Computer aided calculation of reflectors for linear fluorescent lamps

Alfonz Smola[1], Miroslav Kropáč[2]

Department of Power engineering, Faculty of Electrical Engineering and Information Technology, Slovak University of Technology, Ilkovičova 3, 812 19 Bratislava

[1]smola@elf.stuba.sk

[2]kropac@elf.stuba.sk

ABSTRACT

This paper aims to bring out present work performed at the Department of Power Engineering FEI, Slovak University of Technology in Bratislava, The Lighting Technology Branch. The principle of the forward ray tracing method was used for algorithm creation for calculation and design of reflectors for linear fluorescent lamps. Analysis of variable optical system consisting of reflectors can be performed by this algorithm and the luminous intensity distribution curve (LIDC) is obtained.

INTRODUCTION

The computers improvement offers new opportunities for calculation of the optical systems for luminaires and makes development in this scientific area easier. It is possible to improve existing methods that have been developed during the last fifty years, but grounds of their theory are based on principles, that have been already checked by manufacturing.

SCIENTIFIC GOALS

The new approach to a subject is described in this paper, as far as ray-tracing simulation and LIDC creation are concerned. Goals can be summarised as follows:

- Application of the forward ray-tracing and Phong´s model of reflection for determination and simulation of reflected rays
- Modification of the elementary image method for calculation of the LIDC algorithm in accordance with shading of the light source
- Creation of the algorithm for calculation of the LIDC and application to program

In the first phase of solving the problem, we assume only the first, 100% specular reflection.

1. RAY-TRACING CALCULATION

History of reflected ray-tracing calculation is connected with differential equation of reflection. Its solutions were difficult and many times didn't aim to obtain usable results. Using trivial computer graphics knowledge as e.g. Phong´s illuminating model [3], that is based on basic vector calculus, is easier and more flexible.

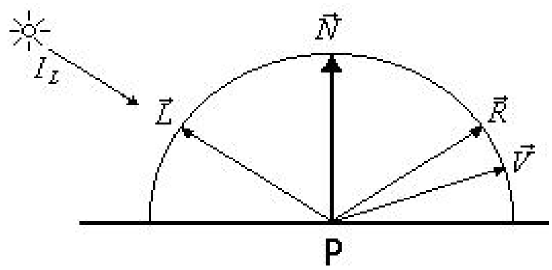


Fig.1 Reflection of the light ray

For the present we assume only 100% specular reflection , so we can use just the relevant part of the Phong´s illuminating model

$$I_S = I_L r_S \left(\vec{V}.\vec{R}\right)^h \qquad (1)$$

I_S - specular component

r_S - coefficient of specular reflectivity

h - coefficient of the definition

$\vec{V}$ - view unit vector

$\vec{R}$ - symmetrical unit vector to $\vec{L}$

In fact, from equation (1) calculation of the $\vec{R}$ unit vector in situation, when $\vec{R}$ is identical with view unit vector is for us interesting. Unit vector $\vec{R}$, that represents direction of reflected ray-tracing can be calculated as

$$\vec{R} = 2(\vec{L}.\vec{N}).\vec{N} - \vec{L} \qquad (2)$$

Forming curve is given by boundary points of elements, so it is no problem to get normal vector $\vec{N}$ of the element.

2. ELEMENTARY IMAGE OF THE LINEAR FLUORESCENT LAMP

Elementary image ξ_i can be calculated for midpoint of the certain zone M_{imid} from equation

$$\xi_i = \arcsin \frac{d}{2r_{imid}} \qquad (3)$$

d – diameter of the linear fluorescent lamp

r_{imid} **-** radius-vector of the midpoint

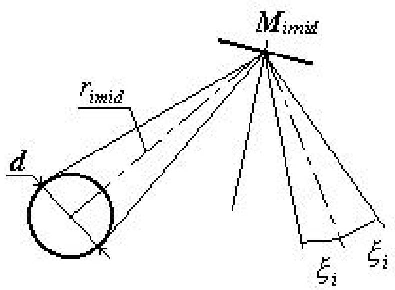


Fig.2 Elementary image of the linear fluorescent lamp in meridian plane

Luminous intensity of the appropriate zone in different directions of reflection can be calculated as :

$$I_i = \rho\ \Delta x_i \left(\frac{\Phi}{\pi^2 d}\right)\cos\theta_i \qquad (4)$$

ρ - coefficient of reflectivity

Δx - length of appropriate zone

Φ - luminous flux

d - diameter of linear fluorescent lamp

θ - angle from (β-ξ) to (β+ξ)

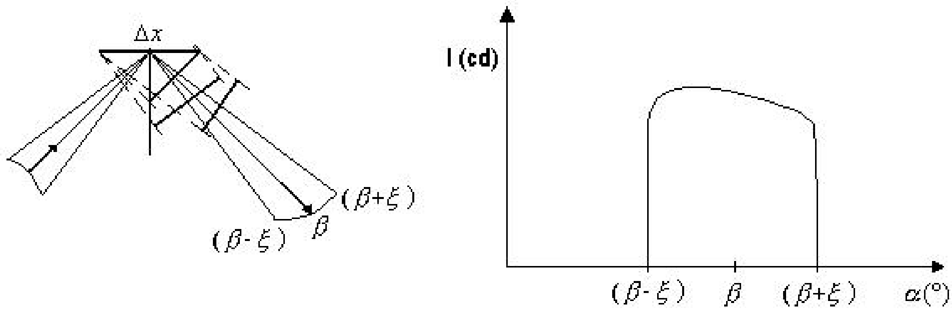


Fig.3 Creation of the LIDC of the appropriate zone

3. SHADING OF THE LIGHT SOURCE

Position of the light source has important influence on light benefit of the reflector zones, that are above the light source and elementary image-tracing pass through it. In these cases, light source forms a shadow and it is displayed on LIDC of the appropriate zone.

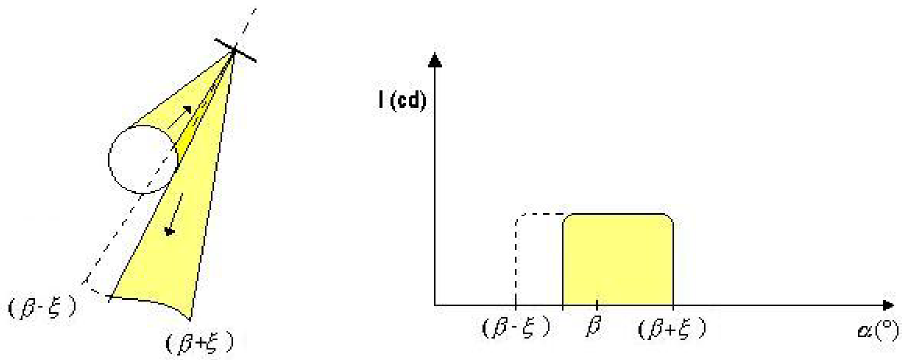


Fig.4 Shading of the light source and influence on LIDC of the appropriate zone

4. ALGORITHM OF THE REFLECTOR ANALYSIS

We have supposed, that the algorithm was created on the right base and principles, so the following step of our work was its application and creation of a program tool by Visual Basic under MS Excel. This solution was sufficient for us. Output from this program consists of visualisation forming a curve of the reflector and its LIDC in polar and linear diagram.

Main principle of the LIDCs of the reflector zones stacking is shown in the following figures. Different parts of the reflector's forming curve have their own LIDC. In accordance with this fact, final LIDC of the whole reflector is obtained by stacking of partial LIDCs, as you can see in Fig.7.

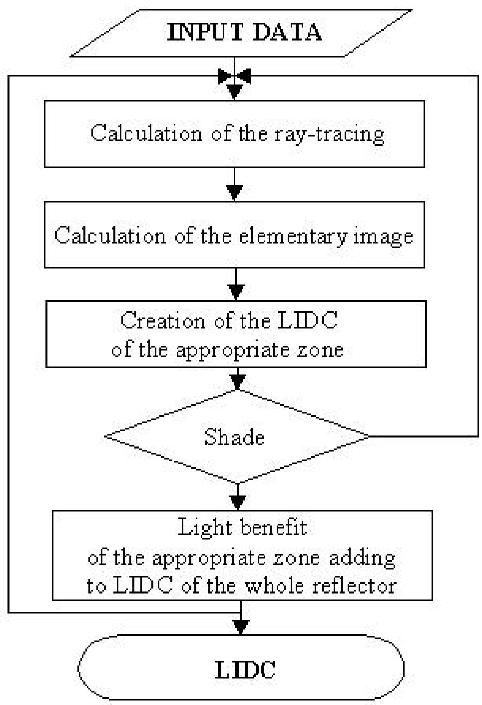


Fig.5 Algorithm of the reflector analysis

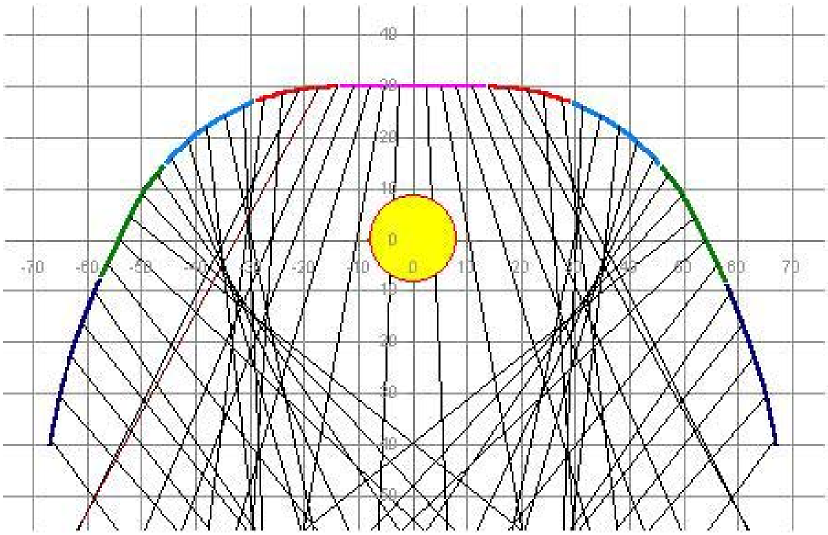


Fig.6 Reflector can be divided in to several zones

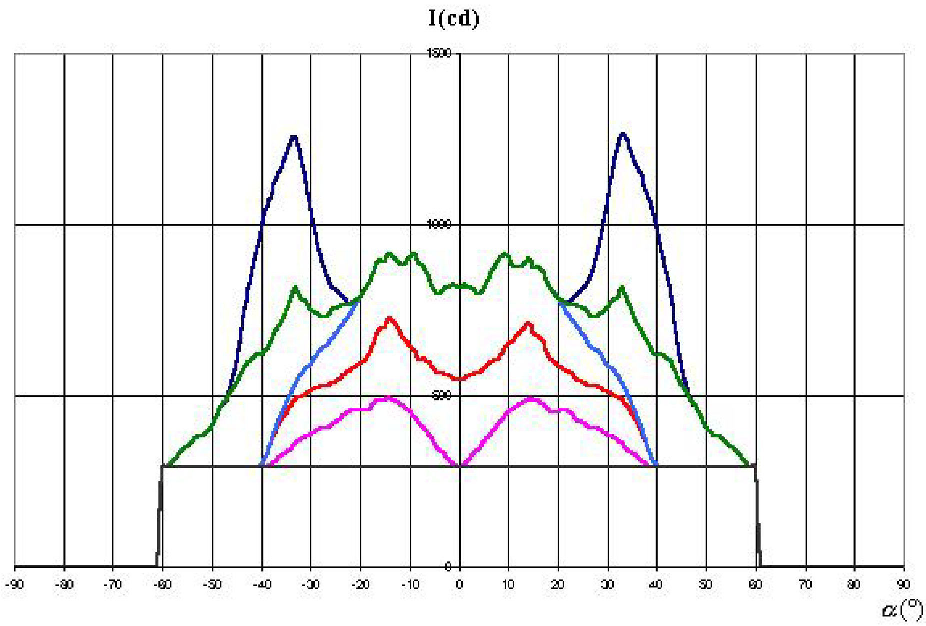


Fig.7 Stacking of the LIDCs of the reflector zones

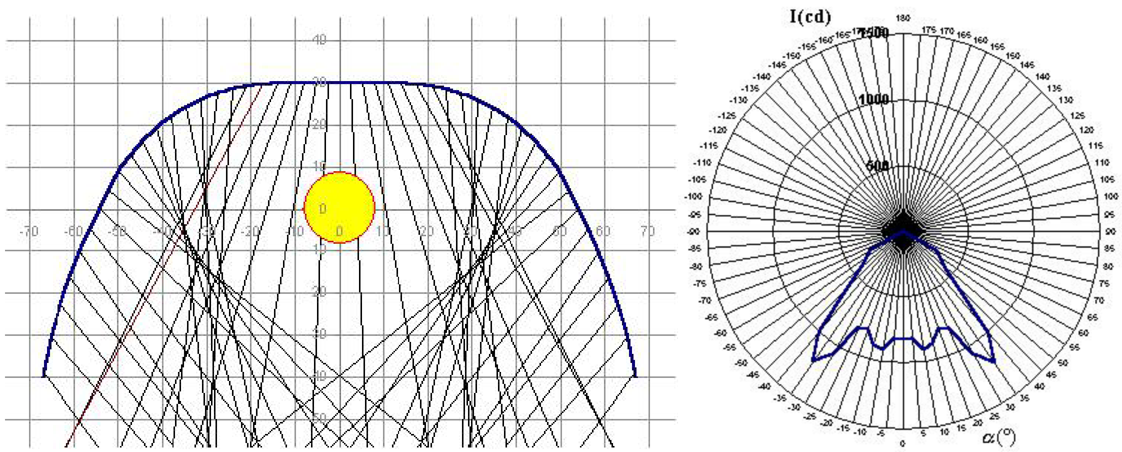
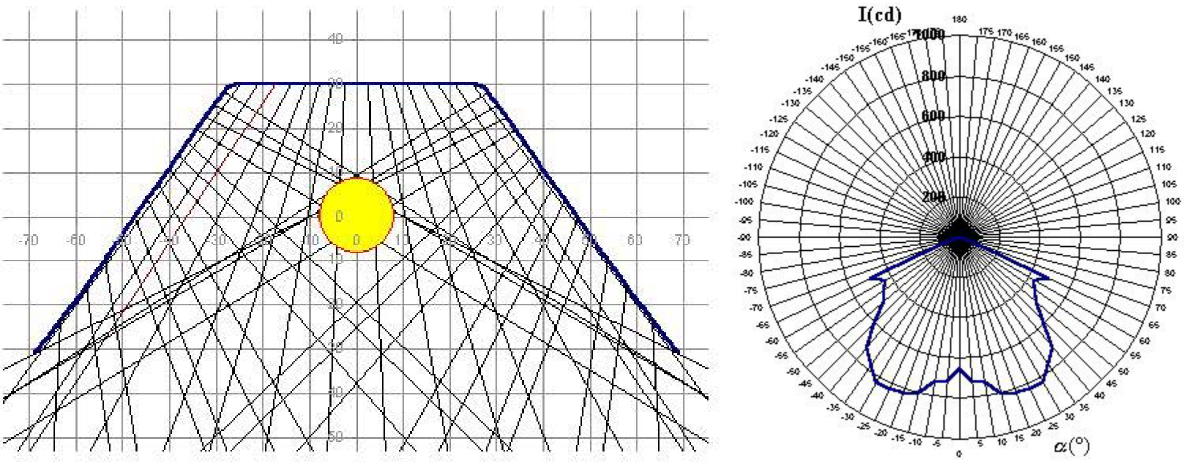


Fig.8 Final forming curve of the reflector and its LIDC

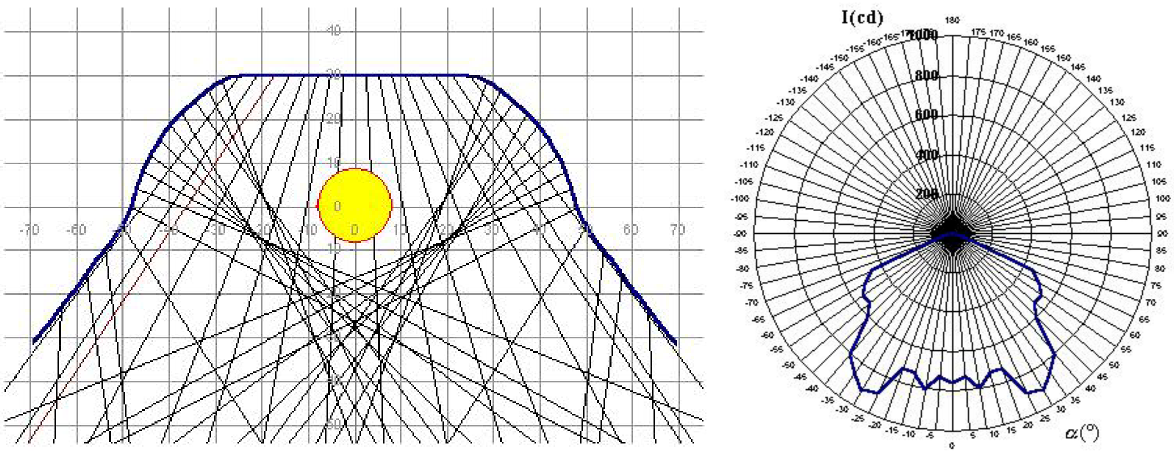
5. RESULTS AND DISCUSION

Following figures show the possibility to analyse different forming curve types for reflector. We are able to input a wide range of forming curves and their modifications, even asymmetrical forming curve usually used for vertical illuminating.

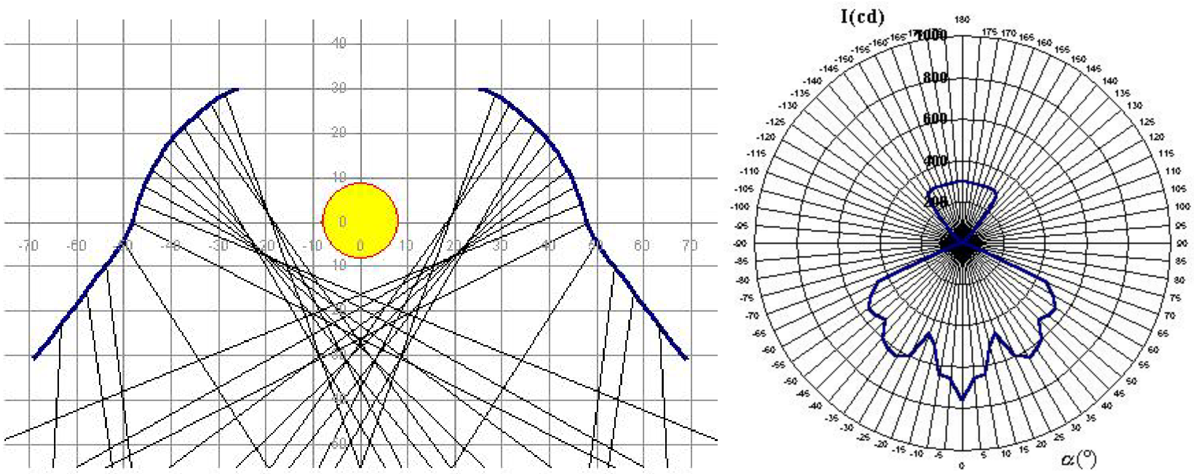
In following cases was used linear fluorescent lamp T5 (ϕ = 2900 lm) as light source.



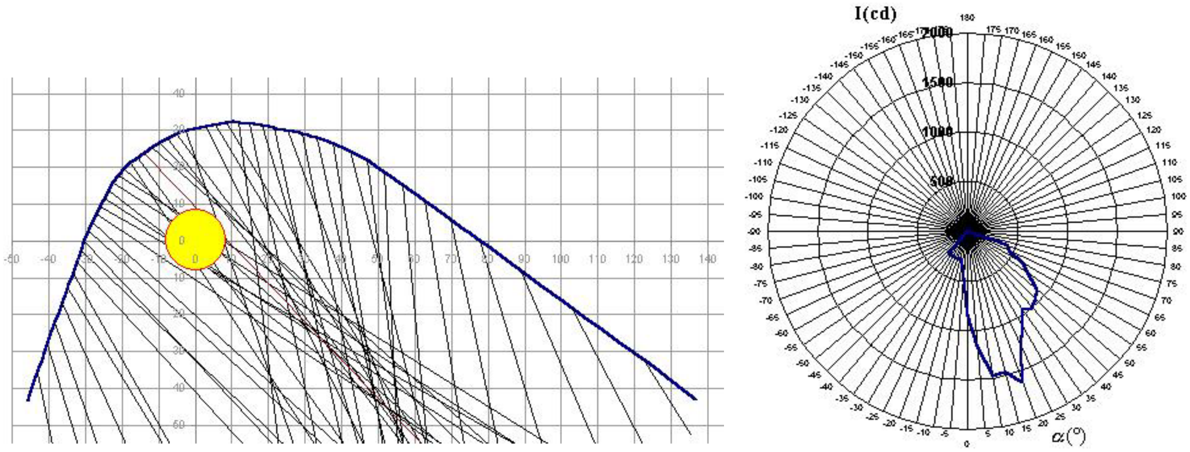
Obr.9 Example No.1 (forming curve of the reflector and its LIDC)



Obr.10 Example No.2 (forming curve of the reflector and its LIDC)



Obr.11 Example No.3 (forming curve of the reflector and its LIDC)



Obr.12 Example No.4 (forming curve of the reflector and its LIDC)

CONCLUSIONS

Design of reflectors is too difficult and time-consuming process, that is impossible without software, in fact. Creation of the universal program tool for calculation of reflectors for linear fluorescent lamps was divided into several parts.

This first phase of solving the problem, was based upon assumption, that rays can have only first, 100% specular reflection, although program tool was created, that can be used for different mathematical curves and curve systems analyses.

It is necessary to realise, that the surface of the real reflective material can have different photometric properties, from 100% specular reflection to total diffuse reflection. Our further work will be continue in solving this phenomenon.

REFERENCES

[1] VESELOVSKÝ, J., SMOLA, A.: Mechanical components and systems. SVST, Bratislava 1989 (in Slovak)

[2] GAŠPAROVSKÝ,D.: Mathematische Modelierung der Reflectoren von Leuchten. In Proc: “Lux Junior #97”, Ilmenau 1997 (in German)

[3] ŽÁRA,J., BENEŠ,B., FELKEL,P.: Modern computer graphics. Computer Press, Praha 1998 (in Czech)

[4] VESELOVSKÝ,J., KROPÁČ,M.: Design methods of luminaires’ reflector. Osvetľovacia technika, 2002,č.2, s.34 –37 (in Slovak)

[5] GAŠPAROVSKÝ,D.: Novel Approach to Derivation of Differential Equation of Reflection at Conformal Angle Definition. In: Journal of Electrical Engineering, 2003, Vol. 54, No. 3-4