HYDROGEN EFFECTS IN THERMOPLASTICS AND ELASTOMERS IN HIGH-PRESSURE AND LOW-PRESSURE CYCLING ENVIRONMENTS UNDER AMBIENT AND COLD TEMPERATURE CONDITIONS

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Polymeric O-rings are an integral part of components employed in fueling operations as part of the hydrogen infrastructure and often, are subject to high and low pressure cycling at ambient temperature and frequently, under cold conditions. In dynamic and static sealing applications and as liners in storage tanks, common elastomers (FKM, EPDM, HNBR, NBR) and thermoplastics (PEEK, PTFE, and Nylon 11) can be exposed to temperatures between -40°C and +85°C and pressures up to 5000-10,000 psi (350-700 bar). This study focuses on the comparison of the behaviors of select polymers in hydrogen environments under high-pressure and low-pressure cycling conditions. High-pressure cycling involved cycling between 12500 psi and 2500 psi and low-pressure cycling was performed between 4500 psi and 1500 psi. Each test included 100 cycles of exposure. Filled and unfilled model compounds of the polymers were used, wherever possible, to be able to understand the role played by additives such as fillers and plasticizers. Experiments were conducted at ambient (21-23°C) and cold temperatures (-40°C) temperatures with high-pressure and low-pressure cycling. In addition, experiments were conducted for evaluating the effect of changing the rates of depressurization (1, 10, 20, and 40 MPa/minute) in high-pressure cycling at ambient temperature on the same polymers. All tested specimens were examined for external damage and characterized for changes in density (or specific volume changes which represent degree of swell), mechanical properties changes using Dynamic Mechanical Thermal Analysis (DMTA), localized hardness and elastic modulus changes using nanoindentation, and internal damage in the form of cracks and voids using X-ray CT (computer tomography). Compression set was determined for the elastomers and X-ray diffraction was used to analyze changes in crystallinity in thermoplastics.

Polymer behaviors observed were found to strongly depend on their chemical micro and macro-structure, and on whether they were filled or unfilled. For the same polymer type, the filled versions showed less differences for high- and low-pressure cycling compared to the unfilled versions. Depending upon polymer type, percent change in polymer properties increased or remain relatively unchanged with increasing rates of depressurization. From data collected so far, EPDM rubber showed significant changes in storage modulus and compression set with changing rates of depressurization which was further corroborated with micro-CT imaging which showed more damage in EPDM rubbers, compared to other polymers. Findings from low-temperature pressure cycling experiments will be compared with results from ambient-temperature cycling to understand temperature influence on polymers tested in cycling hydrogen environments.

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