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Multi-material Reinforcement Bars on Display Backplates to Improve Stability

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Multi-material Reinforcement Bars on Display Backplates to Improve Stability

ABSTRACT

Existing computer monitors do not provide sufficient thermo-mechanical and geometric stability required for hyper-realistic telepresence. This disclosure describes techniques to achieve nearly zero deformation through the thermal cycle of a display by adding reinforcements to the interior of the display backplate. The reinforcements are made of a material such as carbon fiber that has a coefficient of thermal expansion much lower than that of the metal backplate. To reduce stored elastic energy induced by thermal stress, reinforcements are attached to the display backplate at their ends. The reinforcements span areas of symmetric distortion on the display, such that sections of unwanted motion oppose each other. The reinforcements are covered with light reflective material such that they integrate well into the display backlight unit. To avoid dark areas in the display, the surface normal vectors to the exterior of reinforcement elements intersect the front of the display.

KEYWORDS

- Camera array
- Co-located cameras
- Telepresence
- Virtual presence
- Three-dimensional video (3D video)
- Thermo-mechanical stability
- Thermal expansion
- Glass fiber reinforced polymer (GFRP)
- Carbon fiber reinforced polymer (CFRP)
- Reinforced plastics
- Composite reinforcements
- Display backlight unit (BLU)
- Carbon fiber

BACKGROUND

Hyper-realistic displays require significant thermo-mechanical stability

Hyper-realistic displays are displays capable of displaying three-dimensional content without requiring the user to wear glasses or other eyewear. Hyper-realistic displays use lenticular films that redirect light emitted by each pixel to one of the left or right eye of the user. Hyper-realistic displays find application in three-dimensional video conferencing, virtual telepresence, entertainment, virtual reality, video games (especially those that rely on precisely recording user movements or representing the user on the screen), etc. Hyper-realism is contingent on the availability of displays (monitors) that are thermo-mechanically stable and nearly free of geometric deformations or distortions.

Computer monitors and televisions experience thermally induced geometric distortion since light-emitting diodes (LEDs) and other electronics produce heat that expands their structural components. Such expansion is often uneven and causes warping. Recording three-dimensional video content typically requires multiple cameras that are located with high precision relative to each other for the entirety of the recording. A computer monitor, with multiple cameras along the outer bezel, that is utilized to display and record three-dimensional content requires geometric stability substantially better (e.g., an order of magnitude better) than current commercial displays. Hyper-realistic telepresence requires a measure of stability and precision that current displays are unable to provide.

Achieving less than a small threshold amount of distortion during thermal cycles in conventional displays adds substantial costs to manufacturing, design, and materials. Even if successfully manufactured, environments in which conventional displays can successfully perform are limited to those with relatively constant temperatures and no major heat sources such as sunlight through a window.

Backplate of a display which mounts LEDs deforms significantly during operation

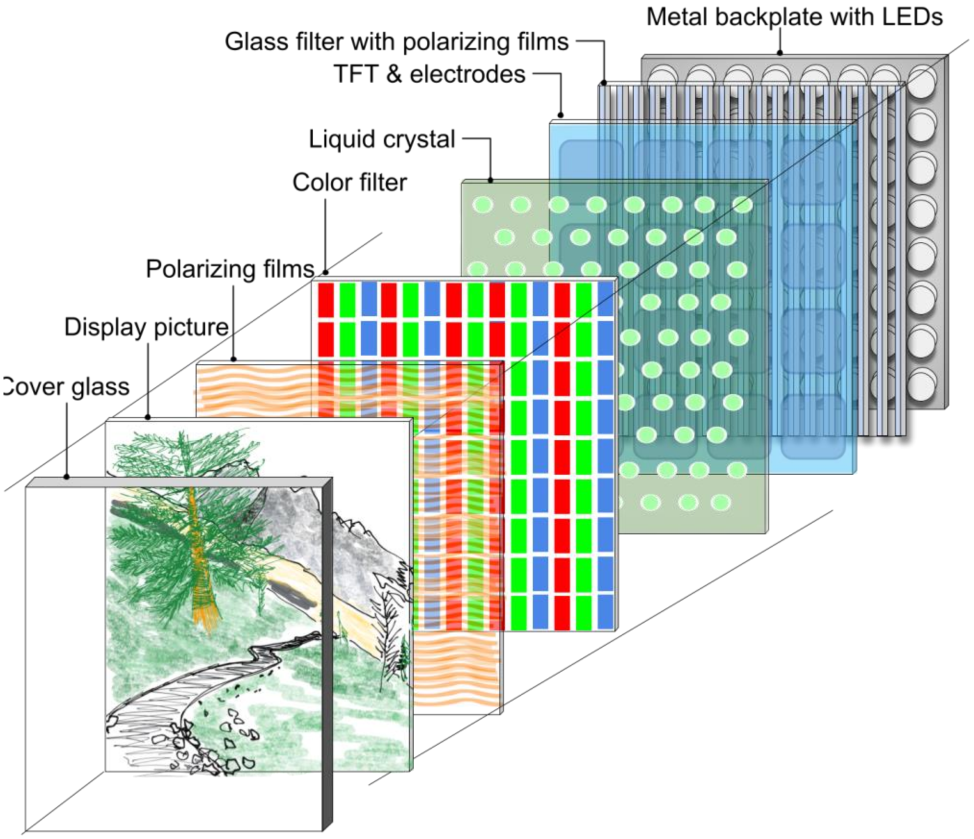


Fig. 1: Example optical stack of a monitor

Fig. 1 illustrates an example optical stack of a monitor. A planar array of light-emitting diodes (LEDs) mounted on a metal backplate provide white light, which passes through polarizing films, a thin-film transistor (TFT) plate (used to turn pixels on or off), a liquid crystal layer, and color filters to produce a display picture that is protected by a cover glass. Such a metal backplate, which houses LEDs, is also known as a display backlight unit (BLU).

The LEDs each produce, as a side effect, about 1 Watt of heat, such that the array of LEDs produces a total of 200-400 W. The metal backplate on which the LEDs are mounted has a relatively large coefficient of thermal expansion. Combined with the heat expended by the LEDs, the metal backplate can undergo substantial distortion such that, during operation, particular points on the backplate may deviate from their room temperature positions by up to 3 mm.

The backplate of a display, which is typically a single metal piece, serves the functions of reinforcement as well as heatsink. However, in the context of hyper-realistic displays, which demand very high thermal stability and tightly calibrated geometries, the reinforcement and heatsink functions of the backplate are mutually exclusive.

Additional reinforcement (for structural strength/stiffness or mounting) can be added to a display backplate by stamping additional profiles to the exterior of the sheet metal. However, such reinforcement does not provide geometric stability through the thermal cycle.

DESCRIPTION

This disclosure describes techniques to achieve nearly zero thermal deformation and very high geometric stability through the thermal cycle of a display by adding reinforcements to the interior of the display backplate. The reinforcements, which comprise structural elements that prevent the display backplate from distorting under mechanical or thermal loads, are made of a material such as carbon fiber that has a coefficient of thermal expansion much lower than that of the metal backplate. The reinforcement elements are joined to the sheet metal backplate during fabrication.

To reduce stored elastic energy induced by thermal stress, reinforcements are attached to the display backplate at their ends, enabling some expansion or contraction of the backplate at locations where it is not detrimental to performance. The reinforcements span areas of symmetric distortion on the display, such that sections of unwanted motion oppose each other. For example, if the top of the display tends to expand upward and the bottom of the display tends to expand downward, then, through the reinforcement elements, the top and the bottom of the display pull against each other, thereby neutralizing each other’s motion.

In displays with attached video cameras, the reinforcements have a load path physically connected at or near the camera mounting locations. The reinforcement elements are interior to the display backplate and are covered with a light reflective material such that they integrate well into the display backlight unit. To ensure that light reflecting from the reflective material covering the reinforcements comes out of the front of the display via relatively short paths, surface normal vectors to the exterior of reinforcement elements intersect the front of the display. This also ensures that dark areas do not make an appearance on the display.

Geometry of reinforcement elements

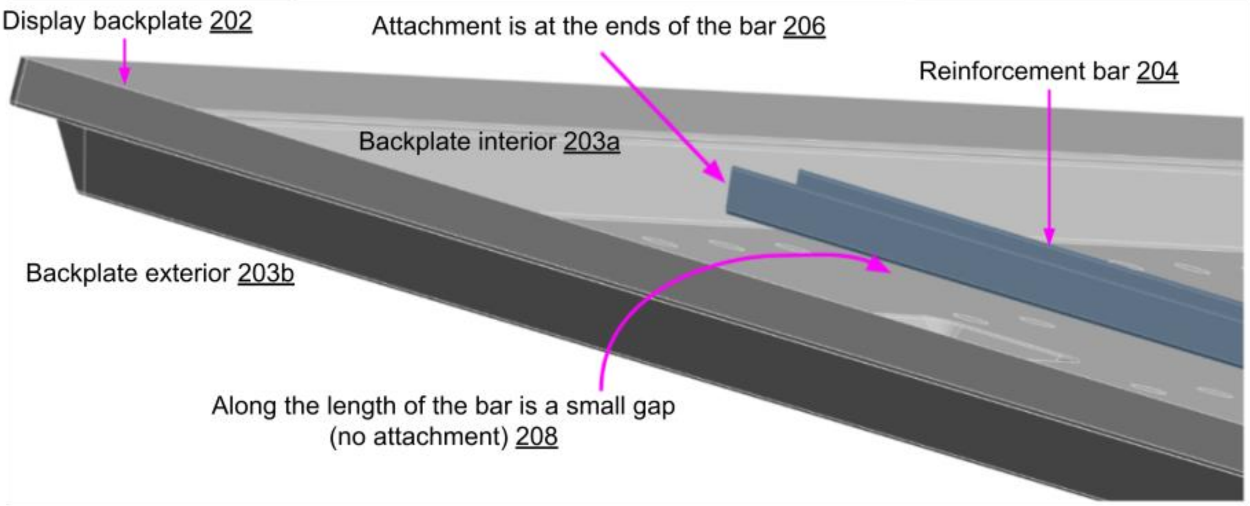


Fig. 2: Reinforcing the backplate of a display to stabilize it during thermal cycles

Fig. 2 illustrates an example of reinforcing a display backplate (202) to stabilize it during thermal cycles. As illustrated, a reinforcement bar (204) of low thermal expansion coefficient is attached to the interior (203a) of the display backplate but not to the backplate exterior (203b). To prevent buildup of stored elastic energy, the reinforcement bar is attached at its ends (206) to the display backplate, such that a small gap exists along its length (208). The gap provides a slight separation of the reinforcement bar from the bulk of the flat area of the display. The reinforcement bar stabilizes the outer sections of the display where cameras are mounted.

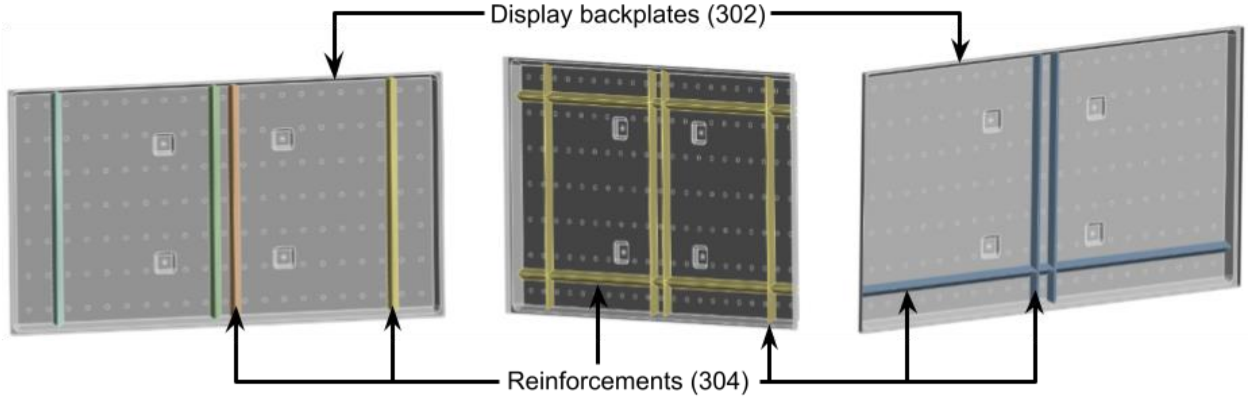


Fig. 3: Example cross-sections and layouts for reinforcements

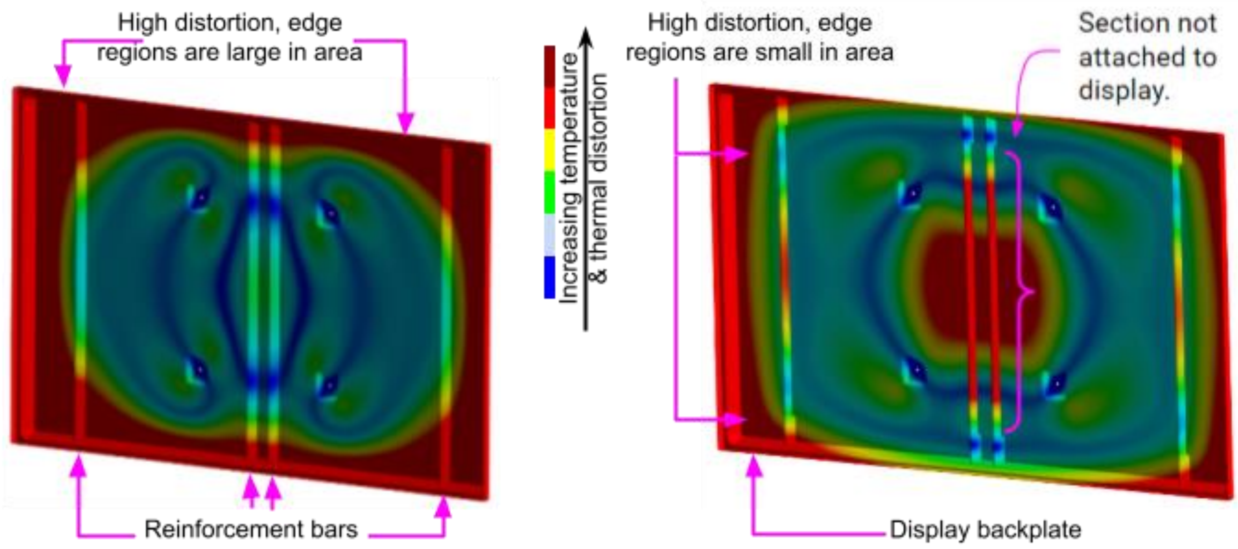
Fig. 3 illustrates example cross-sections and layouts of reinforcements (304) for display backplates (302).

<u>Reinforcements are made of materials with low coefficient of thermal expansion</u>

A steel rod of a given length expands about ten times more than a rod of 0/90 woven carbon fiber of the same length over the same temperature change. For example, a temperature change of 20°C results in a one-meter-long steel rod expanding by 0.240 mm, while a carbon fiber rod of the same length expands by only 30 µm. To maintain geometric stability over thermal cycles, reinforcements made of material less sensitive to temperature (low coefficient of thermal expansion) are advantageous.

<u>Reinforcements have a load path physically connected at or near camera mounting locations</u>

As mentioned before, video cameras that are mounted on a hyper-realistic display require extremely tight tolerances and high geometric stability through thermal cycles. The fixed ends of the reinforcements usually have smaller local distortions than the areas around them. It is therefore advantageous to have the fixed ends of the reinforcement at locations where the video cameras are to be mounted on a display.



(a) **(b)**

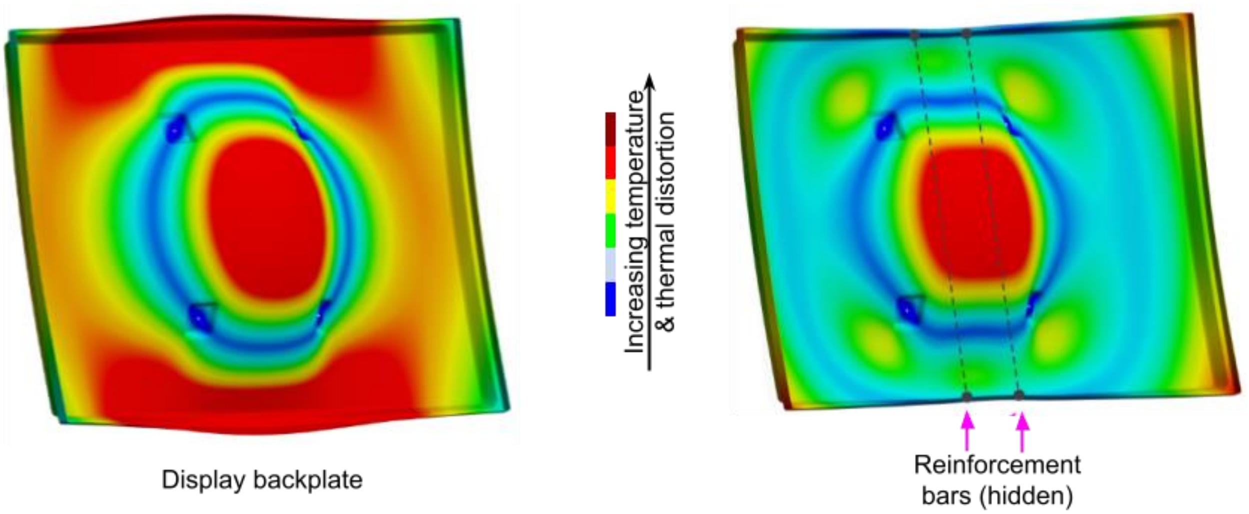
Fig. 4: Maps of thermal distortion: (a) when the reinforcement bars are attached along their entire lengths to the display backplate; (b) when the reinforcement bars are attached at their ends to the display backplate

Fig. 4 illustrates examples of maps of thermal distortion on a display backplate. When the reinforcement bars are attached along their entire lengths to the display backplate as illustrated in Fig. 4(a), the regions of high thermal distortion (deep red) along the edge are large in area, a suboptimal condition, since the distortion is at the edges where the cameras are placed. When the reinforcement bars are attached at their ends to the display backplate as illustrated in Fig. 4(b), the regions of high thermal distortion along the edge of the display backplate are small in area, which is better for camera operation.

Fig. 4(b) also illustrates that as the attachment lengths of the reinforcement bars are decreased, the stability of the display backplate at the attachment points improves, while the center of the display backplate, relatively unimportant from the point of view of camera placement, experiences greater distortion. Thus, attaching the reinforcement bars at their ends causes distortion to reduce at precisely the regions that benefit from stabilization.

Opposing distortions by different sections of the display backplate nullify each other

Reinforcements are attached at points of the display backplate that have opposing thermal motions (expansions or contractions). For example, since the top of the display expands upward and the bottom of the display expands downward, by connecting reinforcement bars across the top and bottom of the display, the top and bottom pull against each other through the reinforcement bars and mutually nullify their motions.



(a) **(b)**

Fig. 5: Maps of thermal distortion of a display backplate as seen from the back of the plate: (a) without reinforcement; (b) with reinforcement bars

Fig. 5 illustrates maps of thermal distortion of a display backplate, as seen from the back of the plate. As illustrated in Fig. 5(a), without reinforcement, the display backplate experiences considerable thermal distortion (large red areas). As illustrated in Fig. 5(b), with reinforcement bars, thermal distortion across the display backplate reduces substantially (large green-to-blue regions; the central red region is of relatively low importance).

Light reflective material on the display backplate

The interior of the display backplate is typically covered in reflective film. When reinforcements are added, the film can be applied on top of the reinforcements (instead of having the reinforcements on top of the film).

Surface normal vectors to the exterior of reinforcement elements intersect the front of the display

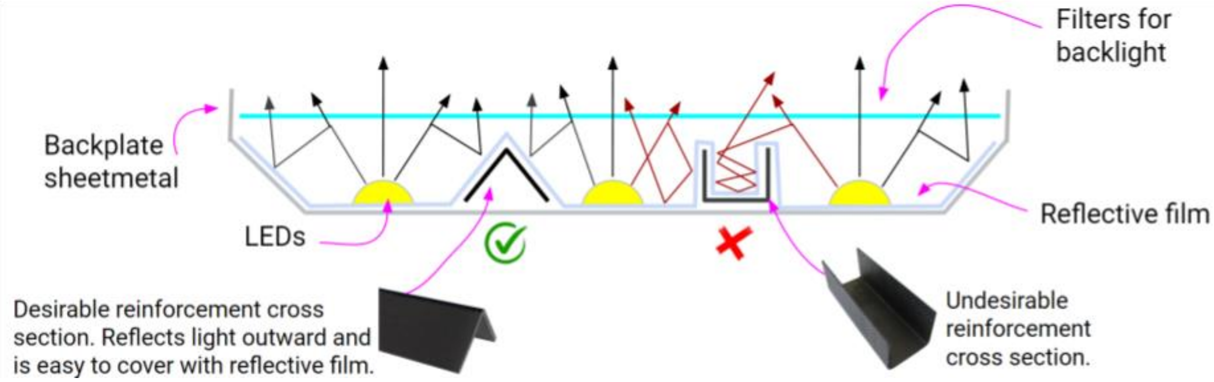


Fig. 6: Surface normal vectors of the reinforcement bars intersect the front of the display

As illustrated in Fig. 6, the surface normal vectors of the exterior of the reinforcement bars intersect the display front. This ensures that light reflecting off the material that covers the reinforcement bars comes out the front of the display via relatively short paths. Dark areas, which have their origins in long-path light rays, do not appear on the display. Fig. 6 also illustrates an advantageous type of reinforcement bar, which is a right-angled bar with its spine facing the front of the display. This type of reinforcement geometry is also easier to cover with reflective film.

Aside from improving the thermo-mechanical and geometric stability of display backlight units over thermal cycles, additional advantages of the described techniques include:

- Reinforcement bars can be cheaply and easily added to existing display backplate geometries, enabling the modification of existing commercial display assemblies and existing display stamping tools, both of which are expensive.
- Where a reinforcement bar is attached to the backplate, a closed cross-section can be formed. Closed cross sections are stiffer and better at resisting twist loads than open cross sections.
- By having reinforcements on the interior of the display, the total packaging footprint and the exterior aesthetics of the display remain unaffected.
- Adding reinforcements as separate components to the backplate enables a selection of materials for the reinforcements that can be different from the material of the backplate. The material of each component can be optimized for different purposes.
- Adding reinforcements as separate components enables easier experimental tuning of the reinforcement geometry and provides improved design flexibility for positioning cameras. Changing reinforcement locations and geometry does not require new and expensive backplate stamping tools.
- Having reinforcements of simple geometries and constant cross-sections enables easier development and application of new reinforcement layouts.
- The construction of a separate structure or frame to house cameras is obviated. The design and construction of hyper-realistic displays is made robust, simple, and economically viable.

CONCLUSION

This disclosure describes techniques to achieve nearly zero deformation through the thermal cycle of a display by adding reinforcements to the interior of the display backplate. The reinforcements are made of a material such as carbon fiber that has a coefficient of thermal expansion much lower than that of the metal backplate. To reduce stored elastic energy induced by thermal stress, reinforcements are attached to the display backplate at their ends. The reinforcements span areas of symmetric distortion on the display, such that sections of unwanted motion oppose each other. The reinforcements are covered with light reflective material such that they integrate well into the display backlight unit. To avoid dark areas in the display, the surface normal vectors to the exterior of reinforcement elements intersect the front of the display.

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