

Using FloEFD™ to design Liquid-Cooled Nozzles for Cutting Tools



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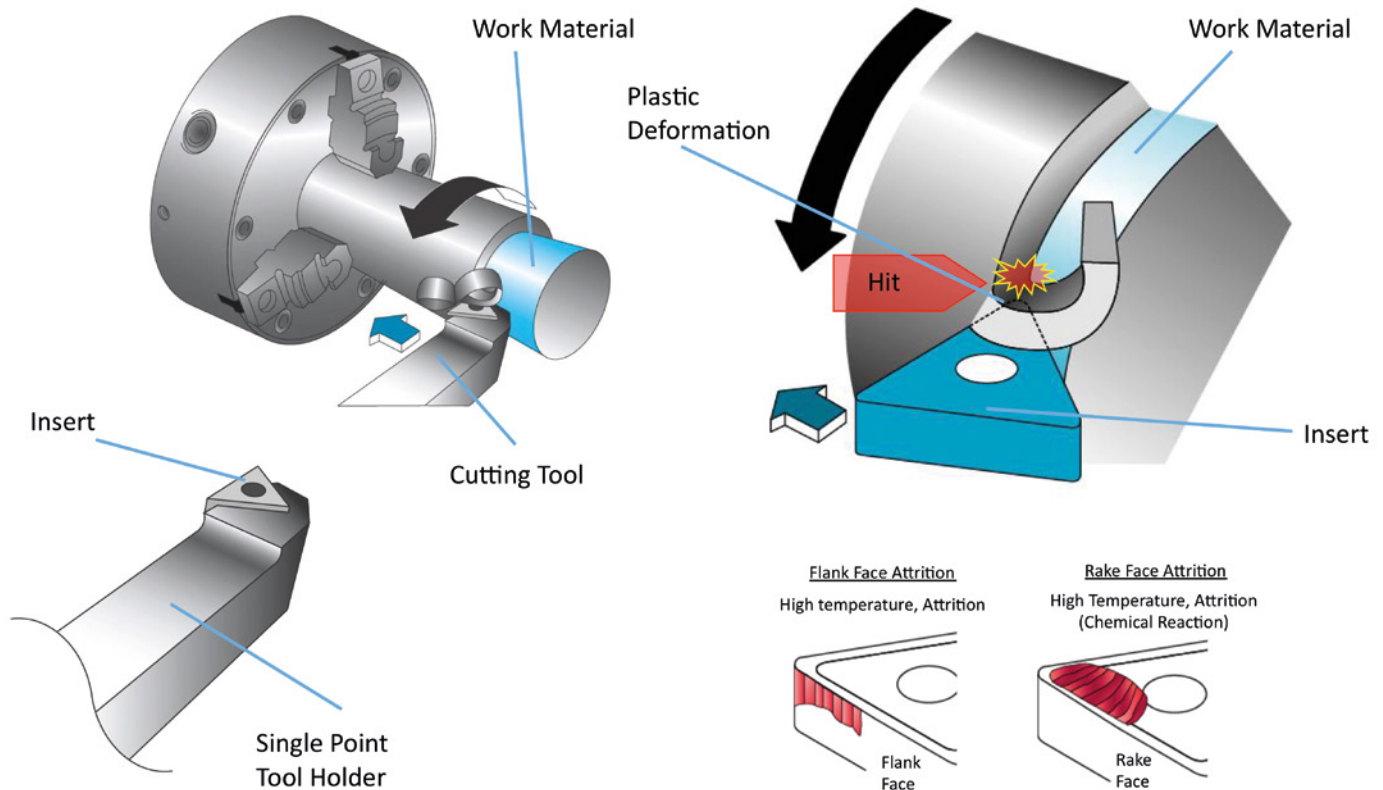


Figure 1. Typical Cutting Bits used in Lathe Turning and the wear issues they face

The Mitsubishi Group is a huge Japanese industrial conglomerate and Mitsubishi Materials Corporation is one of the subsidiary companies of Mitsubishi Mining Company Ltd. and has been in existence for approximately 100 years. Its Advanced Materials & Tools Company and its consolidated subsidiary companies employ approximately 6,800 people worldwide, making and delivering a wide range of machine

cutting tools based on tungsten carbide. A subset of these tools is in rotating lathe applications (Figure 1) that tend to generate surface temperatures of 600 – 700 degrees at the contact cutting point (at the rake and flank faces) and the cutting tool's lifespan can consequently be low. Tungsten Carbide triangular tool inserts are typically used on all six of their corners before they are disposed. They therefore experience several thermo-mechanical effects that

damages them and affect their lifetime – attritional wear on the rake and flank faces of the tool, frictional heating effects, mechanical separation due to the extreme forces involved in the cutting, and even chemical reactions.

Traditional cooling systems for such cutting tools have used a single circular nozzle cooling hole near the insert. The tungsten carbide insert can last for 20 minutes per corner edge whereas better cooling could

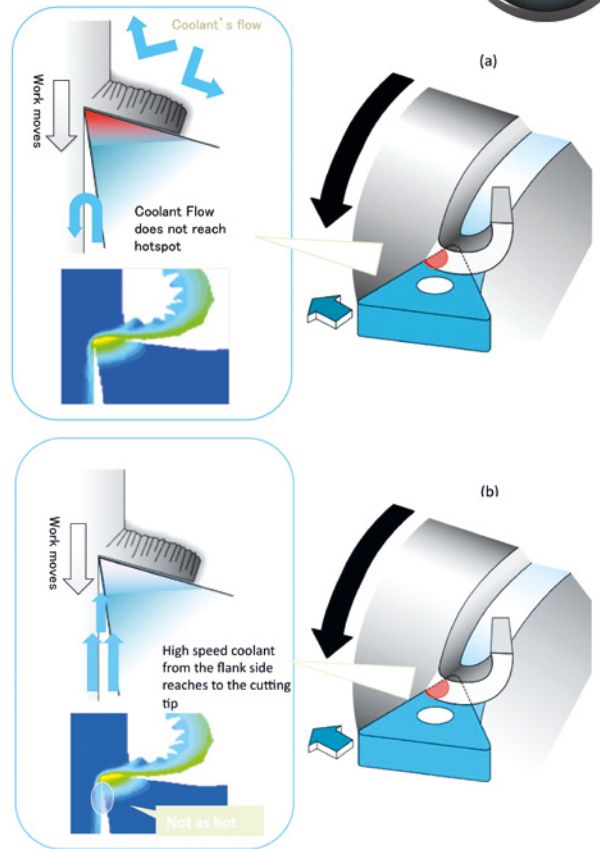


Figure 2. Typical Cutting Bits Coolant Spray and good hot spot cooling (b) versus bad (a)

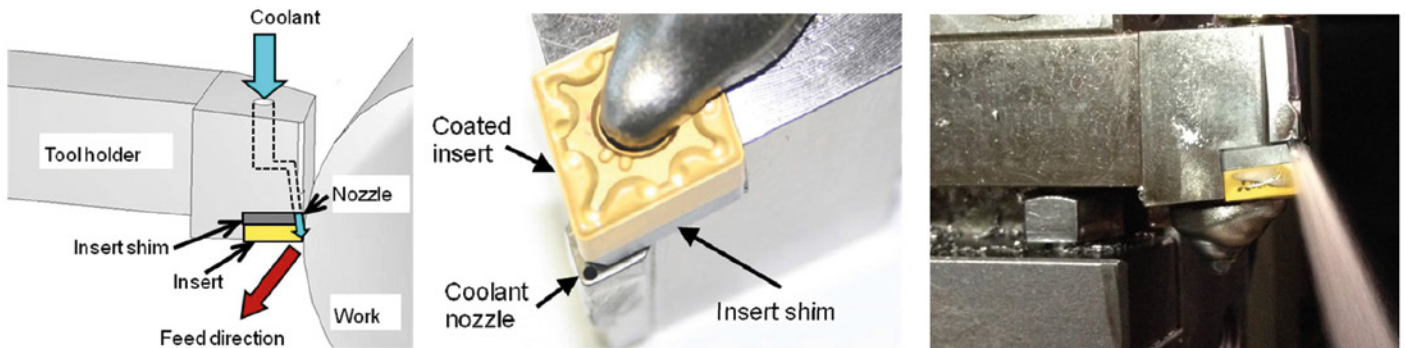


Figure 3. JC Technology's laboratory concept for a Tool Bit Cooling Jet (with circular nozzle)

increase the insert's lifetime by 40%, to 28-30 minutes per corner edge. Such well-cooled tool holder's lifetime performance is an advantage to productivity for cutting tool users.

Mitsubishi turned to Prof Obikawa of the Institute of Industrial Science at Tokyo University and established an academic-industrial partnership to extend the life of their tools. He came up with ideas for new cooling technology for the Mitsubishi tool holder that needed to be tested. The goal of the new cooling technology was to reduce extreme frictional heat generated while cutting (Figure 2), which in turn has the adverse effect of reducing product lifetimes. Prof Obikawa's "Jet Coolant Tech" (JC Technology) came out of the collaboration.

SUS304
 $V_c : 220\text{m}/\text{min}$
 $a_p : 1\text{mm}$
 $f_r : 0.2\text{mm}/\text{rev}$

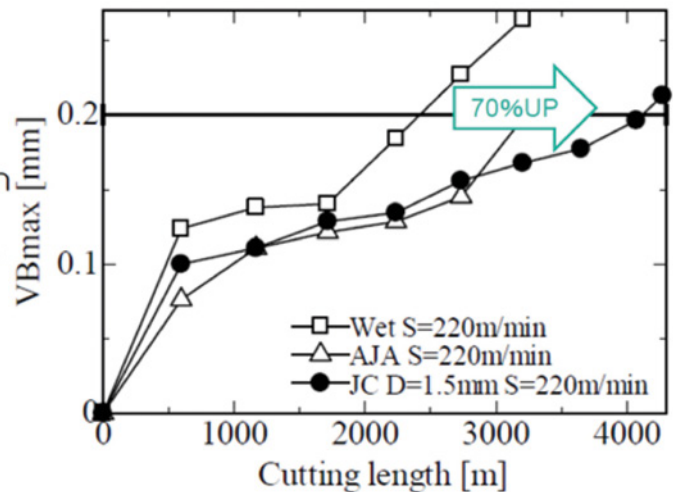


Figure 4. JC Technology's results in a Cutting test - Jet Coolant effect is proved by the basic lab study

Usually it is hard to make the nozzle coolant liquid reach the hottest point on the tool, thereby cooling is not working effectively, (Figure 2a), versus the ideal scenario of coolant getting to the hot spot (Figure 2b). Making the coolant spray reach the heat source by applying high speed targeted jets from the flank face in particular is key.

The crucial idea from JC Technology was to apply the liquid coolant as a “high speed jet” spray from the bottom part of the insert sheet, cooling it down directly, and thus extending the insert’s lifetime (Figure 3). At SUS304 laboratory test, JC Technology was able to show significant improvements (70%) in the laboratory, in cutting length for the coolant jet configuration employed (Figure 4).

Mitsubishi worked with JC Technology to come up with an “L” Shaped nozzle that they believed would perform better than a circular nozzle in terms of jet performance in cooling (Figure 5) within their laboratory tests.

Mitsubishi needed a methodology to simulate the cooling and mechanical effects of its new nozzle. Would it produce enough cooling? Would the nozzle component be durable enough? As such engineers and designers assembled an array of computer-aided engineering tools to virtually test the new design (Figure 6). With regard to fluid flow and heat transfer analysis, they decided to use FloEFD™ from Mentor Graphics and Particleworks™ from Prometech Inc. They only used the standard functions of FloEFD (Figure 7) and Particleworks (Figure 8) software in their coupled simulations with no user subroutines required.

The coolant used in the holder itself was 5-10% diluted water but regular water was used in the CFD simulations. The main goal of the simulations was to optimize the liquid cooling channel opening geometry for enhanced cooling purposes with as few prototypes as possible. Hence, the best cooling geometry was sought for the system. FloEFD showed that for the same pressure drop, the “L” shaped nozzle allowed 11% more liquid flowrate and produced 57% higher peak velocities than the round nozzle. Liquid flow rates and pressures were extracted from the FloEFD CFD simulation as inputs into the Particleworks simulation tool. It simulated the way droplets emerged from the nozzles and where they ended up on the Holder for cooling purposes (Figure 8). Commenting on how Mitsubishi used FloEFD, Hidebumi Takahashi said, “We like

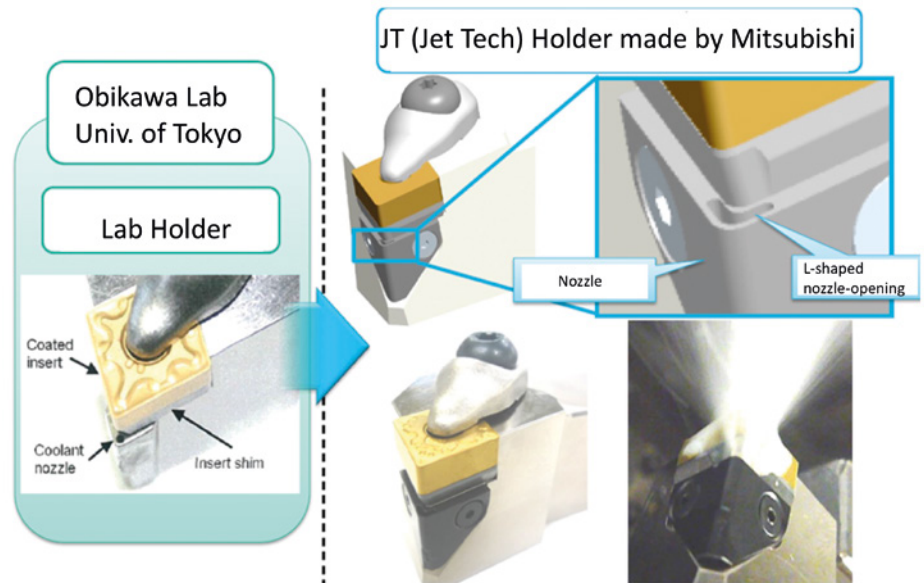


Figure 5. Mitsubishi's Jet Tech Holder configuration and associated CAD model

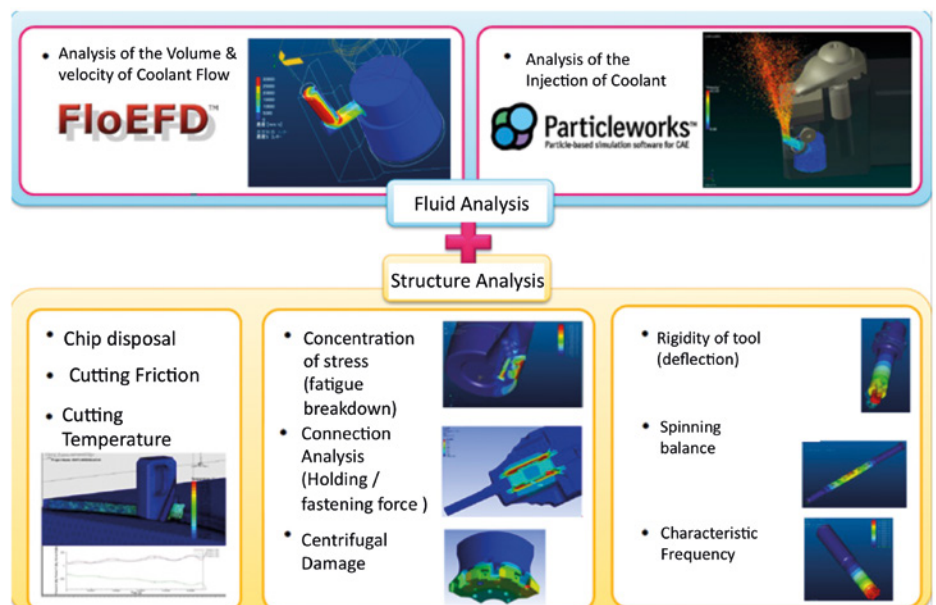


Figure 6. Mitsubishi's Coolant Nozzle Computer Aided Engineering Design Process Methodology

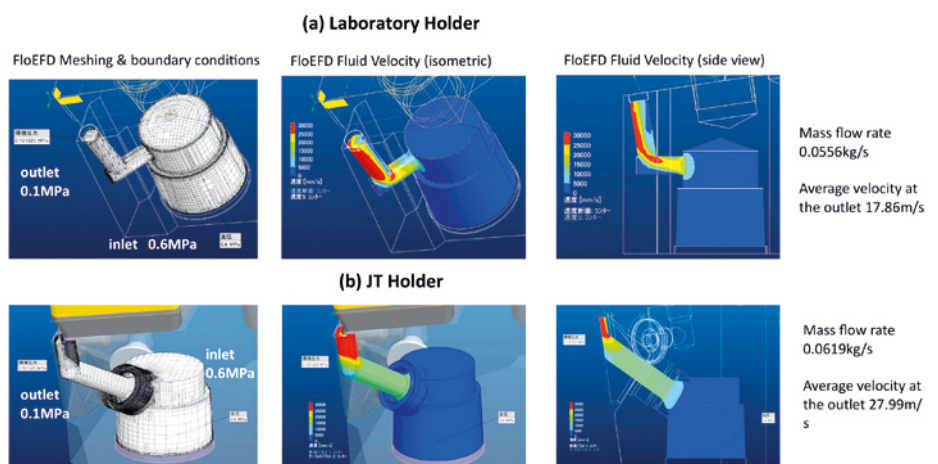


Figure 7. CFD Analysis inside FloEFD of the Laboratory Holder (a) & JT Holder (b) Volume Flow Rate and Velocity of Coolant Flow

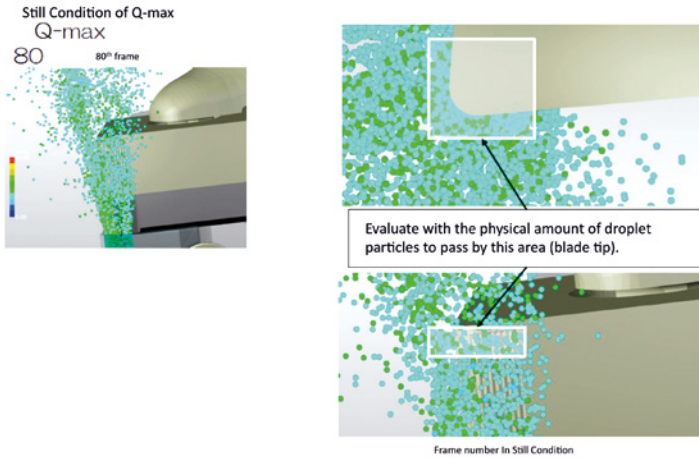


Figure 8. Spray Analysis of the JT Holder in Particleworks™



Figure 9. Final JT Holder Nozzle Spray Configuration

FloEFD because it is fast in calculation for steady analysis. Since we have no specialist CFD experts, our designers take care of simulation analysis. FloEFD is the best for CFD because of its simplified auto-meshing setting inside our preferred CAD package, PTC Creo. We found the cut cell CFD function to be very valuable.”

Subsequent experimental test measurements of the JT Holder system prototype created by this approach proved to be very satisfactory in thermal performance as was structural simulation analysis of the rigidity and durability of the nozzle. The methodology devised by Mitsubishi allowed them to patent the JT Tech nozzle (Figure 9) they devised and can be used to create other Holder nozzle configurations relatively quickly. In future Mitsubishi would like to see a closer coupling of the two fluid simulation software tools for similar analyses.

Cutting Test Results

Figure 10 shows the damage of the wear after cutting test and figure 11 shows the line graph of frank wear. In figure 10, the level of wear describes the wear distance from the cutting edge, and the end of the life time is based on when the amount of frank wear reaches to 0.2mm. As seen in figures 10 and 11, with conventional coolant, the edge is worn out with 0.5mm of the frank wear in 14 minutes of cutting, when the remarkable attrition can be seen on the cutting edge, in the meanwhile, with JT holder, the frank wear is only 0.15mm at the time of 14 minutes and it finally became worn out with 0.2 mm of frank wear, in 20 minutes of cutting time. The JT holder performs 40% better in lifetime extension compared with the case of conventional coolant.

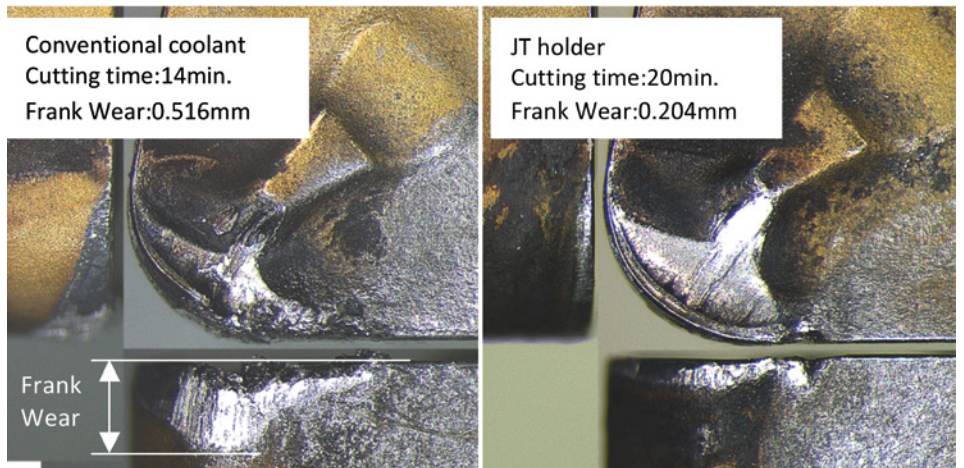


Figure 10. Wear apparatus after cutting test.

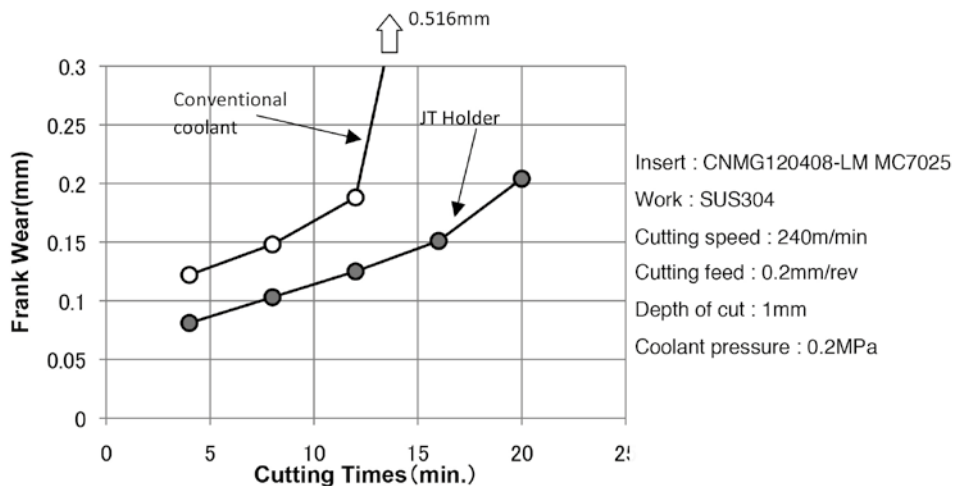


Figure 11. Frank wear of JT holder compared with Conventional coolant.

Mitsubishi Material succeeded in applying the lab testing result to the design process and achieved their target of extending the lifetime of the cutting tools, with an efficient

cooling method. The fluid analysis tool, FloEFD, is an extremely efficient tool for product development.