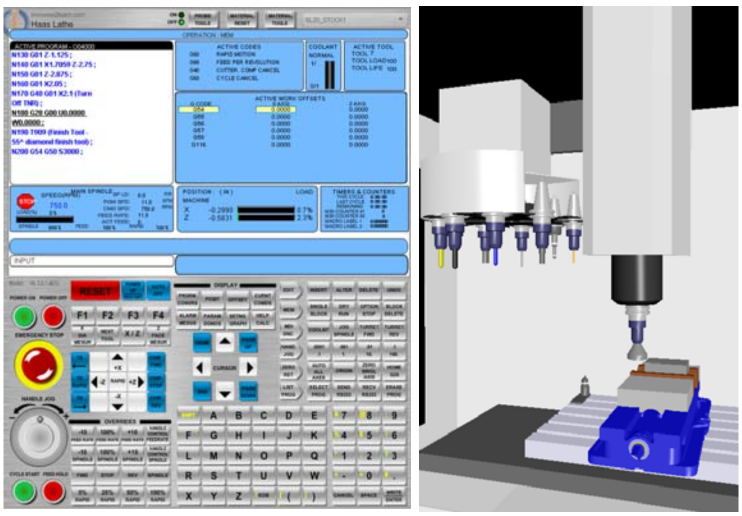
Virtual Training Environment
CNC Machining

Flight Simulator Technology

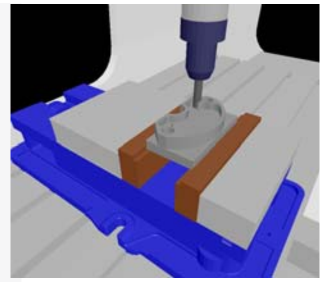
The Virtual Training Environment for CNC Machining combines *powerful* "flight-simulator" technology with a *flexible* Internet-based learning content management system to deliver a truly innovative learning experience.



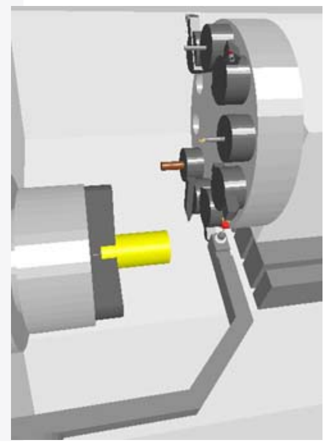
Simulated 3D machine models

Mimic Reality

- Virtual mills and lathes
- Industrial control panels
- Edit, load, run and save NC programs
- Set tool and work offsets
- Touch probes
- Stock material removal
- Canned cycles
- Control alarms



Real-time material removal



Mill and lathe touch probes

Learning Productivity Tool

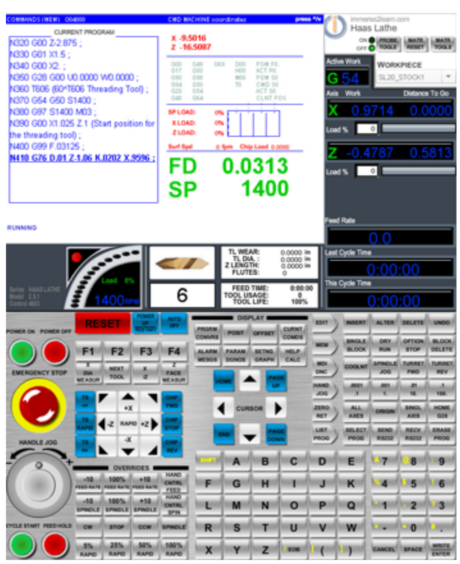
Unlimited access to train and rehearse in the Virtual Training Environment for CNC machining enables learners to develop greater confidence and proficiency prior to performing actual procedures and operating equipment.

Learn at Your Convenience!

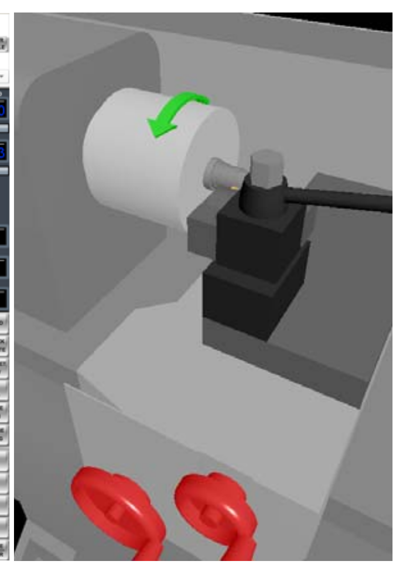
Learn CNC machine setup and programming with popular control panels for Haas Machine Tools.

Major Benefits

- Cost-effective and safe
- 24/7 access at your convenience
- Track and measure learner progress
- Reduce risk to people and equipment
- Increase control panel training contact-time
- Learn with virtual controls and 3D machines



Popular control panels

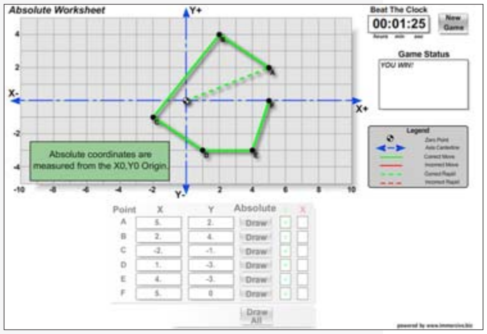


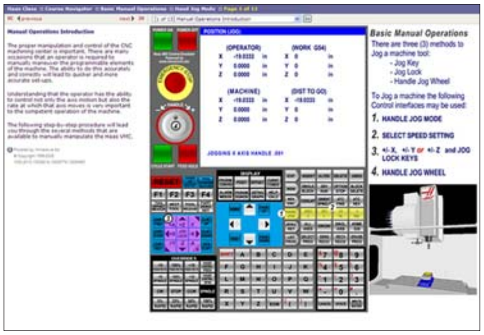
Lathe applications

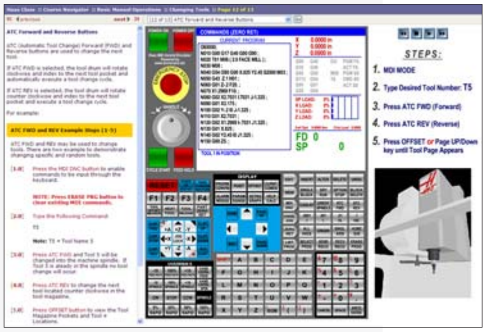
Additional Products

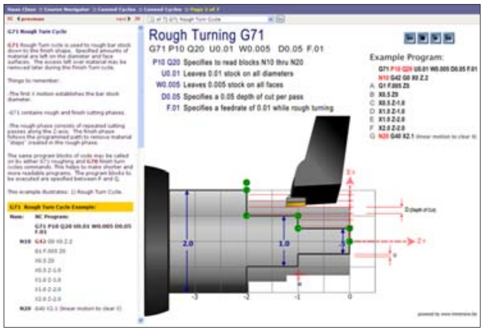
Online Learning Courses and Virtual 3D CNC Machine

Mill and *Lathe* CNC online courses provide the learner with comprehensive learning content, interactive exercises and virtual CNC panels and 3D machines. Depending on the course selected learning modules may include:









Interactive online courses

Setup

- Machine Motion Description
- CNC Panel Interface
- Machine Start-up
- Manual Operations
- Job Setup
- Edit Capabilities
- Program Entry
- Program Run

Programming

- Codes and Programs
- Program Structure
- Cartesian Coordinates System
- Cutter Compensation
- Tool Nose Radius Compensation
- Circular Interpolation
- Hole Manufacturing
- Programming Labs

Color Manuals, Exercises and Projects

Mill CNC Programming Level 1

An introduction to codes and programming, this manual is designed for beginner to intermediate level *Mill* CNC operators and programmers. The content and sample programs provided cover a broad range of CNC programming requirements. Basic mathematics and formulas are used.

Lathe CNC Programming Level 1

An introduction to codes and programming, this manual is designed for beginner to intermediate level *Lathe* CNC operators and programmers. The content and sample programs provided cover a broad range of CNC programming requirements. Basic mathematics and formulas are used.

Mill CNC Programming and Applied Mathematics Level 2

This intermediate to expert level manual provides much more advanced application of codes, programming, and use of canned cycles. The content and sample programs provided cover a broad range of CNC programming requirements. Advanced mathematics and formulas including applied shop floor trigonometry and geometry are used.

Other Products and Services

- Robotic simulation
- Learning content management system
- Online evaluation tools
- Content development
- Onsite training
- CNC programming

Lansing Community College

From Art to Part
A Continuous Line of Teaching

Prepare Students for Today's Shop Environment by Seamlessly Linking CAM Programming to CNC Machining

Mark McComb, Computer Aided Design and Manufacturing Instructor

"With VTE-CNC, students come to class enthusiastic and better prepared. In the first year, we realized our return on investment."

- Jeff Tarr

At Michigan's Lansing Community College (LCC) Mark McComb, CAD/CAM Instructor and Jeff Tarr, CNC Machining Instructor teach the two ends of the art to part manufacturing process. McComb focuses on product design and cutter path creation. Tarr is responsible for developing flawless NC programs, ensuring productive and safe CNC machine operation, and producing high quality parts. The two men use the Internet-based, Virtual Training Environment for CNC (VTE-CNC), powered by Immerse2Learn.com to create a continuous line of teaching.

Increased Productivity

McComb and Tarr credit the Internet-based Learning System with dramatically boosting their productivity. "With VTE-CNC," says McComb, "I can teach the same material in 96 contact hours that once required 288 hours. We've consolidated three courses into one because we're more time-efficient."

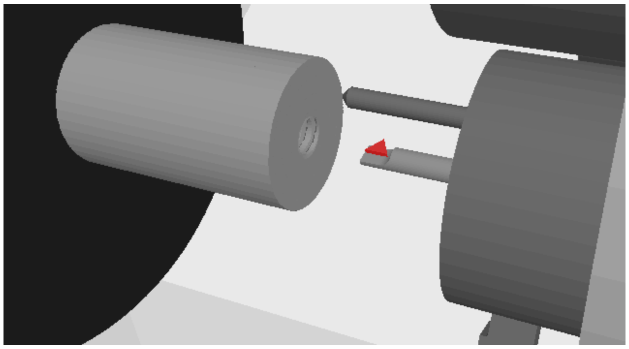
- Students spend much less time waiting to use machines.
- Students use the machines more productively when they're on them.
- Tightly link CAD/CAM to CNC machining instruction, so students can transition fast from automated to manual programming, CNC control interface, and general machining operations.
- Learning can be customized to meet changing industry demand.

"Our student's basic instinct is to get through our program, find a job, and start earning a good quality of life," McComb states. This won't be hard, because there are more than 200 machinist jobs vacant in the five-county area around Lansing, Michigan. Some students receive offers prior to graduation.

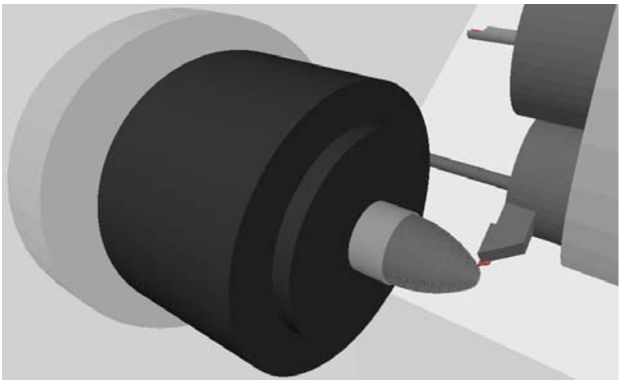
Total Training Solution

VTE-CNC's complete system consists of software with tutorials and quizzes and virtual CNC control panel and 3D machining centers that help teach machine tool operation. Students can access the materials 7/24 on line in school or at home, learn at their own pace, and back up to review or repeat as much as they wish.

"With VTE-CNC, students come to class enthusiastic and better prepared," says Tarr, "The virtual training environment is more interactive than a textbook. "Students can read about the subject, view an operation on interactive video, play it forwards and backwards, take it apart, and see how it works.



Egg design and machine project: threading process.
Simulated with virtual CNC panel and 3D machines in VTE-CNC.



Egg design and machine project: contour roughing and finishing.
Simulated with virtual CNC panel and 3D machines in VTE-CNC.

"Today's young people are computer oriented," he continues. "They work comfortably with the fast-paced VTE-CNC materials, which provide a tremendous amount of information. I've had instructors tell me that they taught more in thirty minutes to students prepared with VTE-CNC than they did in three contact hours before using the virtual training environment."

VTE-CNC has tools that allow instructors to customize the system to meet a variety of training needs. When students required more information about Cartesian Coordinates, the

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"Based on the increased throughput... our payback is 2.5 to 1."

- Mark McComb

3D spatial system, McComb inserted a Power Point presentation as an additional "learning resource." VTE-CNC also lets Tarr pick and choose the learning modules he wants to use. "If I'm teaching lathe," he states, "I can activate the appropriate learning modules to deliver a controlled and focused lathe class."

250% Throughput Increase with Virtual Training

Students use VTE-CNC to edit the CAD/CAM generated or manually written part programs. "If the code they've written will crash the machining center, the software tells them," says Tarr, "and they correct it in a truly virtual environment." Once the program is visualized in a 3D interactive environment, students move to a machining center and make parts with it.

In the past, students edited programs on a machine tool and sometimes monopolized it for an entire class period while others had to learn by observing. "I wasted valuable instruction time managing student access and answering the same CNC operation questions for each individual," says Tarr.

After proving their knowledge in VTE-CNC, some of Mark McComb and Jeff Tarrs' students are ready to advance to real CNC panels and machines.

LCC has five mills and five lathes in its advanced manufacturing program, says McComb. "Before we had VTE-CNC, we could teach ten students at once on those machines, but nowadays our capacity is 25. Based on our increased throughput, I guess you'd say the payback is 2.5 to 1."

Once they have demonstrated that they are ready in VTE-CNC, up to ten students can work on the mills and lathes while the others learn with virtual CNC panels and 3D machines. VTE-CNC reproduces the controls of a Haas CNC machine and the steps it takes to make a part. Students access it on line, practice machining in a virtual environment, and even make a virtual part before they work with a real machine tool. McComb can project any image from VTE-CNC in class, so a roomful of students can observe a virtual machine at work instead of crowding around a real one. Virtual preparation means more self-confident students, McComb reports. Machine tools can be frightening to a beginner, because they work so fast and make chips and noise. Students who have worked on VTE-CNC virtual control panels and machines know what the controls look like and are better prepared for everything that will happen in the real world.

Local manufacturers need advanced CNC training for new hires and current employees who wish to upgrade their skills, but industry wants to keep its machines—and its people—working. This has created an opportunity for LCC. "We use our online curriculum and VTE-CNC for the first level of training," says McComb, "and can deliver custom instructor-led training." Once trainees complete their virtual preparation, they get hands-on experience on LCC's machines—or on the job.

"In the first year, we realized our return on investment with the VTE-CNC training system." Says Tarr. "Immerse2Learn.com has always been very responsive to our product support needs."

Macomb Community College

Students go from Virtual Machining to Cutting Metal at Internet Speed

Online Training System Combines Internet with Hands-on Instruction to Produce Skilled Machinists

Gary Walters, Professor of Advanced Technology Applied Processes

"Students run the virtual CNC panels and 3D machines anytime and anywhere."

\- Gary Walters

In just thirty credit-hours—two per week for 15 weeks—Macomb Community College, Warren, Michigan, can teach a complete beginner how to program and operate a CNC machining center—and much more. Macomb's secret is the turnkey Virtual Training Environment for CNC Machining (VTE-CNC), powered by Immerse2Learn.com. VTE-CNC combines learning content management; virtual CNC mill and lathe panel and 3D virtual machines; and interactive graphical learning content.

"Along the journey to a 62 credit hour Associate Degree of Applied Science," says Gary Walters, Professor of Advanced Technology Applied Processes at Macomb, "students can earn CNC Machinist and CAM Technologist certificates. They find it's easier to learn with VTE-CNC—and they keep coming back for more.

Combination Technologies

"Along with CAD/CAM and CNC, we teach how to get the most out of the manufacturing process by utilizing varying levels of automation, such as lasers and probes to define fixture and tool length offsets, magnetic tables, 80,000 RPM spindles, and state of the art cutting tools," Walters continues. He wants graduates to feel confident that they can perform a variety of functions for a Tier 2 or Tier 3 employer. Macomb's flexible class schedules and online capabilities mean that it can provide on demand training to small and medium sized job shops that want to remain globally competitive. These shops use VTE-CNC to introduce new technology to operators or upgrade operator skills in CNC, EDM, rapid prototyping, reverse engineering, and laser. VTE-CNC scalable program makes this happen fast without a big investment.

"It's a *combination* of technologies that allow us to machine at high speeds and feeds, such as 300 to 400 IPM for tool steels and 1,000+ IPM for softer materials such as aluminum," Walters explains. "The machine can't do it alone, nor can the program or the cutting tool." He's excited to provide this level of technology training to beginners and experienced people alike.

Macomb's facility—a Haas Technical Education Center—is one of several around the US. Haas Automation, the world's largest CNC machine tool builder, partnered with the college through the Haas Technical Education Program and the local Haas factory outlet. A key member of this winning team is Immerse2Learn.com.

Learn by Doing

"The best way to learn CNC machine technology is to actually use it!" Says Walters. All registered students get a personal login, which allows them to run the virtual CNC panels and 3D virtual machines—anytime and anywhere. Working at their own pace and repeating material as often as needed, students learn basic tool movements and machine motion; tool response to controller commands; canned-cycle concepts like peck drilling, tapping, circular and linear motion;

Red electric guitar is the final product from an art-to-part process by reverse engineering, CAD/CAM, and high speed machining on Haas machining centers.

cutter and tool length compensation; and work offset procedures complete with probing. Students also learn how to create, run, edit and save programs. They can manually program M&G code, and can load and save NC programs and offsets. VTE-CNC combines virtual, 3D, interactive industrial machines; popular industrial CNC panels; and dynamic CNC mill and lathe curriculum and assessment.

"Plotting out coordinates is the tough part of programming and students must learn it first," Walters explains. "In VTE-CNC, they learn it

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quicker because it's taught through games. Next, they write code, which is the easy part." Steady progress keeps them motivated and they perform better in class.

Gary Walters and Eric Lewicki, Associate degree student, CNC certificates graduate, and MCTEAA- Macomb County outstanding student award recipient.

That's not all! Students make virtual parts risk-free, then come to class confident and pre-qualified to work on a real machining center under supervision of a teacher. Virtual preparation makes the classroom experience efficient and safe. In 2.5 years of teaching, Walters has seen just one end mill break.

"The virtual training environment is invaluable!" Walters states. "Quite honestly, we purchased the training system to get more done in less time."

Now, students are able to train with VTE-CNC anytime and anywhere. Also, during lectures, I can project VTE-CNC onto a large screen, so everyone clearly sees the control interface and 3D machines. This is much better than trying to gather 20 students around an actual control panel."

"We purchased the training system to get more done in less time."

- Gary Walters

The training system has all classroom lecture material built in for access anytime. Walters likes the Learning Content Manager, which he uses to manage his students, set up additional classes, create quizzes, and develop new courses. He recently wrote an EDM course with it and has more in the pipeline. In addition, VTE-CNC provides manuals to accompany the interactive learning content so students have something to hold in their hands.

Walters calls VTE-CNC a great marketing and recruiting tool because it allows him to show off his program visually. "It's always been hard to describe CNC to non-manufacturing students," he says, "but now I can clearly show them CNC technology. I've seen it attract many that never heard of this field. Parents see CNC and it just blows them away."

Walters uses VTE-CNC to link more closely with local high schools and vocational centers where he's expanding the advanced manufacturing program.

VTE-CNC is helping to put manufacturing back into classrooms that have been limited to computer-aided-design for years, due to space restrictions, liability and a shortage of qualified instructors. It's a real win-win.

Return on Investment... BIG TIME!

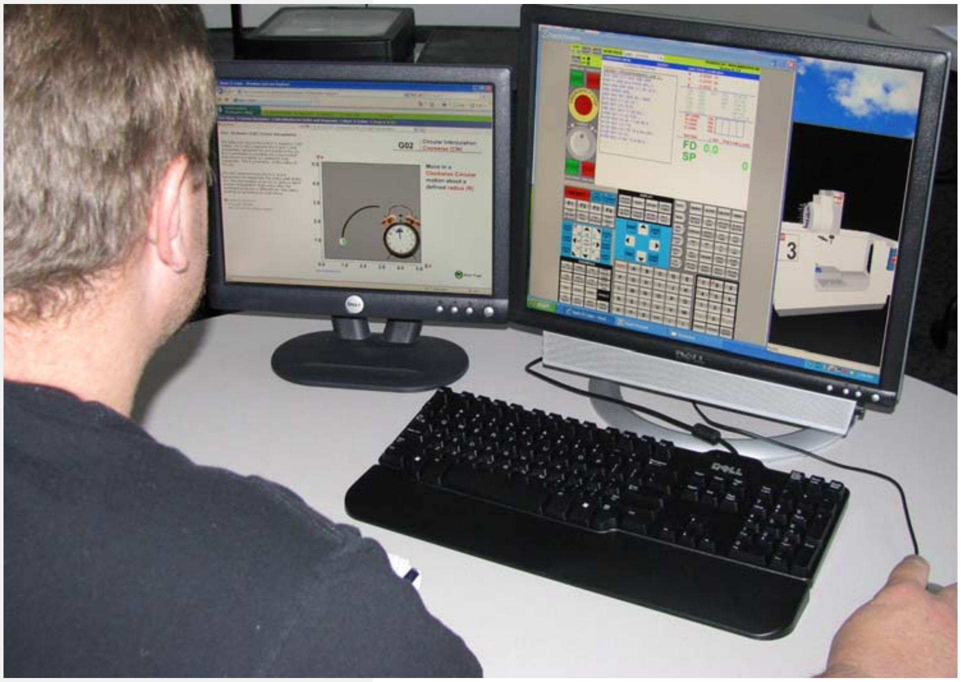
The Virtual Training Environment for CNC (VTE-CNC) delivers:

- Attract and keep more students.
- Learning is fun, even the tough parts. Students perform better, stay motivated.
- All learning tools available 7/24.
- Students work at own pace and come to class better prepared.
- Students learn machine operation in risk free virtual environment, pre-qualify before using real machine tools under supervision.
- Teachers get more done in less time.

Northwestern Michigan College

Teachers and Students Do More In Less Time with Online Virtual CNC Training

Students Access Virtual Machining Centers Online 24/7, Before Advancing to the Real Deal!



Instructors and students benefit from online interactive learning content, exercises, assessments and virtual CNC panels and 3D machines that run actual M&G code programs.

"There will probably be a lot of programs that benefit from this technology."

-Ray Niergarth

In just over a year, the Virtual Training Environment for CNC (VTE-CNC), powered by Immerse2Learn.com has made the Manufacturing Technology program more efficient and effective at Northwestern Michigan College (NMC) in Traverse City. Ray Niergarth, Instructor in Manufacturing Technology, credits VTE-CNC online accessibility and interactive features.

Northwestern Michigan College's (NMC) Manufacturing Technology program comprises basic mill and lathe operations (two semesters) and CNC machining and CAM programming (two semesters). Graduates can earn a Machining Certificate or an Associate Degree.

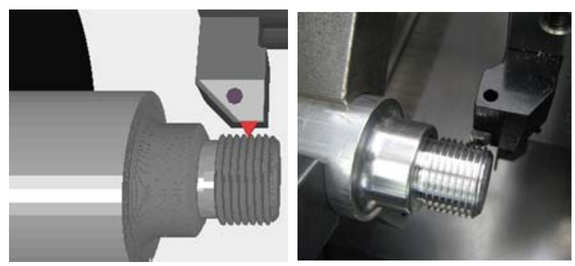
Students Work Smarter

NMC uses VTE-CNC to teach actual CNC operations in the virtual world, so that students work smarter in the real-world. Niergarth says, "Students develop CNC programming and setup skills in VTE-CNC, before they are able to work one-on-one with instructors at actual CNC machines on the shop floor." Niergarth adds, "This training process helps make the learning experience more productive."

When NMC purchased a mill and lathe from Haas Automation, it licensed VTE-CNC, which consists of software with tutorials and quizzes; and the virtual CNC panels and 3D machining centers that aide in teaching machine tool operation. Now, students can access class materials 24/7 on line at home or in NMC's computer lab. They learn at their own pace—and can back up to repeat material as much as needed.

Teaching software can be a powerful tool when it's used to reinforce classroom instruction—and it helps to make everything more efficient. The Virtual Training Environment for CNC (VTE-CNC) has vivid, easily understood graphical demonstrations of tool movement. The software includes self-tests with immediate feedback that helps students come to class better prepared.

Niergarth's classroom presentations reinforce what students get from VTE-CNC. "Different people have different ways that they learn better," he states. The combination of VTE-CNC and classroom instruction ensures that the college is providing the most comprehensive learning environment available today.



Students learn how to load, modify and run NC programs with virtual CNC panels and machines, before the real-world.

With VTE-CNC, the learning material is "always the same for each class, for each student," he continues. "There's always a chance that something gets overlooked or presented a little differently in the classroom. The software gives everyone the same information and it's always easy to find there."

Bottom Line—everyone works smarter. Classroom instruction and software reinforce each other, so students learn more and learn it quicker. Instructors make better use of classroom time and present more material in the same number of hours.

Northwestern Michigan College

Teachers and Students Do More In Less Time with Online Virtual CNC Training

Students Access Virtual Machining Centers Online 24/7, Before Advancing to the Real Deal!

"Teaching with the virtual CNC panels and 3D machines sure beats having everyone crowd around one machine"

-Ray Niergarth

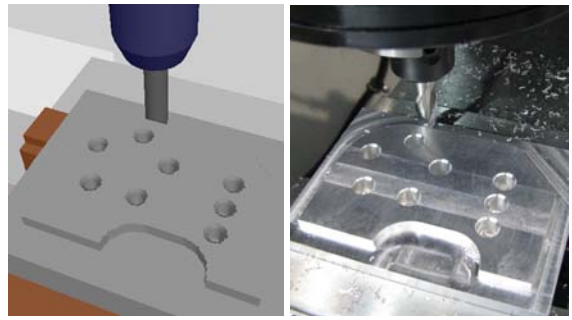
Like the Real Thing

Niergarth has one Haas lathe and one Haas mill in his classroom, which means that he can supervise only two students as they work hands-on. While they wait their turn, other students complete assignments with VTE-CNC's virtual CNC panels and 3D machining centers with graphic imagery that looks and behaves like the real thing. Niergarth says that it's important to instruct students on the machine one by one to ensure safety and also because he can give them tips from his personal experience. If he wants to demonstrate an operation to the entire class, he can project VTE-CNC virtual CNC panels and Machines at the front of the classroom. Students interactively follow along at their own computer stations. This beats having everyone crowd around the machine.

Students learn CNC programming in VTE-CNC's Internet-based virtual environment, troubleshooting as they go. The virtual CNC panel sounds an alarm if they make an error that would crash a real machine. This saves time and all but eliminates the risk of costly machine crashes. "We catch a lot of potential problems," says Niergarth.

There are other VTE-CNC features that Niergarth likes. He can customize or edit test questions in the material to fit the learning style of students or his personal preference.

"The instructor editing capability is definitely a benefit," he says. The instructor's automatic grade book/student performance tracking feature speeds and simplifies record keeping for large classes, freeing Niergarth to teach.



Students zoom-in and rotate around a virtual mill to review programs, before cutting actual parts.

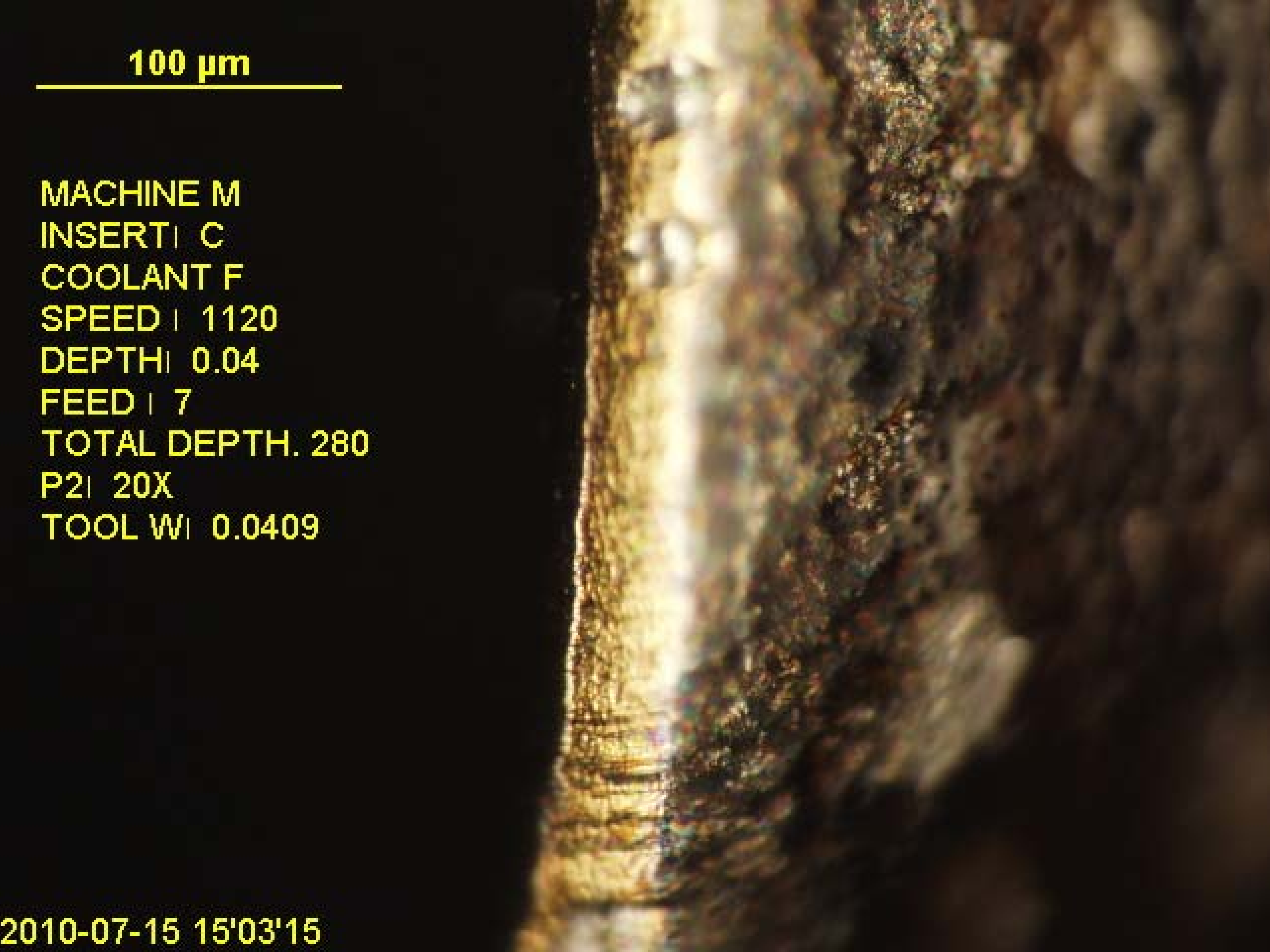
To continually promote NMC's Manufacturing Technology program, Niergarth creates awareness among high school counselors with presentations and tours to manufacturing sites. He tells them that machining has changed over the past few years with increasingly sophisticated technology and a highly trained workforce.

NMC shares its machine lab and equipment with the high school machine shop program. Younger students learn CNC operation and setup. CNC Programming starts when they reach college level. VTE-CNC helps here too. The software is wonderfully flexible, which allows instructors to make selected portions available to beginning students.

Industry calls NMC looking for graduates. As Niergarth tells it, auto-related manufacturing in Michigan is "slowing down or closing," but other area manufacturers are "going strong" with products like stainless surgical instruments. There are plenty of openings and opportunities for graduates in northwestern Michigan's growing manufacturing sector.

Niergarth sees VTE-CNC as the coming thing. "There will probably be a lot more programs that benefit from this technology," he states. It could be used to teach "computer-assisted drafting, solid modeling, programming logic controllers, and many other skilled trades."

Instructor, Ray Niergarth at the controls.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Impact of Micromist in CNC Machining

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Present at
Texas HTEC Conference
Waco, Texas
Oct 29, 2010

INTRODUCTION

- The cost of cutting fluids is around 17% of the machining costs of automotive components.
- 1.2 million workers are affected by the chronic effects produced by cutting fluids.
- OSHA demands tighter control on cutting fluids (cost, maintenance, disposal, emission standards…)
- Propose solution: use micromist as minimum quantity lubrication in machining

Source: (Marksberry and Jawahir, 2008)

OBJECTIVES

1) Characterize micromist
2) Apply micromist in macro/micro machining
3) Identify technical issues
4) Study economics of micromist

NSF-RET program (summer2010)

INVESTIGATION: setup

1) **Machines: Haas OM2 CNC micromill**, **VF1 CNC mill**, and **SL20 CNC** lathe.
2) **Workpieces:**
   - **Micromachining**: 12 mm (**1/2 in**) square bars of **316L stainless steel**, **CP titanium PEEK plastics, H11 tool steel, 1010 steel, 6061-T6 aluminum**.
   - **Macromachining: 4140 steel** bars / plates
3) **Tools**
   - **Micromill**: **TiN un/coated** WC, Ø100-1016μm (**0.004-0.040 in**)
   - **Microdrill:** Uncoated WC Ø50-203μm (0.**002-0.008** in)
   - **Macromill**: **TiN un/coated** WC Ingersoll APKT102308R-HS insert, Ø15.8 (**5/8** in)
   - **Marcroface: TiN un/coated** WC Hertel TNG431 **insert**
4) **Tool failure criteria**: 50 μm (**0.002 in**) flank wear for **microtool**, 300 μm (**0.012 in**) for **macrotool.**

INVESTIGATION: setup

5) **Machining parameters**:
   - **Micromilling**: 15-157 m/min (**50-520 ft/min**),10 µm/tooth (**0.0004 in/tooth**), 0.35mm (**0.014 in) axial depth**, 0.56 mm (**0.022 in) radial depth**, climb (down) side milling.
   - **Macromilling**: 55-102 m/min (**183-343 ft/min**), 0.043-0.178 mm/tooth (0.0017-**.0070 in/tooth**), 1-2 mm (**0.04-0.08 in) axial depth**, 4.25-8.5 mm (0.017-0.333 in) radial depth, down milling on **D2 tool steel**.
   - **Macrofacing:** max 44-80 m/min (**147-265 ft/min**), 0.5 mm (0.020 in) depth of cut, 0.1-0.3 mm/rev (**0.004-0.006 in/rev**) feedrate, **constant RPM, on 4140 steel.**

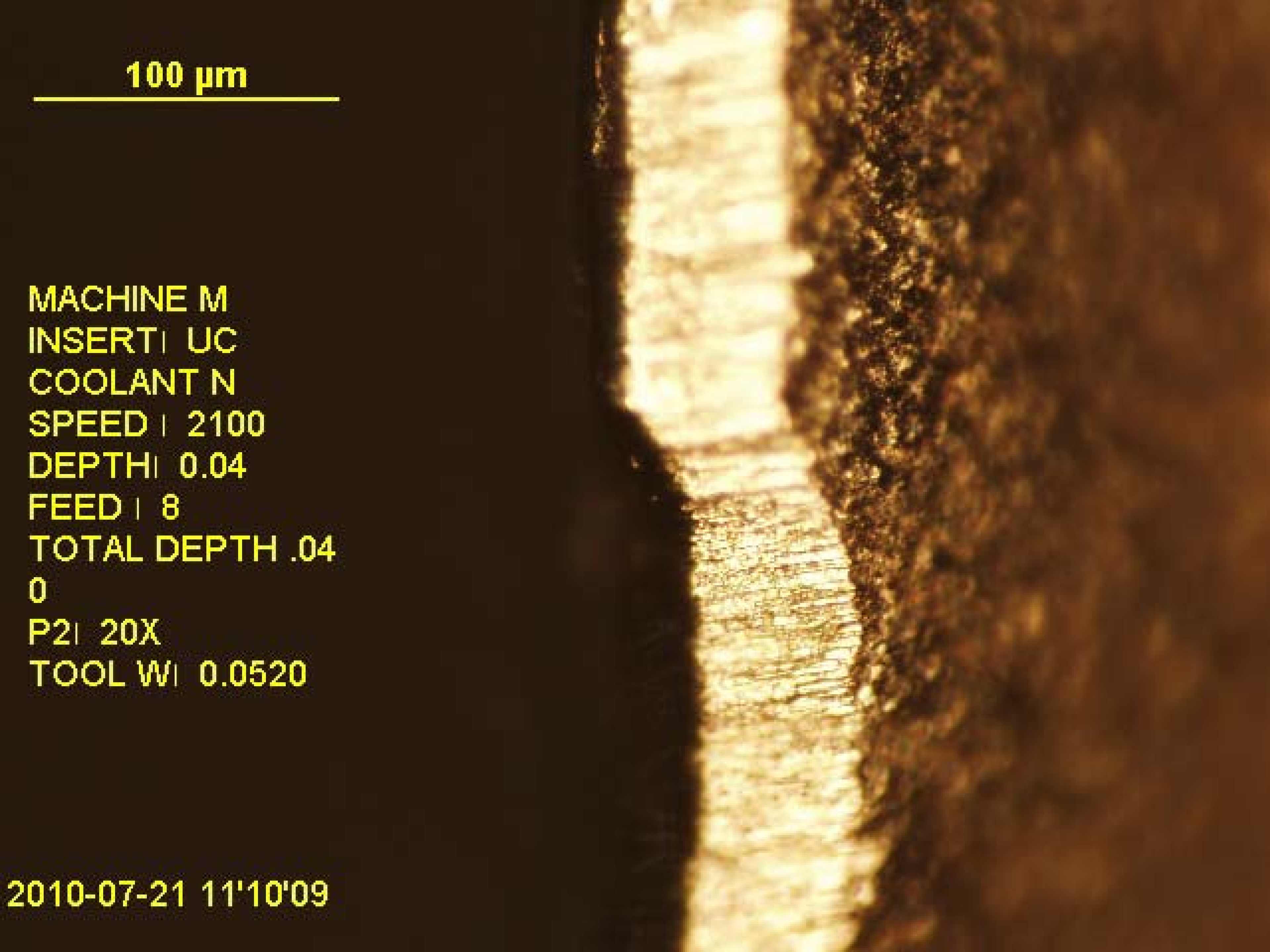
6) **Cutting fluids**:
   - **Dry**
   - **Flood cooling**: synthetic **Blasocut 2000** Universal, 5:1 mixture
   - **Micromist**: UNIST Uni-MAX system, **2210EP oil**, 0.022 cc/min.Use with **Mistbuster500.**

INVESTIGATION: setup

7) **Measurement:**
   - **Keyence LK-G82 laser system**, 70μm beam, 50 kHz sampling rate, 0.2 μm resolution
   - **Olympus STM6 measurement microscope**, 0.1 μm resolution
   - **JEOL JSM 6400 scanning electron microscope**
   - **Video tensiometer** FTA 188, 001 mN/m accuracy

8) **Computer aided tools**
   - **SolidWorks, FeatureCam, and MasterCam** software
   - **Cosmos finite element software**

Computer Imaging Lab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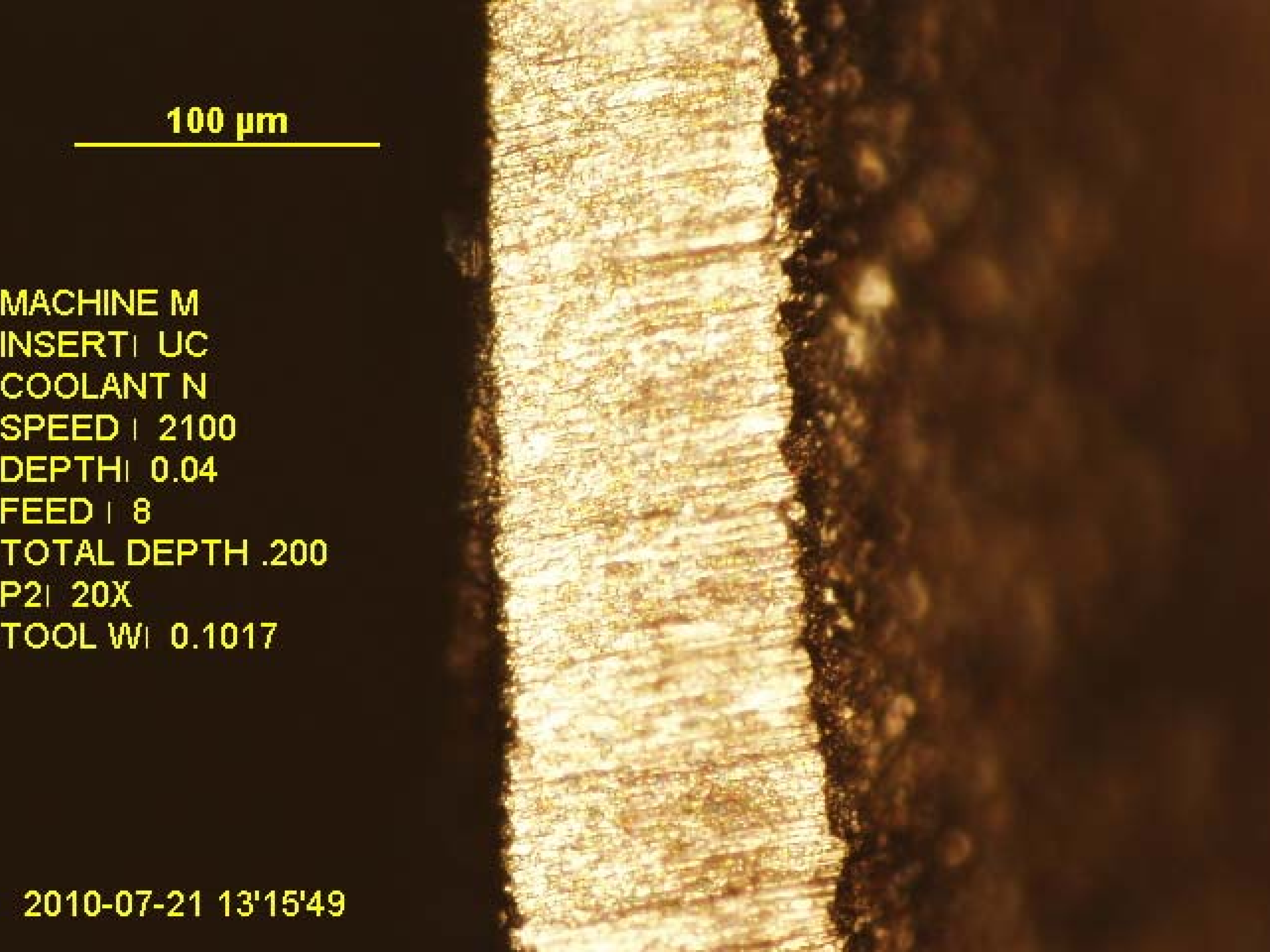
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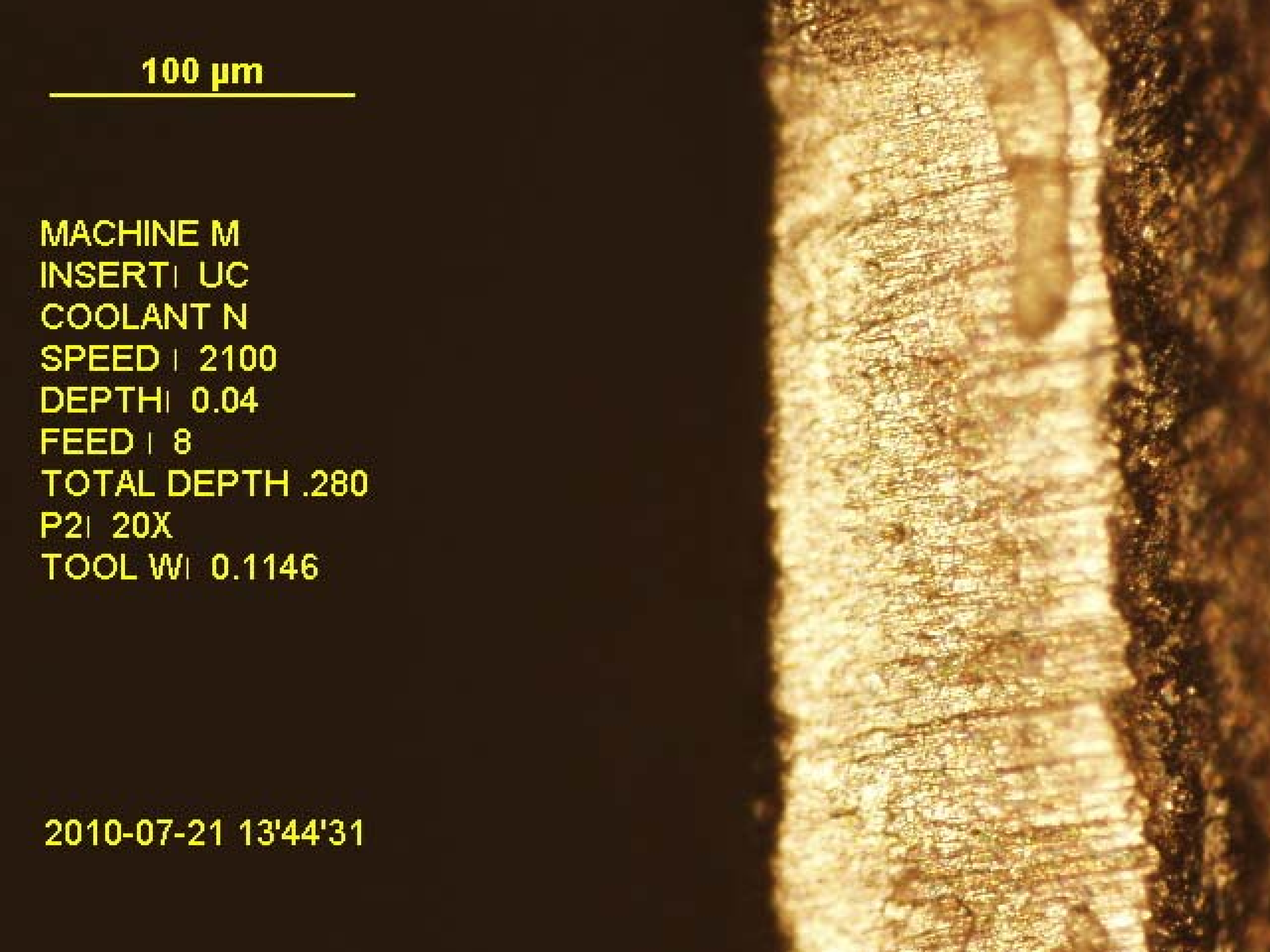
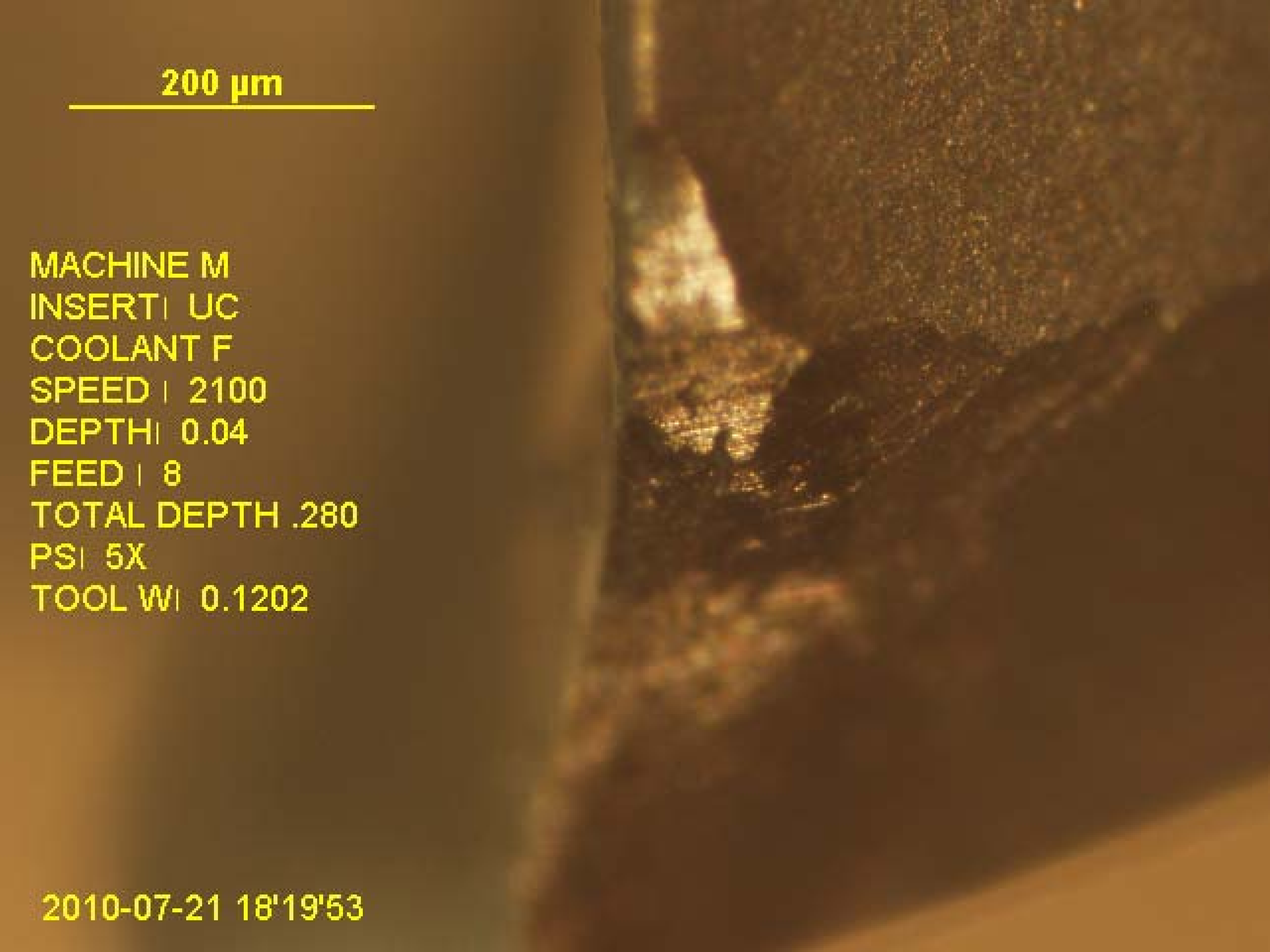
TOOL W: 0.1017
2010-07-21 13'15'49


100 µm
MACHINE M
INSERT: UC
COOLANT N
SPEED : 2100
DEPTH: 0.04
FEED : 8
TOTAL DEPTH .280
P2: 20X
TOOL W: 0.1146
2010-07-21 13'44'31


200 µm
MACHINE M
INSERT UC
COOLANT F
SPEED 2100
DEPTH 0.04
FEED 8
TOTAL DEPTH .280
PS 5X
TOOL W 0.1202
2010-07-21 18'19'53


100 µm
MACHINE: L
INSERT: UC
COOLANT N
SPEED : 310
DEPTH: 0.02
FEED : .004
PASSES: 05
P2: 20X
TOOL WEAR .0144
2010-07-08 15'33'31


100 µm
MACHINE L
INSERT UC
COOLANT N
SPEED 310
DEPTH 0.02
FEED .004
PASSES 50
P2 20X
TOOL W 0.0883


100 µm
MACHINE: L
INSERT: UC
COOLANT N
SPEED : 310
DEPTH: 0.02
FEED : .004
PASSES: 70
P1: 10X
TOOL W: 0.1265
2010-07-09 11'00'23

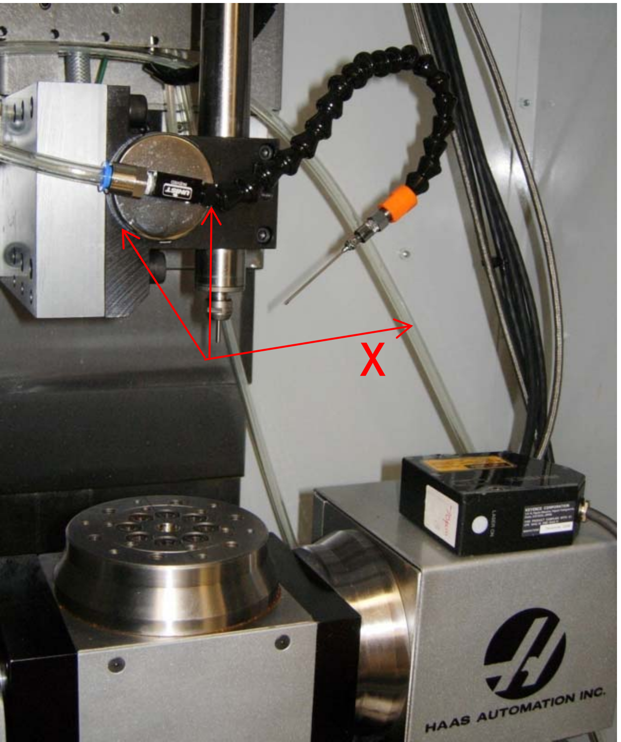
INVESTIGATION: machines

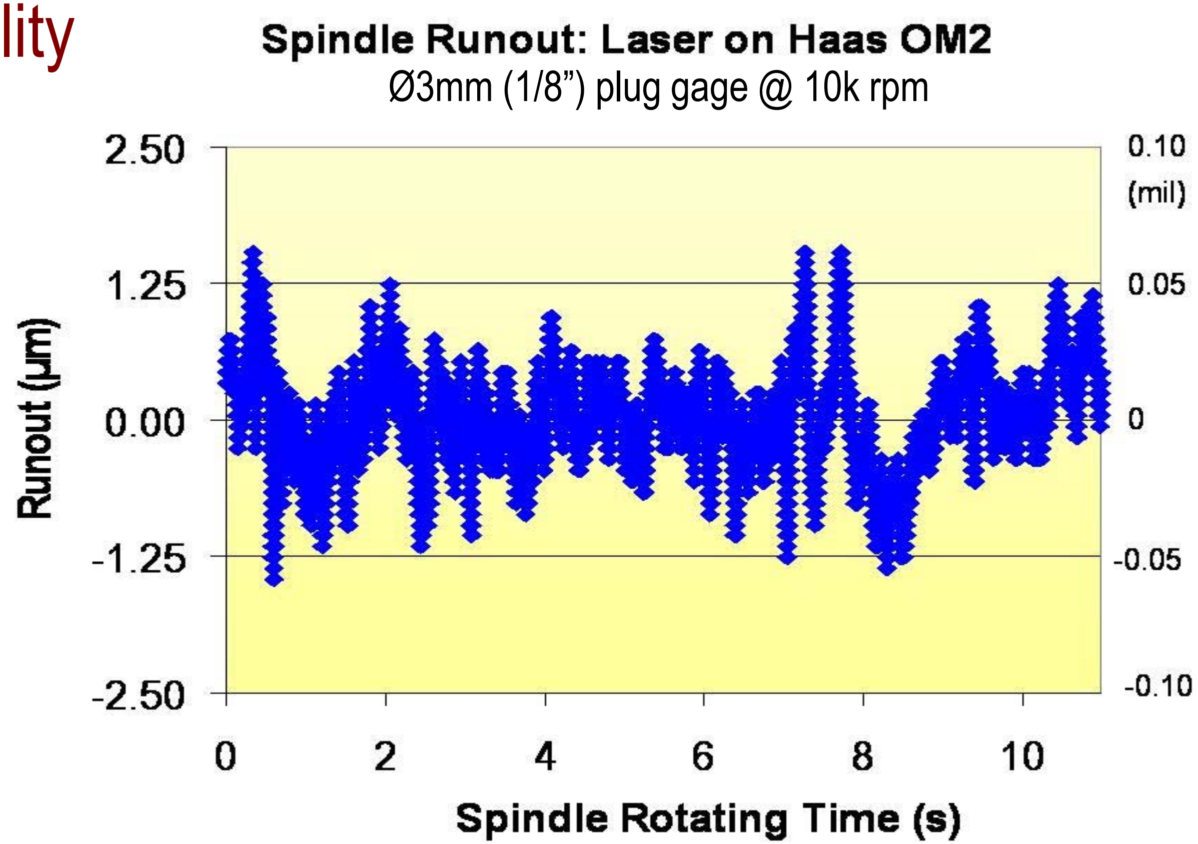
Haas OM2 CNC micromill:

- 5-axis capability
- 50,000 rpm air spindle
- 1 µm spindle runout
- 3 µm repeatability

Micromist

- **2210EP oil, 0.022 cc/min**
- **30 mm @60 from z axis**
- **-45 in x-y plane**





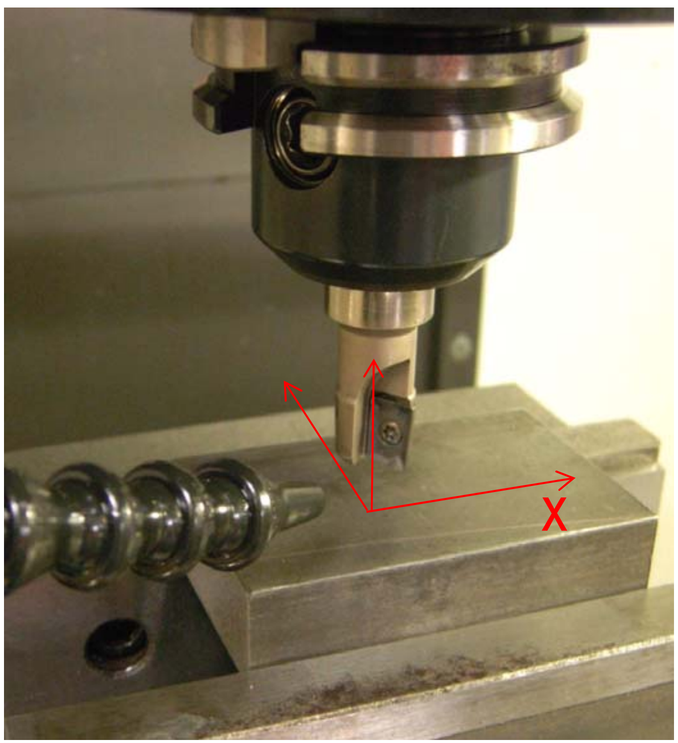
INVESTIGATION: machines

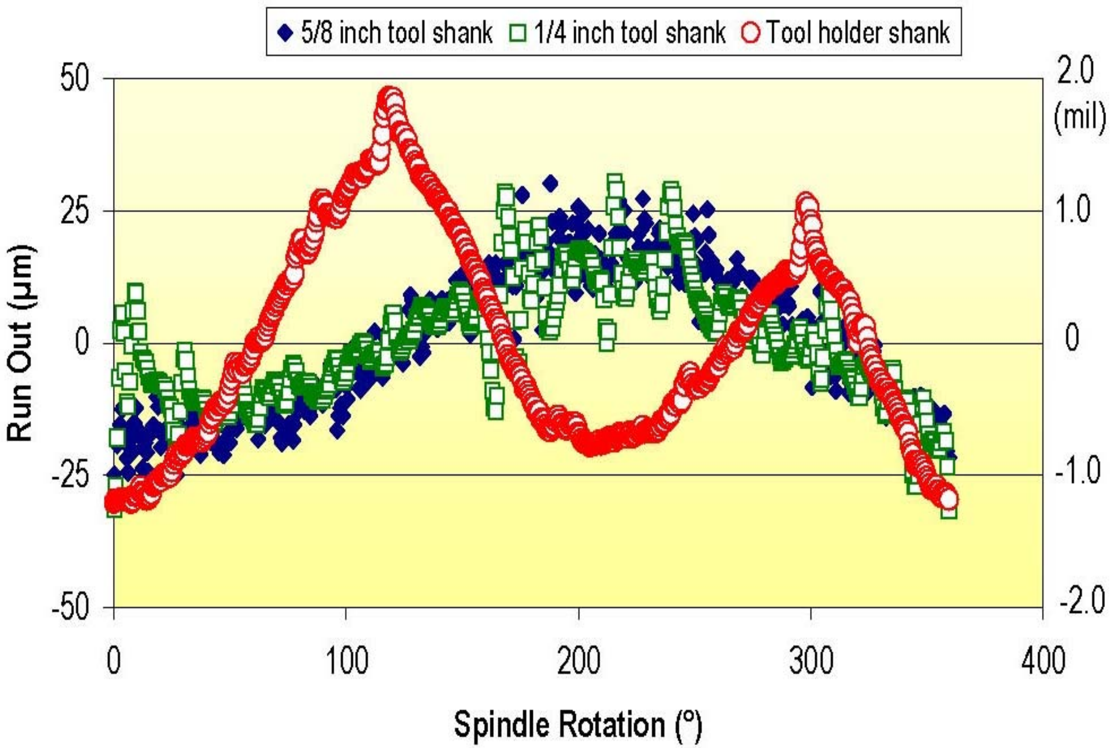
Haas VF1 CNC mill:

- 5-axis capability
- 7,500 rpm spindle
- 25 µm spindle runout
- 3 µm repeatability

Micromist

- **2210EP oil, 0.022 cc/min**
- **25 mm @70   from z axis**
- **-120   in x-y plane**





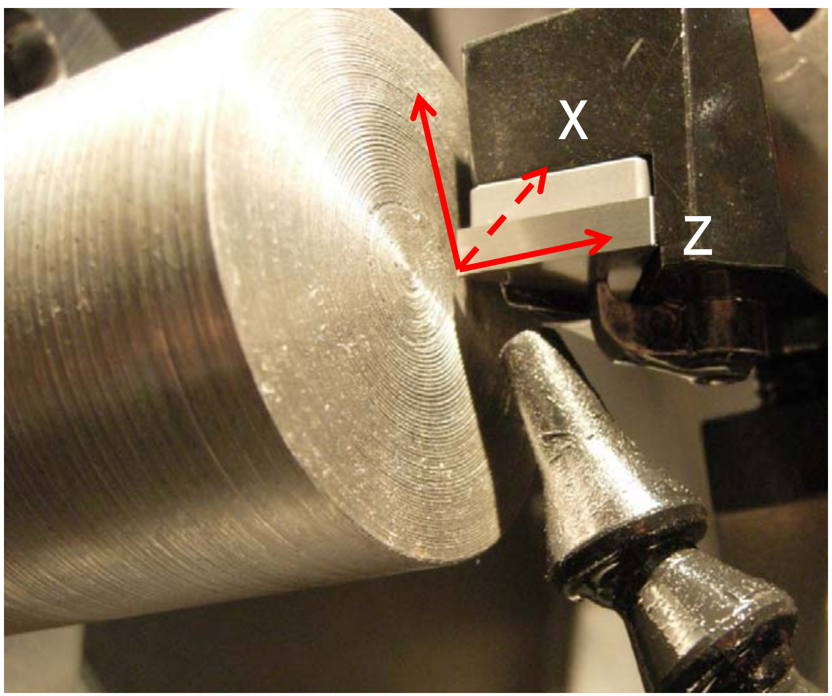
INVESTIGATION: machines

Haas SL20 CNC lathe:

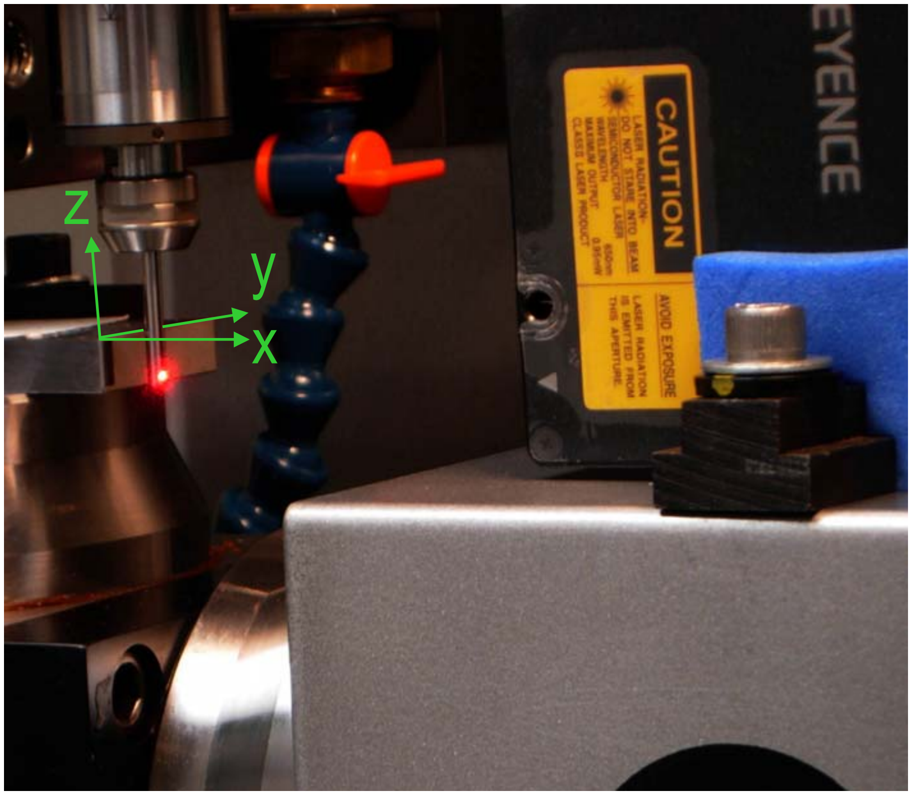
- Live tooling capability
- 3,400 rpm spindle
- 3 µm repeatability

Micromist

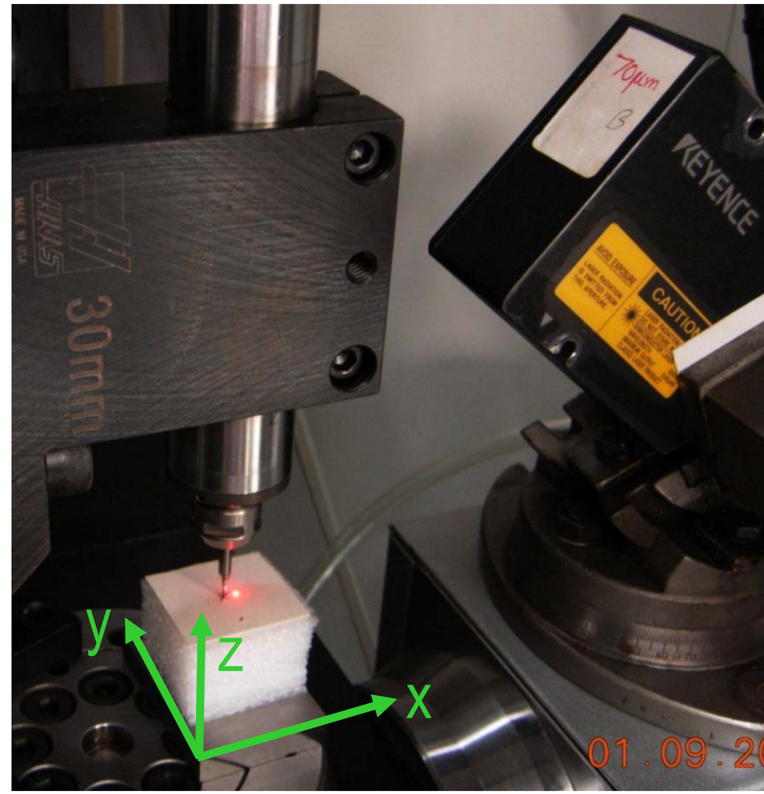
- **2210EP oil, 0.022 cc/min**
- **6 mm @150 from y axis**
- **-60 in x-y plane**



MICROMACHINING: tool setting



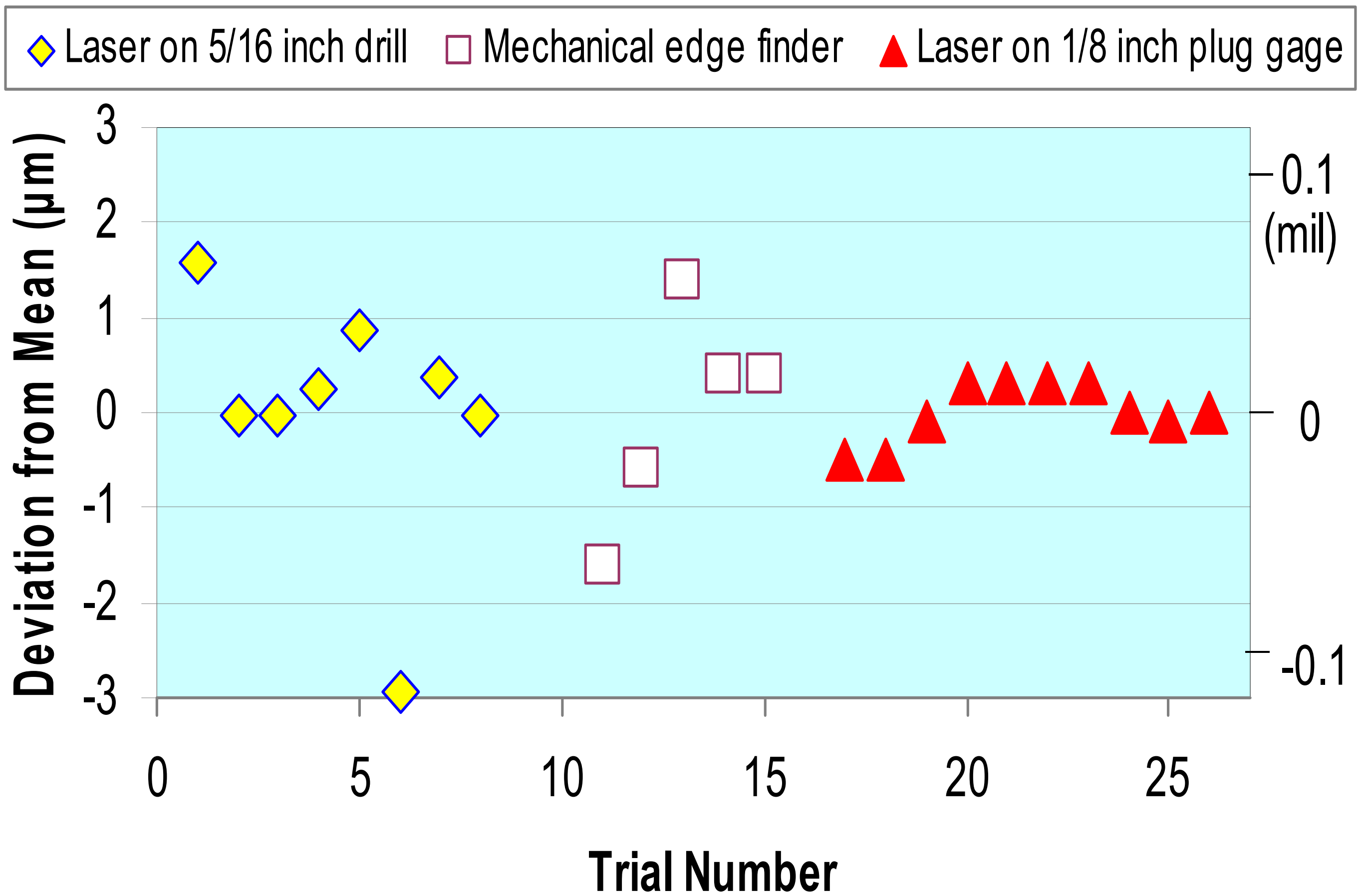
(a)
Set up for edge detection on x-y plane



(b)
Set up for tool height z-offset

Microtool offset using laser sensor

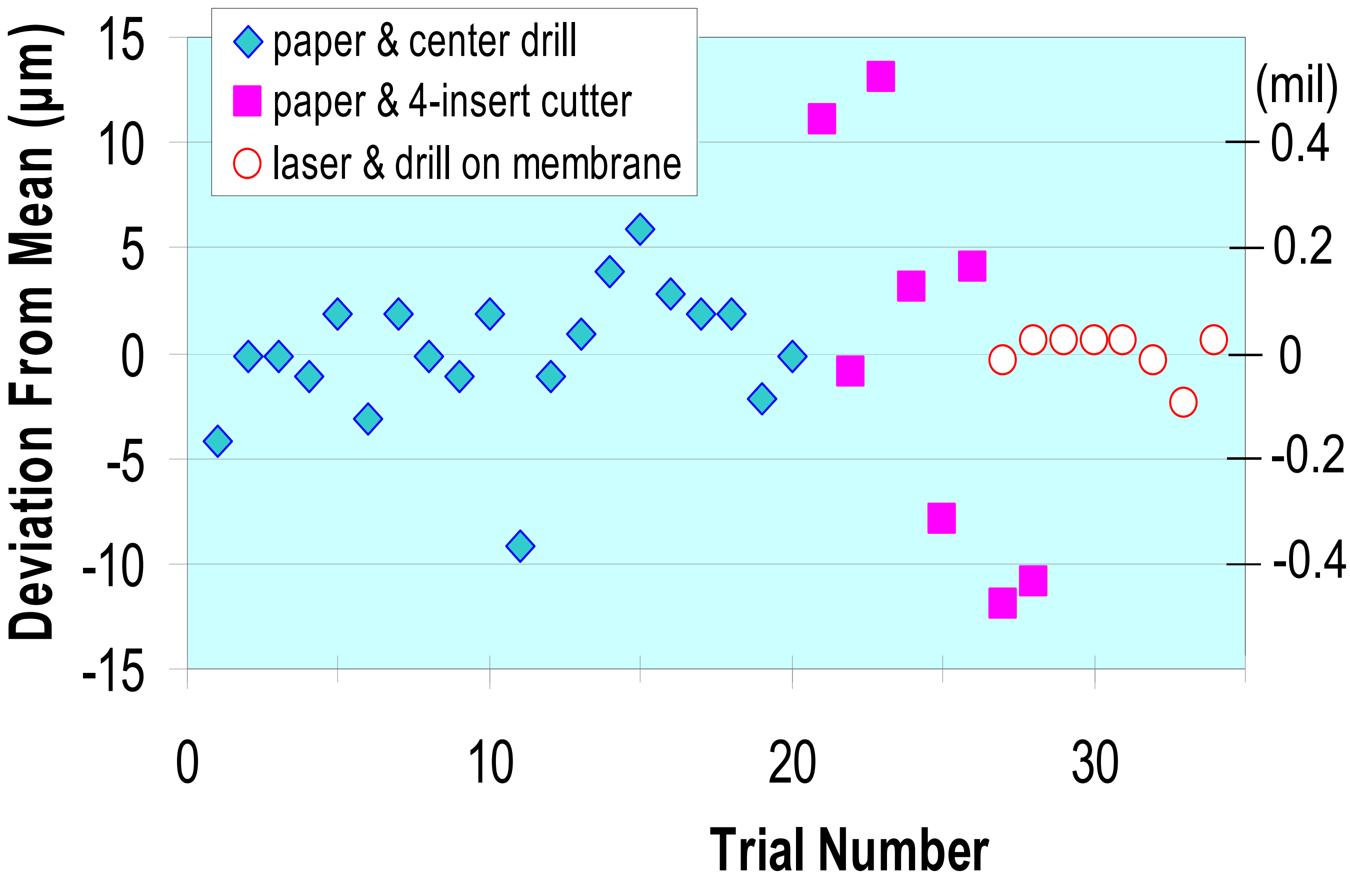
MICROMACHINING: tool setting



- X, Y settings depend on tool quality
- A precision plug gage should be used

Edge detection for tool offsets in x, y directions.

MICROMACHINING: tool setting



- Z offset depends on tool geometry
- Expect a larger z offset error than x, y offsets

Tool height offset in z direction.

MACHINING: cutting fluid

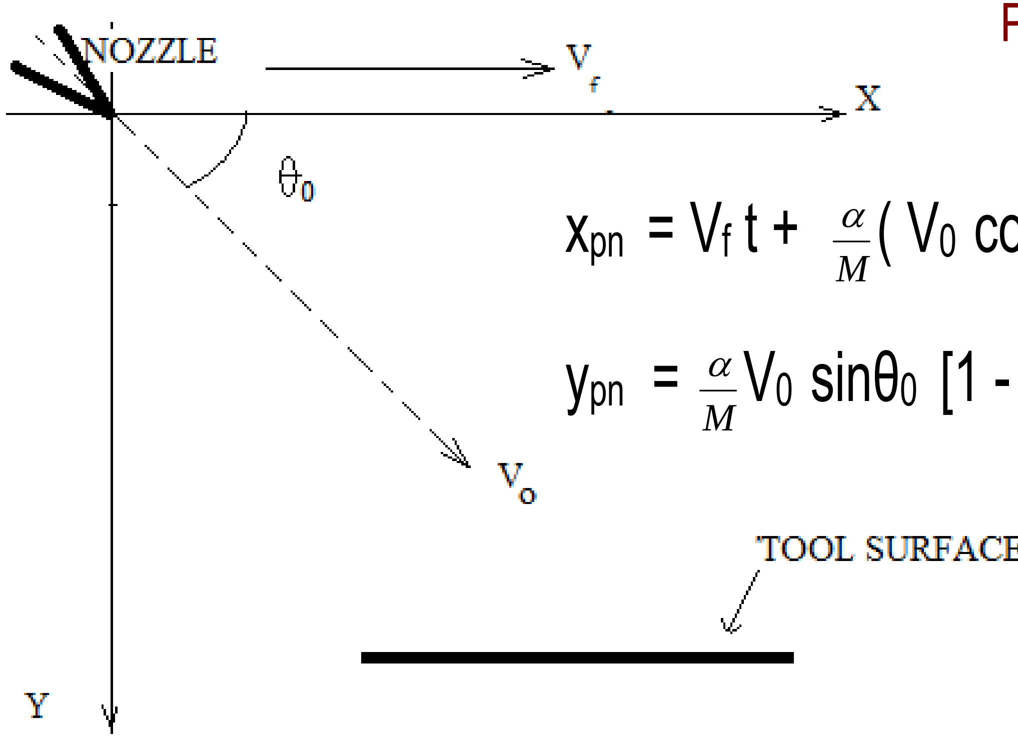
For effective cooling/lubricating, cutting fluid must:

1) **Penetrate the boundary layer of a rapidly rotating tool,**
2) **Adhere to a tool surface despite centrifugal force,** and
3) **Wet the tool/chip interface to provide lubricating/cooling**

MACHINING: micromist

Particle Trajectory

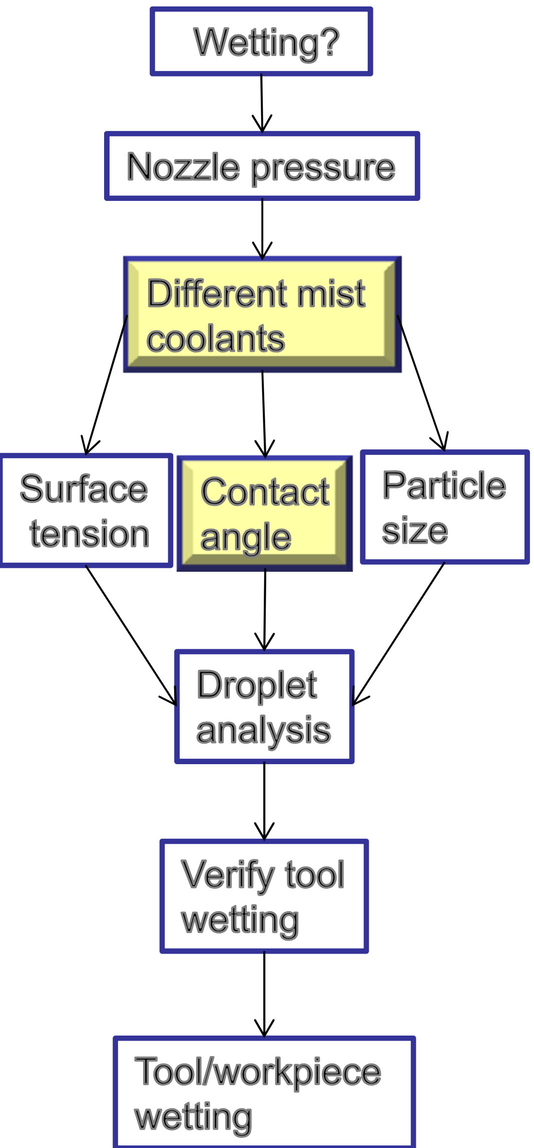
Penetrate?
↓
Particle trajectory
↓
CFD modeling
↓
Optimal tool/workpiece/ nozzle positions

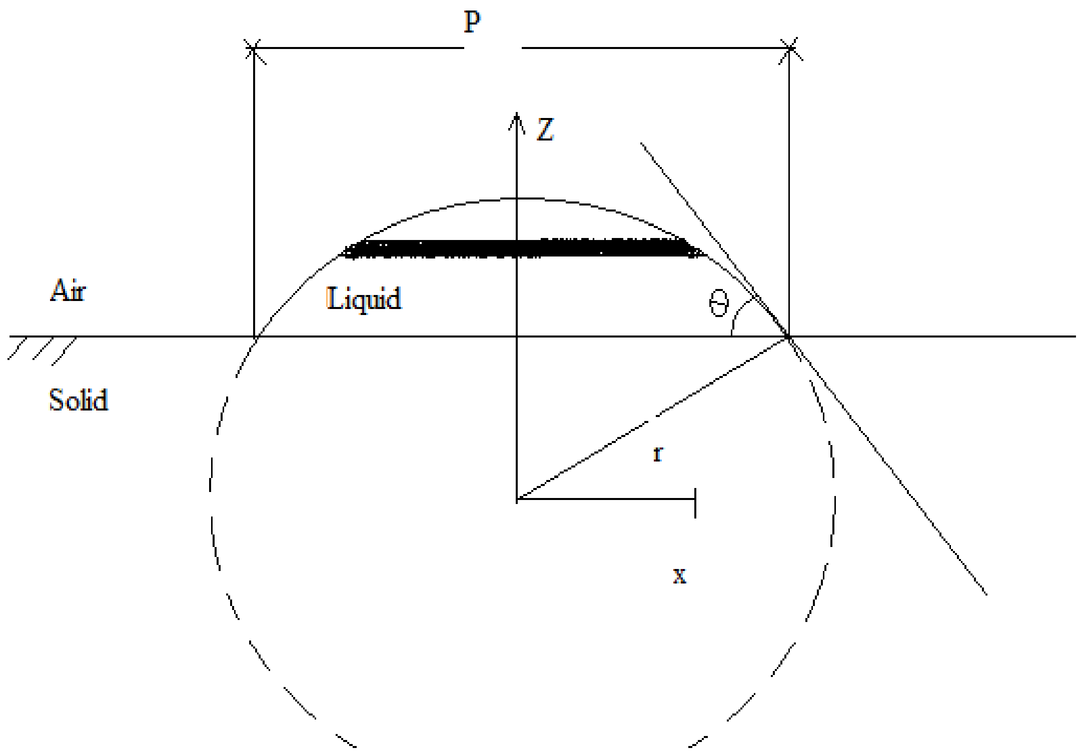


$$x_{pn} = V_f\, t + \frac{\alpha}{M}\left(V_0 \cos\theta_0 - V_f \right)\left[1 - e^{-(\alpha/M)\,t}\right]$$

$$y_{pn} = \frac{\alpha}{M} V_0 \sin\theta_0 \left[1 - e^{-(\alpha/M)\,t}\right]$$

MACHINING: coolant wetting

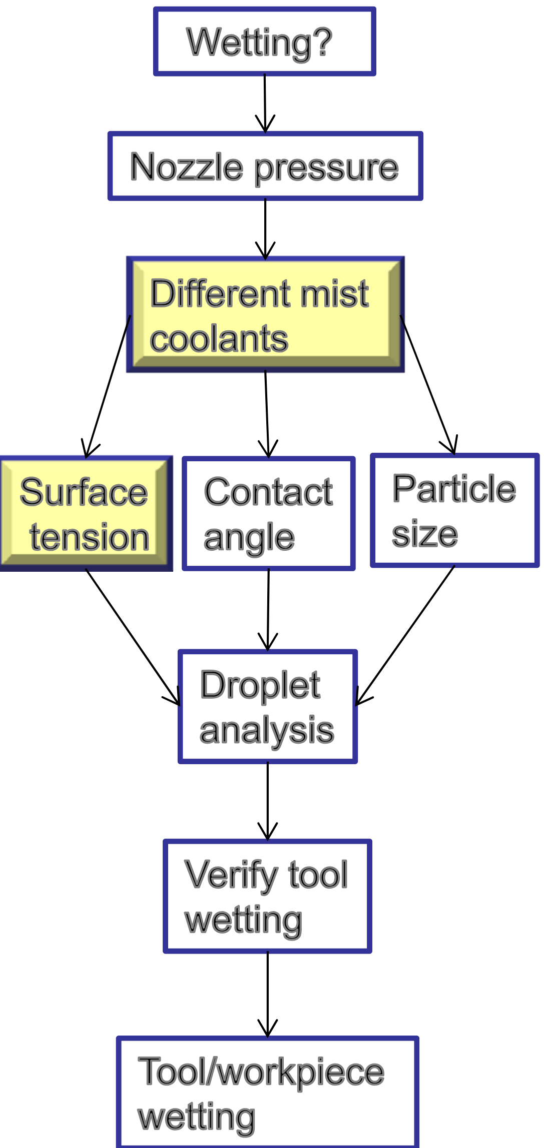


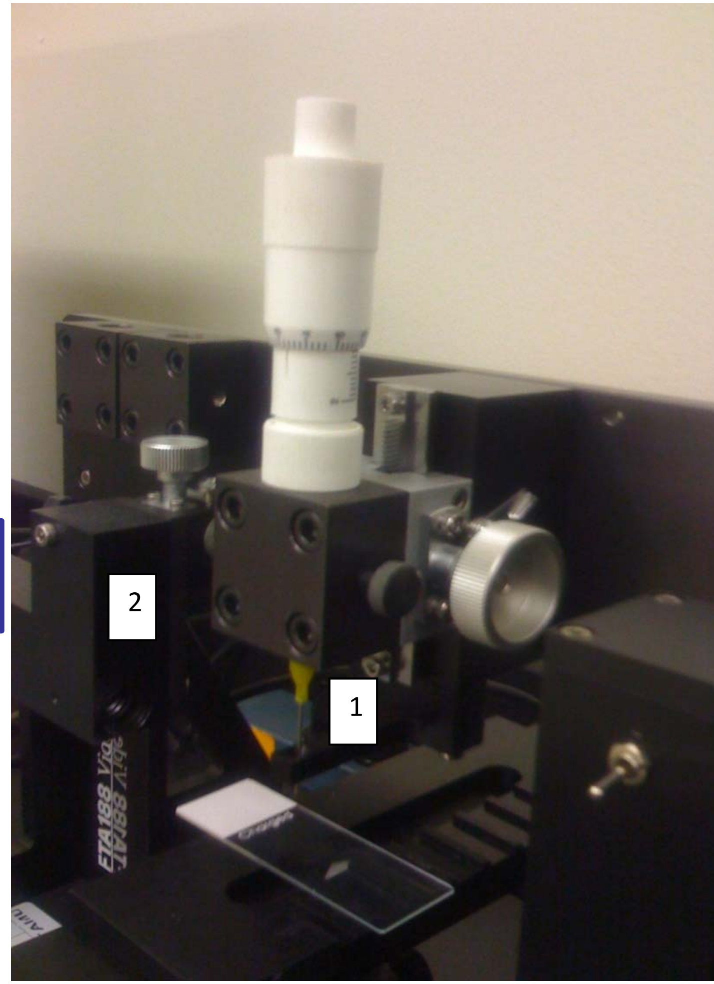


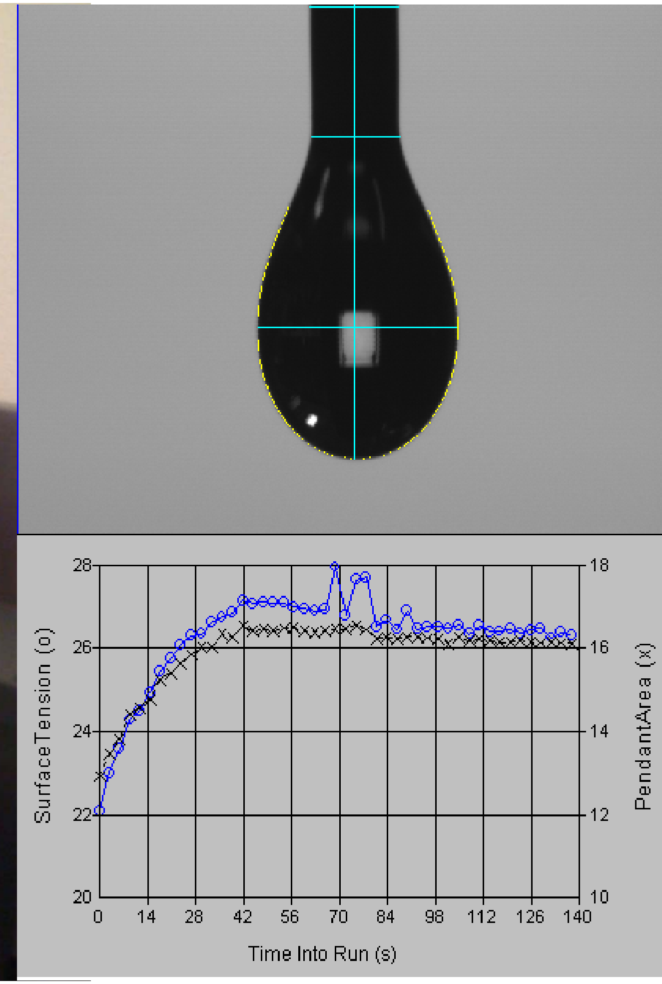
$$\frac{P}{V^{1/3}}(\theta) = \left[\frac{24}{\pi} \cdot \frac{(1 - K\cos^2\theta)^{3/2}}{2 - 3\cos\theta + \cos^3\theta}\right]^{1/3}$$

V: volume of droplet
P: diameter of droplet
K: 1 for $\theta < 90^0$; 0 for $\theta > 90^0$
θ : contact angle

MACHINING: micromist



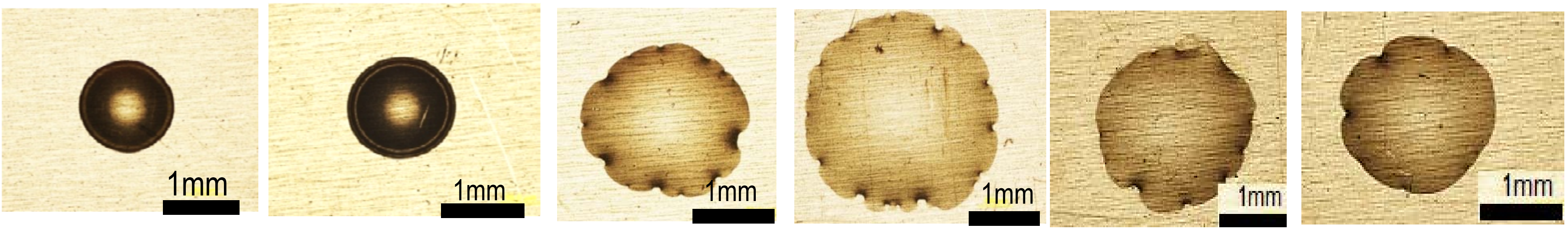


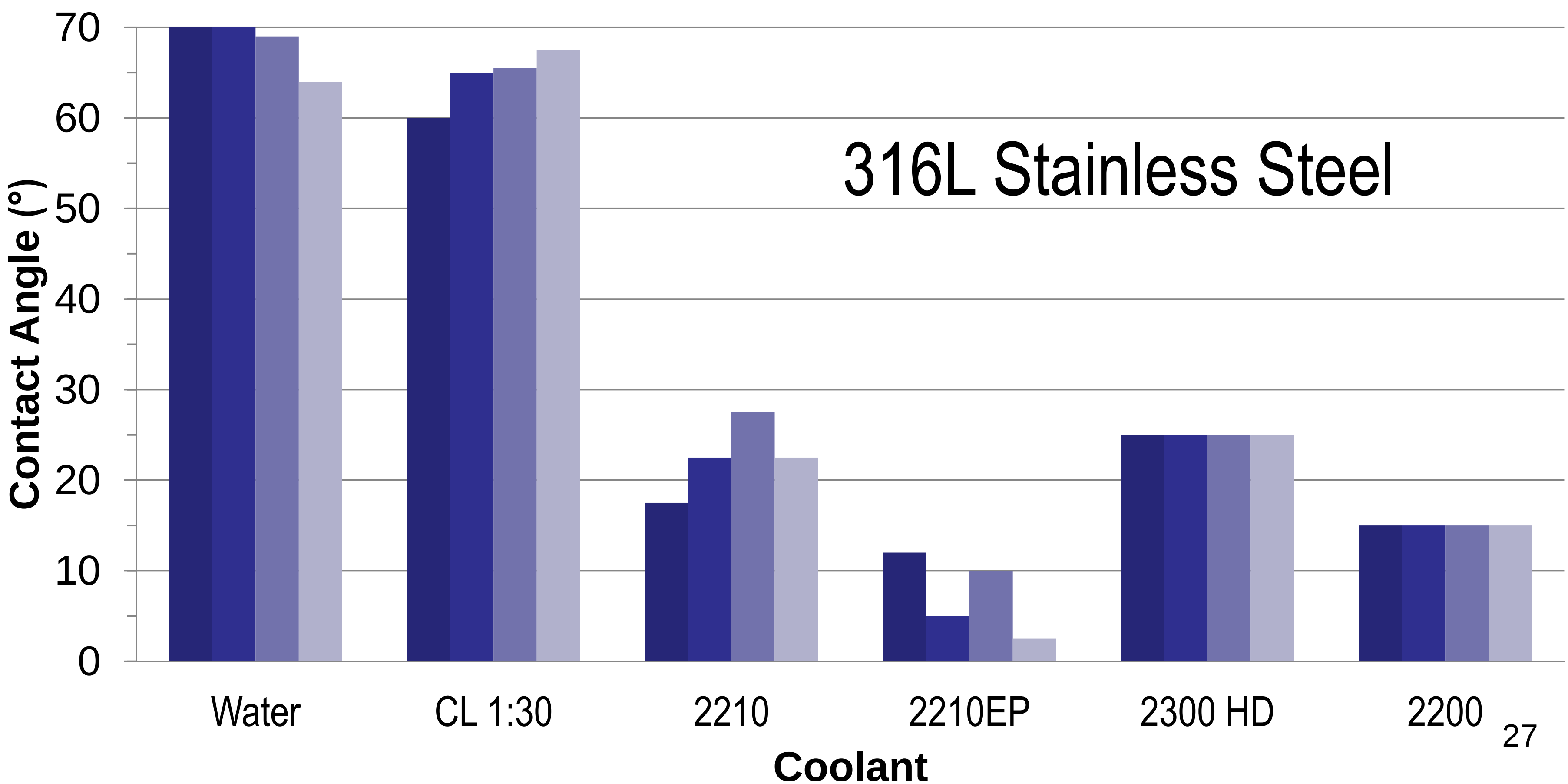


Apparatus for Surface tension measurement

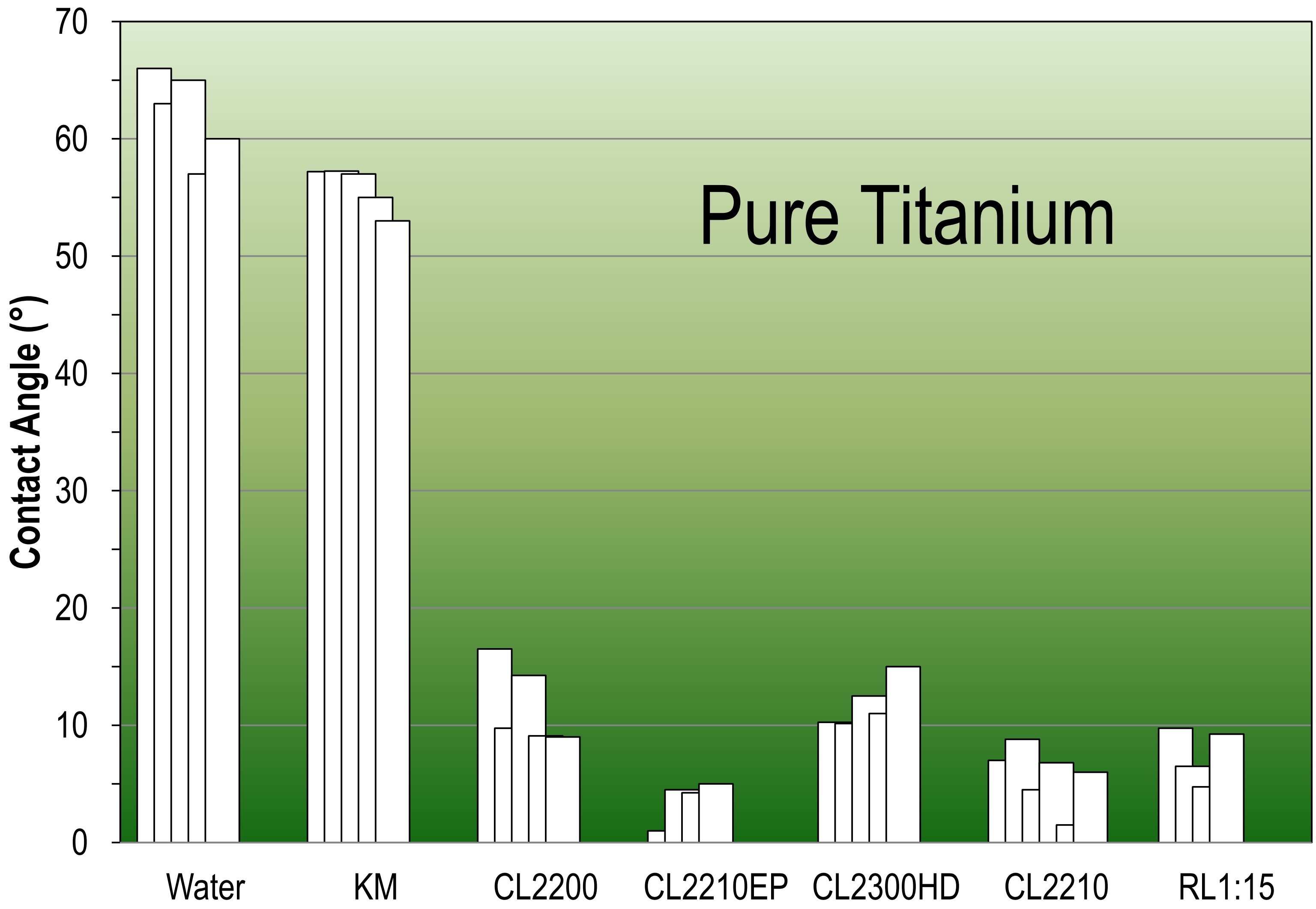
1. Needle for delivering liquid droplets
2. Camera

MACHINING: micromist

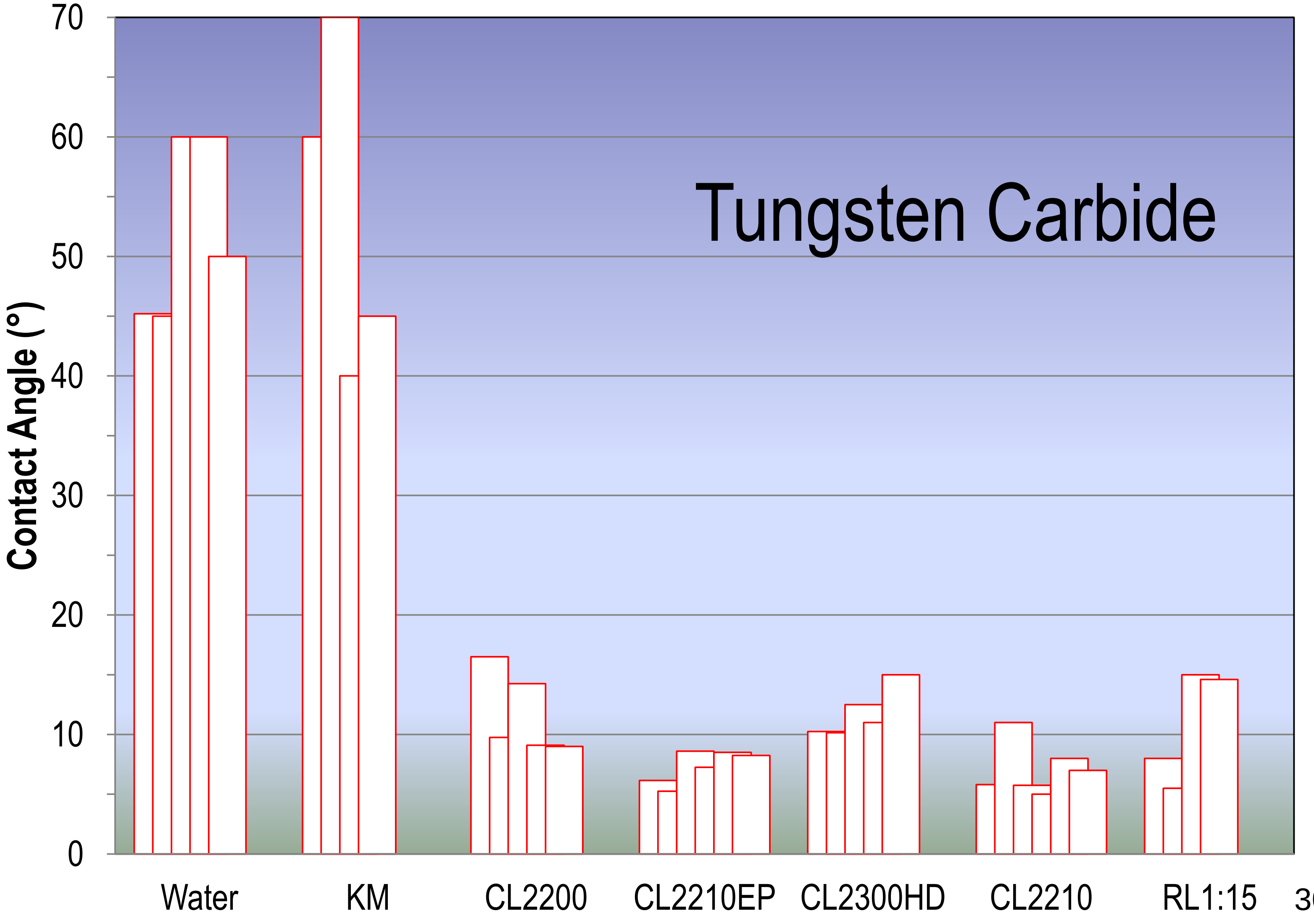




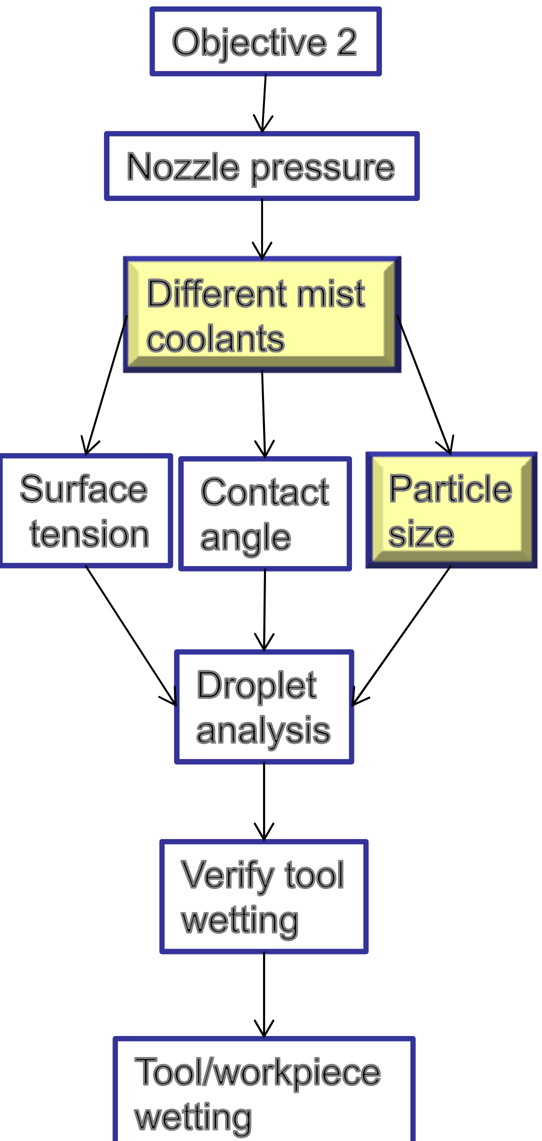
MACHINING: micromist

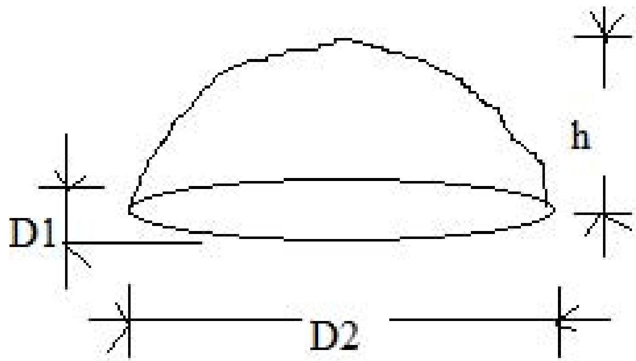


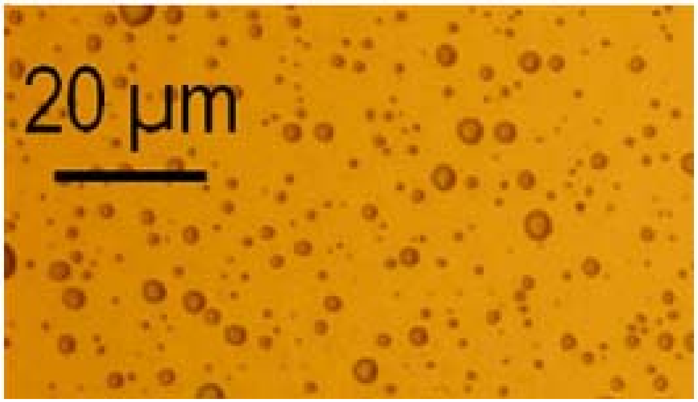
MACHINING: micromist



MACHINING: micromist





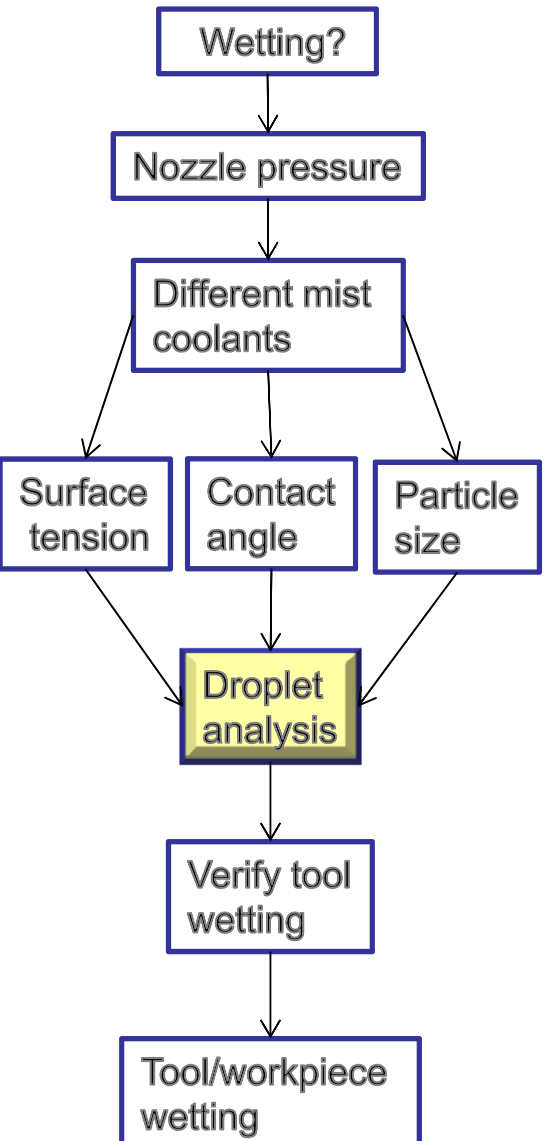


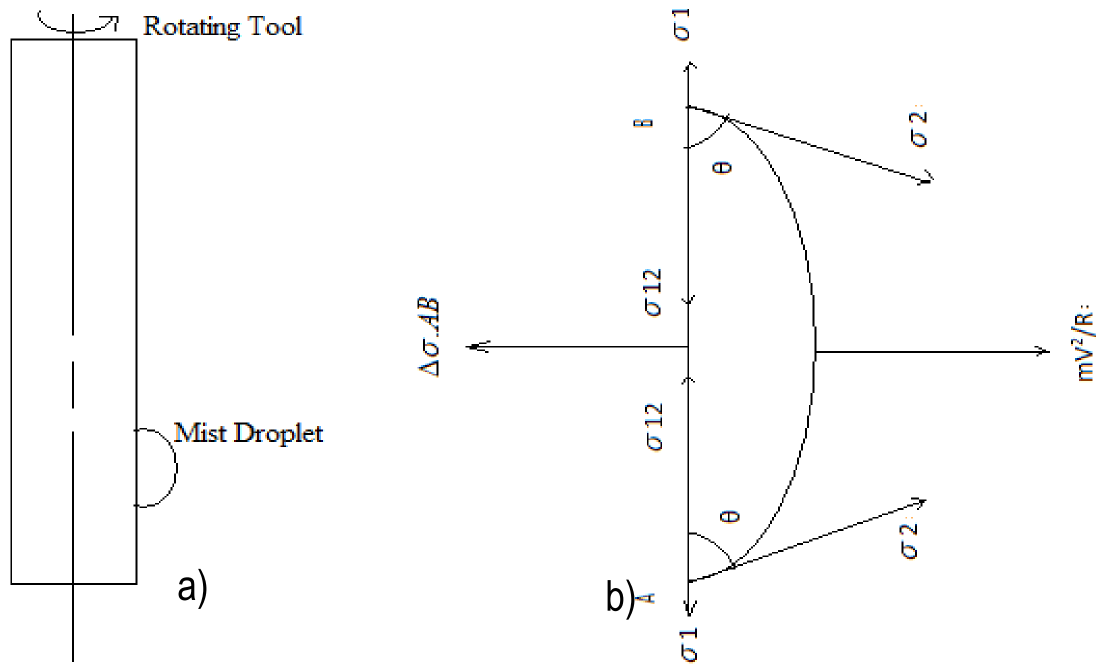
$$V = \pi h^2 \left[\frac{h}{6} + \frac{r^2}{2h} \right]$$

$$V = \frac{4}{3}\pi R^3$$

V: volume of droplet
h: height of droplet
R: radius of airborne droplet
r: $(D_1+D_2)/4$

MACHINING: micromist



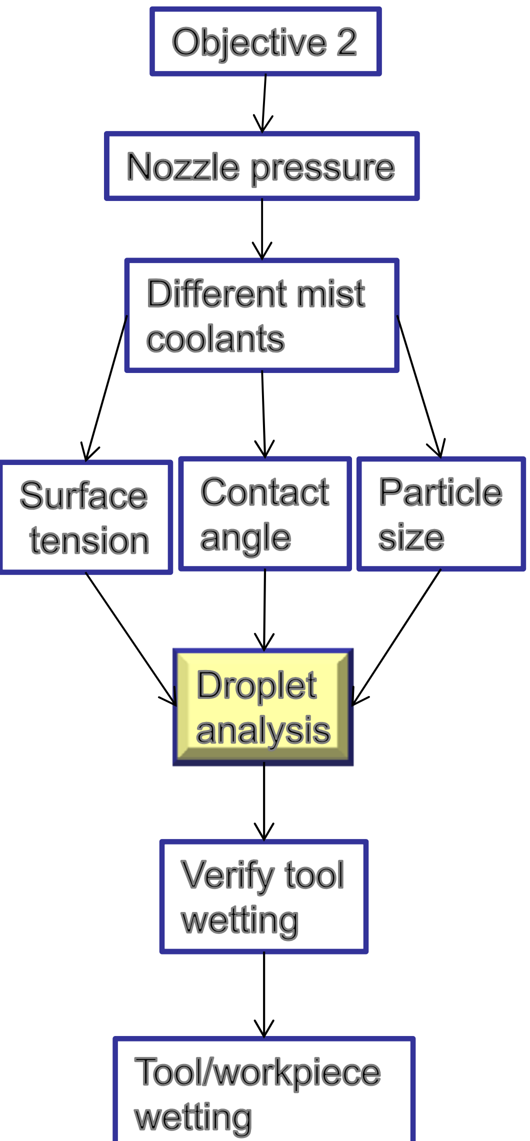


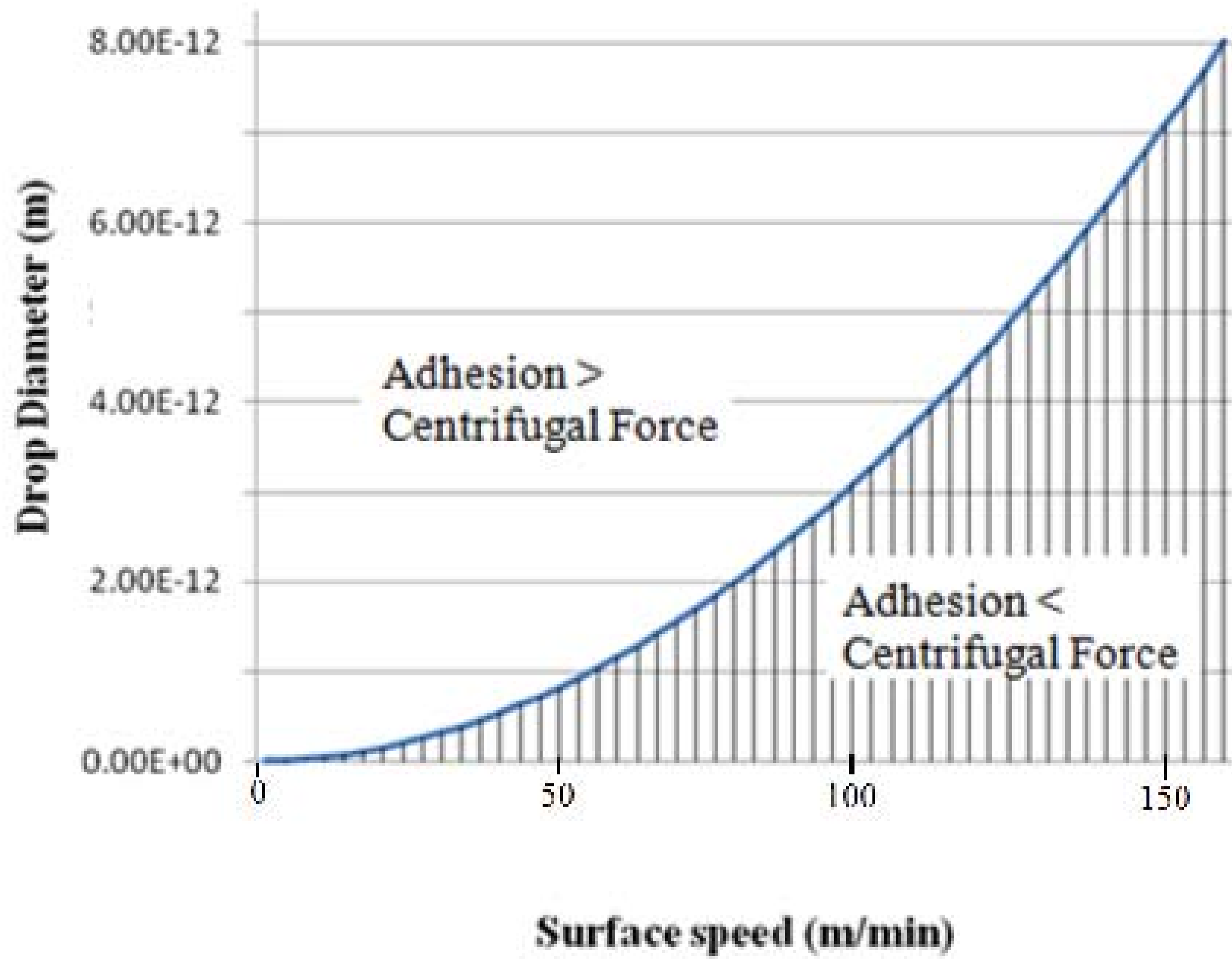
(a) Micro-droplet on a rotating tool;
(b) Free body diagram of forces acting on the micro-droplet

$$\frac{mv^2}{R} + 2\,\sigma_2 \sin\theta = \Delta\,\sigma\,D$$

m: mass of droplet
v: surface speed of tool
R: radius of tool
D: diameter of droplet
σ_2: surface tension of liquid

MACHINING: micromist

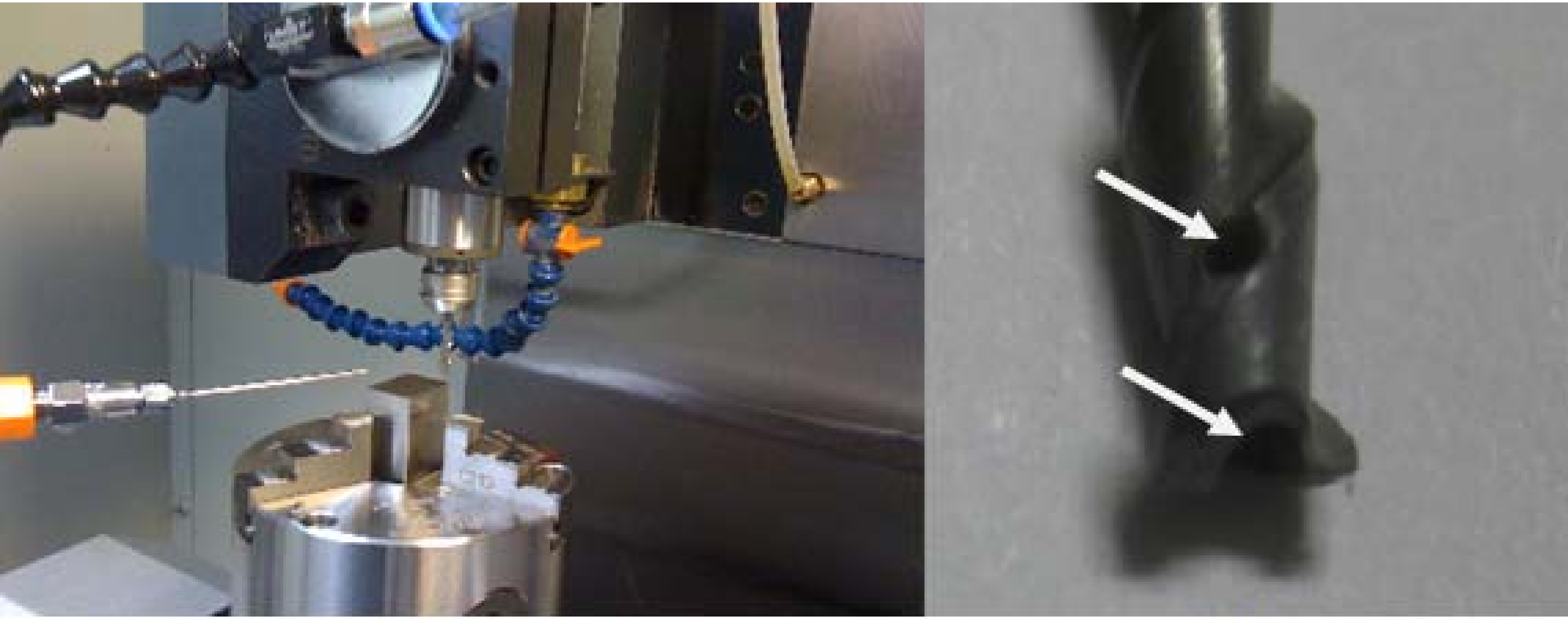




Balance of adhesion and centrifugal force on a 2210EP microdroplet

APPROACH – OBJECTIVE # 2

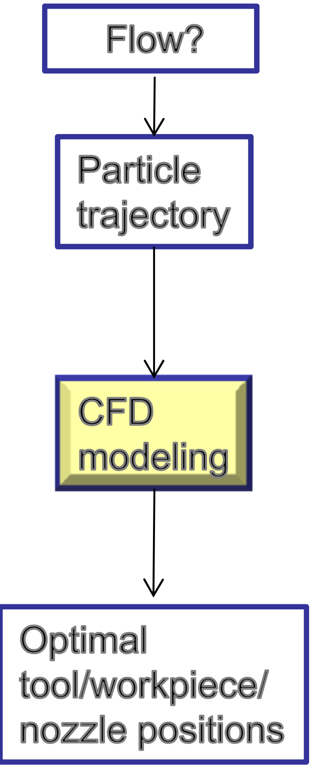
Setup for validation of tool wetting

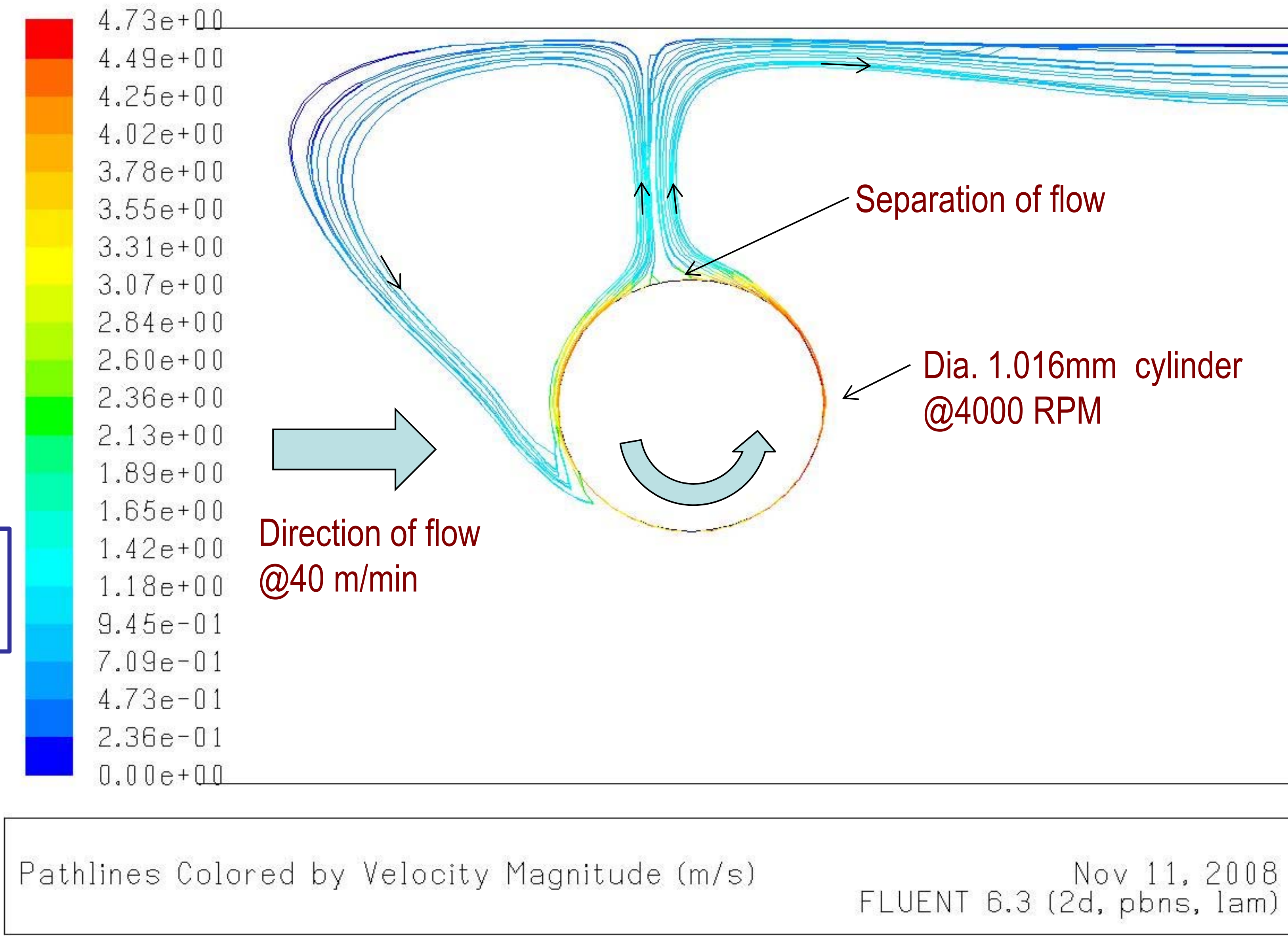


(a) (b)

(a)Mist spray setup (b) 3.175 mm 2 flute end-mill
12.7mm 2 flute end-mill (not shown)

RESULT: flow of micromist





RESULT: flow of micromist

Flow?

↓

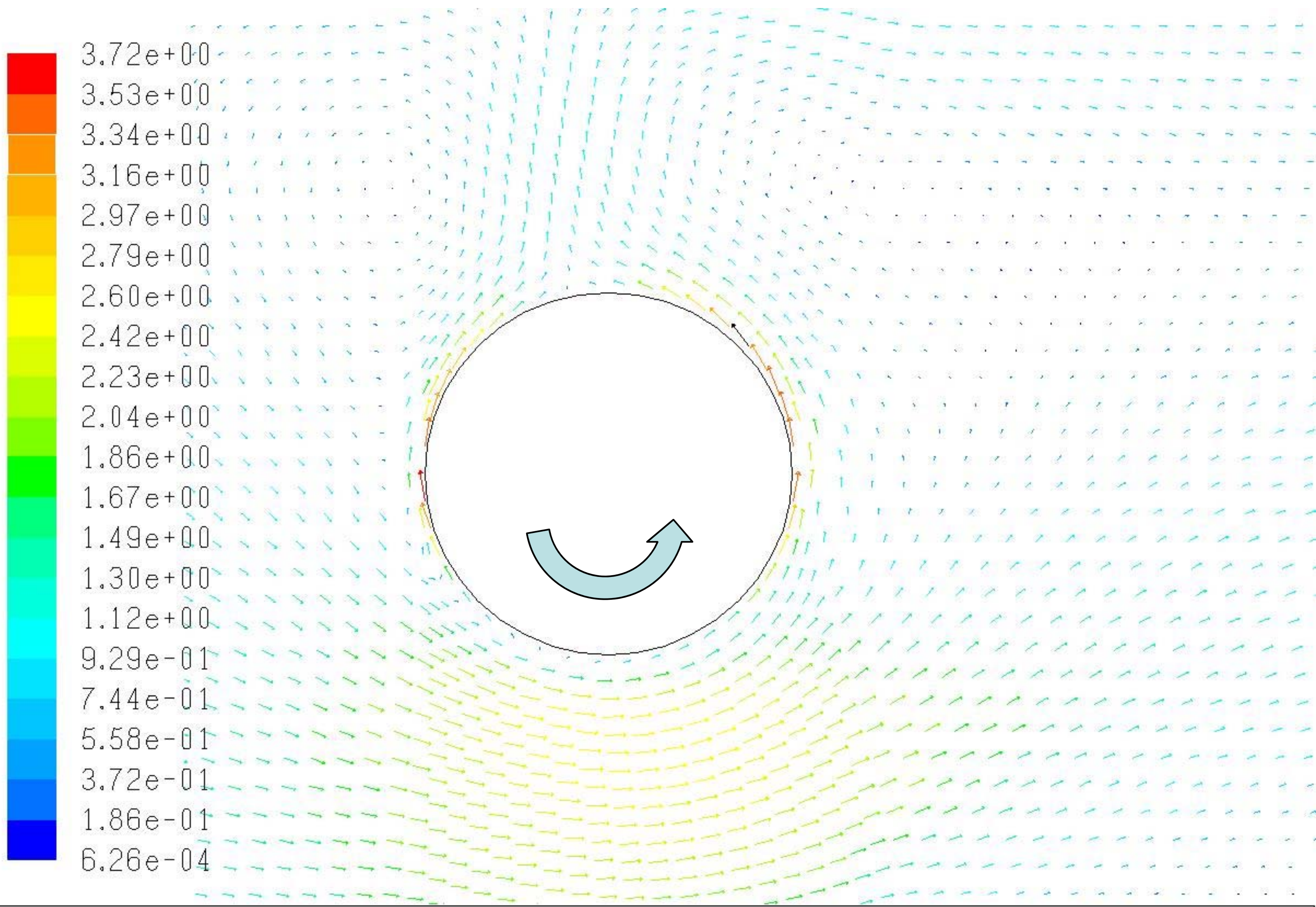
Particle trajectory

↓

CFD modeling

↓

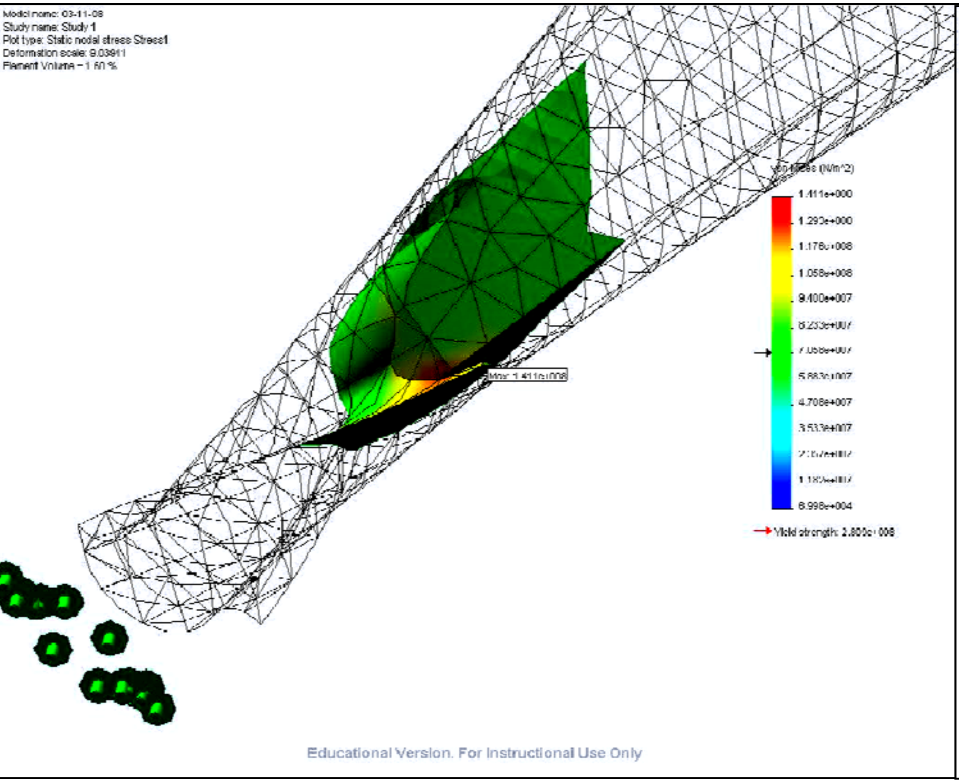
Optimal tool/workpiece/ nozzle positions

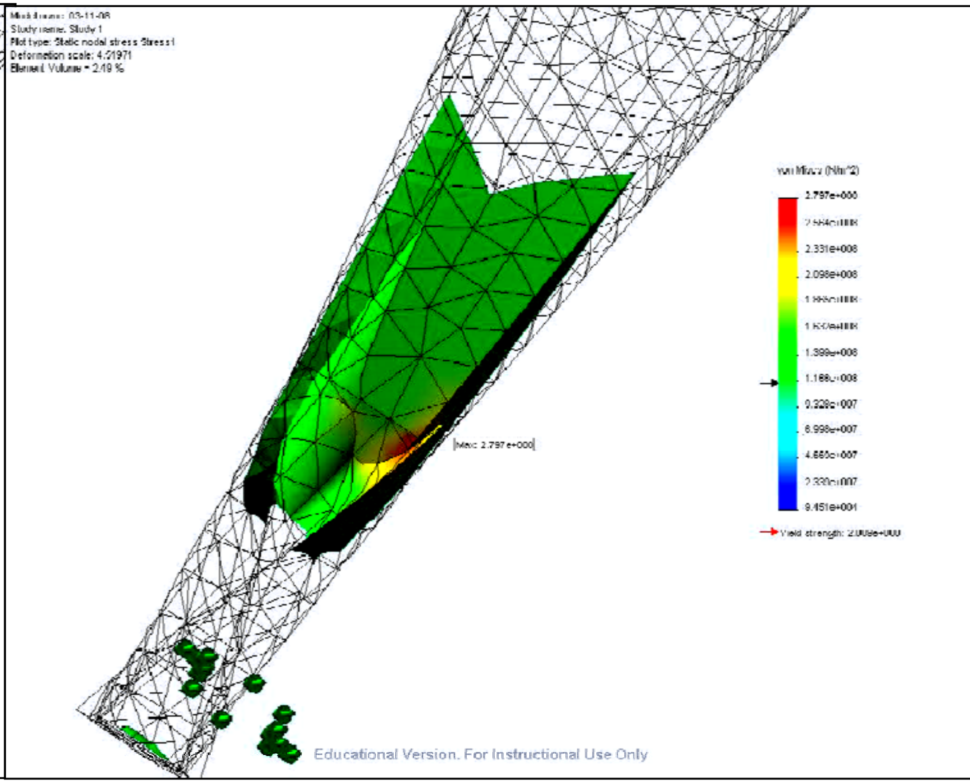


Velocity Vectors Colored By Velocity Magnitude (m/s) Nov 11, 2008
FLUENT 6.3 (2d, pbns, lam)

MICROMACHINING: tool deflection

Spindle runout, built-up edge, uncontrolled chip, and/or cutting force deflect a microtool cyclically and cause premature tool failure.



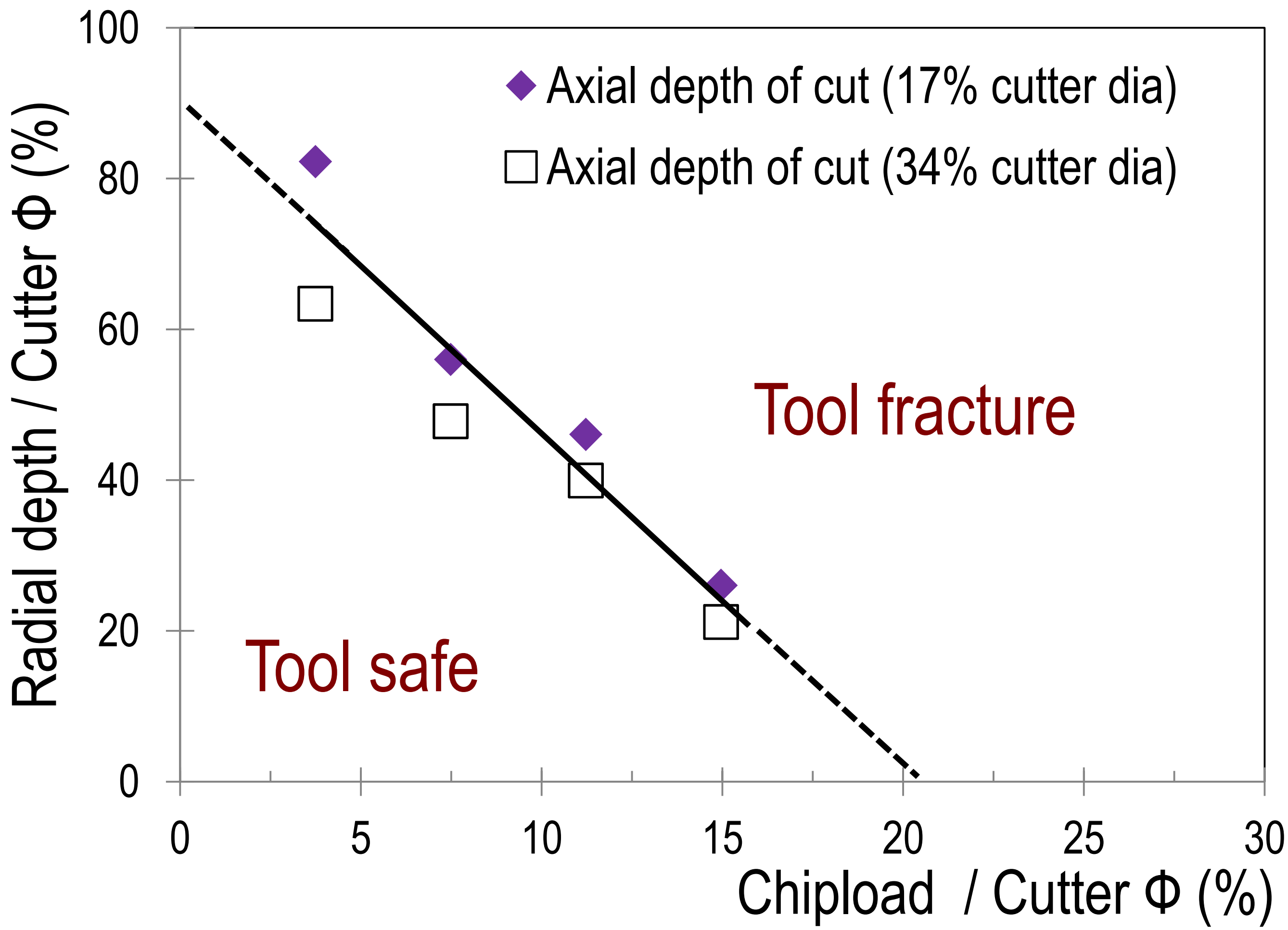


End deflection=17% tool diameter
Bending stress= 50% tool strength

End deflection=34% tool diameter
Bending stress= 100% tool strength

Finite element analysis of bending stress on a micromilling tool.

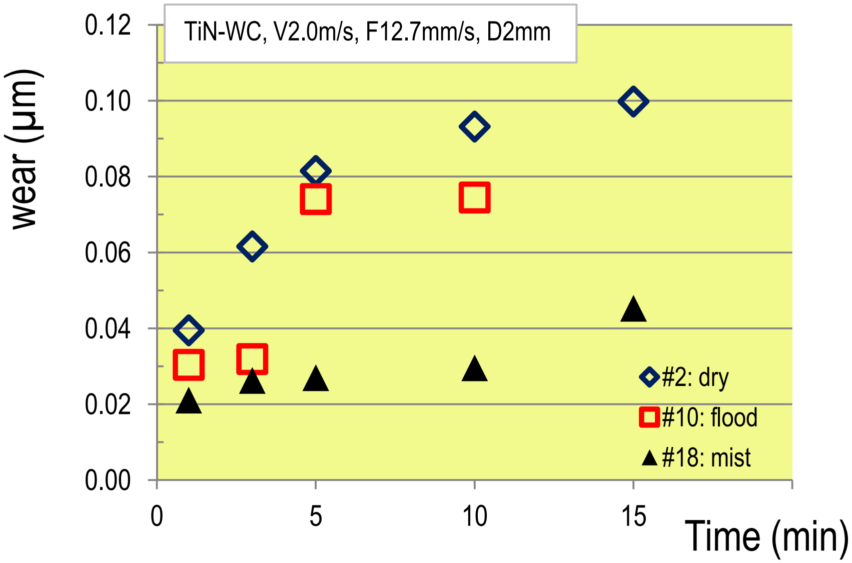
MICROMACHINING: limit of parameters

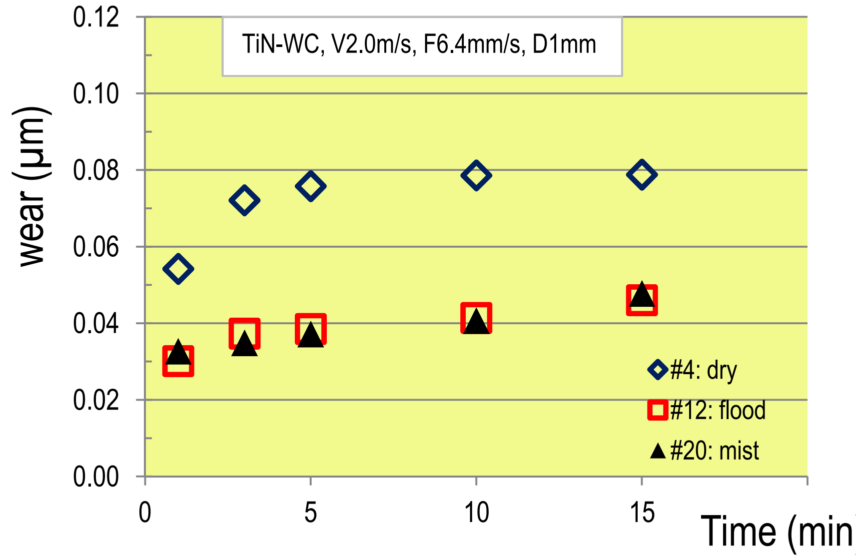


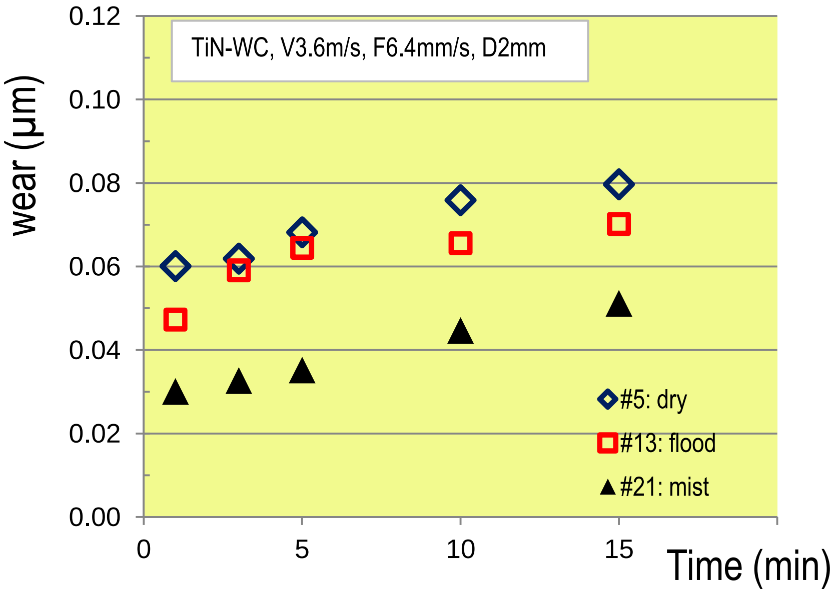
Catastrophic failure threshold of micromilling tools.

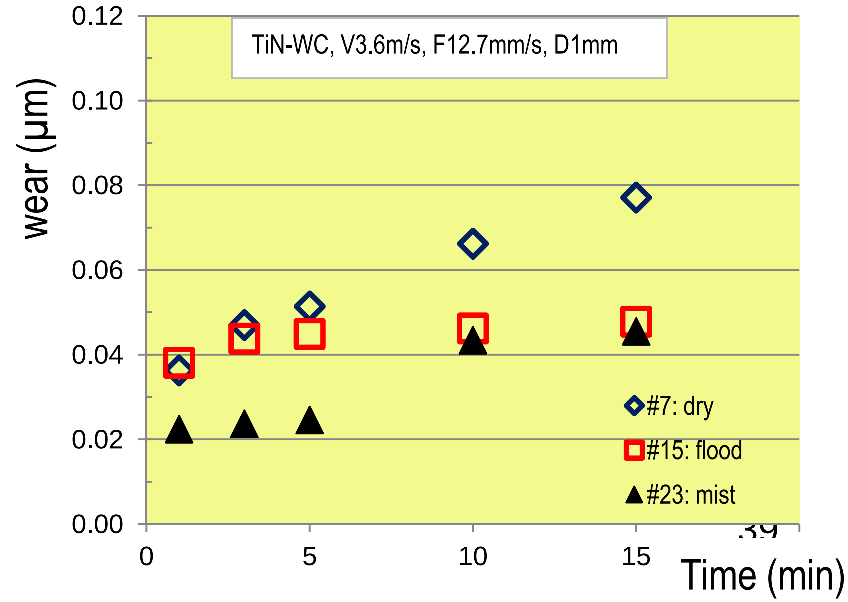
0.35mm (0.014 in) axial depth, dry , climb (down) side milling of 316L stainless steel.

MICROMIST: macromilling

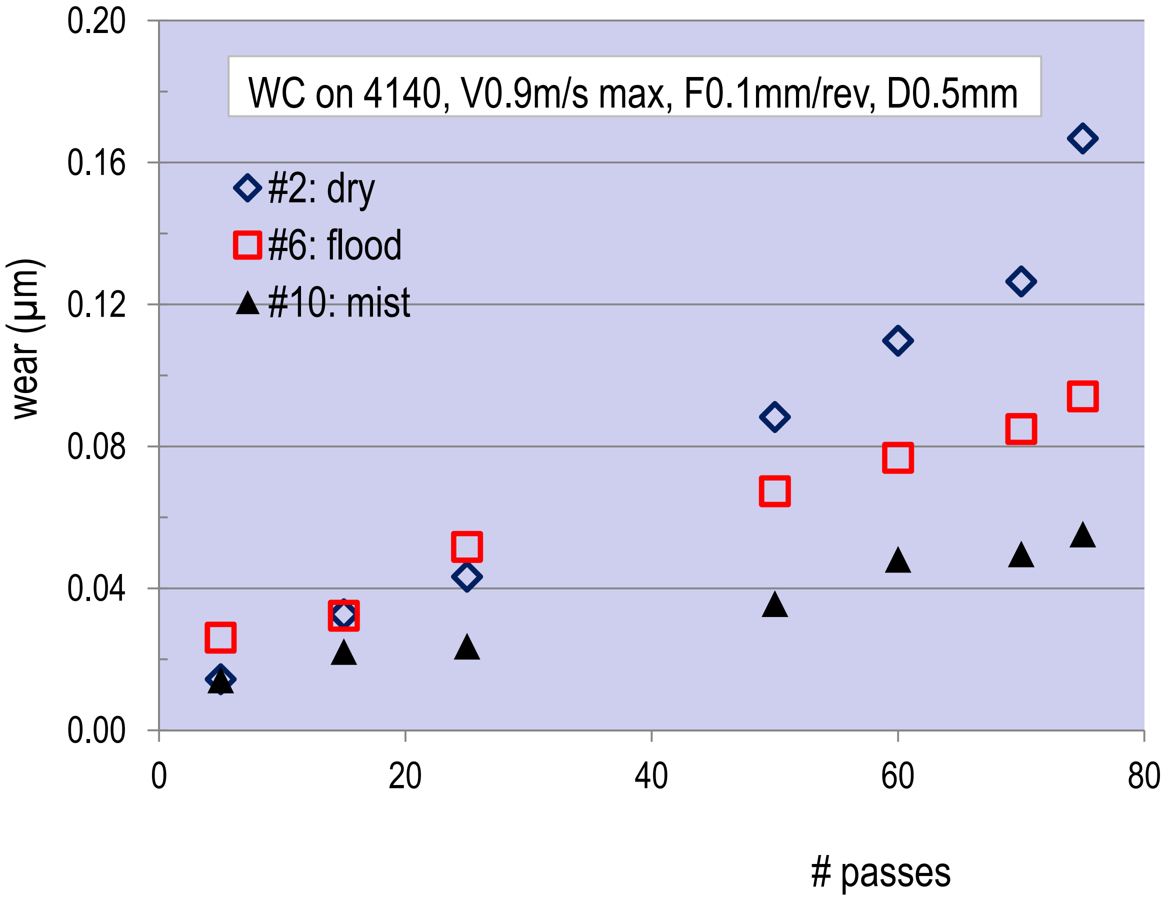


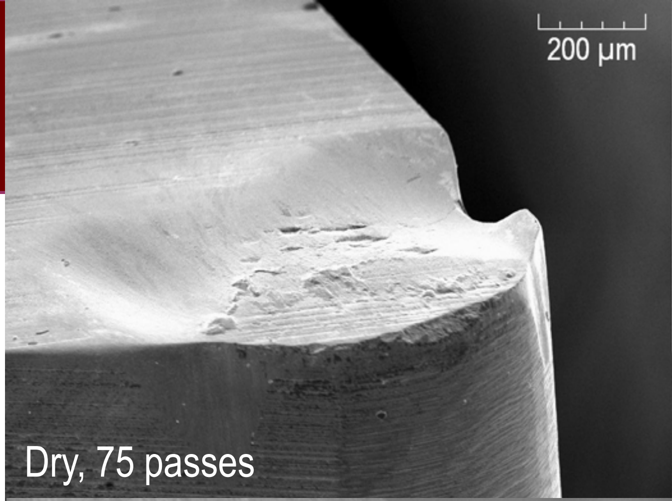


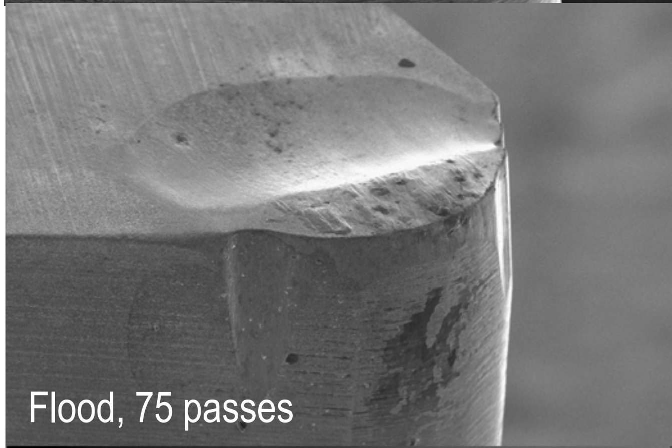


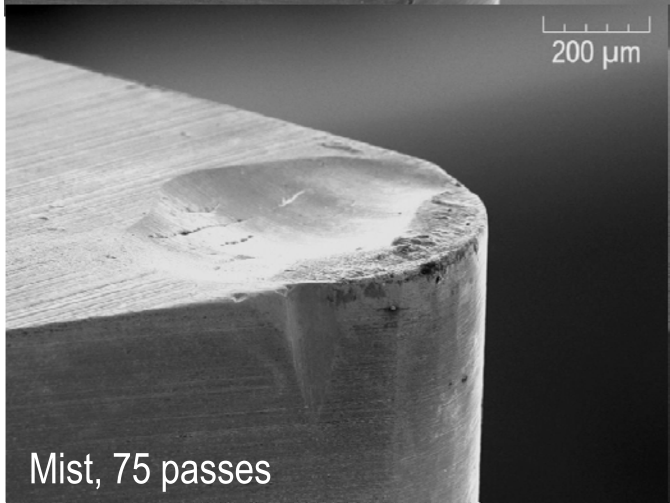


MICROMIST: macrofacing









MICROMIST: summary

1) Conclusions
   - In general, the dry machining produced the most flank wear vs. time. Flooding came in second, with misting obtaining the best results for tool flank wear longevity vs. time.
2) From a cost standpoint:
   - Dry machining is the least expensive in our experiment, but of course for long term machining one would have to factor in purchasing the more expensive coated carbide or ceramic inserts, dimensional stability notwithstanding.
   - Flooding is the most expensive, as coolant cost is high, must be checked regularly for contaminants, and must be disposed of according to environmental procedures
   - Misting, by far is less costly to flooding

Summary Continued

3) Misting Fine points
   - Oil volume of Misting has little effect on the cutting performance once the minimum amount of coolant is established.
   - It is recommended that less oil volume be used to prevent pollution of the environment and to prevent adverse health issues.

4) Submicron mist particles
   - Contaminate other equipment.
   - Pose potential health issues.
   - Should be used with air cleaner unit.

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- Mr. Patrick Anderson, PMT Inc.