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DETECTION OF THERMAL DEFORMATION ON ARTIFICIAL TOOTH USING HOLOGRAPHIC INTERFEROMETRY SINGLE EXPOSURE TECHNIQUE

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ABSTRACT

Holographic interferometry technique with a single transmission exposure was used to detect thermal deformation on an artificial tooth. This is a non-invasive testing and produce very high accuracy in temporal deformation detection. Two artificial tooth: the second incisive anterior and the first upper molar tooth, from acrylic and ceramic materials, were employed as objects in the holography system. He-Ne gas laser was utilized as a source of illumination. A soldering iron was conducted as a source of heat. The hologram was first recorded on the holographic film. The exposed film was then developed manually in the dark room. The hologram film was later used as an object for reconstruction process. The real part of the hologram was permanently recorded using digital camera. The hologram was captured before and after heating with soldering iron. The difference of fringes distance was analyzed using a Matrox Inspector 2.1 software. The observation result show that the fringe pattern before and after heated are entirely difference due to the volume expansion. In general both fringes patterns after heating tend to be linear and the fringe spacing become narrow and close to each other. The distance change on incisive tooth is found to be 40 micron and on the upper molar tooth is 17.5 micron.

Keywords: holography interferometry, single exposure, artificial tooth, acrylic material, thermal deformation.

INTRODUCTION

Damage in dentin is hard and difficult to determine directly on the teeth. Normally an invasive test is carried out which is time consuming. In this present paper the thermal deformation of an artificial tooth was recorded by using holography interferometry single exposure technique. The fringe pattern generated from object and reference wave was shifted as the temperature changes. An optical path length as small as one wavelength can be achieved through this interference method. Hence, holography interferometry is non destructive method to study temporarily change, due to thermal deformation process in artificial tooth.

Fundamentally interference pattern comprise of bright and dark fringes. Bright fringes appear due to constructive interferences which have maximum intensity. Meanwhile dark fringe appears due to destructive interferences which produce minimum intensity. Bright and dark fringes distributed alternatively in the space.

Holography method is described by many researchers [1,4]. Holography normally used to analyze binary solution diffusion coefficient [5], to detect finger print [6], to determine coefficient of linear expansion of metal [2], to detect reshuffle thing [7], and analyze vibration in music instrument [8]. The result of this study can be suggested as an alternative instrument in characterizing of artificial tooth materials. The method is based on phase difference measurement, without direct contact on the tooth. This non-invasive method, having high accuracy, with non-ionize source so that promising with minimum side effects.

THEORY

Holography interferometry is based on the recorded interference pattern from object wave and reference wave. For this reason, holography system needs monochromatic light and coherent light. Holography system consists of two processes that are recording and reconstruction such as shown in Figure 1. In recording process, laser beam is divided in to two sections. First is known as an object beam. Secondly is called as reference beam. Reflected beam from object is called object beam, written as a wave function of

$$U_0 = A_0 \exp(j\,\varphi_0) \tag{1}$$

while the second beam is used as reference beam, given as wave function of

$$U_r = A_r \exp(j\,\varphi_r) \tag{2}$$

where A_0 and A_r are amplitude of the object wave and reference wave respectively. φ_0 and φ_r are phase of the object and reference wave. In recording process, object beam and reference beam are recorded in the holography film having wave function of :

$$U_f = U_o + U_r \tag{3}$$

So the intensity recorded in the holography film:

$$I = U_f U_f^* = |U_f|^2 = (U_r + U_0)(U_r^* + U_0^*) \tag{4}$$

$$\text{or } I = |U_r|^2 + |U_0|^2 + U_0 U_r^* + U_r U_0^* \tag{5}$$

Symbol (*) is referred as complex conjugate.

In reconstruction process, holography film was developed to form hologram. Then it is illuminated with reference beam, which is the same source used in recording process. So the equation of reconstruction:

$$\begin{aligned} U_r I &= U_r \left(|U_r|^2 + |U_0|^2 + U_0 U_r^* + U_r U_0^*\right) \\ &= |U_r|^2 U_r + |U_0|^2 U_r + |U_r|^2 U_0 + [U_r]^2 U_0^* \end{aligned} \tag{6}$$

In Equation (6), three dimensions information can be produced form third and fourth terms. Third term produce virtual image and fourth term produce real image that can be captured on the screen. This paper will represent the real image of fourth term that can be captured with single exposure recording technique. A method of single exposure on holography plate in single recording was conducted. Holography film was placed carefully into the holder at the original location like in the recording process. The reconstruction process produced real image.

When object was heated using soldering iron, the image will change. So the interference phenomenon will appear between original object beam and reconstruction beam. The appearance fringe pattern is referred as thermal deformation on artificial tooth. The shifted fringe between object and the reconstruction beam is closed to $\lambda/2$, $3\lambda/2$, $5\lambda/2$ and so on. Since thermal deformation on tooth is real image it can be observed and measured.

RESEARCH METHOD

An artificial acrylic tooth of second incisive and first upper molar were employed as an object. Helium neon gas laser was utilized as a source of illumination. A soldering iron was conducted as a source of heat. The Object in this case an artificial tooth was heated by using the soldering iron until temperature of 30°C. The experimental set-up and the optical alignment for recording system is shown in Figure 1. Holography film model Agva Gevaert 10E75 and Kodak 649 LC were utilized as recording media. Artificial tooth was recorded with film plate PEG-01 with normal sensitivity of 28-39 $\mu J/cm^2$ and exposure time is 5-7 second in film holography.

The exposed holography film was developed using developer and fixer solution in the dark room. The same He–Ne laser was also used as a source in the reconstruction process. The developed film or hologram was placed at the same location it was recorded. The diffraction beam is used to reconstruct the object. The interference is observed in the same location of the object. The picture of the real image was taken using a digital camera Canon A640 10 Megapixel. Thermal deformation in artificial tooth image was analyzed by using Matrox Inspector 2.1..

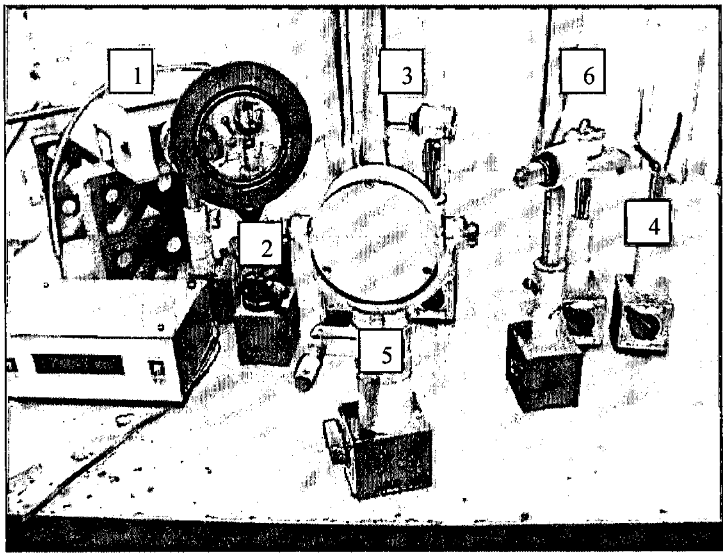
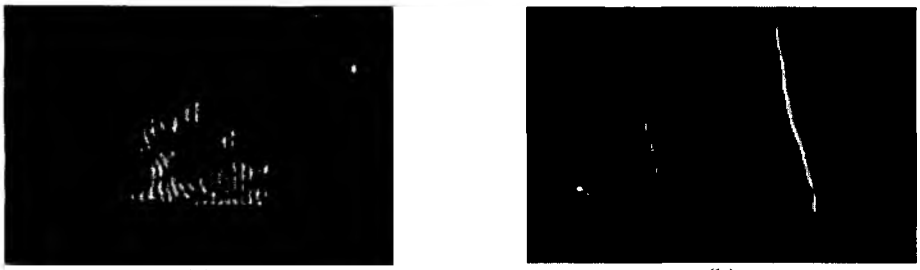


Figure 1: Set Up of Holography Interferometry (1=Laser; 2=beam splitter; 3 : lens: 4= layer/holder of holography plate; 5 = mirror: 6=sample)

RESULTS AND DISCUSSION

Real image of optical reconstruction have been captured. It comprised a closed fringe spacing information. The typical results obtained from this experiment are shown in Figure 2, 3 and 4. The fringe patterns are captured before and after heating the object which consisted of an artificial tooth.



(a) (b)

Figure 2. Fringe on artificial acrylic of second incisive tooth (a) before and (b) after heating.

Figure 2 shows the hologram of fringes pattern on an artificial acrylic of second incisive tooth. Figure 2(a) the hologram before heating, comprises of curly vertical fringes. After heating the incisive tooth the fringes pattern on the hologram changes such as depicted in Figure 2(b). Obviously of the hologram image tends to be more blurry. The fringe spacing becomes wider and linear in certain part of the fringes pattern.

(a) (b)

Figure 3. Fringe for artificial acrylic of the first upper molar (a) before and (b) after heating

Figure 3 depicted the hologram image of an artificial acrylic of the first upper molar. Entirely difference fringes pattern are observed. Figure 3(a) shows the peculiar fringe pattern, more like centrifugal fringe, having a center and a series of curvatures fringes. Just next to the center, the curvature fringe having relatively wide spacing. As the fringe move outwards, the spacing becomes narrow. In contrast, the hologram captured after the upper molar tooth being heated, the fringe pattern tends to be more linear and closed spacing fringes such as indicted in Figure 3(b).

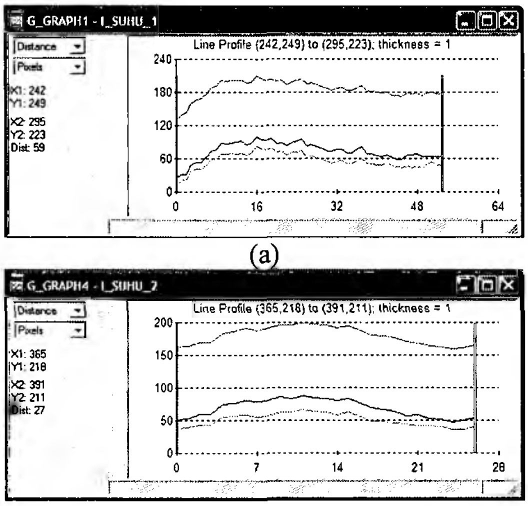
In general difference fringe patterns are observed in both artificial tooth objects. The hologram before heating indicate the object have entirely difference configuration. The fringe pattern of the first object is rather flat as indicate by the vertical curly fringes.

Whereas the second object of upper molar is considered more curvature as a result almost circular fringes tend to appear. However, as the object is heated, the hologram shows almost similar result which tend to be linear fringes.

Physical reason for such occurrence could be explained as followed. When the material is heated, its volume increases due to the size of the object expended. Increasing in volume causes the differences in optical path length become greater. Hence affect the fringes spacing which turned to be more closer in comparison with the object before heated. The greater the optical path length also subjected to blur the hologram image.

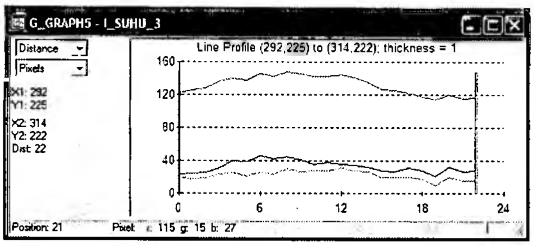
In order to quantify the hologram image, Matrox Inspector 2.1 software was employed to analyze the distance of shifted fringes. The raster graphic of the fringes analysis on both hologram are shown in Figure 4 and 5 respectively

For artificial acrylic of second incisive tooth, the changed of fringe distance is found to be from arbitrary value of 59 to become 27 of pixel (more closer). For artificial acrylic of the first upper molar, the fringe distance changing from 22 to become 8 of pixel (more closer). The calibration written in the program of Matrox Inspector 2.1 is that 10 mm equivalent with 80 pixel. Taking into account the magnification of the image is 10X. Hence the difference or the changes generated in artificial acrylic in second incisive are from 0.07375 mm to become 0.03375 mm. The changes in the first upper molar tooth are from 0.0275 mm to become 0.01 mm. Consequently the holography interferometry method not only can sensitively detect the thermal deformation on artificial acrylic tooth which normally occurred during treatment, the method also can be used to measure precisely the changes of the physical properties. Hence the transmission interferometry holography can offer both qualitative and quantitative study. As an improvement of this method, is better to include the measurement of pressure influence by knowing the degree of shifted fringes.

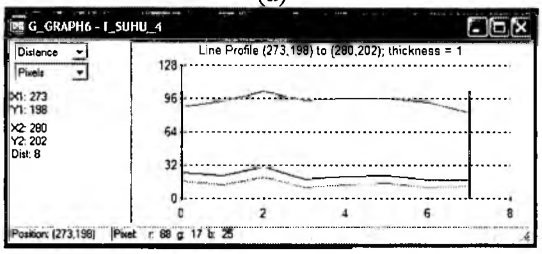


(b)

Figure 4. Analysis using Matrox Inspector 2.1 for Figure 2 (distance fringe in pixel a. before b. after heating)



(a)



(b)

Figure 5: Analysis using Matrox Inspector 2.1 for Figure 2 (distance fringe in pixel a) before b) after heating)

CONCLUSION AND SUGGESTION

Thermal deformation on artificial acrylic tooth have been detected by using holography interferometry single exposure technique. The hologram was recorded before and after heating, each of the tooth objects. The reconstruction of the holograms was permanently recorded by a digital camera. The hologram of the heated object forming almost linear fringes with more closer and narrow fringe's spacing. The difference generated on the incisive tooth is 40 micron and 17.5 micron on the upper molar tooth.

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