Design simulation of nonlinear static 2D and steady state thermal for sustainability downlight casing base

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Abstract. This paper explains the design and simulation of nonlinear static 2D and steady state thermal for sustainability downlight casing base. The main problem in designing of downlight casing base is to ensure the heat transferred to the surrounding while maintaining the quality of light. This study simulates of 6-in casing base downlight and Polycarbonate/acrylonitrile butadiene styrene (PC-ABS) based material. New product design methodology was presented using SolidWorks simulation to represent the phenomena of heat transfer in the downlight casing base at the design stage. The result shows the nonlinear static 2D for main base was achieved. The parameters of materials, dimension, and thickness was contributed in the seamless of heat transferred form casing base to the surrounding at ambient temperature. This practice prevents the quality of light while heat flux as applied to be further study. In addition, the steady state thermal simulation shows significant heat flux and convection changes to every face of casing base parts. Thus, this study is proposed to manage the development of new design relates with nonlinear static 2D and steady state thermal analysis for sustainability downlight casing base.

Keywords: Design, simulation, nonlinear, thermal, downlight casing

1. Introduction

Sustainability in the product design and development has been discussed both researcher and engineer in making better product design. Design simulation has been encountered and proven to study and develop a new product as an economical way. Most of engineers is started to study from hand-sketching, two-dimensional (2D), and three-dimensional (3D) model, prototyping and fabrication. The study of design and simulation using computer aided drawing (CAD) was emphasized to minimize the waiting of time in generating the alternative design.

In the study of design and simulation of electrical parts and devices, most of researchers have been explained the use of simulation to perform thermal analysis. In September 2021, heat loss simulation was presented by applying a coupled-electrical-electrical-thermal modelling to investigate the heat generation and dissipation [1]. A novel device also was introduced to utilize desiccant coating to implement energy and thermal behavior [2]. By using electro-thermal TCAD simulations to study the self-heating effect and behavior and revealed high-electron mobility transistors as a promising technology [3]. This study explained the necessity thermal simulation in implementing the material and found the new technique as an alternative solution.

Applications of CAD software to simulate the product or new product at the design stage have been discussed recently. Computer-generated splints were presented for clinical application using CAD/CAD [4]. CAD and CFD was performed to establish 3D printer reactors to reduce cycle time [5]. Design method was described to solve complex geometry. This method was applied for coherent
structural turbulence model [6]. However, the study was focused on the CAD simulation still gain the knowledge particularly in thermal behavior at early-stage prior making prototype.

When designing the new electrical products, the common issues such as reliability, safety and cost-effective are the main considerations. In other hand, the electrical industry must deliberate the use of visible and manufacturing processes to achieve minimum cost. Therefore, this paper describes the simulation advantage of nonlinear static 2D and steady state thermal to presents design economy during the design stage, so the engineer could perform the significant analysis in designing a new product in the perspective of cost effective and increase the functionality and reliability. In addition, the implementation of this simulation could be as reference for manufacturing industries to attract the customer with low-cost products.

2. Materials and Methods
First stage of this study is selected the design of downlight casing and material selection. The design parameters of downlight casing such as pattern, fillets, shape, thickness, and material selection were studied to the result of heat transfer from base to tip and surrounding.

In this study, 6-in downlight casing base made from polycarbonate/acrylonitrile butadiene styrene (PC-ABS) based material as shown in Figure 1. This material was chosen due to low-cost and easily available in the market. This design was selected due to the most popular downlight casing base in the market.

![Figure 1. 6-in downlight casing](image)

Downlight casing is very important for lighting industries to make sustainable and reliable product. Design engineers must study the material and heat transfer phenomena in downlight casing. The purpose of this practice is for reliability reasons. The heat created by the current through electronic components for specific purposes, such as lighting the room. Material properties for nonlinear 2D static as listed in Table 1. Loads and Fixture was setup 4 edges with fixed geometry type. The material properties were used to define design characteristic for specific purposes. Some properties must identify first, such as model type of simulation, tensile strength, elastic modulus, Poisson’s ratio, mass density and shear modulus. These properties were representative of the design to further study using SolidWorks simulation. In the right column of Table 1 explains the component or part of the design to be selected for simulation study. The surface body in this design were selected as shown model references to apply thermal transferred and applications. ABS PC material was selected to be further study and applied for 6-in downlight casing.
Table 1. Material properties of 2D static simulation

| Model References | Properties             | Components                   |
|------------------|------------------------|-------------------------------|
| Name:            | ABS PC                 | SurfaceBody                  |
| Model type:      | Linear Elastic Isotropic | 1(Fillet6-2)(PS holder02),   |
| Default failure criterion: | Unknown                      | SurfaceBody                  |
| Tensile strength: | 4e+007 N m²            | 2(Fillet6-1)(PS holder02)    |
| Elastic modulus: | 2.41e+009 N m²         |                              |
| Poisson's ratio: | 0.3897                 |                              |
| Mass density:    | 1070 kg m⁻³            |                              |
| Shear modulus:   | 8.622e+008 N m²        |                              |

Material properties for steady state thermal simulation as listed in Table 2. The model reference shows a significant design parameter such as fillets, thickness, patterns, dimension, and shape of downlight casing in solid model.

Table 2. Material properties of thermal simulation

| Model References | Properties             | Components                   |
|------------------|------------------------|-------------------------------|
| Name:            | ABS PC                 | SolidBody                    |
| Model type:      | Linear Elastic Isotropic | 1(Fillet6)(PS holder02)      |
| Default failure criterion: | Unknown                      |                              |
| Thermal conductivity: | 0.2618 W m⁻¹ K⁻¹      |                              |
| Specific heat:   | 1900 J kg⁻¹ K⁻¹        |                              |
| Mass density:    | 1070 kg m⁻³            |                              |

3. Results and Discussion

At the beginning result from nonlinear static 2D simulation, the original model and the model analyzed were presented in Figure 2(a) and 2(b) respectively. A part of 2D was represented of downlight casing base as attached with bulb light.

![Figure 2. Original model and the model analyzed](image-url)

The base model analyzed of current configuration was presented in Figure 3. This figure also shows model information of fillets with 2 criteria the inner and outer of the base. The purpose of this study to predict the strength of plane stress when certain load is applied.
The detail of fillet to study plane stress as listed in Table 3 that represents 2D bodies references, inclusive section deptm weight, volume, mass, and density. Volumetric propertis for fillets were indentified and plain stress of study type was applied in this simulation.

| Document Name and Reference | Study type | Volumetric Properties |
|-----------------------------|------------|-----------------------|
| Fillet6-2                   | Plain Stress | Section depth: 0.5 mm  
Weight: 0.000469304 N  
Volume: 4.47097 x 10^{-8} m$^3$  
Mass: 4.78394 x 10^{-5} kg  
Density: 1070 kg m$^{-3}$ |
| Fillet6-1                   | Plain Stress | Section depth: 0.5 mm  
Weight: 0.000362726 N  
Volume: 3.45562 x 10^{-8} m$^3$  
Mass: 3.69751 x 10^{-5} kg  
Density: 1070 kg m$^{-3}$ |

By applying nonlinear-static 2D simplification, with planar 2D mesh type, auto stepping, include temperature loads, the simulation results as depicted in Figure 4.

Figure 5 shows the similar pattern in describing the simulation results for nonlinear static 2D. Figure 5(a) defines the planar 2D mesh with standard mesh were applied. It was informed that element size and tolerance of mesh was 0.503638 mm and 0.0251819, respectively. It was presented the total nodes and total elements were achieved at 2606 and 1235, respectively. Figure 5(b) the expected results of
nonlinear nodal stress, displacement, and total strain were found at the high of factor safety, when the base was applied the load 1N to 10N. It is found that the downlight casing base withstand with the given load.

![Planar 2D mesh](image1)

![Nodal stress, displacement, and total strain](image2)

**Figure 5.** Simulation result for nonlinear static 2D

Table 4 lists the thermal load simulation with mode heat flux and convection. For heat flux was applied 1 face in casing base as shown in load image where the heat power was started at that point. For the study of convection, 2 faces were selected to ensure heat comes from casing base to the tip and surrounding. As part of heat transfer behavior, convection coefficient was applied in this simulation was achieved with value of 100 W m⁻² K⁻¹.

| Load name     | Load Image | Load detail                        |
|---------------|------------|------------------------------------|
| Heat Flux-1   | ![Heat Flux Image](image3) | Entities: 1 face(s)  
               | Heat Flux Value: 200 W m⁻² |
| Convection-1  | ![Convection Image](image4) | Entities: 2 face(s)  
               | Convection Coefficient: 100 W m⁻² K⁻¹ |
               |             | Time variation: Off  
               | Temperature variation: Off |
               |             | Time variation: Off |

In presenting the thermal analysis, the model was applied solid and standard mesh type. It was used Jacobian points of 4 with element size and tolerance were defined as 1.43076 mm and 0.07153832 mm, respectively. Based on the simulation results also presented the total nodes and total elements were achieved with the value of 21285 and 11613, respectively. The mesh result also shows the number of maximum aspect ratio with 18.87.
Figure 6 shows the simulation result for steady state thermal with different views. It is found that the material selected achieved the goal to transfer heat seamless to the surrounding with ambient temperature. Heat flux result shows, the PC-ABS material withstand and distribute the heat from the base to the tip or outer surface significantly.

![Figure 6. Simulation result for steady state thermal](image)

The contribution of this research is to study the phenomena of thermal behavior using CAD simulation. After several simulations have been made for steady state thermal, the 6-in downlight casing base using PC-ABS has made significant lead sustainability, reliability, and safety for further prototyping. The design parameters of downlight casing such as pattern, fillets, shape, thickness, and material selection influence the effect of heat transfer from base to surrounding. It depicts, 6-in downlight performs lighting at maximum level and sustain with heat flux achieved with value of 200 W m\(^{-2}\). In addition, the casing base sustained the maximum load and thermal load as a result from material selection and specified design parameters.

4. Conclusion
The design and simulation of nonlinear static 2D and steady state thermal analysis for 6-in downlight casing base was presented. Based on the simulation result, PC-ABS material withstands when specific loads were applied from 1 N to 10N. By applying heat flux and convection to the downlight casing based, the material selected also significant reliable and constantly deliver the heat from the base to the tip and surrounding.

Design parameters pattern, fillets, shape, thickness, and material selection of downlight casing influences the performance of lighting and lead sustainability of the product. It is proposed to fabricate the 6-in downlight casing base with PC-ABS to comply cost effective and safety. This study performs 6-in downlight casing with PC-ABS material to be potential as a sustainable product.

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