DESIGN OF AN AUTOMOTIVE HEADLAMP CONSIDERING STYLE AND PERFOMANCE

***Tom K. Philip, M. Sivapragasam, Vignesh Ravichandran**

Department of Automotive and Aeronautical Engineering

M. S. Ramaiah School of Advanced Studies, Bangalore-58

*Contact Author e-mail: tomkphilip@gmail.com

Abstract

Headlamps serve the purpose of an eye to an automobile both in style and function. They illuminate the road space in front of the automobile and ensure the dual purpose of to see and to be seen. The aim of this project was to design an automotive headlamp considering style and performance.

A study of various headlamps designs available is made to understand the basic requirements of a headlamp and to understand the latest technologies being used inside the headlamp. The standard norms that need to be followed in design and installation were reviewed. A user study was conducted and customer voice was converted into technical voice and QFD was prepared.

Three concept designs of headlamps were made and the final concept is selected using weighted ranking method. A detail design is made for the final selected concept. The finalised design concept is further validated using photometric and thermal analysis. A mock-up model is also made for the validated concept using polymer sheets. A better styled and better performing headlamp was designed.

Keywords: Automotive headlamps, Aesthetics, Headlamp standards, Photometric analysis, Thermal analysis, Mock-up.

Abbreviations

AIS	Acrylonitrile Butadiene Styrene
CAD	Computer Aided Design
CFD	Computational Fluid Dynamics
QFD	Quality Function Deployment
PDS	Product Data Specification
PU	Polyurethane
LED	Light emitting diode

1. INTRODUCTION

Automotive headlamp is one of the major styling parts and also in current days it is one of the technology-driven parts of a vehicle. It is mounted in front of the vehicle to illuminate the road during night time or low visibility.

In order to cater to various customers in various countries, according to their specifications, it is necessary to supply the products with high quality and better performance to meet their expectations in short time cost effectively.

Design and development of automotive headlamp in a systematic manner by considering post-failures can avoid as much as modification costs and rejection costs as possible and can meet customer requirements.

Automotive lighting is classified in two categories, to see and to be seen. Headlamps such as low beam, high beam are meant for 'to see'. Signal lamps such as stop lamp, direction indictors etc., are meant 'to be seen'.

1.1 Functions of headlamp

Headlamps illuminate the road space in front of the car and must meet the requirements of all users of the road. In particular, the low-beam functions are subject to legal regulations designed to protect oncoming traffic from being dazzled.

1.2 Signal function lamps

Signal lamps also called as rear lamps are used for providing various signals to the road users as the driver is applying brake, turning left or right, parking, indicate position of the vehicle or hazard warning during emergency situations and breakdown etc.

2. BACKGROUND STUDY

The main functions and the various requirements for the installation and performance for the headlamp were evaluated in the background study of the headlamp, for example, as in Figure 1. These studies were later used to do a detailed literature review about the headlamp.

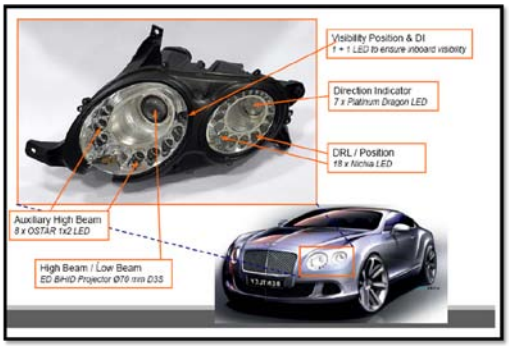

Fig. 1 Major functions of headlamp [1]

2.1 Low beam

The low beam (see Figure 2) is intended for use whenever other vehicles are present ahead. The automotive industrial standard AIS 012 specify a beam with a sharp, asymmetric cutoff preventing significant amounts of light from being cast into the eyes of drivers of preceding or oncoming cars.

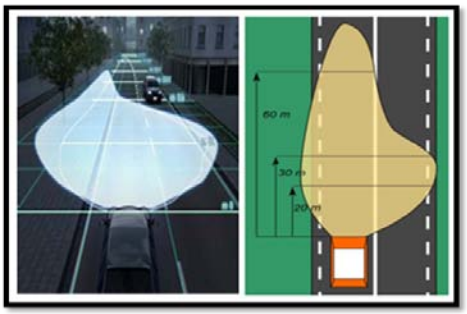

Fig. 2 View of low beam on road [2]

2.2 High beam

High beam (also called as main beam) (Figure 3) headlamps provide a bright, centre-weighted distribution of light with no particular control of light directed towards other road users' eyes. As such, they are only suitable for use when alone on the road or on the median highways, as the glare they produce will dazzle other drivers.

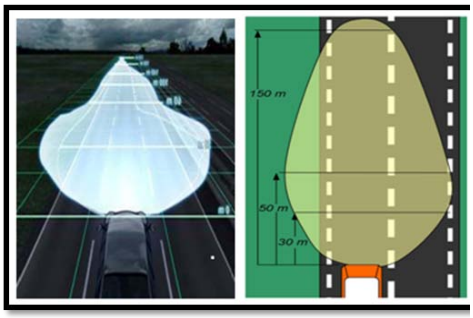

Fig. 3 View of high beam on road [2]

3. LITERATURE REVIEW

A review of the literature was conducted to understand the importance of headlamp on the design perspective of cars. Also a study was conducted to understand how to improve the light output performance of the headlamp. Further an understanding of how to improve the thermal endurance of the headlamp was also achieved. Details of these studies are illustrated in the literature review of the headlamp.

3.1 Summary of Literature Review

- Sivak *et al*. [3] studied the quantitative comparisons of factors influencing the performance of low-beam headlamps. The factors included were vertical aim, horizontal aim, mounting height, lateral separation, lens dirt, lamp voltage, and number of functioning lamps, vehicle type, beam pattern and light source.
- The flow of air inside the headlamp is mainly due to natural convection. This is forced by the heat that is being transmitted from the heating bulb. The bulb heats the surrounding air which rises and the new colder air enters the headlamp through the vents designed in the bottom of the headlamp [4].
- Touichirou and Masatoshi [5] conducted thermal analysis on the flow inside an automotive headlamp. Surface heat transfer method was used for making an accurate estimate of temperature and velocity in the automotive headlamp.
- Mieleke [6] conducted an investigation on the temperature simulation inside an automotive headlamp. It was concluded that for the temperature transport all the three heat transfer mechanisms, namely conduction, convection and radiation are important. The study also shows that the current method of analysis is robust enough and delivers necessary accuracy.

4. PROBLEM DEFINITION

To design an automotive headlamp taking into consideration style, photometric output and thermal endurance.

4.1 Project Objectives

- To carry out a literature review on car headlamps and understand the latest trends, present practices and collect relevant data.
- To carry out a user study and generate Quality Function Deployment (QFD) to understand the issues related to current headlamps and arrive at Product Data Specification (PDS).
- To generate concepts for the headlamp and arrive at the final concept.
- To design the final concept model in ALIAS and CATIAV5.
- To perform photometric analysis for the high beam and low beam functions of the headlamp.
- To conduct a Computational Fluid Dynamic (CFD) analysis for the headlamp to and understand the heat transfer and flow inside the headlamp.

To make a mock up model of the proposed design.

4.2 Project Methodology

- Conducted literature review about different types of headlamps available in the market with references from books, journals, patents, company catalogues and websites.
- Conducted QFD based on identified needs and arrived at target PDS.
- Three concept designs were generated using hand sketches and were modelled with detailed features using software such as ALIAS Studio tools, CATIA V5, Adobe Photoshop.
- Rendering of the headlamp was done using the software KEYSHOT.
- Concept evaluation for selecting the final concept was carried out by weighted-ranking method.
- Light output efficiency and the following of norms were ensured using LUCID SHAPE software.
- Thermal analysis of the headlamp was done using FLUENT software.
- Mock up model of headlamp was made in design studio.

5. DATA COLLECTION, ANALYSIS & PDS

5.1 User Study

User survey was carried out to understand the user's response about the aesthetics and performance about the headlamp. To serve this purpose, a questionnaire was prepared and the same was circulated for study amongst various car drivers; a collage of such interactions is depicted in Figure 4.

Fig. 4 User study

After the user study from the feedback the main concerns of users on the headlamp are listed as follows

- Style and appearance
- Better night visibility
- Long life
- Less maintenance
- Less glare complaints
- Less dust accumulation
- Less scratches on outer lens
- Cost effective in after market

5.2 Quality Function Deployment

Quality Function Deployment (QFD) has been derived by converting customer voice into technical voice. Attributes are prioritised and ratings are given in order to define the relations between them. Higher priority elements are listed in QFD analysis chart as shown in Figure 5. The relationships between technical voice parameters are also rated at the top of the matrix. The sums of each rating were computed and the technical attributes which are to be given more emphasis was formulated by analysis as in Figure 6.

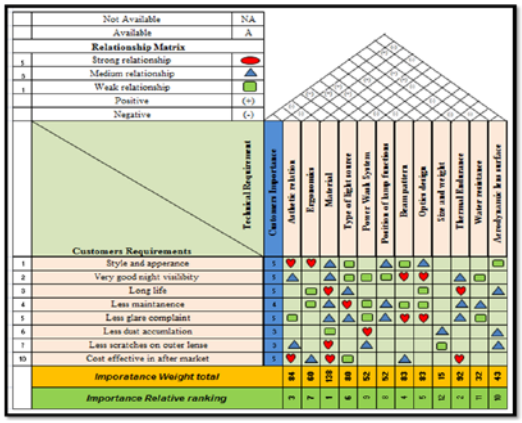

Fig. 5 Quality Function Deployment (QFD)

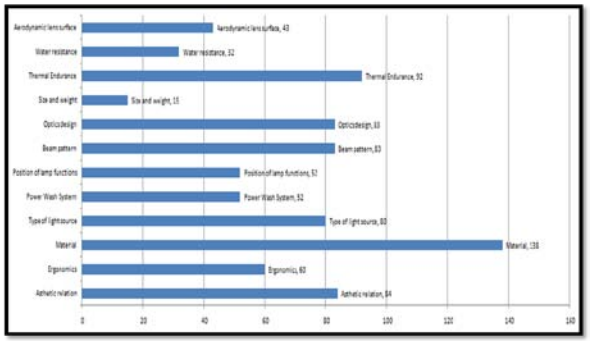

Fig. 6 QFD Analysis

5.3 Product Design Specifications

Product Design Specification (PDS) compiles various requirements that have to be included in the product. This can very well ensure that the user's aspirations are fulfilled.

The PDS shows all those technical details that needs to be considered with regard to the QFD. The parameters that are needed for the development of the headlamp were plotted and the specifications for those parameters are identified in the PDS sheet in Table 1.

Table 1. Product Data Specifications

Product design Specification			
Sl no	Parameter	Specification	
1	Beam Pattern	High beam	
		Low beam	
		Day time running light	
		Cornering light	
2	Type of reflection	Reflector Type	
		Projector Type	
3	Colour of Light Emitted	White	
		Seletive Yellow	
		Red	
		Amber	
4	Geometric Visibilty	Inward Angle Visibilty	45 degrees inboard (as per AIS 008)
		Outward Angle visibilty	80 degrees outboard (as per AIS 008)
5	Width	Edge of the apparent surface to be maximum 400 mm away from the outer most edge	
6	Height from the ground	>500 mm when measured from the lowest point	
		<1200 mm when measure from the highest point	
	Individual Specification		
7	High beam	Presence	Mandartoy
		Number	2
		Length	No discomfort on the rear view mirror
		Maximum Intensity	2,25,000 cd
8	Low beam	Presence	Mandartoy
		Number	2
		Length	No discomfort on the rear view mirror
		Maximum Intensity	AS per AIS 012
9	Optical output		As per AIS 012

6. CONCEPT GENERATION

Concept generation is one of the vital parts in development of any successful product. Hence, one has to consider various factors identified from collected data such as literature survey, product study, market study, user study and trend study. These concepts have been further fine tuned to shortlist three among them for development in 3D CAD software CATIA V5.

6.1 Design Inspired by Nature

For the concept generation of headlamp design an inspiration of form generation was required. Headlamps at many occasions follow the form of the vehicle. At many occasions the headlamp forms represents the emotions to the entire car. So, for the concept of form generation the consideration of eyes was taken for representing the emotions as illustrated in Figure 7.

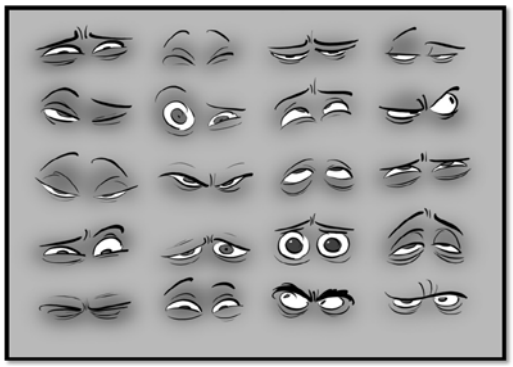

Fig. 7 Inspiration board [7]

6.2 Concept Generation

Concept sketches were generated from the derived PDS and visual elements. Some of the doodles are selected and further developed for better interpretation and fine tuning. Also eye patterns from nature (as in Figure 8) were taken as motivation for the headlamp concept generation.

Fig. 8 Eye patterns from nature

6.3 Concept 1

The devil's eye was considered as metaphor. Form for the concept was generated from the image of devils eye as in Figure 9.

The first concept is planned to have the following features

- A standard module which ensures low beam functions
- The light guide function for the high beam representation
- Takes the design intent of devil's eye

6.3.1 Disadvantages of Concept 1

- It was identified that the light output from the light guide will not be enough for the high beam function
- Lot of empty spaces were found in the lamp design which made the lamp aesthetically undesirable.

6.4 Concept 2

Second concept was planned with the following features, also as shown in Figure 10.

- Standard modules to achieve the multiple functions of high beam, low beam, daytime running lamps and side marker lamps.
- More functions could be added to headlamp and could be produced from the headlamp function itself.

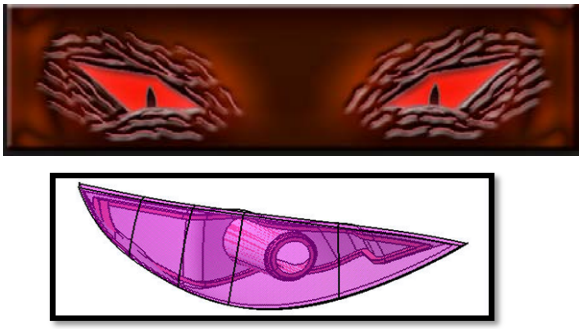

Fig. 9 Concept 1

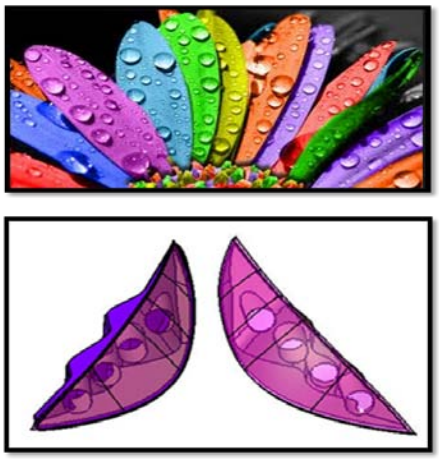

Fig. 10 Concept 2

6.4.1 Disadvantages of Concept 2

The main disadvantages identified with this concept were

- More number of sources were identified to create difficulties in achieving the light cut off.
- Standard modules were not available at the dimensions of design consideration.

6.5 Concept 3

In the concept three, the main functions of high beam and low beam were considered. High beam was considered to be from the reflector bulb concept and the low beam function was considered from the standard low beam module. Flying wings of an eagle was taken as metaphor; see Figure 11.

6.6 Concept Selection

Weighted ranking method was used to select the final concept for detailing. From the three concepts designed, the final concept was selected as illustrated in Figure 12.

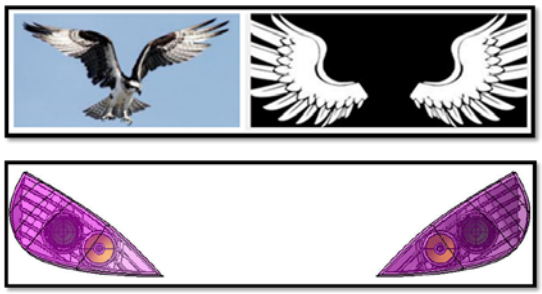

Fig. 11 Concept 3

Concept Scoring		Concept 1		Concept 2		Concept 3	
Criteria	Weightage	Rating	Score	Rating	Score	Rating	Score
Aesthetics	30%	3	10	3.0	10.0	4.0	13.3
Efficiency	30%	3	10	4.0	13.3	5.0	16.7
Functions	30%	3	10	5.0	16.7	4.0	13.3
Reliability	10%	2	20	2.0	20.0	2.0	20.0
Score summary	50			60.0		63.3	

Fig. 12 Weighted ranking method

7. MOELLING AND VALIDATION

Product detailing has been done for the final concept selected considering manufacturability aspects and dimensional details. All the sub parts and sub assemblies in final concept are analysed to understand its manufacturing process, its function and assembly sequence.

7.1 Detail Design

Exploded view of designed headlamp, as shown in Figure 13, has been captured for better understanding of assembly sequence. Major components are top cover, base cover, side covers, thermal printer, touch screen unit, receiver unit and power adapter. Some of the sub assemblies are readymade electronic units available in market.

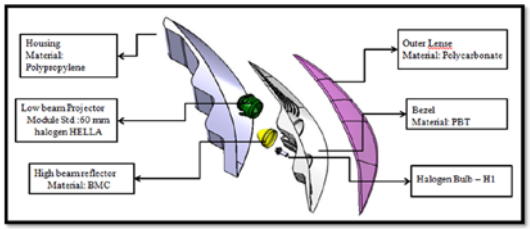

Fig. 13 Exploded view of headlamp

7.2 Design Validation

Photometric analysis and thermal analysis of the designed headlamp was carried out to ensure validation of the detailed final design of the headlamp.

7.2.1 Photometric analysis

The photometric output requirements of the headlamp as per AIS 012 restricts the amount of light at certain angular location above the horizontal and just right of the centre of the beam pattern for the low beam. They also specify a minimum amount of light directly ahead and just below the horizontal plane of the headlamp. This is being done to ensure long vision in night and to avoid glare on the oncoming traffic. The designed headlamp is being validated using the optics designing software LUCID SHAPE to ensure that the AIS standard is met.

Reflector type design was planned for the high beam.A geometric model was designed to provide as input for the LUCID SHAPE software for the light output evaluation. Iterations were made considering the focal distance of 25 mm from the centre of the reflector. The contours of light intensity on a target wall 25 m from the source, as shown in Figure 14, were evaluated to be as per the AIS standard.

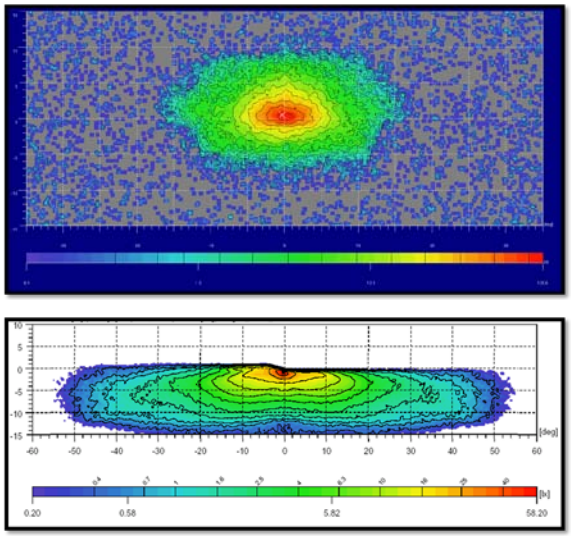

Fig. 14 Photometric analysis

7.2.2 Thermal analysis

The thermal analysis of the design data was done to ensure that the designed headlamp is thermally stable. In order to carry out the thermal analysis a simplified computational model was generated to avoid the geometric complexities. Radiation was accounted by discrete ordinate representation

- Radiation heat transfer analysis was performed
- Maximum temperature inside the headlamp was found be close of 722 °C which was observed on the surface of the bulbs
- On the high beam reflector the temperature was found to be close to 350 °C
- Maximum temperature of 120 °C was observed on the outer lens

The temperature contours on the bulb surfaces are shown in Figure 15.

7.3 Mock up Model

Mock up model was made for the final concept in 1:1 scale. Tools used for model works are carving tools, drilling machine, steel rule, cutter, hammer, spray painting unit, belt grinder, hacksaw, chisel, compass and scissors. Model has been made in number of steps such as roughing of outer block, carving of the profiles, grooves and cut outs, additional features, finishing and painting stage, as illustrated in the sequence in Figure 16. These templates were cut from thin plastic sheets.

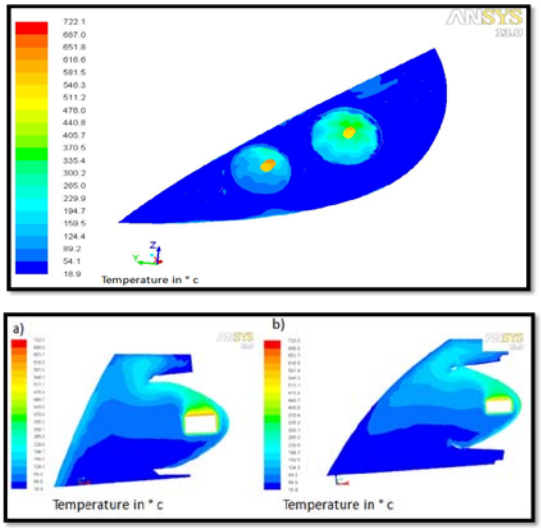

Fig. 15 Results from thermal analysis

Fig. 16 Final mock up model

Final mock up model has all the intricate details as it was rendered in 3D software.

8. CONCLUSION AND FUTURE WORKS

8.1 Summary

Summary of work reported in this paper are listed below

- Study about the headlamps and a literature review on different types and functions of headlamp were made
- A user study was carried out understand the various problems of headlamps in market.
- Questionnaire was prepared to collect information from car drivers.
- Depending on the above survey customer voice and technical voice were determined and QFD was prepared.
- PDS was generated based on the prioritized features from the QFD.
- Three concepts were generated based on the QFD and one was selected as final based on weighted-ranking method.
- Product validation was done using photometric and thermal analysis
- The mock-up model of the final concept was made.

8.2 Conclusion

This project was aimed at designing an automotive headlamp considering style and performance. It was concluded that a headlamp design considering better style and performance could be done.

- Headlamp design was done considering better style and performance
- Photometric output was ensured for the proposed design
- It was ensured that the design proposed was thermally stable
- A mock up model for the proposed design was made at 1:1 scale.

8.3 Recommendations for future work

Night vision is ensured by headlamp in an automobile. Glare on the incoming vehicles is the major issue with headlamps. Proper optical design would ensure that this glare is avoided. Some of the recommendations for the future work are as follows.

- Addition of more functions into the headlamp like side indicators and day running lights
- Addition of latest technology like Light Emitting Diodes for even the main functions
- Detailed thermal analysis considering the headlamp venting and to consider condensation inside the headlamp.

9. REFERENCES

[1] Unknown, *The new Bentley Continental GT - Car Body Design,* http://www.carbodydesign.com/archive/2010/09/bentley-continental-gt/, Retrieved on 11th Oct. 2012.

[2] Hella, *Headlamps and headlamp modules,* www.hella.com/hella-com/620.html?rdeLocaleAttr=en, Retrieved on 07th Jan. 2013.

[3] Sivak, M., Quantitative comparisons of factors influencing the perfomance of low beam headlamps, http://lrt.sagepub.com/content/31/4/145.short, Retrieved on 24 Jan. 2013.

[4] Brunberg, J., Aspelin, M., *CFD modelling of headlamp condensation*, Master Thesis, Chalmers University of Technology, 2011.

[5] Touichirou, S., Masatoshi, Y., *Thermal air flow analysis of an automotive headlamp,* 2013.