DRAGY Workshop

Skin-friction drag reduction, and how to assess it

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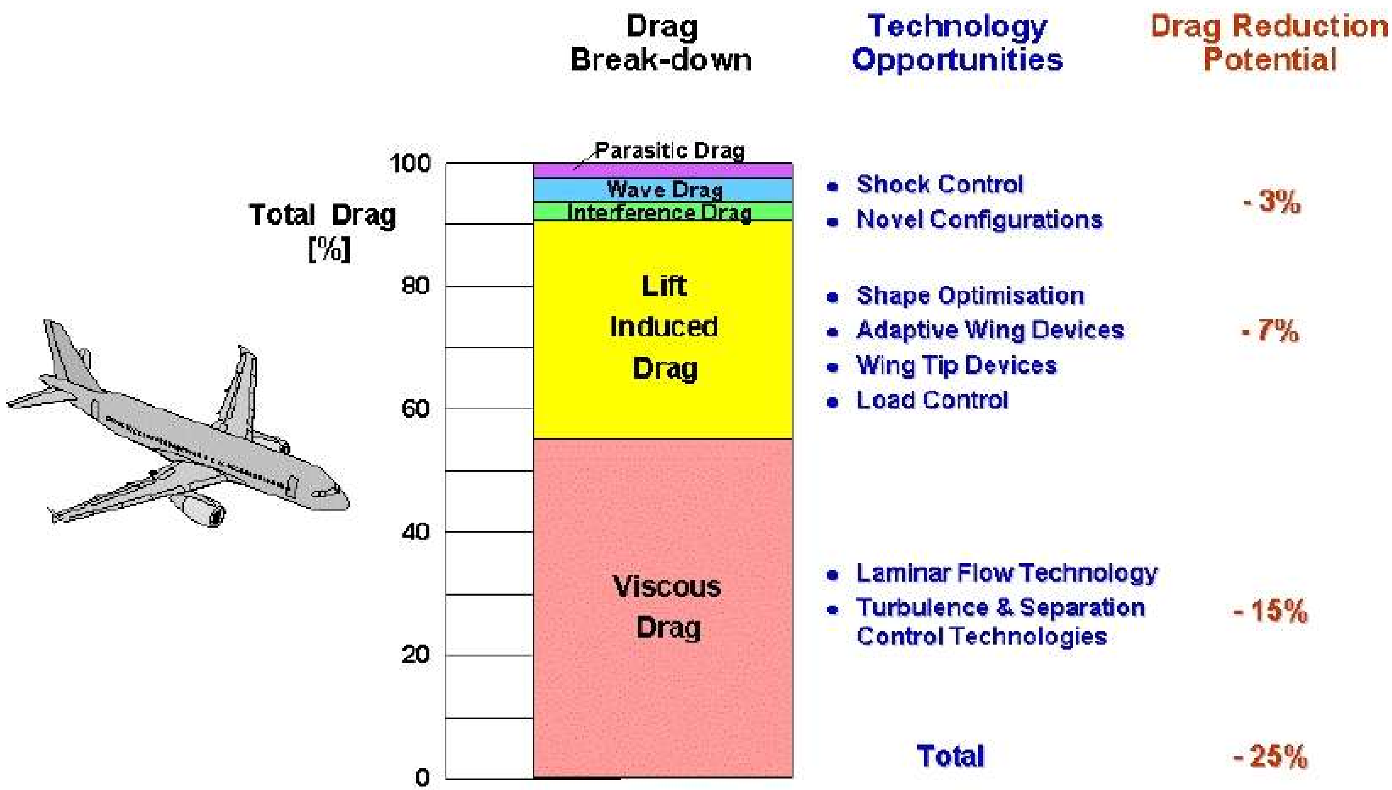
WP2: Inner-layer control concepts for drag reduction

The potential for drag reduction

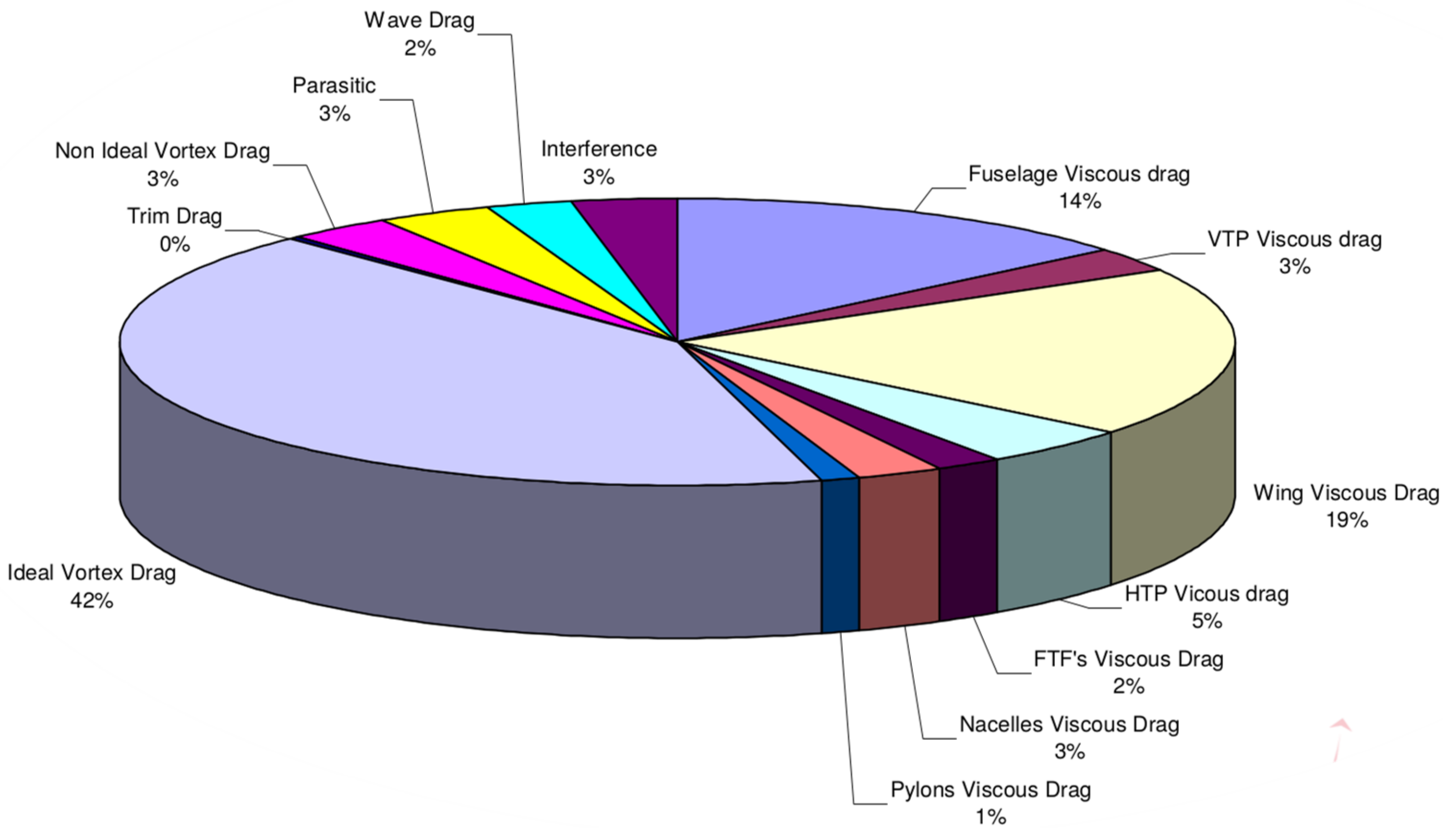
DRAGY

Status ca.2006



Percentages are not changing

Status ca.2015



Drag reduction = Hot topic!

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Drag reduction, turbulence and industry 1557

especially higher bypass ratios, and by structures' technology and especially higher aspect ratios. These are quantitative evolutions, rather than 'visible' inventions. The rate of improvement would appear to be naturally slowing (other than the leap allowed by composite materials), but the political authorities do not see it this way. In the recent 'N+3' exercise, meaning the third generation beyond aircraft in service, NASA requested a very striking fuel-burn reduction of 70 per cent for a given Boeing 737 mission. Now a 5 per cent reduction represents a very respectable achievement, yet this amounts to combining 23 such reductions. This was found possible with 'somewhat exotic' technologies such as wing struts and/or load alleviation, and modest speed reductions. Some teams declared LFC extensively on the wing, but others did not, and instead sought efficiencies in configurations more favourable structurally, and innovations of another type such as boundary-layer ingestion. None mentioned riblets. European institutions via the Advisory Council for Aeronautics Research in Europe have, similarly, set fuel-burn reduction goals in the 50 per cent range, and this with a far shorter deadline. Note how neither authority set any guidelines for the cost of the aircraft. Compare this with the general expectation that a new airliner generation, which is built for decades, needs a cost reduction of the order of 15 per cent to make the business case for its introduction. In short, the pressure towards drag reduction has more than one source and remains very high for management, as does the fascination for engineers including the authors.

WP2 – Inner-layer control for drag reduction

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13 Partners (8 EU, 5 CH) and 171 PM

- Only near-wall control is considered
- Focus on spanwise forcing (Task 2.1)
- From basic physics to actuator development (Task 2.2)
- Active and passive strategies (Task 2.3)

Partners in WP2

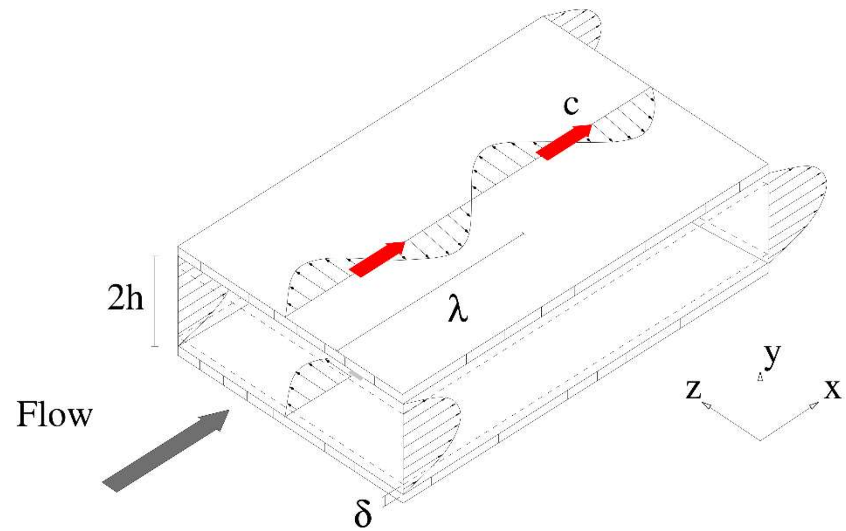
EU

Partner #	Partner name	MM
1	CIMNE	24
2	UPM	11
3	USFD	11
4	DLR	6
5	ONERA	6.25
6	CNRS-PPRIME	41.5
8	CHALMERS	5
9	POLIMI	13
13	ZJU	8
14	THU	8
16	PKU	8
18	BUAA	12
19	XJTU	17

CH

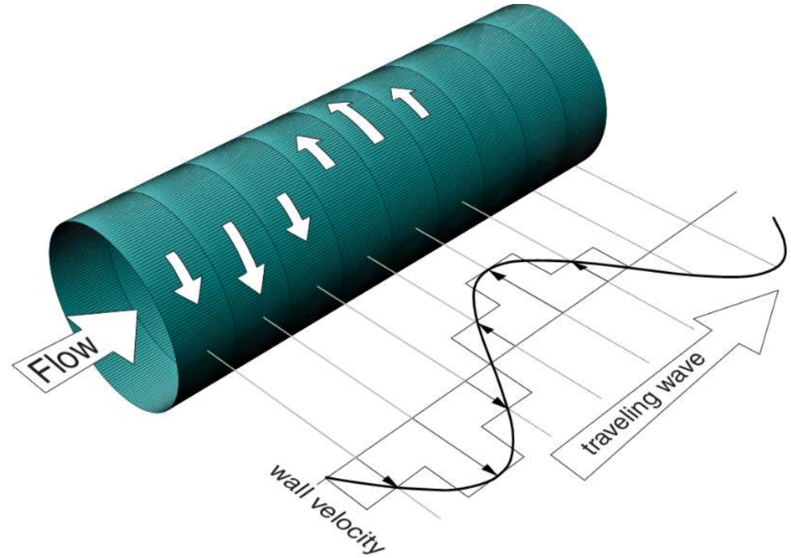
Why spanwise forcing?

- Effective interaction with near-wall turbulence
- Goal: disrupt / interrupt / weaken the near-wall turbulence cyle
- Energy efficient
- StTW-W: up to 50% "drag reduction"



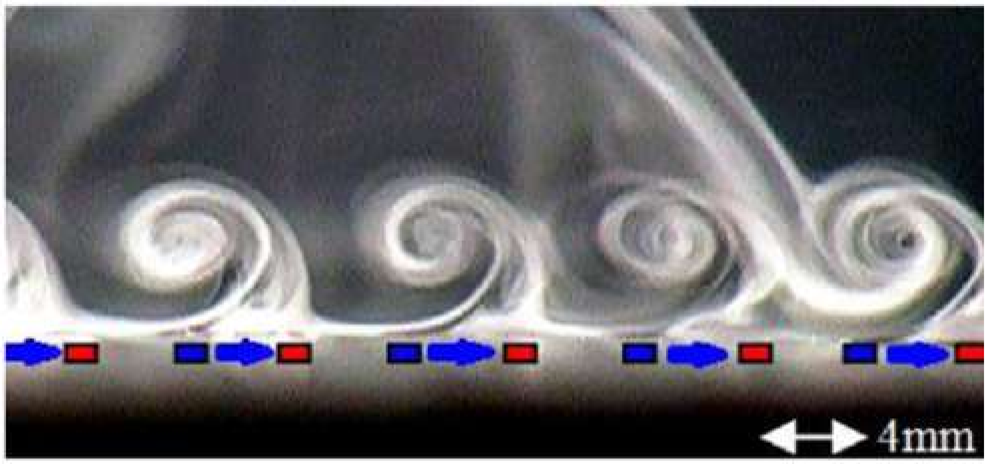
Why an experiment?

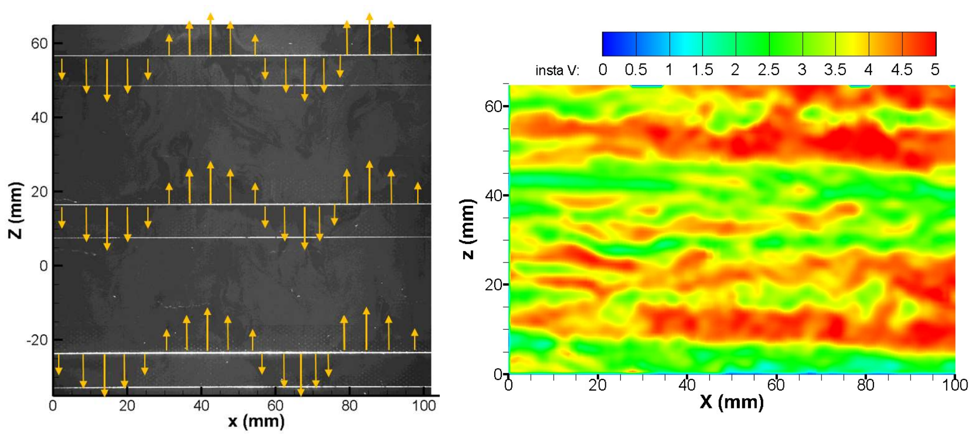
- Need to go beyond prrof-of-concept experiment
- More than 40% “drag reduction” measured
- Abysmally low energy efficiency



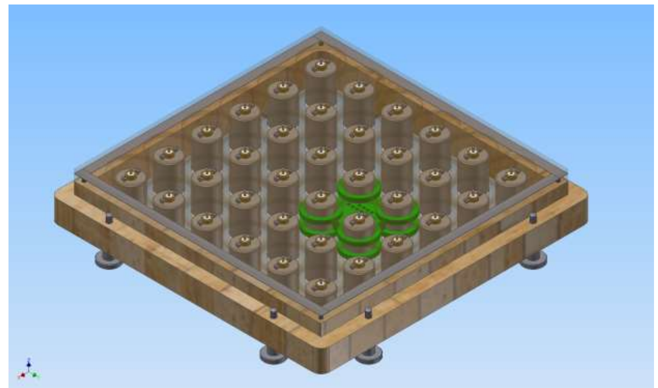
Experimental efforts in DRAGY

Plasma DBD actuator

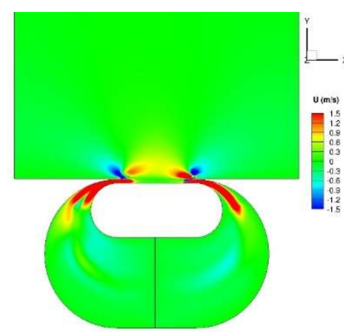




Rotating-disc actuator

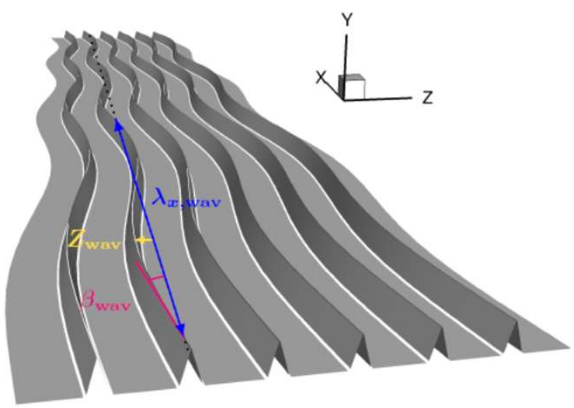


Synthetic-jet actuator

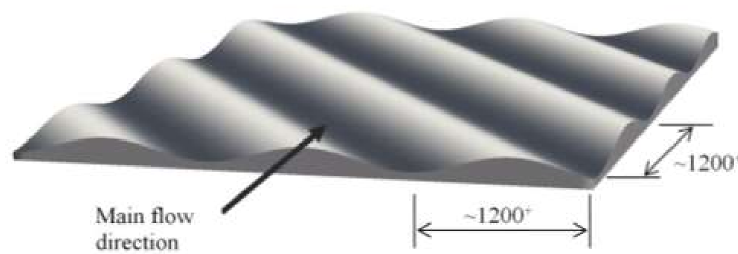


Spanwise forcing made passive

The sinusoidal riblets



The undulated wall



The CPI framework

Comparing two flows with/without drag reduction is easy

Example: the spanwise-oscillating wall

CFR: drag is reduced

$$C_f = \frac{2\,\tau_w}{\rho\,{U_b}^2}$$

CPG: drag is unchanged

However, interpreting changes is non-trivial

A non-CPI experiment

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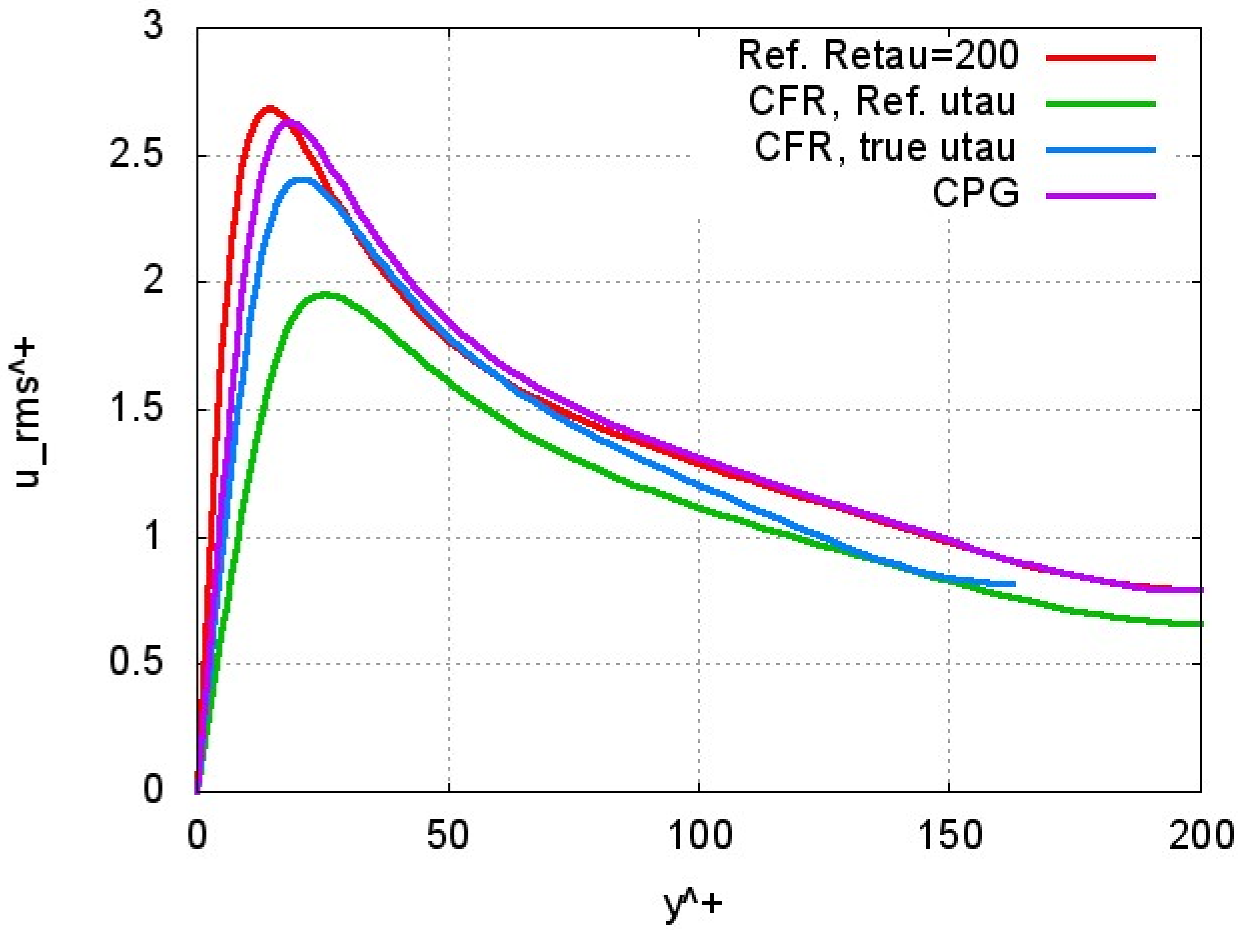

Key CPI concepts

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The Constant Power Input approach is:

- a way to carry out experiments
- “the” way to carry out drag-reduction experiments
- essential to address the *scaling* problem
- unable to solve the *chicken-egg* problem

More in the next talk by Davide Gatti!

Concluding remarks

- Drag-reduction on airplanes is more than welcome nowadays
- Its implementation is challenging but potentially rewarding
- Slow but continuous progress
- Understanding of physics is still partial
- Setting framework for proper comparison (e.g. CPI) is important