A. Use of Crack Tip Opening Angle to Assess the Resistance of Pipelines to Running Cracks

by Tom Siewert, David McColskey, Arry Bussiba, and Chris McCowan, NIST

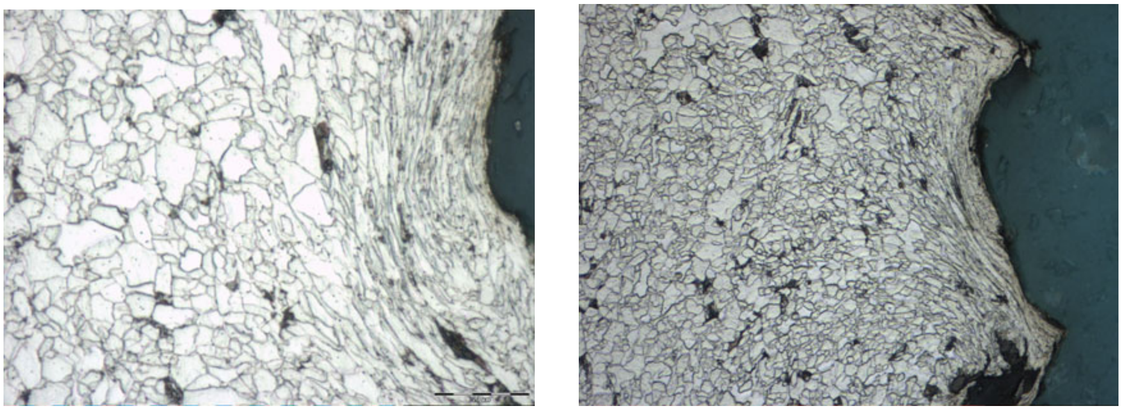
Pipelines in the U.S. are not always being replaced as they reach the end of their original design lives. Rather, their owners would like to extend their productive service life, and minimize the cost and impact of putting in new pipe. In this scenario, improved tests can provide detailed data on their condition, allowing better estimates of their remaining life and safe range of operation.

NIST has been studying the use of the crack tip opening angle (CTOA) test to develop such data. This test is an extension of the crack tip opening displacement (CTOD) test, in that optical techniques are used to measure the angle at which a crack runs through the steel. The output is a angle at which stable crack growth occurs during tensile loading. The test technique is still in development in ASTM (Task Group E08.08.06) and in ISO, and we will be feeding our data back to them to help in tuning the final standard. For example, we will describe the use of a guide plate to prevent buckling on very ductile materials, such as these linepipe.

We have set up an optical data acquisition system and have used it to acquire crack growth data and crack tip opening angle during tests on a number of pipes (50 to 60 cm in diameter with wall thicknesses near 6 mm) characteristic of cross-country pipelines. The pipes represent both current production (X70 produced in the past ten years), and older pipes (as old as 1936) removed from service for a variety of reasons. This has allowed us to evaluate the effect of aging and service conditions on the microstructure.

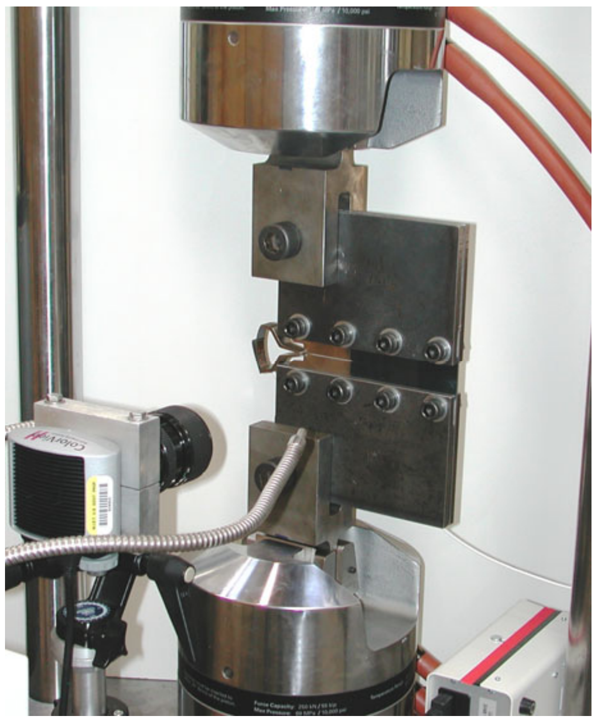
We will present data on five different pipes in this time span, and with a range of conditions. In addition, we will describe the effect when one of these running cracks reaches a circumferential butt weld. For background information, these data will be compared with conventional tensile strength data, da/dN curves (from 50 cm long by 8 cm wide pipe sections with center crack starter notches), and Charpy impact data on the same steels.

Other interesting observations include the effect of protective coatings and their application on the fatigue life. For example, a fusion-bonded epoxy coating inhibited the growth of fatigue cracks at the other pipe surface. This effect is attributed to the abrasive blasting used to clean the pipe, causing a thin layer of compressive stress in the outer layer, including the longitudinal submerged arc weld.



Deformed layer at the outer side of the pipe

Figure 1. Cross section and damage feature characterization of selected pipes.



New Set-up

Figure 2. CTOA Specimen test setup. The camera captures stable crack growth on specimen, permitting visual analysis of images.