ENVIRONMENTAL IMPLICATIONS OF CUTTING FLUIDS

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AGENDA

- Introduction
- Agenda
- Objectives
- Analytical Model
- Experimental Work
- Future Work
THE EFFECT OF CUTTING FLUID ON ENVIRONMENT AND PROCESS PERFORMANCE

Legend
- analytics
- experimentation
- prediction

- BUE formation
- tool wear rate
- thermal expansion
- FEM analytical solutions
- temperature distribution
- predict and optimize cutting conditions
- evaporation model
- spinning-off model
- splattering model
- airborne particulate concentration
- aerosol monitoring
OBJECTIVES

❖ Determine the controlling factors that influence the cutting fluid dosage in the shop floor environment.

❖ Determine an analytical model to describe the causality between the controlling factors and the resulting airborne fluid particle concentration.

❖ Verify the analytical model by comparing measured cutting fluid concentration in the shop floor environment.
ANALYTICAL MODEL

- The analytical model is determined for turning a circular cylinder on an open-lathe.
There are 3 mechanisms for the cutting fluid to leave the cutting zone. These methods include:
- Evaporation
- “Spin-off”
- “Splatter”

Each mechanism has different controlling factors that influence how the cutting fluid will permeate into the shop floor environment.
ANALYTICAL MODEL (cont.)

EVAPORATION

uniform evaporation (3-D)

workpiece

Evap_rate = \left(\frac{\text{Measured_evap_rate}}{\text{Calculated_evap_rate}}\right) \sqrt{\frac{\text{MW}}{2\cdot\pi}} \left(\frac{p_{\text{tr}}}{\sqrt{T_{\text{tr}}}} - \frac{p_{\text{min}}}{\sqrt{T_{\text{v}}}}\right)

\text{Concentration}_{\text{fluid_evap}} = \int_{t_1}^{t_2} f_0 \cdot \text{Evap_rate} \cdot \left(\frac{1}{\text{distance}^2}\right) dt

(f_0 \text{ will be calculated experimentally})
ANALYTICAL MODEL (cont.)

“SPIN-OFF”

workpiece + thin fluid layer

uniform “spin-off” (2-D)

distance = \( f_1 \cdot \text{rpm} \)  
(f_1 will be calculated experimentally)

Concentration_{\text{fluid evap}} = \int_{t_1}^{t_2} \left[ f_2 \cdot \left( \frac{1}{\text{distance}} \right) \cdot \left( \frac{1}{\mu_{\text{fluid}}} \right) \cdot \rho \right] \, dt  
(f_2 will be calculated experimentally)
ANALYTICAL MODEL (cont.)

“SPLATTER”

Jet Nozzle at $\theta = 90$°

workpiece

$U_{\text{workpiece}} = (2 \text{ accel } \cdot y)^{1/2}$  
(y will be found experimentally)

$U_{\text{jet}} = \frac{V}{A_{\text{jet}} \cdot t}$  
(U$_{\text{jet}}$ will be found experimentally)

$f_3 = \frac{U_{\text{workpiece}}}{U_{\text{jet}}}$

$V_{\text{splatter}} = f_3 \cdot V_{\text{jet}}$  
(V$_{\text{splatter}}$ will be verified experimentally)

$\text{Concentration} = \int_{t_1}^{t_2} \frac{V_{\text{splatter}} \cdot \rho}{V_{\text{DataRAM}}} \, dt$
EXPERIMENTAL WORK

- Using a real-time particle measurement device (DataRAM from MIE, Inc.), the experimental work seeks to accomplish the following goals:

  - Provide real-time data of shop floor environment particle concentration.

  - Determine amount of particles that are due to cutting fluid.

  - Verify the analytical model by comparing measured cutting fluid concentration in the shop floor environment.
EXPERIMENTAL WORK (cont.)

DataRAM

HotMeter

10/2.5 μm Selector

Omni-directional Inlet
The proposed formulation is valid for:
- Turning a circular cylinder on an open-lathe

Several more levels of complexity must be added to the system in the form of:
- Optimizing cutting operation to minimize toxic airborne particles
- A closed environment formulation for the Hardinge machine
- Different operations
  - (e.g. milling, grinding, drilling)
- More complex part geometry.