EXPERIMENTAL STUDY ON THE CLEANING EFFECT OF PULSATING SPRAYS

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Discontinuous spray cleaning Configuration



- cleaning fluid
- water at 23°C
- pressure: up to 6 bar
- full cone and flat fan nozzle

- substrate: stainless steel, horizontal, distance 150 mm
- soil: vanilla pudding and rice pudding



pulsation: pivoted-armature valve





Characteristics of pulsating spray

High-speed image recording

- calming section for disturbance-free flow
- industrial nozzle directly after valve
- LED panel in backlight arrangement with high-speed camera
- frame rate: 1000 Hz





Characteristics of discontinuous spray flow Full cone nozzle

3 bar, 50%, 10 Hz

- flow interrupted
- pronounced start-up phase
- beginning: highly concentrated coherent liquid lump
- opening angle increases with time
- developed flow after $\approx 40 \text{ ms}$
- swirl-driven expansion and disintegration
- uniform droplet distribution in cone





Characteristics of discontinuous spray flow Flat fan nozzle

3 bar, 50%, 10 Hz

- start-up phase
- opening angle virtually constant
- thin, compact front with slower liquid
- developed flow after $\approx 25 \text{ ms}$
- spreading direction controlled by orifice
- disintegration by film instability
- uniform droplet distribution in spray





Cleaning experiments Experimental Setup

- soiled test sheets, easily interchangeable
- diluted soil sprayed with industrial robot
- dried for 1 day
- fluorescence-based, time-resolving measurement
- tracer added to vanilla pudding
- 3 cleaning tests per parameter combination







Cleaning experiments Detection of cleaned surface

- time series of images
- distortion correction
- cleaned pixel detection by threshold
- cleaned area as function of time





Cleaning results Vanilla pudding, full cone nozzle



- maximum cleaned diameter: continuous operation, duty cycle has positive effect
- positive effect of pulsation at small times,
- cleaning of impact region of liquid lump



Cleaning results Vanilla pudding, flat fan nozzle



- evaluation quantity: average rate to clean 10 000 mm²
- no positive effect of pulsation
- cleaning rate decreases almost linearly with duty cycle



Cleaning results Rice pudding, flat fan nozzle



- discontinuous nozzle operation reduces cleaning time
- possible reason: grains that protrude from dried layer are subjected to very strong stresses by a spreading film flow
- for given duty cycle, increasing switching frequency decreases cleaning rate



6 bar

Conclusions

- study on cleaning with discontinuous full cone and flat fan sprays
- focus on mechanical action
- reduction in cleaning time compared to continuous flow is possible
- likely reason: repetitive, increased maximum load
- additional benefit: reduced consumption of cleaning fluid

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- additional studies needed to identify mechanisms in detail and influences of parameters
- beneficial: CFD simulation
- insight in flow field including stresses on soil
- project on simulation with mesh-free code
- cooperation partner: Fraunhofer ITWM





Thank you!



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