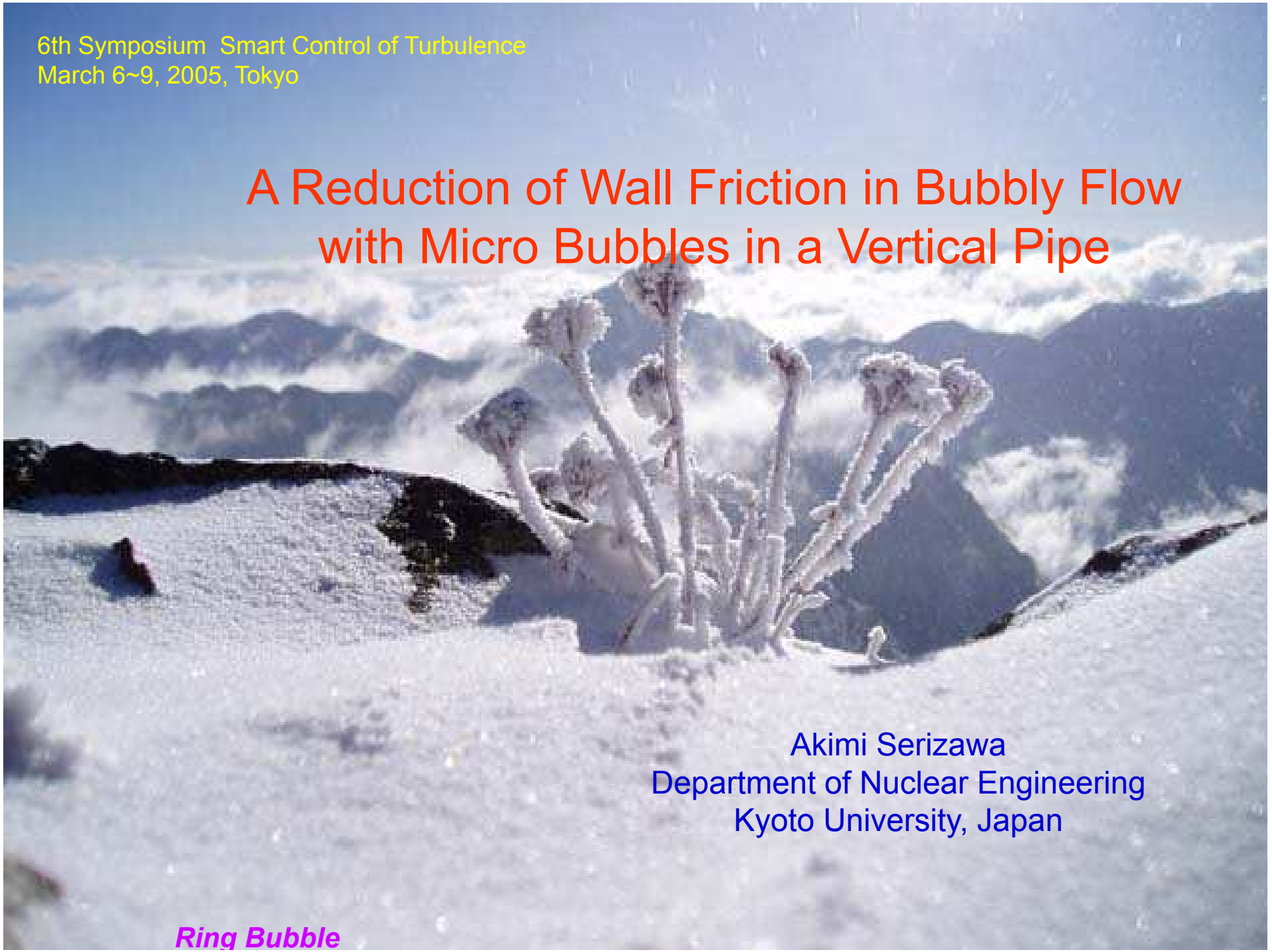
6th Symposium Smart Control of Turbulence
March 6~9, 2005, Tokyo

A Reduction of Wall Friction in Bubbly Flow with Micro Bubbles in a Vertical Pipe



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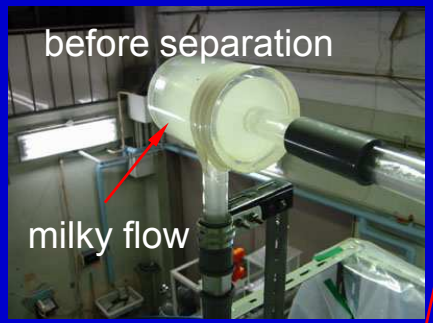
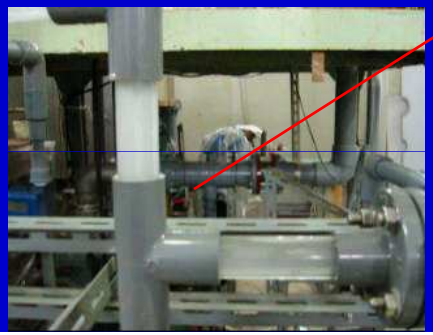
Ring Bubble

Air-Water Test Loop

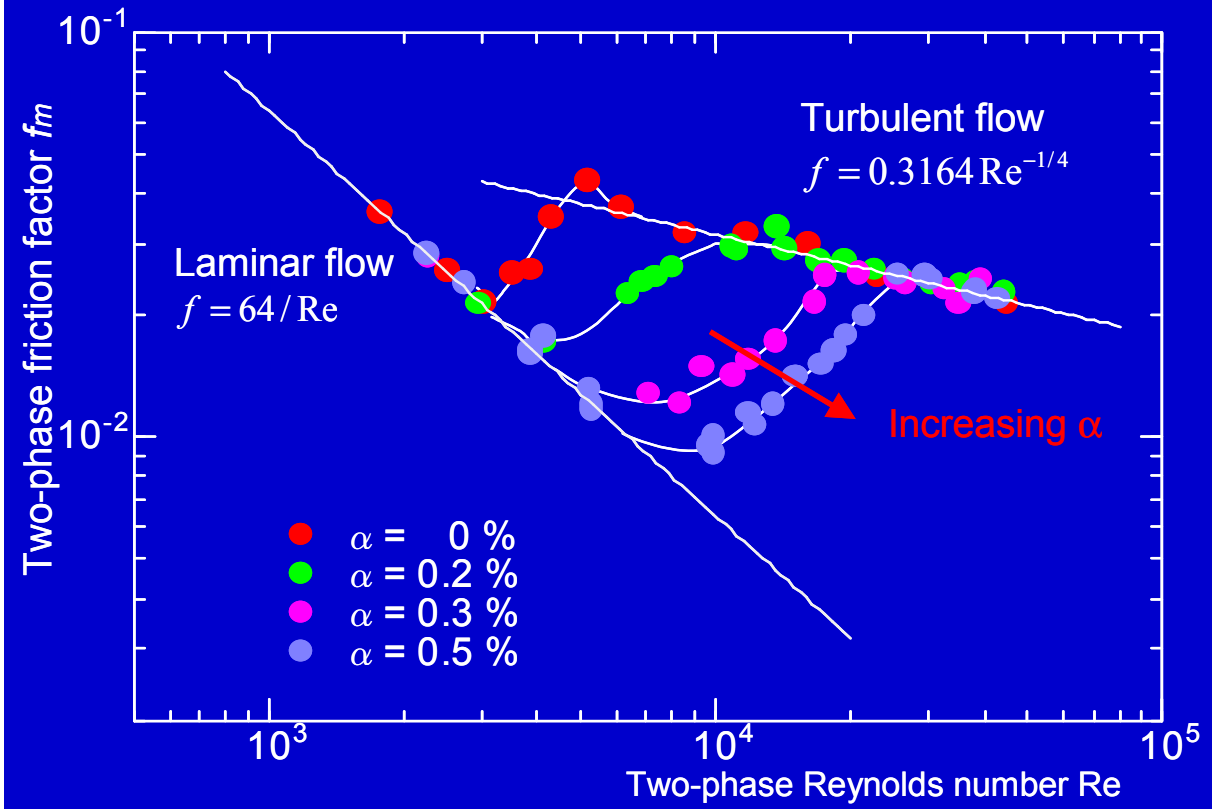




separator
air
sampling tank
storage tank
pressure gauge
Temperature control unit
Local parameters measurement
pressure drop measurement
500
1000
2000
test section
bypath line
fm
fm
pressure gauge
fm
micro-bubble generator
pump
air
air suction
pump
Main flow line

Test section
transparent acrylic tube
4000mm long, 20mmID

Frictional Pressure Drop - Results



Single-phase flow : follows

Laminar flow $f_m = 64/\mathrm{Re}$

Turbulent flow $f_m = 0.3164\,\mathrm{Re}^{-0.25}$

Laminar-turbulent transition

=

Milky bubbly flow :

Significant reduction in wall friction (provisionally called as pseudo-laminarization)

Laminar-turbulent transition

α=0.2% Re ~ 4,000

α=0.3% Re ~ 5,500

α=0.5% Re ~ 7,000

Possible applications

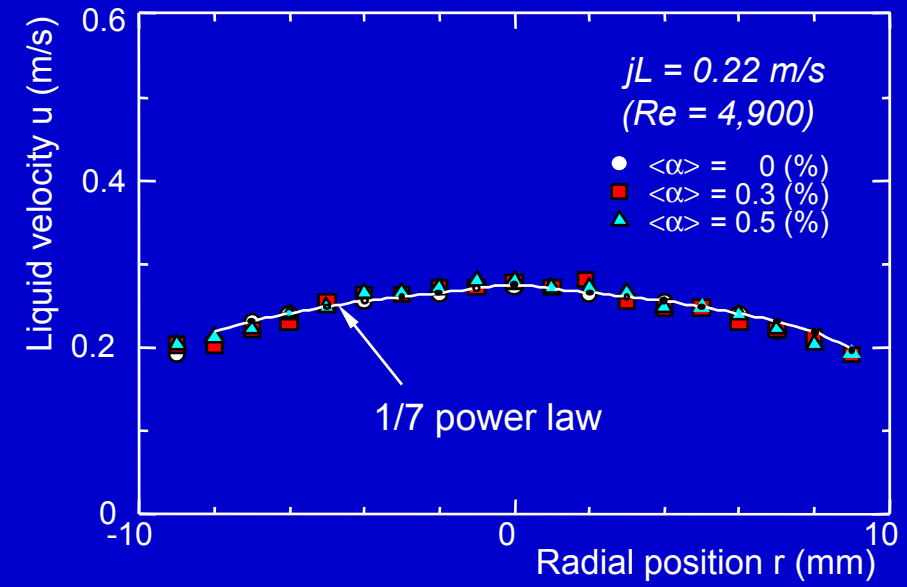
・ low drag fluid transport in pipe line without chemical additives

No pollution

・ towards smart fluids

WHY such significant reduction occurs?

Liquid Velocity Profiles - Results

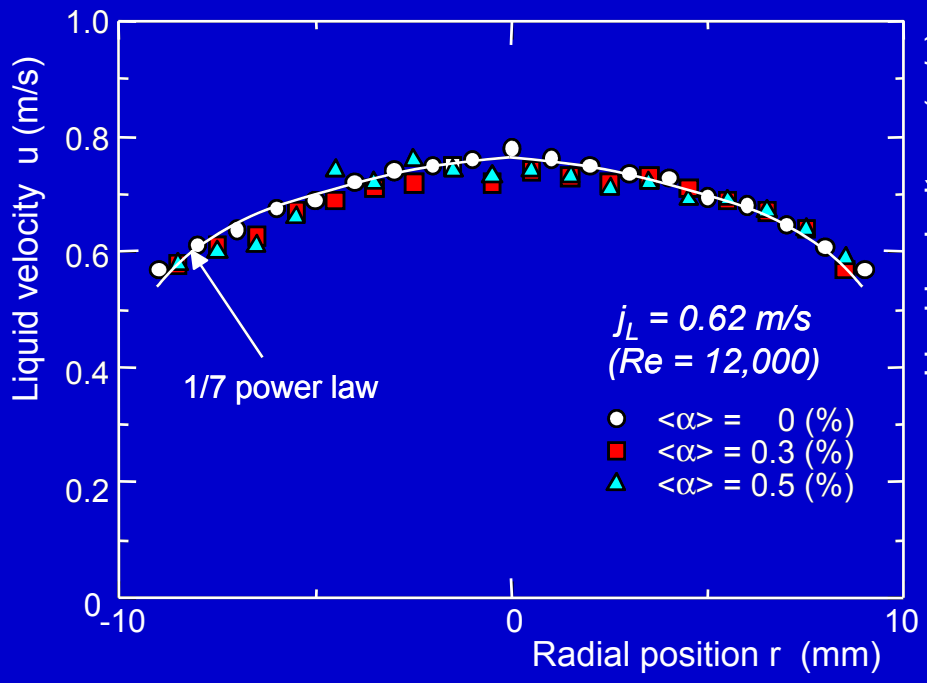


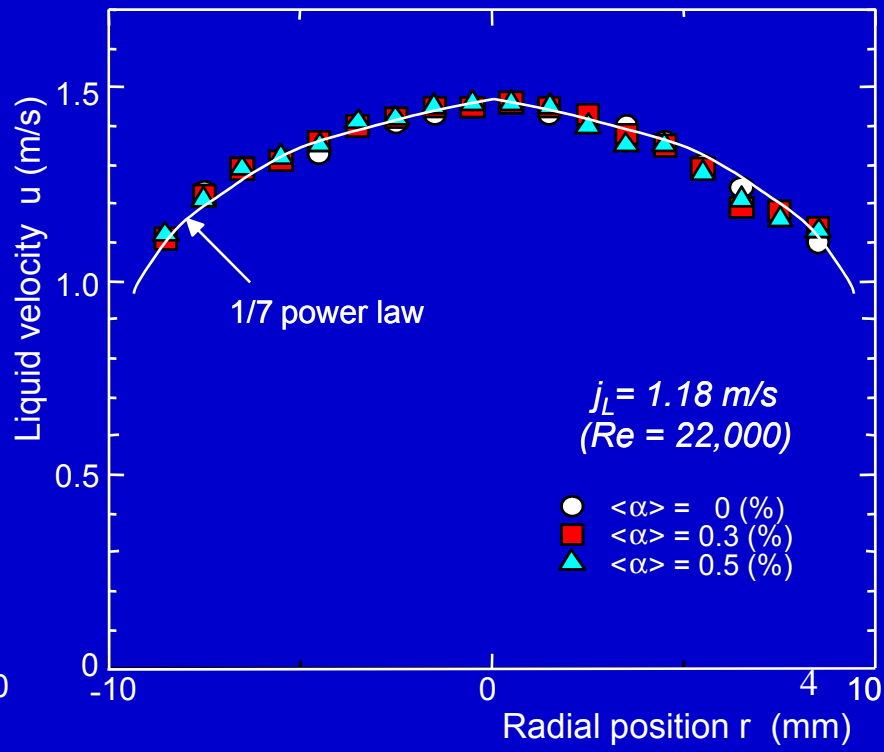
Flow conditions (friction factor)

	Re=4,900	Re=12,000	Re=22,000
α = 0 %	turbulence	turbulence	turbulence
α = 0.3 %	pseudo-laminar	transition	turbulence
α = 0.5 %	pseudo-laminar	transition	turbulence

Liquid velocity profile □ experimental evidence
turbulence profile at all conditions

Why still pseudo-laminarizaion ?





A Change of Laminar Sublayer Structure ?

(Comparison with Universal Velocity Profile)

Single-phase water flow : well correlated by the von Karman's universal velocity profile

Milky bubbly flow : turbulent flows follow the universal velocity profile

psuedo-laminar flows are far from the universal velocity profile.

not on the extension of the velocity in the laminar sublayer

transition flows are intermediate between the two