Experimental Study of Thermal Deformation Effects on LCD Backlight Module

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ABSTRACT

Liquid crystal displays (LCDs) have been widely used in the information technology such as LCD-TV, LCD monitor, laptop computer and mobile phones. Because liquid crystal does not emit lights by itself, a backlight source should be needed in order to produce viewable images on a LCD. The module which provides the light source is usually called backlight module (BLM) and a cold cathode fluorescent lamp (CCFL) is used as the light source, which is placed behind the panel of the LCD. Due to the temperature increase of the CCFL in a BLM of a LCD subjected to lighting state, micro-deformation will occur in the BLM and result uneven luminance phenomena. The purpose of this research is to study the effects of heat source from CCFL on luminance in the BLM of a 7-inch LCD. The temperature distributions were measured by using thermal couple and the luminance variations of the BLM were measured by using luminance meters and CCD camera. The results show that the luminance distribution is more even because of the heat source from CCFL in BLM.

1. Introduction

Backlight module (BLM) is one of the key components of the liquid crystal display (LCD). Because liquid crystals do not emit lights by themselves, a light source should be needed to provide good brightness uniformity and high luminance in order to process viewable images on a LCD. The light source is usually called
backlight module because the light source, which is cold cathode fluorescent lamps (CCFLs), is placed behind the panel of the LCD. Generally, BLM may be classified into two categories in terms of the location of the light source inside the LCD module, i.e. edge lighting and direct lighting.

Tagaya et al. and Okumura et al. simulated scattering characteristics of particles by using Mie scattering theory in LGP, and got better luminance and uniformity compared with conventional LGP [1-3]. Ide et al. utilized molecular-dynamics to design dot patterns irregularly and thus to improve the distribution of dots [4]. Kim et al. studied diffusion plate with PET/PC/PBT copolymer and PMMA diffusion plate modified with glass fibers in a direct-lit BLM of a LCD, and both of them have better thermo-physical properties and water absorption compared with conventional PMMA [5,6]. Chu et al. set up a systematic analysis by using finite element analysis (FEA), computational fluid dynamics (CFD), and structure-heat transfer, to simulate warpage due to heat source from CCFLs in the backlight module of a TFT-LCD TV [7].

When an edge-lit BLM in lighting state, the heat source from CCFLs acts on LGP and optics films’ side, the heat source not only affects optical properties, such as index of refraction, angle of refraction, and the angle of incidence, but also causes micro-deformation to result in uneven luminance phenomena. For this reason, the purpose of this research is to study the effects of heat source from CCFL on luminance in the edge-lit BLM of a 7-inch LCD.

2. Experimentation

The 7-inch edge-lit BLM, in which CCFL is L-type, was used in this study as shown in Fig. 1. The BLM was...
driven by two different inverters, which were named as inverter A and inverter B. The temperature distributions and the luminance variations corresponded to these two different converters were measured. Then the temperature impacts on luminance can be studied.

2.1 Measurements of Temperature
The temperature histories of three pre-selected points in every sides of BLM corresponded to each converter were measured and recorded in order to study the temperature variations of every sides of BLM corresponded to different converters under lighting state. The temperature was measured by using thermal couple, and the lighting time for each converter was 30 minutes. The environmental temperature was controlled at 25±3°C.

2.2 Measurements of luminance
Luminance was measured by using both luminance meter LS-110 and CCD camera. The luminance meter can only be used to measure the luminance of single point on luminous surface in BLM one time. The LS-110 luminance meter used is perpendicular to BLM, and then luminance was measured one by one point on luminous surface and the BLM was moved by using a XY table, as shown in Fig. 2.

![Fig. 2 The set up of the measurement of the LS-110 luminance meter](image)

However, the CCD camera can get an overall luminance distribution of luminous surface by image capture board at the same time. The gray levels of an image analyzed can be digitized from 0 to 255. The higher the value is, the higher the luminance is.

3. Results and Discussions
3.1 Results of temperature measurements
Fig. 3 shows the temperature versus lighting time curves of each pre-selected point under the drives of the inverter A and the inverter B, respectively. It can be seen that the temperature variation will become stable after the BLM was on for 30 minutes. The raises of temperature, after 30 minutes of BLM is on, of all pre-selected points under the drives of the inverter A and the inverter B, respectively, are shown in Table 1. In the Table 1,
the $\Delta T = T_{30\text{ minutes}} - T_{\text{environmental}}$. It can be concluded from the Table 1 that the thermal deformations of the BLM driven by converter B are serious than thermal deformations of the BLM driven by converter A.

![Fig. 3](image)

**Table 1.** The raises of temperature, after 30 minutes of BLM is on, of all pre-selected points under the drives of the inverter A and the inverter B, respectively (unit: °C ±0.1 °C)

<table>
<thead>
<tr>
<th>No. of points</th>
<th>Inverter A</th>
<th>Inverter B</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.1</td>
<td>$\Delta T = 33.0$</td>
<td>$\Delta T = 40.8$</td>
</tr>
<tr>
<td>No.2</td>
<td>$\Delta T = 30.8$</td>
<td>$\Delta T = 39.6$</td>
</tr>
<tr>
<td>No.3</td>
<td>$\Delta T = 35.0$</td>
<td>$\Delta T = 45.0$</td>
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<tr>
<td>No.4</td>
<td>$\Delta T = 22.0$</td>
<td>$\Delta T = 33.8$</td>
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<tr>
<td>No.5</td>
<td>$\Delta T = 10.4$</td>
<td>$\Delta T = 15.3$</td>
</tr>
<tr>
<td>No.6</td>
<td>$\Delta T = 4.9$</td>
<td>$\Delta T = 7.2$</td>
</tr>
<tr>
<td>No.7</td>
<td>$\Delta T = 3.2$</td>
<td>$\Delta T = 5.0$</td>
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<td>No.12</td>
<td>$\Delta T = 31.0$</td>
<td>$\Delta T = 39.0$</td>
</tr>
</tbody>
</table>
3.2 Results of luminance measurements

In order to measuring luminance of a BLM, the BLM must be lit first and waiting until the BLM reached its warm-up time. The warm-up time purposes to avoid abrupt temperature change during measuring, and in order to stabilize the luminance. From literatures reviewed, it can be concluded that luminance reached its stability after the BLM was lit 3 minutes. However, in this study, the warm-up time was chosen as 5 minutes for the purpose of conservative.

There are two purposes in this study. The first purpose is to study the effect of the thermal deformations caused by temperature raised of a BLM on its luminance. It is noted that luminance will become stable after a BLM was lit 5 minutes and the temperature variation will become stable after the BLM was on for 30 minutes. Therefore, the luminance of the BLM corresponded to 5 minutes and 30 minutes, respectively, after the BLM was lit were recorded and compared with each other. The second purpose is to compare uniformities of luminance corresponded to different thermal deformations of a BLM. Thus, the luminance of a BLM driven by the inverters A and B, respectively, at 30 minutes after the BLM was lit were recorded and compared with each other.

In the beginning, a LS-110 luminance meter was adopted in order to measure luminance of the BLM and nine measuring points were chosen as shown in Fig. 4. Fig. 5 shows the curves of luminance of point No.1 with respect to lighting time of a BLM which was driven by the inverters A and B, respectively. The corresponding curves of luminance of the other 8 points are similar to the curves shown in Fig. 5. It can be seen that the luminance of any point under the drive of the inverter B is brighter than that under the drive of the inverter A. This observation matches with the conclusion from Table 1. However, the corresponding luminance variations from 5 minutes to 30 minutes are not obvious. One can’t get the information about the effect of the thermal deformation on the luminance from Figure 5. The values of the luminance measured at the nine points on the luminous surface after the BLM was lit for thirty minutes are shown in Fig. 6. The calculated luminance uniformity of the BLM driven by inverter A is 76% while the uniformity of the BLM driven by inverter B is 74%. It seems one can conclude that the luminance uniformity will be decreased if the thermal deformation of the BLM increases. However, what is the reliability of this conclusion since the two calculated uniformities are so close to each other and the uniformities were calculated based on the data of 9 points only? Therefore, a CCD camera system was utilized later in order to get an overall luminance distribution of luminous surface and using those data to study the effects of thermal deformations on the uniformities.
Three BLM specimens with the same type were used in this experiment and these three specimens were named as BLM-1, BLM-2, and BLM-3. The image of luminous surface of a BLM at any specific time was captured by CCD camera and then loaded the collected data into the gray level analysis program to get the values of the gray levels of the full luminous surface. The gray levels of an image analyzed can be digitized from 0 to 255. The greater the value of the gray level, the brighter the corresponding luminance.

In order to study the variations of luminance of the full luminous surface caused by thermal deformations, the gray levels corresponded to full luminous surface at 5 minutes after a BLM was lit were subtracted from the gray levels corresponded to full luminous surface at 30 minutes after a BLM was lit. The results are shown in
Fig. 7. In Fig. 7, a red spot means the subtracted result is positive, i.e., the corresponding luminance increases, and a blue spot means the subtracted result is negative, i.e., the corresponding luminance decreases. Under the same drive of the inverter A, the overall luminous surfaces of BLM-1, BLM-2, and BLM-3 are all red. On the other hand, under the same drive of the inverter B, some areas of BLM-1, BLM-2, and BLM-3 are red, but some of them are blue. Therefore, one can conclude that thermal deformations of a BLM do affect the strength of its corresponding luminance. However, thermal deformations would not definitely causes the strength of luminance getting worse, thermal deformations may cause luminance increases.

![Fig. 7](image)

(a) BLM-1

(b) BLM-2

(c) BLM-3

Fig. 7 The difference of gray levels corresponded to full luminous surface at 5 minutes and 30 minutes, respective, after a BLM was lit. The figures at left hand side corresponded to the BLM under the drive of the inverter A, and the figures at right hand side corresponded to the BLM under the drive of the inverter B.
Finally, the effects of thermal deformations on the luminance uniformity will be discussed. Usually, luminance uniformity is obtained from the luminance of 9 pre-selected points (refer to Fig. 4) and is calculated as \( L_{\text{uniformity}} = \frac{L_{\text{min}}}{L_{\text{max}}} \times 100\% \), where \( L_{\text{max}} \) and \( L_{\text{min}} \) are the maximum and minimum values, respectively, of luminance of the 9 pre-selected points. However, one cannot guarantee that the luminance distribution of a luminous surface with luminance uniformity of 75% is actually more even than a luminous surface with luminance uniformity of 74% since those luminance uniformities were calculated based on the data of 9 pre-selected points only. Therefore, in this experiment, a full luminous surface was divided into eighty-one blocks and the luminance uniformity of each block was examined and compared.

Firstly, gray level distribution of the luminous surface of each BLM of all 3 BLM specimens at 30 minutes after the BLM specimens were driven by inverter A and B, respectively, was recorded separately. Secondly, the 9-point luminance uniformity of each block of all eighty-one blocks of each luminous surface was calculated by using the values of gray level. Finally, the calculated luminance uniformity of each block of a BLM specimen driven by inverter B was subtracted by the calculated luminance uniformity of the corresponding block of the same BLM specimen driven by inverter A. The results are shown in Fig. 8. It is assumed that if the difference between two corresponding luminance uniformities is greater than 3% or less than –3%, then it is claimed that one of these two uniformities is superior or inferior, respectively, to the other. Fig. 8 shows that the number of blocks of better uniformity obtained under the driven of inverter B was much more than that obtained under the driven of inverter A. In other words, it illustrates that the actual uniformity of the luminous surface of a BLM driven under inverter B was better than that driven under inverter A. However, it is recalled that thermal deformations of a BLM driven by inverter B are greater than thermal deformations of a BLM driven by inverter A. Therefore, one can conclude that the thermal deformations of a BLM do affect its corresponding luminance uniformity. But larger thermal deformations would not definitely cause the corresponding luminance uniformity worse.

(a) BLM-1
4. Conclusions

In this study, the effects of thermal deformations of a BLM caused by the CCFL on strength and uniformity of the corresponding luminous surface were investigated. The luminance variations of the BLM were measured by using both luminance meters and CCD camera. Because one cannot guarantee that a more even luminance distribution definitely corresponds to a higher value of luminance uniformity if the luminance uniformity was calculated based on the luminance of 9 pre-selected points only. So, another approach for a comparison of uniformity of luminance distribution is proposed in this study. The gray levels of the full luminous surface of a BLM were recorded through a CCD camera system initially. Then the full luminous surface was divided into eighty-one blocks and the 9-point luminance uniformity of each block was calculated by using the values of gray level and compared. The results show that thermal deformations of a BLM do affect the strength and the luminance uniformity of its corresponding luminance. However, thermal deformations
would not definitely causes the strength and uniformity of luminance getting worse, thermal deformations may cause luminance increases or make luminance distribution more even.

Acknowledgements
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References