Seismic Behavior of Welded Tee-Joints and Elbows used in Natural Gas Networks (Task 4d: Surface Infrastructure)

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Task Description/Goals/Outcomes

Task 4d is focused on analyzing the natural gas pipeline and gas storage *surface* infrastructure and ultimately contributing seismic fragility curves of representative components of the most critical above ground elements of the network to OpenSRA. Fittings that transition these pipelines in size and/or direction specifically, either welded tee-joints and elbows, play a critical role in characterizing this behavior. In this regard, Task 4d undertook an extensive component-level experimental campaign and complementary high fidelity finite element modeling in support of the development of surface infrastructure seismic fragility curves. This work complements the efforts of the University of Nevada, Reno subsystem shake table testing program, with fittings and pipe runs selected in conjunction.

Introduction

To enrich the existing understanding of the seismic behavior of steel welded elbows and tee joints commonly used in the above-ground network of natural gas systems, eight pseudo-static full-scale component experiments were performed at the Powell Laboratories at the University of California San Diego. Specifically, 4-inch Schedule 80 components typical of high-pressure facilities, such as those in storage fields, and Schedule 40 pipes, commonly used in the distribution network, were subjected to reversed cyclic displacement-controlled loading while under constant internal gas pressure. High-fidelity finite element models of each specimen tested were developed, with material properties calibrated against experimental results. This poster presents an overview of this experimental campaign and the associated numerical investigation, with specific focus on presenting the global moment-rotation behavior and limit states associated with instances of response important to overall gas network seismic risk, such as the initiation of gas leakage.

Experimental Program: Component Tests

In total, eight in-plane and out-of-plane quasi-static reversed cyclic tests on straight tee joints and in plane tests on 90-degree and 45-degree elbows were conducted, see Table 1. Two types of diameter (D) and Schedule combinations were selected, namely: 8-inch (20 cm) diameter Schedule 40 and 4-inch (10 cm) diameter Schedule 80. Though all components have very similar thicknesses (t), the value of the diameter-to-thickness ratio (D/t) for the 8-inch Schedule 40 pipes is double that of the 4-inch Schedule 80 pipes. Test specimens were assembled as shown in Figure 2, with a double-acting hydraulic actuator imposing cyclic loading, and internal pressure controlled via a closed loop system.

Table 1. Component specimens tested (left: tee-joint, right: elbow)

Component	Nominal Diameter [Schedule]	Outside Diameter D (inch)	Nominal Thickness t (inch)	D/t	Loading direction	Specimen name
90-degree Elbow	4 inch [Schedule 80]	4.5	0.337	13.3	In-plane	4E-90
	8 inch [Schedule 40]	8.625	0.322	26.8	In-plane	8E-90
45-degree Elbow	4 inch [Schedule 80]	4.5	0.337	13.3	In-plane	4E-45
	8 inch [Schedule 40]	8.625	0.322	26.8	In-plane	8E-45
Tee-joint	4 inch [Schedule 80]	4.5	0.337	13.3	In-plane	4T-IP
					Out-of-plane	4T-OP
	8 inch [Schedule 40]	8.625	0.322	26.8	In-plane	8T-IP
					Out-of-plane	8T-OP

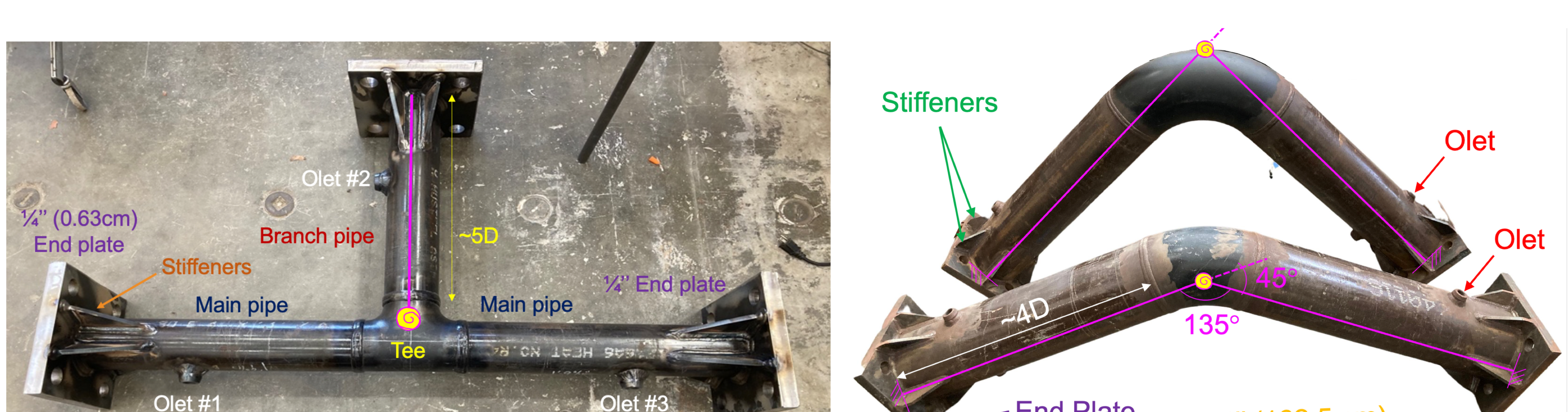

Figure 1. Test setup for in-plane loading (left) and out-of-plane loading (right).

Simulated Seismic Behavior

Figure 2 (top) presents select moment-rotation hysteretic response results for the tee-joint specimens as measured during component experiments. Highlighted are instances of important limit states, including the identification of full loss of gas pressure (LS3). Comparison with high-fidelity FE modeling of specimen 4T-OP are presented in Figure 2 (bottom). Results across the analyses cases offer very good comparison with the FE model, leading to the development of simplified phenomenological models for use in seismic fragility curves of surface components.

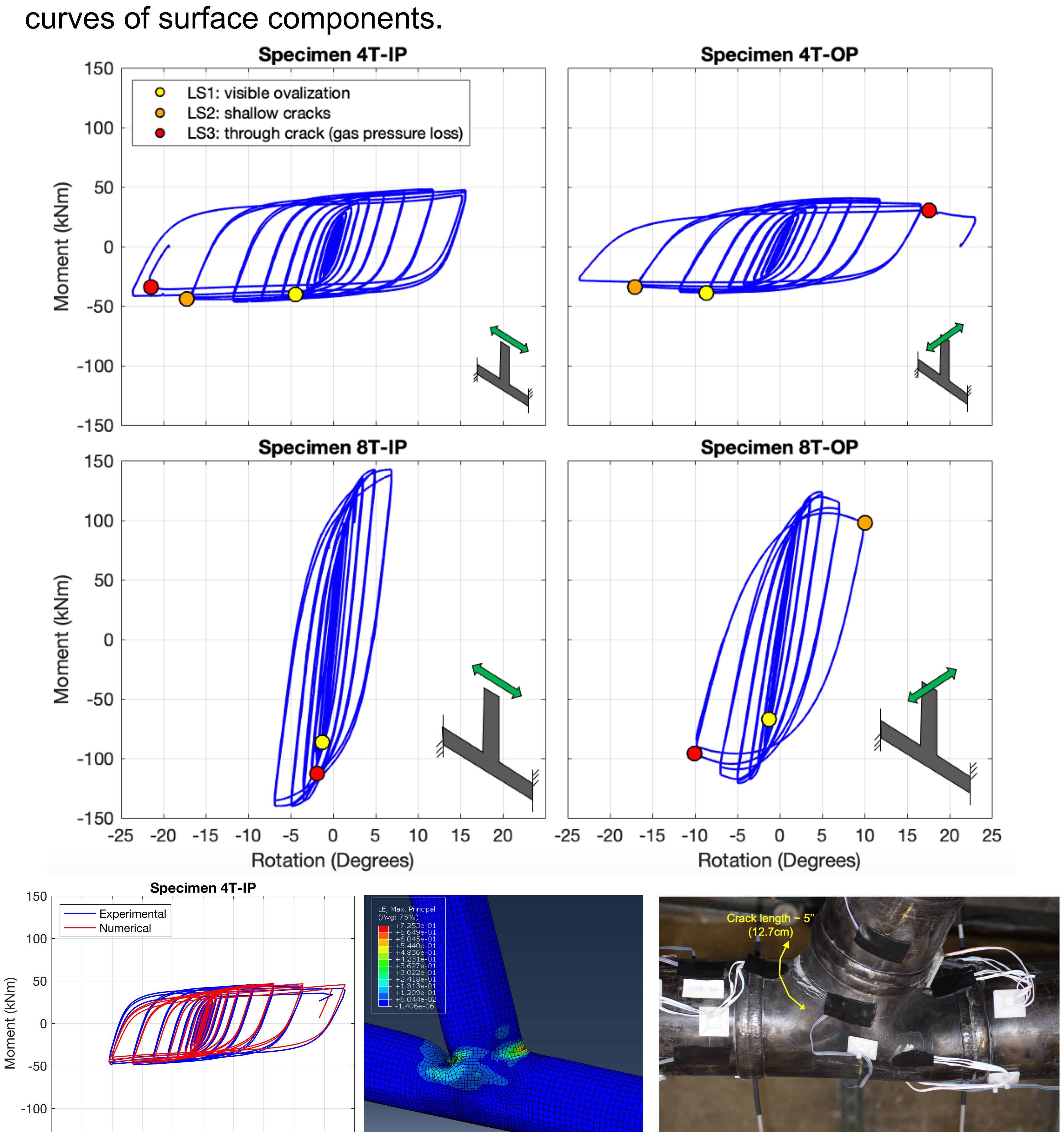

Figure 2. Select experimental moment-rotation hysteretic response of tee-joint specimens (top) and comparison with Abaqus FE modeling (bottom).

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