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Laser marking system for light guide panel using design of experiment and web-based prototyping

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ABSTRACT

A light guide panel (LGP) is an element of the liquid crystal display (LCD) back light unit (BLU), which is used for display devices. In this study, the laser marking process is applied to the fabrication of light guide panels as the new fabrication process. In order to obtain a light guide panel which has high luminance and uniformity, four principal parameters such as power, scanning speed, ratio of line gap, and number of line were selected. A web-based design tool was developed to generate patterns of light guide panel via the network, and the tool may assist the designer to develop various prototype patterns. Topcon-BM7 was used for luminance measurement of each specimen with 100 mm × 100 mm area. By Taguchi method, optimized levels of each parameter were found, and luminance of 3523 cd/cm^2 and uniformity of 92% were achieved using the laser machined BLU.

1. Introduction

Recently, the display industry has been rapidly expanding, and companies have developed new technologies such as electro-luminescence, plasma display panel (PDP), and thin-film transistor (TFT)-LCD. Among these, TFT-LCD needs a light source because TFT-LCD does not have its own lighting mechanism. The back light unit is one of the components of an LCD which provides light source from the back side of a TFT-LCD panel [1].

BLU has many components as shown in Fig. 1. High luminance, uniformity, and low current consumption are the key factors to determine BLU's performance, and pattern design for the LGP is critical. LGP, which is one of the BLU's main components, is used to transform linear source of light to planar beams by creating patterns for light reflection, and is usually made of PMMA (polymethylmethacrylate). Currently, such technologies are available to manufacture BLU as silk screen printing, injection molding, stamping, and V-cutting [2].

Each technology has the advantages and disadvantages in terms of performance, cost of manufacture, productivity, and reproducibility. Recently, laser marking technology has been used in order to reduce the time for design and development, which includes adjustment of model's patterns, mold, and stamper [3]. As laser marking employs print-less technology, it does not reflect light by printed patterns. In addition, cutting surface is more specular than that of mechanical V-cutting, resulting in higher reflection, and thus luminance is higher than that by printed patterns [2].

To cope with customer' needs and to survive in the highly competitive business environment, companies have to develop effective methods in the product development and configurations of manufacturing organizations. As a result, integrated information technology (IT) models that one enterprise possesses and uses to manage their required IT infrastructure are rapidly changing into distributed manufacturing area offered by specialized IT services [4,5]. In accordance with this trend, many manufacturing enterprises are employing strategies whereby they carry out research on highly applicable technologies in the design and manufacturing processes to save the time and cost. The increasing importance of information in product development processes is leading many researchers to consider a web-based collaborating environment for design and manufacturing [6–8].

The objective of this research is to utilize advantages of laser marking technology, which enables short patterning time and high luminance in the fabrication of BLUs and develop a web-based design system for pattern design. Designers can access the tool via the web browsers and prototype design can be rapidly made. Also, the concept of D.O.E. (design of experiment) was applied in order to obtain uniform and high luminance LGP.

2. Web-based design system of LGP

In this paper, a laser-marking process is applied to the patterning of V-groove reflectors in LGP. V-groove is a reflector [9], and the gaps between patterns are important parameters in

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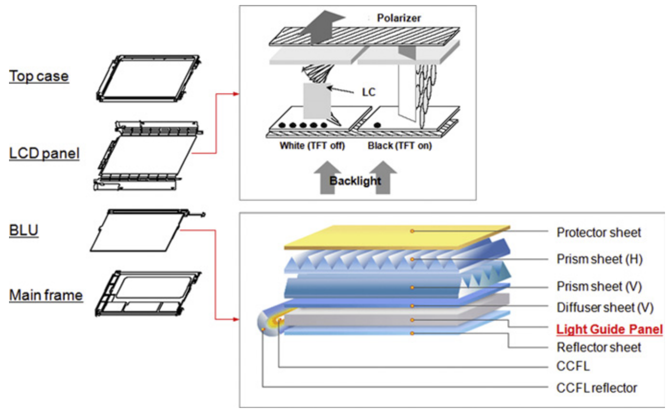

Fig. 1. The typical structure of TFT-LCD.

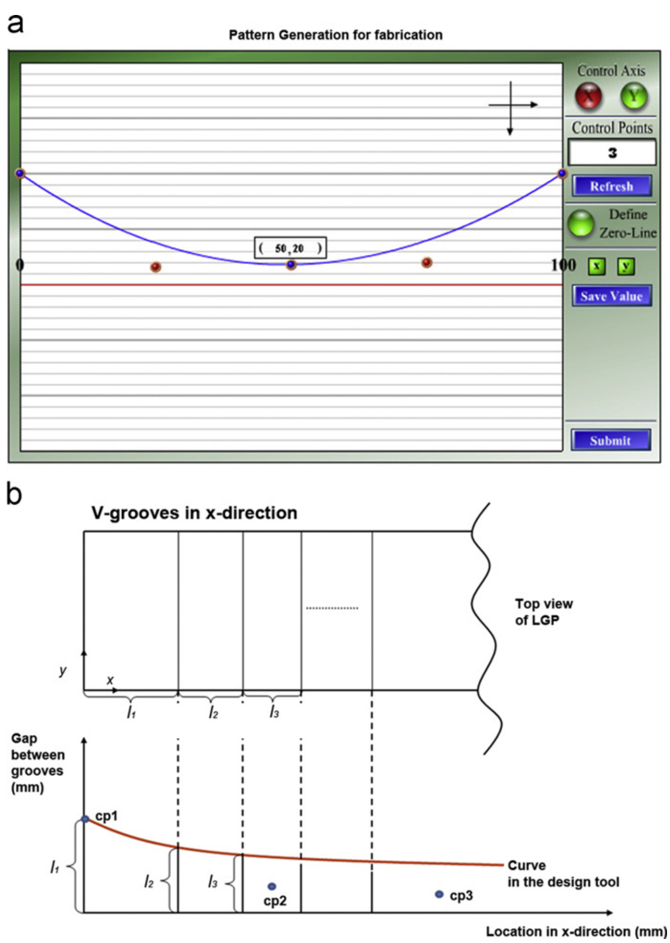

Fig. 2. (a) User interface of web-based pattern design tool for light guide panel and (b) definition of the gap between grooves.

order to improve uniformity of reflected light. The most important role of grooves is to reflect light from the lamp and to make uniform distribution of the reflected light.

Grooves near the source of light get sufficient amount of light from the lamp. So, in this location, to reflect the light to the front-face direction, less number of reflectors are necessary. On the other hand, many reflectors are required at distant locations from the source of light.

Designer adjusts the interval between each pattern and the number of patterns during design process of LGP. In this research,

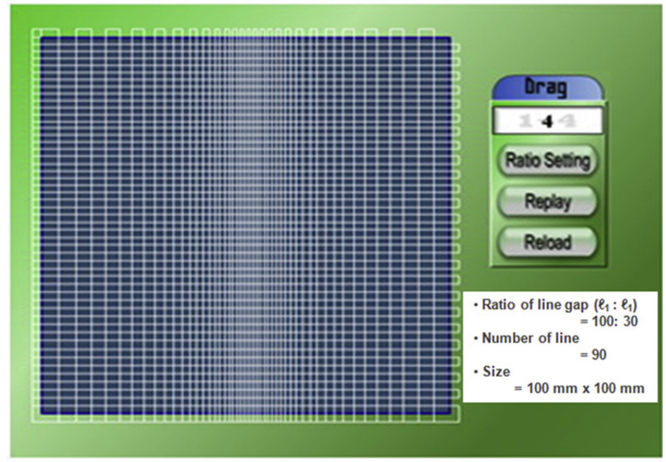

Fig. 3. Generated tool path of laser machining for light guide panel (both in x and y directions).

a design tool was developed, and the interface is based on a web browser. Fig. 2(a) shows the web-based pattern design tool for LGP. The design tool may assist designers to design patterns of LGP without using generic design programs like CAD.

The design tool uses control points of Bezier curve, so it is able to easily change the gap between patterns (Fig. 2(b)). The gap between patterns governs the difference in the amount of reflected light from the light source. For a BLU with twin lamps at each longitudinal edge, center of the LGP receives less amount of light than sides of LGP. So, it is required to make dense pattern at the center in order to increase reflected amount of light. The control parameter ℓ_1 refers to the first gap between the one edge of LGP and the first groove, ℓ_2 refers to the gap between the first groove and the second groove, and ℓ_n refers to the gap between the $n-1$th groove and the nth groove.

This web based design tool uses the flash (Flash FX) as user interface [10]. Using flash script, the Bezier curve is interactively generated by the control point data. Those generated points are automatically converted into NC (Numerical Control) codes for laser machining by a Matlab code, and the NC codes are transmitted to the designer through the web. The x- and y-directional groove patterns can be reviewed on the web-based viewing tool. Fig. 3 shows the generated tool path of laser machining when the ratio of line gap is 100:30 and size of work piece is 100 mm × 100 mm (x and y directions). The sequential procedure of pattern design is described in detail as follows:

1. Define number of required points.
2. Select an axis of pattern.
3. Control a curve using blue and red points.
   A. Blue points: base point of curve
   B. Red points: gradient control point
4. Define zero line (base line of the pattern).
5. Click 'Save value' button (x, y axis).
6. Click 'Submit' button.

The laser equipment used in this research recognizes DWG (Drawing) files; therefore, a module was developed to convert NC codes into DWG files. Fig. 4 shows a communication system of the design tool for prototyping of LGP patterns. Such procedures are quickly performed through the web, thereby facilitating the designer to produce the trial product of a prototype in short period of time [11]. In addition, the web communication has an advantage in accessibility. Through the internet, the designer and