VERIFICATION OF 3D DIC SOFTWARE FOR CURVILINEAR SURFACES USING FE METHOD AND RAY-TRACING

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1. Introduction

Digital Image Correlation (DIC) is currently one of the most popular methods of shape and strain field acquisition during structural and material testing. For planar strain cases single camera 2D DIC usually gives accurate results, but it cannot be used for measuring out-of-plane deformations. 3D DIC (stereo or multi-view stereo) systems allow acquisition of specimen's shape and deformation without aforementioned limitations. Because of this, they are popular in disciplines like biomechanics and structural testing. This paper presents method for verification of 3D DIC system for large strain, out of plane biomechanics cases, using FE model and physically based ray-tracing software for generating test images.

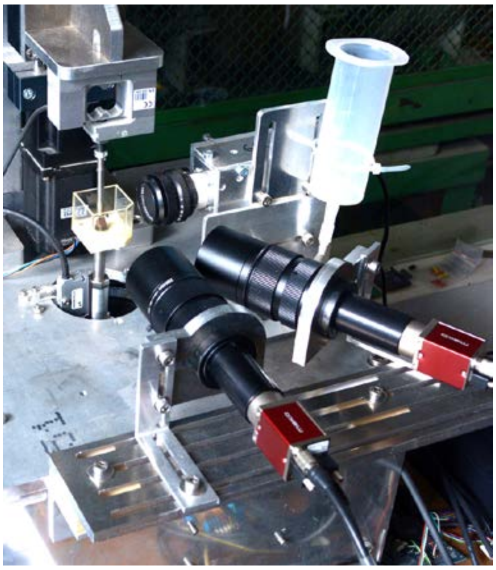

Fig. 1. 3D DIC setup for testing mechanical properties of ring-shaped rat aorta specimens.

2. Methods

Presented 3D DIC system was developed for biomechanical material testing with large out-of-plane deformation and non-planar specimens.

Planned use cases include circumferential loading of ring-shaped rodent aorta samples and inflation test of aorta samples. Experimental setup for ring-shaped aorta samples is presented on Fig. 1. Setup consists of testing machine with electrodynamic actuator and three-camera setup for DIC and image analysis. During the initial phase of test specimen deforms from initial ring shape (Fig. 2), resulting in large out-of-plane displacement. The sample is coated with printer toner particles for providing contrast necessary for DIC method. The load is applied vertically, by moving one of the fixtures. Second fixture is attached to a load cell. During testing the sample is submerged in saline solution inside transparent vessel attached to lower fixture.

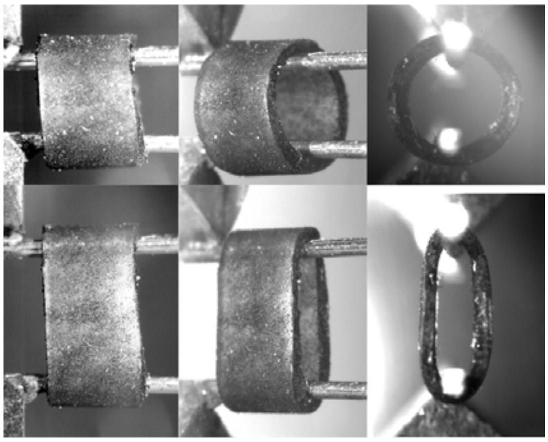

Fig. 2. Ring shaped specimen, unloaded and under load. Specimen is made from natural rubber and has inside diameter of 2 mm.

Verification method is based on aforementioned use case. Test case consists of Finite Element (FE) model (Fig. 3) representing ring shaped aorta and fixture through which load is introduced. The FE model behavior was compared to real rat aorta samples in [1], and gave satisfactory results.

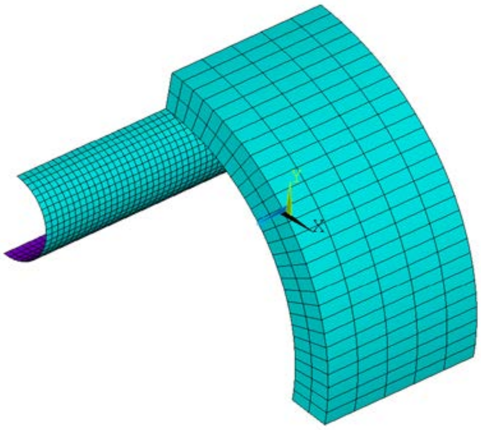

Fig. 3. Finite Element mesh representing specimen and loading conditions.

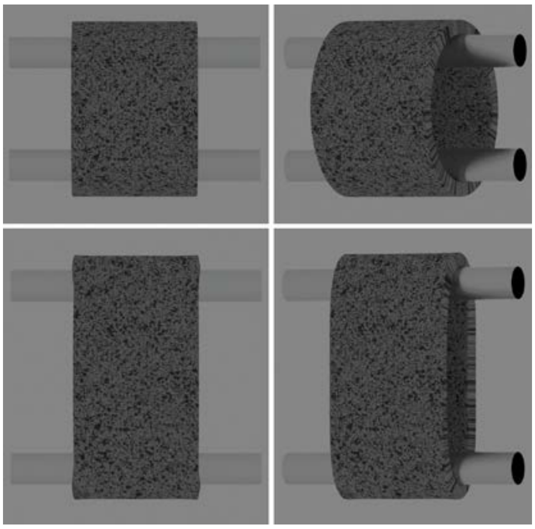

Fig. 4. Test images generated from FE model

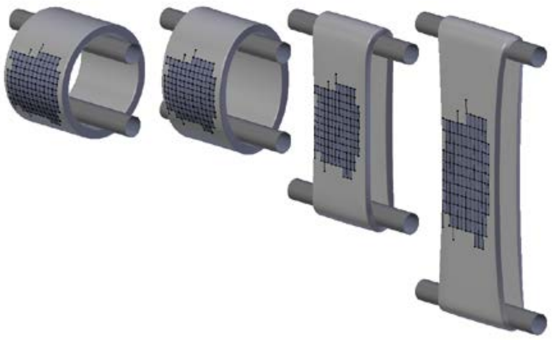

Fig. 5. Mesh generated by DIC algorithm overlaid on FE model.

Results from FE model were imported to Blender mesh editing software [2] to apply optical material properties, camera and lighting parameters.. Texture resembling toner particles was applied to specimen's surface. The model was then exported to physically based ray-tracing software LuxRender [3] (based on academic PBRT project[4]). Images for each camera and each loading step (Fig. 4) were computed using ray-tracing software. Images of calibration board used by DIC software for calibrating camera parameters were computed in similar way.

Generated images were used by 3D DIC software, first to determine camera parameters and then to acquire specimen's shape and deformation for each loading step.

3. Results

Shape, displacement and strain fields computed by 3D DIC algorithm are compared to results from FE model (Fig. 5). For specimen with 2mm diameter, shape and displacement measurements had typical measurement error of less than 0.01mm. Results were used to determine optimal angle between cameras for real-life experimental setup.

4. Conclusions

Initial results have proven usability of tested DIC algorithm. In later phase optical model will be extended to check DIC algorithm's response to lens distortion, light refraction and subsurface light scattering inside specimen. Investigation of optimal light sources' positions will also be conducted.

References

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