Milorad Murić[1], Aleksandar Milovanović[1], Marko Pavlović[2]*

LED DIODES ARRANGEMENT INFLUENCING THE HEAT TRANSFER TO PASSIVE ALUMINIUM HEATSINK IN AN INDUSTRIAL REFLECTOR

UTICAJ RASPOREDA LED DIODA NA PRENOS TOPLOTE NA PASIVNI ALUMINIJUMSKI HLADNJAK INDUSTRIJSKOG REFLEKTORA

Originalni naučni rad / Original scientific paper
UDK /UDC:

Rad primljen / Paper received: 30.10.2022

Adresa autora / Author's address:
[1)] Western Serbia Academy of Applied Studies, Užice, Serbia, email: aleksandar.milovanovic@vpts.edu.rs
[2)] University of Belgrade, Innovation Centre of the Faculty of Mechanical Engineering, Belgrade, Serbia

Keywords
- LED light
- finite element analysis
- heat transfer

Abstract

The paper presents an analysis of the influence of light-emitting diodes (hereinafter referred to as LEDs) arrangement on heat transfer to a passive aluminium heatsink of industrial LED light with an installed power of 1100 W. The structure of a passive heatsink as well as the characteristics of the heatsink material are shown. The LED light mode is displayed. The finite element method is used to analyse heat transfer and determine the maximum temperature at the observed points of the passive heatsink structure for three different arrangements of LEDs on the LED board of industrial LED light. The obtained results are analysed and the most favourable arrangement of LED diodes is determined from the aspect of even heat transfer to passive heatsink and long service life of LED industrial light.

Ključne reči
- LED svetlo
- metoda konačnih elemenata
- prenos toplote

Izvod

U radu je predstavljena analiza uticaja rasporeda LED dioda na prenos toplote na pasivni aluminijumski hladnjak industrijskog LED svetla instalisane snage 1100 W. Prikazana je konstrukcija pasivnog hladnjaka kao i karakteristike materijala od koga je hladnjak izrađen. Dat je prikaz režima rada LED svetla. Metodom konačnih elemenata izvršena je analiza prenosa toplote i utvrđena je maksimalna vrednost temperature u posmatranim tačkama konstrukcije pasivnog hladnjaka za tri različita rasporeda LED dioda na LED ploči industrijskog LED svetla. Dobijeni rezultati su analizirani i utvrđen je najpovoljniji raspored LED dioda sa aspekta ravnomernog prenosa toplote na pasivni hladnjak kao i dugog veka trajanja LED industrijskog svetla.

INTRODUCTION

A LED industrial reflector of 1100 W installed power is analysed. The passive reflector heatsink is made of Al6063 material /1/ (Table 1). Heatsink dimensions are 120×530× 620 mm (Fig. 1), and the total usable heat transfer area is P = 7.52 m^2. LED industrial reflector is used in industrial halls, mines, shipment stations, and ports. It has two operating modes that depend on maximum allowable temperature which is detected by a constant reading in the middle of the heatsink:

1. an operating mode of 1100 W maximum power with 99 % efficiency giving illumination above 100.000 lm with a detected temperature of up to 80 °C;
2. an operating mode with thermal protection and generated power of 800 W with 80 % efficiency, giving illumination of 80,000 lm into which the LED light enters when a temperature above 80 °C is detected.

The reasons why LED light enters the second operating mode are: outdoor temperature rise, reduced air flow, tight space between the roof and heatsink, dirty environment in which it is used, as well as the arrangement of LEDs on the LED board. The mentioned operating mode is designed due to the longer lifespan of LEDs, electronic components, and therefore, LED light.

Table 1. Chemical composition, physical and mechanical characteristics of Al6063 (EN 573-3: 2009).

Mn	Fe	Mg	Si	Zn	Ti	Cr	Cu
0.0-0.10	0.0-0.35	0.45-0.90	0.20-0.60	0.0-0.10	0.0-0.10	0.0-0.10	0.0-0.10

Density (g/cm³)	Modul of elast. (GPa)	Thermal conduct. (W/mK)	Proof stress (MPa)	Tensile strength (MPa)	Hardness Brinell (HB)	Elongation (%)
2.70	69.5	201	170	215	75	8

LED light main features

LED light is designed with the latest in LED and power management technology. Built-in thermal management electronics monitors system performance to ensure constant and maximum light output. LED array with 52 CREE XHP-70 /2/ diodes (Fig. 2) delivers over 100,000 lumen output. Built-in electronic thermal management with a state of the art current driver provides optimum light output and a luminary lifespan that exceeds 50,000 hours.

Electrical specification:
- power consumption: 1,100 W
- input current 4.6 A @ 240 VAC
- power factor correction > 95 %
- lumen output > 100,000 lm
- luminaire life expectancy 50,000 hours

Built-in reliability:
- electronic thermal management
- EMI filtering
- under-voltage shutdown
- transient voltage suppression

Optical specifications, Fig. 3:
- cool white 5000K - 8300K CCT CRI 65
- neutral white 3700K - 5000K CCT CRI 75
- warm white 2600K - 3700K CCR CRI 80

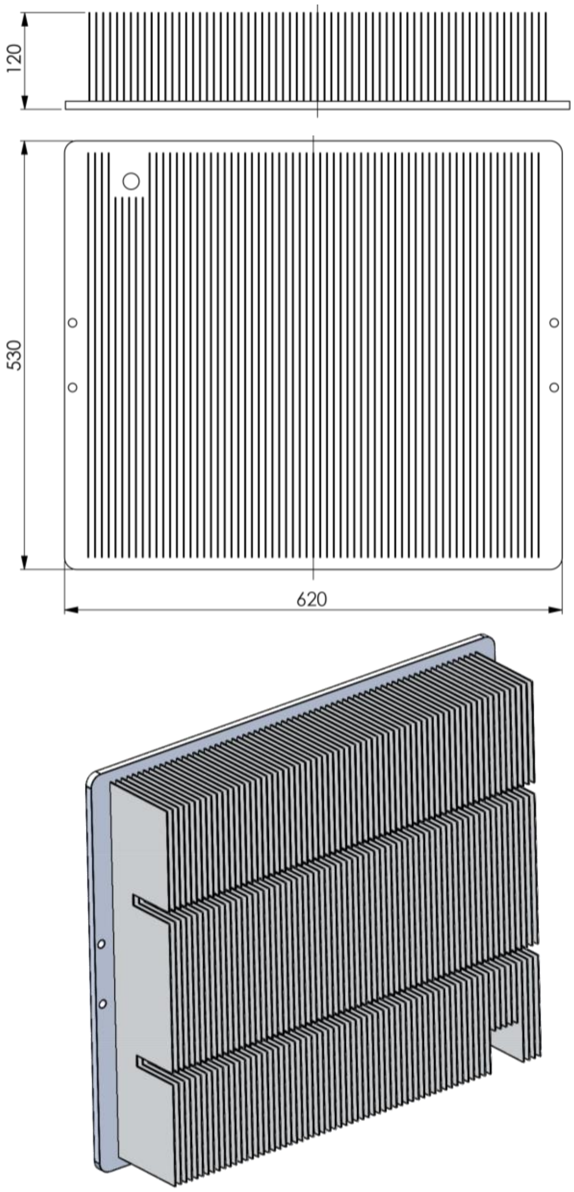
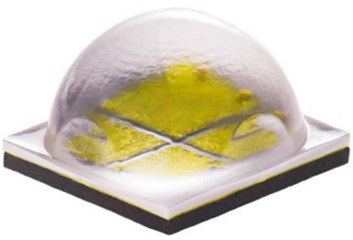


Figure 1. Passive LED light cooler.



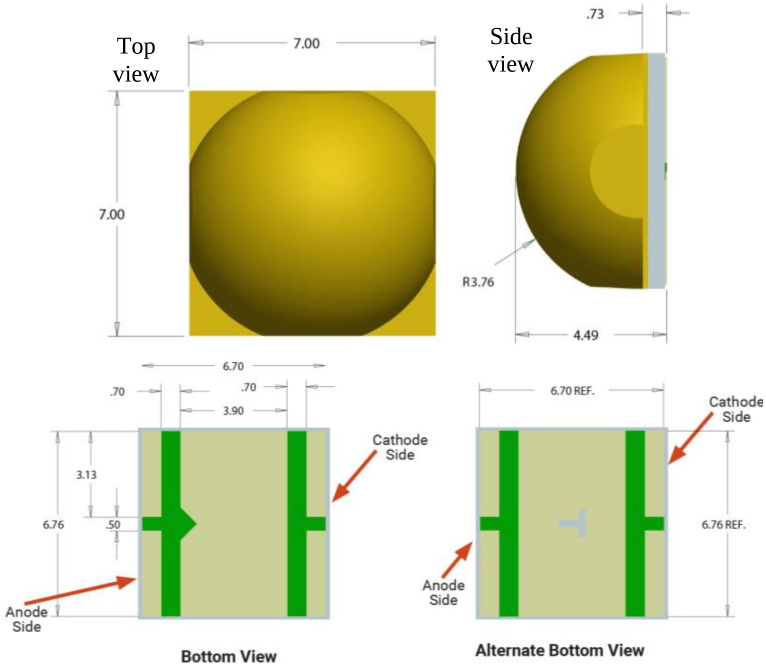


Figure 2. CREE XHP-70 diode.

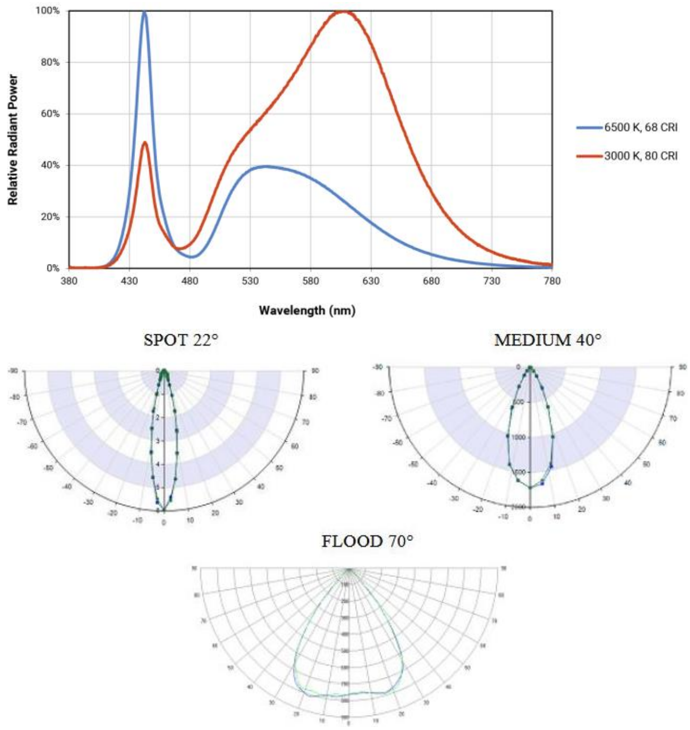


Figure 3. Optical specification and lens options.

FINITE ELEMENT MODEL OF THE LED LIGHT

The finite element method (FEM) is used to analyse the influence of LEDs position on the LED board of the LED industrial light with installed power of 1100 W, on the heat transfer to the passive heatsink. Numerical solutions presented here by FEM, are based on thermal analysis, /3-6/.

To form a finite element model of the structure of LED light of completely realistic geometric shape /7/, it was necessary to draw all its details in 3-D form on the basis of the original documentation (Fig. 4).

a)

b)

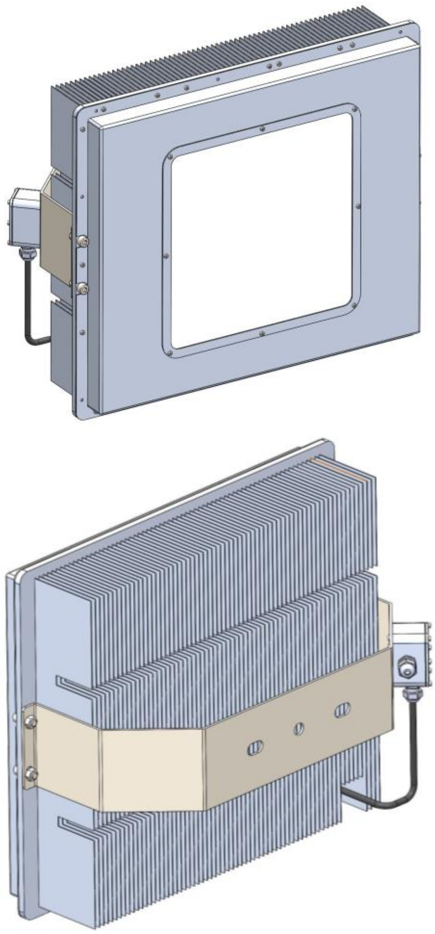


Figure 4. LED light structure.

By synthesizing the presented elements, a 3D model of LED light is formed. It represents a continuum for the formation of a finite element model. The whole continuum is discretized by finite elements of the tetrahedron type.

Figure 5 shows an automatically generated finite element mesh of uniform size of 10 mm with a maximal deviation of 0.5 mm from model geometry. The finite element mesh consists of 354391 finite elements and 704173 nodes.

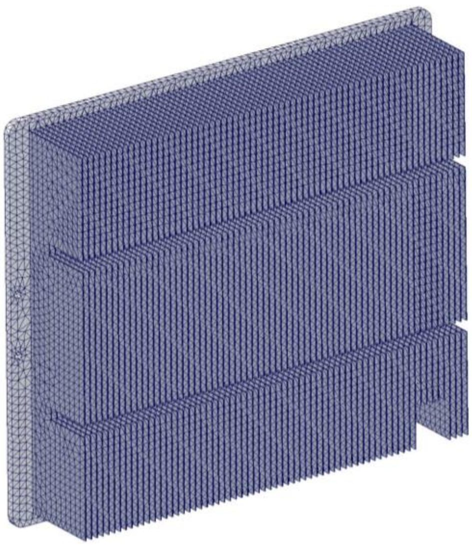


Figure 5. Finite element mesh.

LOAD ANALYSIS

The basic load of LED lights is power (W), which is applied to each of the LEDs of the LED board /8/. For the particular construction of the LED light, there are 52 CREE XHP-70 LEDs on the LED board. Each of the LEDs is loaded with a power of 22 W (Figure 6) /9/. The mentioned load was entered on each LED for the three considered cases (Figure 7), respectively, that is for the three considered LED arrangements on the LED light board:

- First case, removed LEDs from the ends of the board,
- Second case, removed LEDs from the ends and from the middle of the boards,
- Third case, removed LEDs from the middle of the board.

During the specifying of the material in the software package for the finite element method, the value of thermal conductivity for the Al6063 material, which is 201 W/mK, was entered. The parameter that is also set is the ambient temperature in which the light works, 300 K = 27 ° C.

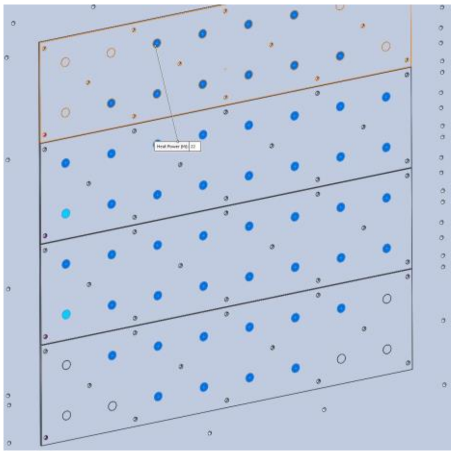
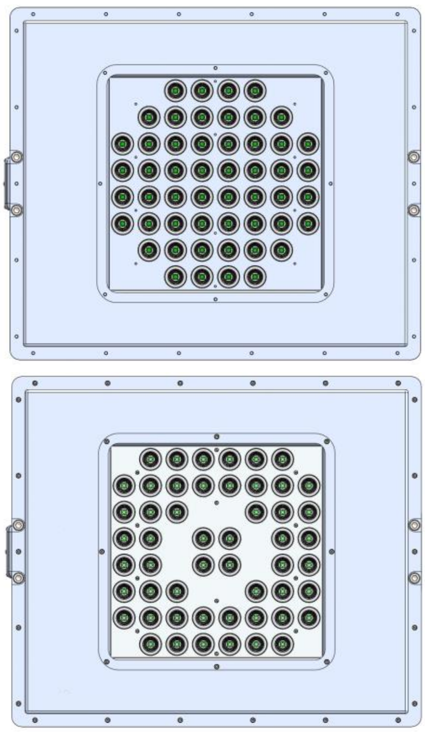


Figure 6. Load input on LEDs

a)

b)



c)

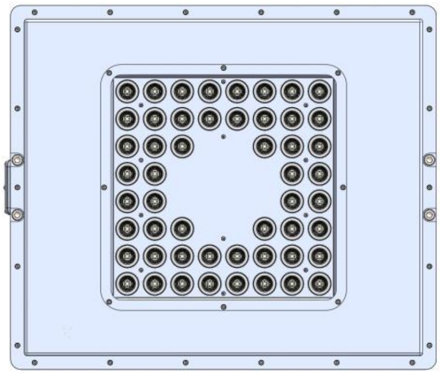


Figure 7. Analysed cases of LEDs arrangement on the board.

RESULTS OVERVIEW

By observing the results of the analysed first case of LED arrangement (Fig. 8) we notice that the temperature at the ends of the light at points 1 to 10 is from 44.2 to 47.4 °C, while at the middle part of the light, at points 11 to 15 the temperature is from 58.5 to 83.9 °C. This temperature distribution on the heatsink is not acceptable for the following reasons:

- uneven temperature distribution on the heatsink, that is a large difference in temperature between the middle of the heatsink and the ends of the heatsink, which is 36.5 °C on the left (difference between points 3 and 13), or 36.7 °C on the right (difference between points 8 and 13);
- LED light enters safety management mode at more frequent intervals (thermal management).

By observing the obtained results of the second analysed case of LED arrangement (Fig. 9) we can notice that the temperature at the ends of the light at points 1 to 10 is from 45.5 to 49.2 °C, while in the middle part of the light, at points 11 to 15 the temperature is from 58.3 to 76.2 °C. This temperature distribution on the heatsink ensures that the LED light works in the first operating mode, maximum power mode, because the temperature in the centre of the heatsink is lower than 80 °C, 76.2 °C to be exact. Further analysis of the obtained results shows that the temperature distribution on the heatsink is not acceptable due to a significant difference in temperature between the middle and the ends of the heatsink, which is 27.3 °C on the left (difference between points 3 and 13), and 27 °C on the right (difference between points 8 and 13).

By observing the obtained results of the third analysed case of LED arrangement (Fig. 10) we notice that the temperature at the ends of the light, at points 1 to 10, is 46.3 to 50.2 °C, while in the middle part of the light, at points 11 to 15 the temperature is 58.4 to 71.8 °C. This temperature distribution on the heatsink ensures the LED light works in the first operating mode, maximum power mode, because the temperature at the centre of the cooler is below 80 °C, actually 71.8 °C to be exact. Further analysis of the obtained results shows that the temperature distribution on the heatsink becomes acceptable due to the reduction of the temperature difference between the middle and the ends of the heatsink, which is 22.8 °C on the left (difference between points 4 and 14) and 23.6 °C on the right (difference between points 9 and 14).

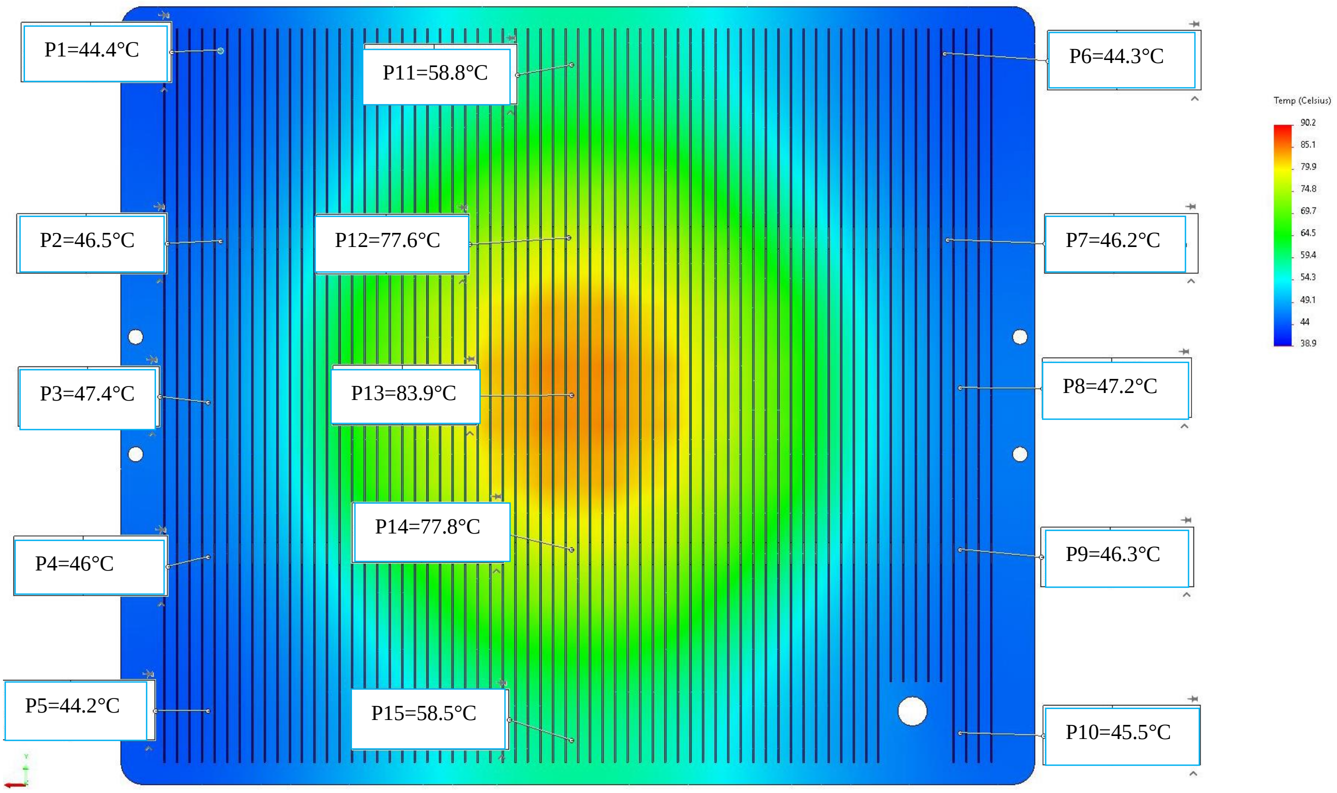


Figure 8. Heatsink temperature distribution field for the first analysed case.

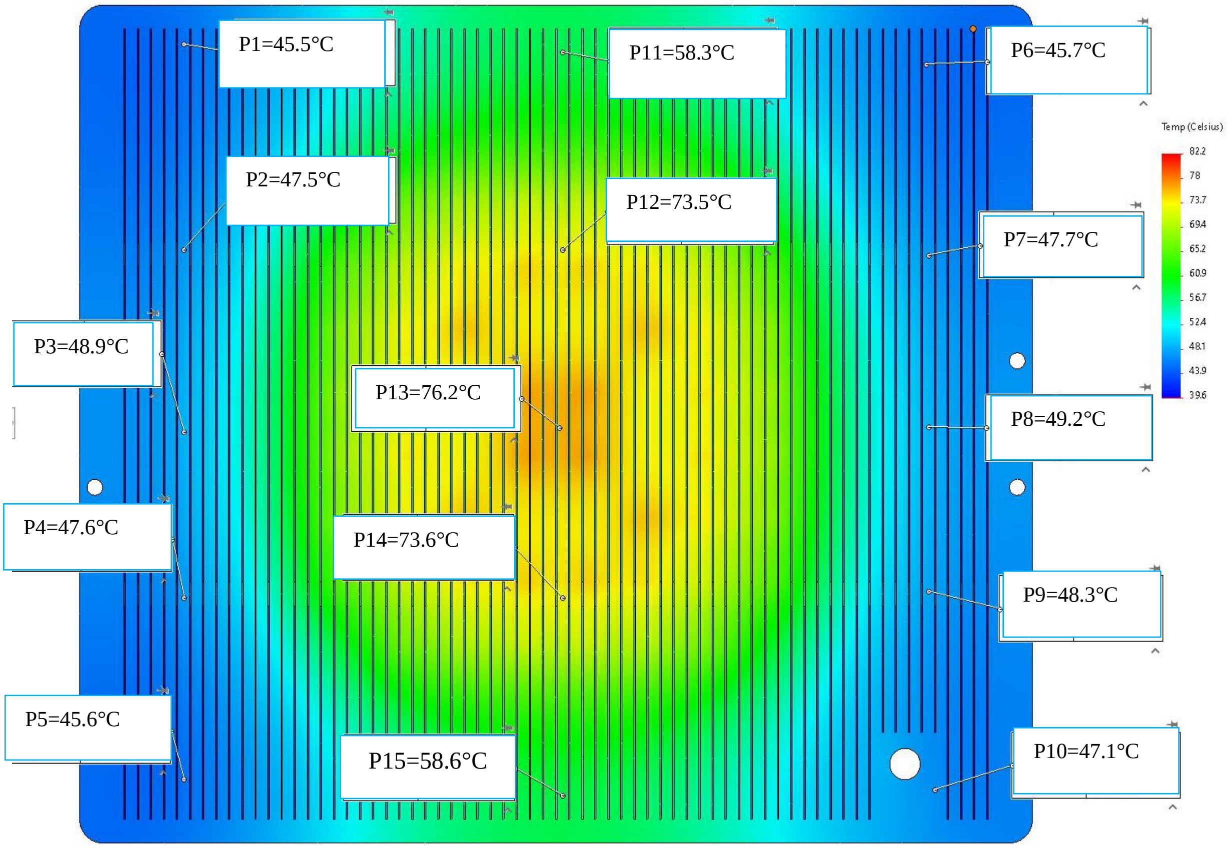


Figure 9. Heatsink temperature distribution field for the second analysed case.

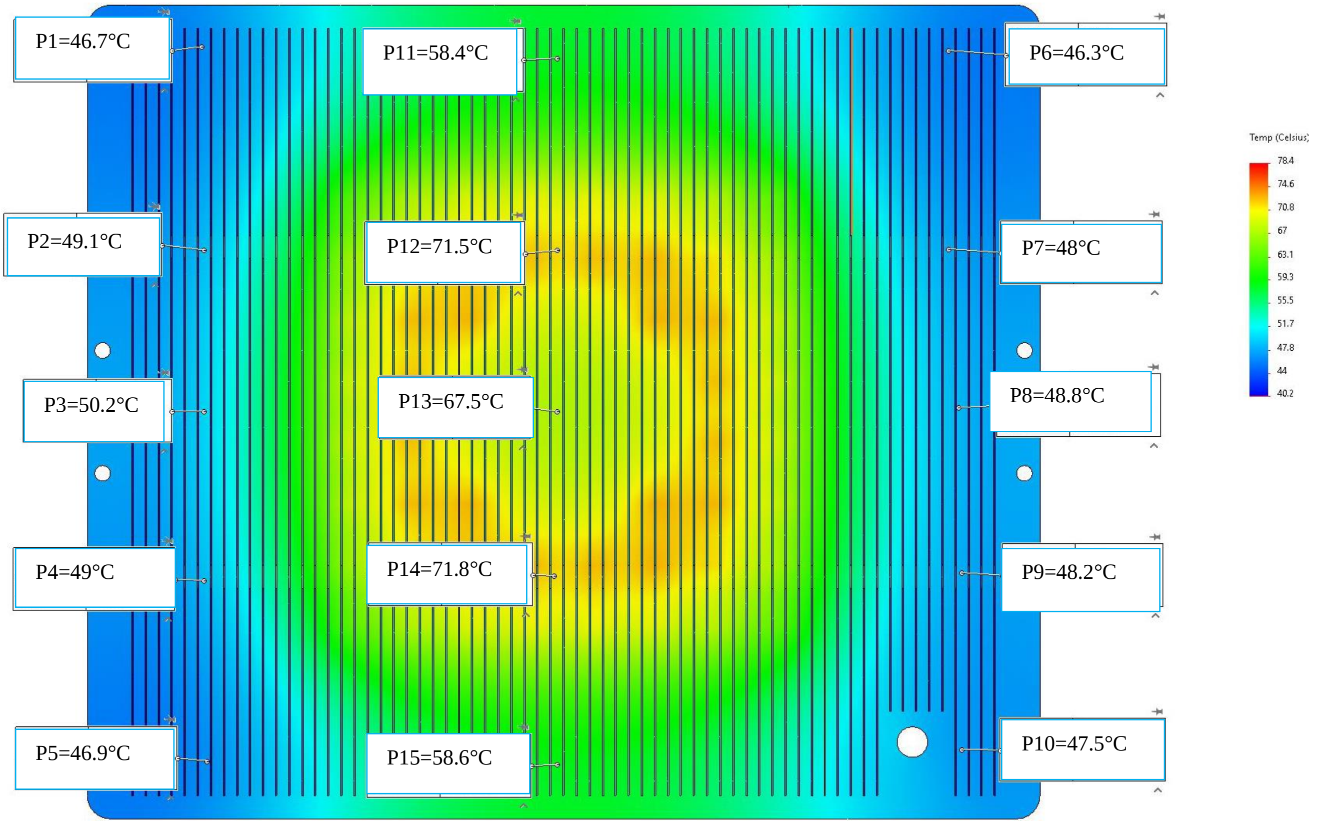


Figure 10. Heatsink temperature distribution field for the third analysed case.

CONCLUSION

The presented paper analyses heat transfer in three considered cases of LED panel industrial light with 1100 W installed power, to the passive heatsink made of material Al6063, dimensions 120×530×620 mm, whose total usable area for heat transfer by convection is P = 7.52 m^2. According to the technical documentation, a 3D model of industrial light LED is created, based on which a finite element model is formed, which is exposed to a basic load of 22 W, applied to each of the 52 LEDs for the considered distribution cases. By analysing the results obtained by applying the scientifically verified finite element method, the zones of highest temperatures are determined for the three analysed cases.

By analysing the obtained results for the first analysed case of LED distribution, a maximal temperature of 83.9 °C in the middle of the heatsink is determined, as well as the uneven temperature distribution on the heatsink, being the large temperature difference between the middle and heatsink ends, at 36.5 °C on the left and 36.7 °C on the right side.

By analysing the obtained results for the second analysed case of LEDs distribution, a maximal temperature of 76.2 °C in the middle of the heatsink is determined, as well as the uneven temperature distribution on the heatsink between the middle and heatsink ends, which is more acceptable than the first case of distribution, which is 27.3 °C on the left and 27 °C on the right side.

By analysing the obtained results for the third and most favourable case of LEDs distribution, a maximal temperature of 71.8 °C in the middle of the heatsink is determined, as well as a more acceptable temperature distribution on the heatsink between the middle and the ends of the heatsink, which is 22.8 °C on the left and 23.6 °C on the right side.

As a result of the presented analysis, and from the determined values of temperature at the observed points of the passive heatsink, the most favourable case of LED distribution on the LED board, the third analysed case of LED distribution, is determined. The above mentioned arrangement of LEDs will ensure proper functioning of the LED industrial light, long lifespan, and use without obstruction.

REFERENCES

1. Kumar, A., Pathania, D.S., Singh, S. (2018), *Thermo-mechanical behaviour of microstretch thermoelastic medium with microtemperatures subjected to input heat source*, Struct. Integ. Life, 18(2): 121-127.
2. Kumar A., Ailawalia, P. (2020), *Thermomechanical analysis of magneto-micropolar solid subjected to thermal laser heat source*, Struct. Integ. Life, 20(2): 176-183.
3. Kumar, N., Thakur, P. (2021), *Thermal behaviour in a rotating disc made of transversely isotropic material with rigid shaft*, Struct. Integ. Life, 21(3): 217-223.
4. Zahaf, S., Dahmane, M., Benkhettab, et al. (2022), *Numerical study of combined effect of fluid and thermal induced free vibration on pipe with supported ends*, Struct. Integ. Life, 22(1): 75-83.
5. EN 573-3: 2009, Aluminium and aluminium alloys - Chemical composition and form of wrought products - Part 3: Chemical composition and form of products.
6. Cree LED, XLamp® XHP70 LEDs, Product family data sheet.
7. Zamani, N.G. (2011), Catia V5 FEA Tutorials - Release 20, SDC Publications.
8. Bathe, K.J. (2016), Finite Element Procedures, 2nd Ed., Printed and distributed by K.J. Bathe, Watertown, MA, USA.
9. Sergent, J.E., Krum, A. (1998), Thermal Management Handbook: For Electronic Assemblies, 1st Ed., McGraw Hill.