# Influence of temperature and testing media on fatigue crack growth performance of polyethylene tested via cracked round bar specimen

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## Abstract

Static loading test methods to characterize the resistance against slow crack growth use surfactants to shorten testing times. In comparison, the cracked round bar test method uses cyclic loading but no accelerating media and/or temperatures. To allow for a comprehensive knowledge on the effect of media influence, this research investigates the effect of air as well as deionized water with and without surfactant on the crack growth performance of blow-molding polyethylene in cracked round bar experiments at various temperatures. As also seen in literature, first test results show a crack growth decelerating effect of surfactant in cyclic tests at an elevated temperature. Ongoing tests will show the temperature dependency of these effects.

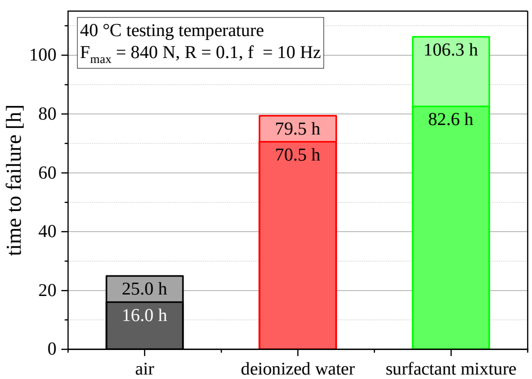
## Introduction

Several standardized test methods for the experimental characterization of the slow crack growth resistance of polyethylene are in use. Some of these test methods make use of accelerating media and/or test temperatures to shorten testing times, especially if environmental stress cracking resistance (ESCR) is also investigated. A widely used test method, the full-notch creep test uses elevated temperatures (50 °C – 90 °C) and a creep crack growth accelerating mixture of deionized water and 2 m% surfactant. Other ESCR methods like the ASTM D 1693 “bent strip method” or the ASTM D 2561 “bottle ESCR method” also use surfactants and elevated temperatures. The cracked round bar (CRB) test method uses neither elevated temperature nor harsh media, but cyclic loading for acceleration of crack growth. The effect of elevated temperatures and harsh media applied to CRB experiments was already investigated by different publications, often to show the accelerating influence of a certain medium at an elevated temperature or rather the vulnerability of a material to defined conditions (e.g., hot chlorinated water for pipe materials). Materials which are used in packaging of e.g., detergents are exposed to crack growth accelerating effects by the packed medium. The used ESCR tests for these applications use surfactants like Arkopal® or Igepal® to investigate the materials resistance in an appropriate way. The effects of surfactants in combination with cyclic loading were investigated before on compact tension specimen and showed, contrary to creep loading, an increase of testing times or rather decrease of the accelerating effect of cyclic loading, at least at the elevated temperatures investigated. If and to what extent surfactants influence crack growth performance at room temperature and to which extend elevated temperatures change its effect is unclear. Therefore, this paper investigates the effect of the commonly used surfactant Igepal® CO-630 on CRB experiments of blow-molding high density polyethylene (PE-HD) at different temperatures.

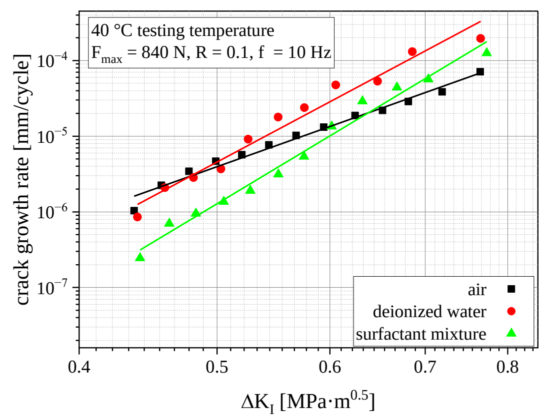
## Results

Cracked round bar (CRB) specimen were produced out of the virgin PE-HD blow molding type BB2581 from Borealis AG. An environmental testing chamber, which was constructed for testing of CRB specimens in harsh media, was used for the tests within air, deionized water and a surfactant mixture consisting of deionized water with 10 m% Igepal® CO-630. Tests are performed at 23 °C and for estimation of realistic storage conditions at 40 °C. For tests in air a fan was used to prevent heat accumulation from hysteretic heating at the crack tip. For the tests in liquid media a circulating pump was used to homogenize the mixture and to prevent the mixture from segregating. Furthermore, the flushing of the crack tip eliminates air bubbles and ensures the wetting of the crack tip. While being tested at a sinusoidal loading profile at 10 Hz, the specimen also rotates around its own axis, so the fan and circulating pump can reach the whole specimen circumference. A camera system was used to capture images of the crack tip at a fixed time interval for measurement of crack tip advancement and subsequent generation of crack growth rate vs. stress intensity factor range curves.

Measurements at 40 °C were already finished and depict an unexpected outcome. The specimens tested in air failed after a vastly shorter testing time (25.0 h) than in water (79.5 h) and in the surfactant mixture (106.3 h) as can be seen in Figure 1a. The crack initiation times, which can also be seen as lower numbers for each bar in Figure 1a, show another differentiation between the media. While crack initiation happened fast for the measurement in air (16.0 h), it took longer for the measurement in water (70.5 h) and in the surfactant mixture (82.6 h). Crack growth time (from crack initiation to failure) of the specimen in air and in water are the same (9 h), while the crack growth time in the surfactant mixture was 2.6 times longer (23.7 h). As only data points with measurable crack growth can be depicted in crack growth kinetic curves, Figure 1b comprises the different behavior of crack growth in the various media. The vertical shift between the measurement in water and surfactant mixture is due to different fatigue crack growth resistances in the various media and explains the difference in testing time. At all stress intensity factor ranges observed, the measurement in water has higher crack growth rates and hence has a lower crack growth time (9 h vs 23.7 h). The measurement in air is more difficult to explain, as the testing time is the same as for water (9 h) but the crack growth kinetic curve looks different. The air measurement shows a higher crack growth rate at the first few measurement points and decreases compared to water during the crack growth.




(a)




(b)

Fig.1 – Time to crack initiation time and failure (a) and fatigue crack growth kinetic curves (b) at 40 °C in the three media.

## Conclusions

While a difference in testing time was expected, the outcome was surprising on several accounts. First, the elongated testing time in aqueous media compared to air was not observed in literature and cannot solely be explained by crack growth accelerating effects of the media. Measurements at lower temperatures and lower frequencies are necessary to exclude the effect of hysteretic heating and/or other influencing factors introduced by cyclic loading and will help to differentiate environmental effects from unwanted testing influences. Second, the addition of surfactant to deionized water shows a crack growth deceleration, expanding testing times for the elevated temperature. Ongoing tests will determine if this effect can also be observed at lower temperatures.

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