# NUMERICAL MODELLING OF ELECTROMAGNETIC FIELD IN A TORNADO

**P. Fiala[1], T. Jirku[2], T. Kriz[3]**

[1] *Department of Theoretical and Experimental Electrical Engineering,*
*Brno University of Technology, Kolejni 2906/4, 612 00 Brno, Czech Republic*
*[1]fialap@feec.vutbr.cz , [2]kadlec@feec.vutbr.cz, [3]kriz@feec.vutbr.cz*

**Summary** - This study deals with the numerical model of both the physical and the chemical processes in the tornado. Within the paper, a basic theoretical model and a numerical solution are presented. We prepared numerical models based on the combined finite element method (FEM) and the finite volume method (FVM). The model joins the magnetic, electric and current fields, the flow field and a chemical nonlinear ion model. The results were obtained by means of the FEM/FVM as a main application in ANSYS software.

## 1. INTRODUCTION

The full electromagnetic-hydro-dynamic (EMHD) model of a tornado is a coupled problem in which there are coupled the electric, magnetic, fluid flow fields, electric circuit and chemical (dynamical ions) models. This model was built with the combined finite element methods (FEM) and the finite volume methods (FVM).

A more complete understanding of tornado-genesis must be developed before the feasibility of mitigation by heating fine structure, such as cold downdraft regions, can be determined. Also, the present severe storm diagnostic capability and numerical simulation codes are not yet suitable for real-time assessment of electromagnetic heating results. It is suggested that their be used in a tornado-genesis mitigation system:

- Real-time calculations. It would be desirable to predict the development faster than real-time to be able to provide better targeting.
- Continuously updated with fresh data from diagnostic systems. Validation using extensive field data.
- Nested grid calculations down to 58 meters or less in horizontal grid dimensions.
- Ability to calculate heating patterns with complex electromagnetic heating beam geometry.
- Inclusion of important microphysics considerations.

The diagnostics must also be capable of real-time operation, a one-second or less response time. It is generally known [1]-[7] that the tornado produces characteristic sferics of its own. In this regard, Jones [I] reported that the 10 kHz sferics associated with the tornado, but observed prior to the occurrence of the tornado, were much more intense than those associated with ordinary thunderstorms. Furthermore, after the tornado forms, a shift in the sferics frequency response is reported from low frequencies (app.10 kHz) to high frequencies. Jones [2] reported that tornados have characteristic waveforms, and that there is a significant correlation between the number of sferic flashes at 150 kHz and the occurrence of tornados. Jones [3] also concludes that the flashing rate is a good indication of the intensity of the storms, and has given a tentative storm classification system based upon the flashing rate. Huebner et al. [6] were able to show that a variation of the sferic frequency spectra of tornados with respect to storms does exist. However, they were unable to confirm all of the predictions made by Jones.

According the last work of Kikuchi [9], [10] is possible to build model EMHD for numerical simulation of transient effects in the tornado. The examples of different tornado are showed in figure Fig. 1.

## 2. MATHEMATICAL AND NUMERICAL MODEL

**Electromagnetic part** is derived from Maxwell equations

$$rot\,\mathbf{H} = \boldsymbol{J}_T\,, \tag{1}$$

$$div\,\boldsymbol{B} = \boldsymbol{0}\,,\ div\,\boldsymbol{D} = \rho \tag{2}$$

where $\boldsymbol{H}$ is the vector of magnetic field intensity, $\boldsymbol{B}$ is the magnetic flux density, $\boldsymbol{J}_T$ is the vector of total current density, $\boldsymbol{D}$ is the electric flux density , $\rho$ is the electric charg density.

$$rot\,\mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t} \tag{3}$$

$$div\,\mathbf{J}_T = -\frac{\partial \rho}{\partial t} \tag{4}$$

where $\boldsymbol{E}$ is the vector of electric field intensity. Vector functions of electric, magnetic field are expressed by means of a scalar electric $\phi_e$ and vector magnetic potentials $\boldsymbol{A}$. Final current density from (4) $\boldsymbol{J}_T$ is influenced by velocity $\boldsymbol{v}$ of the flowing ion solution and outer magnetic field.

$$\boldsymbol{J}_T = \gamma\left(\boldsymbol{E} + \boldsymbol{v}\times\boldsymbol{B}\right) - \frac{\partial\left(\varepsilon\boldsymbol{E}\right)}{\partial t} + \gamma\frac{m\,d\,\boldsymbol{v}}{q\,dt} \tag{5}$$

where $m$ is particle mass, $q$ is the electric charge, $\gamma$ is the conductivity of parts tornado body from the macroscopic view.

The model from relations (1) to (5) was solved by finite element methods (FEM) [11] with ANSYS system. The geometrical model was built with two modifications. First of them is simply geometrical model, showed in Fig. 2a.

The parameters of the first tornado can be written as a several parameters. We have used the bold signed parameters. Inner velocity: 100 – 190 km/h, speed of rotation: 72 – 720 km/h , outer diameter: 10 – 100 m inner diameter: 15 – 30.48 m, speed of movement: 0 – 120 km/h , height: 50 – 500 m.

*Fig. 1 Different type of tornado body*

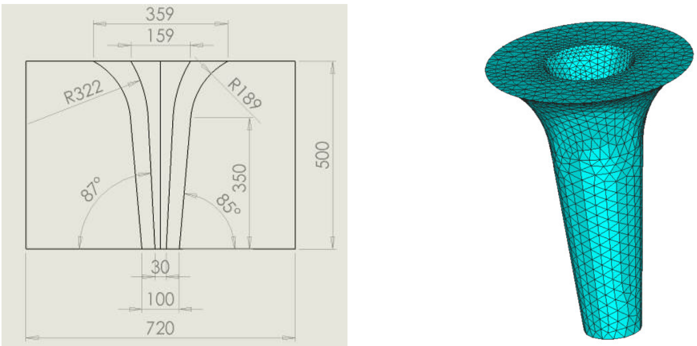


*Fig. 2a Basic geometrical dimensions of the first tornado model (left) in meters and its FEM model (right)*

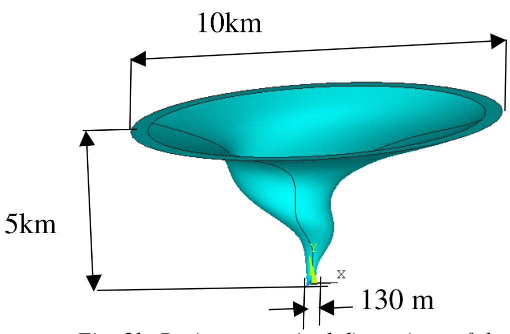


*Fig. 2b Basic geometrical dimensions of the second tornado model*

## 3. NUMERICAL SOLUTION FEM/FVM

The numerical model was prepared by means of ANSYS tools [11] and main FEM/FVM solution was solved with APDL program over ANSYS system. In the Fig. 3 we can see boundary condition for basic solution of electric charge moving. This model definition is not so perfect expression of tornado state. There are only 50 points where were different electric charge placed and started the transient EHD effect. A first results from the model are showed in the figure Fig. 4. Therefore was built full EMHD tornado model according of (1) to (5) condition. The model is under the test just now. Both model was solved for time interval from $t \in \langle 1.10^{-12}, 1.10^{-2} \rangle$ sec. Then we can observe the ions moving trend and changing of electromagnetic field in the tornado body during the time interval.

## 4. CONCLUSION

This work deals with EHD and EMHD numerical tornado model. There is basic mathematical and numerical description in the article and first results of electromagnetic field distribution and ions moving in the critical part of tornado body. Such analysis could be used for understanding of time state and time dependent of tornado effects in the breadth time interval observation. On the two different tornado geometrical model was tested the EHD and EMHD numerical model.

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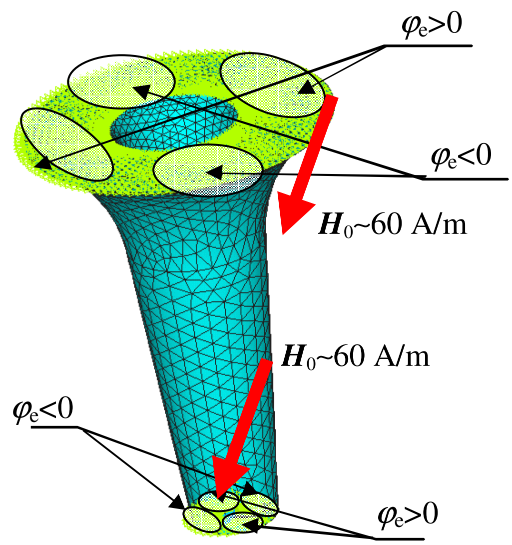


*Fig. 3 Boundary and initial condition of EHD and EMHD tornado model, scalar electric potential $\varphi_e$, magnetic field intensity $\boldsymbol{H}_0$*

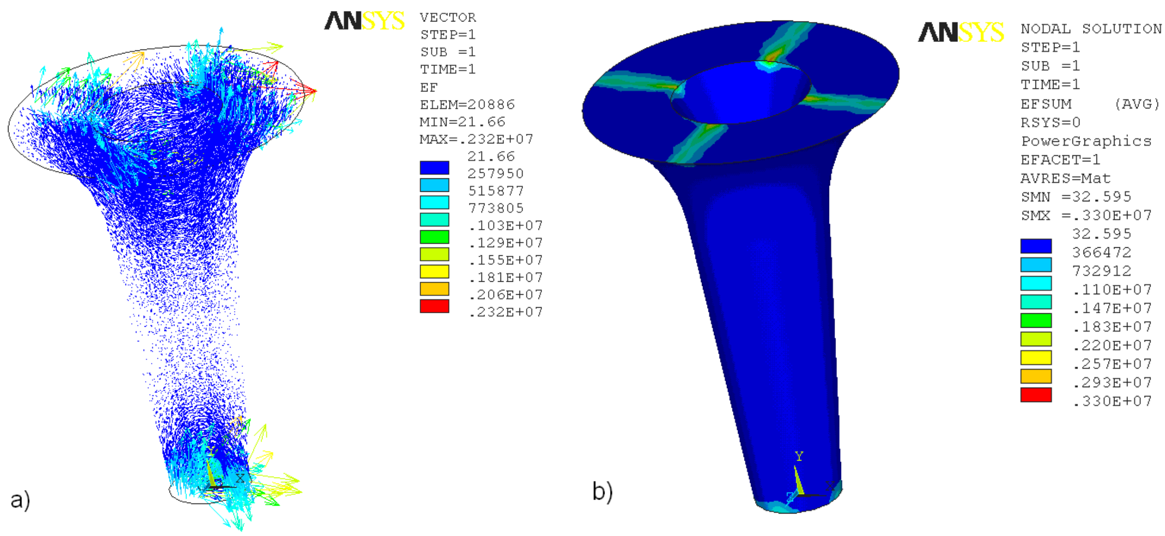


*Fig. 4 Simply solution of EHD tornado model, displacement of a vector electric field intensity a) and its module b)*

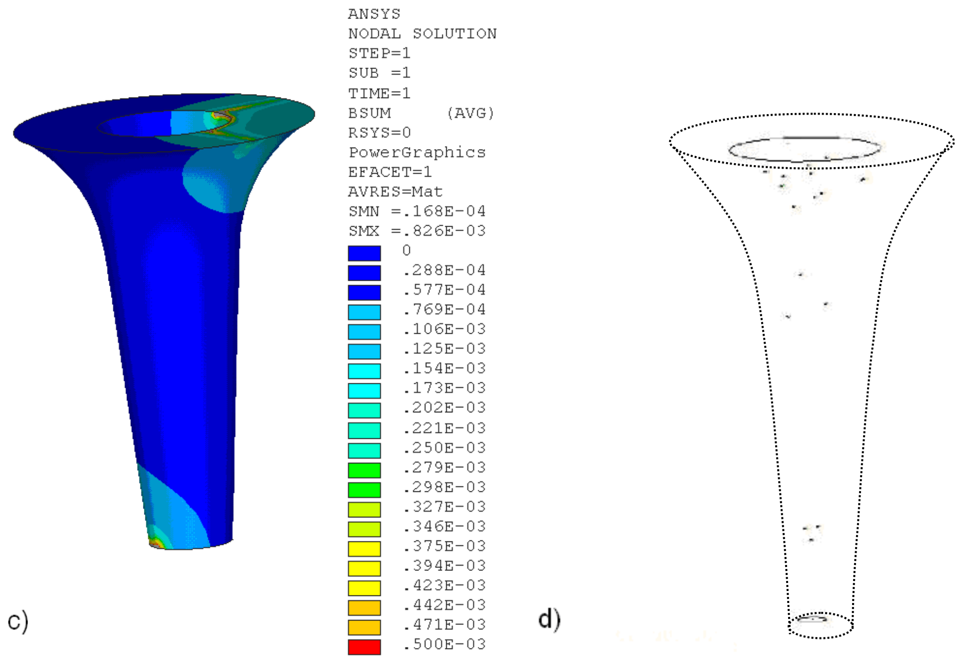


*Fig. 4 Simply solution of EHD tornado model, displacement of a magnetic field intensity module c), positive charge moving, t=0.5ps d),*

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