Simulation of visual comfort in selected industrial hall

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Abstract. Industrial halls are usually subjects to high energy demand. It is due to the many manufacturing processes, lighting, and the corresponding amount spent on space conditioning. The industrial buildings is one of the heaviest consumers of energy. Natural daylight is a vital element in our daily life. Providing natural daylight into the working environment is of fundamental importance for the comfort, efficiency and safety for the people in that environment. This paper deals with visual comfort evaluation in selected hall. Its calculated by the radiance simulation program.

1. Introduction

Through vision, one gets 75% to 90% of information from the surrounding environment. Visual comfort is the psychological state in which the entire visual system performs its function optimal. Good daylighting is an important factor. Convenience affects the type of light sources, the type and layout of the luminaires, the level of luminance and their uniformity in different planes and also the distribution of brightness in the space. The geometric parameters of the space, surface properties, including colour, also play an important role in the assessment of suitable working conditions. What matters is whether or not there is glare. Lighting should be sufficient and even, without excessive brightness and contrast. When the light is properly distributed in space, the objects appear plastic.

Drahos et al. studied the problems of measurement and assessment of lighting in the working environment of industrial plants have been occupied by a relatively large number of households in the rest of the decade.

Turekova et al. studied several of them point to the fact that in the comprehensive assessment of lighting in the work environment, the individual qualitative and quantitative lighting parameters should be assessed not only on the basis of objectivity - measurement, but also the subjective response of employees. The subjective assessment gives a closer picture of the working environment and presents the satisfaction and well-being of the workforce in the workplace.

Reinhold et al. investigated relationship between office lighting conditions and occupational health. Measuring health aspects in combination with measuring lighting requires knowledge of both fields. Bellia et al. investigated the recent discoveries in photobiology to those interested in lighting design. Tzempelikos A investigated present new developments on daylighting research, visual comfort and non-visual effects related to health and well-being. Present new information on daylight prediction models and simulation techniques, glare evaluation methods.
Konis K studies daylighting performance over daily and seasonal changes in sun and sky conditions in core and perimeter zones of the building. Results show a high frequency of visual discomfort responses at both perimeter and core workspaces and observations reveal a large percentage of façade glazing covered by interior shading devices.

Tabadkani et al studies an improvement in the performance of dynamic facades in comparison with the static systems.

Konis K studies 15 single-variable probabilistic visual discomfort models implemented in software simulation workflows to place quantitative data in context with subjective outcomes. Results show a study conducted in the core zones of a side-lit office building.

The simulations presented in this contribution were performed using the original UNIX-based Radiance Lighting Simulation System [5].

There are different types of glare index calculation:

- DGI – Daylight Glare Index;
- VCP – Visual Comfort Probability;
- DGP – Daylight Glare Probability;
- UGR – Unified Glare Rating;
- CGI – CIE Glare INDEX.

In the article, visual comfort is evaluated through the glare index Visual Comfort Probability (VCP) also known as Guth Visual Comfort Probability. It is defined as the percentage of people that will find a certain scene (viewpoint and direction) comfortable with regard to visual glare. It was defined by Sylvester K. Guth in 1963 [5].

Interestingly, increasing background luminances decreases discomfort glare. The Visual Comfort Probability, or VCP, of a lighting system is a rating that indicates the percentage of people that will find a given discomfort glare acceptable. The VCP rating is applicable direct lighting fixtures with the viewer in a specific location and looking in a particular direction. A VCP rating of 70% is usually considered acceptable, but 80% is required for areas with computer monitors. VCP differences between fixtures of 5 or less are not significant [5].

2. Daylight measurements and calculations

Daylight measurements was realized in the hall in Košice. The hall is located in the Slovak Republic. It is a one-storey building with reinforced concrete pillars and connected windows and toplighting by skylight (Figure 1). The ceiling structure is made up of a space barrier beam located on the pillars. The hall is designed for work on the metal working and forming, production of sheet metal blank. Interior dimensions of hall are 15 m x 60 m x 8,5 m (Figure 2). Sidelighting is created by the windows with dimensions 5 m x 1.8 m and 3 m x 1.8 m, and toplighting is created by one saddle skylight with dimensions 2.4 m x 48 m x 1.1 m (Figure 3). The object is divided into three longitudinal tracts. There are two smaller tracts on the sides, where are offices, laboratories and classrooms.

Daylight measurements were performed on two different days. They were performed on the first day twice and the other days three times. The measurements were made in December when the sky was cloudy. The instruments were two “Hagner EC1 type” lux meters, a “Hagner Universal Photometer type S2 with an accuracy of 5%,” and the “Hagner Reference calibration sample” with factor value and a reflection of 0.966. On the selected days, the value of the outside light in a cloudy sky ranged from 9500 lx-10,500 lx on the first day and 10,500 lx-12,000 lx on the second day.

The boundary conditions for calculations have been observed in the measurement of daylighting. The fenestration systems are created by single wired glass. In the calculation the following coefficients were considered: light loss coefficients 0.8, maintenance factor of glazing on exterior surface 0.9, maintenance factor of glazing on interior surface 0.85, reflectance factor of external terrane 0.15 - dark ground). Table 1 present the light coefficients of reflections. The neighbouring objects are in distance, which does not shade the hall [1], [2].
Table 1. Reflectance factor of surfaces in the hall.

| Surface     | Reflectance |
|-------------|-------------|
| Wardrobe    | 0.3         |
| Machine 1   | 0.2         |
| Machine 2   | 0.5         |
| Ceiling     | 0.7         |
| Wall        | 0.4         |
| Floor       | 0.2         |

The hall is orientated by longitudinal dimensions in the east-west direction. Figure 1 shows the view of the building from the outside. Figure 2 shows the view of the building from indoor and the internal view as a result of daylight simulation with the Radiance simulation program. External view of skylight is illustrated in Figure 3.

The following pictures documented the results of simulation luminances (cd.m$^{-2}$) for interior environment of the hall. For saddle skylight simulation for single wired glass was realized. The calculations of simulation from three views from working place of interior hall was realized. Some points of luminance (cd.m$^{-2}$) and values of glare sources (cd.m$^{-2}$) are shown in Figure 4,5,6,7. The evaluation of visual comfort was realized on based of calculation glare index (Figure 8,9). The single wired glass and diffuse glass were considered.

Figure 1. Exterior view of the hall.
Luminance within the visual field should be limited, for the purpose of avoiding glare and also excessive luminance ratios. For visual comfort to be achieved luminance ratios should also not exceed prescribed values.

Specific recommendations assume a ratio of 1:3 between near surfaces and the visual task in the field. A ratio of 1:2 for the distant surfaces in the visual field. The maximum permissible luminance ratio between the task and surface is 1:40 in the field of view. A deviation for a ratio of 1:50 has been observed when the luminance from the window filled a small portion of the visual field.
3. Results

Guth Visual Comfort Probability (Guth VCP) is a metric used to rate lighting scenes. The Guth VCP provides an indication of the percentage of people in a given space that would find the glare from a fixture to be acceptable. A minimum VCP of 70% is recommended. The most important factor with respect to lighting quality is glare. Glare is a sensation caused by luminances in the visual field that are too bright. Discomfort, annoyance or reduced productivity can result [5].

The visual comfort is affected for relation of illuminances 1:10 and glare for relation 1:100 is occurred [18], [19]. Potential glare sources (cd.m⁻²) are identified as a red circle with the intensity of the source at the centre (Figure 4).

For evaluation of visual comfort for combined daylighting system and single wired glass is showed that in case single wired glass. In case diffuse glass visual comfort is affected. In the pictures (Figure 5,6,7) are represented the luminance values (cd.m⁻²).

The graphs (Figure 8, 9) shows percentage of people who would be satisfied. In case single wired would be satisfied with visual comfort 10-90% of people (Figure 8). In case diffuse glass would be satisfied 60-90% of people (Figure 9). Visual comfort is strongly influenced by view direction.
4. Conclusions
This paper provides new insight on glare evaluation. Our task was to evaluate the visual comfort in selected areas of the factory with production of sheet metal blank that is located in the Slovakia. The visual comfort is evaluated by Guth Visual Comfort Probability. Simulation calculations were made from different views of the interior in clear sky. According to standard STN EN 12464 - 1 users in interior spaces must be protected against glare. The workers must feel a connection with the exterior environment, if it is not, their productivities decrease. The contribution shows that using diffuse glazing improved visual comfort - so satisfaction was higher by 40-100% depending on the viewing angle.

5. References
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