SIMULATION BASED SUBSTITUTION OF THE INTEGRATING PHOTOMETERS SPHERE SHAPE

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Abstract

The integrating photometers are additional devices for lighting measurements. These devices could help to measure photometrical properties - for example luminous intensity - of light sources. The size of the device is the basic delimiter parameter of these types of measurements in the terms of the applicability.

The increasing of the diameter could cause problems during the construction procedure since the shape form is the commonly used geometry in the case of the integrating photometers.
As the shape form's application is required by mathematical necessity in the integrating photometers, the deviation from this form will surely cause some unevenness on the illumination distribution inside the device compared to the sphere shape. Therefore, if we want to substitute the common form of these devices, we also need to investigate this unevenness. The most reasonable solution, to examine this problem, is the use of computer simulations.

The presented simulations are implemented in SPEOS environment, integrated into CATIA V5 CAD-based modeling software. During our simulations we examine a shape based on geodetic polyhedron - which is a commonly used structure in architecture – compared to the basic sphere form and the dodecahedron. We repeated our simulations with the setting of several reflection parameters and compared the simulated data against each other.

Keywords

Integrating photometer, simulation

1 Introduction

The principle of the integrating photometers (Fig. 1) is based on multiple diffuse reflections occurring inside the device. If the inner surface of a sphere wall - covered a coating with uniform and diffuse reflection characteristic – is illuminated, after a sufficient number of reflections, the measurable illumination will be equal in all points of the surface. This concludes that the illumination of any points of the sphere wall - if it is not illuminated directly - will be proportional to the total luminous flux of the light source.

This simulation environment uses off-axis ray tracking. This means that there is no optical axis defined in the simulation, and the rays are started from the light sources to random directions. The mathematical background of the application based on the Monte Carlo method. All of the started rays have several specifics, such as intensity, wavelength and orientation. These specifics are changed, when rays reached a boundary of a medium defined by the CAD model. The optical properties of these boundaries and the materials of the parts are also adjustable. The program gives the possibility to define sensors basically anywhere to the simulated geometry to read out the required data.

Fig. 1 Integrating sphere

2 Simulation settings

The main aim of the simulations regarding to the differences between a sphere form and a geometry bounded by planes is to investigate the effects of the fragmentation of a simpler structure to the evenness of illumination distribution inside the sphere. Since the simulation times are excessively long because of the numerous reflections acted during the simulations, we could analyze only two more shapes beside the sphere form, it was necessary to choose these two geometries carefully. The most important requirement for the substitute geometry after the applicability from the technical point of view was the simple feasibility of the structure. Because of the mentioned reasons we finally choose the geodetic polyhedron which is a structure based on the geodetic dome – commonly used structure in architecture - , and a much-more simpler dodecahedron beside the sphere for the evenness simulations (Fig. 2).

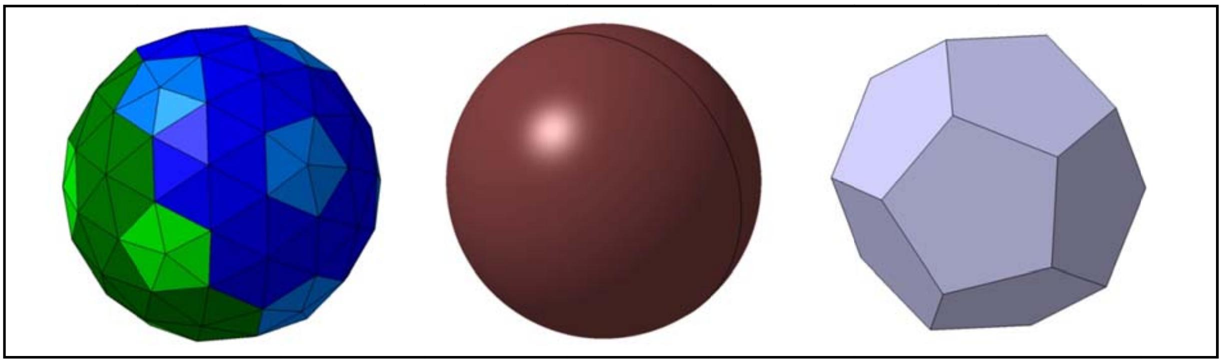

Fig. 2 Geometries used in the simulations.

SPEOS gives the possibility to define a 3D illumination sensor into the geometries, which is virtually covered the whole inner surface of the structure, and gives back the illumination values in all points of it. With this sensor, it is very simple to investigate the illumination distribution inside the geometries. To do so, SPEOS software – just like many other FEM software – is using triangles to recreate the input geometry with a mesh. It should be noted, than from the software side, the meshing of the geodetic polyhedron and the dodecahedron is more accurate than the mesh of the sphere (Fig. 3). This may causes a bit better accuracy of the results with the geodetic polyhedron.

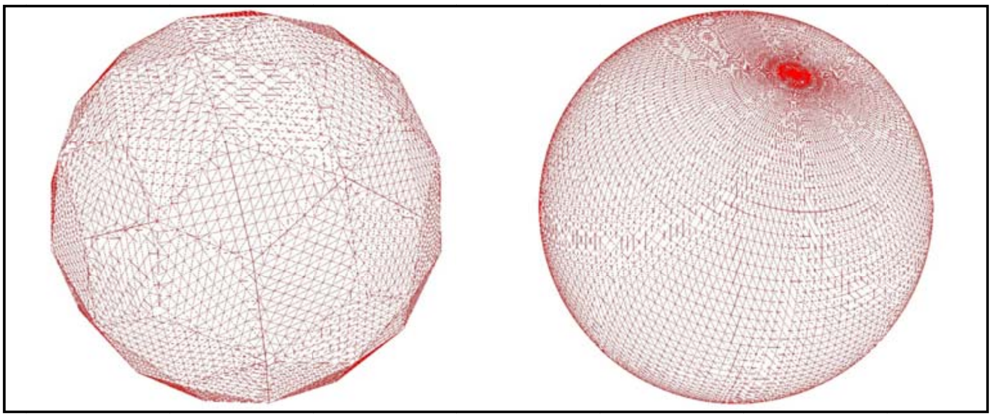

Fig. 3 Differences in meshing.

Since in the case mentioned above, the sensor was takes place at the whole inside surface, just an input port created on the geometries for the simulations. It was a hole on the wall with 80 mm of diameter. Accordingly, the selected source is a coherent, monochromatic light beam with 80 mm of diameter and 1000 lm of total luminous flux. The wavelength of the beam was 555 nm. The reflection parameter of the inputs was set to 0%. The coating of the inner surface was modeled totally diffuse. Two different cases with different reflection parameters of the coating was examined, $\rho = 1$ and $\rho = 0{,}9$ values was set.

4 Results

If we set the reflection parameter to $\rho = 1$, the differences in the results between a sphere and a substitution geometry could ensure only from the differences between the fragmentation. With these settings, we basically examined the effects of the simplification of the geometry to the evenness of the inner wall illumination. In this first phase, the sphere and the geodetic polyhedron shown surpassing evenness as it was expected. The differences between the simulated values on the wall was under 0,5% of the maximum illumination value. Strangely, the geodetic polyhedron had a bit better results with these setting which could be explained with the mesh differences (Fig. 4).

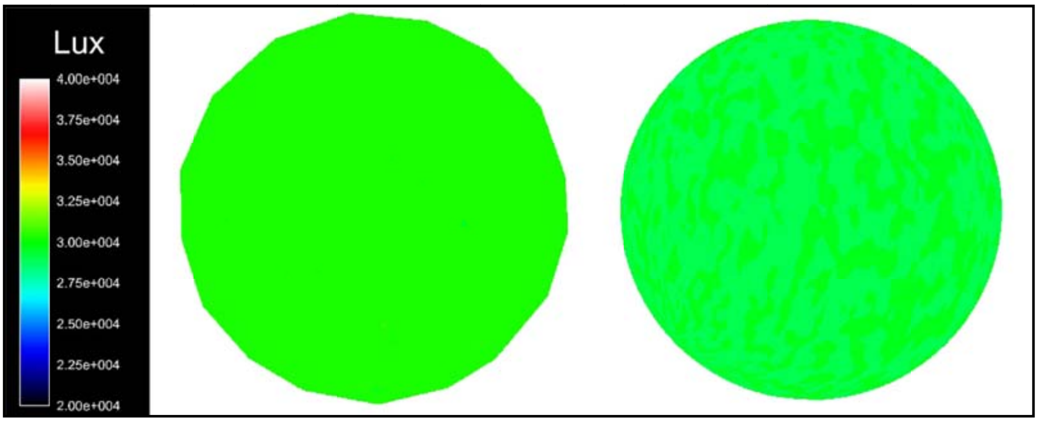

Fig. 4 Simulation results of the geodetic polyhedron and the sphere ($\rho = 1$).

In the case of the dodecahedron we observed small differences in the evenness of the inner illumination distribution compared to the other two geometries. With this form the illumination values shown evincible deviation near the edges even with a reflection parameter set to the theoretical maximum. The differences in the results of the dodecahedron were firmly bigger – around 10% of the maximum value - than in the case of the sphere and the geodetic polyhedron (Fig. 5).

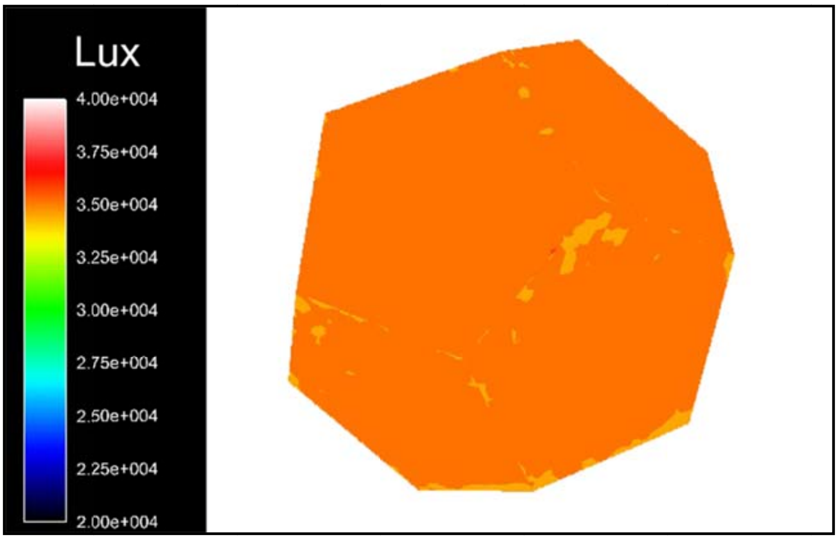

Fig. 5 Simulation results of the dodecahedron ($\rho = 1$).

This may be due to the finite number of rays started and reflections acted during the simulations. Theoretically, because the program uses split Monte Carlo method, the rays started splits to infinite number, and produces infinite number of reflections if the reflection parameter is set to 1. But there is also an upper limit of ray splitting which was surely reached during our simulations. These phenomena imply that simulations with smaller value of reflection parameter of the inner surface are reasonable to investigate the effects of the geometrical differences to the evenness of illumination distribution.

In the next phase we set the reflection parameter to $\rho = 0{,}9$ which is brings our simulations a bit closer to reality. With these settings, the sphere produced the best results as expected. In the case of the sphere form, there are basically no differences noticeable in the evenness compared to the results before. It is also not surprising that a small degradation detected in the evenness if we ran the simulations with the geodetic polyhedron. Although, the deviation still remained below 3% of the maximum value (Fig. 6).

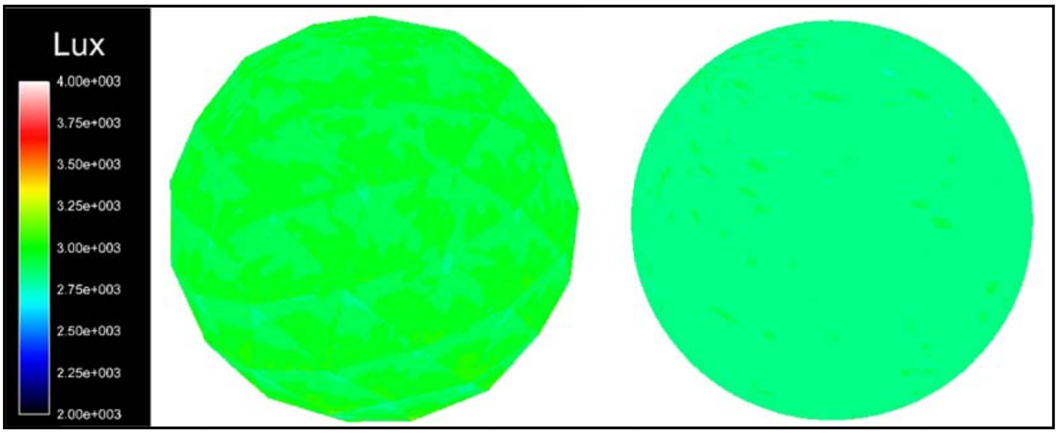

Fig. 6 Simulation results of the geodetic polyhedron and the sphere ($\rho = 0{,}9$).

Bigger deviations are detectable in the evenness of the wall illumination in the simulation results with the dodecahedron. The differences in the illumination values in between the measuring points take places at the center of the pentagon shaped planes and the edges are bigger than 30% of the maximum value. There was also a detectable difference in the characteristic of the distribution depends on the position of the input (Fig. 7).

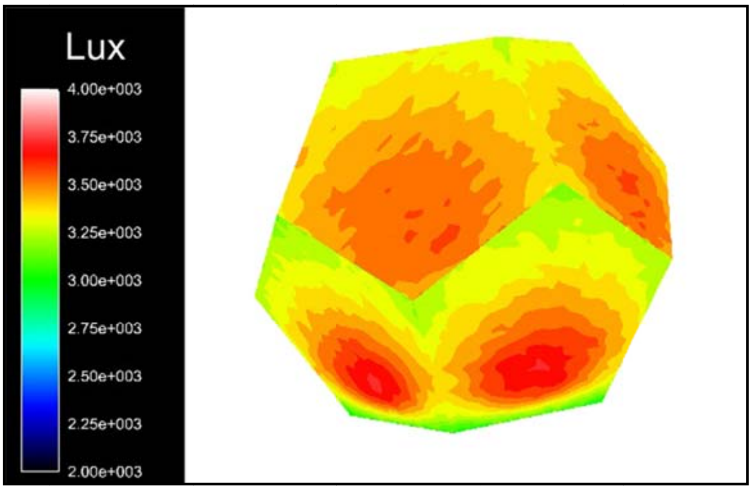

Fig. 7 Simulation results of the dodecahedron (ρ = 0,9).

5 Conclusions

In this paper, we discussed our simulation results regarding to the evenness of the illumination distribution on the inner surface of different shaped integrating photometers. We examined the effects of the fragmentation of the substitute geometry on the evenness against the results reached by the sphere. Based on the simulations, we concluded that the fragmentation has an impact on the distribution, even with high reflection parameter values. We could tell that the dodecahedron form is too simple to produce even distribution of illumination at its inner surface. However, the results of the geodetic polyhedron is promising enough to be worthwhile to do further investigation for its applicability.

Based on the findings above and the results of the further simulations the construction of a geodetic polyhedron shaped integrating photometer with a diameter around 1 meter is started at the BUTE MOEI Department (Fig. 8).

Fig. 8 Geodetic polyhedron shaped integrating photometer.

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