Experimental investigation on interactions among fluid and rod-like particles in a turbulent pipe jet by means of Particle Image Velocimetry

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Rod-like particles

Pulp and paper processing

- Controlling rheological behaviour and wood fiber orientation distribution crucial to optimize operations

Furniture Industry

- Pneumatic transport of wood fibers

Drag Reduction

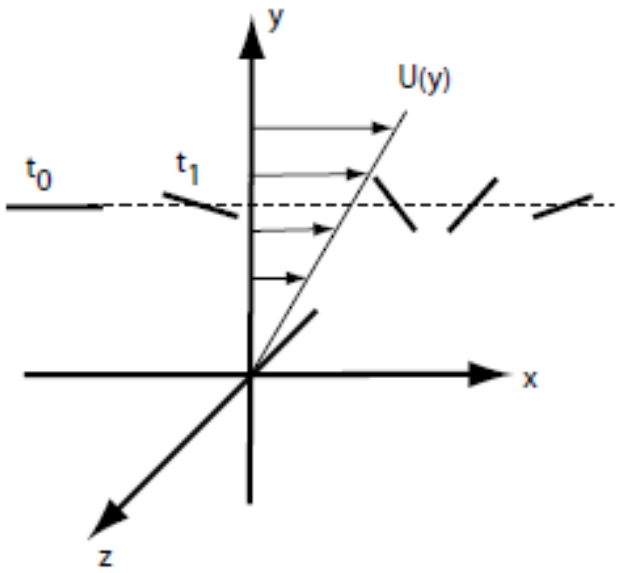
- Fibers as a substitute of polymers

Environmental Phenomena

- Ice crystals in clouds

Rods dynamics

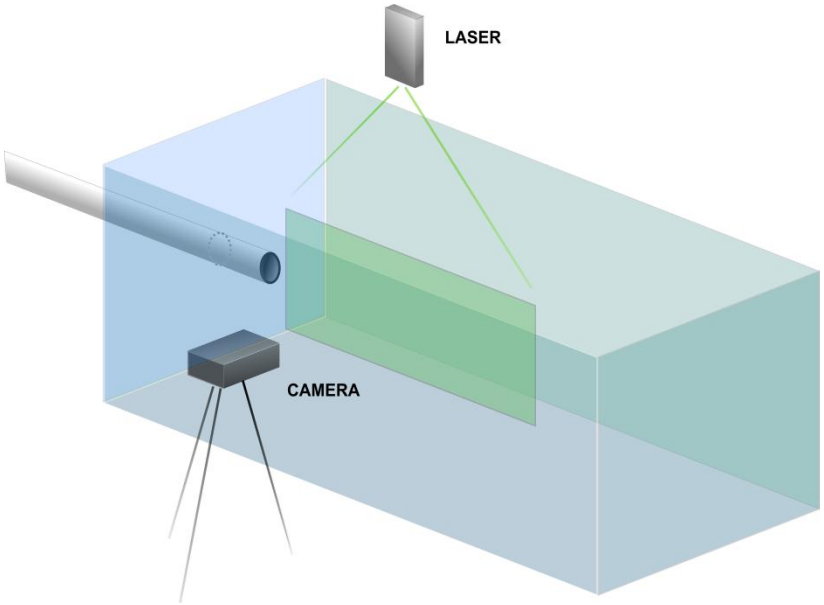
Motion of a single rigid particle in a shear flow described by Jeffery (1922).



Complex flow-particle coupling

Pipe jet set-up

- Time resolved Particle Image Velocimetry with Ar-Ion continuous laser source
- Near field region (x/D=6)
- High-speed camera (1024X1024 pixel res, 1KHz)
- Reynolds number range 12000



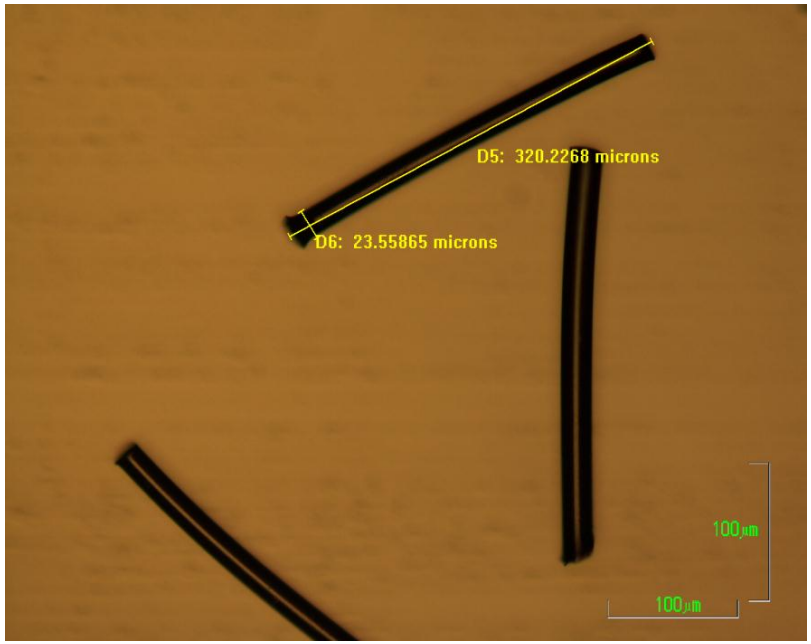
Particles set-up

Flow tracers: hollow glass spheres

- Mean diameter 12um, neutrally buoyant

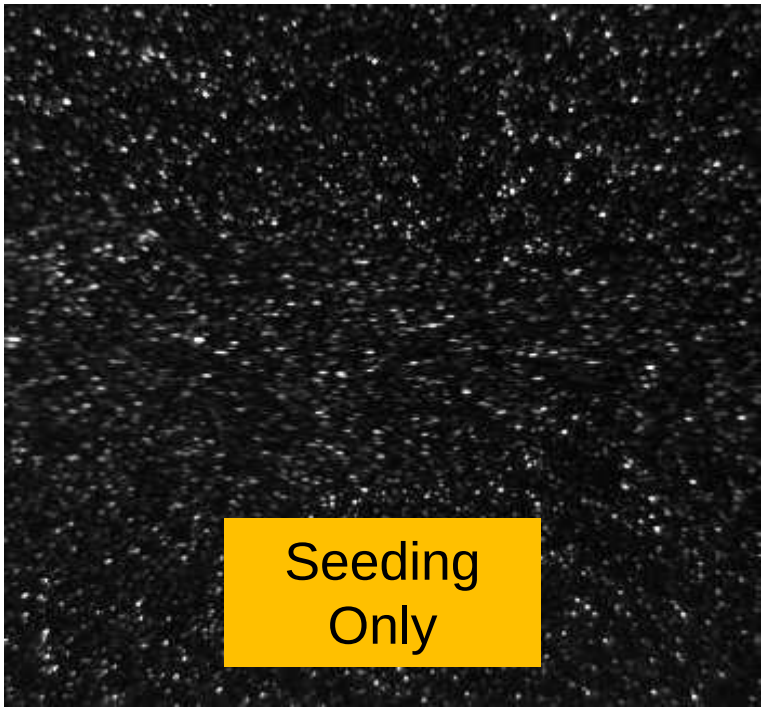
Rods: synthetic plastic fibers (nylon)

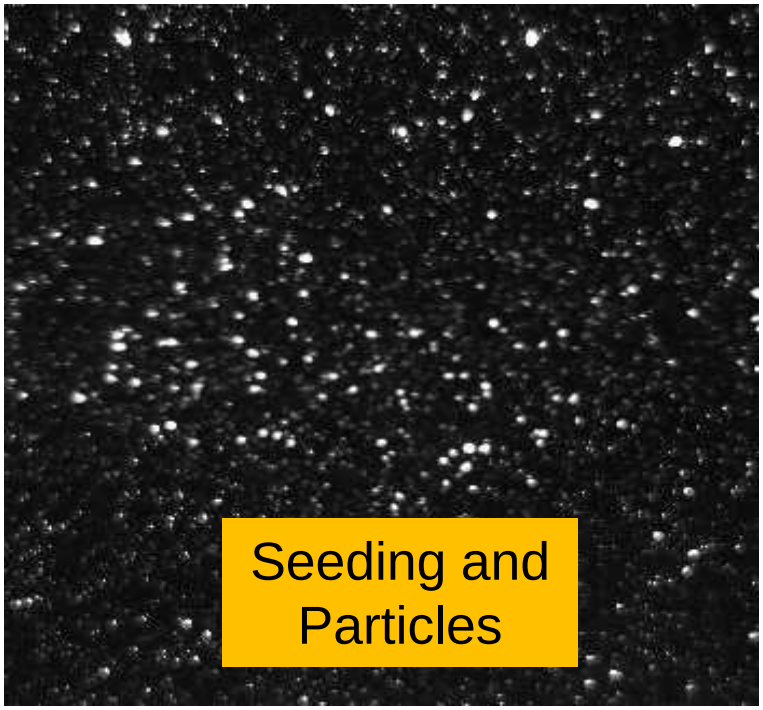
- Density 1.13-1.15 g/cm3
- Mean length 320um
- Mean diameter 24um
- Aspect ratio 13.3
- Tested fiber concentrations: 0.002% and 0.006% mass fraction



Experimental method

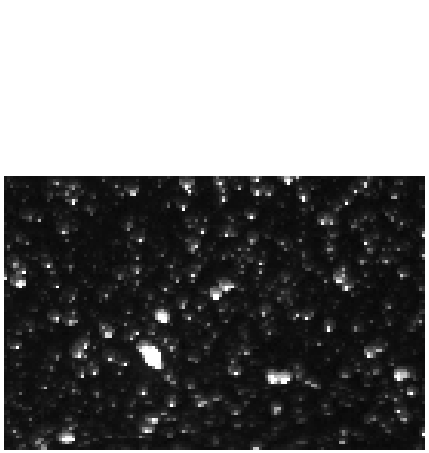
Optical techniques require phase discrimination step.
Single or multiple cameras

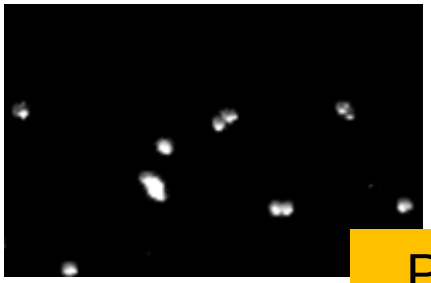




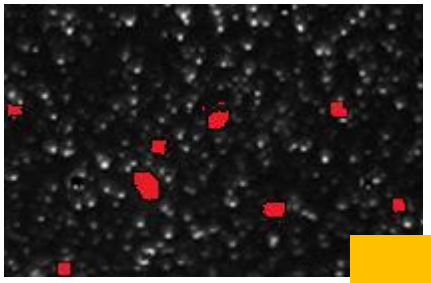
Discriminating Phases

Multiphase flows require phase discrimination before PIV/PTV analysis.





Particles

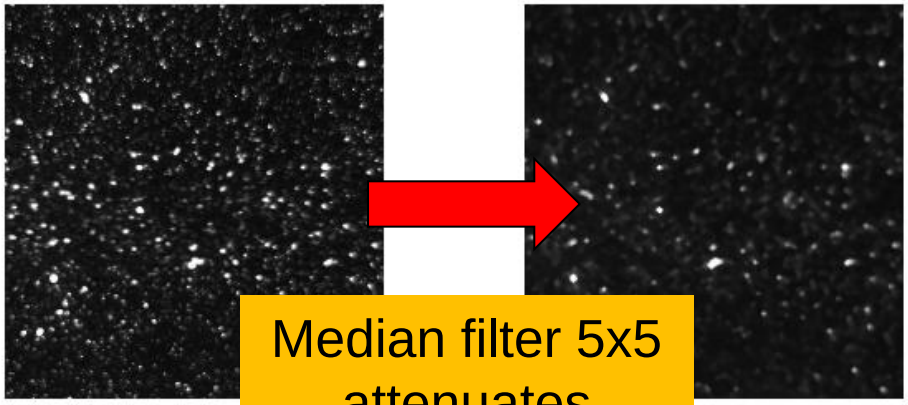


Flow

Simultaneous Fiber/Fluid Data

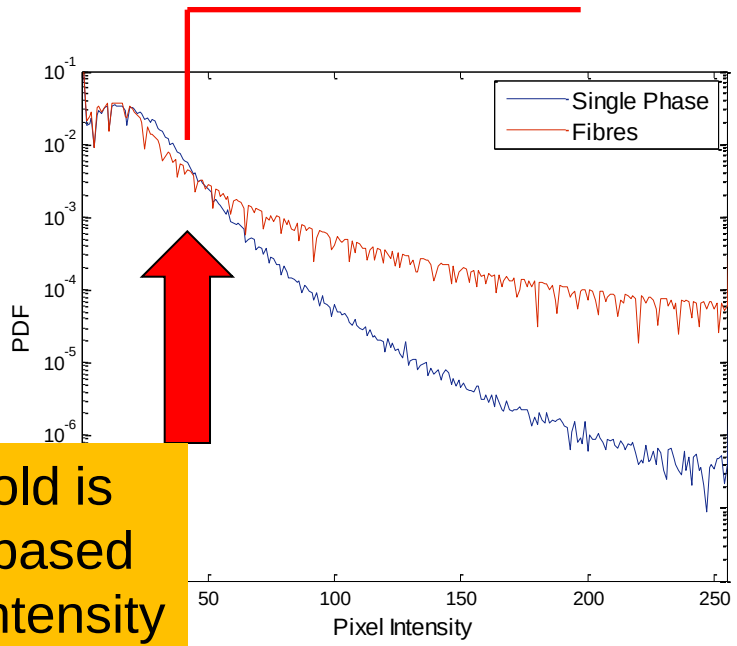
Discriminating Phases

Fibers isolated by spatial median filter and thresholding based on Kiger and Pan (2001).



Median filter 5x5 attenuates seeding particles

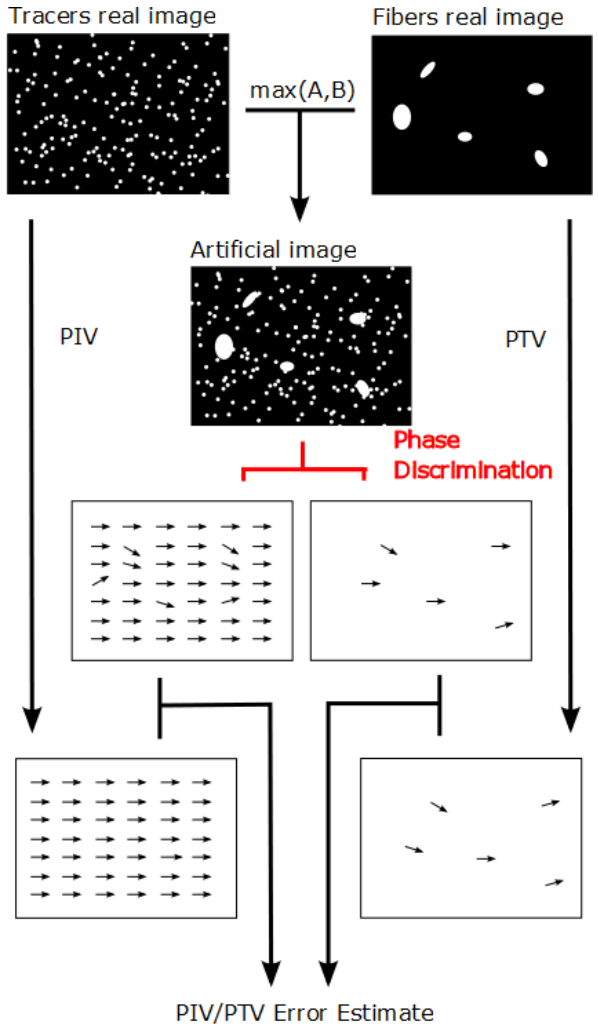
Pixels belonging to fibers



Threshold is applied based on pixel intensity distribution

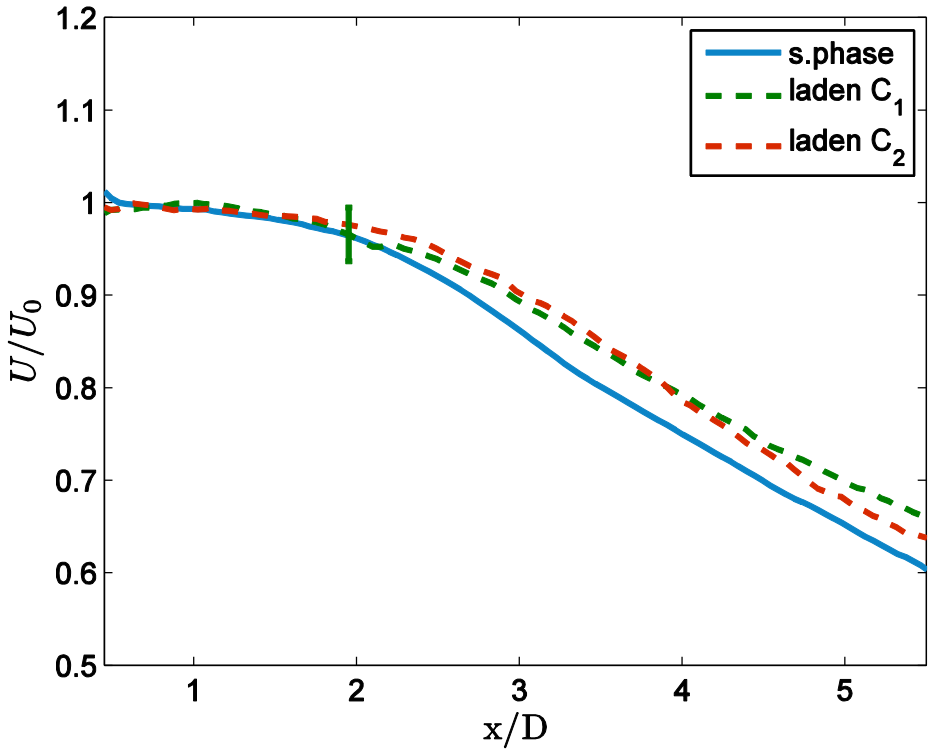
Validation

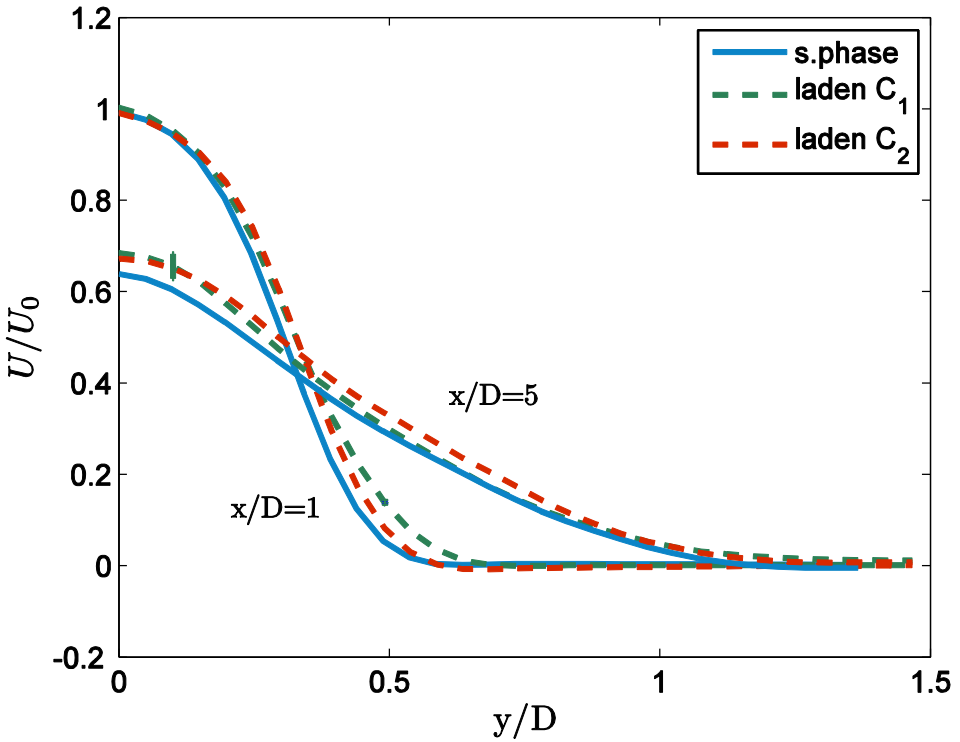
- PIV error evaluated with artificial two-phases images
- Sensitivity to intensity threshold and image features assessed
- PIV avg error on whole field below 3%
- Fibers detection error below 0.1%
- Detected particles 99.8%



Flow:mean profiles

Fiber-laden flow features increased inertia recovering undisturbed condition (Sadr et al (2005)).





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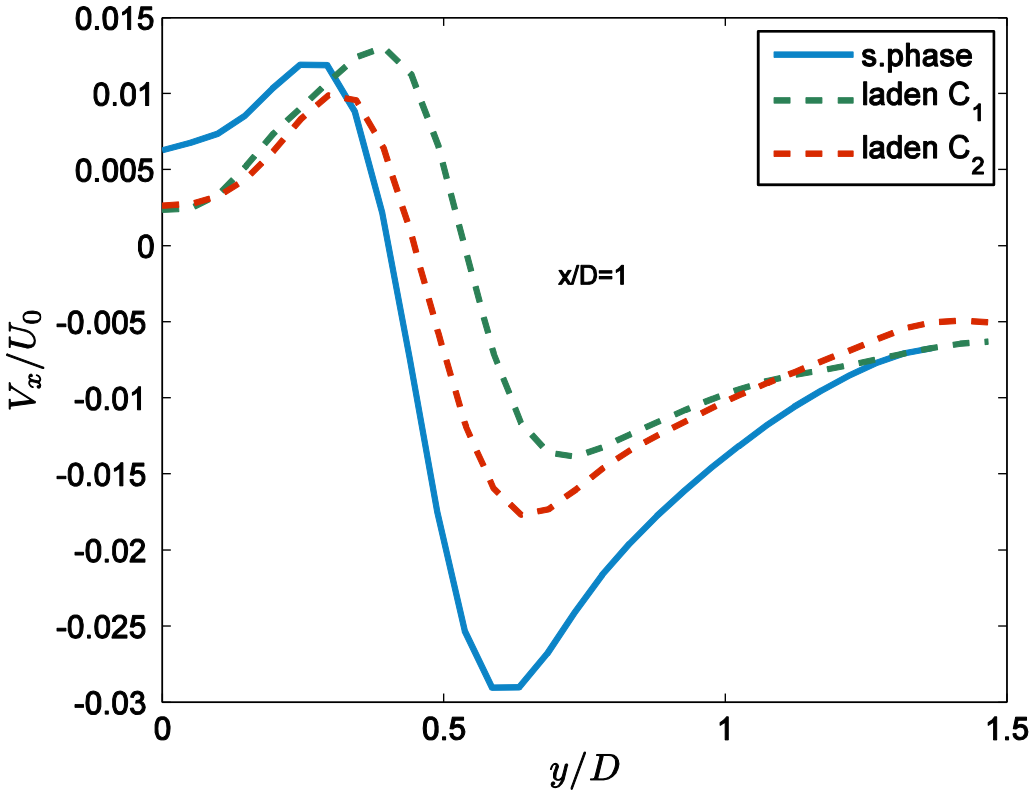
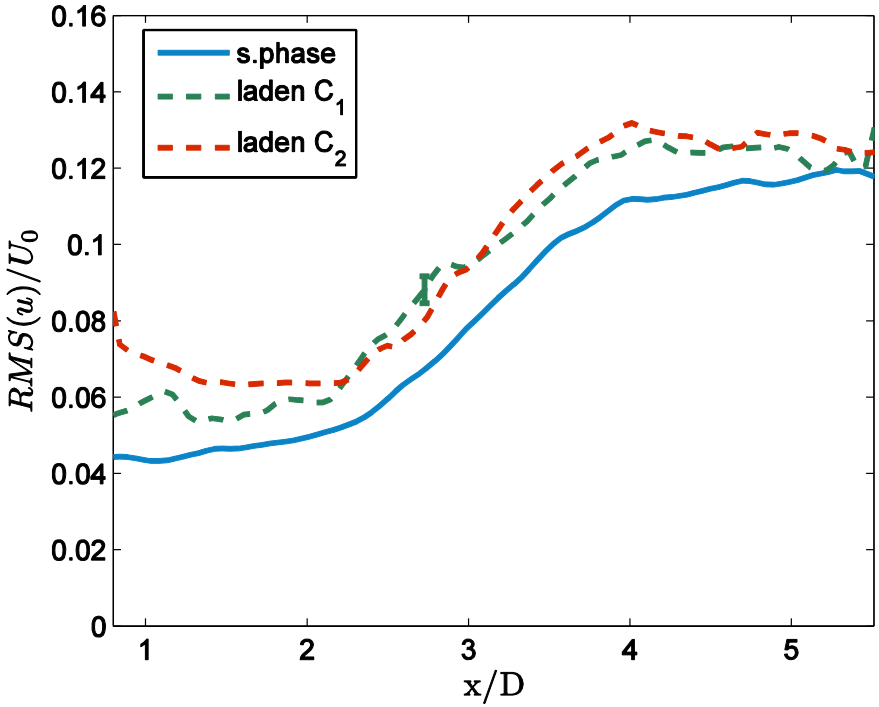
Flow:mean profiles

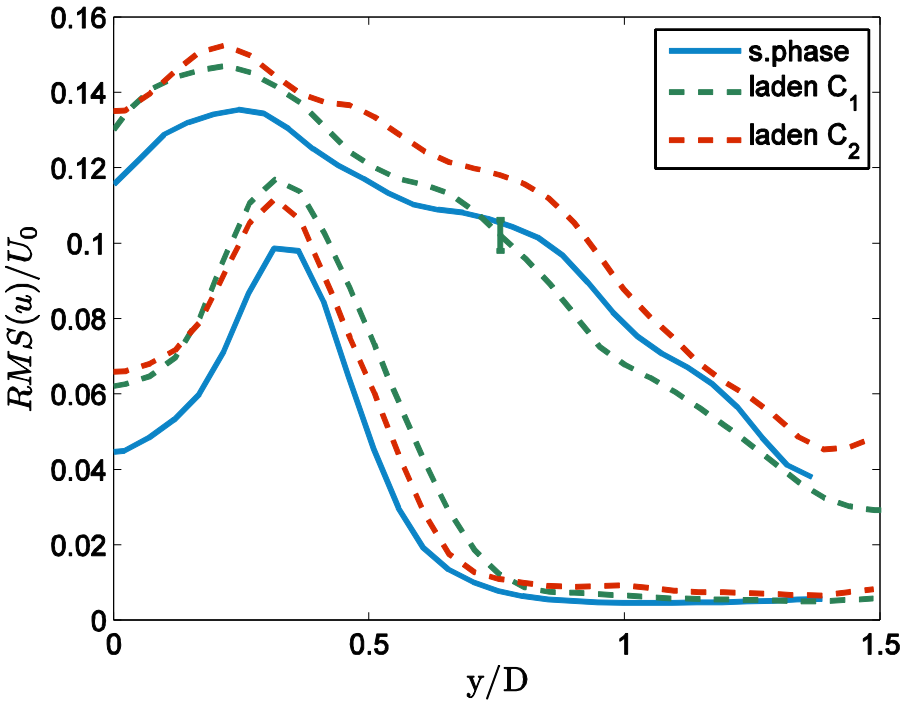
Surrounding fluid entrainment is decreased by the presence of fibers



Turbulence Modulation

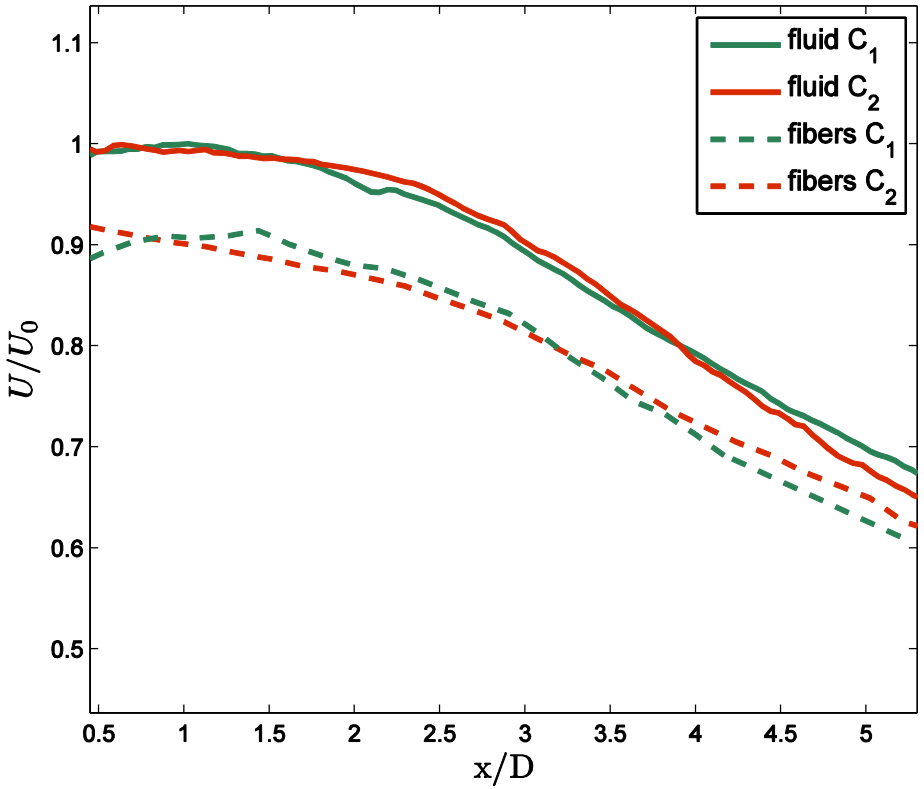
Gore and Crow (1989) d/L ratio criterion: turbulence increased in the core region.

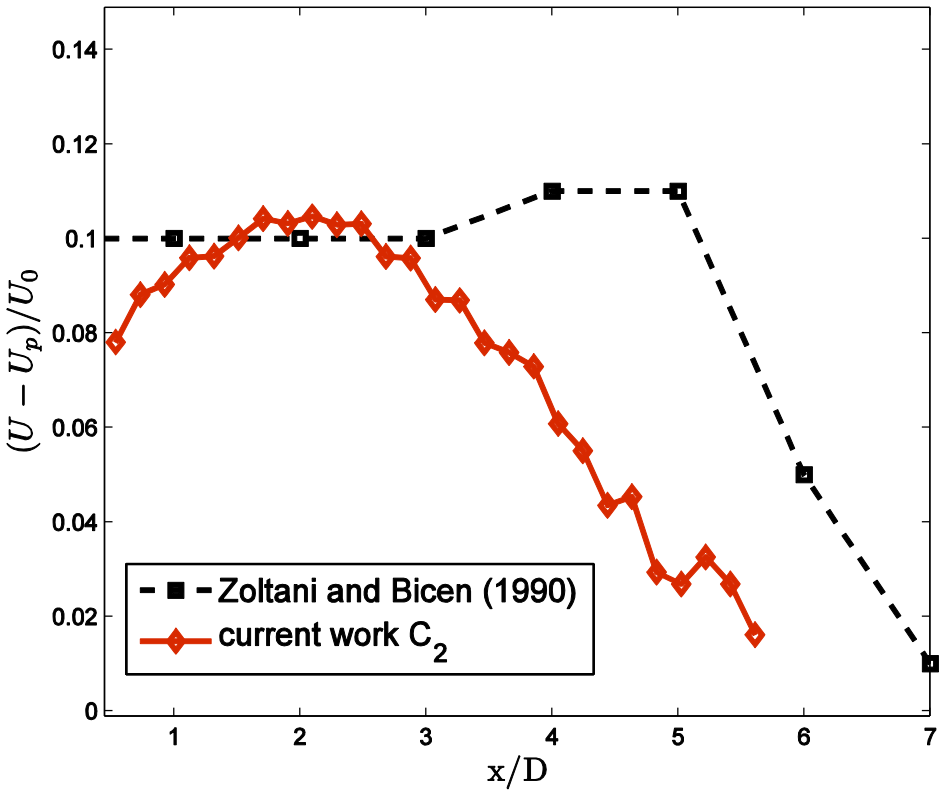




Fibers:mean profiles

Stokes number St= 0.6 (Shapiro and Goldberg (1993)).
Resemblance to sphere case at higher concentration (Zoltani and Bicen (1990))





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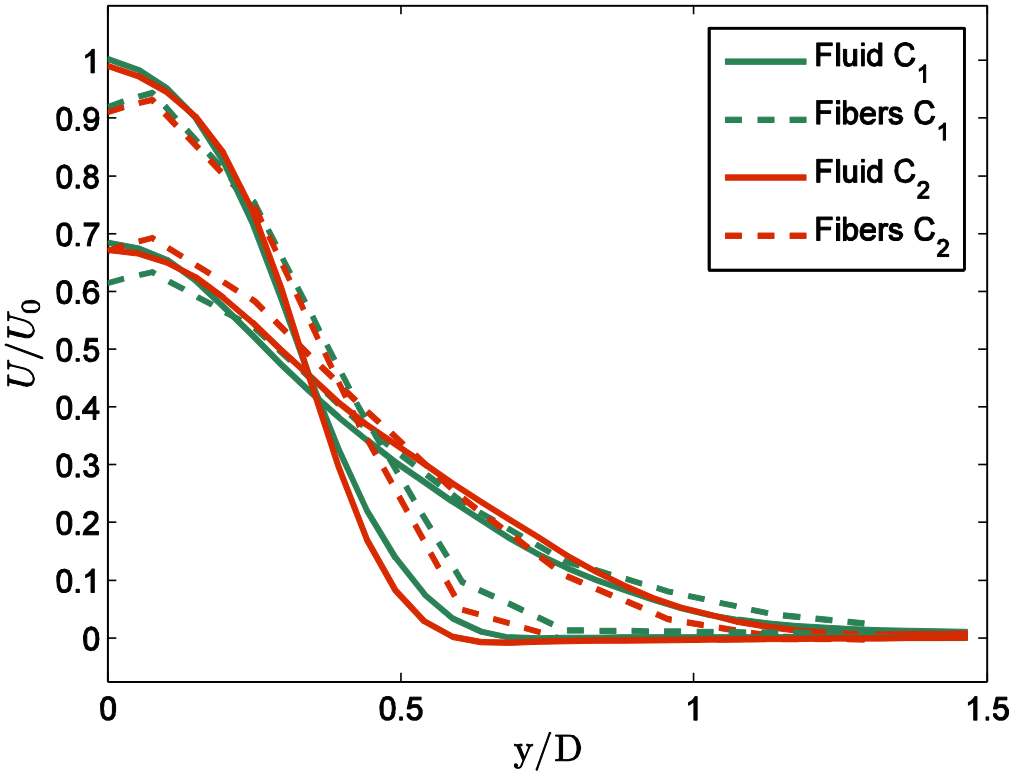
Fibers:mean profiles

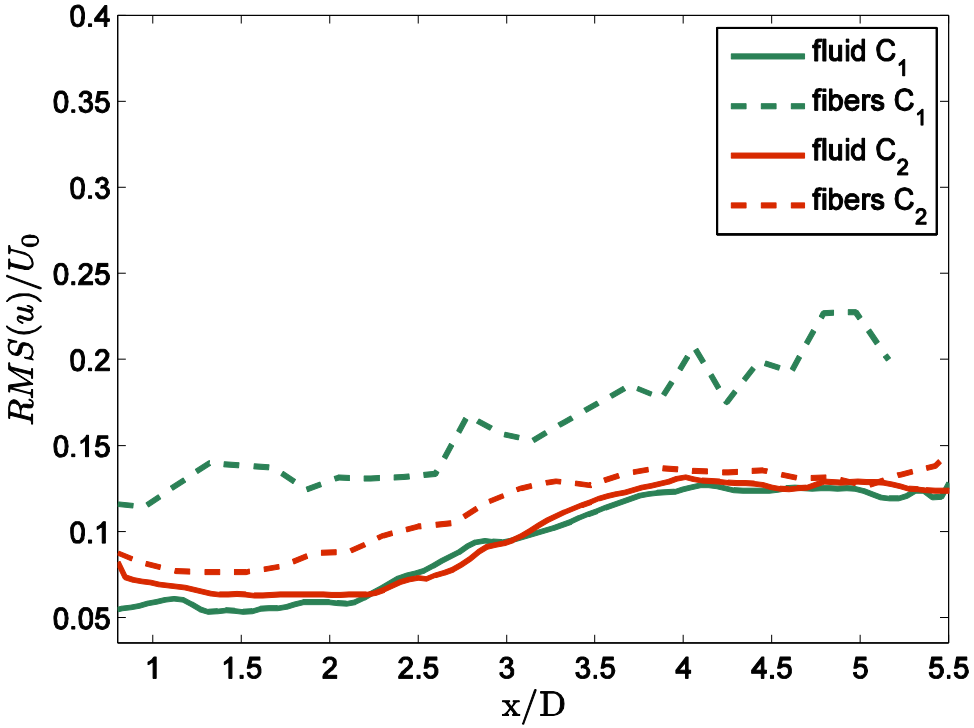
Fiber phase features inertia effects as the jet spreads

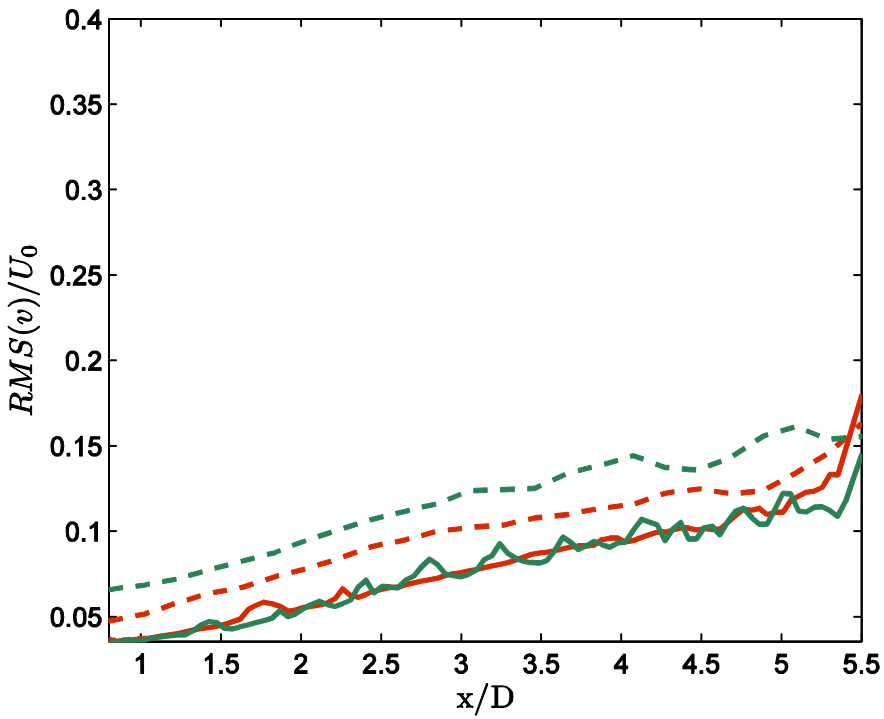


Fiber mean quantities similar to sphere case. Eaton and Longmire (1992).

Fibers:rms profiles

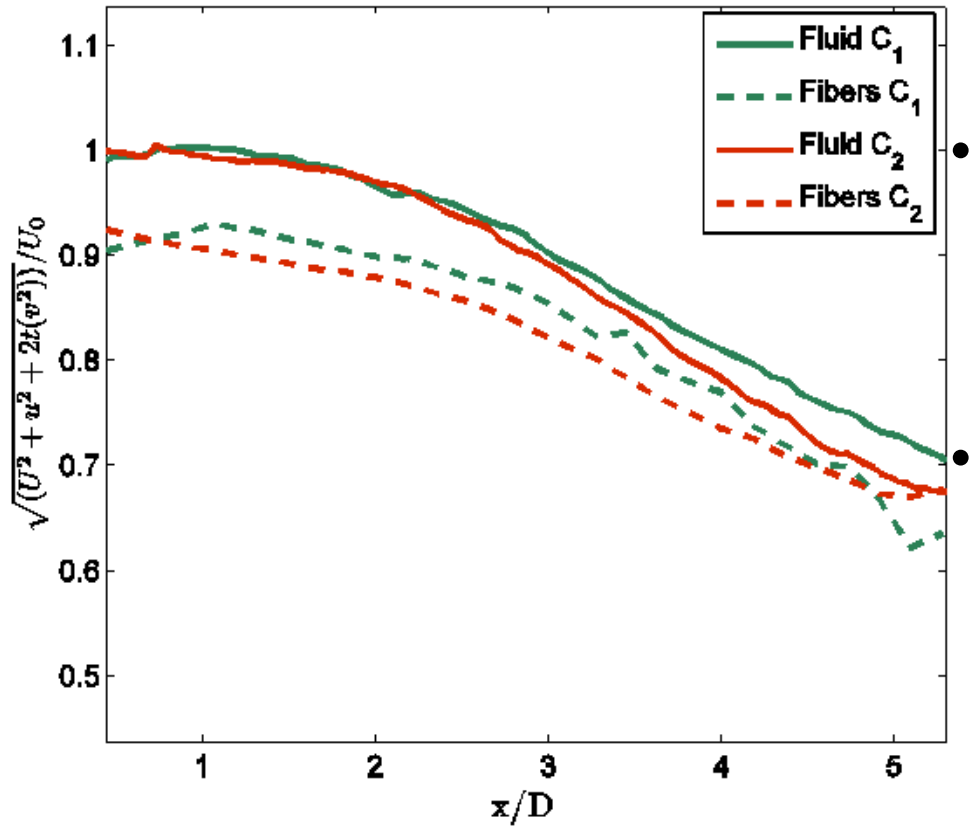
Energy component related to fluctuations higher for fiber phase throughout the jet





Total Energy

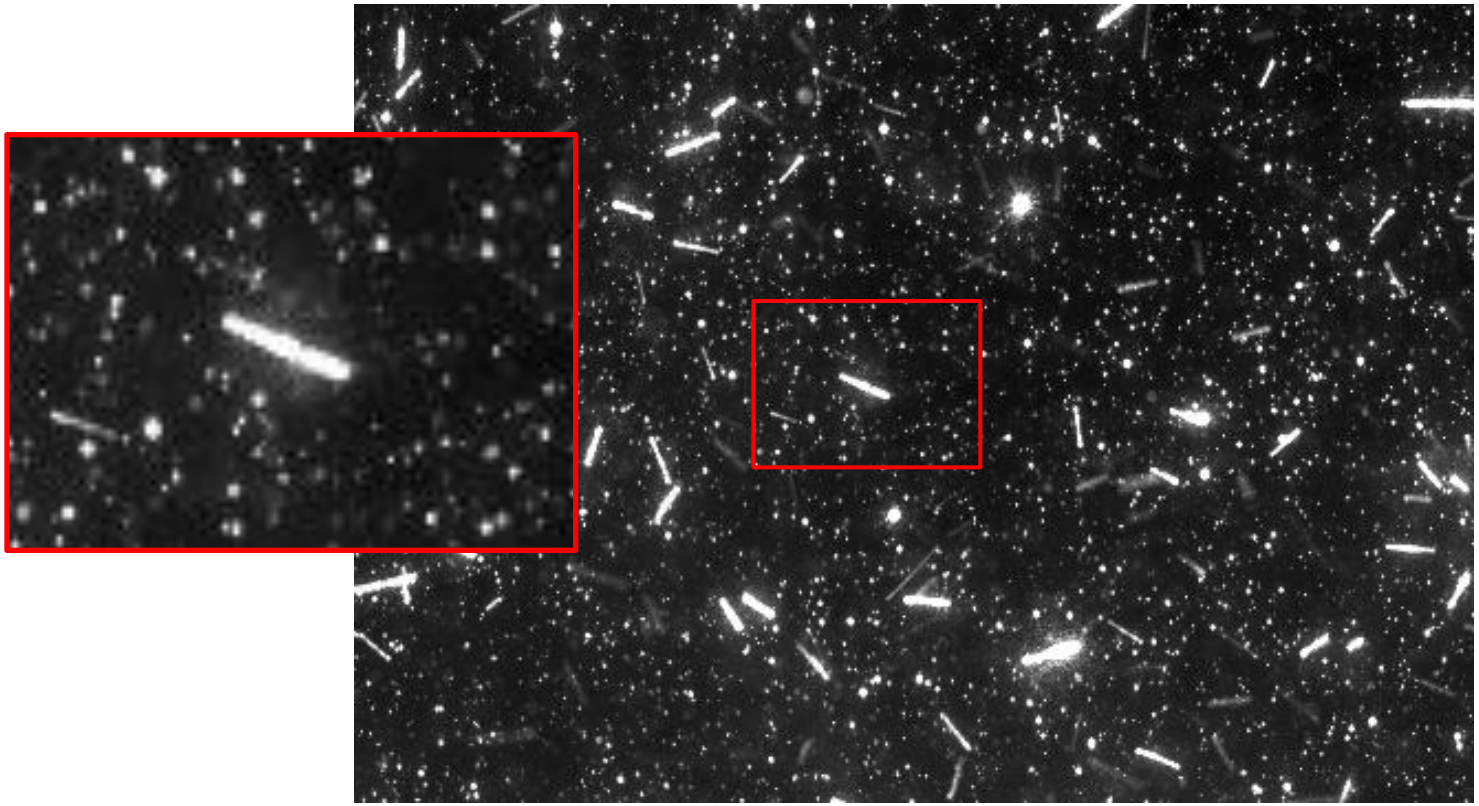
Energy transfer between fluid and dispersed phases



- Along the jet axis mean and turbulent energy of the two phases compensate each other
- Energy transfer occurs between phases

Further development

Rods orientation distribution in a jet flow: behaviour in core region (Lin et al (2011)).



Conclusions

- Phase discrimination (extended from Kiger and Pan (2001)) applied on a jet loaded with rigid fibers. Limitations set by particles/seeding image size and intensity.
- Flow turbulence enhancement independent of tested fiber concentrations, mostly in core region.
- Fibers behaviour resembles spheres' for mean velocities
- Energy transfer occurs between phases

Thank you for your attention!