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APPLICATION OF DIGITAL IMAGE CORRELATION TO THE LOCAL STRAIN ANALYSIS OF MOUSE AORTAS: NOVEL METHOD TO CREATE SPECKLE PATTERN

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INTRODUCTION

Digital image correlation (DIC) is a non-destructive and non-contact optical technique to measure deformation and strain of materials. The method is based on optically tracking the displacements of a speckle pattern created on the material surface. In the case of soft tissues such as mouse aorta, there are several advantages to using DIC since it can provide local, rather than global, deformations and it is suitable for large strain measurements, typical of soft tissues taken to failure [1] [2].

For the optimal use of DIC, several requirements should be met for speckle patterning: 1) randomness, 2) high contrast, 3) appropriate size of speckle in the field of view (3-5 pixels), and 4) firm attachment of speckle to specimen during deformation. In previous DIC studies of soft tissues, the methods employed to create a speckle pattern include the use of an airbrush to spray dye or paint on the specimen, or coating the sample with toner powder. However, biological samples must be partially dehydrated before applying paint which may affect the mechanical properties of the specimen, and toner powder is too hydrophobic to adhere well on specimens when submerged in aqueous solution during mechanical testing. In addition, it is difficult to evenly distribute paint or toner powder on the surface of a hydrated biological specimen [2]. Therefore, a novel method utilizing colloidal gold particles to create a speckle pattern on mouse aorta is proposed in this work. Based on their unique surface chemistry, chemical inertness and stability in aqueous environments, colloidal gold particles are a promising new candidate for speckle patterning for DIC strain measurements of mouse aorta and similar small biological specimens [3].

METHODS

Colloidal gold particles were synthesized by reducing chloroauric acid ($HAuCl_4$) in ascorbic acid solution. In this method, 125 µl of 0.1 M chloroauric acid was added into 10ml of 0.3M ascorbic acid solution with vigorous stirring for 15 min. The solution was then incubated at room temperature for at least 96 h. Gold nanoparticles start to aggregate, and eventually the size of aggregated gold particles can be tuned in the range of 1-10 µm. The suspension was centrifuged (5000 rpm/2min) to remove acidic supernatant, and the remaining precipitated gold particles were resuspended in phosphate-buffered saline (PBS) solution. The mouse aorta samples were soaked in the colloidal gold particle suspension. Due to coordinate covalent and hydrophobic interactions, spontaneous adsorption of gold particles onto the mouse aorta surface occurs to form a random speckle pattern. The patterned sample was mounted on a Bose mechanical test bed to conduct uniaxial tensile tests with CCD camera tracking the displacement of the speckle pattern on the mouse aorta samples. Strain fields were analyzed using VIC-2D software. Image acquisition and DIC settings include 2 MP Point Grey camera, 25 mm macro lens, 35 x 35 subset for VIC-2D.

Ten consecutive images of a stationary speckled mouse aorta in the Bose set-up were captured and analyzed in VIC-2D for system error analysis.

RESULTS

Figure 1 shows a random speckle pattern created on the mouse aorta specimen. The size of a typical random speckle covers 3-5 pixels in each direction. In Figure 2, the intensity histograms of patterned specimens had greyscale values in the range 60-255, indicating a sufficient level of contrast between the mouse aorta and the speckle pattern for reliable image matching by DIC. Figure 3 demonstrates that after the sample has been submerged in PBS for 1 hour, the random speckle pattern is still stable in an aqueous environment.

In Figure 4, strain measurement of speckle patterned mouse aorta was compared over the whole specimen (a) and in the central region (b) in the y-direction during a uniaxial mechanical tensile test. In Figure 4a, ε_{yy} is not uniform on the sample due to bending and friction at the mounting arms during deformation. Thus, the local strain of mouse aorta in uniaxial tension can be obtained from the central region as illustrated in Figure 4b.

For system error analysis, the corresponding pseudo-strain measurements (mean, median and standard deviation) for ε_{xx} , ε_{yy} and ε_{xy} are summarized in Table 1.

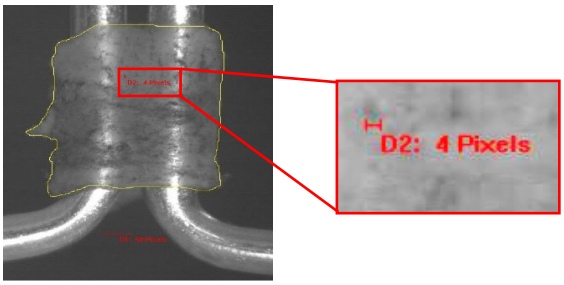

Fig. 1. Patterned mouse aorta mounted on Bose set-up

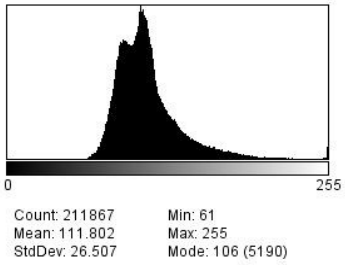

Fig. 2. Intensity histogram analysis of region of interest illustrated in Figure 1

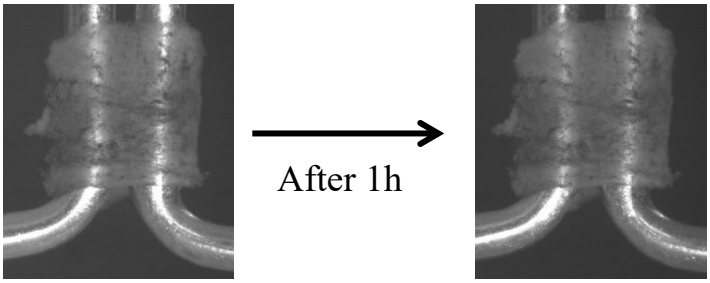

Fig. 3. Patterned mouse aorta submerged in PBS for 1 hour

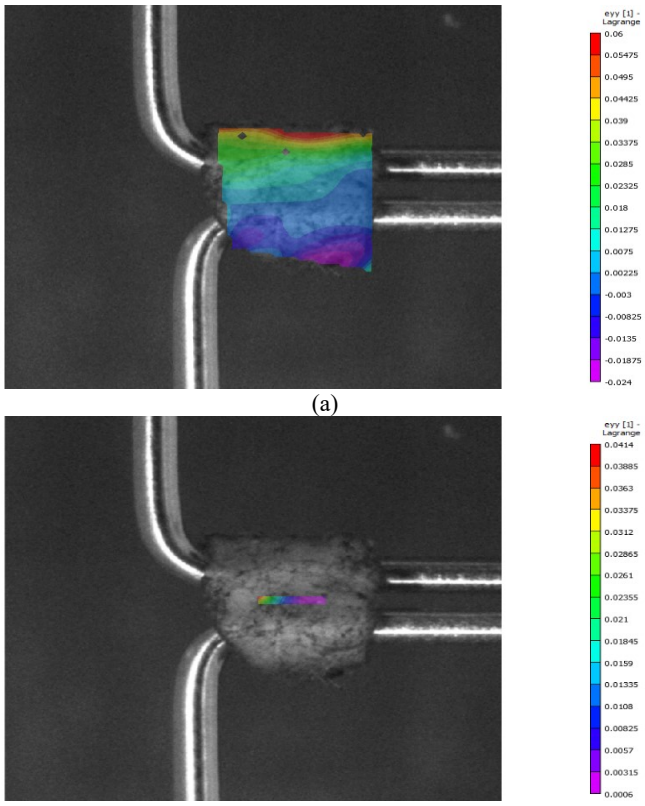

Fig. 4. Strain analysis of mouse aorta in y-direction (a) over the whole specimen; (b) in the central region;

Table 1. System error analysis: pseudo-strain data in different directions

	ε_{xx}	ε_{yy}	ε_{xy}
Mean	0.00228	-0.00065	-0.00435
Median	-0.00357	0.0043	-0.00643
Standard deviation	0.01134	0.01254	0.00666

DISCUSSION

The novel method utilizing colloidal gold particles to create a speckle pattern on mouse aorta shows promising results compared to previous patterning methods. The colloidal gold particles can form random, stable, high contrast, suitable sized speckles on mouse aorta suitable for DIC analysis to track the specific pattern before and after deformation to measure local strain of mouse aorta. Thus, it can be considered as an efficient patterning method for future application of DIC strain measurements in soft biological tissues.

ACKNOWLEDGEMENTS

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