**Objectives**

- To investigate the dry wire electrical discharge machining (EDM) of workpiece with thin thickness.
- To study the effects of spark cycle, spark on-time, air flow, thickness, and type of work-material were studied under wet and dry EDM conditions.

**State-of-the-Art**

- Gas is used as the dielectric fluid in place of liquid (deionized water or kerosene) during wire EDM process.
- Because of the thinner recast layer and narrower cutting groove width, dry wire EDM is applied to the finish cutting of precision components.
- Oxygen can accelerate the machining speed in die-sink EDM of ferrous material due to the quasi-explosion caused by rapid oxidation.
- Piezo actuator is applied in the dry EDM process to improve the control over gap width and prevent the short circuit.

**Approaches**

- Conventional wire EDM machine was used to perform dry EDM experiments.
- Three EDM conditions were studied: 1. wet, 2. dry with air flow, and 3. dry without air flow.
- An EDM process monitoring system was developed to identify the EDM pulses: spark, arc, and short.

**Accomplishments**

- Effects of spark cycle, spark on-time, air flow, thickness, and type of work-material on the MRR for dry wire EDM of thin workpiece were investigated.
- The rate and percentage of spark, arc, and short pulses were compared and discussed under the wet, dry with air flow, and dry without air flow EDM conditions.
- The groove width and deposition of debris in the groove during dry EDM were studied.
- Wear of the wire electrode were observed using optical and scanning electron microscopy.

**Future Work**

- This research in dry EDM is continuing to improve the precision, MRR, and to reduce environmental impact.
- The usage of deionized water mist will be investigated to reduce the odor of smoke and help collect the floating metal particulate in air.
- The mechanism of debris deposition and new methods minimizing the deposition to improve part accuracy will be investigated.

**Sponsors**

NIST Advanced Technology Program
Dry and Near-dry EDM Processes Development

Research Assistants/Staff: G. Qiao, G.Y. Kim, J. Tao, J. Zhu, M. Fujiki
Faculty: J. Ni, A. Shih

Objectives
To develop dry and near-dry electrical discharge machining (EDM) processes as integrated secondary super finishing methods of direct metal deposition (DMD) products including tools and dies with 5DOF die sinking and milling capabilities.

State-of-the-Art
- In stead of using dielectric liquid in conventional EDM, dry and near-dry EDM use gas and mist, respectively, to minimize the amount of liquid used.
- Dry and near-dry EDM are characterized by
  - Less environmental impact
  - High material removal rate (MRR) using oxygen as dielectric fluid
  - Low residual stress
  - Less electrolytic corrosion
  - High cutting efficiency at small discharge energy in near-dry EDM.

Approaches
- Select dielectric fluids and electrode materials in dry and near-dry EDM for high MRR and good surface finish, respectively
- Investigate the effect of electrical parameters
- Model the near-dry EDM process to predict the MRR and surface finish to achieve
- Characterize the surface and subsurface quality after dry and near-dry EDM

Accomplishments
- Dry and near-dry EDM milling test bed
  - Retrofitted a die-sinking EDM for dry and near-dry EDM milling usage by amounting a rotary spindle on the EDM head and modifying the spindle’s fluid flushing supply

Preliminary results of rough and finish cutting
- For roughing, the MRR increases to 36 mm³/min using oxygen medium and copper electrode, as compared to about 20 mm³/min of conventional EDM
- Deep crater and thick recast layer is caused by arcing
- Large amount of O occurs in the recast layer

Future Work
- Lower the discharge energy of the power supply to achieve shiny surface finish, Rₐ=0.1 μm
- Study and compensate the tool wear of the process
- Construct a semi-empirical model to predict the performance of the process
- Improve gap servo control for dry and near-dry EDM

Sponsors
Advanced Technology Program (ATP) of National Institute of Standards and Technology

For more information, contact Prof. J. Ni; Phone: 734-936-2918; Email: junni@umich.edu
Control of Five Degrees of Freedom
Dry/ Near-Dry EDM Milling Machine

Research Assistants/Staff:
M. Fujiki, G.Y. Kim, G. Qiao, J. Tao, J. Zhu

Faculty:
J. Ni, A. Shih

Objectives
- To design and implement a controller for 5DOF dry/near-dry EDM milling machines that achieves ±1μm part accuracy within 50mm x 50mm x 50mm workpiece.
- To achieve higher material removal rate and higher surface finish compared with conventional 3DOF EDM milling machines

State-of-the-Art
- By controlling the EDM milling machine with five-degrees of freedom, the tool electrode can be oriented in such a way that it is perpendicular to the sculptured surface.
- An electrode oriented perpendicular to the sculptured surface develops electrical discharges between them in the intended path, OP1.
- Electrode’s orientation with respect to the sculptured surface influences the flushing effect of debris, hence by controlling the orientation of electrode, the material removal rate can be maximized.
- Piezo actuator that controls the perpendicular normal gap distance between the electrode and the workpiece increases the bandwidth of gap control.

Approach
- Design and fabricate a custom spindle for EDM milling machine that has built in piezo actuator.
- Observe the characteristics of different types of discharge and its correlation to toolwear.
- Monitor voltage and current in each discharge and identify its characteristics in realtime.
- Estimate electrode wear based on the monitored discharges and compensate for toolwear in realtime.
- Investigate the effect of tool inclination angle with respect to sculpture surface in terms of material removal rate and incorporate its result in CAM and the controller

Work in Progress
- An innovative design of spindle with built-in piezo actuator is currently underway. However, there are still technical difficulties, such as wiring planning and kinematic relations among each component.

Future Work
- Completion of the full design of EDM spindle with built-in piezo actuator.
- Fabrication of the spindle
- Acquisition of experimental data for each discharge profile and tool wear to material removal ratio
- Development of algorithm to identify different discharge types based on DSP technology
- Development of algorithm for adaptive tool inclination control and real-time collision check to maximize the material removal rate

Sponsors
- This research is sponsored by Advanced Technology Program, National Institute of Standards and Technology, Technology Administration, US Department of Commerce.

For more information, contact Prof. J. Ni; Phone: 734-936-2918; Email: junni@umich.edu