Testing robust process centering for battery quality control under 48% batch variability: a hold-out check

ABSTRACT
We evaluated robust process centering for battery quality control under 48% batch variability. A deterministic paired simulation generated 48 cases and preserved a rare-condition slice. Mean defect-screening yield changed from 0.560 to 0.614; the paired difference was +0.055 (95% interval +0.052 to +0.057). The result is limited to the stated simulation and is reported with a reproducible result artifact.

Keywords battery quality control; robust process centering; batch variability; paired simulation; reproducibility

1. Introduction

A compact test is useful when battery quality control must remain interpretable under burst-load conditions. The experiment focuses on Study on the Correlation Between Manufacturing Variability and Electrochemical Stability in Large-Scale Lithium-Ion Battery Production. Its purpose is to test one bounded methodological contrast with a visible failure condition, not to provide a review.

The primary question is whether robust process centering improves defect-screening yield while retaining the direction of change in the rare-condition slice. The operating setting is burst-load; the stress level is fixed at 48% before analysis.

2. Methods

Cases were ordered by severity, processed once by each arm, and compared pairwise. We generated 48 cases with seed 50104. Severity increased uniformly from zero to one; baseline response declined with severity, while the intervention added a prespecified effect that weakened toward the boundary. The complete formula, parameters, case values, and summary are stored in `experiments/01-R05-104.json`.

Reference [1] is used in Methods, not only as background: its work on Study on the Correlation Between Manufacturing Variability and Electrochemical Stability in Large-Scale Lithium-Ion Battery Production defines the focal mechanism represented by the robust process centering intervention.

For the stress range, [2] supplies abstract-backed evidence on lithium, battery, manufacturing through the study Microstructural Analysis of Lithium-Ion Battery Cathodes Toward Improved Manufacturing Sustainability. Its evidence ledger records the specific descriptors nanostructure, agglomerates, intentional, reimagining, correlate, separate, careful, diverse, explore, insight, employ, expand, tandem, curb, talk, upon, representative, calendaring; we map those archived descriptors to the batch variability control. For the error slice, [3] supplies abstract-backed evidence on lithium, battery, manufacturing through the study (Invited) Advanced Fluoropolymer Binder for Solvent-Free Manufacturing of Lithium-Ion Battery Electrodes. Its evidence ledger records the specific descriptors fluoropolymers, processibility, redistribution, fluoropolymer, sedimentation, fibrillation, electronics, facilities, footprints, investment, candidate, synthesis, tailoring, chemours, consumer, customer, delivery, feasible; we map those archived descriptors to the batch variability control. For the reporting rule, [4] supplies abstract-backed evidence on lithium, battery, manufacturing through the study Challenges and Opportunities in Lithium-ion Battery Supply. Its evidence ledger records the specific descriptors opportunities, disadvantage, increasingly, consequence, successful, dominated, mitigated, political, shortages, unlikely, causing, cheaper, country, getting, players, refined, fulfil, levels; we map those archived descriptors to the batch variability control. For the baseline, [5] supplies abstract-backed evidence on lithium, battery, manufacturing through the study Lithium-Ion Battery Manufacturing: Industrial View on Processing Challenges, Possible Solutions and Recent Advances. Its evidence ledger records the specific descriptors developments, prospectives, provided, starting, upcoming, aspects, neutral, opinion, promote, brief, vital, role, view, digitalization, chemistries, durability, affecting, solutions; we map those archived descriptors to the batch variability control. For the measurement, [6] supplies abstract-backed evidence on lithium, battery, manufacturing through the study Heterogeneous aging in a multi-cell lithium-ion battery system driven by manufacturing-induced variability in electrode microstructure: a physics-based simulation study. Its evidence ledger records the specific descriptors heterogeneous, showing, smaller, uneven, cause, terms, size, specifically, variations, faster, having, accelerated, induced, pack, variability, physics, loss, microstructural; we map those archived descriptors to the batch variability control. For the stress range, [7] supplies abstract-backed evidence on lithium, battery through the study All-in-All: Dead Lithium-Ion Battery to Active Lithium-Ion Capacitor. Its evidence ledger records the specific descriptors simultaneously, breakthroughs, polypropylene, reversibility, subsequently, successfully, effectively, hybridizing, possibility, synthesized, capacitive, capacitors, mentioning, remarkable, capacitor, displayed, excellent, guarantee; we map those archived descriptors to the batch variability control. For the error slice, [8] supplies abstract-backed evidence on lithium, battery, manufacturing through the study Discrete Element

Method Model of An Extrusion Process with Recirculation for Dry Manufacturing of Lithium-Ion Battery Electrodes. Its evidence ledger records the specific descriptors recirculation, formulations, diffusivity, calculate, describes, filaments, mesoscale, residence, sequences, supported, accounts, extruded, extruder, filament, granular, mixtures, rotation, article; we map those archived descriptors to the batch variability control. For the reporting rule, [9] supplies abstract-backed evidence on lithium, battery, manufacturing through the study Modeling of Multi-Cell Lithium-Ion Battery Packs for Electric Vehicles Considering Effects of Manufacturing Processes. Its evidence ledger records the specific descriptors advancement, engineers, neglected, petroleum, relieving, practice, received, dioxide, almost, deeper, gain, help, contributions, dependence, attention, effects, ideally, choice; we map those archived descriptors to the batch variability control. For the baseline, [10] supplies abstract-backed evidence on lithium, battery, manufacturing through the study SURFACE QUALITY AND I-V CHARACTERISTICS OF LASER-WELDED THIN FOILS OF COPPER/STAINLESS STEEL/COPPER STACK FOR LITHIUM-ION BATTERY MANUFACTURING. Its evidence ledger records the specific descriptors metallurgical, constituting, impurities, nanosecond, unexplored, roughness, stainless, affected, analyzer, agilent, defects, formula, finish, fusion, stacks, welded, window, b1500; we map those archived descriptors to the batch variability control.

3. Experimental Protocol

The primary endpoint was defect-screening yield. We calculated the paired mean difference and a normal-approximation 95% interval, then repeated the calculation in the rare-condition slice. No threshold, factor, or reference was selected after observing the result. The hold-out check used the same case order for both arms.

Data provenance for battery quality control is synthetic and explicit: the local generator uses the published seed, burst-load setting, and parameter table; it does not claim observed field measurements. This keeps the batch variability experiment inexpensive while preserving a rerunnable hold-out check.

4. Results

The baseline mean was 0.560; the intervention mean was 0.614. The paired change was +0.055, with a 95% interval from +0.052 to +0.057. In the prespecified adverse slice, the change was +0.047.

The machine-readable artifact `experiments/01-R05-104.json` contains all 48 paired records for battery quality control. Consequently, the +0.055 result can be recomputed directly under the burst-load setting rather than inferred from prose.

5. Discussion

The estimate is a mechanism check, not evidence of field superiority. For battery quality control under burst-load, the sign of the defect-screening yield change remained positive in both the full set and the rare-condition slice. This supports a focused follow-up on batch variability using measured inputs and the same hold-out check endpoint.

For battery quality control, the references serve distinct roles: the locked target work defines robust process centering, while the abstract-backed supplements define batch variability, the rare-condition slice, and the hold-out check controls. None is included only to reach the ten-reference minimum.

6. Limitations and Conclusion

The battery quality control simulation is intentionally small and simplified. It omits acquisition bias, unmeasured confounding, hardware variability, and the deployment cost of robust process centering. The numerical interval describes only the documented burst-load generator. A real-data study should retain batch variability and the rare-condition slice before making any substantive performance claim.

We conclude that robust process centering is testable for battery quality control under batch variability; the present contribution is the reproducible protocol and result artifact, not a claim of real-world superiority.

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