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Experimental Study of Crack Propagation in Single Crystal Halite (Rock Salt) Using Digital Image Correlation Techniques

Tyler Galyon
University of Tennessee-Knoxville, tgalyon3@vols.utk.edu

Amirsalar Moslehy
University of Tennessee, Knoxville, amoslehy@vols.utk.edu

Khalid A. Alshibli
University of Tennessee, Knoxville, alshibli@utk.edu

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361. Experimental Study of Crack Propagation in Single Crystal Halite (Rock Salt) Using Digital Image Correlation Techniques

Tyler C. Galyon[1], Amirsalar Moslehy[2], Khalid A. Alshibli[3]

INTRODUCTION

Cavities in deposits of rock salt below the earth's surface have been used by the energy industry to store nuclear waste and petroleum due to its impermeable and self-healing material characteristics. During excavation and service, stresses applied on the cavity walls by surrounding material can cause fracturing that can damage boreholes and cause contaminants to leech out of the cavity. Halite single crystals are homogenous, anisotropic crystalline materials that exhibit different compressive strength characteristics when stresses are applied to different crystallographic orientations. In this study, fracture tests were conducted on single salt crystals to determine the facture toughness and crack propagation in specimens with different crystallographic orientations.

SPECIMEN FABRICATION

Double-cantilever fracture specimens were fabricated from single crystal rock salt with the dimensions provided in Figure 1. Each specimen was cut from a larger rock salt block using either a reciprocating saw or by activating crystallographic planes with a hammer and chisel. Removal via plane activation yielded specimens with less imperfections and was favored over the reciprocating saw. A bandsaw was used to cut the specimens to the desired dimensions, and sandpaper was used to finish the surfaces. The mounting holes and mouth were cut with a drill bit and end mill, respectively. Mouth openings were cut in relation to crystallographic orientations parallel to [1 0 0], 19º to (1 0 0) in (0 1 0), and 30º to (1 0 0) in (0 1 0), each referred to as 0º, 19º, and 30º specimens, respectively.

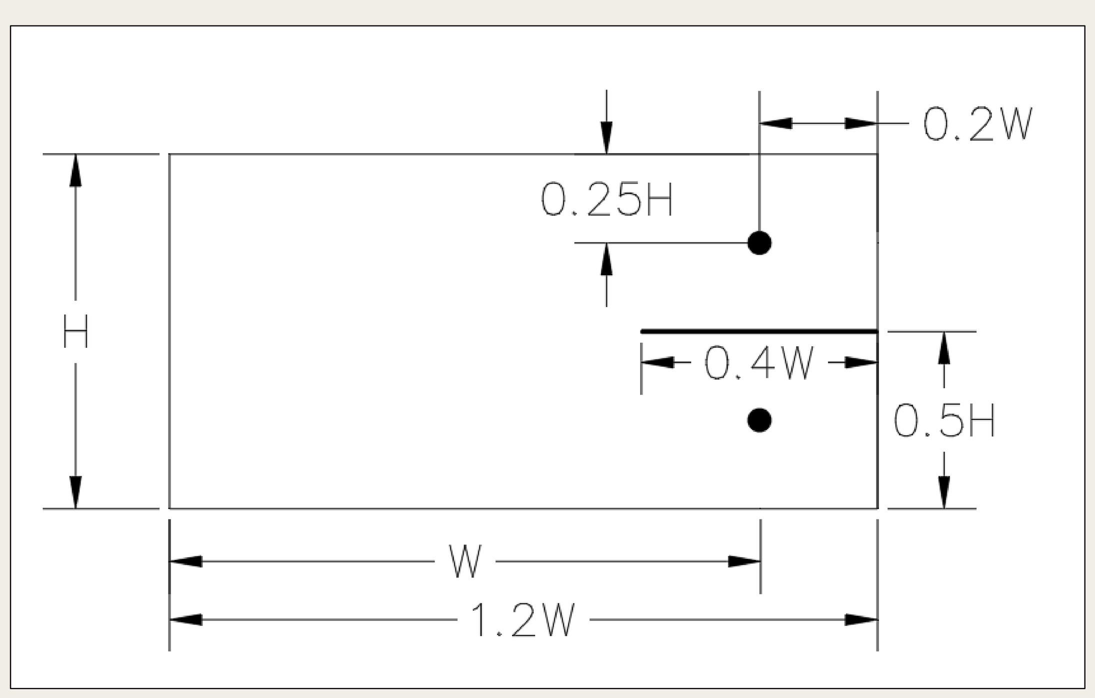

Figure 1. specimen Dimensions

Black and white speckled patterns were applied to the face of the specimens for digital image correlation (DIC) analysis. Each specimen was painted with matte white spray paint followed by a black speckled coat. Black spray paint was used to apply the black speckled coat by intermittently applying a small amount of pressure to the nozzle on the paint can. The can was held approximately one foot above the specimen spraying parallel to the specimen surface. Paint fell onto the specimen surface from a distance and was not directly sprayed onto the surface. This process yielded a pattern that was semi-uniform. The DIC software was able to analyze the pattern, but some samples encountered issues due to the concentration of particles in certain areas. Future experiments should utilize a more uniform form of painting such as airbrushing.

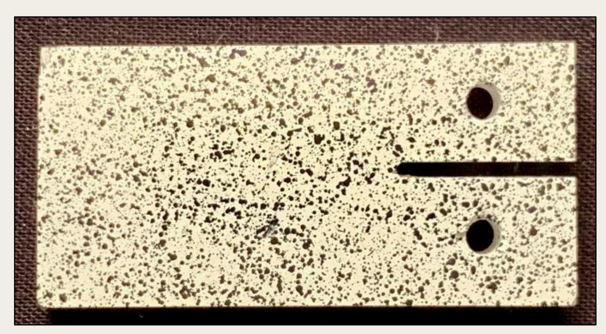

Figure 2. Speckle Pattern

EXPERIMENTAL PROCEDURE

Specimens were fixed to a tensile testing machine via steel flanges that attached to the specimen with lubricated pins through the mounting holes. The experimental configuration is shown in Figure 3. A constant strain rate of 0.0017 mm/sec was applied to the specimen at ambient room temperature. A Fastcam APX RS high-speed optical camera captured images of the specimen during the experiments. Eight total specimens were analyzed during this experiment, 3x0º, 3x19º, and 2x30º.

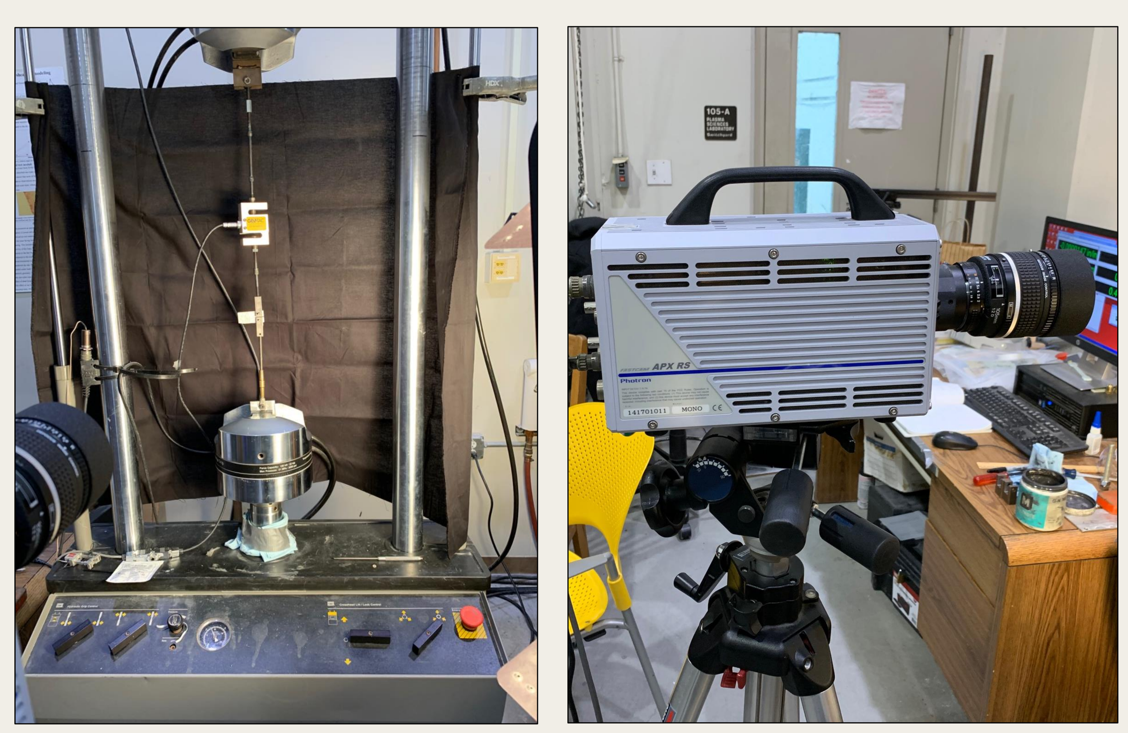

Figure 3. Experimental Setup

DIC ANALYSIS

DIC techniques were used to evaluate the crack propagation and stress concentrations in the specimen. Crack propagation was determined using ImageJ software, and strain concentrations were determined with VIC-2D software. The strain concentrations were exported from VIC-2D and further analyzed using MatLab to determine stress concentrations. Figure 4 provides an example of major strain data for a 0º specimen.

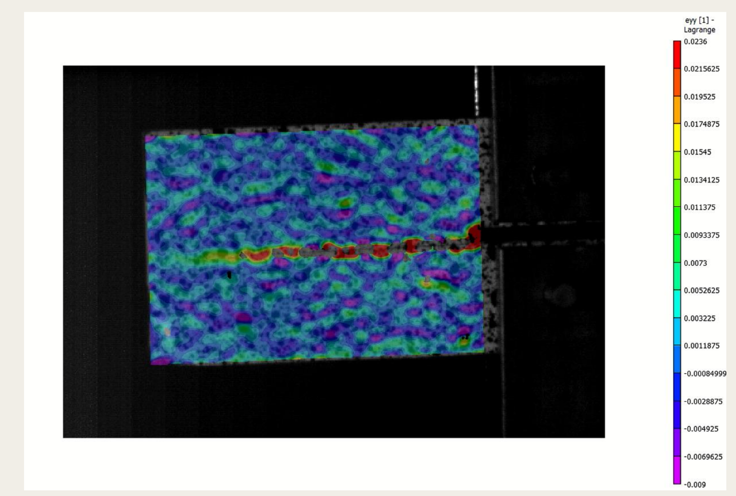

Figure 4. Strain concentrations from VIC-2D

RESULTS

Crack propagation results are provided in Figure 5. Crack growth fraction was defined as the length of the crack at a given time relative to the total crack length. The need for defining a crack length fraction was determined due to the small differences in sample dimensions. It was determined that highest crack growth velocity occurs during crack initiation when critical resolved shear stress is reached but slows down before reaching the end of the specimen. The flat portion of the curve in Figure 5 represents the period when crack growth velocity becomes zero. The zero crack-growth period could be due to the rotation of the specimen allowed by the experimental setup.

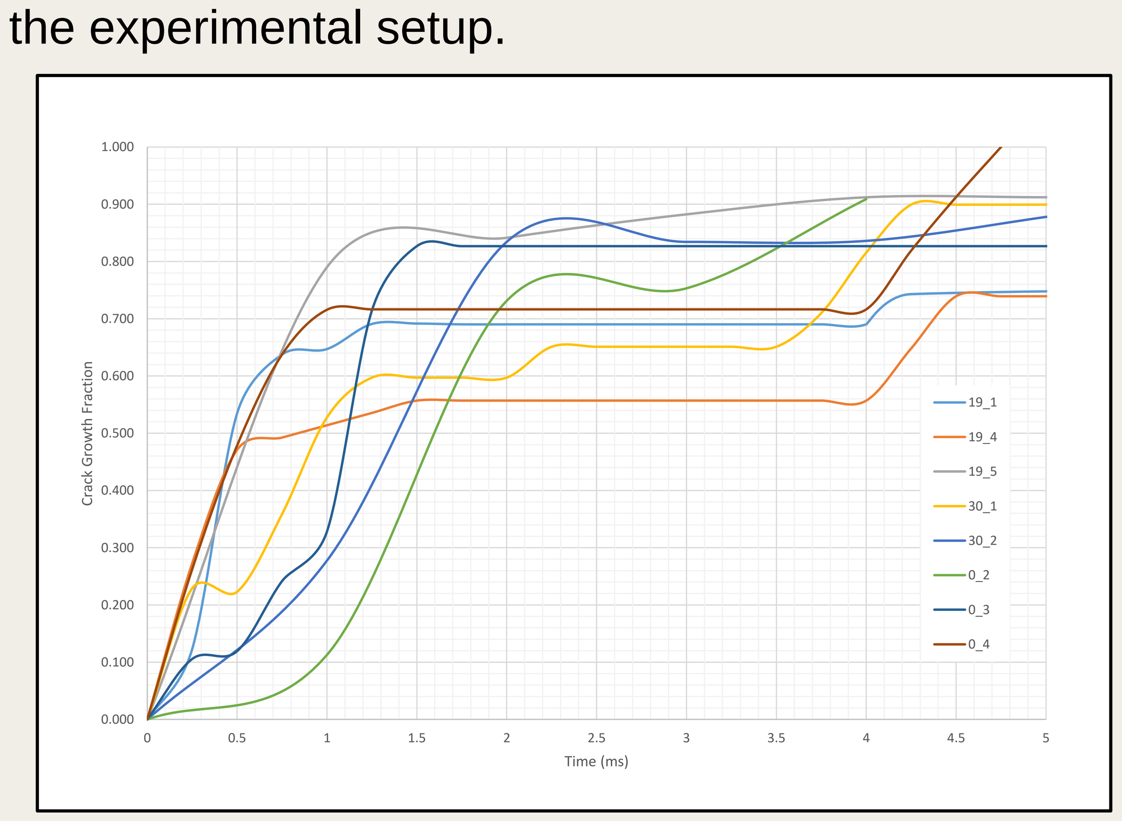

Figure 5. Graph of Crack propagation

It was determined that the highest stress concentrations in the specimen occur at the crack tip. Most of the resolved shear stress in the specimen occurs around the crack, while areas not adjacent to the crack do not encounter significant stress concentrations. Figure 6 provides a representation of the stress concentrations in a 19º specimen.

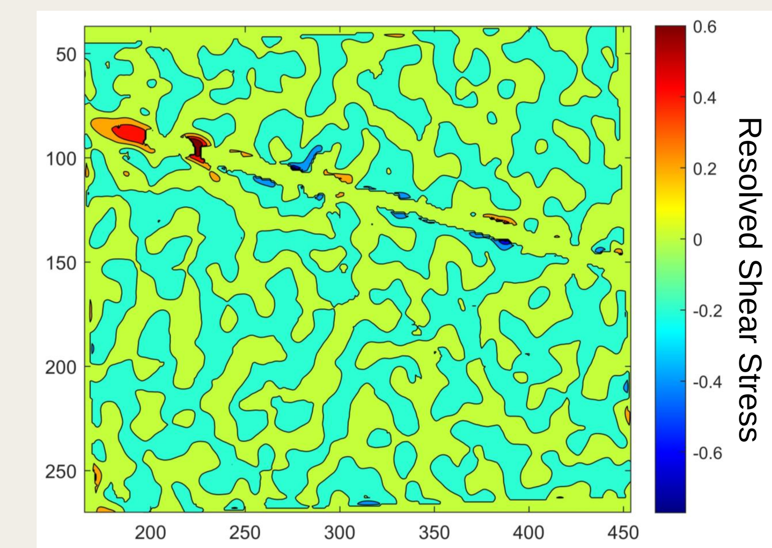

Figure 6. Stress Concentrations in a 19º specimen

CONCLUSION

Understanding crack propagation in single crystal halite is critical for determining stability for subsurface excavation for hazardous material storage. Tensile fracture tests were conducted on double-cantilever specimens to determine stress concentrations and crack propagation. 2-D DIC techniques were utilized to analyze the results. It was determined that the highest stress concentrations occurred at the crack tip and around the crack surface, while surrounding portions of the specimen experienced low resolved shear stress fields. Crack velocity was highest during crack initiation but slowed before reaching the end of the specimen.

AUTHORS

[1] Undergraduate student, Dept. of Civil & Env. Engineering, 325 John Tickle Building, University of Tennessee, Knoxville, TN 37996, USA, Email: tgalyon3@vols.utk.edu

[2] Graduate student, Dept. of Civil & Env. Engineering, 325 John Tickle Building, University of Tennessee, Knoxville, TN 37996, USA, Email: amoslehy@vols.utk.edu

[3] Professor, Dept. of Civil & Env. Engineering, 325 John Tickle Building, University of Tennessee, Knoxville, TN 37996, USA, Tel. 011-865-974-7728, Email: Alshibli@utk.edu

TICKLE COLLEGE OF ENGINEERING
THE UNIVERSITY OF TENNESSEE, KNOXVILLE