Simulation Tool of Rectangular Deflection Yoke for CRT

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Abstract

We have developed the three-dimensional simulation tool for the design of deflection yoke. This tool consists of a modeler, a solver and a post-processor. The modeler easily makes models of Deflection Yoke (DY) and ferrite core (Circle, RAC and RTC) by the parameters and supports several element types (line, surface and quadrilateral). The solver calculates charge density and magnetic field of DY by boundary element method (BEM). We can simply evaluate misconvergence, distortion and inductance of DY in the post-processor, so we apply this simulation tool to 32" rectangular deflection yoke. We can conveniently implement the efficient development of DY in the future.

1. Introduction

CRTs have been popular display devices because of their low cost and excellent display performance. Recently, high resolution and low electric power consumption are required in CRT. In order to satisfy these requirements, DY has to be designed in consideration of precise control of beam convergence, distortion and inductance together with low deflection power. However, many tube companies still put a lot of time and effort into this field, manufacturing deviations still exist in the coil winding process experimentally and the yoke's current sources are not accurate analytically. Therefore, it is necessary to analyze with the more accurate calculation and to reduce development time of D.Y. For this requirement, we developed this simulation tool with an improved algorithm.

And we could use enough results from various element types and user interface (UI). To keep track of magnetic field and trajectories in DY, yoke field should be modeled directly from its current sources in the presence of the core. For this purpose, we have developed a yoke simulation system which can make finite models for the charge sources (ferrite core, horizontal and vertical coils). And it is also able to 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, we can make ferrite cores (Circle, RAC, and RTC) and coils as well as automatically meshing by input parameters. Then, user can immediately check the geometric information of cores and coils on simulation system which we have enhanced prior UI. So if a given input data is wrong, we can correct directly.

In coils, accumulative coil turns means the coil winding potential τ with Ampere's law and the lines τ is considered to be lines of current (or coil wires). That's, coil sources can be depicted by surface and line charges. Their information is derived by relaxing and interpolating input data. This simulation tool supports the following element types in Fig.1. Also this system treats some pieces of permanent magnets to adjust misconvergence or geometric distortion and includes the electric analysis tool to calculate the electric field of electrodes in some kind of slim CRT.

Ferrite core and coil modeling are made by critical value line (CVL) that is at least the number of mesh element to reduce calculation time and amount of memory. Fig.2 shows ferrite core with quadrilateral surface elements, horizontal and vertical coil with lineal line element of 32" wide-flat rectangular DY by the automatic mesh generator.

Ferrite Core	Coils
- Quadrilateral surface element - Elliptical surface element	- Quadrilateral surface element - Elliptical surface element - Lineal line element - Quadratic line element

Fig. 1 Supporting Element of the simulation system

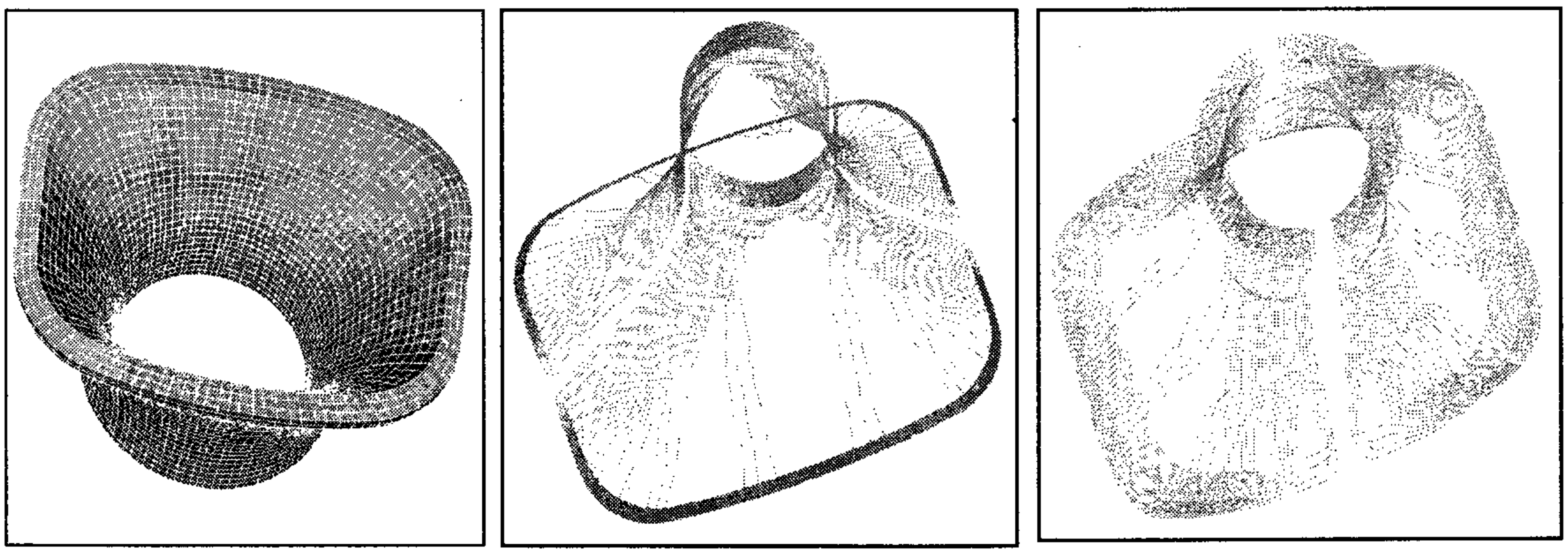


Fig. 2 Ferrite core(Left), H-coil(Center) and V-coil(Right) made by the simulation tool

2) Solving

The block diagram of the solver to calculate magnetic fields of models is shown in Fig.3. The results are used for the beam trajectory calculation.

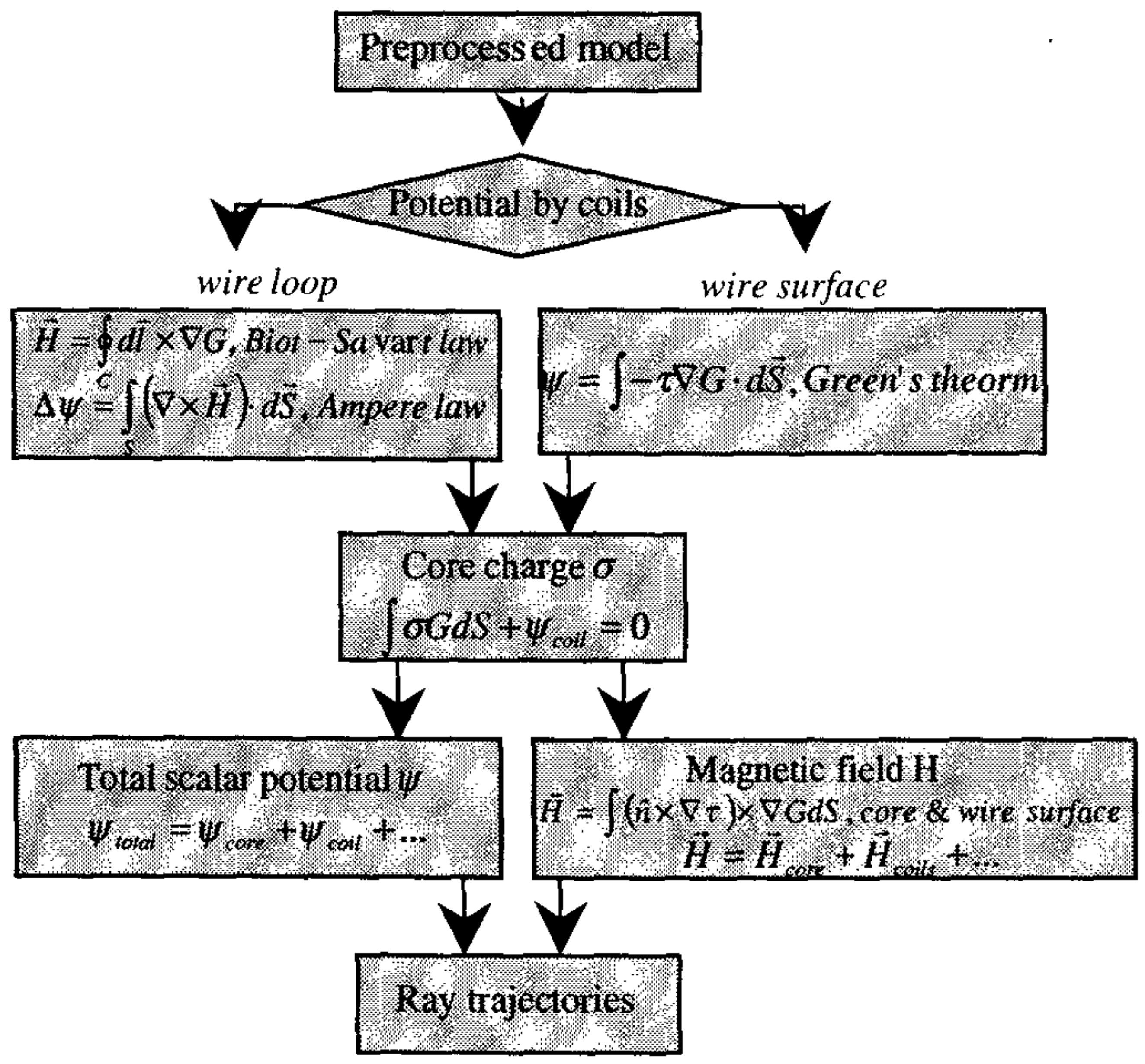


Fig.3. The block diagram of the solver

Magnetic flux density $\vec{B}$ can be described by a magnetic intensity $\vec{H}$.

$\vec{H}$ is derivable from a scalar potential ψ.

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

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

The magnetic intensity $\vec{H}$ is divided by two kinds of fields (induced magnetization field $\vec{H}_m$ and current field $\vec{H}_s$) calculated by boundary element method (BEM).

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

BEM is a numerical technique for solving boundary integral equations.

$$\Phi(P) = \int_S \sigma(P) G(P,Q) dS_Q - \int_S \tau(P) \frac{\partial G(P,Q)}{\partial n_2} dS_Q$$

Where, P and Q are observation and source point, and $G = \dfrac{1}{4\pi R(P,Q)}$ is Green function.

In wire surface, Surfaces C may exist on which the normal derivative of ψ is discontinuous.

$$\frac{\partial \psi}{\partial n^-} - \frac{\partial \psi}{\partial n^+} = \sigma$$

Surfaces W may exist on which ψ is discontinuous across surface.

$$\psi^+ - \psi^+ = \tau$$

Then, ψ is specified by the sources ∂ and τ as following equations.

$$4\pi\psi = \int_{surface\ C} \frac{\partial}{|r_P - r_C|} dS_C + \int_{surface\ W} \tau \frac{\partial}{\partial n}\left[\frac{1}{|r_P - r_W|}\right] dS_W$$

$$\psi(P) = \int -\tau_Q \nabla_Q G \cdot d\vec{S}_Q$$

The tangential derivative of ψ is continuous across all surface elements except those carrying a surface current K (tangential BC).

$$\hat{t} \cdot (\vec{H}_+ - \vec{H}_-) = 0, \qquad \hat{n} \times \nabla \psi_- - \hat{n} \times \nabla \psi_+ = K$$

Consequently, the surfaces are not necessarily closed one and winding surface can be generalized. Coil's scalar function τ is given by

$$\hat{n} \times \nabla \tau = -K, \qquad \nabla \psi_- - \nabla \psi_+ = \nabla \tau$$

Unlike winding surface, a scalar potential is not obtained from wire loop (line charge). Firstly, magnetic field is known from the Biot-Savart law and a scalar potential is calculated from Ampere law with the known symmetric boundary condition.

$$\vec{H} = \oint_C d\vec{l} \times \nabla G$$

$$\int_S (\nabla \times \vec{H}) \cdot d\vec{S} = \oint_S \vec{H} \cdot d\vec{l} = \psi(P) - \psi_{BC}$$

A scalar potential ψ on the core boundary is zero by Gauss law(no mono pole in magnetism). Hence, core charge can be calculated with matrix manipulation.

$$\psi(Q) = 0 = \int_{core\ surface} \sigma G \cdot d\vec{S} + \psi_{coil}(Q)$$

Total potential of an observation point P in free space is from the sum of potential ψ_{coil} and ψ_{core}. Total magnetic field also derives from the same manner.

Once the magnetic fields in the tube space are calculated, the beam trajectory is easily determined by Lorentz momentum equation and the Runge-Kutta method.

3) Post-processing

The magnetic field distribution, inductance, the trajectory of electron beam, convergence, and distortion by the calculated results are depicted in the post-processing session.

It takes so long time to calculate the magnetic field and the beam trajectories in deflection yoke. In order to reduce computational time and obtain reliable results, the element type and the mesh numbers have to be decided for verifying our simulation system. We simulated several times by varying the mesh number of ferrite core, horizontal coil and vertical coil respectively. Then we could find the number satisfied with the minimum accuracy that the critical value line (CVL) crosses. The results are shown in Fig.4. Error rate of the CVL is 5%.

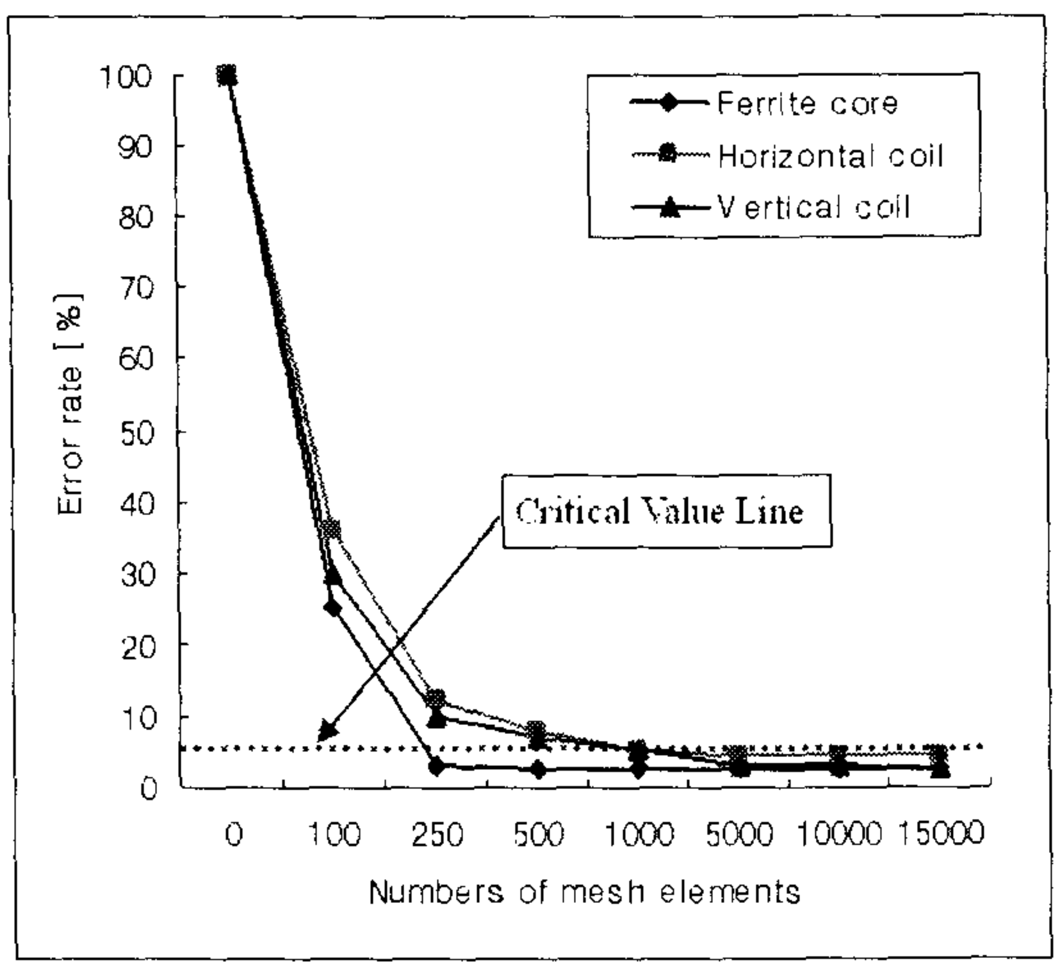
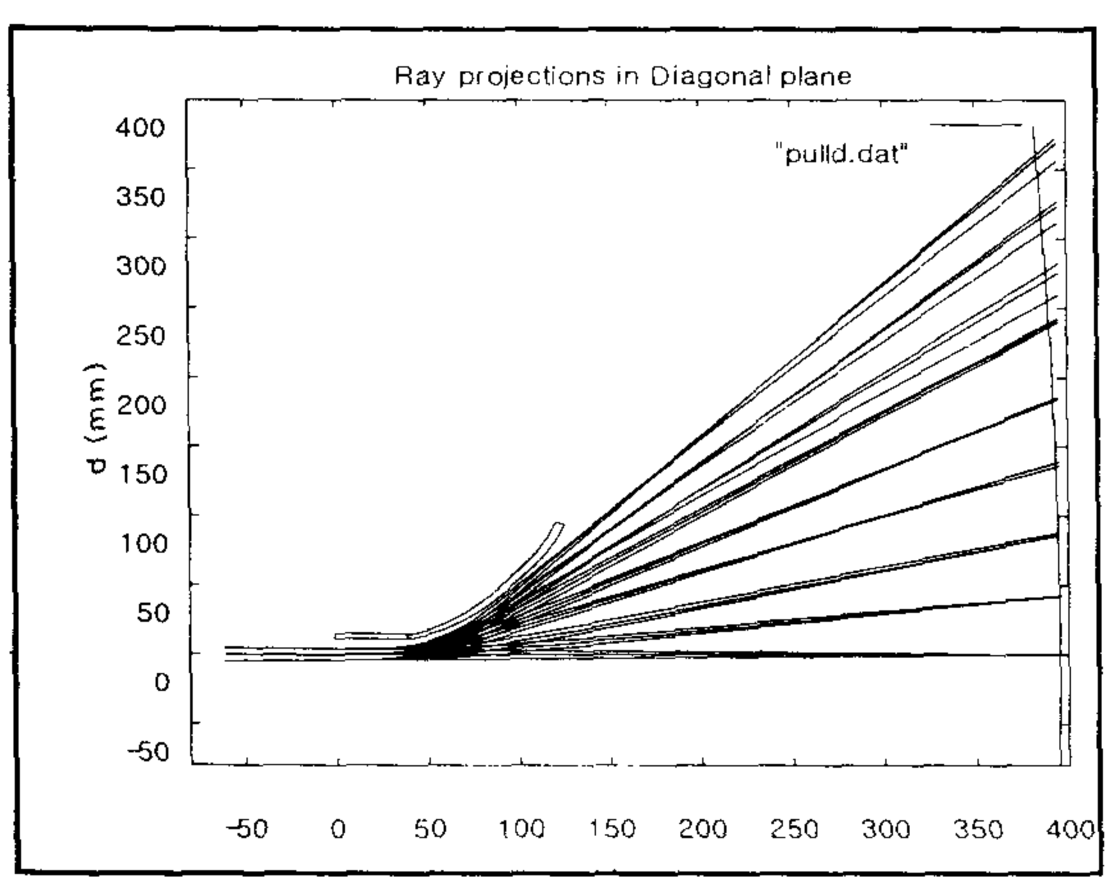


Fig. 4. Error rate of ferrite core, horizontal and vertical coil

From the minimum number of mesh element, the evaluated results of beam trajectory and misconvergence are shown in Fig.5.



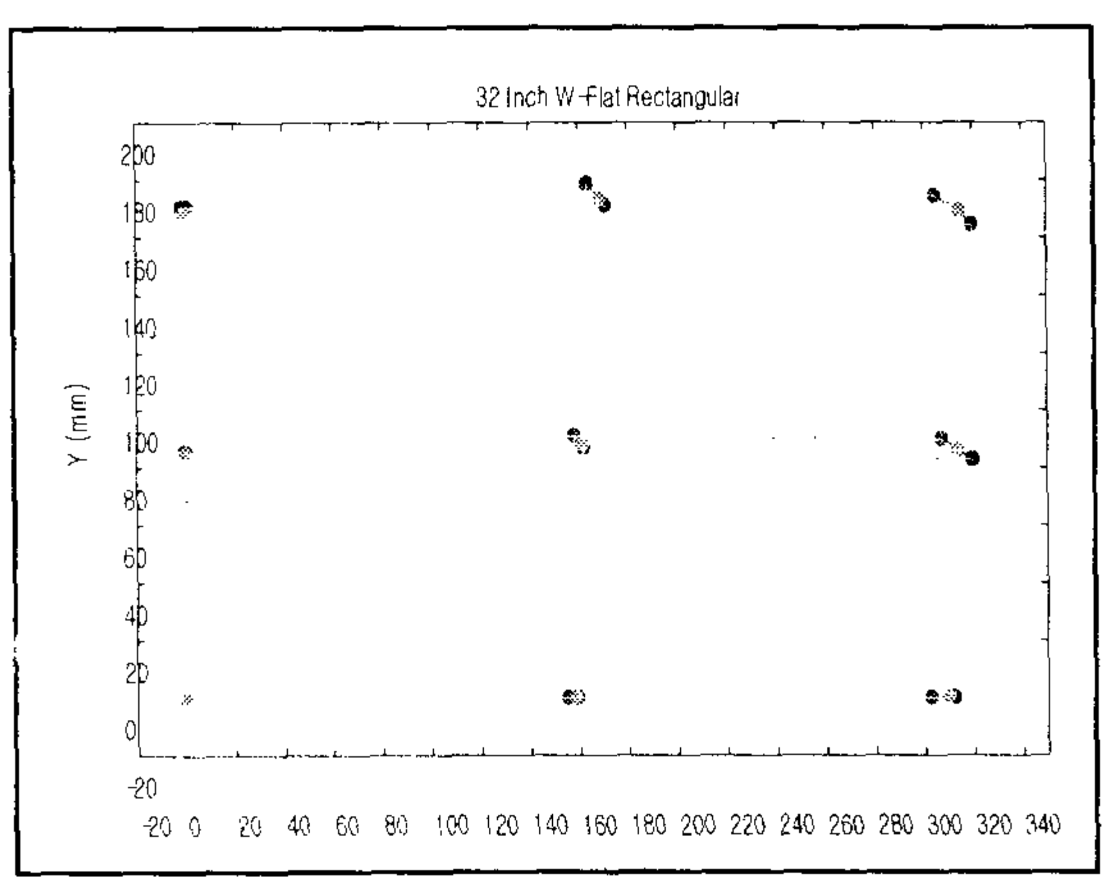


Fig.5. Beam trajectory and misconvergence of 32" wide-flat rectangular DY

This process can be used in the first step of DY development when the quick results are necessary. In the final step, more accuracy results can be obtained when the CVL is reduced. In some cases, the use of the CVL is very useful to reduce calculation time and obtain accurate results in our system.

3. Conclusion

This simulation system with the improved algorithm and user interface has been developed to evaluate inductance, distortion and misconvergence by the method base on BEM. A few elements are supported. After some evaluation by changing the number of mesh element, we could find the effective method for calculation time and accuracy. This tool was applied to 32" Wide-Flat Rectangular Deflection yoke and a good performance was implemented in a short time.

References

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