An Experimental Study on Deformation Analysis of an Indented Pipe via Fringe Projection Profilometry and Digital Image Correlation

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Abstract: We studied the surface displacement of a steel pipe during indentation via Fringe Projection Profilometry and 2D-Digital Image Correlation. Experimental results show that a 3D strain approximation is possible for comparison with numerical simulation.

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1. Introduction

Pipeline defect assessment is carried out considering an appropriate factor to account for the model uncertainty [1]. Although, the model uncertainty is derived from statistical analyses, in the case of dents, irregular and complex geometries may contain stress concentrators not analyzed in the numerical model. The stresses in the material allow to determine the service life of the pipe [2], therefore, it is necessary to establish the boundary conditions adequately. An essential part of these calculations relies on finding the strain in the material. The strain is determined with the displacements field, which is the length change ratio on the surface of the pipe. In this work, we focus on calculating the strain from the displacements field employing fringe projection profilometry and 2D digital image correlation (2D-DIC) [3].

2. Experiments and results

We studied a 4-inch diameter pipe, schedule 40 with a length of 50 cm. The pipe was painted white to improve contrast. To introduce a random speckle-like pattern on the pipe surface, we sprayed red paint from varying distances and angles of incidence. The pipe and the indenter were placed in a universal testing machine and set to dent the pipe at a speed of 10 millimeters per minute. The acquisition consists of alternating fringe projection with full illumination to capture the surface speckle-like pattern. With the fringe projection system, we projected a phase shifting pattern with a central line for 3D surface recovery. Also, with the projector, we illuminate the scene with the complementary color to the color red (RGB 0,255,255) to improve the contrast of the speckle-like pattern (Fig. 1). This process was carried out throughout the pipe indentation, which was synchronized with the acquisition for a total of 30 captured frames. In Fig. 2 we show three frames from the acquisition.

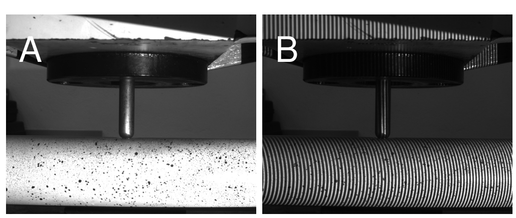

Fig. 1. Camera Captures in one of the loops. (a) Pattern type specke under complementary color light (b) Fringe projection on the pipe.

We processed the images in MATLAB to obtain the 3D reconstruction and the 2D displacement on the surface of the pipe. To obtain the displacement along the z-axis, we mapped the 2D displacements to the 3D reconstruction to approximate the 3D displacement field. This 3D displacement field can be analyzed using 4-node quadrilateral elements to find the strain. In Fig. 3 we show the deformation results. Note how the region near the dent shows the greatest strain along the surface of the pipe.

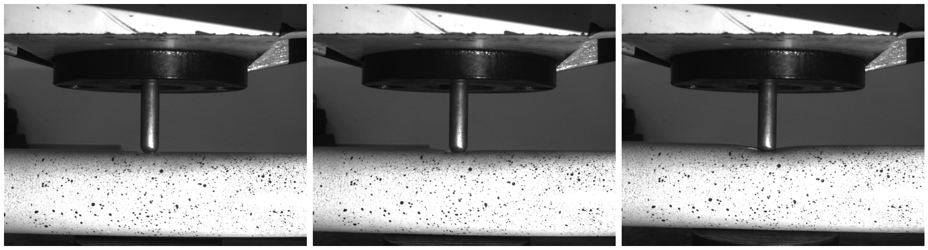

Fig. 2. Three frames from the pipe indentation process. From left to right: The initial frame, an intermediate frame, and the final frame.

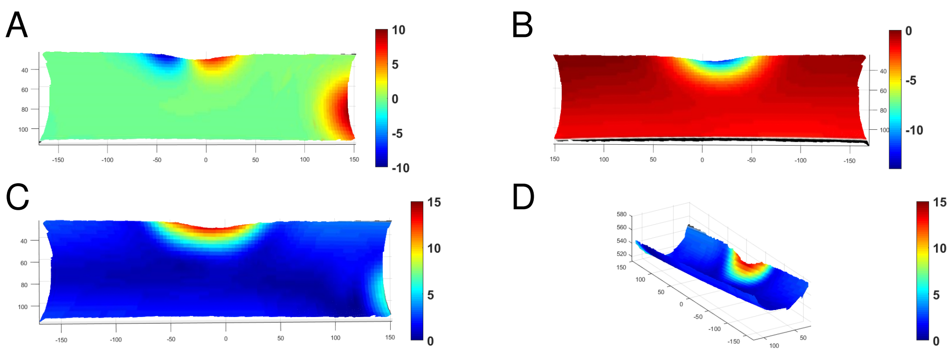

Fig. 3. results of the calculation of the unit deformation. (a) X-axis Deformation (b) Y-axis Deformation (c) Deformation magnitude (Front view) (d) Deformation magnitude (Axonometric Perspective)

3. Conclusions

In this work, we proposed a valuable tool for the experimental assessment of pipe indentation. The strain results can be used to find an approximation of the stresses in the pipe [4]. The obtained results give an accurate estimation of the displacement along the surface of the pipe. Ongoing research is being conducted to validate numerical simulations with the experimental results.

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