NEAR DRY MACHINING

IAB Presentation

Kuan-Ming Li, Steven Y. Liang

OUTLINE

- INTRODUCTION
- INTEREST OF STUDY
- PROPOSED RESEARCH – AIR QUALITY MODELING
- CURRENT RESULTS
- CONCLUSION

INTRODUCTION

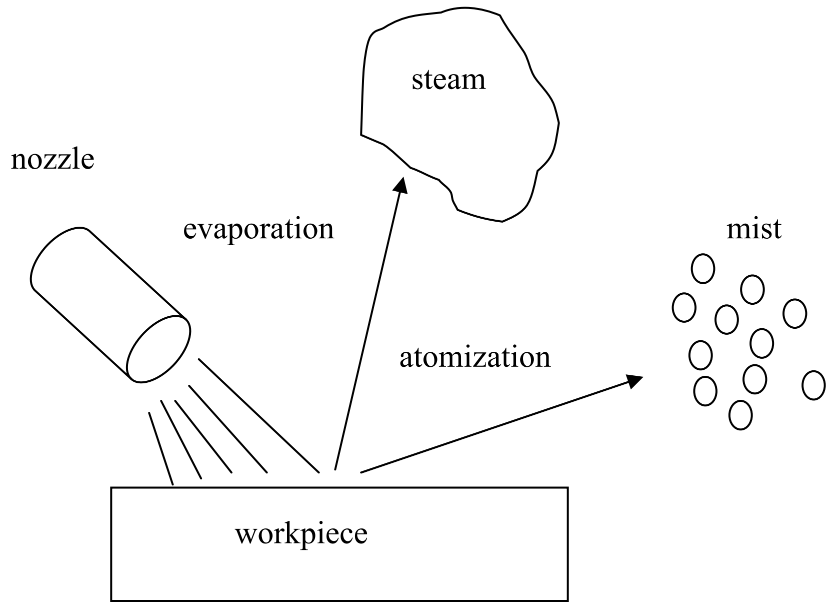
- Dry Machining vs. “Wet” Machining
- Benefits of Cutting Fluids
  - Cooling
  - Lubricating
  - Chip flushing
- Disadvantages of Cutting Fluids
  - Health
  - Environment
  - Cost
    - 20% of total manufacturing cost due to cutting fluids vs. 7.5% of total manufacturing cost due to cutting tools
- Near Dry Machining
  - A small amount of cutting fluid, typically lower than 50 ml/hr
  - Only empirical observations

INTEREST OF STUDY

- Tool Wear Analysis
  - Tool wear mechanism
- Cutting Fluid Aerosol Generation Analysis
  - Aerosol generation mechanism
- Compare Near Dry Machining with Dry and “Wet” Machining
  - Temperature
  - Forces
  - Aerosol generation
  - Tool life
  - Surface roughness

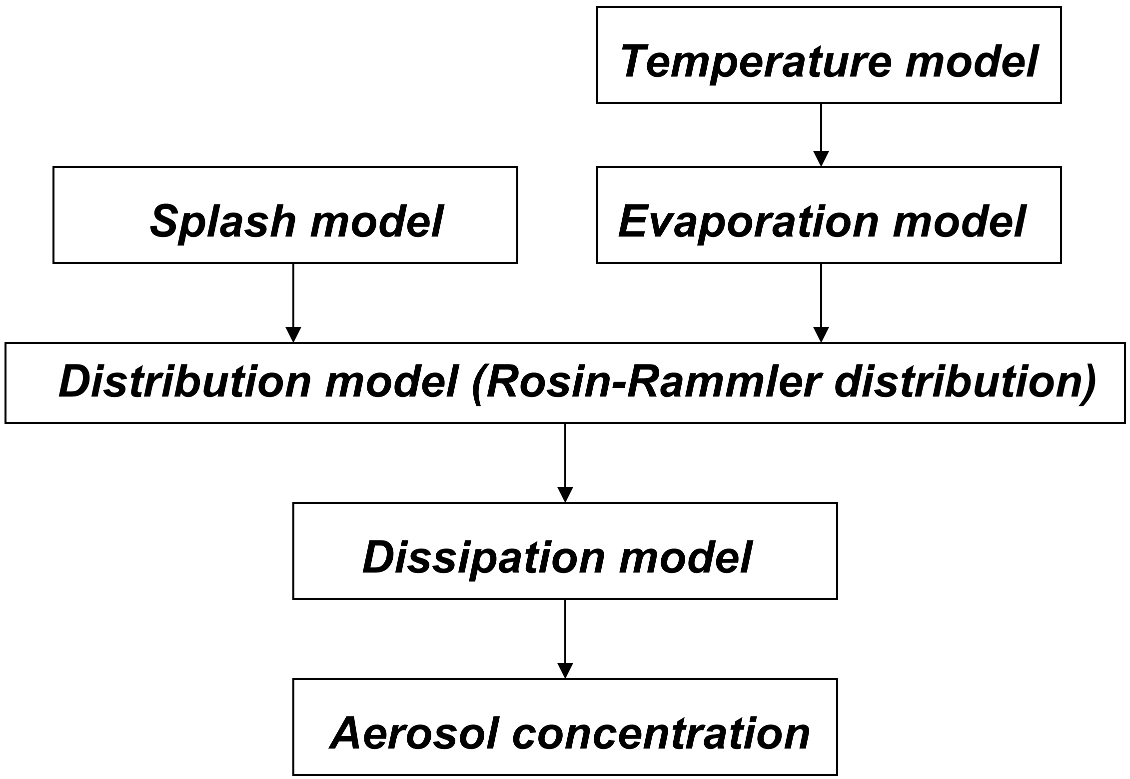
Aerosol generation mechanism

- Evaporation
- Air blast splash



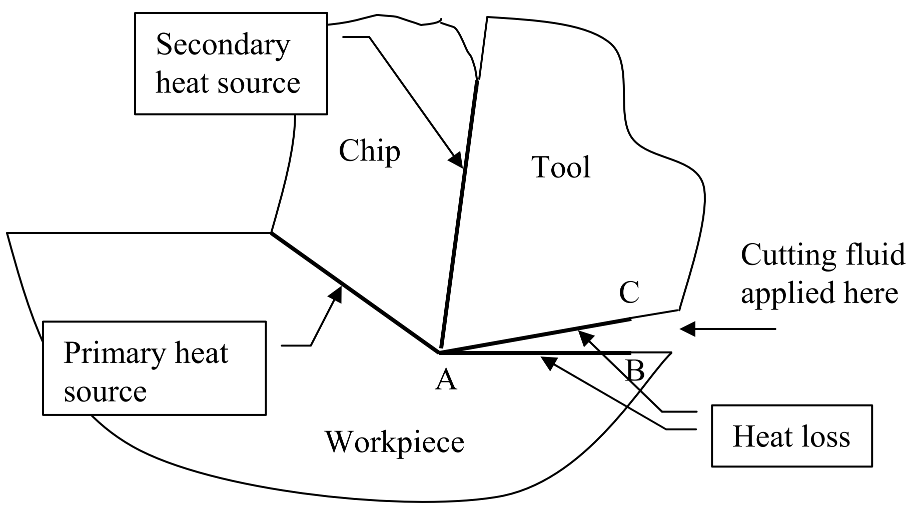
PROPOSED RESEARCH – MODELING

- Current research – air quality modeling



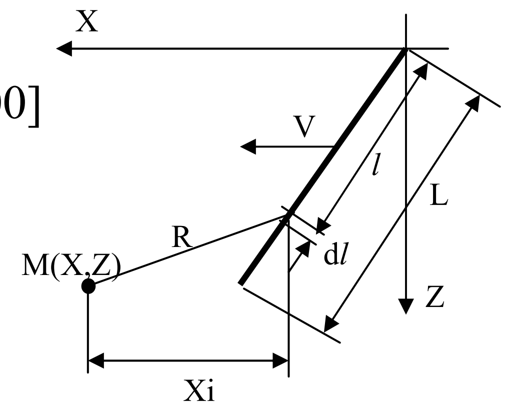
TEMPERATURE MODEL (1)

- Primary heat source
- Secondary heat source
- Heat loss due to cutting fluid



TEMPERATURE MODEL (2)

- Moving heat source
  - Heat conducted into chip and workpiece
  - $\Delta\theta_M = \frac{q_{pl}}{2\pi k}\int_0^L e^{-\frac{X_i}{2a}} K_0\left(\frac{V}{2a}\right) dl$ [Komanduri, *et al.*, 2000]



- Stationary heat source
  - Heat conducted into tool insert
  - $\Delta\theta_M = \frac{q_{pl}}{2\pi k}\int_0^L dx \int_{-\frac{w}{2}}^{\frac{w}{2}} \frac{dy}{R}$ [Komanduri, *et al.*, 2001a;Shaw, 1984]

- Heat loss intensity
  - Flow parallel to the tool flank face
  - $\overline{N_{u_L}} = \frac{\bar{h}L}{k} = 0.664 P_r^{1/3} R_e^{1/2}$

    $q'' = \bar{h}(T_w - T_\infty)$

EVAPORATION MODEL

- Hertz-Knudsen formula

$$Q_{net} = \sqrt{\frac{M}{2\pi R}}\left(\frac{Ep_{tr}}{\sqrt{T_{tr}}} - \frac{Cp_{atm}}{\sqrt{T_v}}\right)$$

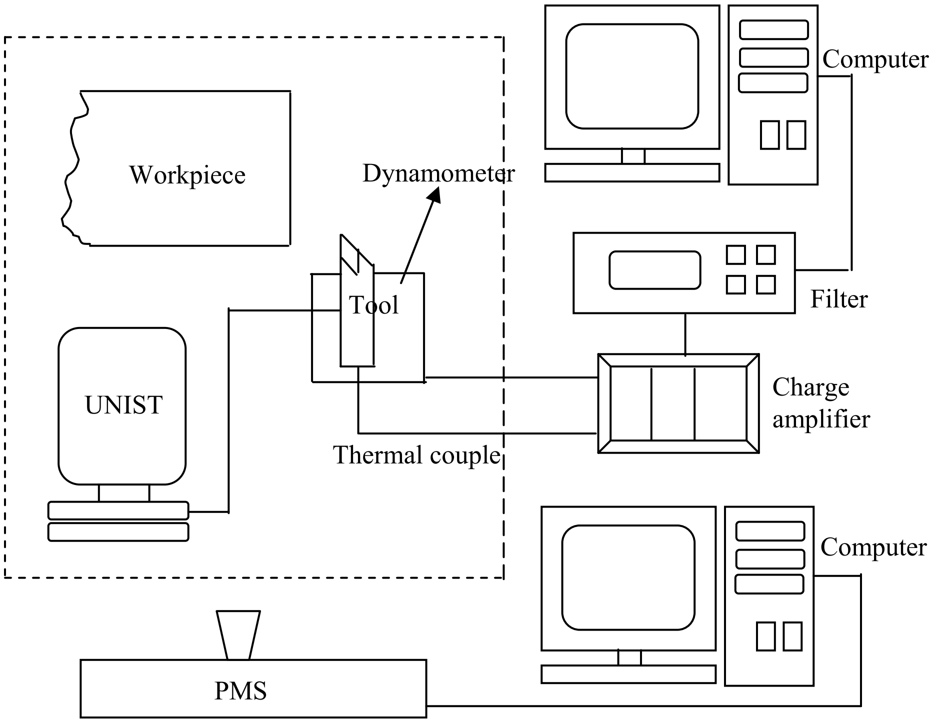
  - Q_{net} is the net rate of evaporation
  - M is the molecular weight of cutting fluid
  - R is the universal gas constant
  - E is the evaporation coefficient
  - p_{tr} is the vapor pressure at the temperature
  - T_{tr} is the cutting fluid surface temperature
  - C is the condensation coefficient
  - p_{atm} is the vapor pressure in the ambient environment
  - T_v is the ambient temperature

SPLASH MODEL

- Assuming the spray distribution can be described by Rosin-Rammler distribution function
  - $$1 - Q = \exp\left[-\left(\frac{D}{X} \right)^q \right]$$
  - Distribution parameter: $q = K \times \mathrm{Re}^n$
  - Characteristic diameter (the drop diameter when $Q = 0.632$):

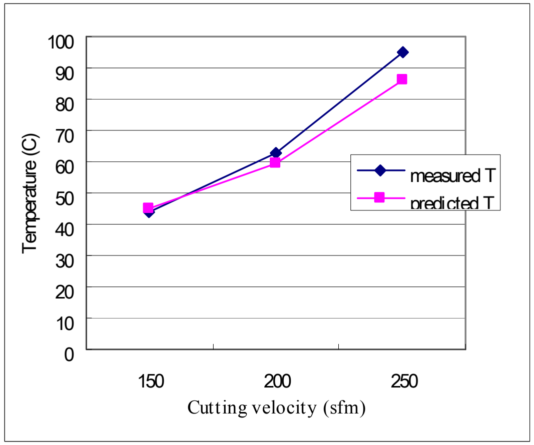
$$X = \frac{C_a v^{0.5} \dot{m}_{oil}^{2} \left(1 + \frac{\dot{m}_{oil}}{\dot{m}_{air}} \right)^{0.5} d_{avg}^{0.1} \sigma^{0.2}}{\rho_{air}^{0.3} u_{oil}}$$

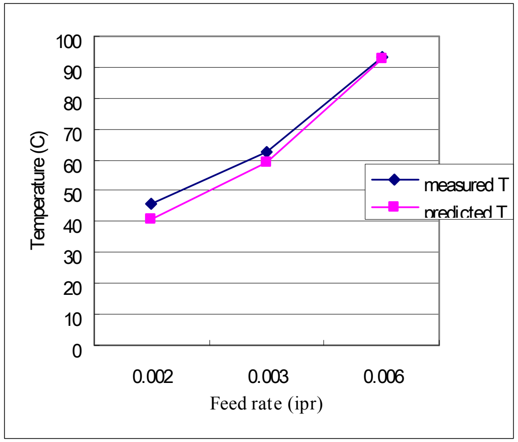
EXPERIMENT SETUP

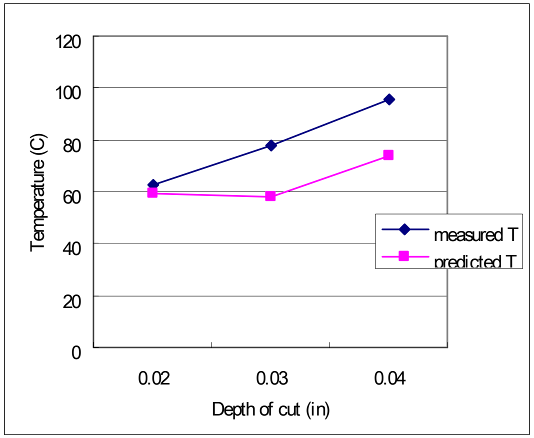


CURRENT RESULTS (1)

- Cutting temperature (dry machining)
  - Steady state temperature at thermal couple location

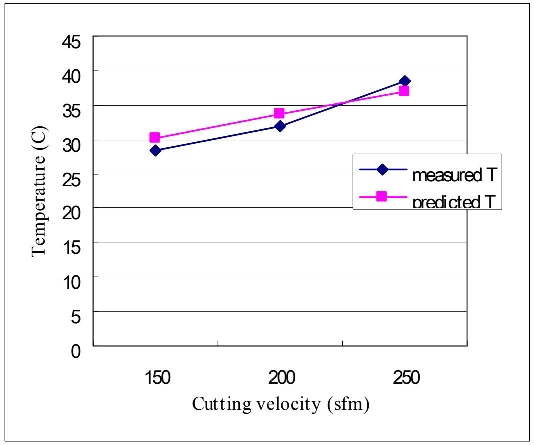


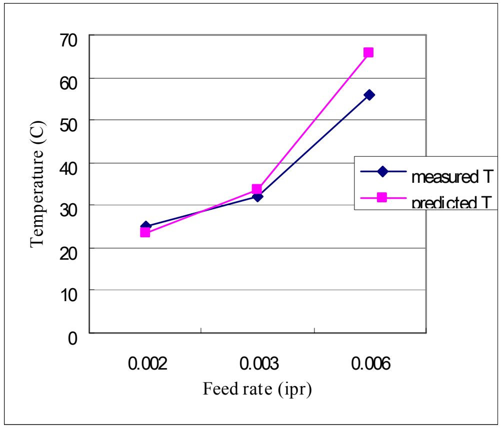


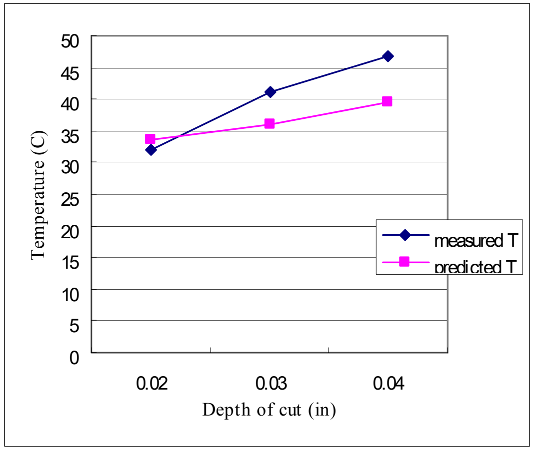


CURRENT RESULTS (2)

- Cutting temperature (near dry machining)
  - Steady state temperature at thermal couple location

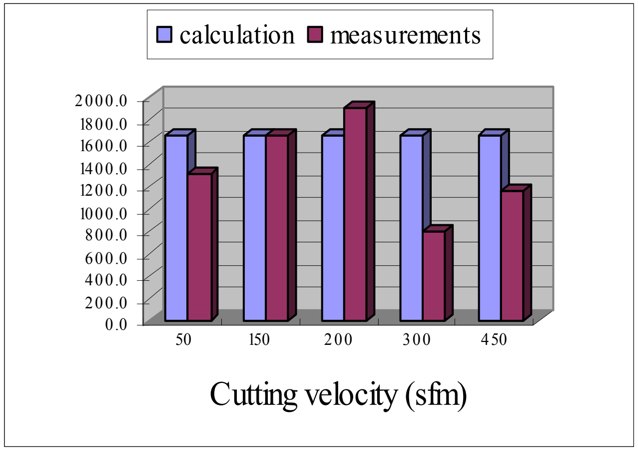


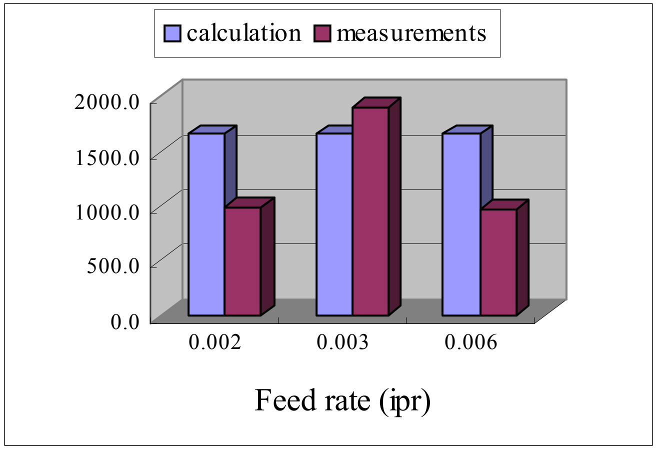


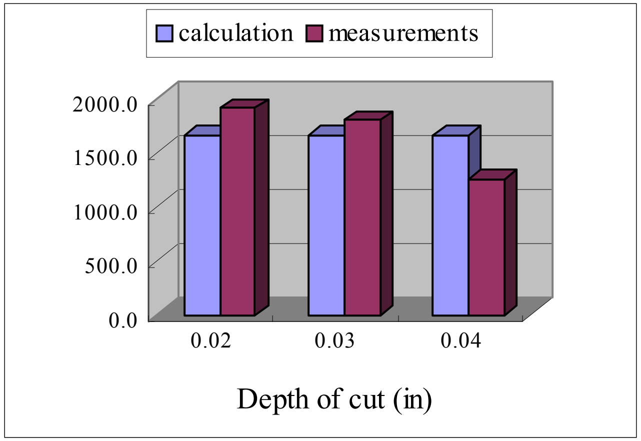


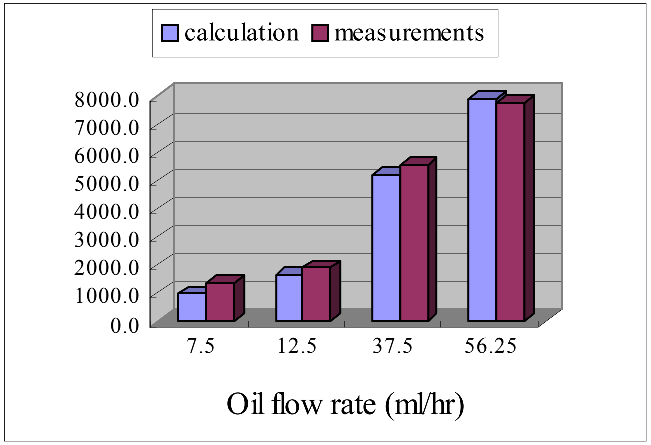
CURRENT RESULTS (3)

❖ Aerosol generation rate in near dry turning



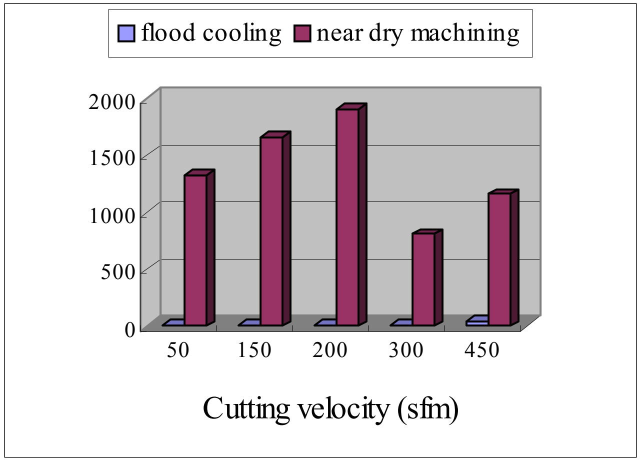


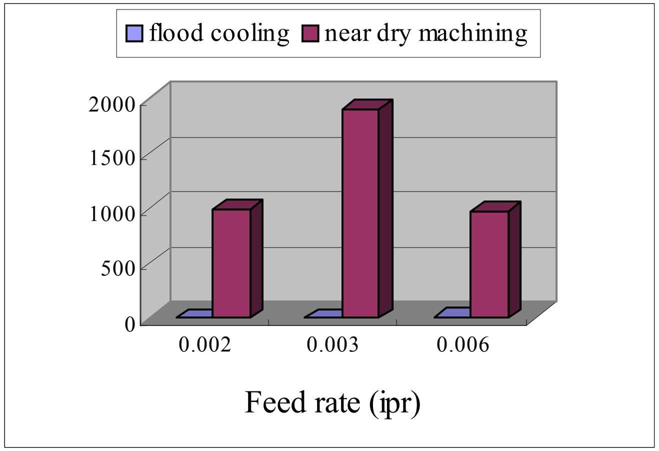


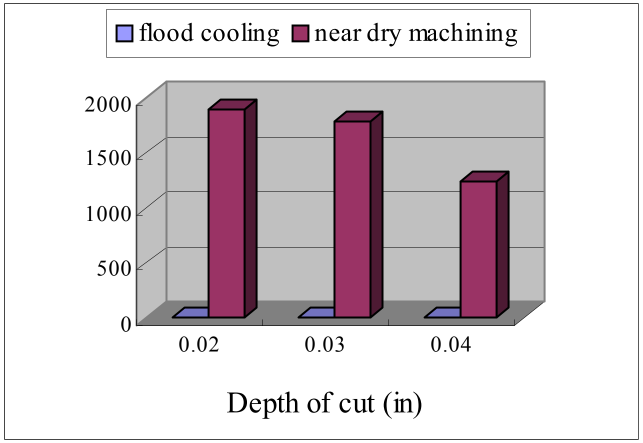


CURRENT RESULTS (4)

- Experiment results for near dry turning and flood cooling
  - Near dry turning: ~1000 $\mu g / m^3 s$
  - Flood cooling: ~10 $\mu g / m^3 s$







CONCLUSION AND FUTURE WORK

- Cutting temperature results shows a good agreement with the analysis model
- Only cutting fluid flow rate affect the aerosol generation rate in near dry turning
- Aerosol generation rate in near dry turning is much higher than that in conventional flood cooling
- Force model establishment and validation
- Tool wear model establishment and validation