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Evaluation of high-power LED floodlight luminaires using CAE techniques

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Structural and thermal performances of LED floodlight luminaires were designed using computer aided engineering (CAE) and then, after securing their structural and thermal safety, simulated in order to develop 400W high-efficiency LED floodlight luminaires. Maximum strain was detected in the glass, yet they appeared largely safe. An analysis of its radiation observed the highest temperature (94 °C) around the case cooling fin. Thus, it is important for the design to focus on the cooling fin. Regarding the lifespan of LED, it is necessary to have a plan for minimizing errors when testing designs for optimizing air-cooling structures.

Key words: LED, Floodlight luminaires, Computer Aided Engineering (CAE).

Introduction

Demand has increased for energy-efficient and environment-friendly LED sources. In conventional lighting technology, LED sources have substituted for incandescent, halogen and fluorescent lamps. They can now replace all these kinds of lights [1].

Along with the development of technology, LED sources have been used in a variety of applications. Examples include computers, display boards, guide lights, street lamps, floodlights and automotive lights. It is necessary, however, for this new technology to address problems that can be caused by high power [2-4].

This study aims to examine structural safety and thermal problems using Computer-aided-engineering (CAE) software for developing a high-power projector based on new LED air-cooling radiation technology [5]. The CAE analysis estimates an actual phenomenon by realizing the structural shape in latticed units called ‘finite element’ and applying different conditions for each situation. The SIEMENS’ finite element analysis programs, NX-Nastran and NX Flow-Thermal, were used to perform evaluations under conditions nearly equivalent to LED standard and test conditions.

Analysis

Analysis contents

Two analyses were performed for evaluating the structural and thermal stability of LED floodlight luminaries:

• An analysis of the structural strength of luminaires when a structure is set at 45 ° and 90 ° of beam angle in accordance with the standard KS C IEC 7658 (LED Street Light and Guide Light Luminaires) and a 3.6 test of KS C IEC 60598-2-3

• An analysis of heating and temperature effects at maximum LED output when thermal fluid flows at high temperatures.

Analysis model

Two finite element models were used for the two analyses: a model for structural analysis (Fig. 1) and a model which includes flow fields for thermal-fluid flow analysis (Fig. 2). Shapes that have no impact were excluded. The models were prepared using both solid and shell elements. The inner light-emitting part including LEDs was excluded. The structural parts were configured with solid elements

The thermal-fluid flow finite element model designed to check the heating and temperature effects at LED radiation includes flow fields as shown in Fig. 2. It consists of air volume, a case, LED, a reflector and glass. In a symmetrical structure, it has both solid and shell elements.

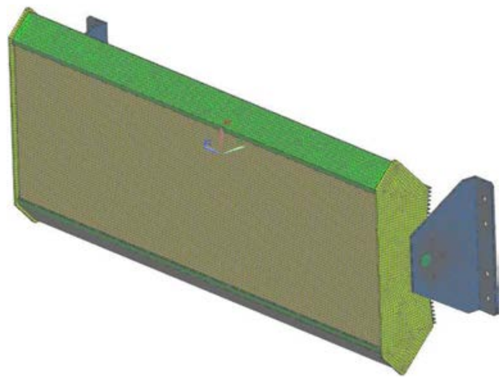

Fig. 1. Structural analysis model (if installed at 90 °).

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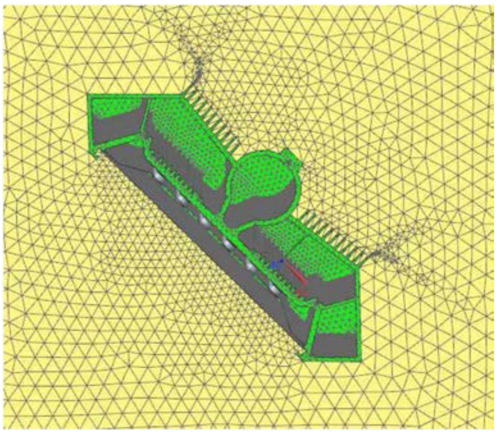

Fig. 2. Thermal-fluid flow finite element model (at 90 ° of beam angle).

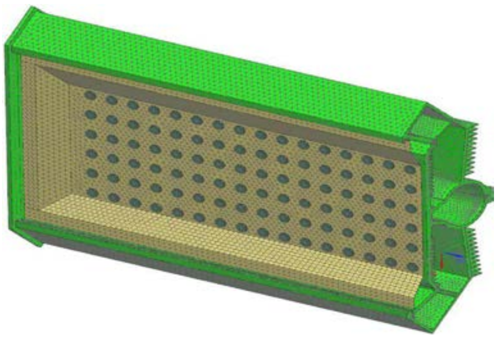

Fig. 3. Finite element model of each part in the flow of fluid.

Table 1. Material properties.

Category	AL6063-T5	PYREX	Steel
Parts	Case	Glass	Bracket, Reflector
MASS DENSITY (Kg/m^3)	2700	2230	7800
MODULES OF ELASTICITY (MPa)	68900	62750	200000
POISSON RATIO	0.33	0.19	0.29
THERMAL CONDUCTIVITY (W/m.k)	209	1.1	26.1

The boundary between flow fields and light-emitting parts was defined efficiently, using a few of the elements of the flow boundary technique from a finite element program. The inner view is shown in Fig. 3. Material properties of machine and heat are included in Table 1.

Results and discussion

Analysis of structural strength of luminaires by beam angle

All loads are applied to the luminaires, provided the luminaire support is strong enough to endure the structural load caused by wind. After applying 42 m/s of wind, structural strength was determined as follows:

$$F = 1/2(Rh \times S \times Cd \times V^2)\ (N) \quad (1)$$

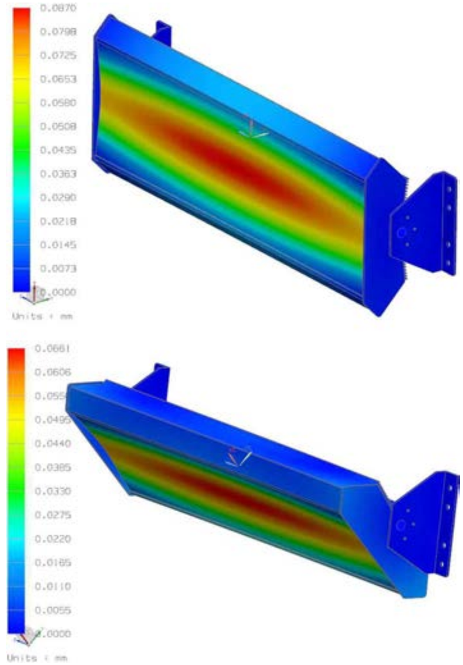

Fig. 4. Result of strain.

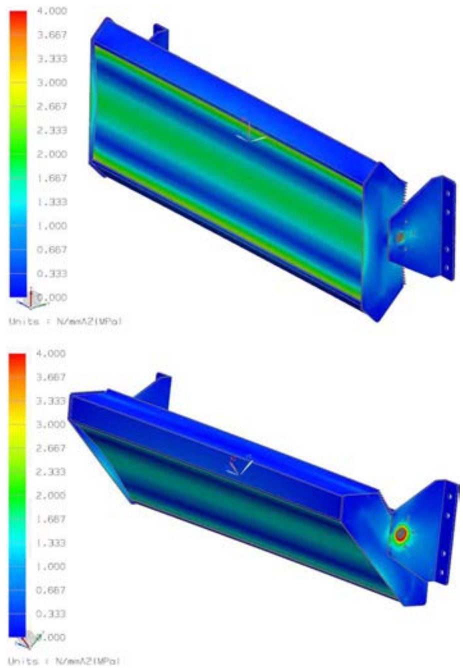

Fig. 5. Result of stress.

Here, Rh is ambient density (1.225 kg/m^3), S is luminaire area to which load is applied (m^2), Cd is drag coefficient (plat plate = 2, circumference = 1), and V is wind velocity (m/s).

Wind the velocity criteria differ depending on the height of luminaires. A single wind velocity was used in the analysis. As the beam angle ranged from 10 ° to 120 °, the evaluation was performed at 45 ° (standard) and at 90 ° (biggest load). The results are shown in Fig. 4 and Fig. 5 respectively.

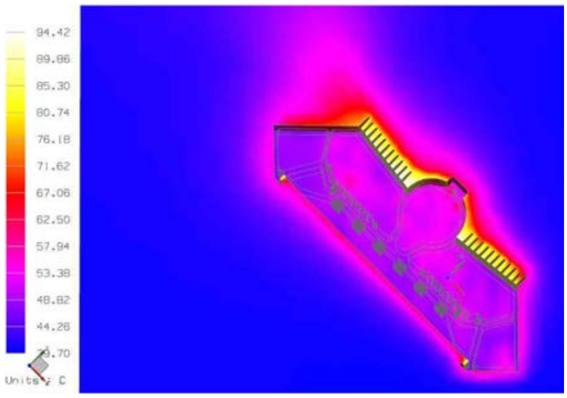

Fig. 6. Ambient temperature.

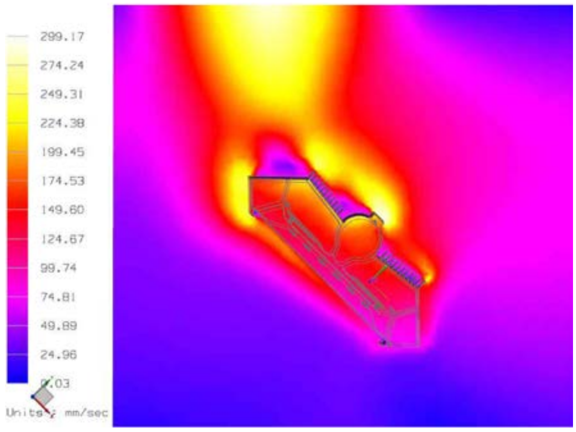

Fig. 7. Thermal-Fluid flow distribution.

The biggest strain was observed in the glass. Its beam angle was greater at 90 ° (0.09 mm) than at 45 °. Maximum stress was observed in the glass with a beam angle at 90 °, confirming that the figure (about 5 MPa) is sufficiently strong for meeting the material yield criteria. Stress was observed in the bracket joint at 45 ° of beam angle, confirming it is also sufficiently strong (about 10 MPa) for meeting material yield criteria.

Check on radiation at maximum LED output and thermal-fluid flow analysis

Because of LED radiation, heat is transferred within the air-cooling case and each of its parts through convection, conduction and radiation. Even though the amount of radiation is the same, the scope of LED cooling can change depending on differences of ambient temperatures.

A thermal-fluid flow analysis was performed at a high-temperature. Ambient temperature was defined based on the air (3D, normal, still) in a high-temperature area (40 °C of ambient temperature). The LED radiation at 45 ° of beam angle was estimated by applying 2.09 W per diode based on 200 W output. (High-temperature regions are thermally weak.)

The results of the analysis are illustrated in the following figures. Fig. 6 pictures an ambient temperature

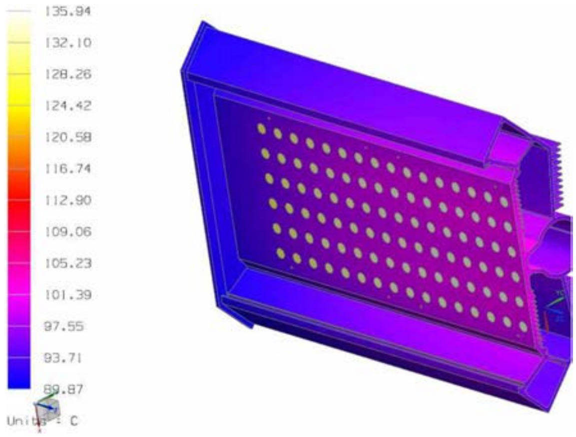

Fig. 8. Case and LED temperature.

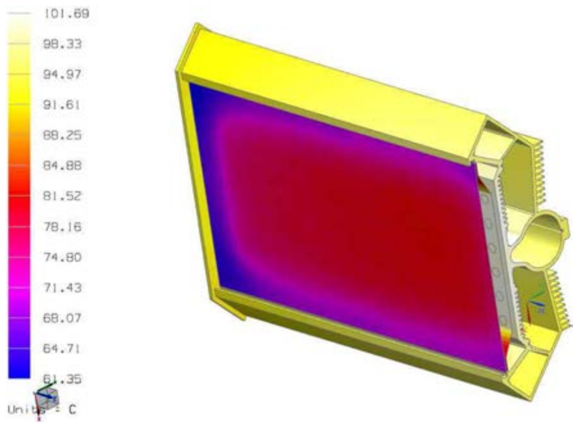

Fig. 9. Case, glass and reflector temperature.

by convection-caused radiation on a thermal-fluid flow finite element. The temperature was highest around the case cooing fin with 94 °C demonstrating that a cooling fin is the major radiation path. Fig. 7 lists the distribution of flow velocity with changes of ambient air caused by radiation. Fig. 8 lists the case and LED temperatures at different outputs. For example, LED temperatures are shown to rise up to 136 °C at 400 W output. Fig. 9 lists case, glass and reflector temperatures. The temperatures range from 61 °C to 100 °C.

Conclusions

Structural strength analyses of LED floodlight luminaires using CAE techniques concluded the luminaires were safe and strong enough to endure external loads such as wind. Generally, structural strength can be evaluated using a 'safety factor' as follows:

Safety Factor = Tensile Strength (or Allowable Stress) / Maximum Stress (2)

If the safety factor is 3 or higher, the structure is generally considered 'Safe'. Because the structure mentioned in this study is 5 kgf/mm^2 in material yield strength, the safety factor is 10. Thus, this structure may be considered safe.

The characteristics of heat transfer by LED radiation and transfer path were determined by performing a thermal-fluid flow analysis. Its applicability was confirmed using CAE techniques in air-cooling structures. These analyses recognize a need for further study to improve tests for optimizing air-cooling structure designs regarding LED lifespan.

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