Contactless Generation and Trapping of Hydrodynamic Knots in Sessile Droplets by Acoustic Screw Dislocations

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1 Global Definitions

1.1 PARAMETERS

PARAMETERS 1

Name	Expression	Value	Description
cl	1910[m*s^ - 1]	1910 m/s	acoustic velocity in liquid
rhol	1230[kg/m^3]	1230 kg/m³	liquid density
mul	0.156[Pa*s]	0.156 Pa·s	viscosity of liquid
b	2.5	2.5	
radius	rc/sin(thetac)	0.001 m	droplet radius
thetac	90[deg]	1.5708 rad	droplet contact Angle
height	-radius*cos(thetac)	−6.1232E−20 m	droplet position_height
rc	0.001[m]	0.001 m	
frequency	20[MHz]	2E7 Hz	
omega	2*pi*frequency	1.2566E8 Hz	
l	15	15	
kSAW	omega/cs	36069 1/m	K
Zs	rhos*cs	1.6201E7 kg/(m²·s)	
rhos	4650 [kg/m^3]	4650 kg/m³	LN density
cs	3484 [m/s]	3484 m/s	acoustic velocity in LN
k2	omega^2/(cl^2*(1 + 1i*omega*ts))	(4.3281E9 − 4.7272E7i) 1/m²	
ts	b*nu/(cl^2)	8.6915E−11 s	
nu	mul/rhol	1.2683E−4 m²/s	
lambda	cl/frequency	9.55E−5 m	
vhydro	0.1[m/s]	0.1 m/s	
sigma0	70[mN/m]	0.07 N/m	

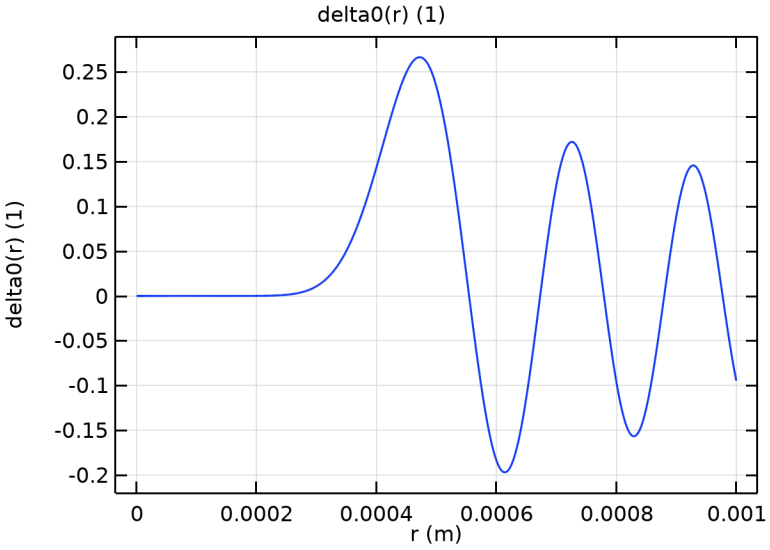
Name	Expression	Value	Description
OMEG	2.3*sqrt(sigma0/(radius^3*rhol))	548.69 1/s	
Fmech	OMEG/(2*pi)	87.326 1/s	
A0	u0_GDPT*5.22[nm]/u0_LDV	5.22E−10 m	amplitude of bessel function
omega_cap	sqrt(sigma0*omega^3/(cl^3*rhol))	1.2731E5 1/s	
h0	l*tanalpha*tau^2/(2*kSAW)	4.3555E−5 m/s^2	PRE2014 cyclones
tau	b*A0^2*omega^3/(cl^2)	0.37055 1/s	
kl0	omega/cl	65793 1/m	
kz	sqrt(kl0^2 - kSAW^2)	55025 1/m	
tanalpha	kz/kSAW	1.5255	
H0	h0*Vd	9.1031E−14 m^4/s^2	
Vd	2.09[ul]	2.09E−9 m^3	
Omega_theta_star	0.5*omega^3*b*tanalpha*A0^2/cl^2	0.28264 1/s	for nomlization
Kr1	kSAW*rc	36.069	PRE2014 cyclones
F0	I0*omega^2*nu*b/cl^4	3803.2 N/m^3	estimate force
I0	rhol*cl*omega^2*A0^2	10109 W/m^2	
v0	F0*(rc/2)^2/mul	0.0060948 m/s	
u0_LDV	500[mV]	0.5 V	voltage during ldv calib pp before 5W ampl
u0_GDPT	50[mV]	0.05 V	voltage during gdpt calib pp before 5W ampl

1.2 FUNCTIONS

1.2.1 Analytic 1

Function name	delta0

Function type	Analytic



Analytic 1

2 Model

2.1 DEFINITIONS

2.1.1 Variables

Variables 1a

SELECTION

Geometric entity level	Entire model

Name	Expression	Unit	Description
vr_ac	1i*pr/(rhol*omega)	m/s	
vtheta_ac	l*p/(rhol*omega*(r + 0.0001*R))	m/s	
vz_ac	1i*pz/(rhol*omega)	m/s	
V_ac	abs(p)^2/(4*rhol*cl^2)	Pa	
K_ac	0.25*rhol*(abs(vr_ac)^2 + abs(vz_ac)^2 + abs(vtheta_ac)^2)	Pa	
L_ac	K_ac - V_ac	Pa	
E_ac	K_ac + V_ac	Pa	
Ir	realdot(p, vr_ac)	W/m^2	
Iz	realdot(p, vz_ac)	W/m^2	
Itheta	realdot(p, vtheta_ac)	W/m^2	
Fr	omega^2*nu*b*Ir/cl^4	N/m^3	
Fz	omega^2*nu*b*Iz/cl^4	N/m^3	
Ftheta	omega^2*nu*b*Itheta/cl^4	N/m^3	
Fn	sqrt(Fr^2 + Ftheta^2 + Fz^2)	N/m^3	

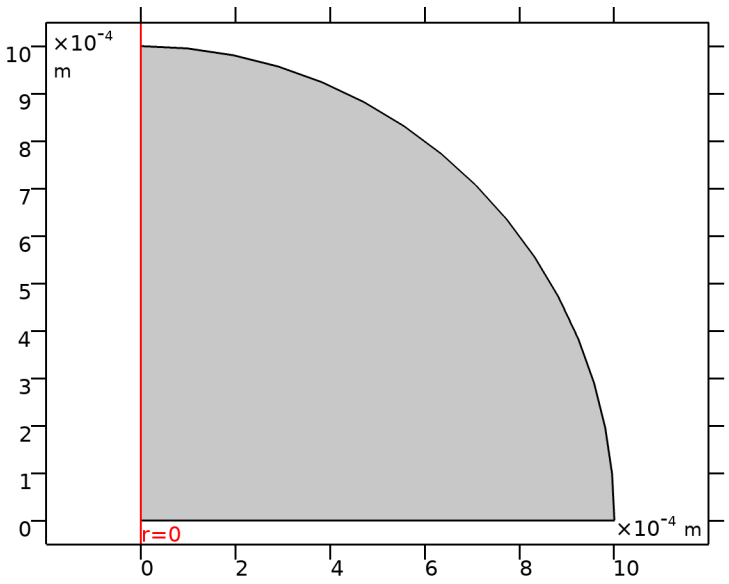
Variables 2

SELECTION

Geometric entity level	Entire model

Name	Expression	Unit	Description
helicity	u*spf.vorticityr + v*spf.vorticityphi + w*spf.vorticityz	m/s^2	

2.2 GEOMETRY 1



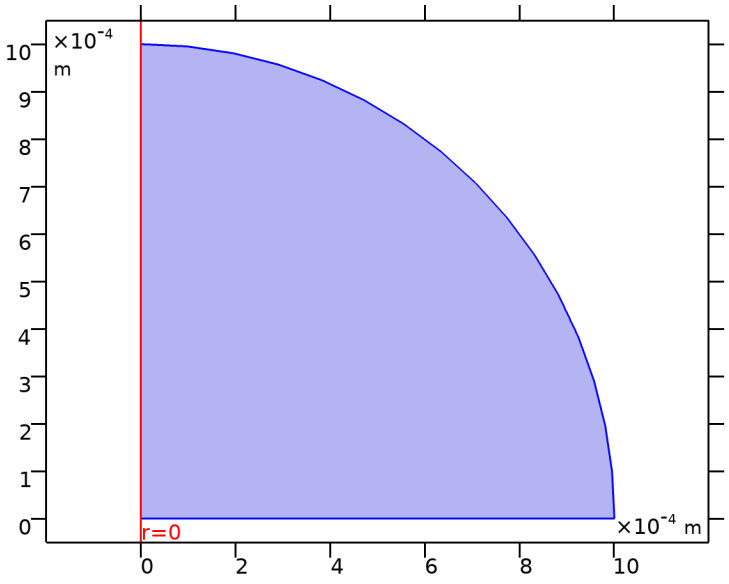
Geometry 1

UNITS

Length unit	m
Angular unit	deg

2.3 MATERIALS

2.3.1 droplet fluid

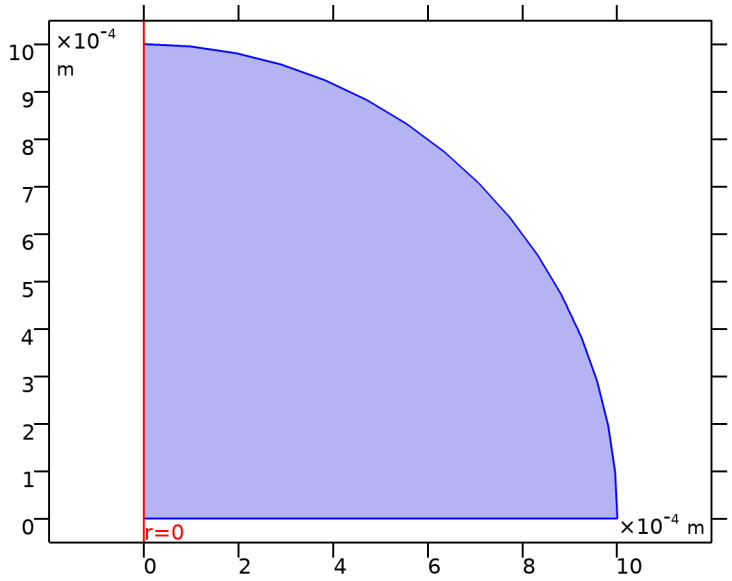


droplet fluid

SELECTION

Geometric entity level	Domain
Selection	Domain 1

2.4 PDE



PDE

FEATURES

Coefficient Form PDE 1
Zero Flux 1
Initial Values 1
Dirichlet Boundary Condition 2
Flux/Source 2

2.4.1 Coefficient Form PDE 1

EQUATIONS

$$e_a\frac{\partial^2 p}{\partial t^2}+d_a\frac{\partial p}{\partial t}+\nabla\cdot(-c\nabla p-\alpha p+\gamma)+\beta\cdot\nabla p+ap=f$$

$$\nabla=[\frac{\partial}{\partial r},\frac{\partial}{\partial z}]$$

2.4.2 Zero Flux 1

EQUATIONS

$$-\mathbf{n}\cdot(-c\nabla p-\alpha p+\gamma)=0$$

$$\nabla=[\frac{\partial}{\partial r},\frac{\partial}{\partial z}]$$

2.4.3 Dirichlet Boundary Condition 2

EQUATIONS

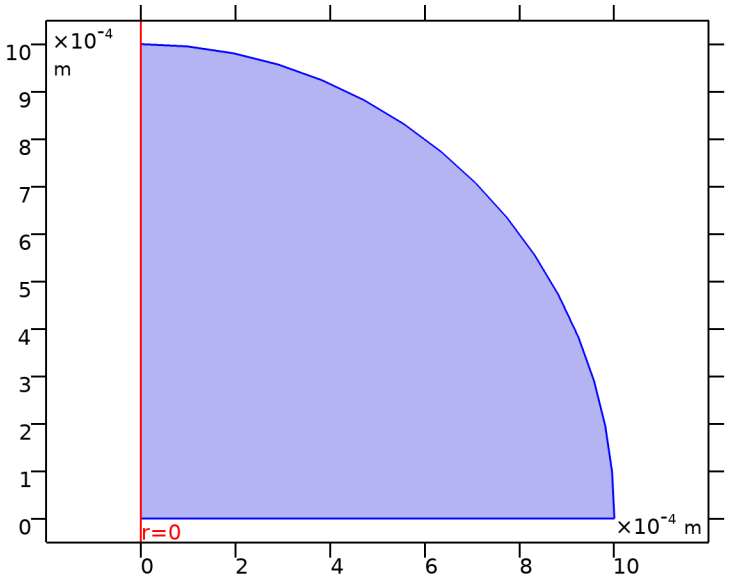
$$p = r$$
$$g_{\text{reaction}} = -\mu$$

2.4.4 Flux/Source 2

EQUATIONS

$$-\mathbf{n} \cdot (-c\nabla p - \alpha p + \gamma) = g - qp$$
$$\nabla = [\frac{\partial}{\partial r}, \frac{\partial}{\partial z}]$$

2.5 LAMINAR FLOW



Laminar Flow

EQUATIONS

$$\rho(\mathbf{u} \cdot \nabla)\mathbf{u} = \nabla \cdot [-p2\mathbf{I} + \mathbf{K}] + \mathbf{F}$$
$$\rho\nabla \cdot (\mathbf{u}) = 0$$
$$\mathbf{K} = \mu\left(\nabla\mathbf{u} + (\nabla\mathbf{u})^{\mathrm{T}}\right)$$

FEATURES

Fluid Properties 1
Initial Values 1
Axial Symmetry 1
Wall 1
Wall 2

Volume Force 2
Pressure Point Constraint 1

2.5.1 Fluid Properties 1

EQUATIONS

$$\rho(\mathbf{u}\cdot\nabla)\mathbf{u} = \nabla\cdot[-p2\mathbf{I}+\mathbf{K}] + \mathbf{F}$$
$$\rho\nabla\cdot(\mathbf{u}) = 0$$
$$\mathbf{K} = \mu\left(\nabla\mathbf{u} + (\nabla\mathbf{u})^{\mathrm{T}}\right)$$

2.5.2 Wall 1

EQUATIONS

$$\mathbf{u}\cdot\mathbf{n} = \mathbf{u}_{\mathrm{bnd}}\cdot\mathbf{n}$$
$$\mathbf{K_n} - (\mathbf{K_n}\cdot\mathbf{n})\mathbf{n} = \mathbf{0},\ \mathbf{K_n} = \mathbf{Kn}$$

2.5.3 Wall 2

EQUATIONS

$$\mathbf{u} = \mathbf{u}_{\mathrm{tr}}$$

2.5.4 Volume Force 2

EQUATIONS

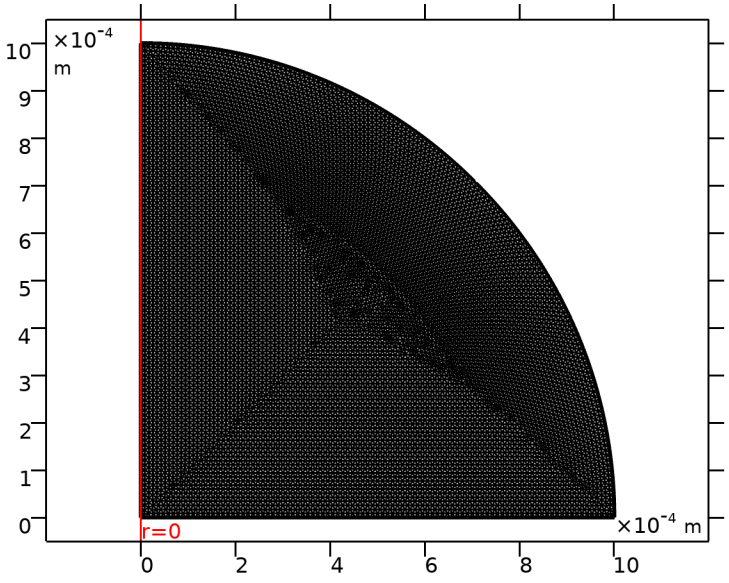
$$\rho(\mathbf{u}\cdot\nabla)\mathbf{u} =$$
$$\nabla\cdot[-p2\mathbf{I}+\mathbf{K}] + \mathbf{F}$$

2.5.5 Pressure Point Constraint 1

EQUATIONS

$$p2 = p_0$$

2.6 MESH 1



Mesh 1

Description	Value
Include geometric nonlinearity	On

VALUES OF DEPENDENT VARIABLES

Description	Value
Settings	User controlled
Method	Solution
Study	Study 1

MESH SELECTION

Geometry	Mesh
mesh1	mesh1

PHYSICS AND VARIABLES SELECTION

Physics interface	Discretization
Laminar Flow (spf)	physics

MESH SELECTION

Geometry	Mesh
Geometry 1 (geom1)	mesh1