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Characteristics of breakup of conical liquid sheets produced by spill-return pressure-swirl atomizers with different designs of spill orifice geometry

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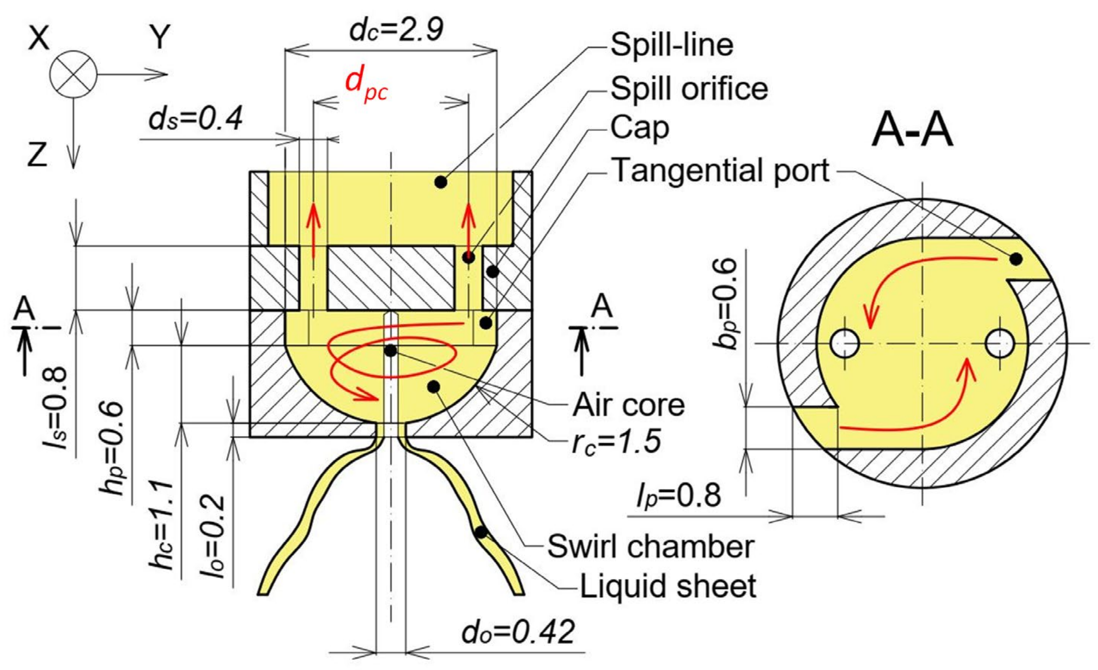
INTRODUCTION

• We in (Maly at al., Iclass 2018) investigated the spill design effect (the axial and off-axis spill orifices, their positioning, number and inclination) on spray characteristics of spill-return atomizers (SRAs). • The liquid sheet breakup process was found responsible for the differences in the spray quality. • So we applied proper orthogonal decomposition (POD) and PIV to investigate the high-speed video records of the near-nozzle liquid structures to find out more details. • Qs: 1) what is the character of the sheet development and its breakup mode in the fully-formed-sheet case, 2) what is the role of inlet pressure p_l spill-to-feed ratio (SFR) and nozzle geometry, 3) which of the factors dominantly modifies the breakup process?

EXPERIMENTAL

- Two atomizers C1 and C3, showing different sheet breakup character were studied here. They have identical internal geometry and differ in the axial distance of the SL orifice axes:
  - C1: SL orifice placed on outer boundary of the swirl chamber at pitch circle diameter d_{pc} = 2.2 mm,
  - C3: SL close to the chamber centreline at d_{pc} = 0.8 mm.
- The SRAs were tested on a cold test bench, the spraying process was documented using a high-speed imaging and phase-Doppler anemometry (PDA) for a range of: p_l = 0.25–1 MPa and SFR = 0–0.9.

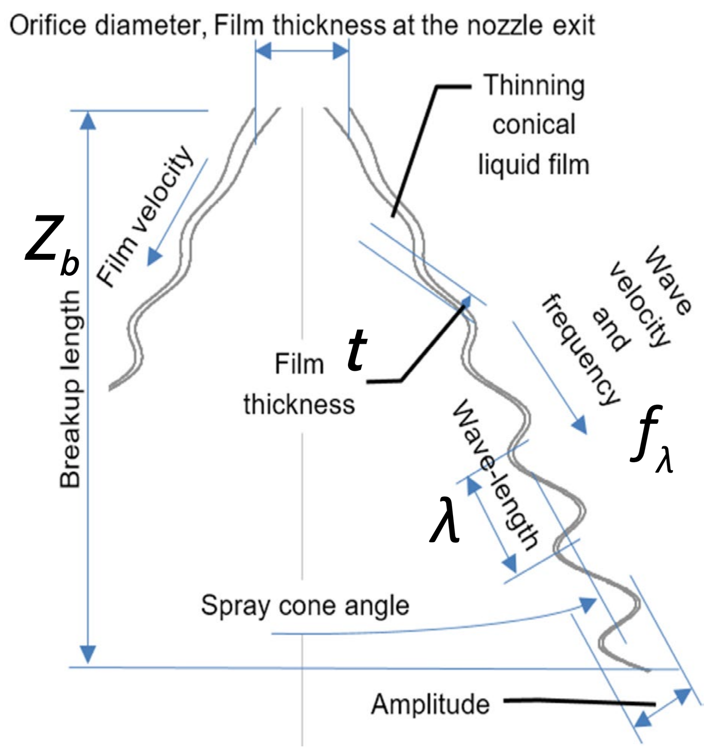
ATOMIZERS TESTED

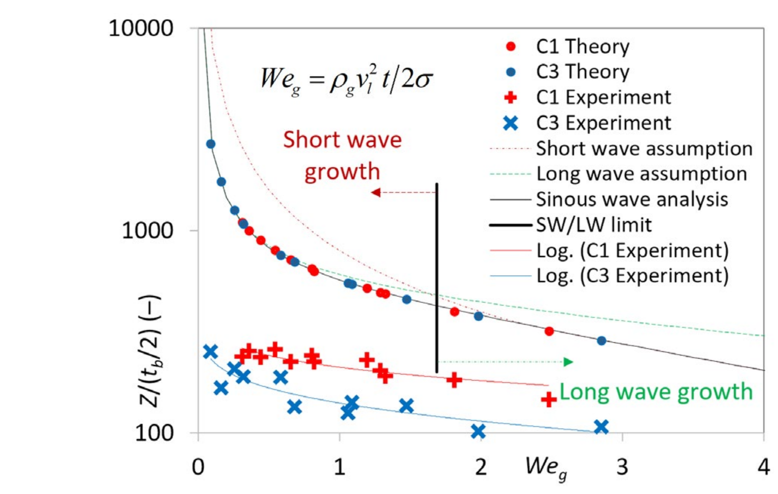


RESULTS

• Table 1. Main characteristics of the flow and spray

		C1						C3					
p_l	SFR	C_D^a	η_n^b	Z_b^c	t_o^d	λ	f_λ	C_D^a	η_n^b	Z_b^c	t_o^d	λ	f_λ
MPa	–	–	%	mm	µm	mm	kHz	–	%	mm	µm	mm	kHz
0.25	0.00	0.49	45	11.4	101	3.1	5.5	0.54	–	9.6	0	2.1	–
0.25	0.31	0.44	39	12.2	94	3.8	4.4	0.44	35	9.8	104	3.0	5.6
0.26	0.61	0.37	27	11.3	95	3.1	4.9	0.31	25	7.5	79	4.4	3.2
0.25	0.80	0.28	17	10.6	89	3.5	3.8	0.12	17	4.1	32	3.8	3.0
0.50	0.00	0.47	53	8.7	85	2.9	9.4	0.51	51	6.8	99	1.5	18.2
0.49	0.28	0.40	45	8.7	76	3.3	8.3	0.41	43	5.9	83	1.5	16.5
0.50	0.59	0.32	38	7.7	64	2.3	10.6	0.30	30	4.5	68	2.1	10.8
0.51	0.85	0.20	21	6.9	54	2.5	7.2	0.12	15	3.1	37	1.9	7.7
1.01	0.00	0.45	49	6.3	86	1.9	20.4	0.50	42	5.8	109	1.3	27.0
1.00	0.32	0.37	46	6.3	69	2.7	9.5	0.41	33	4.9	97	4.5	7.1
1.01	0.60	0.29	35	5.8	61	1.7	13.5	0.27	30	3.8	60	1.7	17.0
1.00	0.84	0.20	27	5.3	47	2.1	9.2	0.09	12	3.0	29	1.6	12.6

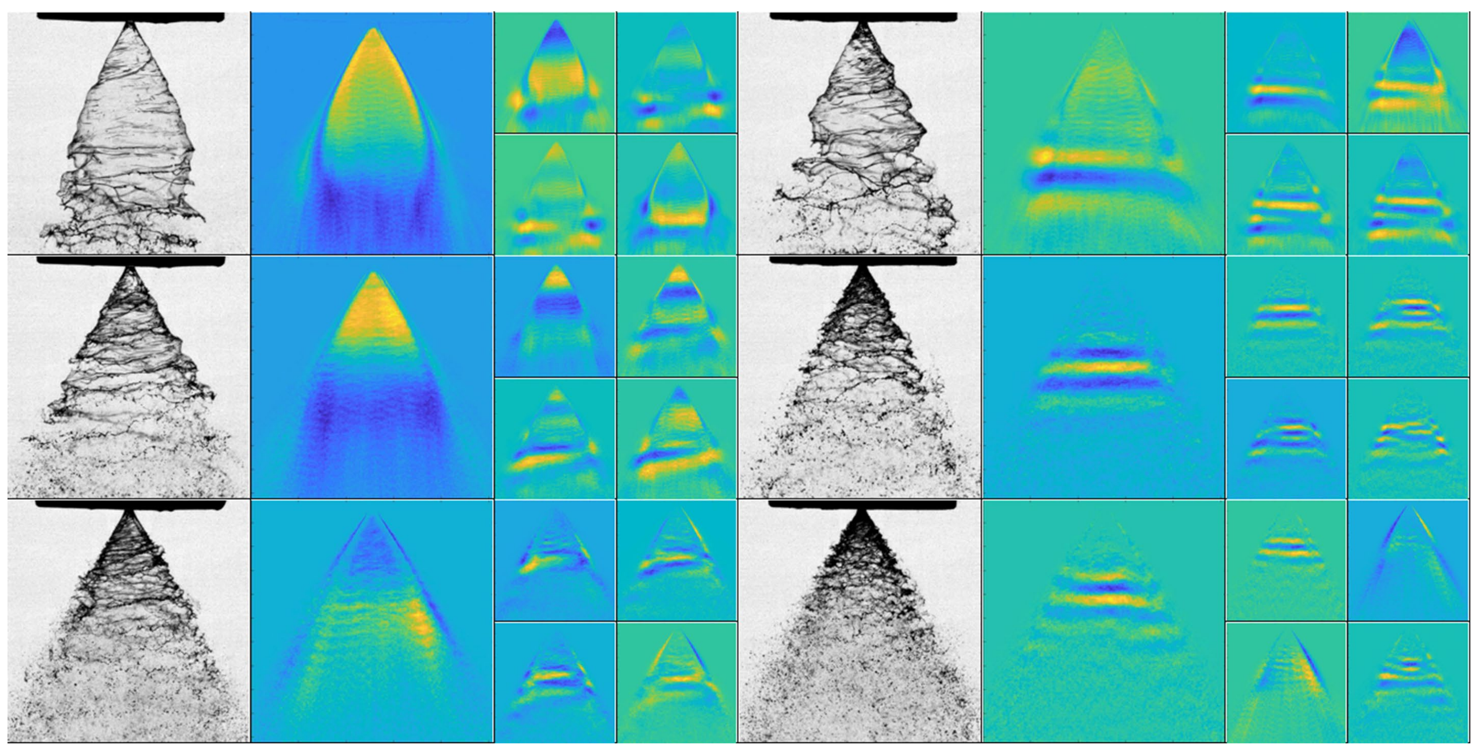




• Predicted dimensionless breakup length as a function of We_g, according to [Senecal et al., IJMF 1999] in comparison with the experimental data.

$$Z_b = 19.5 We_g^{-0.37} \sigma_{SCA}^{-1.58}$$

• The high-speed images were processed using POD to extract systematically hidden deterministic dynamic structure features.
• Its data compression removes smaller-scale and random sheet disturbations and extracts frequent structures.



• The deeply coloured alternately fashioned yellow/blue streaks represent areas of intense changes in image structures; they appear where: 1) the most intense waves form and amplify, 2) the sheet breaks up. The streak spatial frequency = λ.

CONCLUSION

• Characteristics of the liquid sheet and its breakup for two SRAs with different SL geometries successfully revealed using POD. • The breakup mode for both the atomizers differs; the long-wave regime applies in the C1 case, in agreement with theory while the short-wave breakup is attributed to the C3. The long/short mode transition is not triggered by the aerodynamic forces but by the internal flow instabilities. • The actual Z_b is smaller than the length predicted using the inviscid model in the C1 case and even more for C3. • The SL geometry and SFR affect the internal flow and the sheet and spray characteristics. The radial position of the SL orifices crucially affects the spray quality and stability of SRAs.

ACKNOWLEDGEMENT

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