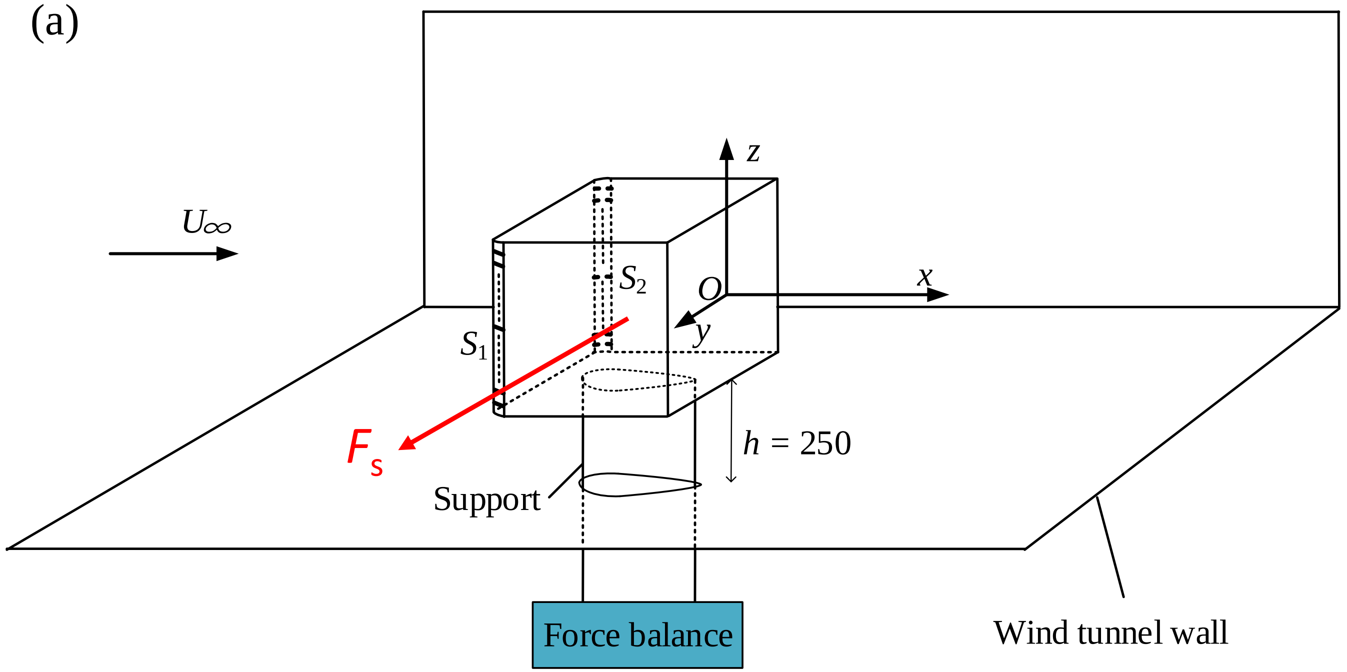


Fig. 1. Main sources of aerodynamic drag for a truck (a). The A-pillar separation and the effect of the actuation (b).

E.g. Minelli et al. (2016, 2017, 2019) and Tokarev (2019)

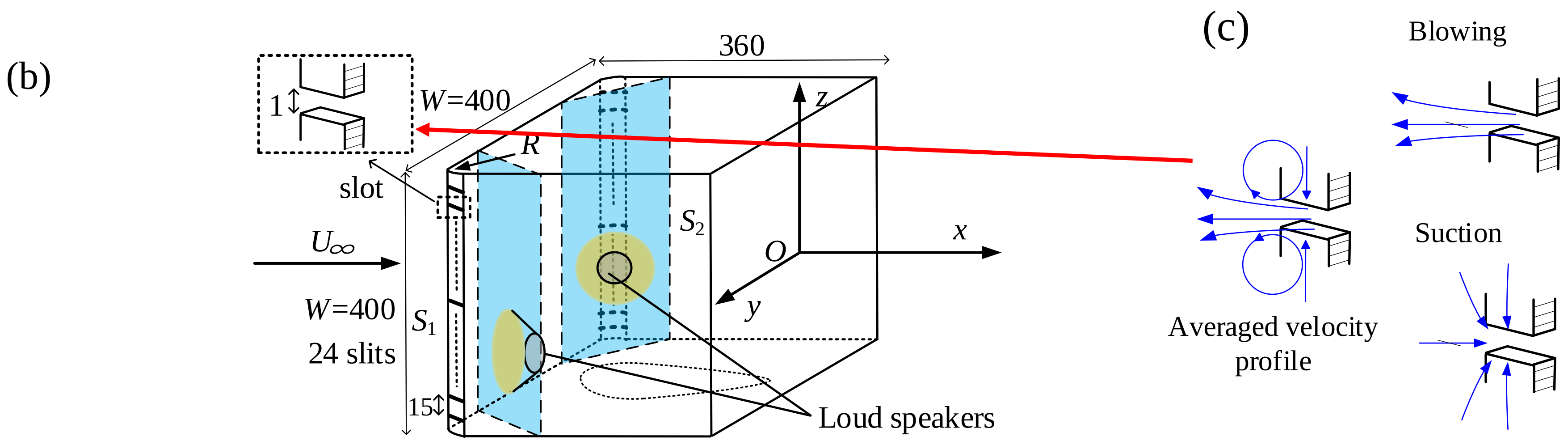
	Drag force F_d	- 17% ↓
Averaged F_s value is 0 N	Side force $F_{s,rms}$	+ 32% ↑

1. Background

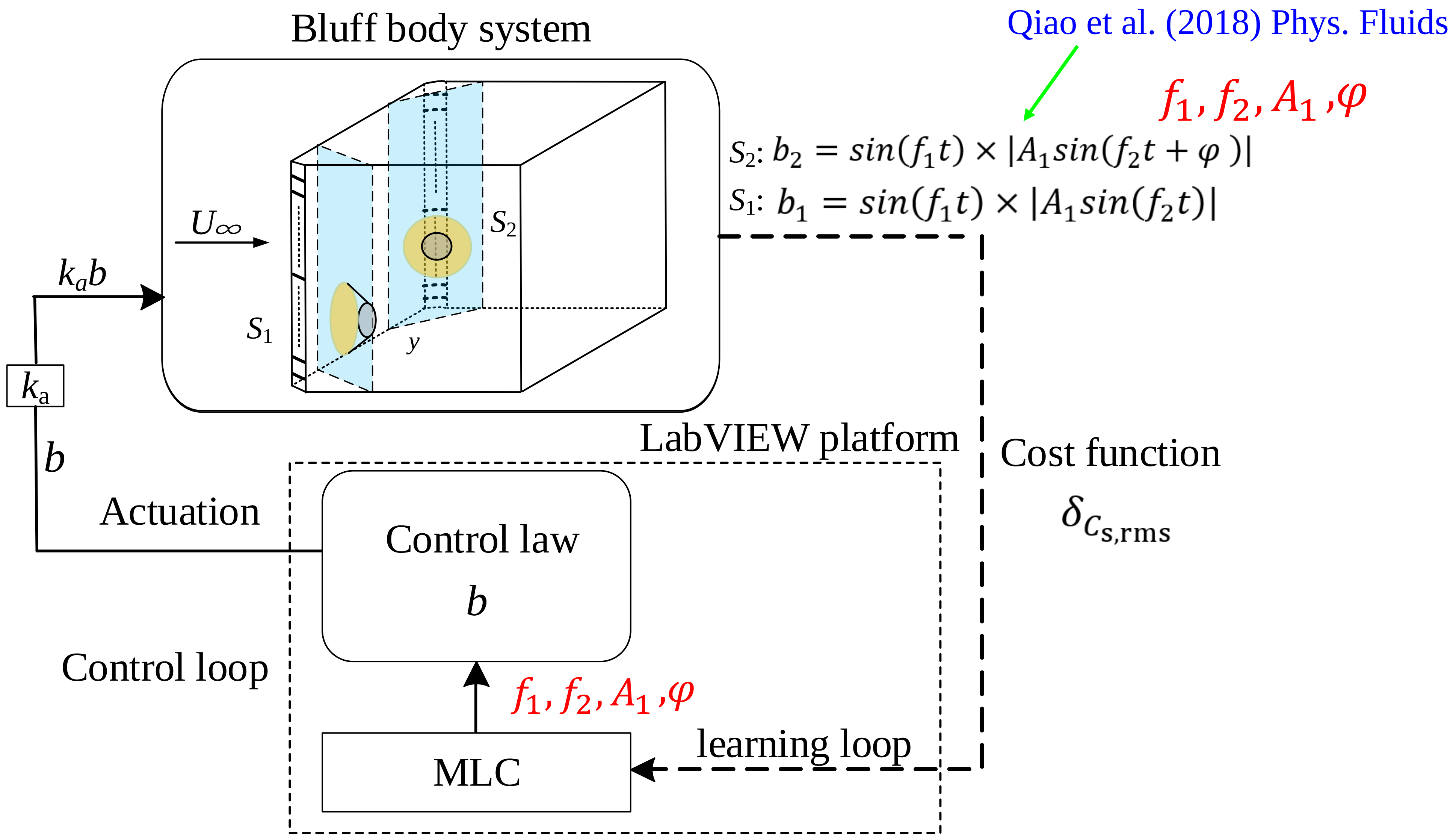


1. Objective function → $F_{s,rms}$

2. Control parameters → A, f and φ



2. Machine learning control (MLC)



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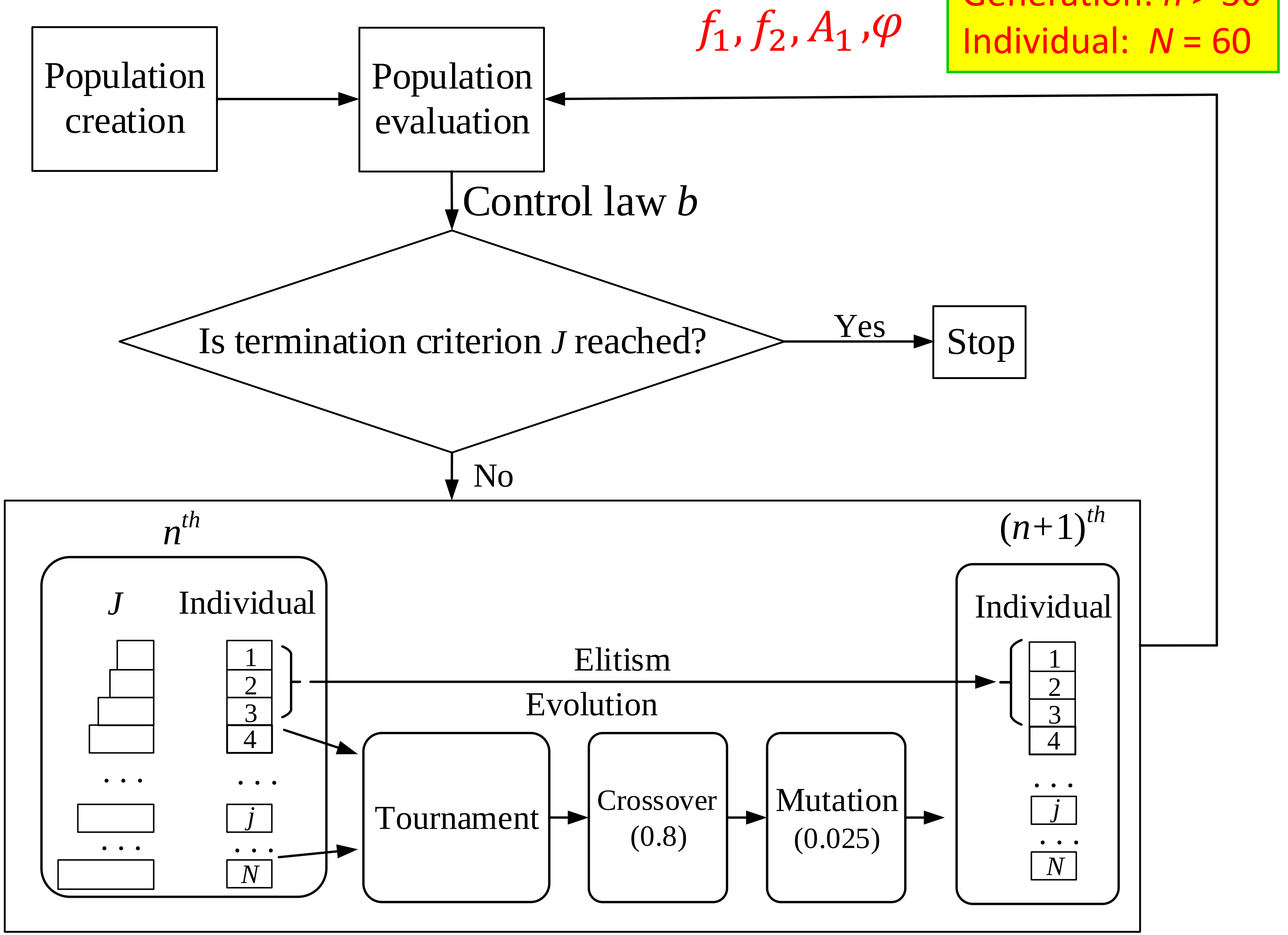
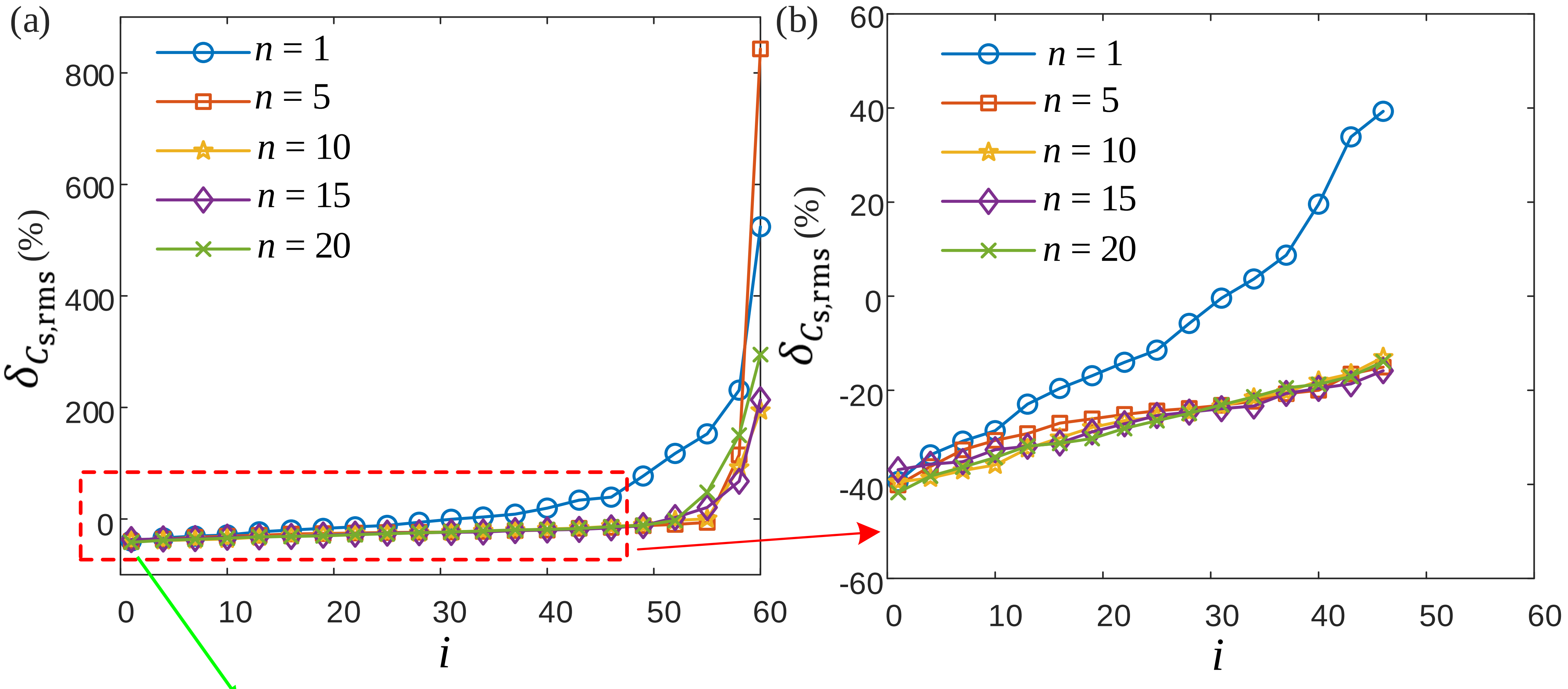


3. Control Results

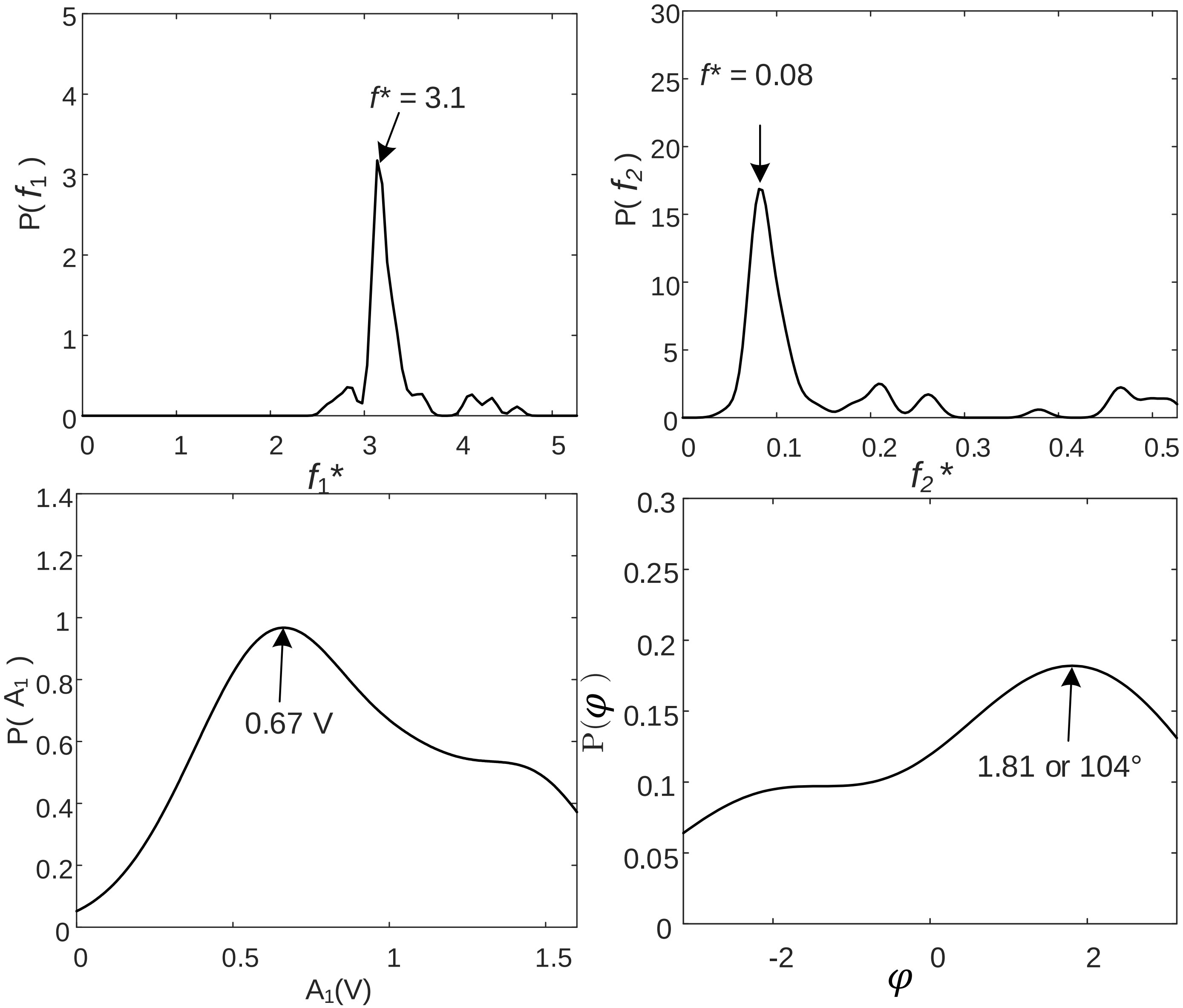


Maximum side force $F_{s,rms}$ - 40%

3. Control Results

Best individual f_1, f_2, A_1, φ

$f_1^* = 3.1$
$f_2^* = 0.08$
$A_1^* = 0.67V$
$\varphi = 1.81$



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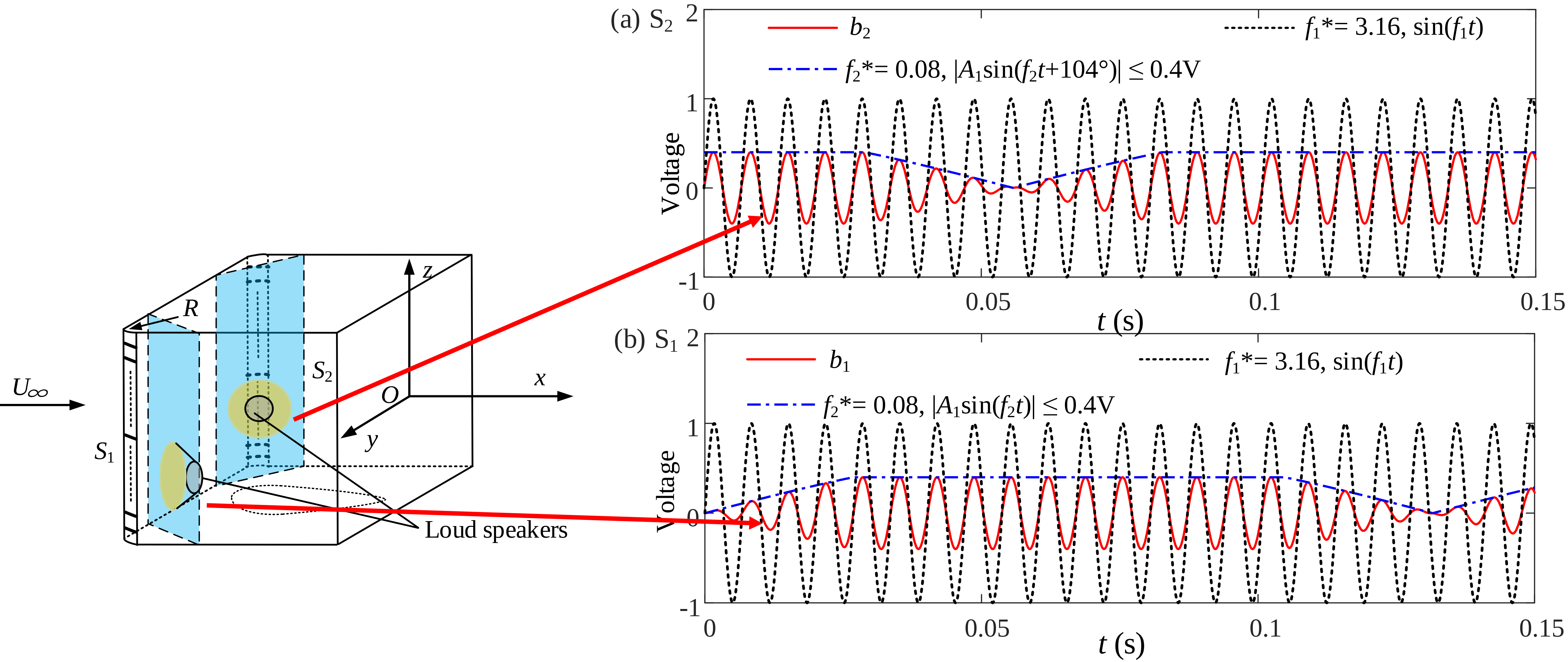
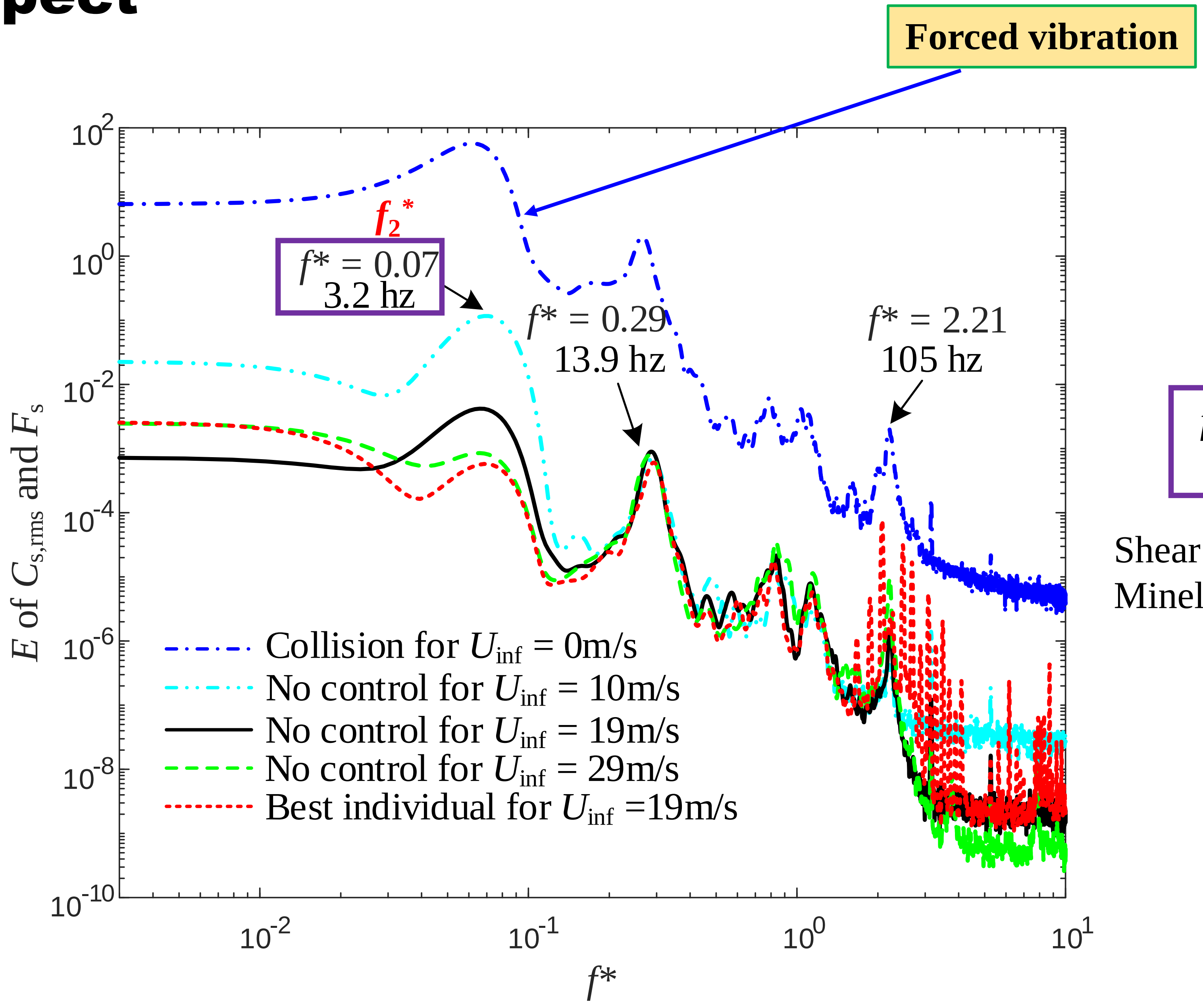


Input energy reduced by 45%

4. Physical aspect

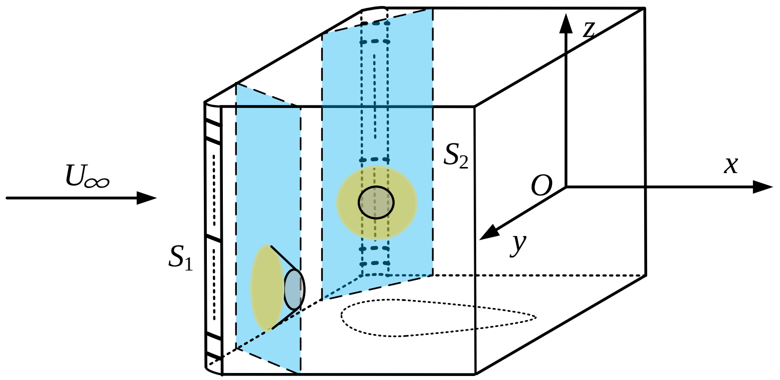


f_1^*

$f^* = 3.16$
149hz

Shear layer frequency
Minelli et al. (2017)

4. Physical aspect

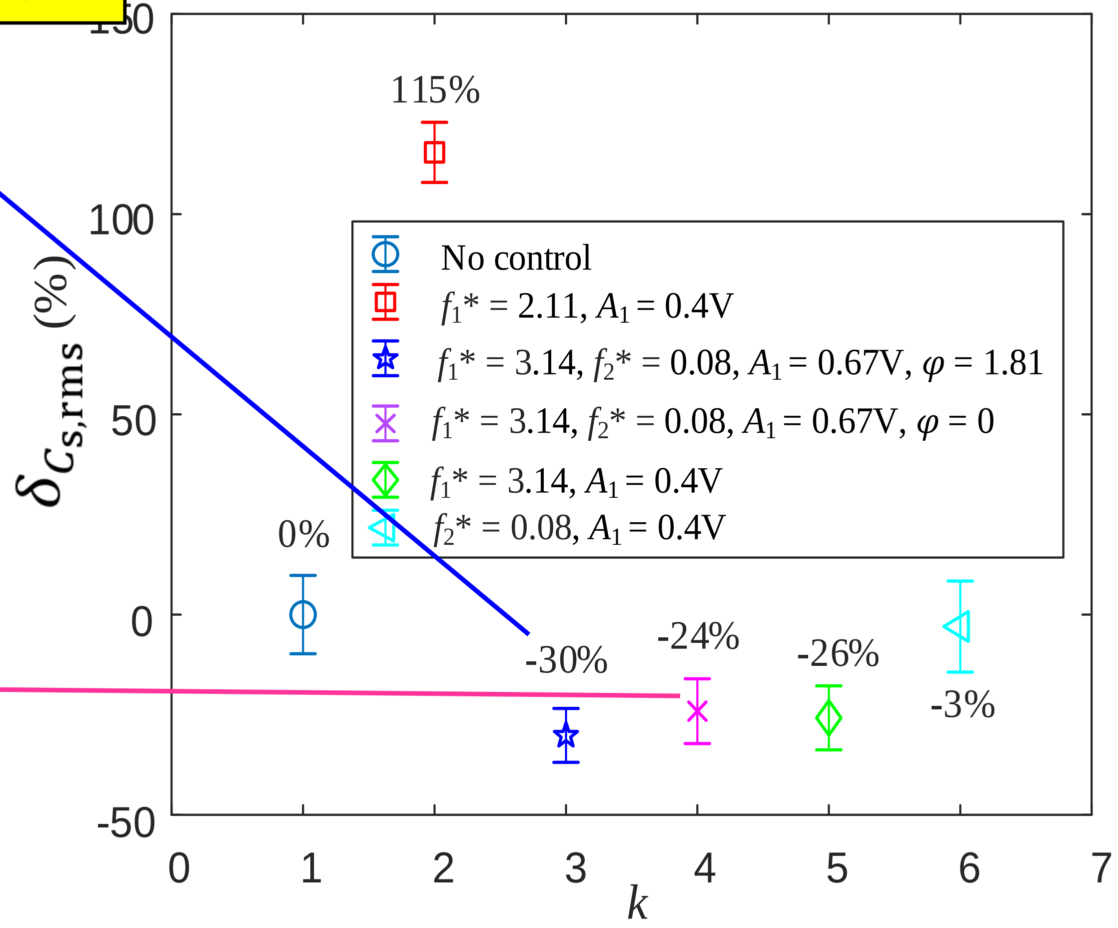


1.Muti-frequencies control → $F_{s,rms}$ **- 30%** ← $f_1^* = 3.1$, $f_2^* = 0.08$

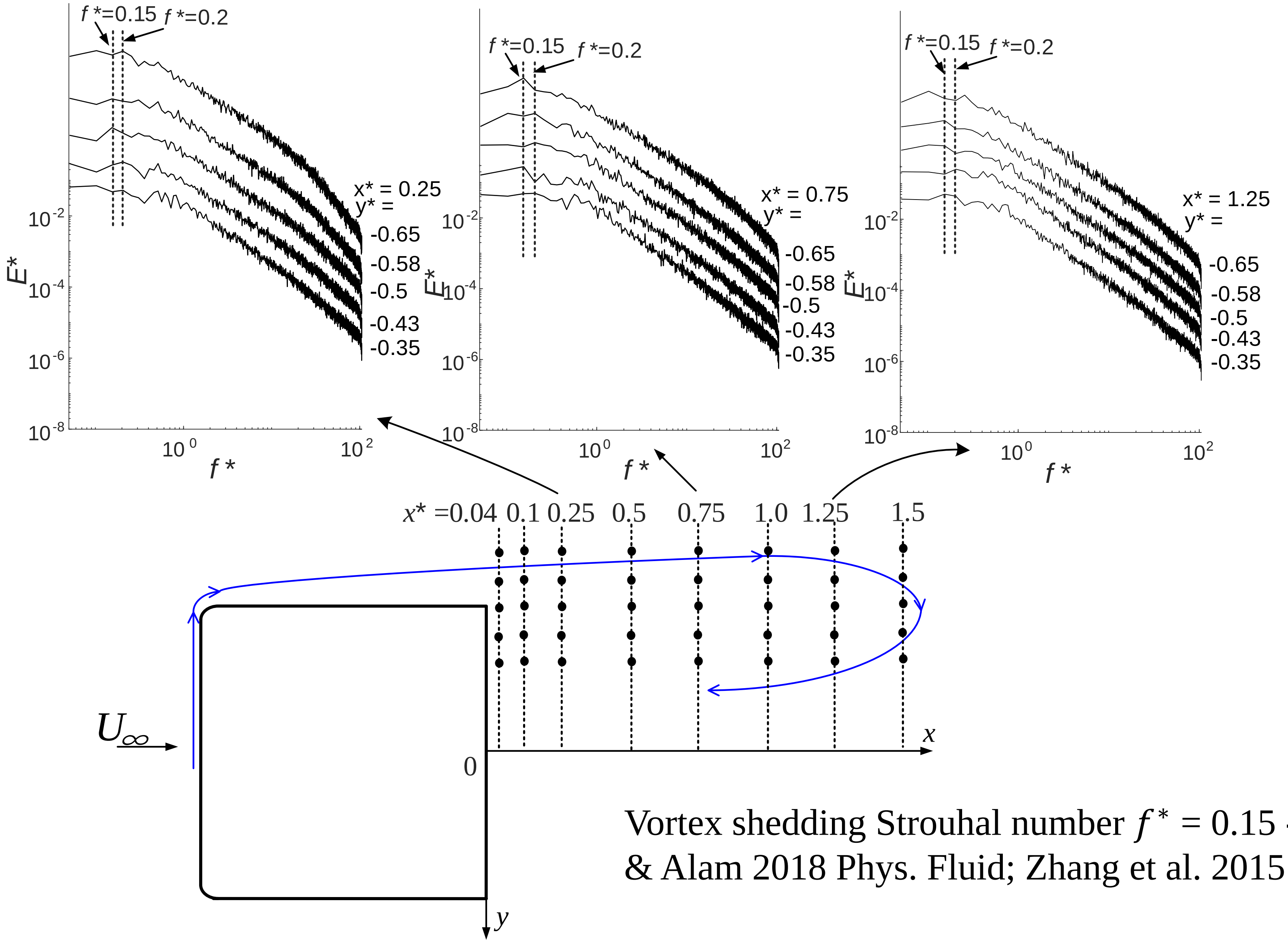
Drag force F_d **- 11%**

2.Single frequency control → $F_{s,rms}$ **-26% and -3%** ← $f_1^* = 3.1$; $f_2^* = 0.08$

3.Phase control → $F_{s,rms}$ **- 6%** ← $\varphi = 1.81$



4. Physical aspect

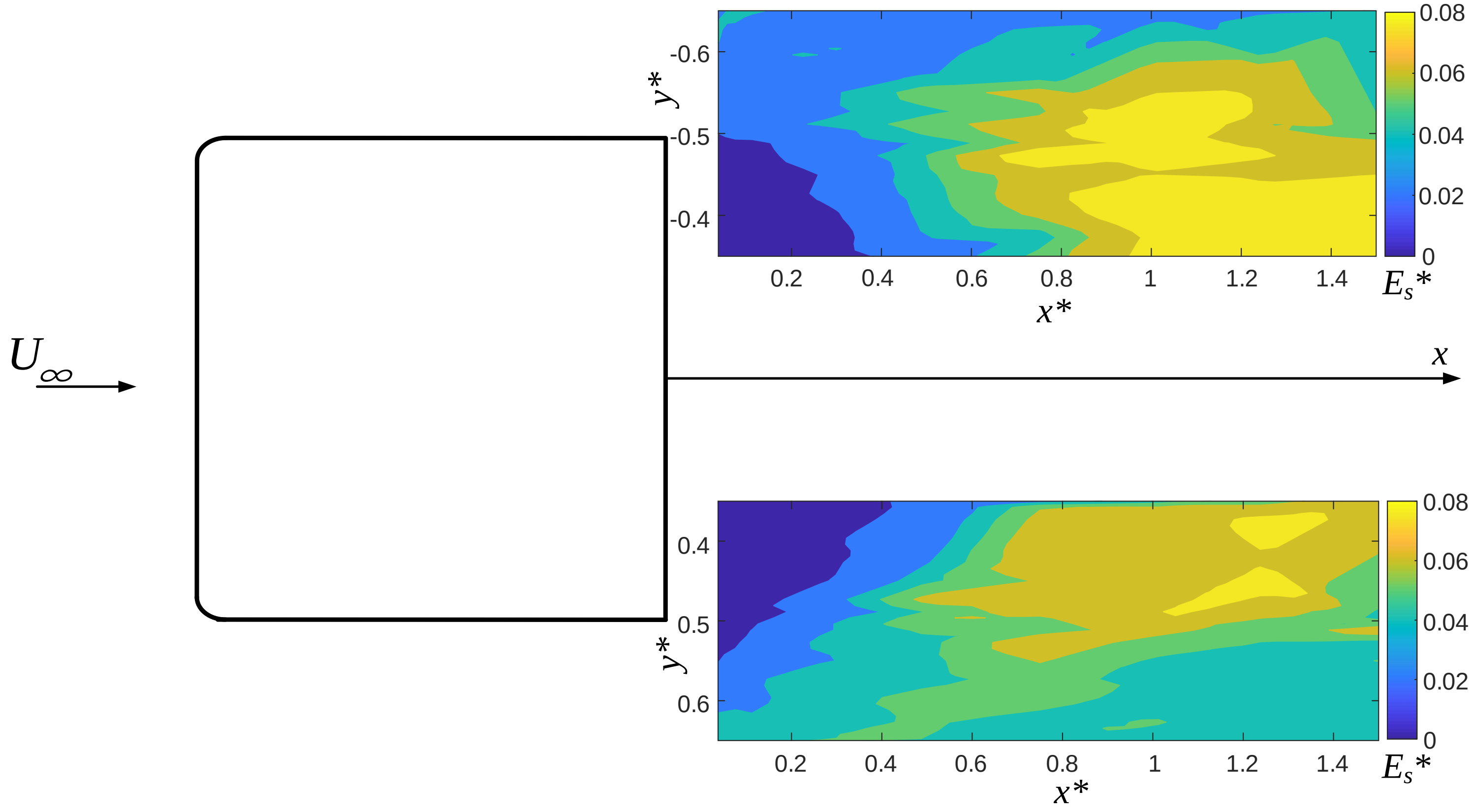


Vortex shedding Strouhal number $f^* = 0.15 - 0.2$ in the wake (Bai & Alam 2018 Phys. Fluid; Zhang et al. 2015 JFM)

4. Physical aspect

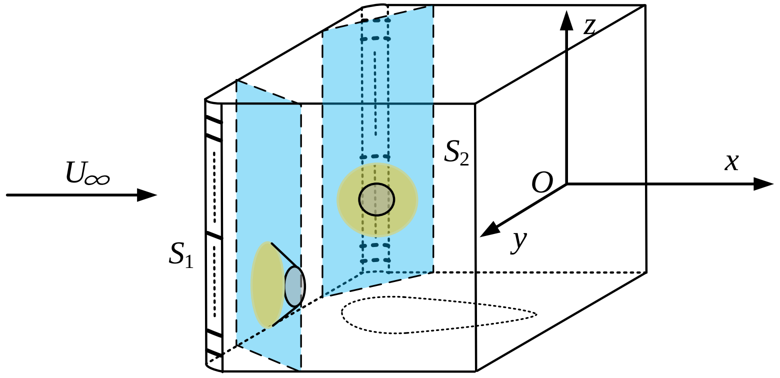
No control

Optimal control



Spectral energies of the vortex shedding in the wake

Conclusion



1 The MLC figure the optimal control parameters out for reducing $F_{s,rms}$ as $f_1^* = 3.1$, $f_2^* = 0.08$, $A_1 = 0.67\text{V}$ and $\varphi = 1.81$ or 104° . The maximum reduction achieved is 30%, larger than 26% attained from the reference single frequency control. Furthermore, the corresponding input energy are reduced by 45%.

2 The power spectra of the force balance indicate unequivocally that the MLC controller has exactly found one natural frequency of the mechanic system and one frequency of the shear layer, thus greatly suppressing the lateral vibration.

3 Under the optimal control, the vortex shedding has been shrunk substantially and reduced in its strength in the wake.

Thank you for paying the attention !