Comparison of Flood vs. Microlubrication on Machining Performance (Part I)

T. F. McClure, R. Adams, and M. D. Gugger
TechSolve, Inc.
Cincinnati, OH

M. G. Gressel
National Institute of Occupational Safety and Health,
Cincinnati, OH

TechSolve wishes to thank

- Illinois Waste Management and Research Center
  - Unist, Grand Rapids MI
  - Hangsterfer' s Laboratories, Mantua, NJ
  - Milacron, Cincinnati, OH
  - Spartan Chemical Company, Toledo, OH
  - Master Chemical Company, Perrysburg, OH
- NIOSH

TechSolve also wishes to thank

- The members of the Industrial Advisory Board who assisted with this project
  - John Burckle, United States Environmental Protection Agency
  - Skip Wolford, Spartan Chemical Company
  - Stuart Salmon, Advanced Manufacturing Sciences and Technology
  - Larry Rissler, Boeing Commercial Aircraft
  - Michael Gugger, TechSolve, Inc
  - Michael Gressel, NIOSH

Project Objective

- **The economic benefits of metal removal fluids**
  - Increased cutting tool lives
  - Higher production rates
  - Lower power consumption

  Have led to their wide spread usage throughout the machining industry
- Traditional application (flood) of these fluids require large quantities

of metal removal fluids

- These large quantities pose significant environmental hazards
  - Prompting federal, state, and local legislation governing their treatment and disposal
  - Increasing the cost of metal removal fluid handling and disposal
- These increasing costs have prompted fluid users to try and extend fluid lives and reduce fluid disposal
  - Fluid Maintenance Programs, Chemical Management

- Pending OSHA Mist Regulations will only add to the cost of using metal removal fluids
- Environmental compliance (including life extension) and new regulations are eroding the economic benefits associated with metal removal fluid usage

- New advances have enabled old machining techniques to challenge the economics of machining
  - Dry Machining (new tool materials and coatings)
  - Microlubrication
    - (aka Minimum Quantity Lubrication, Mist Lubrication)

- For these new/old techniques to work, data required to make decisions

- Compare performance of cutting tools lubricated with metal removal fluid applied by Microlubrication and Flood Application
  - Collect and compare machinability data (tool wear, cutting forces, and productivity) during drilling and milling
  - Evaluate effect on machining costs
  - Compare mist levels generated (Part 2)

Fluids

- Fluid 1 - Soluble Oil
- Fluid 2 - Soluble Oil with EP Additives (10%)
- Fluid 3 - Experimental Vegetable Oil Based Soluble Oil (10%)
- Fluid 4 - Soluble Oil (10 %)
- Fluid 5 - Soluble Oil (10 %)
- Fluid 6 - Straight oil (used in misting tests only)

Fluid Application Conditions

- **Flood**
  - Delivered directly from sump by the pump of a Tongil TVN-80 CNC Vertical Machine Center using typical fluid delivery nozzle
  - Nozzle aimed at cutting tool
  - Flow rate = 1.7 gpm
- **Mist**
  - Three Nozzle Unist Mist Application System, Model # 25034
  - Nozzles located approximately 1200 apart
  - Flow rate = 0.0029 gpm

Same Application Conditions used for both Drilling and Milling

Drilling Test Conditions

- Material: AISI 4340 Steel (32-34 HRC)
- Drill: 0.5 inch heavy duty, oxide coated, high speed steel, 135° split point
- Speed: 55sfpm
- Feed: 0.007 ipr
- Depth of Cut: 0.006 inch
- Hole Depth: 1.0 inch
- End of Life Test Criteria: 0.0 10 inch uniform wear or drill failure
- Repetitions 5 per fluid test condition

* Test procedure published in Pollution Prevention Guide to Using Metal Removal Fluids in Machining Operations (Visit www.techsolve.org)

Drilling Test Conditions

- Typical Drilling Test Setup

add photo here

Drilling Test Results

Average Number of Holes Drilled To Reach End of Life Criteria

Fluid Number	Flood Application	Microlube Application
1	65.0	62.8
2	66.7	58.6
3	60.8	61.4
4	56.8	64.3
5	58.1	61.0
6	*	74.4

Average Thrust Force (lbs) At End of Life

Fluid Number	Flood Application	Microlube Application
1	592	479
2	559	481
3	570	447
4	593	457
5	559	481
6	*	512

* Fluid not tested under this condition

- **Analysis indicates**
  - No statistically significant difference in tool life (number of holes to reach end of life criteria) between drills cooled/lubricated with fluid or microlubrication.
  - In three of five cases, thrust forces significantly lower during microlubrication than flood cooling
  - Greatest variation in microlubrication performances seen with straight oil and Fluid 2

- There is no difference in Machining Cost in Drilling between Microlubrication and Flood Application.
  - Caution — At these given speeds and feeds

Milling Test Conditions

- Material: AISI 4140 Steel (24-26 HRC)
- Cutter Body: RA2 15.44-25 MN25 -15 C (1 inch diameter)
- Cutter Insert: R215.44-15T3O8AAM (grade SM-30 uncoated carbide)
- Speed: 400 sfpm
- Feed: 0.005 ipt
- Axial Depth of Cut: 0.5 inch
- Radial Depth of Cut: 0.06 inch
- Length of Pass: 4 inches
- End of Life Test Criteria: 0.0 10 inch uniform wear or tool failure
- Repetitions 5 per fluid test condition

* Test procedure published in Pollution Prevention Guide to Using Metal Removal Fluids in Machining Operations (Visit www.techsolve.org)

Milling Test Results

Average Number of Passes Made To Reach End of Life Criteria

Fluid Number	Flood Application	Microlube Application
1	64	88
2	72	98
3	66	80
4	102	160
5	76	170
6	*	140

* Fluid not tested under this condition

Average Resultant Force (lbs) At End of Life

Fluid Number	Flood Application	Microlube Application
1	48	38
2	40	37
3	46	36
4	No Data Available	No Data Available
5	No Data Available	No Data Available
6	*	No Data Available

* Fluid not tested under this condition

- **Analysis indicates**
  - In 4 of 5 cases, microlube application of dilute metal removal fluid provide statistically significant improvement in tool life (number of passes to reach end of life crtiteria.
  - Fluid 3 which was an experimental formulation did not show significant improvement in tool life.
  - Limited data indicates that machining forces were not significantly different when microlubrication or flood application was used.
  - Straight Oil outperformed 3 of the 5 soluble oil products tested.
- **Effect on Milling Economic**
- Using Cost Equations from Machining Data Handbook, calculated effect of tool life differences on Total Milling Cost, Productivity, and Operating Time/Piece
- Fluid 1 (Worst Best)
- Fluid 5 (Best Best)
- Calculations based on a single milling pass in a lot of 25 pieces under test machining conditions

Milling Economy

- **Fluid 1**

	Total Milling Cost ($)	Productivity Operating (Parts/Hour)	Time/Piece (minutes)
Flood	$9.14	8.9	1.34
Microlubrication	$9.05	9.0	1.30
Delta	$0.09	0.1	0.04

- **Fluid 5**

	Total Milling Cost ($)	Productivity Operating (Parts/Hour)	Time/Piece (minutes)
Flood	$9.09	8.9	1.32
Microlubrication	$8.92	9.0	1.25
Delta	$0.17	0.1	0.07

- Based on production rates and number of milling passes, economic analysis indicates that microlubrication may offer a benefit.
- Based on improvement in tool life, it may be possible to increase cut speed thereby increasing production
  - Tool Life will decrease

Summary

- Tests indicate there is no difference in performance in drilling between metal removal fluids applied by microlubrication and flood application.
- Tests indicate there is a performance improvement in milling, when metal removal fluids are applied by microlubrication. In some cases, this difference is very significant.

Caution

- These tests represent results on to materials with two machining operations and two sets of machining conditions.
- Further research required to justify wide scale implementation of microlubrication processes

"Disclaimer" *Wally Boelkins - President, Unist Inc.*

This report contains very good and valuable information when WATER BASED FLUIDS are compared.
When the "STRAIGHT OIL" was sprayed, it's application was at the same fluid and air volume settings as when water based fluids were sprayed. This created a oil consumption about 5 times recommended usage.
The same volume of atomizing air also created a much greater breakup of oil than

recommended.
Water basically absorbs heat during evaporation and a fine droplet size encourages rapid evaporation.
Oil, on the other hand primarily lubricates - Preventing heat generation.
Droplets of oil in the atmosphere are not necessary or desirable to effectively lubricate the tool/work piece.
A high quality vegetable lubricant is extremely effective and non-polluting, if properly applied.

UNIST, Inc. - 4134 36th St. SE - Grand Rapids, MI 49512 USA (616) 949-0853 - (800) 253-5462 - Fax (616) 949-9503
mailto:unimail@unist.com