Development of Automobile Light Guide for Lighting Image Enhancement Using Retro-Reflection Principle

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Abstract. In recent years, most automobile manufacturers have been using slim light source images to imprint brand images. A light guide type lamp is widely used for a slim light source image. A light guide lamp uses a LED light source at one end of a long cylindrical pipe. The light from the LED light source moves through the pipe by total reflection principle. Moving light is moved forward by applying various optic structures in the cylinder to emit light.

However, the light guide lamp has a problem that the image of the light differs depending on the viewing direction, and in some cases there is a dark section.

In this paper, trying to improve the fundamental problems of the light guide mentioned above by using various TRIZ methods. Through functional modeling, estimating the factors affecting the light in the light guide lamp and make various ideas to improve the lighting image using the chain effect cause analysis, clone problem, scientific database techniques.

Using various TRIZ techniques, finally find solutions that can improve the brightness and lighting uniformity of the light guide lamp. The ideas obtained in this paper were applied to actual vehicle development, and several patents achievements were obtained.

In conclusion, we can see that the TRIZ method is useful for making ideas in the actual automobile industrial field and is also a useful method for acquiring patents.

Keywords: Retro-Reflection. Light Guide, TRIZ, Chain Effect Cause Analysis .

1 Introduction

In recent years, automobile makers have used lamps to illuminate various lines and surfaces to emphasize the identity of each company. In order to make such a lighting image, a light guide lamp which uses an LED light source at the starting point of the lighting region and then sends the light to the end point of the lighting region through the total reflection principle is used in various models.

Fig.1. Light Guide Lamp Used in Various Models.

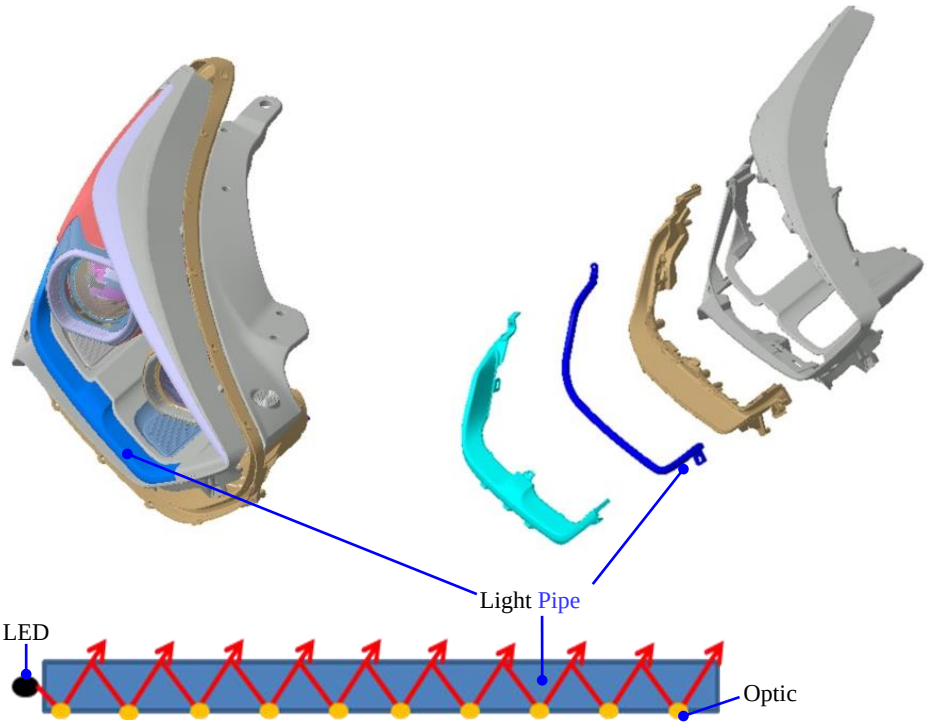


Fig. 2. Light Guide Lamp.

Here, the light guide means the entire optical system which composed of inner lens, light pipe, optic, back cover. A light pipe refers to a single piece of a circular pipe that is a path through which light is totally reflected, and it is just one component in light guide optical system.

However, the light guide lamp has a problem that the image of the light differs depending on the viewing direction, and in some cases there is a dark section.

In this paper, we analyze the factors that may cause the light guide lighting image defects and find out the main causes and make solutions using TRIZ techniques.

2 Finding Solution to Enhance Lighting Image of Light Guide

2.1 Analysis of Lighting Effect Factor

As shown in the figure below, TRIZ function Analysis is used to infer problem factors that can affect the direction of light guide light travel.

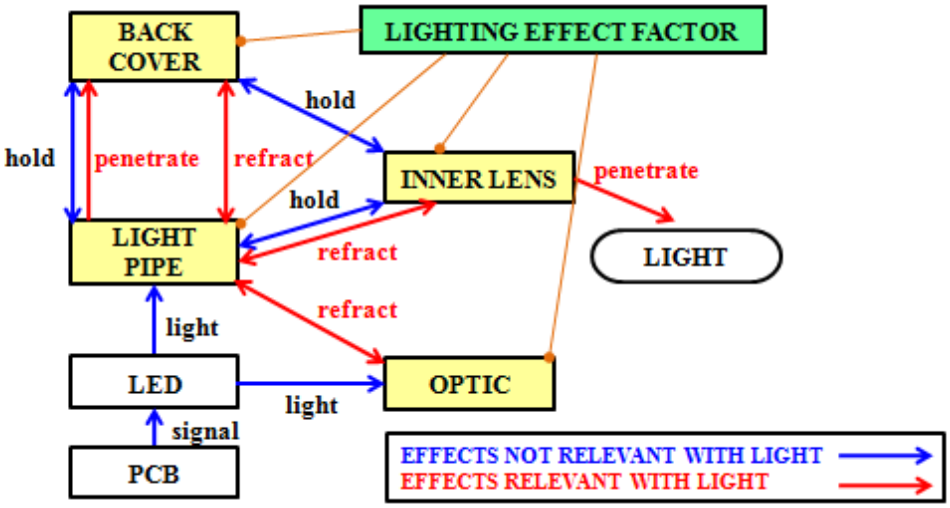


Fig.3. Light Guide TRIZ Functional Analysis

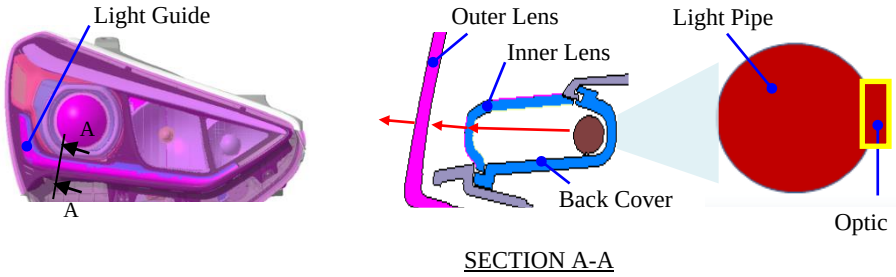


Fig.4. Lighting Affect Factor

When reversing-track the light coming from the lamp, light passes through the outer lens first, but the outer lens is made based on the design skin data, so excluding it from the factor analysis. With the exception of the outer lens, the light is first transmitted through the inner lens, and the light to the inner lens which is moving within the light pipe is refracted forward by the OPTIC structure. Most fundamentally, the light going to the light pipe is produced by the LED. LEDs were also excluded from factor analysis because the types used for each vehicle are uniform. Light pipe, optic, back cover, and inner lens are the main factors influencing the direction of light using TRIZ functional modeling.

2.2 Competitive Car Comparison

The main factors influencing the lighting image were compared with the competition model. I select the factors that can bring about the greatest improvement in lighting image enhancement by using comparing process.

As a result of comparing the competitive car, it was found that there were differences in the back cover and the light pipe among the influence factors of lighting image.

It is confirmed that 1mm size optic structure is applied to back cover in some AUDI models. In Hyundai Motors, it is confirmed that there is no mass-produced model with optic structure at back cover.

In the case of light pipe, it was confirmed that the optic structure was minimized and raising the draft angle to collect light from the competitor's front lamp.

2.3 Ideas Using TRIZ Chain Effect Cause Analysis Technique

Based on the analysis of the lighting affect factor and the results of the comparing with competitive car, making the idea of improving the light guide lighting image

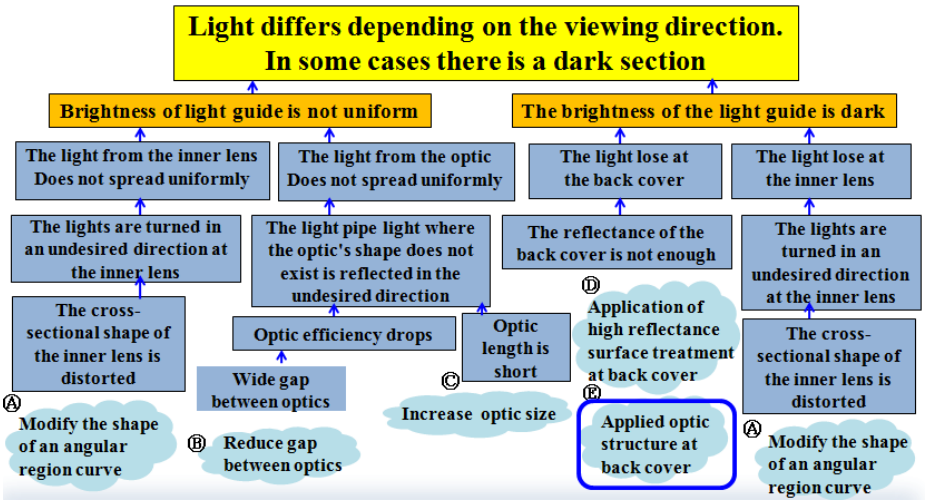


Fig.5. Making Ideas Using TRIZ Chain Effect Cause Analysis Technique

Using the TRIZ CECA method, six ideas from A to F were made. Among them, we analyze ideas E and F. Because back cover is different lighting affect factor from competitive analysis. However, in the case of application of surface treatment with a high reflectivity corresponding to E, it is an idea item that is actually verified, so it is excluded from this paper.

Until now, elements such as inner lens, light pipe, and optic have changed a lot and optimization work has been done very much. However, the design of the back cover has not been changed so far.

In addition, it is confirmed that there are many functions that affect the movement of light in the back cover. We can confirm that in the functional modeling. The light from the light pipe comes to the back cover, and the back cover has the function to refract the light and send it to the light pipe. It is easy to understand by referring to the functional modeling below.

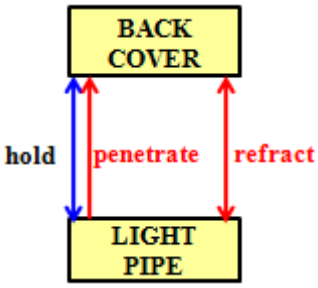


Fig.6. Light Guide TRIZ Functional Analysis about Back Cover and Light Pipe

Note that applying aluminum deposition with a higher reflectance than the white paint on the back cover has better effects on the brightness of the light, but the light guide darkens when the light is not on and the hot spot phenomenon when light occurs.

Therefore, final idea was decided by application of back cover optical optic applicable to idea F.

2.4 Ideas Making Using TRIZ Clone Problem Technique

For the back cover, the optical optic structure using the reflex reflection principle is applied. Various signals written on the road surface, uniform of the cleaners, road signs, etc., commonly use a reflex reflection principle in which light is returned in the direction in which light is turned on. In the figure below, the use case of the reflex reflection principle is attached

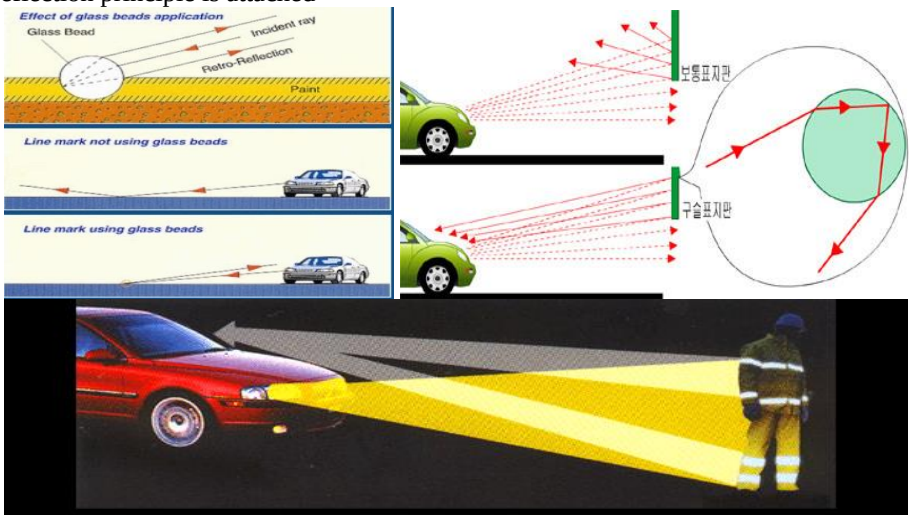


Fig.7 Application of Retro-Reflection Principle

Define the hypothesis that the application of the reflex reflection principle to the light guide back cover improves the brightness and uniformity of the light by returning the diffused light back to the front direction.

2.5 Idea Verification Using Simulation

Confirm the effect of retro reflective optics on the back cover of the vehicle under development.

Table 1. Lumen Value Simulation of Application of Retro-Reflective Optic

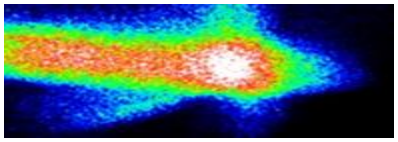
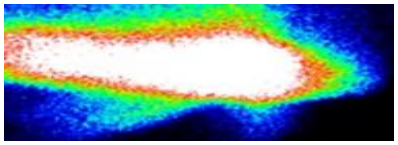
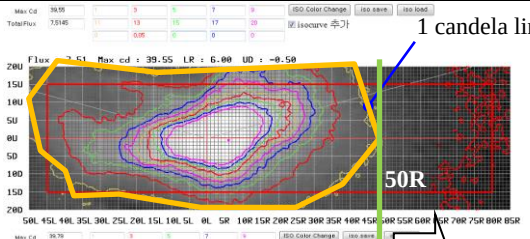
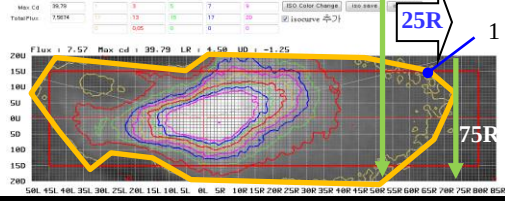
Option	Simulation Result
No Backcover Optic	 22.5 Lumen
Add Backcover Optic	 25 Lumen

Table 2. 25m Screen Simulation of Application of Retro-Reflective Optic

Option	Simulation Result
No Backcover Optic	
Add Backcover Optic	

As a result of simulation, lumen value was changed from 22.5 to 25, which means an improvement of about 11%.

Also, it was improved 0.06 lm value of total luminous flux when applying back cover retro reflective optics in 25m screen light regulation area. Before applying the optic, it had a light intensity of 7.51 lm, but after applying the optic, the total light intensity was increased to 7.56 lm.

Moreover, more light was emitted to 80R (outside of vehicle) which did not have enough light when retro reflective optic is not applied.

In the above picture, observing 1 candela yellow line is much easier to understand the effect of adding back cover optic. After applying the optic to the back cover, you can see that there is more lighting spreading to the right area. In the past, we can see that the light going to the right 50 degree area is further increased to the right 75 degree after applying the back cover optics.

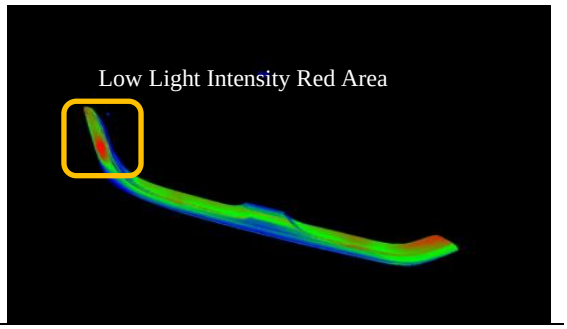
The simulation results show that applying the optic to the back cover increases the total amount of light and is effective in increasing the angle of light spreading.

2.6 Idea Verification in Actual Vehicle

In addition, we would like to verify this idea through the rework that attaches the retro reflective optical tape to the actual mass produced model. When applying retro reflective optics for actual vehicle back cover, check whether there is lighting image enhancement effect as in simulation.

Table 3**.** Add Back Cover Optic at Actual Vehicle

Option	Simulation Result
No Backcover Optic	



Add Backcover Optic

Prior to applying the back cover, there was not enough light like the yellow area above, and there was a dark area. Before applying back cover optics, camera Check the measurement results, you can see that there are many red areas showing dark are-

as. After applying the back cover optics, it was confirmed that the dark areas were much brightened.

As a result, After applying retro reflective optic, we verified the validity of the hypothesis that light guide uniformity, visibility law satisfaction and design freedom can be greatly improved by applying light guide back cover retro reflective optic through simulation and actual comparison.

The light guide lighting fill improvement ideas discussed above were applied to actual development vehicles. It is proved that it is possible to mass production without problems in various reliability tests. It will be mass-produced in USA and Europe in this year.

3 Conclusions

In the process of obtaining the above conclusions, I obtained ideas using TRIZ chain effect cause analysis technique, root cause analysis, resource utilization clone problem technique. This TRIZ technology allowed us to accurately analyze the problem. I also confirmed that these techniques are effective making ideas through simulations and real vehicle verification.

As mentioned earlier, the ideas gained through the use of TRIZ technology will be applied to actual production models and will be sold soon in the US and Europe.

In addition, we were able to obtain the results of 7 patents applications in Korea and 2 applications overseas by proceeding with the tasks of this paper.

In conclusion, the TRIZ methodology proved to be an effective method for patent adoption or solution acquisition in the automotive industry.

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12. Feng Luo, et al.,2014”A comprehensive Survey of Vision Based Vehicle Intelligent Front Light System”, Int.J.on smart sensing and intelligent system, Vol 7. pp701-pp732

Appendix. Patent Applications
: Overseas Application 2 cases, Domestic Application 7 cases

1. Multi-Layered Light Guide with Retro-Reflection
   USA : 15/198.484, CHINA : 201610579042.4, KOREA : 1020150145381.
2. 3 Lighting Lamp Structure Using Type Optical System
   KOREA : 1020150090276
3. Diode Pumping Using Induced Emission Principle Light Guide
   KOREA : 1020150173516
4. Light guide for each principle of Brewster
   KOREA : 1020160050794
5. Multiple Elliptical Light Guide
   KOREA : 10201600629524
6. Multifunctional Film Light Guide
   KOREA : 10201600629524
7. Light Reverse Convergence Principle Using Light Guide
   KOREA : 1020160166722