Towards a Comprehensive Model for the Positive Electrode System of a Lead-Acid Traction Cell

A thesis presented
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Ross Richard Nilson

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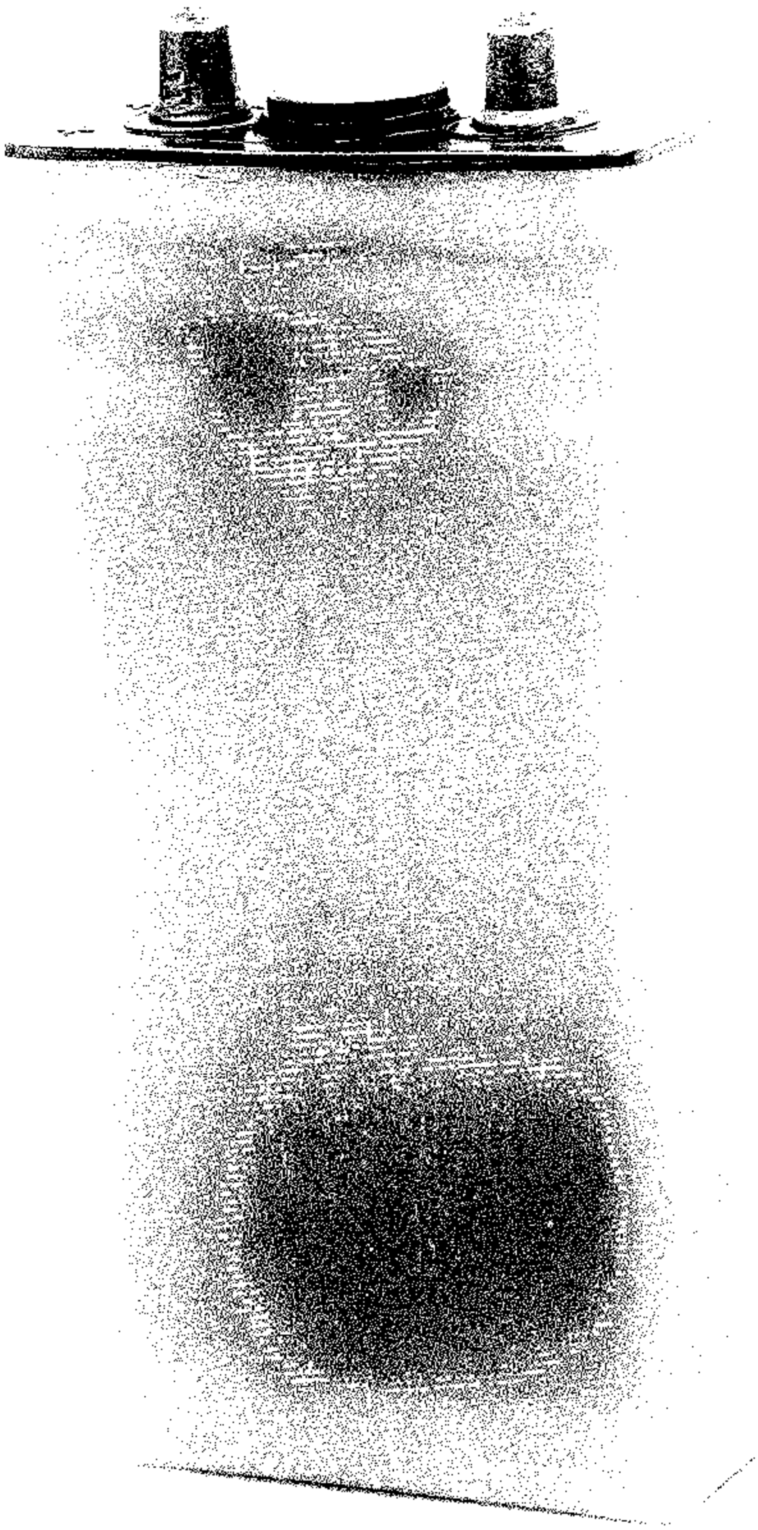

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Abstract

This thesis develops a detailed model for the positive electrode system of an industrial lead-acid traction cell. This is referred to as the VIAM model since it relates the positive electrode voltage (V) and cell current (I) to internal distributions of current, potential, acid concentration and active mass (AM). The model can simulate both discharge and charge for a wide range of practical currents. The model takes account of microstructure, macrostructure and non-reactive structure in the positive active mass (AM). It also takes account of other cell components that affect the supply of acid to the positive electrode. The model has direct application to fundamental cell design (for example AM development) and cell systems design (for example cell charger design).

The model is based on established experimental studies, theories of electrochemical interface reactions and theories of ionic transport in electrolyte solution. From this base, three elemental models and an aggregate model are developed. The elemental models represent details of the microstructure of the positive electrode AM. The aggregate model represents the electrolyte mass (acid) and charge transport system within the positive electrode and other cell components. The combination of the elemental and aggregate models make up the VIAM model. The performance of the VIAM model (and underlying models) is assessed by comparing model results with findings from experimental studies in the literature. In addition, experiments undertaken as part of this work are used to test the model. The model and experimental results are in close agreement.

Acknowledgements

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My thanks also to my wife, Mary, who not only managed two very active children, Jonathan and Elissa, without help for many evenings during the preparation of this thesis, but also had enough energy left to proof-read the text.

Contents

List of Figures

Figure

Figure

Figure

Figure

List of Tables

Units and Symbols

a) Units.

Normal SI units (Chiswell and Grigg (1971)) are used throughout this text with the following additions.

i) Hour(s) (abbreviated to hr(s)) is used as a measure of time (3600 s).

ii) Ampere hour(s) (abbreviated to Ahr(s)) is used as a measure of electrical charge (3600 A.s).

iii) Watt hour(s) (abbreviated to Whr(s)) is used as a measure of energy (3600 W.s).

iv) The gram (abbreviated to g) is used as a measure of mass ($1x10^{-3}$ kg).

These additions are consistent with common practices in the battery industry.

b) Symbols for units.

Normal SI unit symbols (Chiswell and Grigg (1971)) are used throughout this text with the following additions.

i) Hr(s) for hour(s).

ii) Ahr(s) for Ampere hour(s).

iii) Whr(s) for watt hour(s).

iv) g for the gram.

v) v for the volt.

c) Symbols for variables.

Symbols for variables are fully defined in the body of text where they are first used.

d) Symbols for experiment designations.

An example designation for the experiments performed in this work is AD100R20. This should be in interpreted as follows.

i) The first character (A) is the cell label that defines the cell involved (here cell A).

ii) The following four characters (D100) define the depth of discharge (here 100 Ahrs).

iii) The last three characters (R20) define the rate of discharge (here 20 A).