Investigation of the effects of pipe diameter of internal multiphase flow on pipe elbow vibration and resonance.

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2023

Supplementary Table 3. Property details of the pipe structure

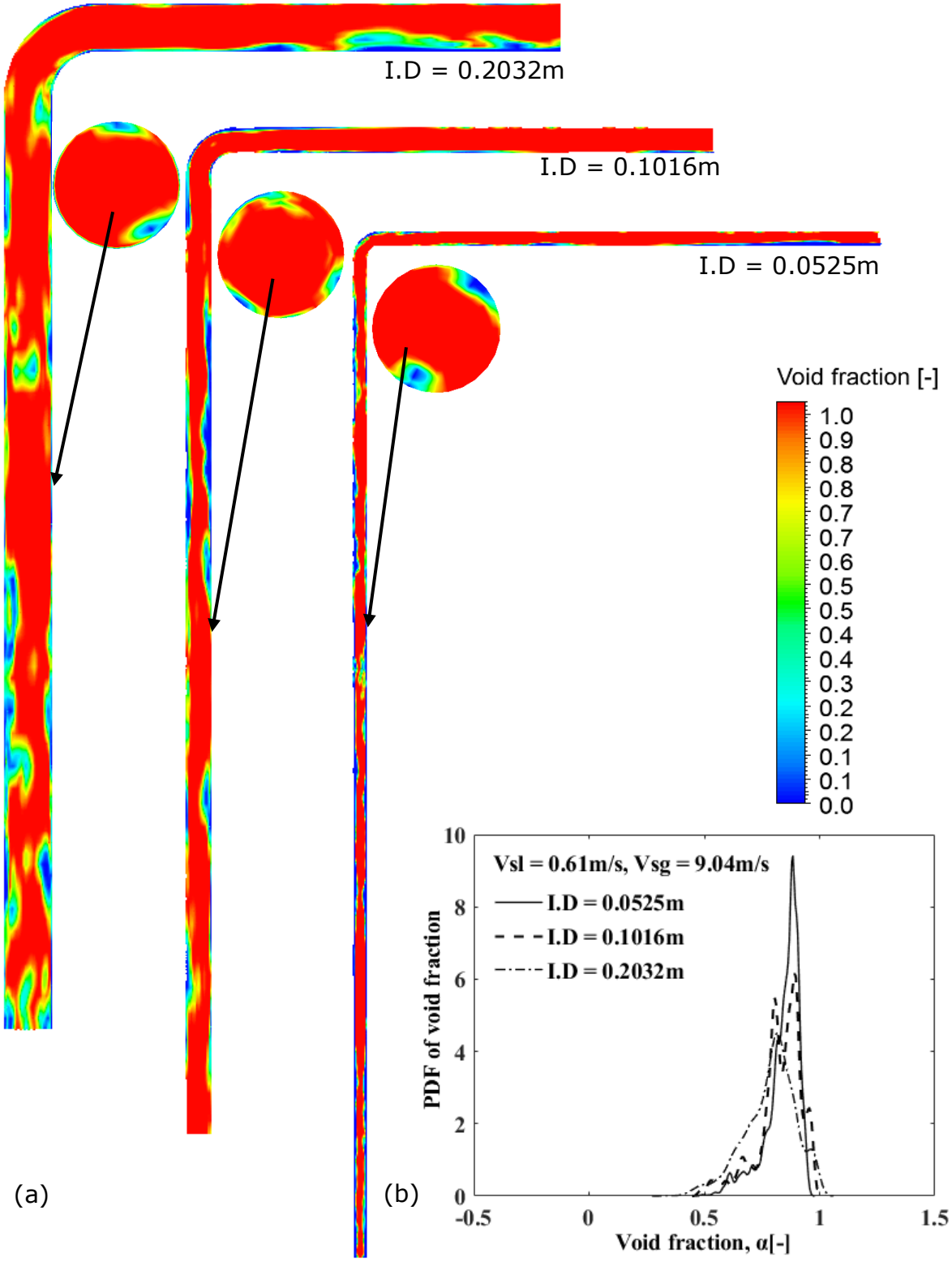
Property	**Definition**
Pipe material	Structural steel
Steel density [kg/m^3]	7850
Young's Modulus [Pa]	2X10^{11}
Tensile Yield strength [Pa]	2.5X10^{08}
Tensile Ultimate strength [Pa]	4.6X10^{08}
Poisson's ratio	0.3

Supplementary Table 4. Pipe sizes scaled with reference to the largest pipe

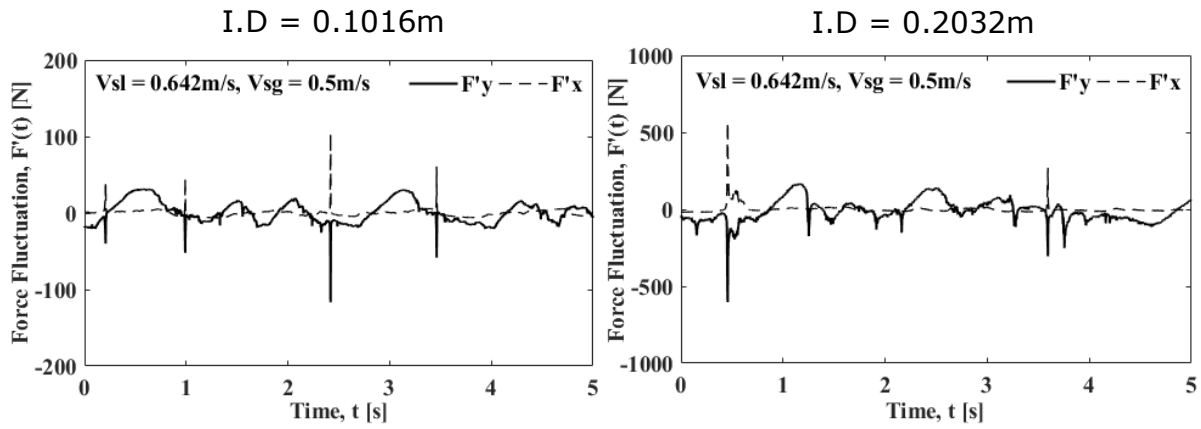
Geometric properties	**I.D (0.0525m)**	**I.D (0.1016m)**	**I.D (0.2032m)**
D_H^*	19.2	37.2	74.5
Diameter scale	1/4	1/2	1
Bend radius scale	1/4	1/2	1
Entry length scale	1/4	5/8	1

Supplementary Table 5. Mesh parameters

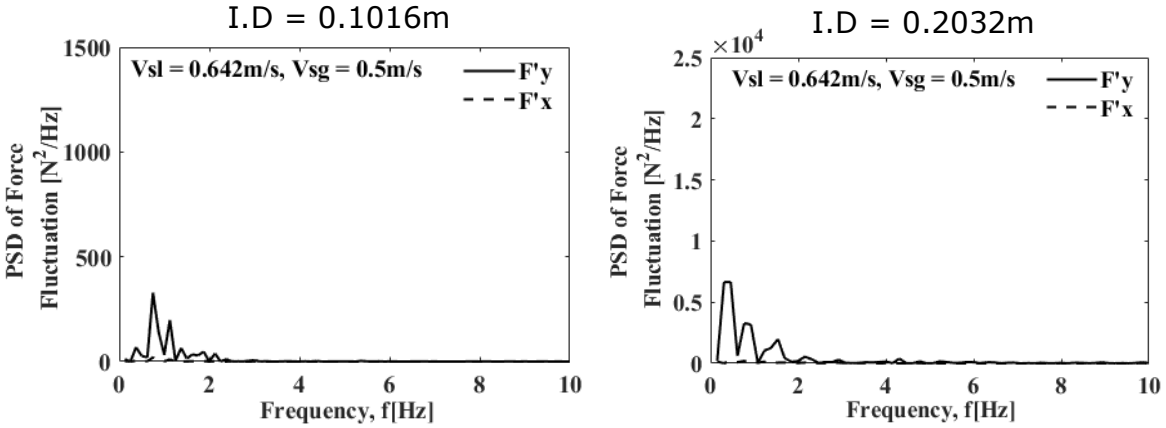
D = 0.0525 m		**D= 0.1016 m**		**D = 0.2032 m**	
Mesh sizes	**1st cell, Δy[m]**	**Mesh sizes**	**1st cell, Δy[m]**	**Mesh sizes**	**1st cell, Δy[m]**
154840	0.0012	688896	0.0011	353002	0.0015
277136	0.001	428032	0.00089	269010	0.001
366912	0.00054	690688	0.0007	647802	0.0005



Supplementary Figure 9. (a) Contour of air volume fraction and (b) PDF for Vsl=0.61m/s and Vsg=9.04m/s in the three pipe sizes.

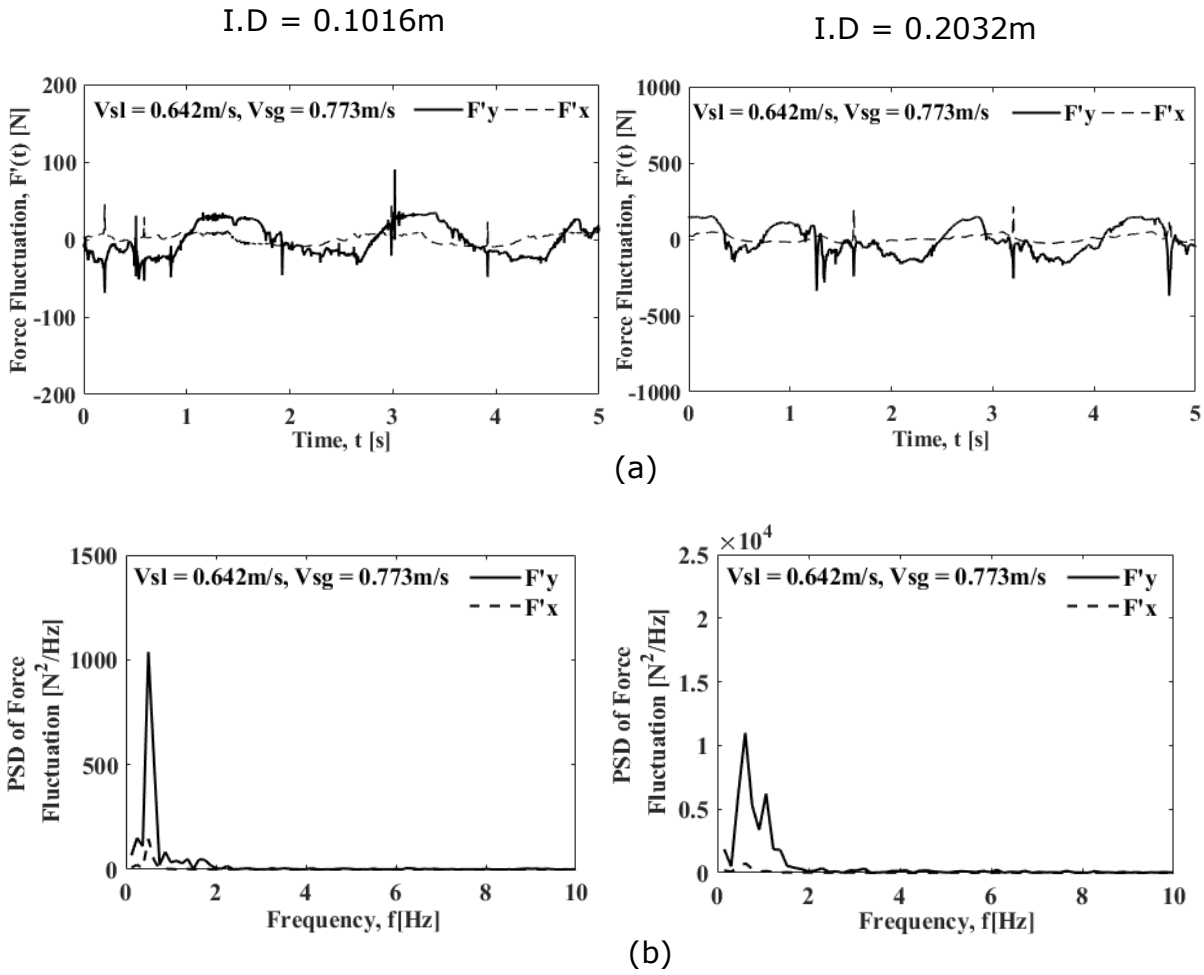


(a)

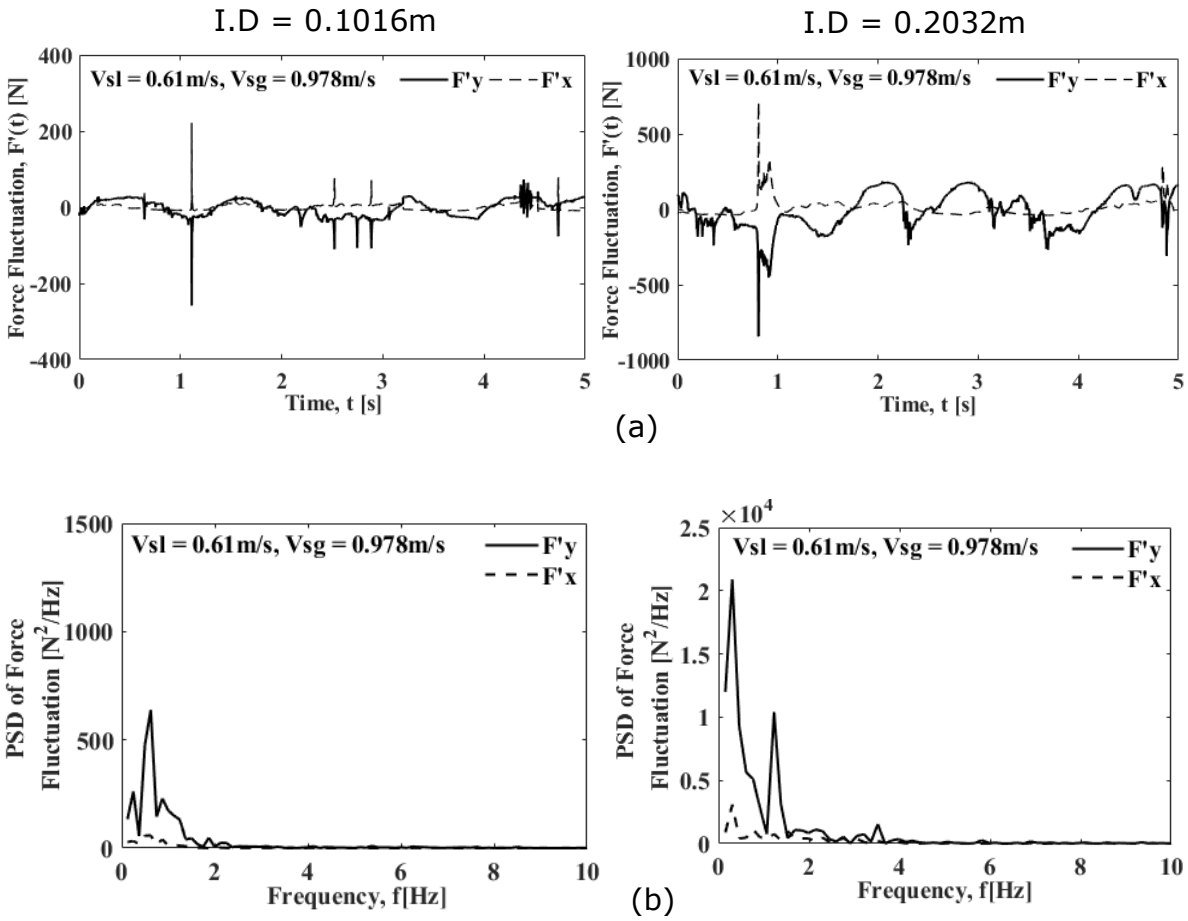


(b)

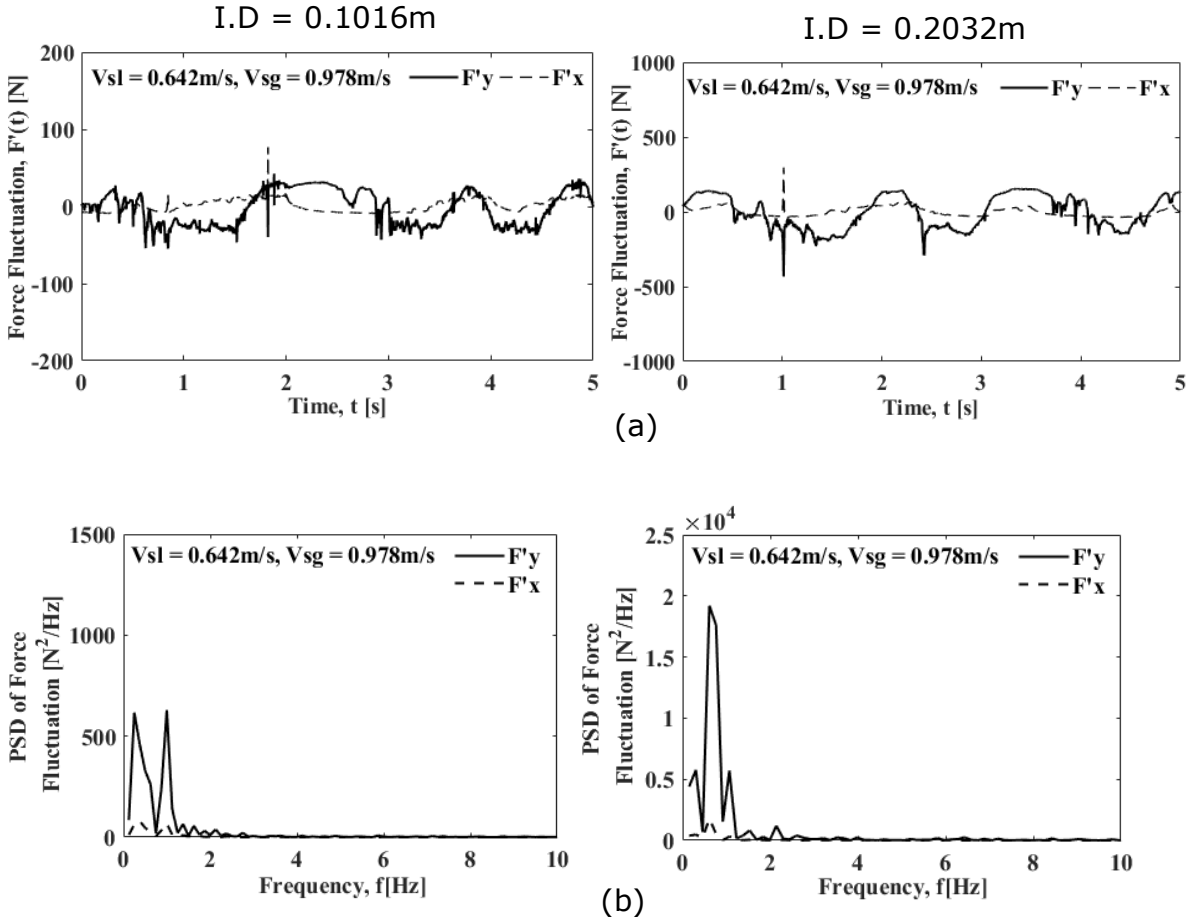
Supplementary Figure 10. (a) Force fluctuation and (b) PSD.



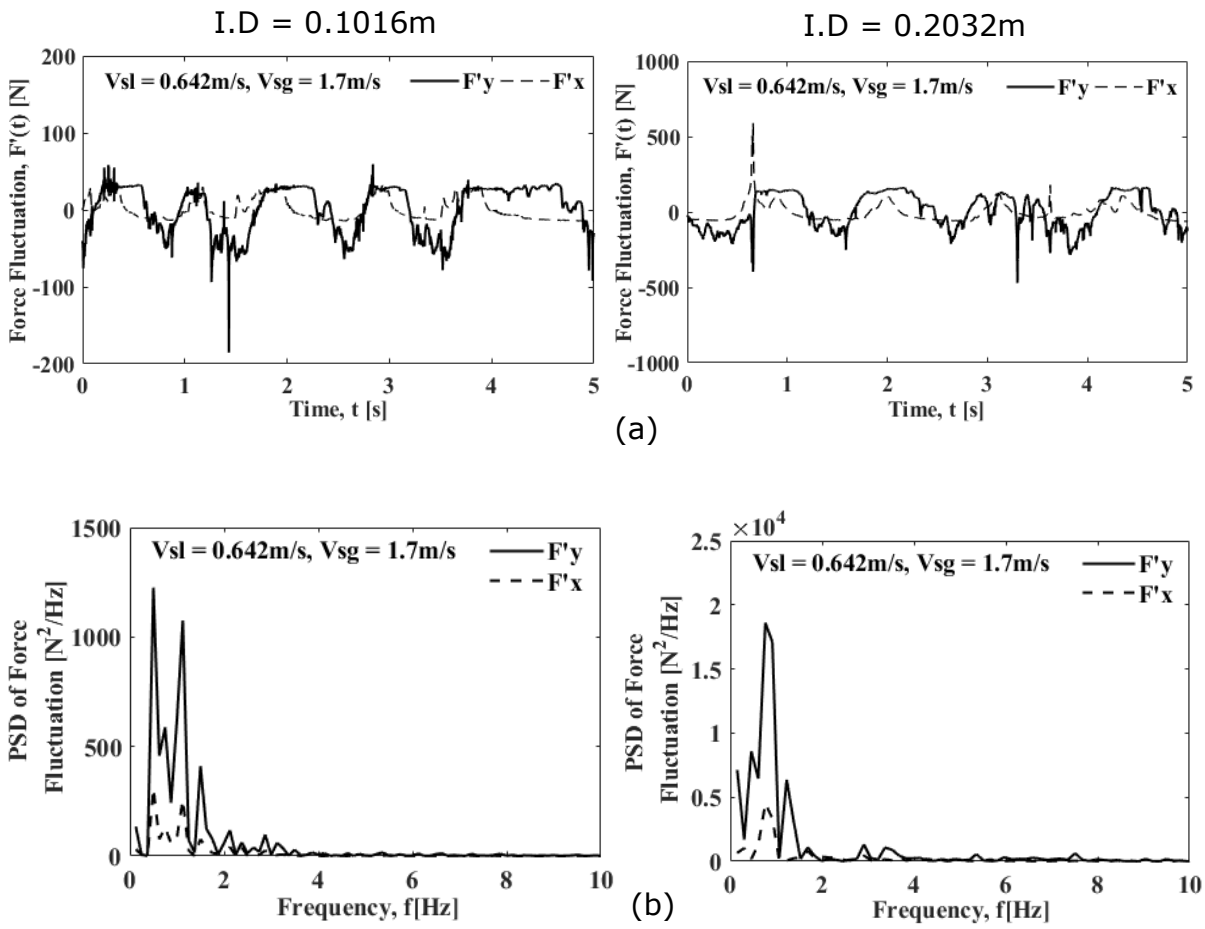
Supplementary Figure 11. (a) Force fluctuation and (b) PSD.



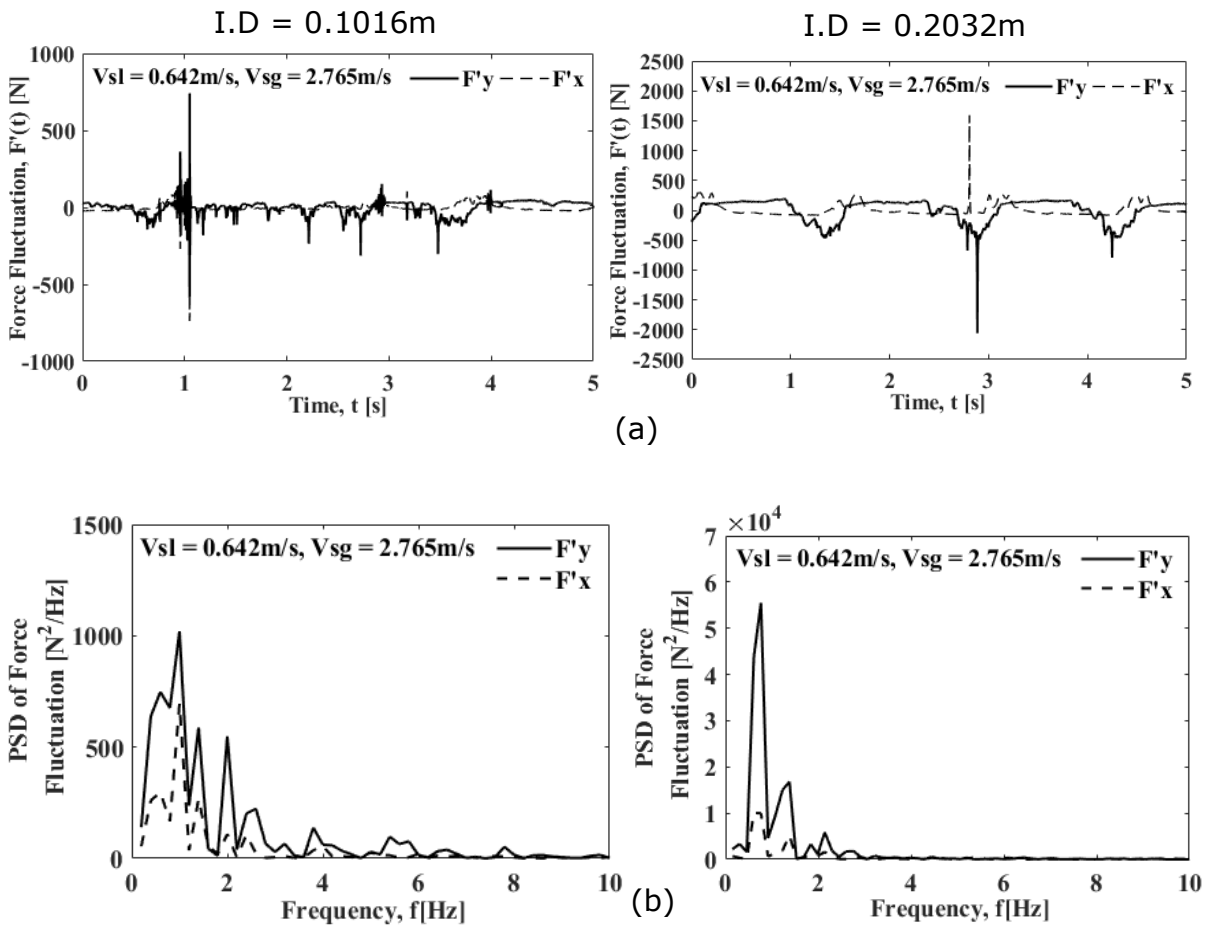
Supplementary Figure 12. (a) Force fluctuation and (b) PSD.



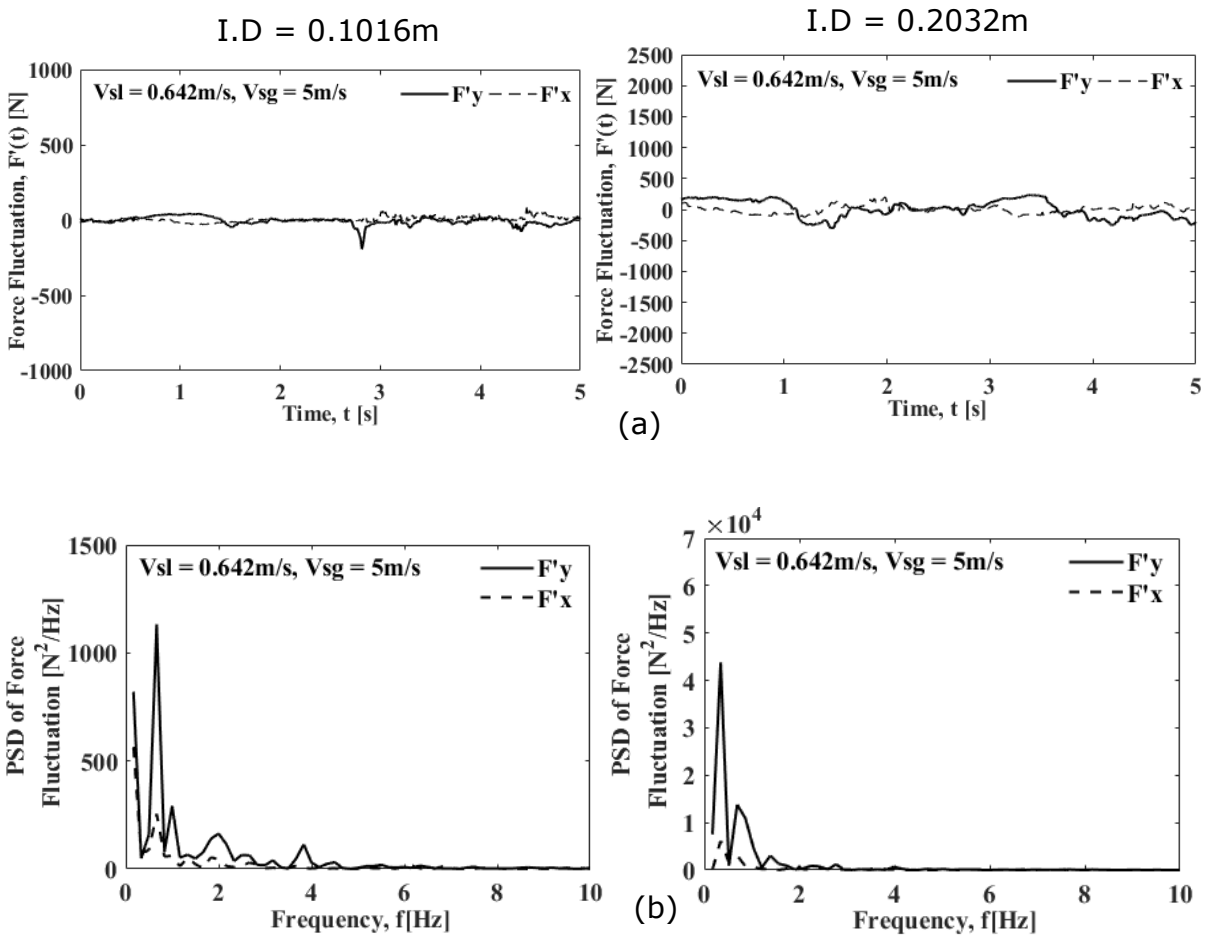
Supplementary Figure 13. (a) Force fluctuation and (b) PSD.



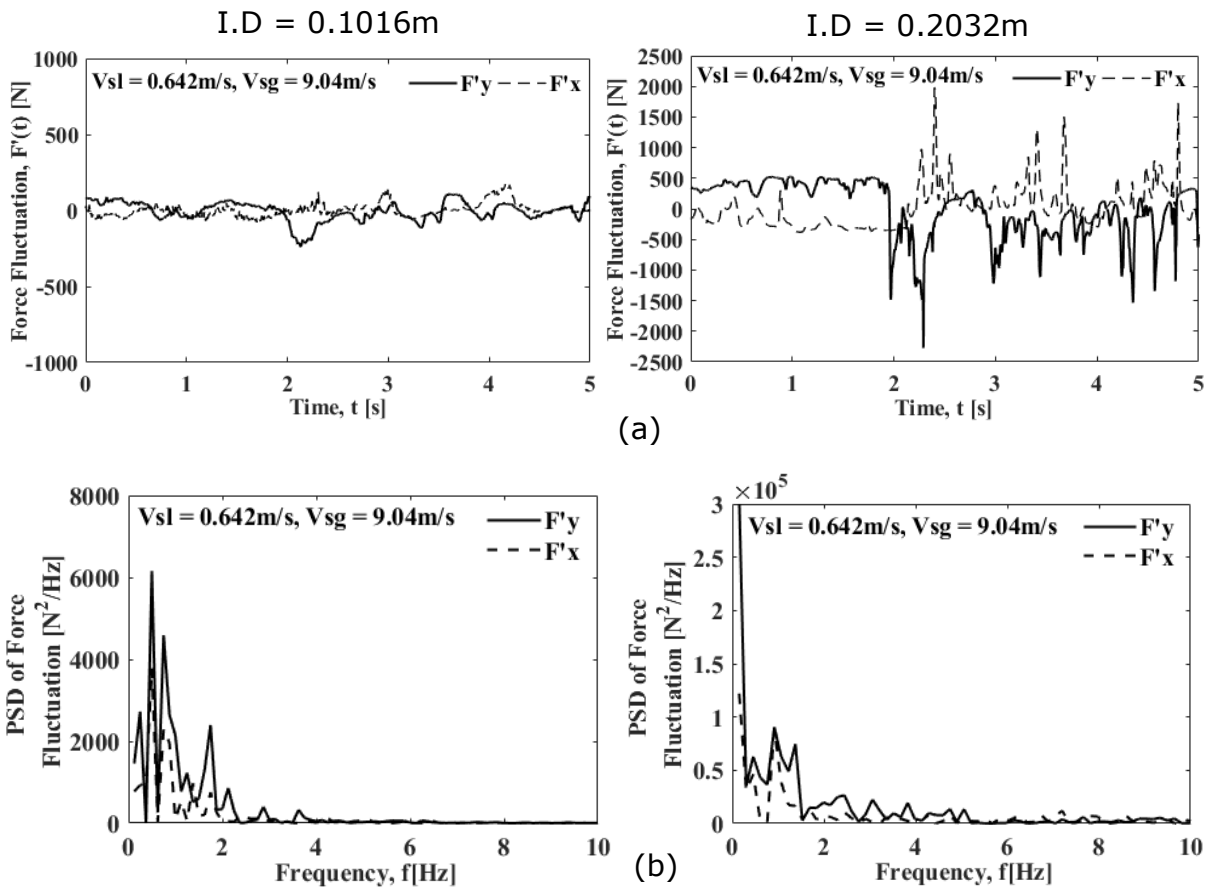
Supplementary Figure 14. (a) Force fluctuation and (b) PSD.



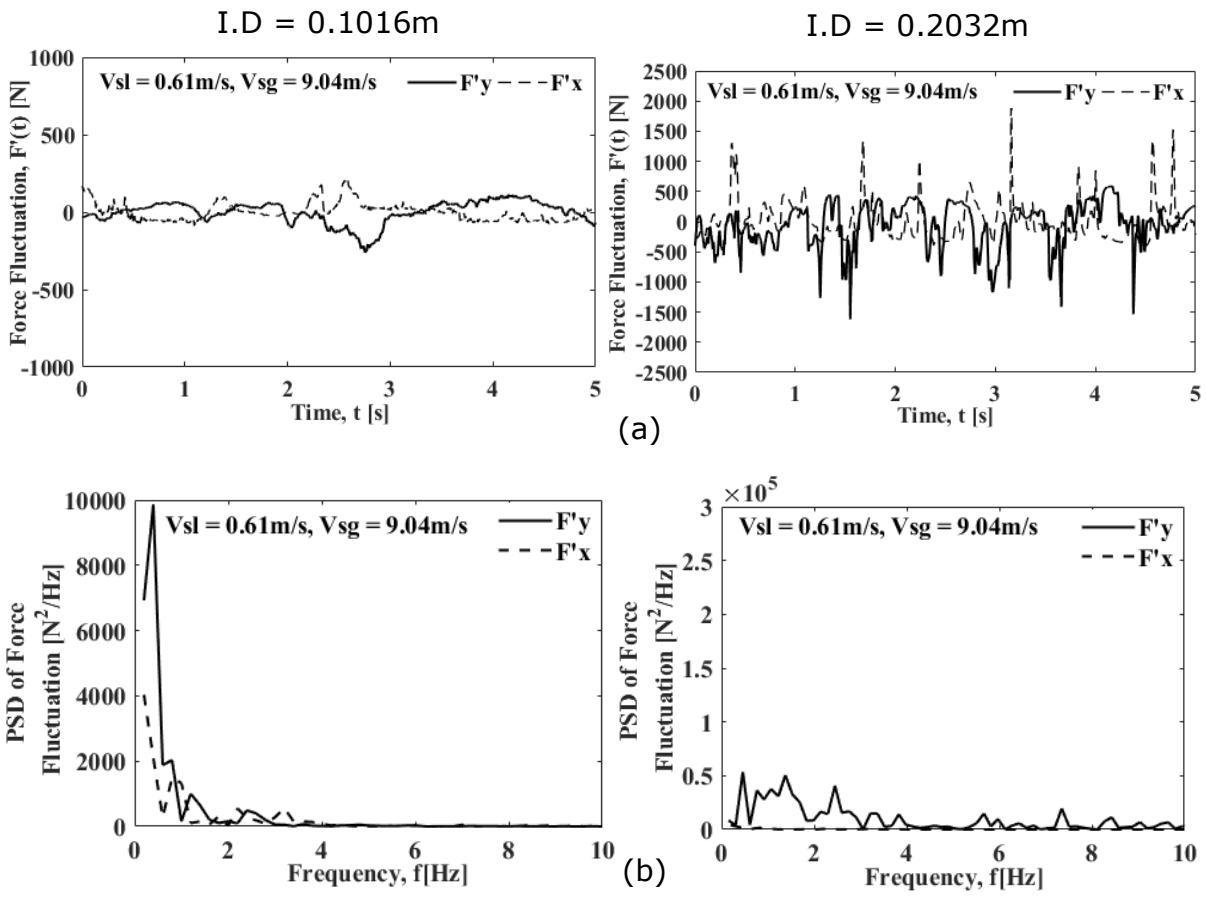
Supplementary Figure 15. (a) Force fluctuation and (b) PSD.



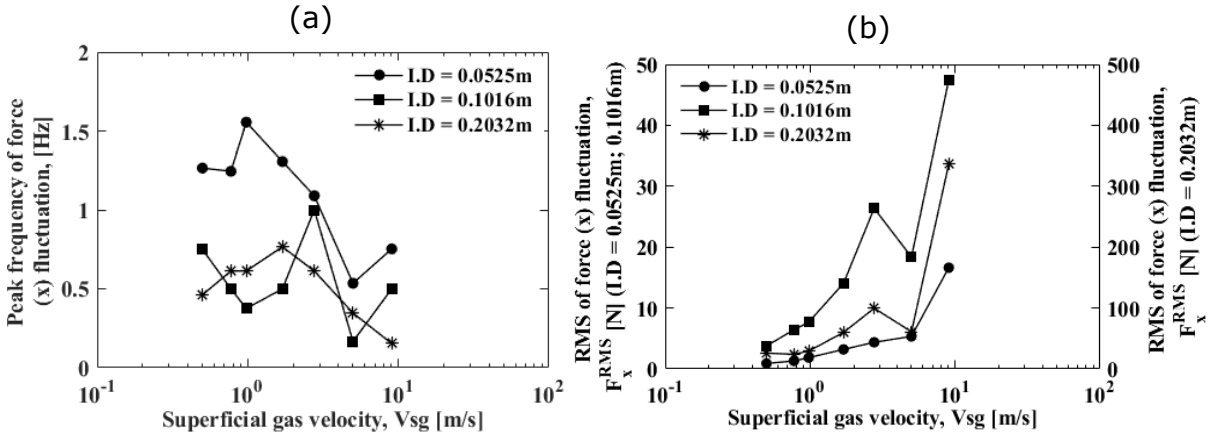
Supplementary Figure 16. (a) Force fluctuation and (b) PSD.



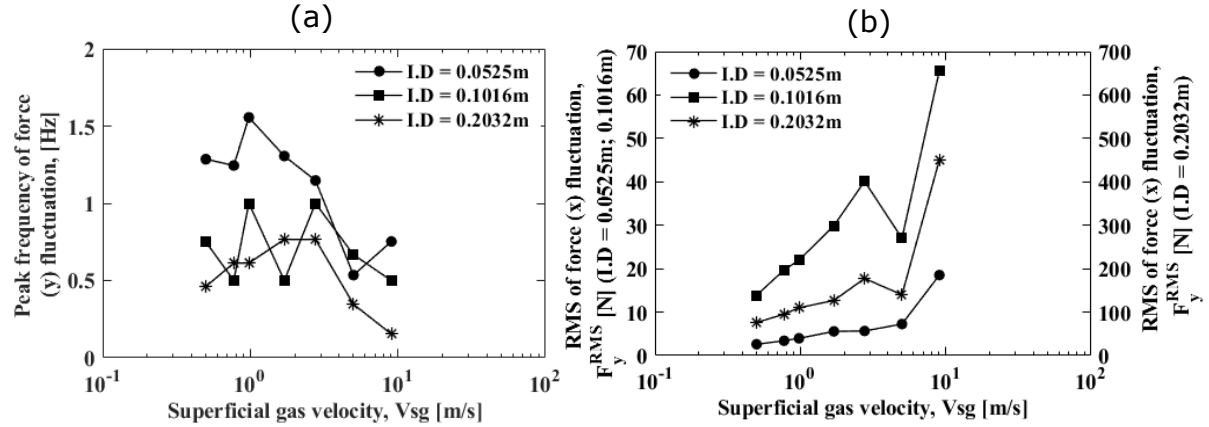
Supplementary Figure 17. (a) Force fluctuation and (b) PSD.



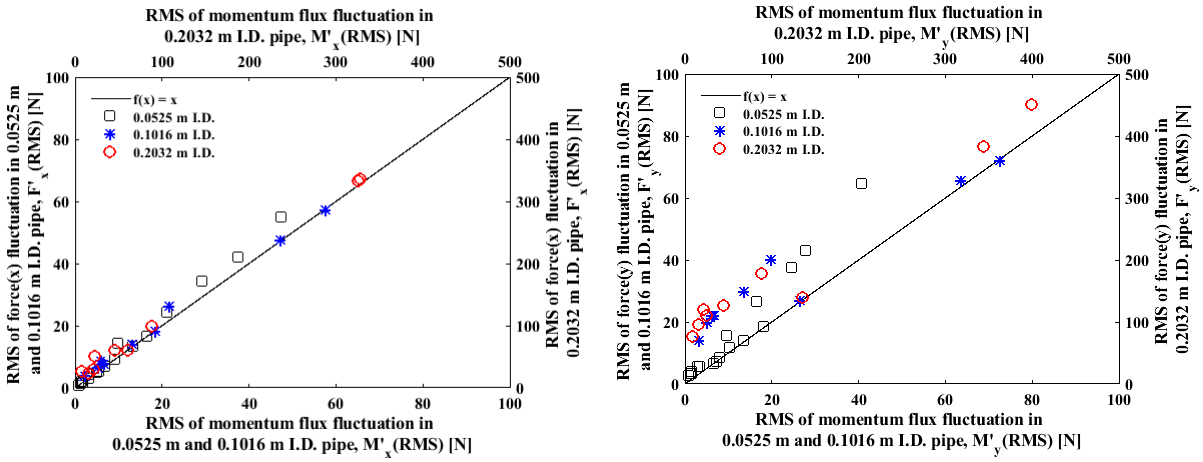
Supplementary Figure 18. (a) Force fluctuation and (b) PSD.



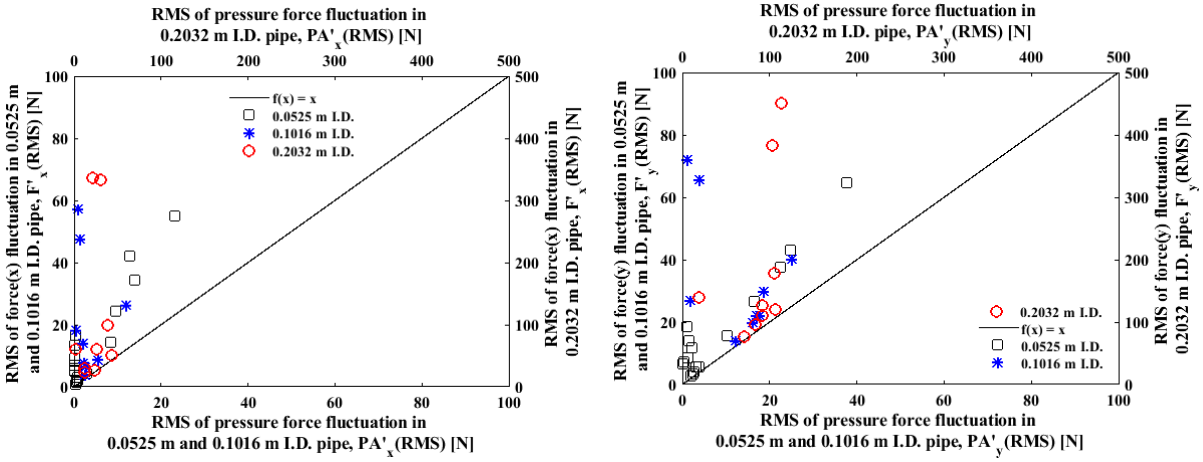
Supplementary Figure 19. The effect of superficial gas velocity on (a) peak frequency and (b) RMS values of x-component of force fluctuation.



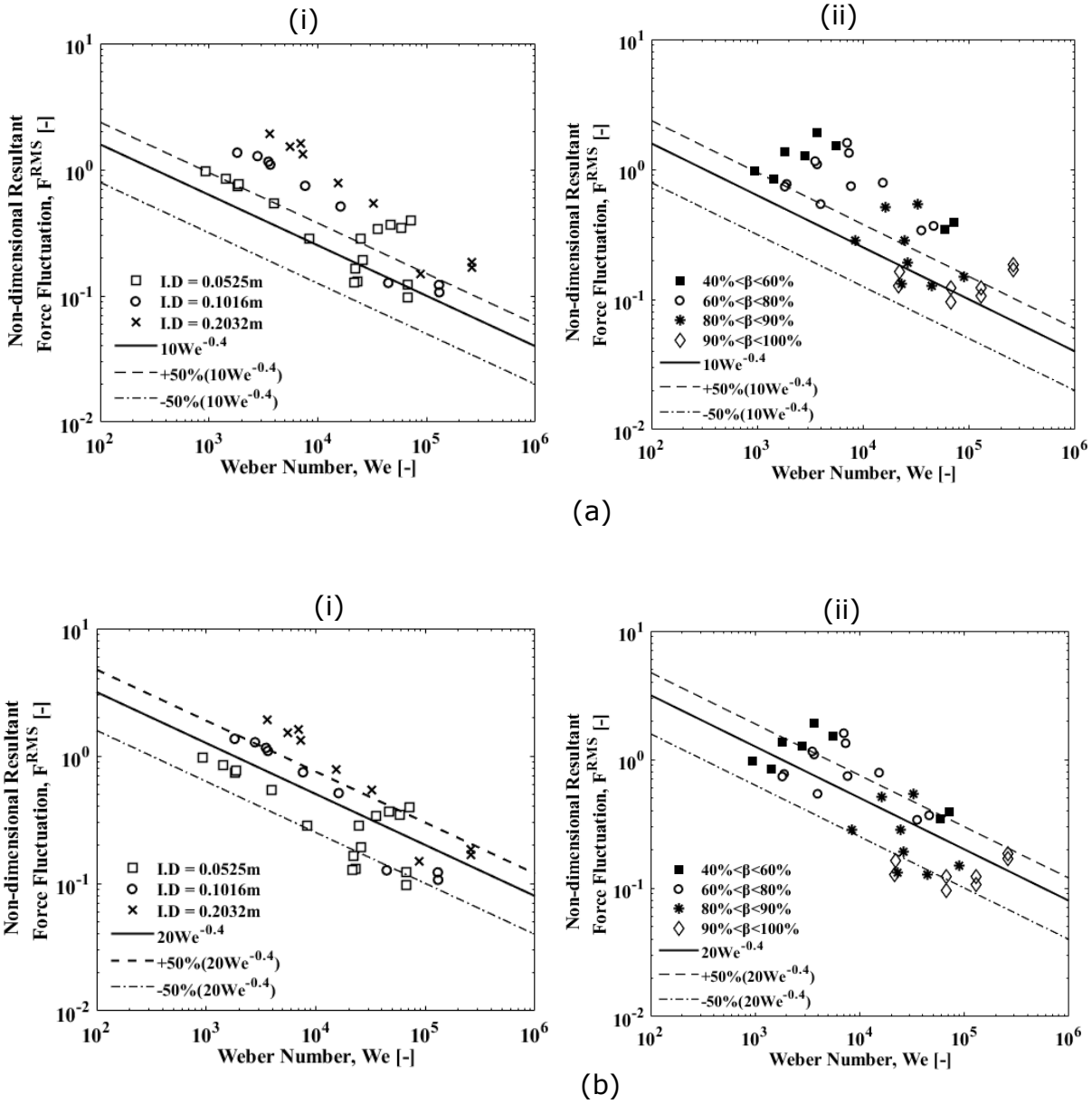
Supplementary Figure 20. The effect of superficial gas velocity on (a) peak frequency and (b) RMS values of y-component of force fluctuation.



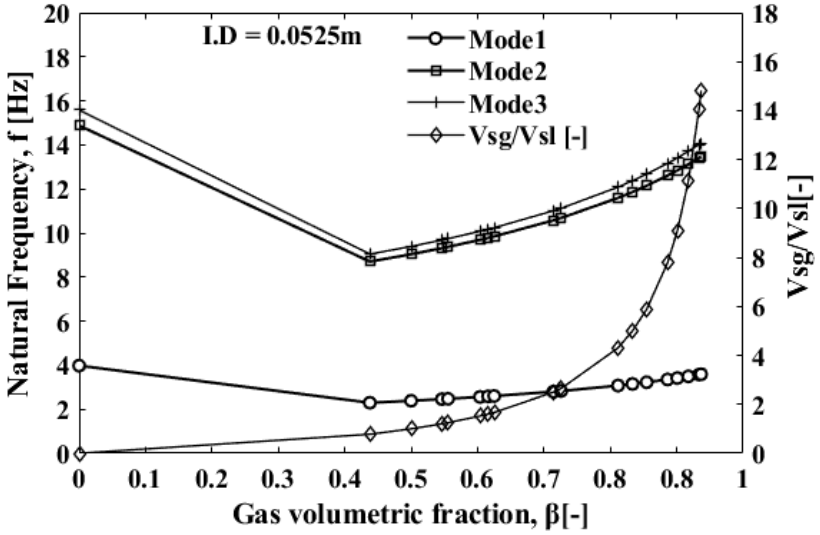
Supplementary Figure 21. Effect of pipe diameter on RMS values of momentum fluxes and total forces; (a) x-direction (b) y-direction.



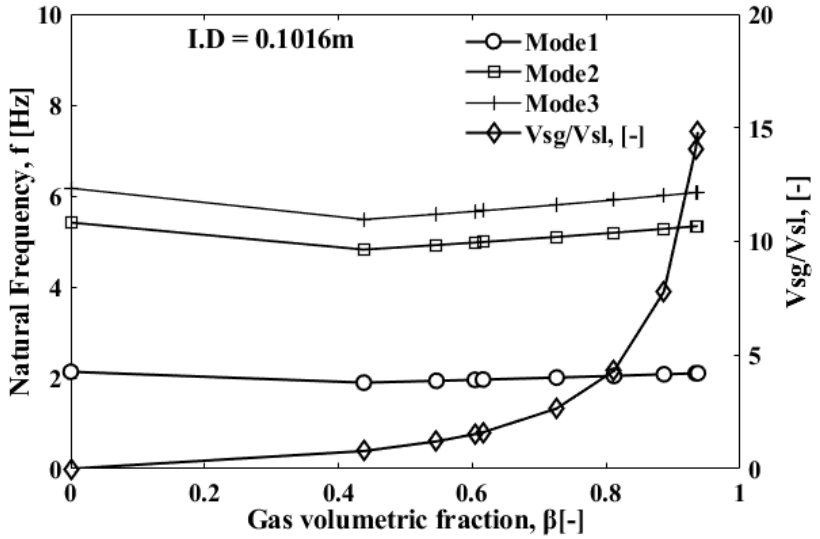
Supplementary Figure 22. Effect of pipe diameter on RMS values of pressure forces and total forces; (a) x-direction (b) y-direction.



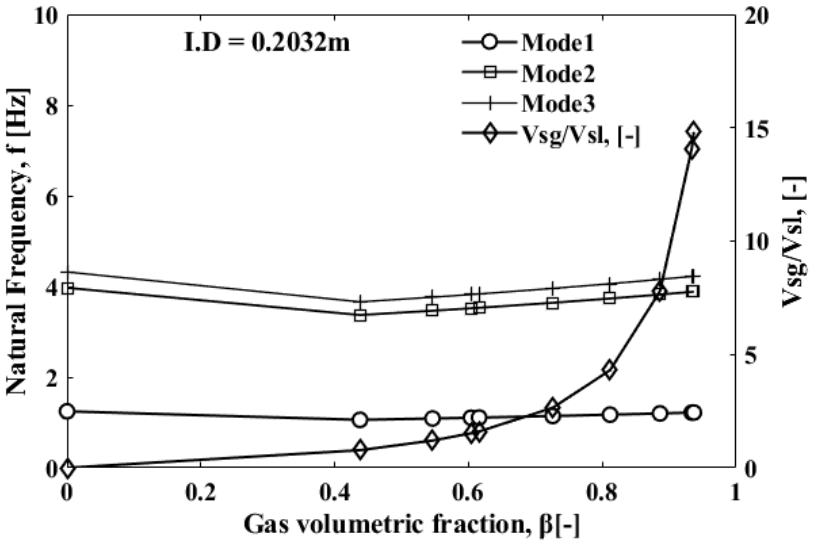
Supplementary Figure 23. Comparison of RMS values of fluctuating forces with Riverin et al.[11] correlation.


I.D = 0.0525m
Mode1
Mode2
Mode3
Vsg/Vsl [-]
Natural Frequency, f [Hz]
Vsg/Vsl[-]
Gas volumetric fraction, β[-]

(a)

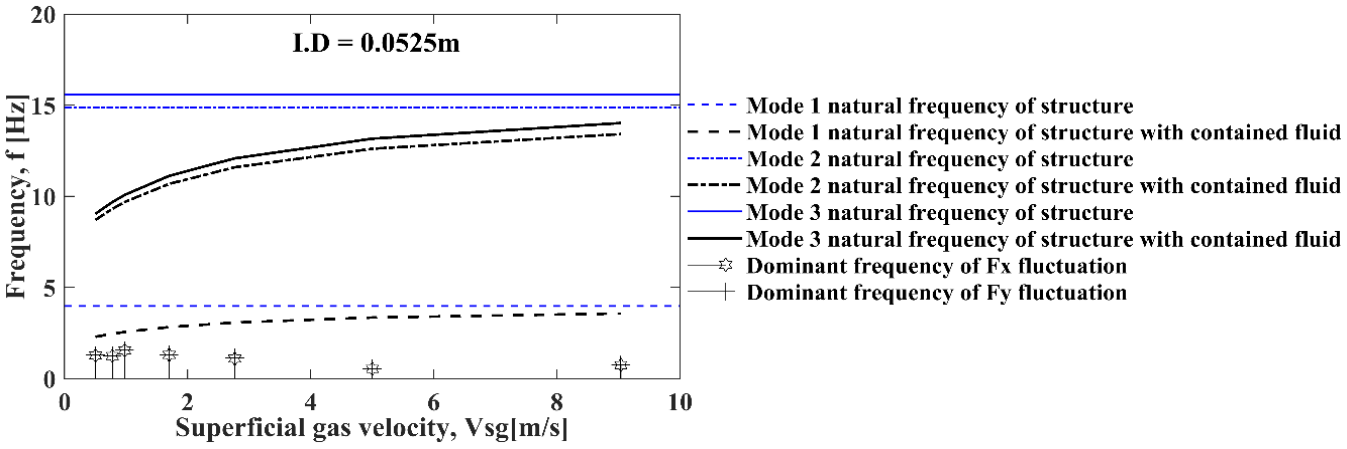

I.D = 0.1016m
Mode1
Mode2
Mode3
Vsg/Vsl, [-]
Natural Frequency, f [Hz]
Vsg/Vsl, [-]
Gas volumetric fraction, β[-]

(b)

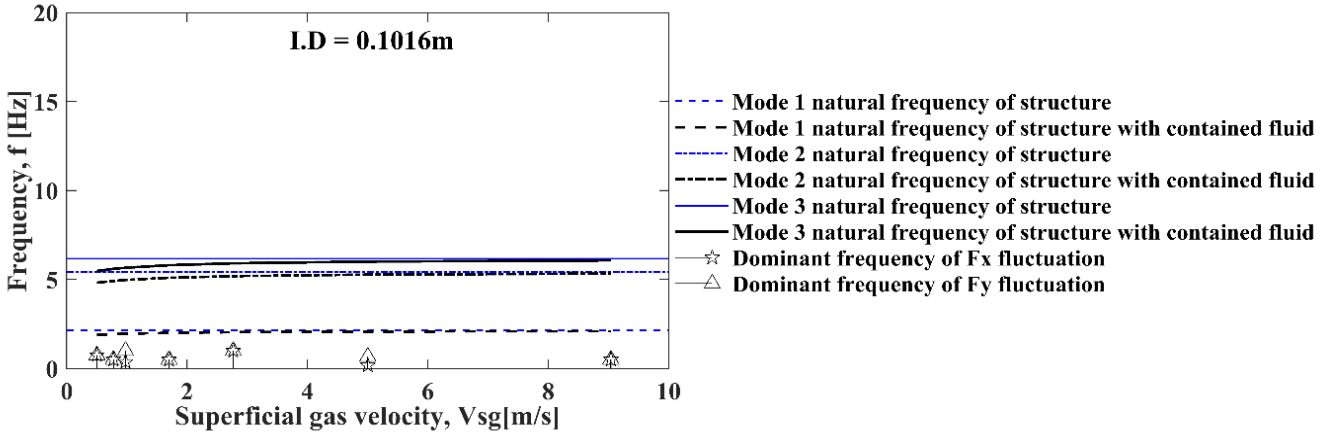


(c)

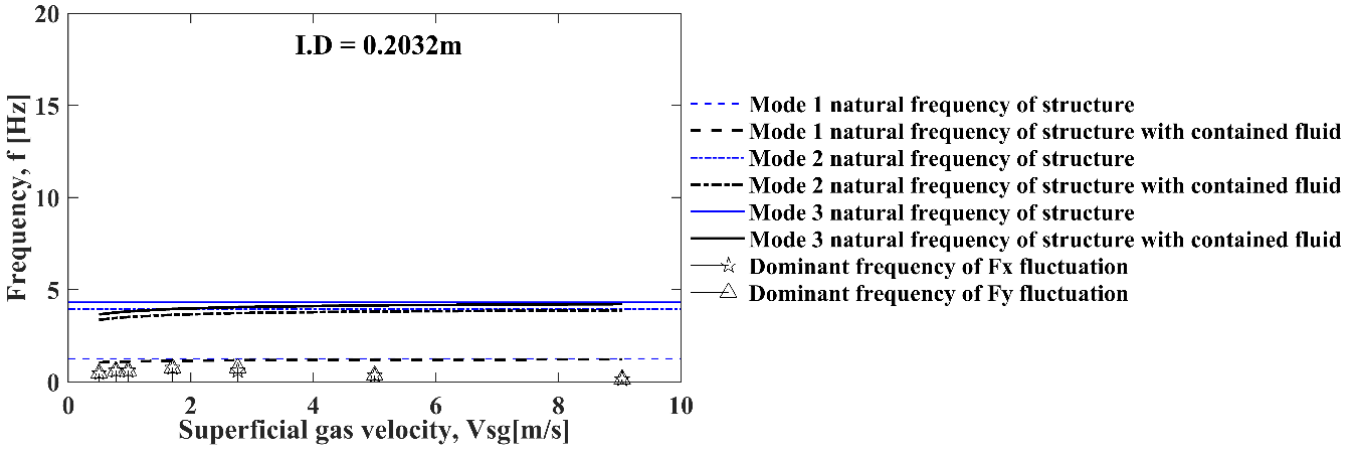
Supplementary Figure 24. The effect of gas volume fraction at inlet and the ratio of superficial velocities on the natural frequencies of pipes I.D. (a) 0.0525 (b) 0.1016 (c) 0.2032.



(a)



(b)



(c)

Supplementary Figure 25. Comparison of natural frequencies to the dominant frequencies of force fluctuations for I.D. (a) 0.0525m (b) 0.1016m (c) 0.2032m