

Thermal Model for Single Discharge EDM process

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DMAVT

Departement Maschinenbau & Verfahrenstechnik Department of Mechanical & Process Engineering Thermal (Anode – Cathode Model)

- Single Discharge: Heat Conduction and Joule Heating
- GUI (Comsol Matlab)
- Residual Thermal Stress







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Heat Conduction

- Governing Equation:
 - Heat Equation: $(\rho C_p \frac{\partial T}{\partial t} + \rho C_p \mathbf{u} \cdot \nabla T = \nabla \cdot (k \nabla T) + Q)$
- Boundary Conditions:
 - Initial Values
 - General Inward Heat Flux $(-\mathbf{n}.(-k\nabla T) = q_o)$
 - Thermal Insulation $(-\mathbf{n}.(-k\nabla T) = 0)$



Joule Heating

• Governing Equations:

•
$$\mathbf{J} = \left(\sigma + \epsilon_0 \epsilon_r \frac{\partial}{\partial t}\right) \mathbf{E} + \mathbf{J}_{\mathbf{e}}$$

- ∇ . $J = Q_j$
- $\mathbf{E} = -\nabla \mathbf{V}$
- Boundary Conditions:
 - Initial Values
 - Normal Current Density $(-\mathbf{n}, \mathbf{J} = \mathbf{J}_n)$
 - Electrical Insulation (-n, J = 0)



Input Parameters

- Plasma Channel Expansion:
 - Empirical
 - Constant Cathode Boiling Temperature
 - Eubank Physical Model
- Flux Profile:
 - Equilibrium
 - Gaussian
 - Parabolic
- Energy Balance:
 - Constant
 - Eubank Physical Model
 - User Defined



Input Parameters: Plasma Channel Expansion



Constant Cathode boiling temp.



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150

100

40 60

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Input Parameters: Flux Profile

Equilibrium:

Gaussian:



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Parabolic:



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Input Parameters: Energy Balance

- Single discharge: Plasma-material interaction
 - Total power E = voltage (U) current (I) pulse duration (t)



E_A, E_C : Constant , User Defined or from Eubank's Model

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Graphite, 150 (µs) (Empirical Equation)



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Results



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GUI (Comsol – Matlab)





Need for GUI ?

- Main use of GUI was to get isotherm plots in matlab figure window for easy editing of plots, obtaining curves for crater radius and crater depth based on results obtained from Comsol.
- Other than that it could update geometrical parameters, change materials and their properties, add time dependent equation for current or time energy balance based on interpolation of values, run the study and get results in Matlab variables by using GUI.





GUI Window: Materials Tab

🛃 GUI COMSOL						
Geometrical Parameters	Electrical Parameters	Flux Properties	Materials	Study	Result	
Materials:						
Material for Electrode:	Dens	ity:	8700[kg/m^3]		
Poco Graphite	Therr	nal Conductivity:	400[V	V/(m*K)]		
Graphite (Comsol)	Spec	ific Heat:	385[J	/(kg*K)]		
Copper (Comsol)	Relat	ive Permittivity:	E 000	1		
	Elect	ncar conductivity:	5.998	e/[5/m]		
Material for Workpiece: Density: Thermal Conductivity: Specific Heat: Relative Permittivity: Electrical Conductivity:	Steel W300		if(T<2700[K],0.000199[kg/m^3]* 3.333e-8[W/(m*K)]*(T/1[K])^3-8. if(T<3000[K],0.00044[J/(kg*K)]*(4.032	(T/1[K])^2-0.5597[kg/m^3]*(T/1[K] 779e-5[W/(m*K)]*(T/1[K])^2+0.075 T/1[K])^2-0.2912[J/(kg*K)]*(T/1[K]) 1 e6[S/m]) 1 •	

GUI Window: Study Tab

GUI COMSOL						_ _ _ _
Geometrical Par	rameters	Electrical Parameters	Flux Properties	Materials	Study	Result
Study:						
Load model:	C:\Users\kı	ıshan\Desktop\gui_comsol\jhgra	aphite_steelprop.mph		Open Load	
Time range:	range(10e	6,10e-6,150e-6)				
Save As:	C:\Users\kı	ıshan\Desktop\gui_comsol\new	files\jhgraphite_steelprop.mph		Save Save As	
	Update (Geometry	Run Study			





GUI Window: Results Tab

J GUI COMSOL					
Geometrical Parameters	Electrical Parameters	Flux Properties	Materials	Study	Result
Plot Isotherms			Plot Results		
Time (us): 10 💌	Plot Isotherms]	Temperature (degC): 700		
Temperature for Isotherms:			Plot Temp(work) Rad	ius	
T1 (degC): 700			Plot Temp(elec) Rad	ius	
T2 (degC): 1400			Plot Temp(work) Dep	oth	
T4 (degC): 3500			Plot Temp(elec) Dep	th	
T5 (degC): 5000					
Generate Plots Animation					



Residual Stress Modeling

(Using Thermal Stress Module)



Residual Stress

- 1. Physics
 - Governing equations
 - Boundary Conditions
- 2. Results
 - Residual Stress Isocontours



- Residual Stress with Depth along central Axis
- 3. Further work
 - Rapid cooling effect





Physics: Governing Equations

•
$$(-\nabla \cdot \sigma = \mathbf{F}_{\mathrm{V}}), (\sigma = \mathbf{s})$$

•
$$(s - S_o = C: (\epsilon - \epsilon_o - \epsilon_{inel})), (\epsilon_{inel} = \alpha(T - T_{ref}))$$

•
$$\epsilon = \frac{1}{2}((\nabla \mathbf{u})^{\mathrm{T}} + \nabla \mathbf{u})$$

•
$$\rho C_p \frac{\partial T}{\partial t} + \rho C_p \mathbf{u} \cdot \nabla T = \nabla \cdot (k \nabla T) + Q$$





Physics: Boundary Conditions

- Initial Values
- Thermal Insulation $(-\mathbf{n}.(-k\nabla T) = 0)$
- Heat Flux $(-\mathbf{n}.(-k\nabla T) = q_o)$
- Fixed Constraint $(\mathbf{u} = 0)$



Results: Residual Stress Isocontours





Results: Residual Stress with Depth



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Thank You for your attention!

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