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Active flow control of S-duct by plasma synthetic jet

Key words:

S-duct, flow control, plasma synthetic jet,
flow separation, pressure distortion

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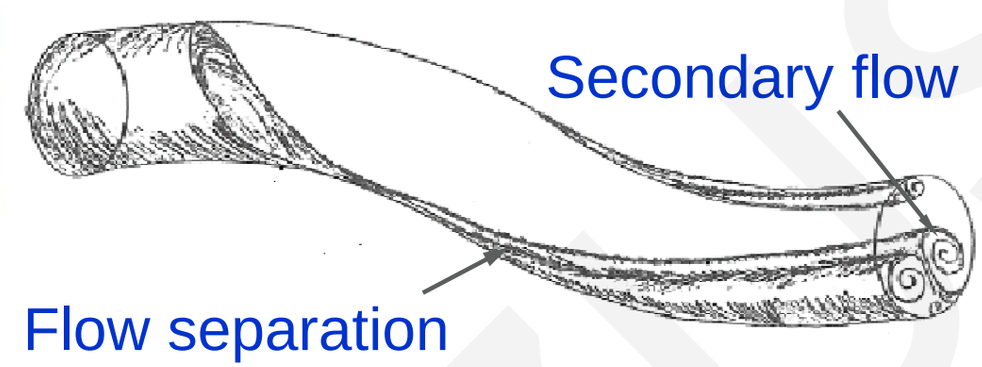
Motivation

- Flow separation and secondary flow in the S-duct of an aircraft engine cause severe pressure loss and airflow distortion at the outlet, lowering engine performance.

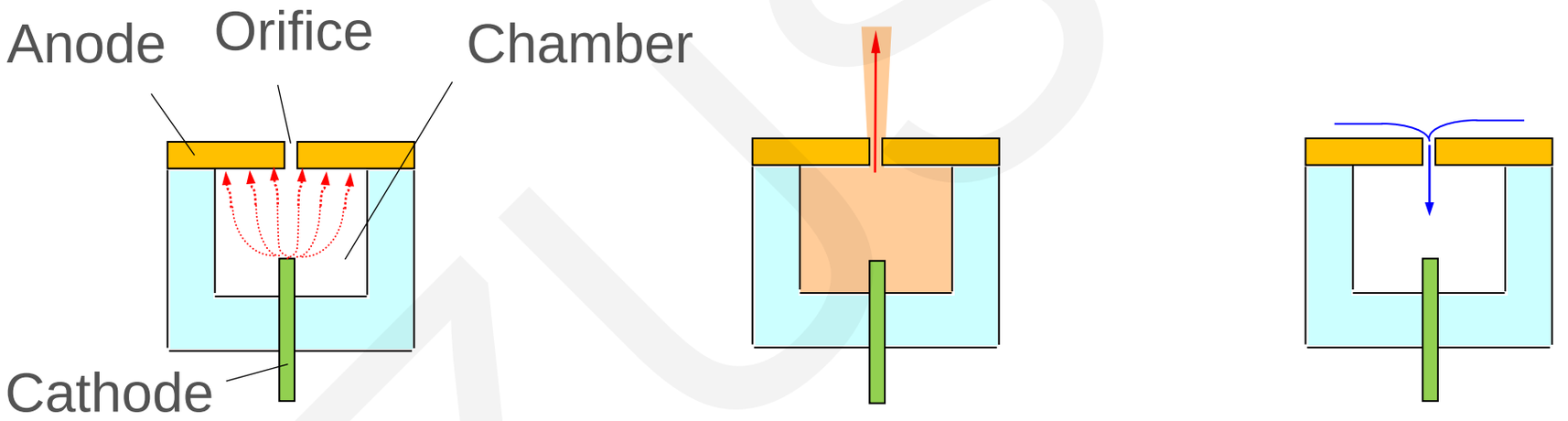


S-duct and its application on the cruise missiles, fighter aircraft, unmanned aerial vehicle(UAV) and the blended wing body aircraft

(Pan, J,J., 2014 and Liu L., 2015)

Main idea

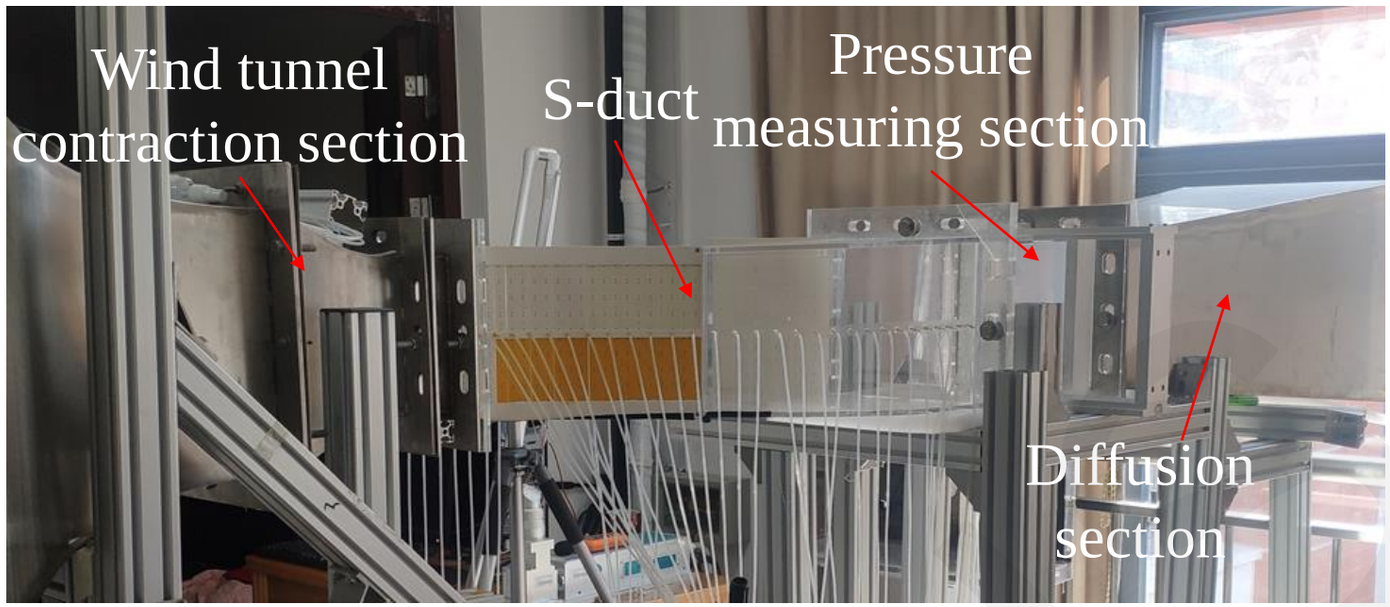
- A serial two-electrode plasma synthetic jet (PSJ) actuator array is used to actively control the flow field in the S-duct and improve the pressure loss and airflow distortion.



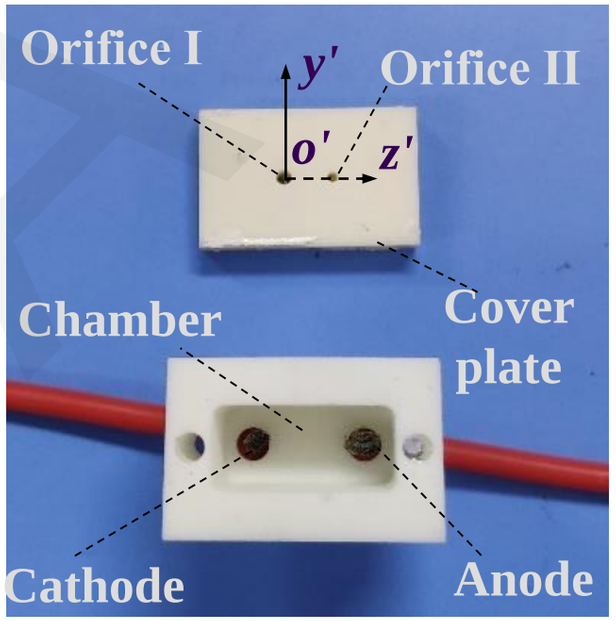
Structure and operation cycle of a plasma synthetic jet (PSJ) actuator

(Cybyk *et al.*, 2006)

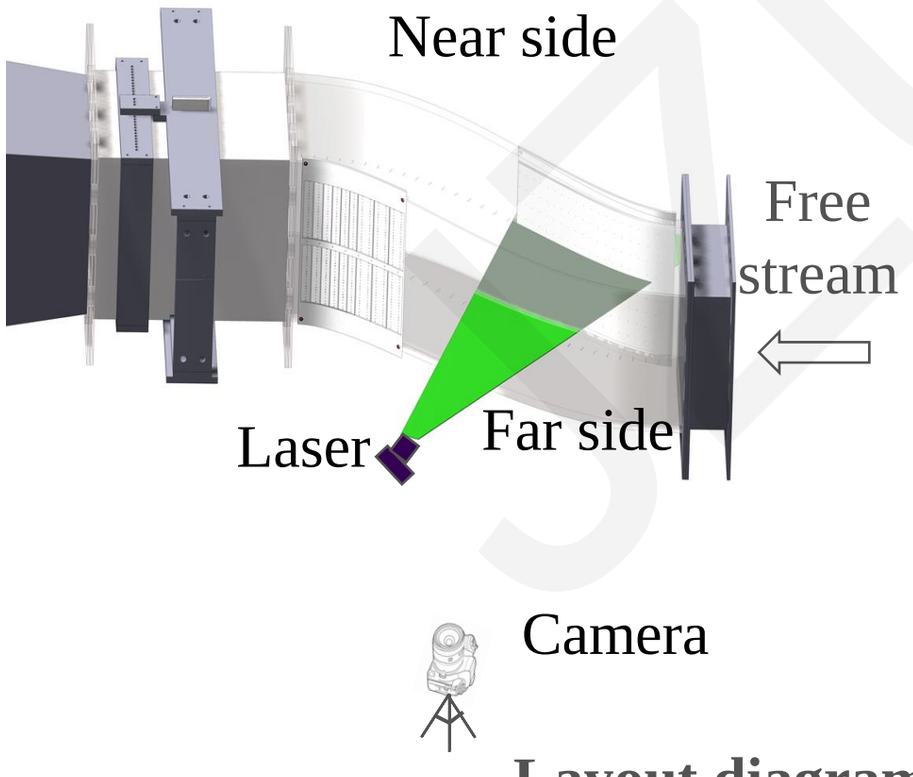
Experimental setup

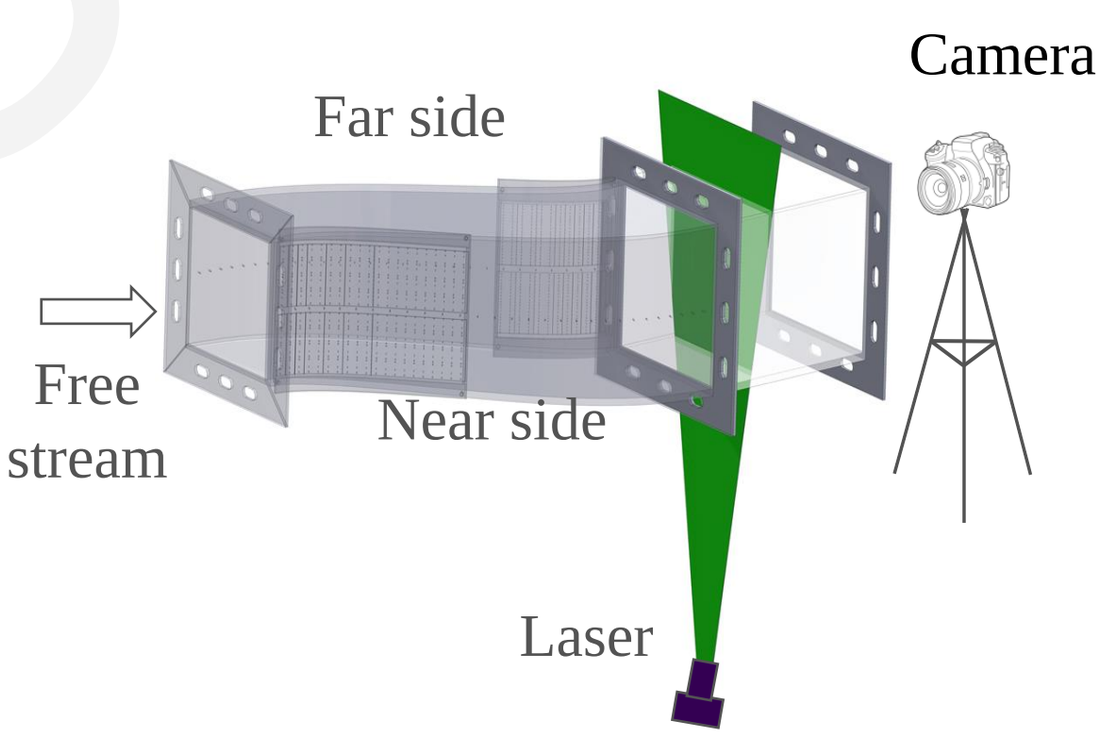


S-duct test setup



PSJ Actuator

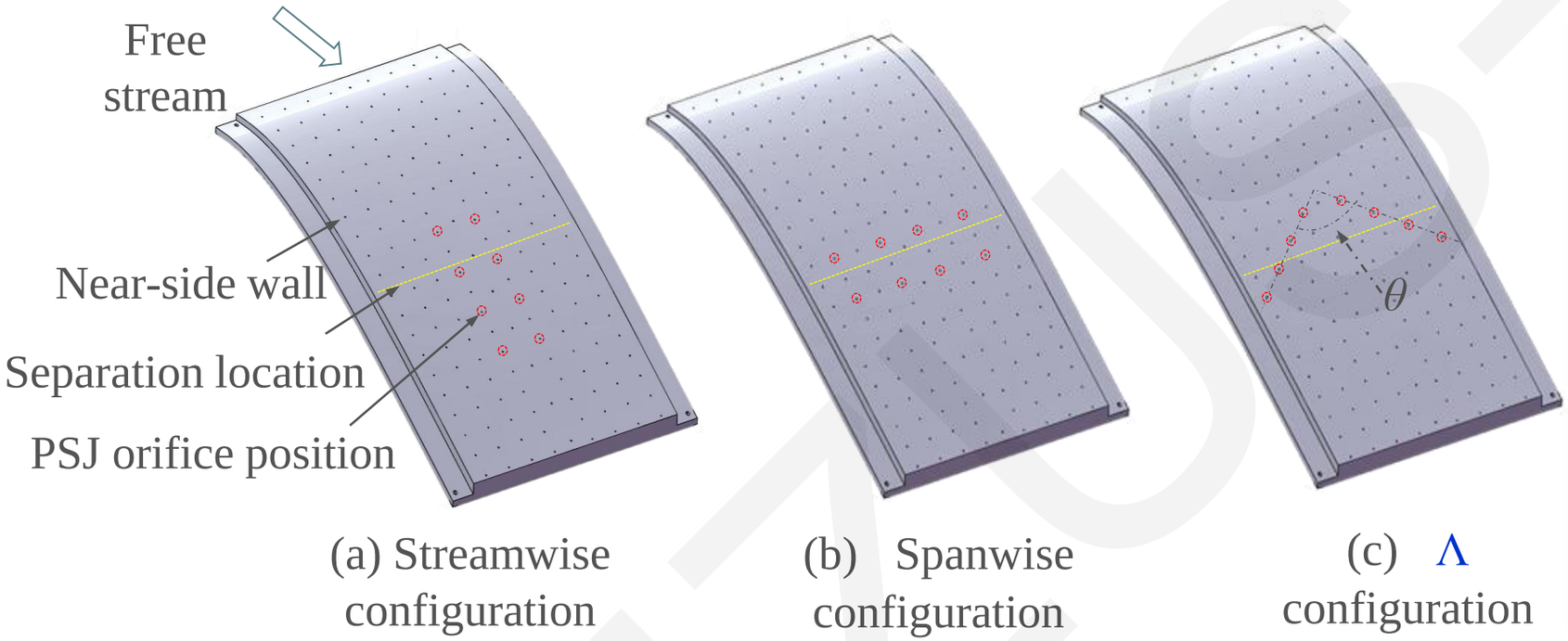




Layout diagram of the PIV flow field test

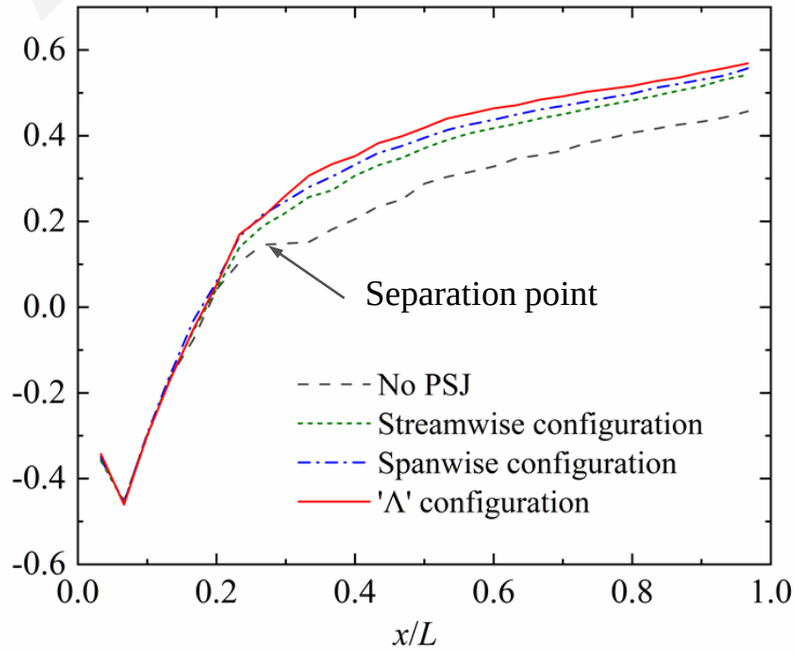
Major results

- The PSJ of the three jet configurations can improve the wall pressure recovery coefficient C_p and reduce the steady pressure distortion index $\Delta\bar{\sigma}$. In particular, the jet control effect of the 'Λ' configuration is the most significant.



(a) Streamwise configuration (b) Spanwise configuration (c) Λ configuration

PSJ actuator configurations



Surface pressure distributions for different jet configurations

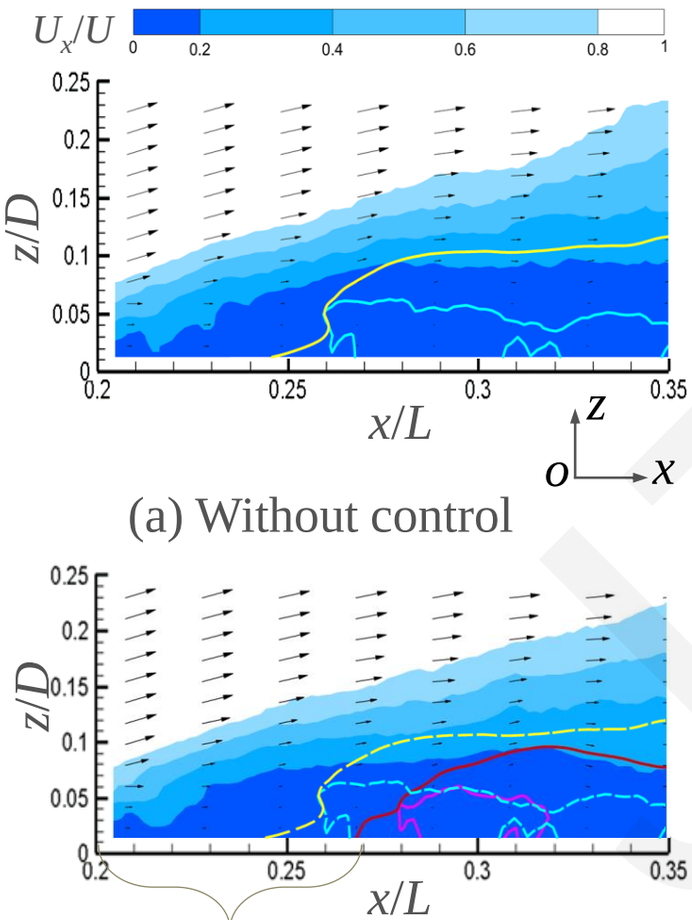
Steady pressure distortion index $\Delta\overline{\sigma}$ for different jet configurations

Parameter	No PSJ	Streamwise configuration	Spanwise configuration	'Λ' configuration
$\Delta\bar{\sigma}$ (%)	0.0666	0.0629	0.0622	0.0616
$\Delta\overline{\sigma_r}$ (%)	/	–6.44	–6.97	–7.29

Major results

➢ Flow control mechanism of duct flow-field performance by PSJ

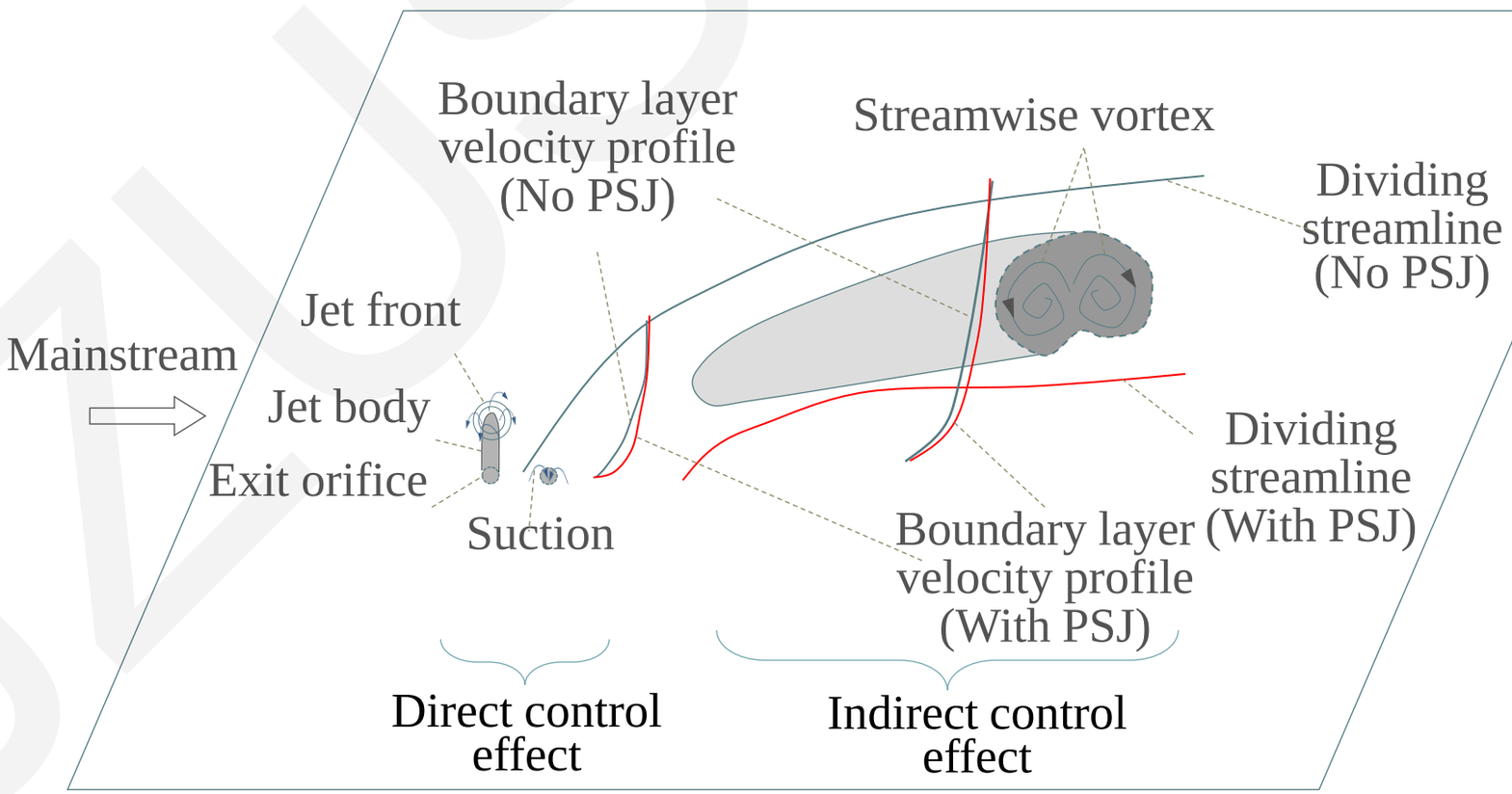
The mechanism by which the PSJ improves the flow distortion at the duct outlet is that the high-speed jet directly injects energy into the boundary layer and induces a streamwise vortex, indirectly controlling the boundary layer .



(a) Without control

(b) With control

Streamwise time-averaged velocity fields



Conceptual model of the PSJ control flow separation mechanism in the S-duct

Conclusions

- The PSJ can significantly improve the wall pressure recovery coefficient, suppress the flow separation of the S-duct, and improve the outlet pressure distortion.
- The primary and secondary orders of the influencing factors of the duct outlet pressure distortion control effect were determined via the orthogonal method as follows: jet control position > jet momentum coefficient > excitation frequency > jet configuration.
- The mechanism is that the high-speed jet directly injects energy into the BL and induces a streamwise vortex, indirectly controlling the BL. These two control effects make the BL velocity profile fuller, and reduces the flow-separation area. Moreover, the high-speed jet reduces the secondary flow velocity, the vorticity and backflow at the outlet cross-section. Finally, the wall pressure increases significantly, and the flow distortion and steady pressure distortion coefficient decrease remarkably.