Electron Beam Simulation Technology for CRTs

Shoji Shirai, Kentarou Oku
Hitachi, Ltd., Displays
3300, Hayano, Mobara-shi, Chiba-ken, 297-8622 Japan

Abstract

The electron beam simulation technology is indispensable for the recent electron gun design. The technology is becoming more and more important for deflection yoke (DY) design and investigation of the interference effects between gun and DY. Further, it may become vital even for shadow mask, glass funnel, exposure lens and magnetic shield.

1. Introduction

In late '70s to early '80s most of the major CRT manufacturers at that time developed their in-house three-dimensional simulators to design electron guns with non-rotational structure(1),(2),(3),(4). The simulator had been refined through '80s to '90s and almost completed at the end of '90s.

On the other hand, late started manufacturers could not invest for the development and just purchased the commercial simulator that had become available in late '80s.

To our understanding, before those simulators for the non-rotational gun design, the simulation technology was not necessarily to be an indispensable tool and design could be managed by trial-and-error procedure. However, there are too many parameters, which could be fixed only by simulation for the recent complex gun design.

Under this situation, beam simulation technology for the CRT design has extended the area to be applied. This paper describes recent advancement of the technology.

2. Simulation for the Electron Gun Design

2.1 The gun design includes following issues that the beam simulation can be applied. Main lens design: shape and position of the Elliptical apertures are to be determined in case of EA lens, for example. Astigmatism, coma, STC (static convergence) and Vf (focus voltage) should be optimized for center and side beams.

2.2 Quadrupole lens design: Astigmatism correction efficiency should be balanced with that for the Field Curvature correction. Also, convergence error caused by application of the dynamic focus voltage at the main lens should be canceled at the quadrupole lens.

2.3 Beam forming region design: thickness, gap, aperture shape and size of the G1, G2, G3 electrodes should be determined to minimize the cross-over size and to control the beam divergent angle to the main lens. Also, the cathode loading is calculated to estimate the lifetime.

Fig.1 shows results of another type of analysis than that for the beam focus performance. The figure shows the electron beam build-up characteristics when the heater is turned on. Warm-up procedure of the cathode and other electrodes causes the complex

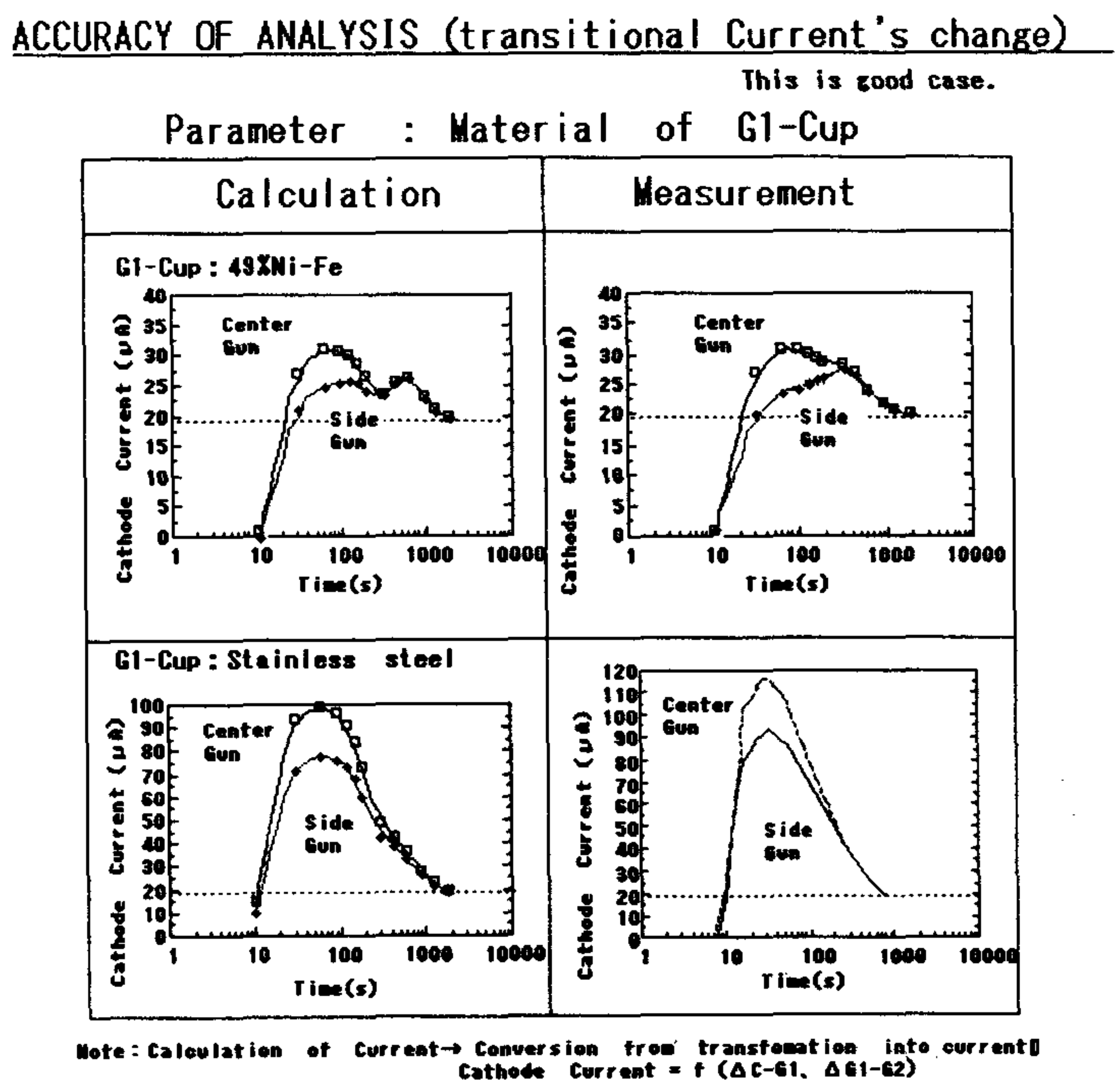

Fig.1 Analysis of build-up of beam current

effects on the beam current as shown in the figure. This analysis needs to take into account the dependency of the work function of the cathode on the cathode temperature(5),(6).

For the electron gun design, the deflection field analysis is not necessarily to be indispensable, because the deflected beam performance can be estimated to some extent. However, of course, it is desirable to analyze the deflection field to obtain the deflected beam spot, not only the expectation.

3. Simulation for the Deflection Yoke design

Along with the development of the three-dimensional electron gun simulator, the three-dimensional magnetic field analysis programs have been developed(7),(8),(9),(10). However, to apply these programs to the DY design, it is necessary to input the coil windings precisely. When the windings are guided only by pin, it is not so difficult to set the boundary conditions for the calculation.

On the contrary, when the pressed coil is used, exact winding distribution is almost impossible to obtain. So, still the DY is designed mainly by the trial-and-error, concerned with the pressed type DY. However, recently, even for the pressed type DY, pre-processor for the coil winding position input has been developed and the DY design by the simulation is now turning into reality.

However, still it is not easy to set the boundary condition of the DY exactly and to obtain the accurate deflection field distribution. For the detailed analysis of the deflected beam, therefore, measured data can be used. In general, the measurement can not be accurate enough for the electron beam simulation. To have the usable data, special data correction method has been developed. One more problem is a period of time for the measurement. It is estimated that to achieve precise beam trajectory, 200,000 point data is necessary and it will take almost one month to complete the measurement.

To overcome this measurement time problem, multi pole expansion method has been introduced. With this method, data on the boundary of the region, in which the field distribution is required, is only necessary. Within the region, the field distribution can be obtained by the calculation quickly. This method reduces the number of measuring points to about 1/100 and the whole measuring time is now only few hours(11),(12).

4. Other Applications to the Tube Design

When the deflection field is obtained either by analysis or measurement accurately, the beam

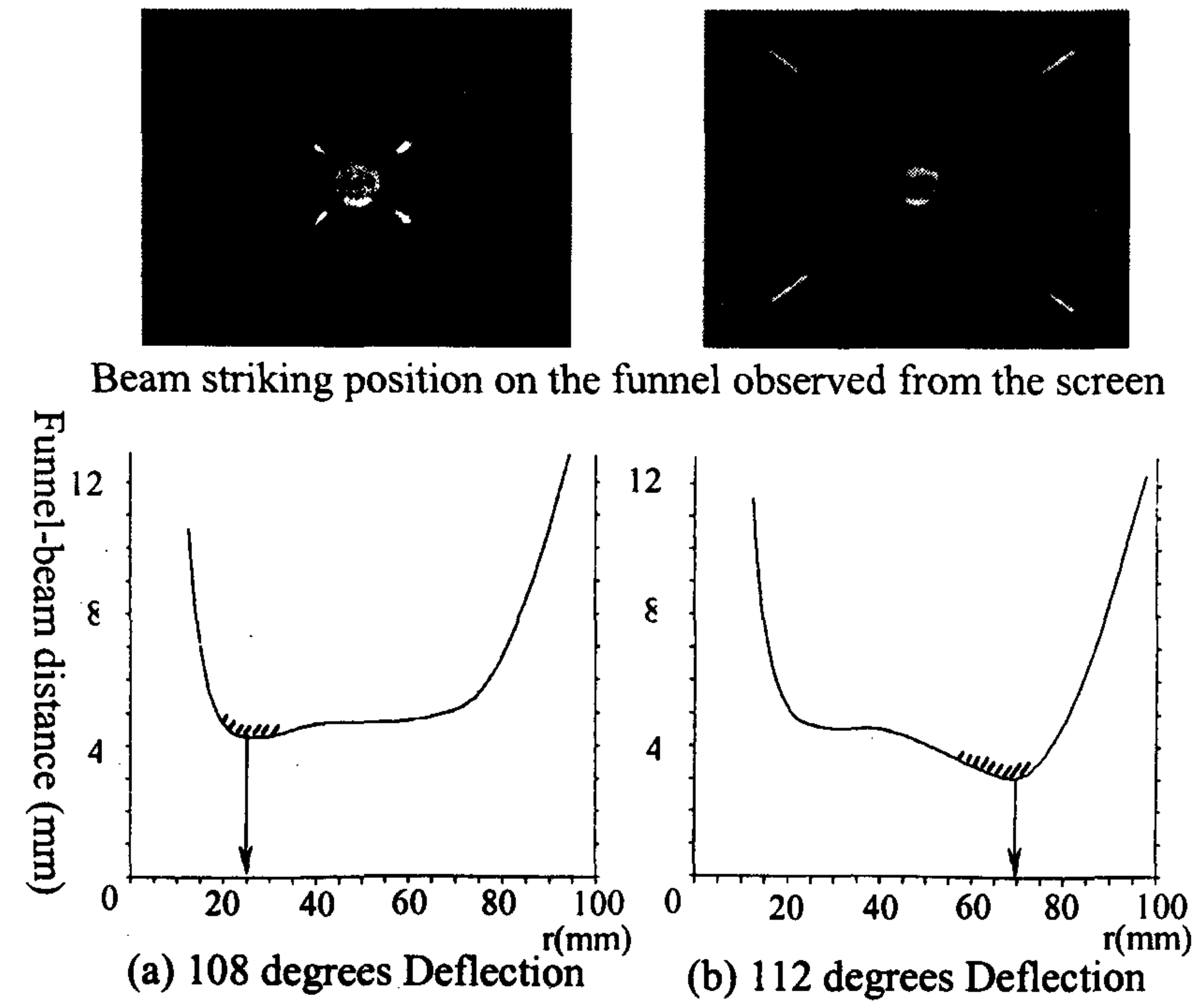

Fig. 2 Beam striking position on the funnel glass : comparison between measurements and analyses

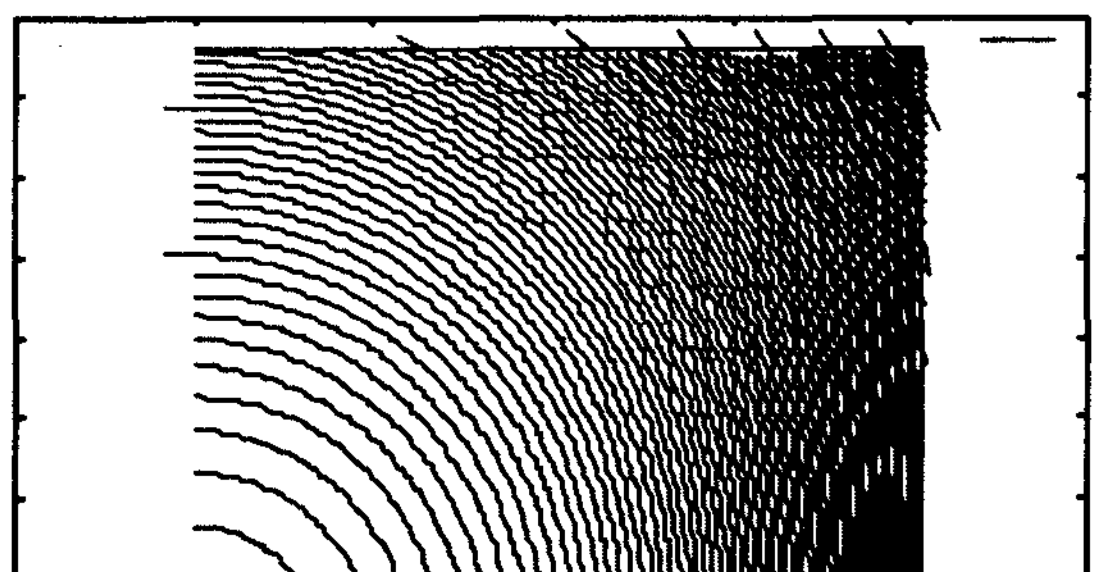

Fig.3 Example of Optimized shadow mask contour

(Only one quadrant is shown in the Figure.)

trajectory can be calculated and used in many ways for the tube design as follows.

4.1 Glass Funnel Design

To minimize the deflection power, it is desirable to reduce the diameter of the funnel. However, if it is too small, the beam strikes the funnel. With the beam simulation technology, the best compromise can be realized. Fig. 1 shows the comparison between the measurement and analysis of the beam striking position for two different CRTs with 108 and 112 degrees deflection angle.

For the measurement, phosphor is coated on the inner surface of the funnel, therefore, the beam striking portion can be seen as white stripes in the Fig. 1. The analyzed data shows at which radius the beam strikes the funnel. As can be seen from the figure, the radius is much smaller for the 108 degrees deflection CRT and this agrees well with the measurement. So, if the deflection field is obtained, the funnel shape that fits best for the field can be calculated.

4.2 Mask Design

Once the beam trajectory is obtained accurately, exact beam landing position on the screen can be calculated. This means if you fix the mask shape, hole positions and phosphor positions on the screen, you can have the landing error value.

Therefore, the margin for the landing error can be maximized using the analysis. Also, out of the masks with larger landing margin, it is possible to choose one, having the most spherical curvature, that is considered to be the strongest against the deformation caused by shock or heat.

Fig.2 shows one example of the shadow mask contour optimized by the beam simulation.

Therefore, it is now possible to achieve the shadow mask optimum design that is almost impossible with the trial-and-error procedure.

4.3 Exposure Lens Design

Also, when the beam trajectory is known, the light rays trajectory to exposure the screen can be attained.

Light optics theory is well established and can be used to design the exposure lens to make the light rays to coincide with the ideal trajectories.

Again, it is possible to achieve the optimum design by the use if electron beam simulation technology.

4.4 Magnetic Shield Design

The magnetic shield analysis is one of the most difficult problem in the CRT technology, because the shield is not saturated and the non linearity can not be neglected.

At the SID'02, there was a presentation to use the measured deflection field distribution for the shield design(13). If the analysis is too difficult, it may be a clever way to apply the measurement.

5. Conclusion

The electron beam simulation technology has been indispensable for the recent non-cylindrical electron gun design.

Further, advancement of the deflected beam simulation and the measurement technology of the deflection field distribution make it possible to widen the area of the application of the technology.

Now the technology can be applied to the glass funnel, shadow mask, exposure lens and magnetic shield design.

6. References

[1] S.Shirai, et al., Proc. of the SID, vol.25, pp.171-175 (1984).

[2] D.J.Bechis, et al., SID 88 Digest, pp.122-125 (1988)

[3] Van den Broek, Optik, vol.19, pp.1389-1409 (1986).

[4] S. Okuda, et al., Proc. Japan Display, pp.462-465 (1989)

[5] K. Oku, et al., SID 98 Digest, pp.433-436 (1998)

[6] N.C. van der Vaart, et al., SID 00 Digest, pp.956-959 (2000).

[7] T. Nomura, Elec. Eng. In Japan, vol.91, p.147 (1971).

[8] Y. Yokota, et al., IEEE Trans. CE., vol.CE-25, p.91 (1979).

[9] G.A.J. van Engelen, et al., Philips Tech. Rev. vol.39, p.277 (1980)

[10] F.J.Cambell et al., SID Proc. Vol.26, p.279 (1985)

[11] J.P. Jhonson, et al., Proc. Of SID, vol.30, pp.33-37 (1989)

[12] K. Oku, et al., Proc. IDRC 97, pp417-420 (1997)

[13] S. You, et al., SID 02 Digest, pp.1306-1309 (2002)