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A Magnetohydrodynamic study of an inductive MHD generator

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OUTLINE OF THE PRESENTATION

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- INDUCTIVE MHD GENERATOR
- PHYSICAL MODEL
- MODELLING IN COMSOL
- SOLVER SETTING
- RESULTS
- CONCLUSION

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GOAL

- Typical drawbacks of MHD generators:
  - The use of the superconductive coils to generate the external magnetic field;
  - The deterioration of the electrodes;
  - The needed of high temperatures of the working fluid.
- Advantages of the proposed devices:
  - No external magnetic field;
  - No electrode is involved by the load current;
  - low temperatures.

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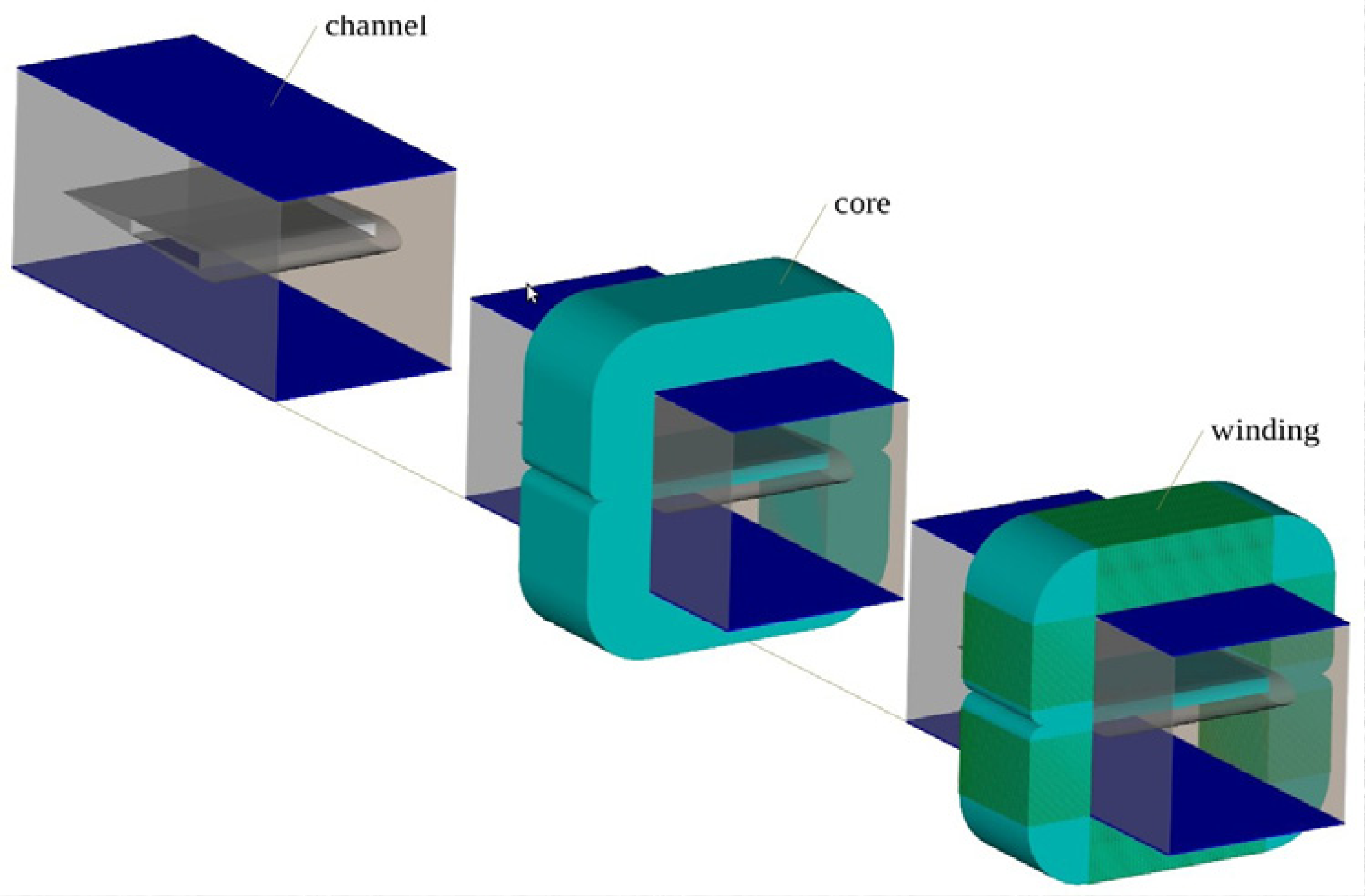
INDUCTIVE MHD MODEL

Assembly of the Generator



INDUCTIVE MHD MODEL

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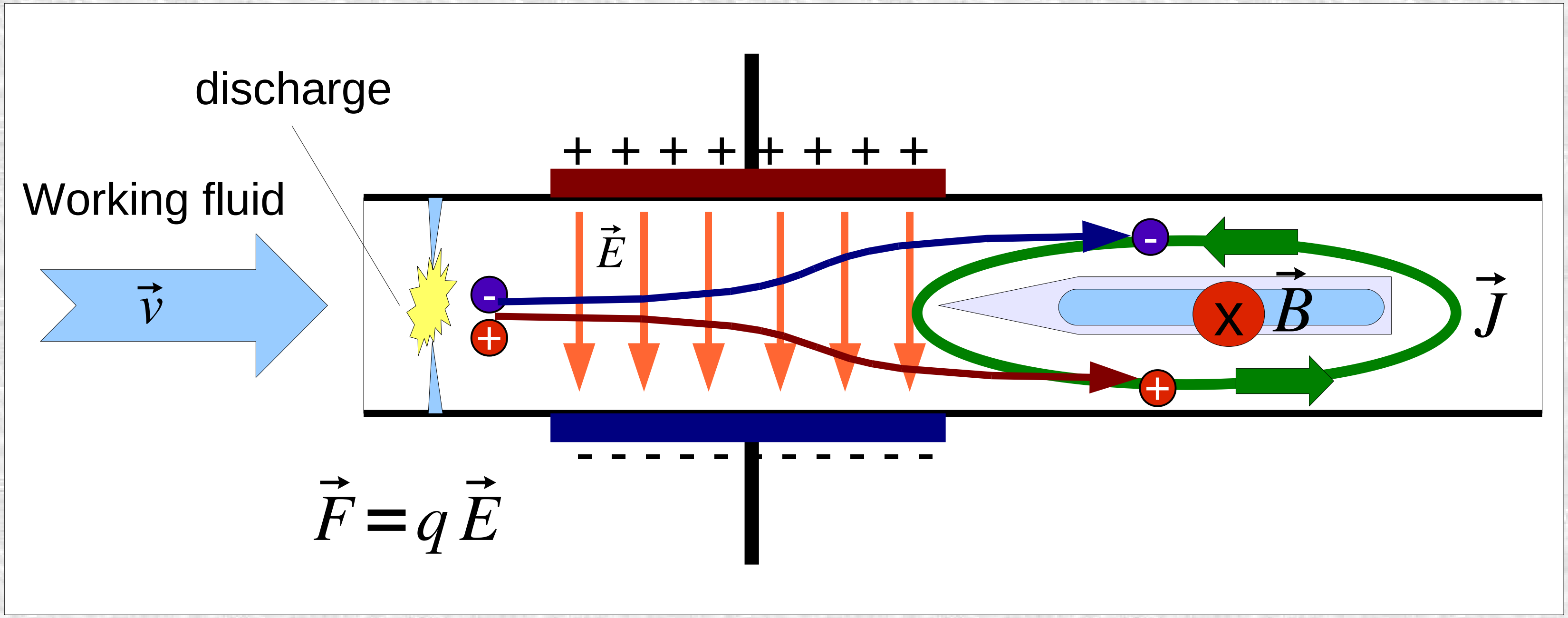
Operating principle



THE APPLIED PHYSICAL MODEL

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- Electrostatic stationary;
- Fluid flow stationary (Navier-Stokes);
- Convection and diffusion transient.

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AC/DC MODULE

- Electrostatic model

$$\nabla^2 V = \frac{\rho}{\varepsilon_0}$$ Poisson equation

where

$$E = -\nabla V$$

ρ space charge density

ε_0 dielectric permittivity

HEAT TRANSFER MODULE

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- Navier-Stokes k-ε model

Continuity equation

$$\frac{\partial u}{\partial x}+\frac{\partial u}{\partial y}=0$$

Momentum equation

<u>x component</u>

$$\rho u\frac{\partial u}{\partial x}+\rho v\frac{\partial u}{\partial y}=(\mu+\mu_t)\left[\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right]-\frac{\partial p}{\partial x}+F_x$$

<u>y component</u>

$$\rho u\frac{\partial v}{\partial x}+\rho v\frac{\partial v}{\partial y}=(\mu+\mu_t)\left[\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right]-\frac{\partial p}{\partial y}+F_y$$

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MULTIPHYSICS MODULE

- Convection and diffusion model

$$\frac{\partial c}{\partial t} = D \nabla^2 c R - \vec{v} \cdot \nabla c$$

where

c concentration of charge

D diffusion coefficient

$\vec{v}$ velocity vector

MODELING IN COMSOL

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- The convection and diffusion, electrostatic and Navier-Stokes equation are coupled;
- Velocity field from Navier's-Stokes equation and electric field from Poisson's equation used as source terms for convection's and diffusion's equation;
- The generation of the charge modeled setting the reaction rate parameter:

$$R = \frac{C_R}{\sqrt{2\pi \cdot \sigma^2}} \left[e^{\frac{(t-t_1)^2}{2\cdot\sigma^2}} + e^{\frac{(t-t_2)^2}{2\cdot\sigma^2}} \right]$$

Where

C_R = maximum charge concentration in the time;

σ = charge diffusion parameter.

BOUNDARY CONDITIONS

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- For fluid dynamic
  - logarithmic wall function in the inner walls;
  - inlet velocity =200m/s;
  - outlet pressure= 101325 Pa.
- For Electrostatic
  - 50 kV DC voltage between capacitor plates;
  - Electric insulation in all inner walls.
- For convection and diffusion
  - Convective flux diffusion in the outlet section;
  - Zero diffusive flux condition in all the other boundaries.

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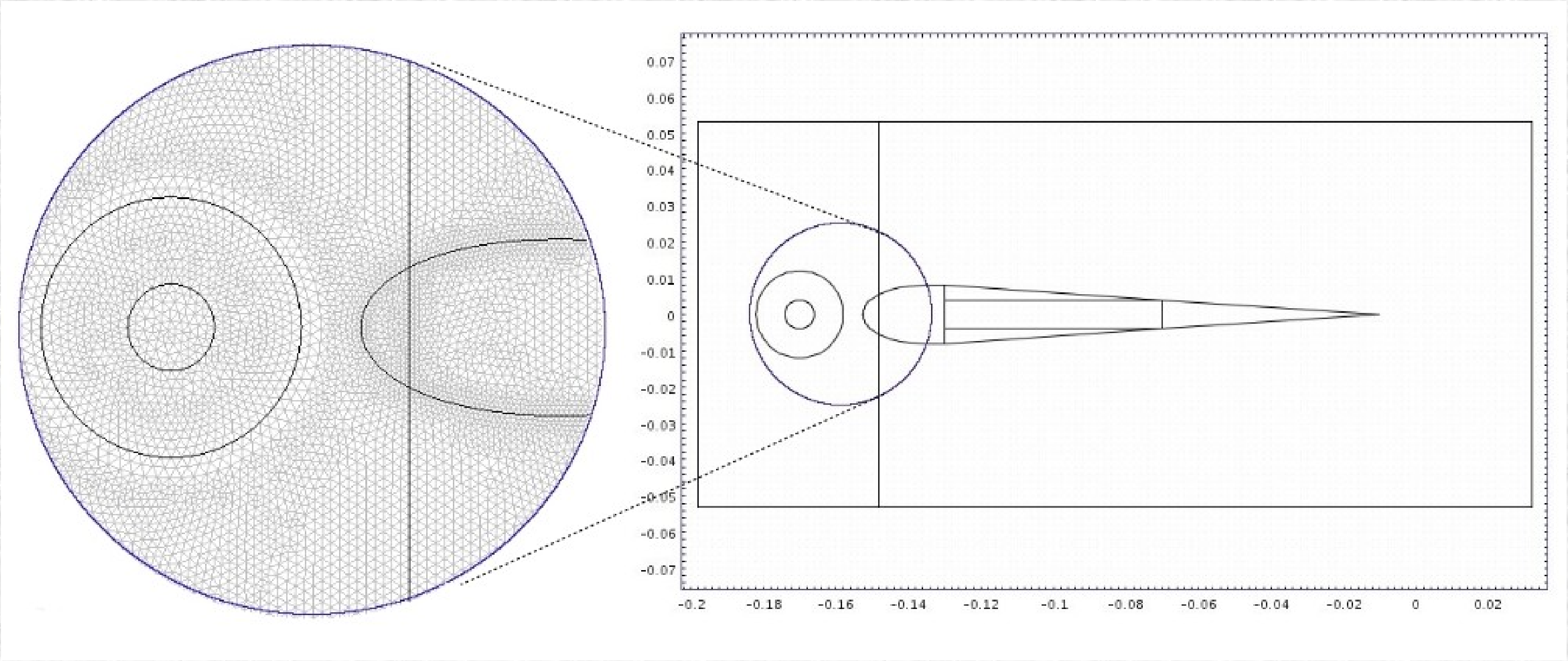
MESH SETTINGS

- 90752 elements
- Degree of freedom:

  - 904213 electrostatics and fluid dynamic model

  - 339236 convection and diffusion model



SOLVER SETTINGS

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- Electrostatics and fluid dynamic modules are separated from a convention and diffusion module;
- Firstly the electrostatic and fluidodynamic module are solved by use of stationary solver.
- Then the velocity field and the electric field are used as source terms to solve the convection and diffusion equations by transient solver.

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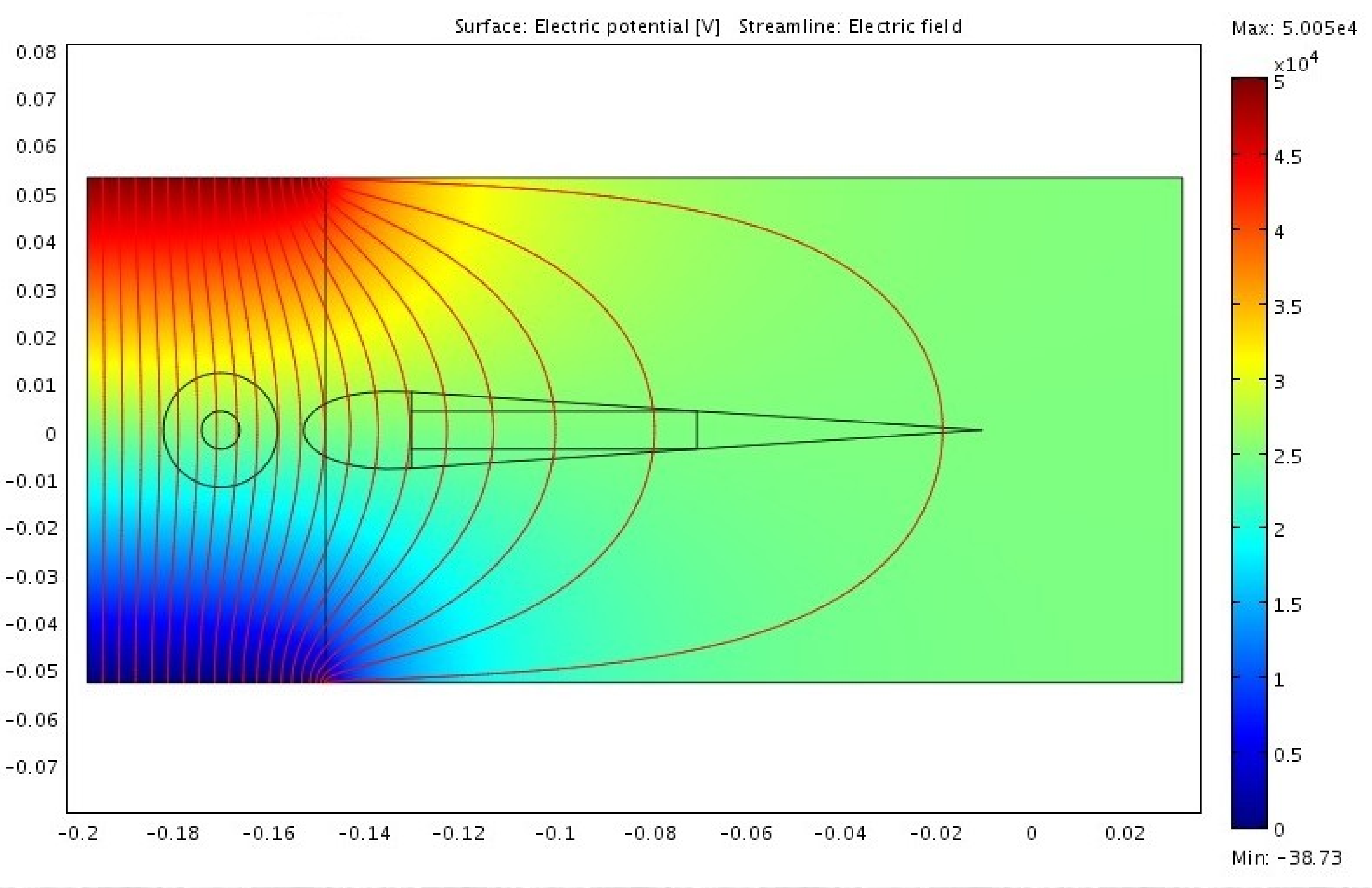
RESULTS

- Surface electric potential and streamline electric field.



RESULTS

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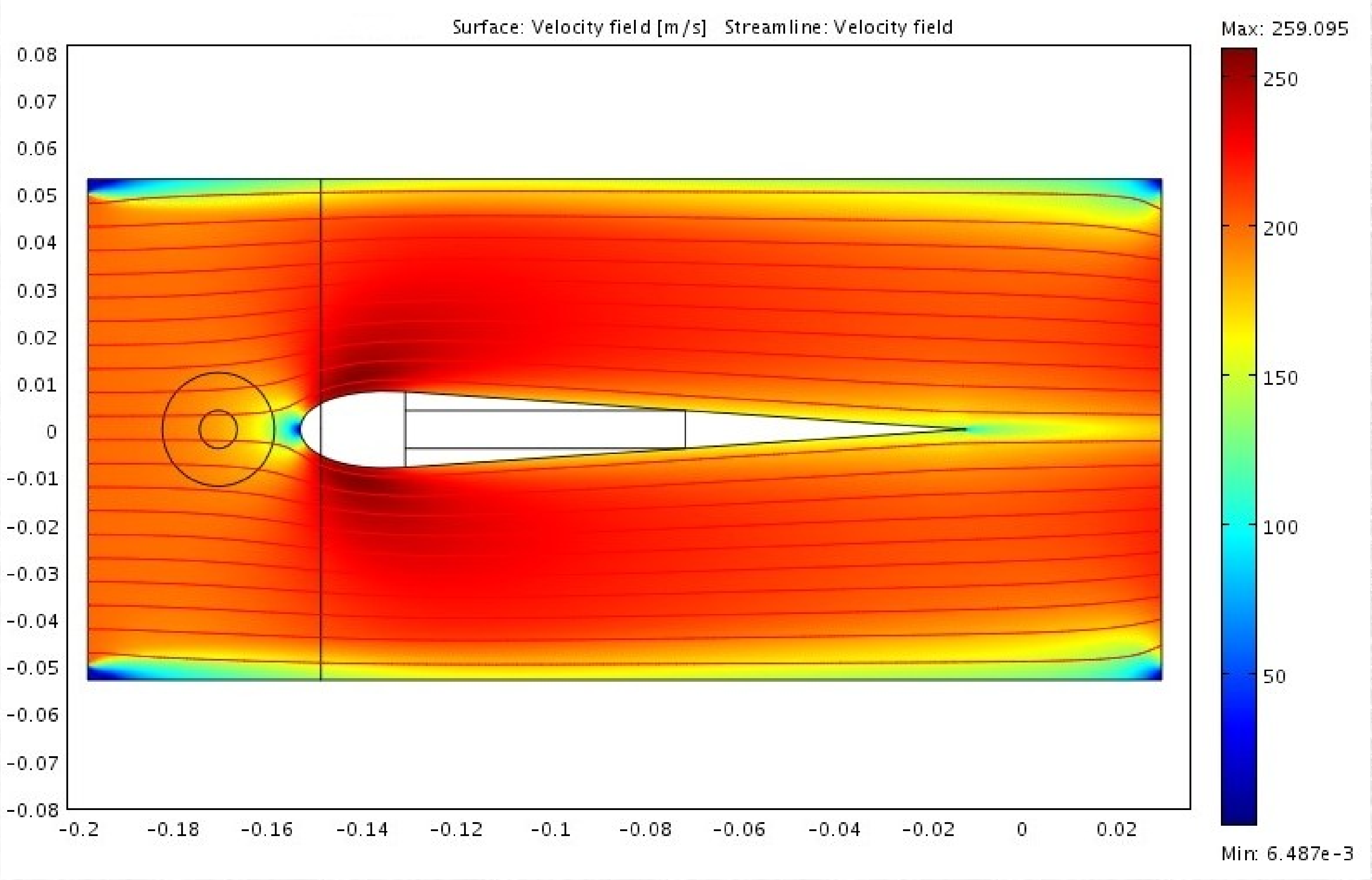
- Surface and the streamline flow of the gas inside of the duct.



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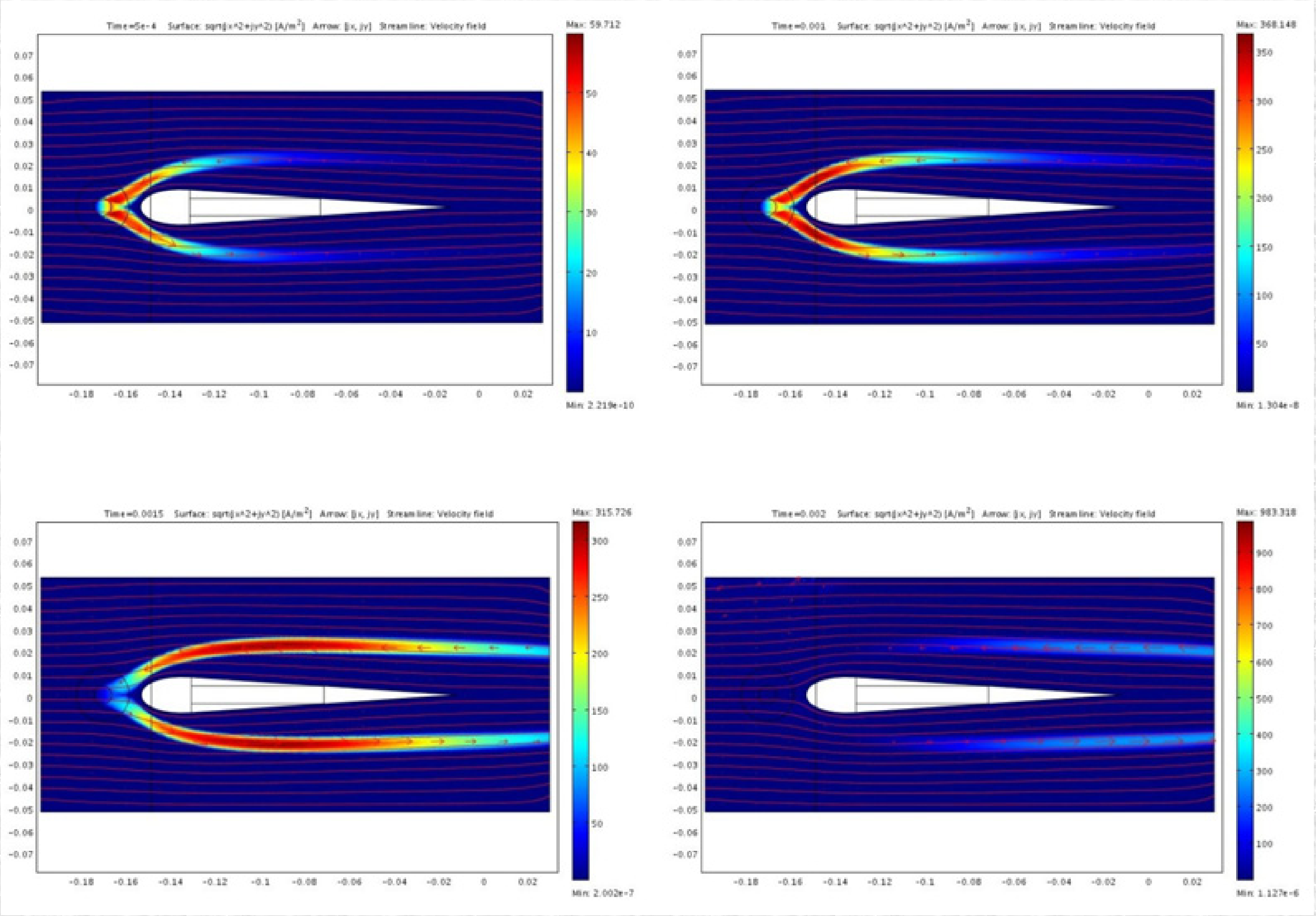
RESULTS

- Movement of the charge inside of the duct.



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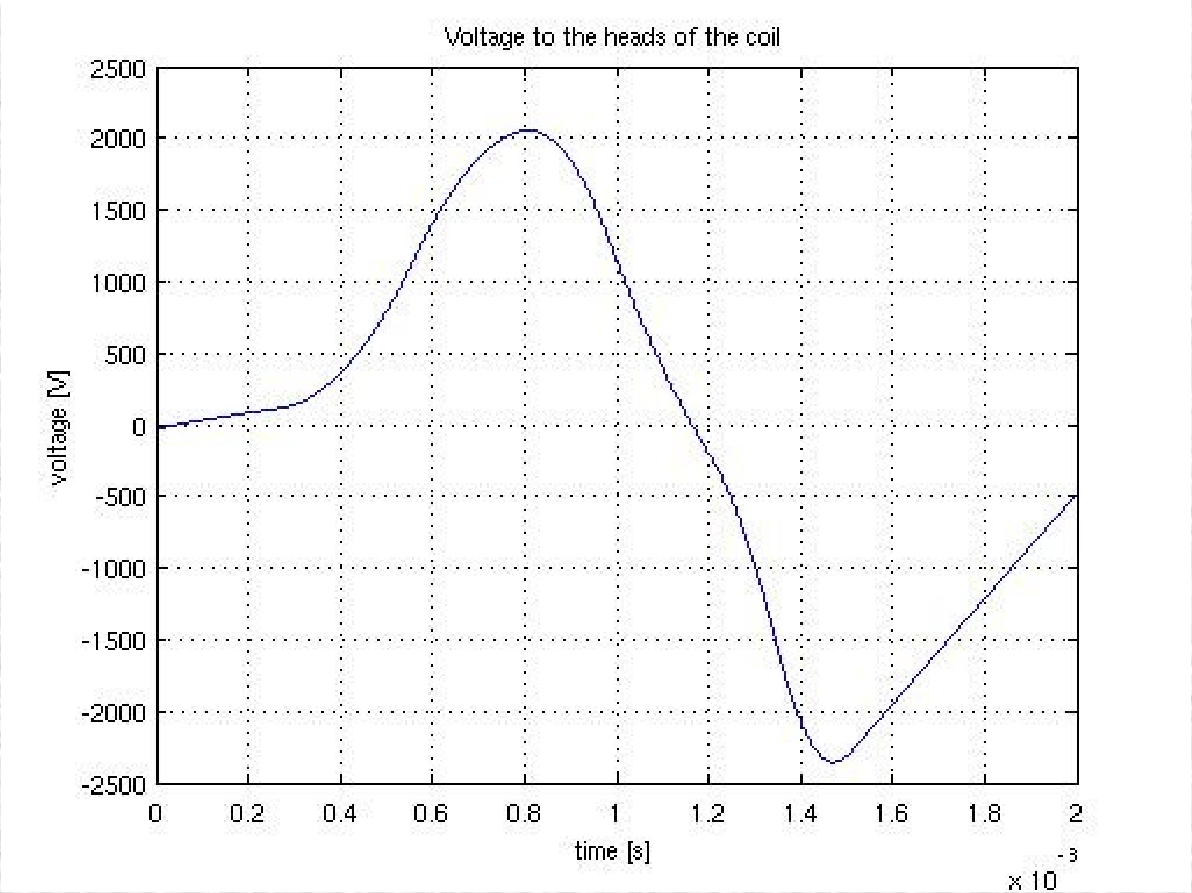
RESULTS

- Trend of a voltage in the secondary winding left open circuited;



- Maximum Power (adapted load) 18kW.

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CONCLUSION

- The COMSOL 3.5a has been revealed as a suitable tool for a preliminary study to evaluate the physical feasibility of a inductive MHD generator;
- The proposed device does not need an external magnetic field to work but it performs the energy conversion by means of the inductive principle. This is possible thanks to a pulsed ionization of the fluid current, carried out with a electrode dipped;
- The possible future works can be represented by the coupling with the heat transfer model and solve the three - dimensional model.