

Evaluation of Pressure Fixture Designs for Improved Stack Pressure Retention

Min-Gi Jeong, Jing Wu, Seungwoo Jun, Dongping Lu*

Energy and Environment Directorate, Pacific Northwest National Laboratory, Richland, Washington 99354, United States
Corresponding Email: Dongping.lu@pnnl.gov

Abstract

Using a dummy cell, this study compares constant-gap and constant-pressure fixtures in terms of their ability to retain pressure over time for precise stack pressure control. The results show that constant-pressure fixtures outperform constant-gap designs in maintaining pressure and are therefore recommended for improving test reproducibility and enabling accurate electrochemo-mechanical analysis.

Key words: stack pressure, fixture, battery, constant pressure, electrochemo-mechanical

Why This Study

Stack pressure plays a crucial role in battery technologies, especially in systems that experience significant volume or interface changes, such as metal-based^{1, 2} and all-solid-state batteries.³ Properly applied stack pressure ensures compact interfaces, enhances electrode contact, and mitigates dendrite formation, leading to improved battery performance. Two common fixture designs are used to apply stacking pressure: constant-gap or constant-pressure. The constant-gap fixture confines the cell within a fixed space between rigid plates (Figure 1a), while the constant-pressure fixture uses springs to apply consistent force between adjustable plates (Figure 1c). Despite their widespread use, the ability of these fixtures to retain pressure and their impact on experimental reproducibility have not been thoroughly studied. Insufficient control over stack pressure could influence the accurate analysis of electrochemo-mechanical behavior in these systems. This study addresses these limitations by comparing the pressure-retention characteristics of constant-gap and constant-pressure fixtures. Dummy cells with only metal blocks were utilized to avoid interference from materials' volume change upon cycling, enabling a focused examination on the pressure fixture only.

How

Different stack pressures of 5 MPa, 2 MPa, and 0.3 MPa have been applied to dummy cells, with pressure changes monitored over 50 hours using load cells (Figure 1). The constant-gap fixture, being a commercial design, exhibited significant pressure relaxation across all preset values (Figure 1a-b), presumably due to mechanical relaxation. Retention was better at higher preset pressures: stabilization at 5 MPa occurred after a 12% pressure drop, whereas at 0.3 MPa, the decline reached 32%. These observations highlight challenges in maintaining precise pressure control, particularly at lower values, which could affect the reliability of data linking stack pressure to battery behavior. Conversely, the modified constant-pressure fixture with uniaxial spring consistently maintained preset pressures across all tested ranges (Figure 1d), demonstrating superior resilience and reliability during prolonged testing. This suggests that defining stack pressure exclusively by initial applied values may be

misleading when using constant-gap fixtures, which is widely used in the area.

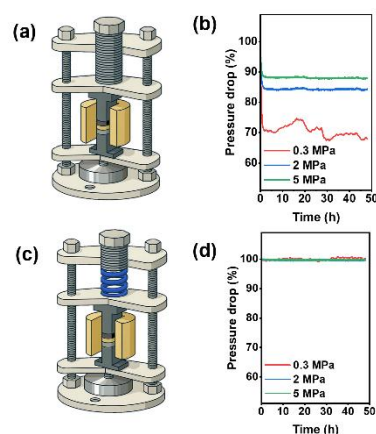


Figure 1. Schematic illustration and pressure relaxation behavior of two pressure application fixtures. Design of (a) constant-gap and (c) constant-pressure fixtures. Pressure relaxation curves demonstrating a significant and rapid drop in the (b) constant-gap fixture compared to the stable performance of the (d) constant pressure fixture.

Conclusions and Recommendations

The findings of this study highlight the critical influence of pressure fixture design on both pressure retention and test reproducibility. To enhance research reliability and data accuracy, several key recommendations are proposed. First, researchers employing constant-gap fixtures should perform baseline evaluations to determine the pressure response and stabilization time across various preset values which will be used in real research. This step is essential to minimize systematic

inconsistencies prior to conducting experiments involving battery materials or cells. Second, the use of constant-pressure fixtures is recommended for pressure application, as these designs demonstrate superior pressure retention and reliability. Implementing such fixtures can ensure consistent pressure control throughout testing and operation, thereby improving experimental reproducibility. Third, to address issues associated with pressure relaxation, it is advisable to adopt standardized terminology—such as effective pressure or retained pressure—to describe stabilized mechanical conditions rather than relying solely on initial stack pressures.

Data Availability

The data that support the the findings are available on request from the corresponding author.

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References and Notes

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