THE ESTIMATION OF CUTTING FLUID EFFECT ON SHOP FLOOR ENVIRONMENT

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Oct. 14 1998

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Introduction of the project

❖ Motivation and background

❖ Objective of the project:

- Establish the physical understanding of the role and functions of cutting fluids.
- Quantify the effects of cutting fluids on process performance and environmental hazard.
- Achieve the optimal use of fluids in pursuit of both process productivity and environmental benignity.
Physical model

- There are three mechanisms for the cutting fluid to leave the cutting zone. These methods include:
  - Splash
  - Spin-off
  - Evaporation
Calculation of spin-off model

* Ideal fluid jet impinging on cylindrical workpiece model. (Peng and Parker’s model)

* Rotary disk atomization model. (Matsumoto and Talashima’s model)
  - drop mode
  - ligament formation mode
  - film mode

* Liquid sheet model. (Bayvel’s model)

* Coating liquid layer. (Preziosi’s model)
Graph of geometry of impinging fluid jet
Graph of rotary disk atomization model
Graph of liquid sheet atomization model
Coating liquid layer

Using Navier-Stokes equation (without approximation)

\[
\rho \left( \frac{\partial u_\theta}{\partial t} + u_r \frac{\partial u_\theta}{\partial r} + \frac{u_\theta}{r} \frac{\partial u_\theta}{\partial \theta} \right) \\
+ \frac{u_r u_\theta}{r} + u_z \frac{\partial u_\theta}{\partial z} \\
= -\frac{1}{r} \frac{\partial p}{\partial \theta} + \mu \left( \nabla^2 u_\theta - \frac{u_\theta}{r^2} - \frac{2}{r^2} \frac{\partial u_r}{\partial \theta} \right) + \rho \cdot f_\theta
\]
Some result of spin-off model (Rosin and Rammler distribution)
Calculation of splash model

Fluid jet

workpiece

\( X \)

\( Y \)

\( (x,y) \)

\( (u,v) \)

\( \omega \)

\( \theta = 0 \) degrees

Lathe Pan

Side View
Calculation of splash model (cont.)

- Dave’s model (based on experiment)

  - The portion of splash that lands on the fluid pen is
    \[
    \dot{S}_1 = \dot{S} \left( 1 - \frac{\int_{\theta_1}^{\theta_2} 2R^2 \sin \theta d\theta}{\int_{0}^{\theta_1} 2R^2 \sin \theta d\theta} \right)
    \]

  - The portion of splash that misses the pan and enters the environment is
    \[
    \dot{S}_2 = \dot{S} \left( \frac{\cos \theta_2 - \cos \theta_1}{1 - \cos \theta_1} \right)
    \]
Calculation of evaporation model

Hertz-Knudsen Equation

\[
\dot{Q} = E \cdot \sqrt{\frac{M}{2\pi \cdot R}} \cdot \left[ \frac{p_{tr}}{\sqrt{T_{tr}}} - \frac{p_{atm}}{\sqrt{T_{atm}}} \right] \cdot \left( \frac{A_j}{\rho_j} \right)
\]

\( \dot{Q} \) = Evaporation rate of fluid (g/cm\(^2\)-sec)

E = Ratio of measured to theoretical evaporation

A\(_j\) = Cross-sectional area of beaker (cm\(^2\))

\( \rho_j \) = Density of fluid (g/m\(^3\))

p\(_{tr}\) = Vapor pressure at fluid surface (dyne/cm\(^2\))

T\(_{tr}\) = Fluid temperature at tool/workpiece interface (K)

p\(_{atm}\) = Pressure of surrounding atmosphere (dyne/cm\(^2\))

T\(_{atm}\) = Temperature of surrounding atmosphere (K)
**Experimental work**

- Using a real-time particle measurement device, the experimental work seeks to accomplish the following goals:
  - Provide real-time data of aerosol concentration in a closed control volume.
  - Measure the mean diameter of aerosol particle.
  - Verify the analytical model by comparing measured aerosol concentration.

- Measurement device:
  - DataRam (MIE, Inc.)
  - CSASP-100 (Particle measuring Systems Inc.)
Graph of the machine

The experiment is determined for turning a circular cylinder in a closed control volume.
Experimental instrument

DataRAM

HotMeter

10/2.5 µm Selector

Omni-directional Inlet
Some experimental result

DataRam experimental result (rotating speed = 390 rpm)

DataRam experimental result (rotating speed = 760 rpm)
Some of the experimental results

Aerosol concentration with different flow rate and rotating speed

- Flow rate = 1.2 \times 10^{-4}
- Flow rate = 2.2 \times 10^{-4}
- Flow rate = 4.4 \times 10^{-4}