

## **Thermal and Electromagnetic Analysis of 2D Inhomogeneous Railgun Using Control Volume Method With Unstructural and Moving Mesh Generation**

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### **Abstract**

In the railgun electrical energy is used to drive the system. In order to reach hypervelocity, a power supply with immense amount of energy must be used which causes an extraordinary current on the rail and the armature. This current makes thermal energy by the ohmic attenuation and warms up various points and therefore changes the electrical, thermal and mechanical specifications of the structure. The purpose of this study is to obtain thermal and magnetic induction distribution in the rail and the armature. In before studies, finite difference method with structural mesh generation is used for this work, but in this study we use control volume method with unstructural and moving mesh generation in the rail and the armature. This type of mesh generation lets us to apply boundary condition carefully. Also, by moving mesh generation we can analyze system in every position of armature.

**Key words: Railgun, Temperature distribution, Control volume method**

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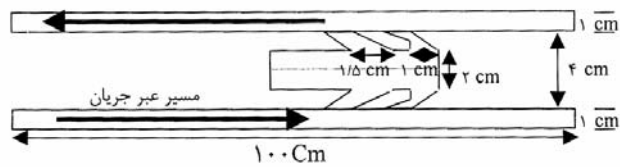
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(Lorentz)



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[2]

( ) x

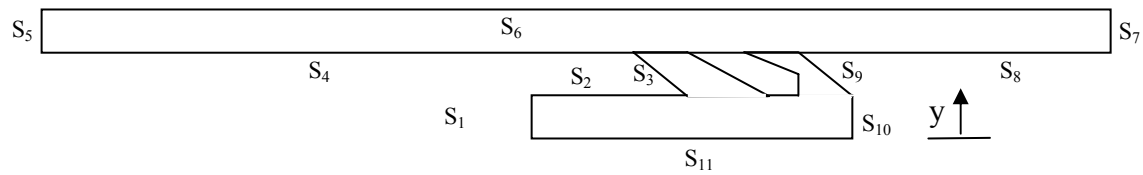
z

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[3,4]

$\sigma$	$1 / * / [ + / *(T- )] \text{ mho/m}$	$1 / * / [ + / *(T- )] \text{ mho/m}$
C	$1 / * T+ \text{ J/kg.K}$	$1 / * T+ \text{ J/kg.K}$
$\rho$	kg/m	kg/m
K	W/m.K	W/m.K

... /



$$\nabla \cdot (k \nabla T) + S = \rho c \frac{\partial T}{\partial t} \quad (1)$$

$$\nabla \times \vec{B} = \mu \vec{J} \quad (2)$$

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} \quad (3)$$

$$\vec{J} = \sigma (\vec{E} + \vec{V} \times \vec{B}) \quad (4)$$

$$\vec{E}, \vec{B}, \vec{J} \quad (5)$$

[7,8]

$$\nabla \cdot \vec{J} = -\sigma \nabla \cdot (\vec{E} + \vec{V} \times \vec{B})$$

$$S_{ohm} = \frac{\vec{J} \cdot \vec{J}}{\sigma} \quad (6)$$

$$\frac{\partial J_z}{\partial x} = \frac{\partial E_z}{\partial x} \quad (7)$$

(8)

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$$\rho c \frac{\partial T}{\partial t} + \rho c V \frac{\partial T}{\partial x} = k \frac{\partial^2 T}{\partial x^2} + k \frac{\partial^2 T}{\partial y^2} + \frac{1}{\mu^2 \sigma} \left[ \left( \frac{\partial B}{\partial x} \right)^2 + \left( \frac{\partial B}{\partial y} \right)^2 \right] + \frac{\partial k}{\partial x} \frac{\partial T}{\partial x} + \frac{\partial k}{\partial y} \frac{\partial T}{\partial y}$$

$$\mu \sigma \frac{\partial B}{\partial t} = \frac{\partial^2 B}{\partial x^2} + \frac{\partial^2 B}{\partial y^2} - \mu \sigma V \frac{\partial B}{\partial x} - \frac{1}{\sigma} \frac{\partial \sigma}{\partial T} \frac{\partial T}{\partial x} \frac{\partial B}{\partial x} - \frac{1}{\sigma} \frac{\partial \sigma}{\partial T} \frac{\partial T}{\partial y} \frac{\partial B}{\partial y}$$

[1]

(9)

$$\sigma \quad (10)$$

$$\rho \quad k \quad c \quad (11)$$

(12)

:

[5]  $x$  -  
( ) ( )

$$\frac{\partial B}{\partial x} = 0 \quad \text{for } S_5 \quad ( ) \quad x$$

$$y \geq 0$$

$$B(y) = B(-y), T(y) = T(-y)$$

( ) -

[6]

$$A_H \frac{dB}{dt} = - \int \frac{\vec{J}}{\sigma} \cdot d\vec{l}$$

$d\vec{l}$   $A_H$  ( )

[5] ( )

$$\vec{n} \cdot \nabla T = 0 \quad ( )$$

( )  $\hat{n}$

( ) ( )

J

[5] ( )

$$B = 2\mu J \quad \text{for } S_1, S_2, S_3, S_4$$

$$B = \mu J \quad \text{for } S_8, S_9, S_{10}$$

$$B = 0 \quad \text{for } S_6, S_7$$

$$\frac{\partial B}{\partial y} = 0 \quad \text{for } S_{11}$$

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[5] J ( )

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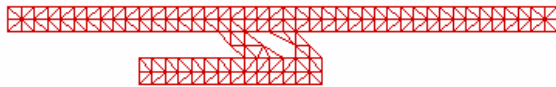
$$J = J_0 \sin\left(\frac{\pi \cdot t}{2t_0}\right) \quad \text{for } t \leq t_0$$

$$J = J_0 \exp[-2(t - t_0)/t_1] \quad \text{for } t \geq t_0$$

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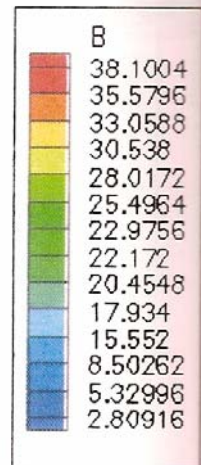
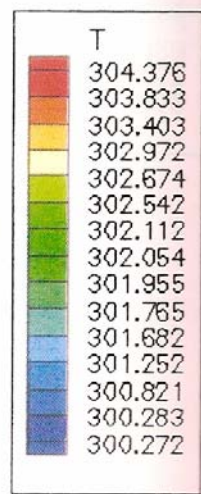
$$t_0 = 260 \mu s \quad J_0 = 17.8 MA/m$$

$$t_1 = 2029 \mu s$$

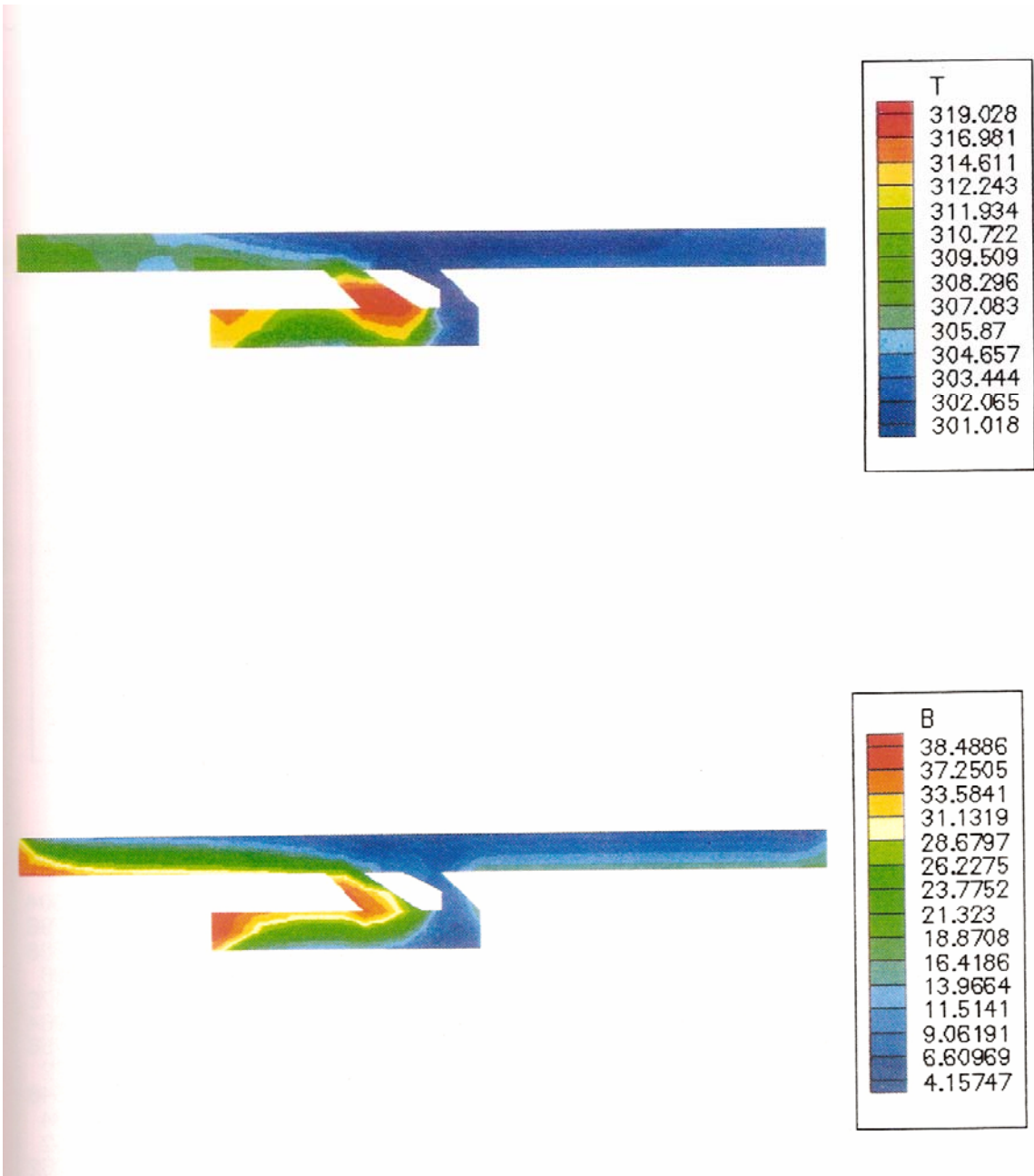


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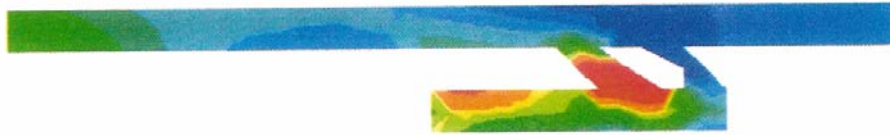
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X=0



X=5



T	
[Red]	320.494
[Orange]	317.544
[Yellow]	315.394
[Light Green]	314.925
[Green]	313.751
[Dark Green]	312.154
[Teal]	310.557
[Light Blue]	308.96
[Medium Blue]	307.363
[Dark Blue]	305.766
[Very Dark Blue]	304.169
[Darkest Blue]	302.572
[Black]	300.975



B	
[Red]	36.749
[Orange]	32.2757
[Yellow]	27.8023
[Light Green]	25.5656
[Green]	23.3289
[Dark Green]	21.0922
[Teal]	18.8555
[Light Blue]	16.6188
[Medium Blue]	14.3821
[Dark Blue]	12.1454
[Very Dark Blue]	9.90873
[Darkest Blue]	7.67204
[Black]	5.43535

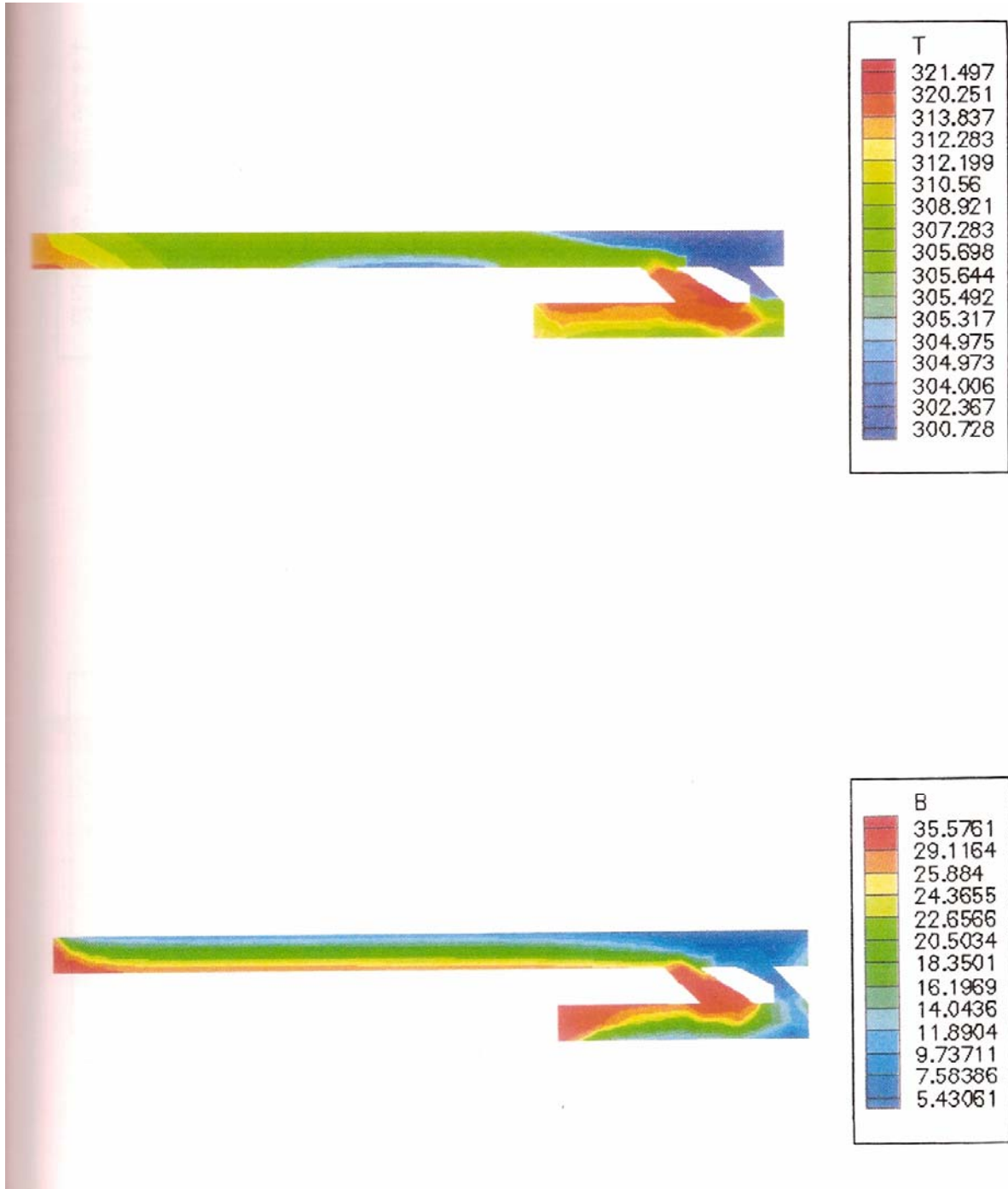
X=10

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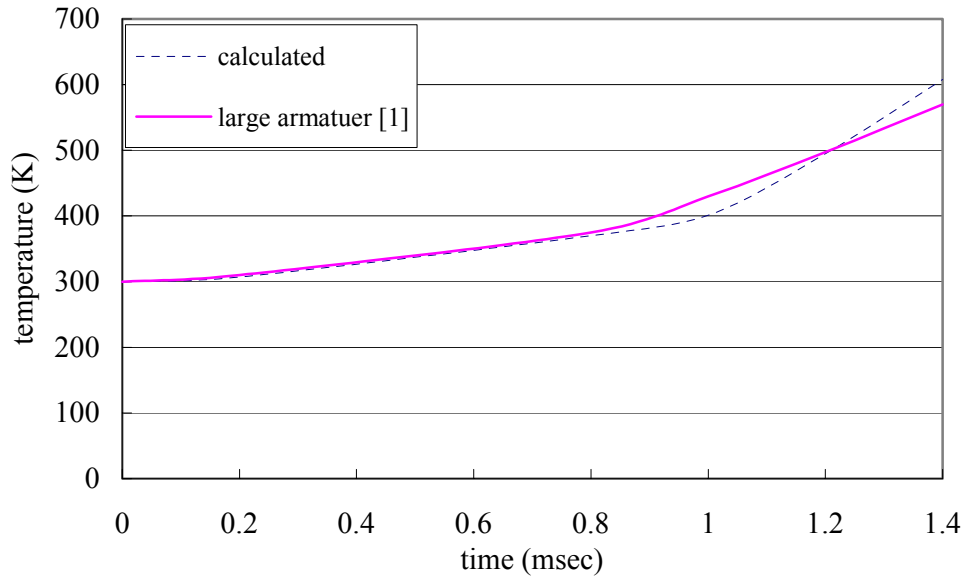
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