Simulation System of the CRT Deflection Yoke

Min-soo, Lee, Duck-kee, Woo, Jong-mok, Cheun

CRT New Technology Team, Orion Electric Co., Ltd, 257 Gogndan-Dong, Kumi, Korea

Abstract

Yoke simulator has been made for understanding beam movements in the deflection fields of the CRT. Consisting of the modeler, solver and post-processor, the simulator makes yoke model (conventional and rectangular yoke) and calculates charge sources and magnetic filed by BEM (boundary element method). This system supports a number of charge elements (line and surface charges) and beam movements can be predicted by the system.

1. Introduction

For the past years we succeeded in understanding design parameters of the picture tube and thanks to these efforts, picture tubes are considered as technically matured products. However, deflection yoke is comparatively in vague and still lots of tube companies put their efforts into this field. That's, manufacturing deviations exist in the coil winding process experimentally and representing yoke's current sources are not accurate analytically.

To keep track of magnetic field and trajectories in a deflection yoke, yoke field should be modeled directly from its current sources in the presence of the core and for this purpose, we developed a yoke simulation system which can make finite models for the charge sources (horizontal and vertical coils and ferrite core) and calculate magnetic fields from the sources with boundary element method (BEM). For the post-processing, we can plot beam trajectories, misconvergence patterns as well as checking its models.

2. Simulation system

The simulation system comprises of modeling, solving and post-processing part and this handles rectangular yoke as well as conventional yoke type.

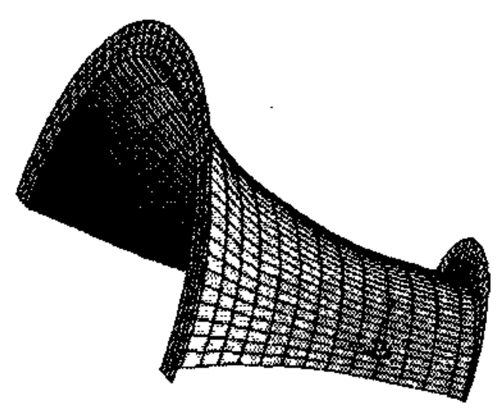
1) Modeling

In the modeling part, charge sources (ferrite core and coils) are automatically meshed using several input parameters. In coils, accumulative coil turns means the coil winding potential τ with Ampere's circuital law and the lines τ is constant are considered to be lines of currents (or coil wires). That's, coil sources can be depicted by surface and line charges and their information is derived by relaxing and interpolating input data. The simulator supports the following elements in Fig.1 Also this system treats some pieces of permanent magnets to adjust misconvergence or geometric distortion.

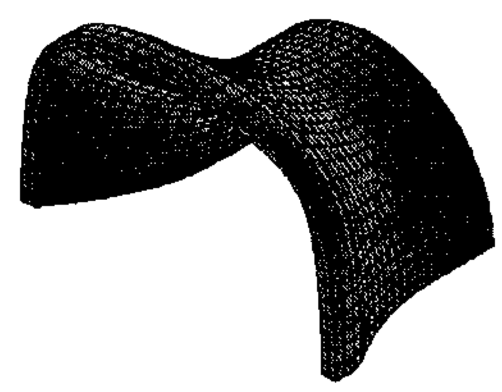
Ferrite core	Coils
-Quadrilateral surface element -Elliptical surface element	-Quadrilateral surface element -Elliptical surface element -Linear line element -Quadratic line element

Fig.1 supporting element of the simulation system

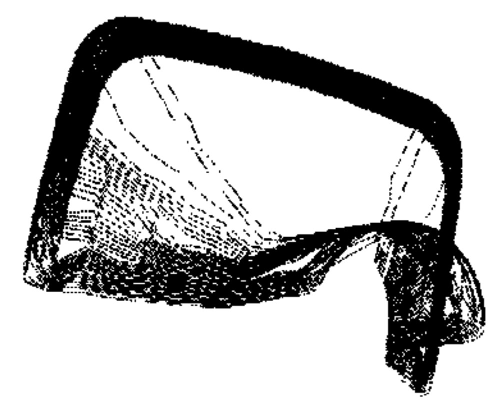
Meshed components are also shown in Fig. 2 and these are mainly 19" rectangular yoke model.



(a) Circular H-coil



(b) RAC core



(c) RAC H-coil

Fig.2 meshed DY model

2) Solving

By Maxwell's equation, magnetic flux density $\vec{B}$ can be described by a magnetic intensity $\vec{H}$ and in this, $\vec{H}$ is derivable from a potential ψ in the following form

$$\vec{B} = \mu\vec{H}, \quad \vec{H} = -\nabla\psi$$

In this, magnetic potentials obey Laplace's equation ($\nabla^2\psi = 0$).

In yoke simulation, the magnetic intensity $\vec{H}$ is divided by two kinds of fields (induced magnetized field $\vec{H}_m$ and current source field $\vec{H}_s$) and this information can be calculated by boundary element method (BEM).

$$\vec{H} = \vec{H}_m + \vec{H}_s$$

In the boundary element method, a potential ψ that obeys Laplace's equation can be represented by an integral of surface charge and (or) dipole layer charge distribution on a two-dimensional boundary surface and for a yoke region (not necessary for the core inside), it's enough to use a charge density σ on core surface and dipole layer τ on the coil surface. As a result, the boundary integral has the following formula.

$$\psi(P_1) = \int_{2)} \sigma(P_2) G(P_1, P_2) \hat{n}_2 dS_2 + \int_{2)} \tau(P_2) \frac{\partial G(P_1, P_2)}{\partial \hat{n}_2} dS_2$$

Where P_1, P_2 is observation and source point and G is fundamental function (Green function). In this, open integral method is used to avoid singularity of Green function.

>From the fact (scalar potential on the core boundary is zero), we can figure out magnetized charge by coil sources on the core as the following expression.

$$\phi(Q) = 0 = \phi_{core} + \phi_{coil} = \int_{core} \sigma\, G ds + \phi_{coil}(Q)$$

That's, potentials on the core by charge sources are obtained by boundary integral and magnetized core charges are calculated by matrix inversion.

In case of line charge loop, scalar potential is not obtained from the charge source like surface source charges and rather than this, scalar potentials are calculated with the Ampere law from the known symmetric boundary condition. (Potentials on the symmetric axis are zero)

$$\phi(P) = \int -\tau_Q \nabla_Q G \cdot d\vec{S}_Q \text{ , surface charge}$$

$$\oint_C \vec{H} \cdot d\vec{l} = \int_S \left(\nabla \times \vec{H}\right) \cdot d\vec{S} = \phi_2 - \phi_1 = I \text{ , line charge}$$

By the Biot-Savart law, we also calculate magnetic intensity $\vec{H}$ by integrating core surface charges (and/or line coil charges).

$$\vec{H} = \int (\hat{n} \times \nabla\tau) \times \nabla G dS \text{, for the surface charge}$$

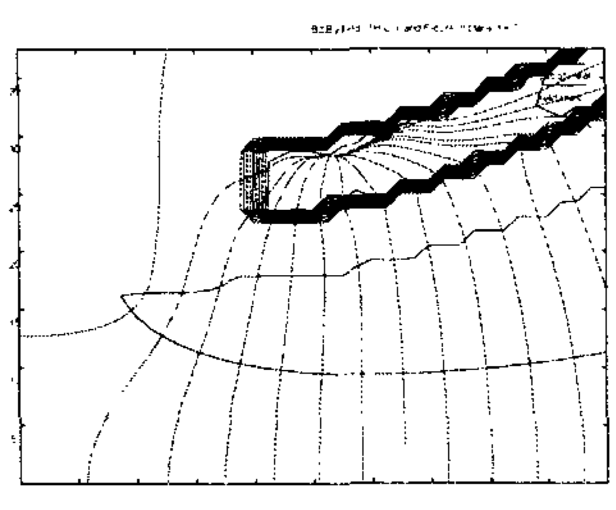
$$\vec{H} = \oint_C d\vec{l} \times \nabla G \text{, for the line charge}$$

As a result, we know magnetic flux density $\vec{B}$ in the tube space and beam trajectories are calculated with Lorentz momentum equation and numerical method for the ordinary differential equation.

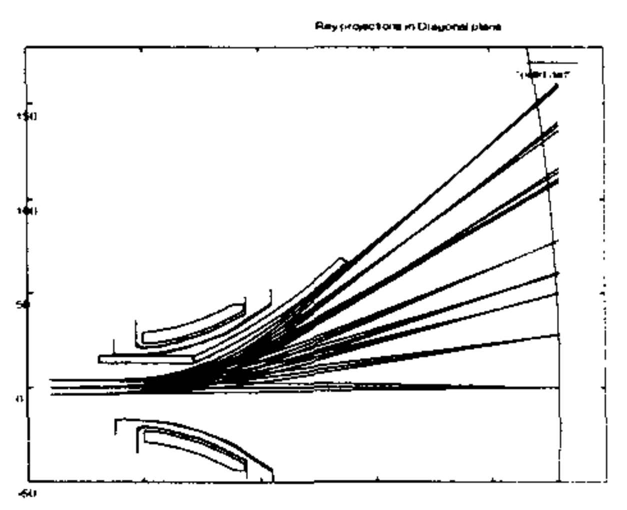
$$\vec{F} = \frac{d}{dt}\left(\frac{mv^2}{\sqrt{1 - v^2/c^2}}\right) = -e\vec{v} \times \vec{B}$$

3) Postprocessing

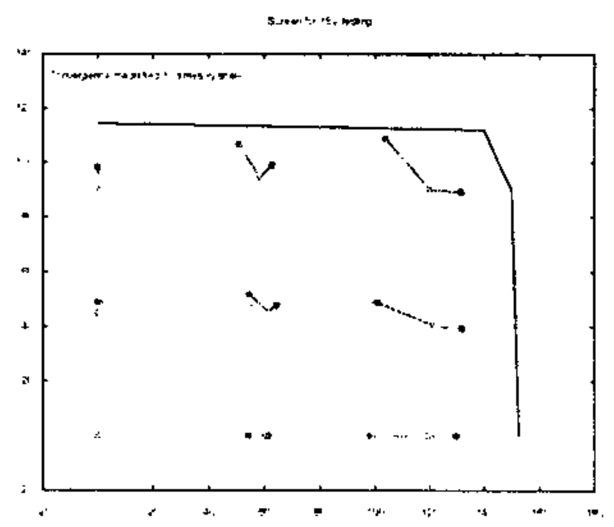
Not only checking yoke model, but calculated results are depicted by the postprossing session. Results include magnetic fields of each components, beam trajectories and convergence patterns. Fig.3 has some of the results.



(a) B-field by core charge



(b) beam trajectories



(c) Convergence patterns

Fig.3 postprocessed results

3. Conclusion

Yoke simulator has been developed and it's capable of rectangular yoke as well as circular yoke. Before BEM had some problems in terms of calculation time, but due to computer hardware improvements and optimized open integration, the program can give results in relatively short time. Although the simulated results follow the experimental values, the further study of each coil element types and their optimizations are still needed for the future work.

4. References

[1] Y.Yamada. Numerical analysis of deflection yoke. IDW 97. p.429~432

[2] Yan Tu, A new method to design a rectangle deflection coil, IDW 00, p.577~580

[3] T.G.Beelen, A CAD tool for designing and simulating deflection units, IDW 97 p.425~428

[4] Takahisa Mizuda, Modeling system of deflection yoke for CRTs, IDW 01, p.715~717

[5] P.Tuyls, 3D simulation tool for RAC magnetic deflection units, SID 01, p.1017~1019