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Cost and performance prospects for composite bipolar plates in fuel cells and redox flow batteries

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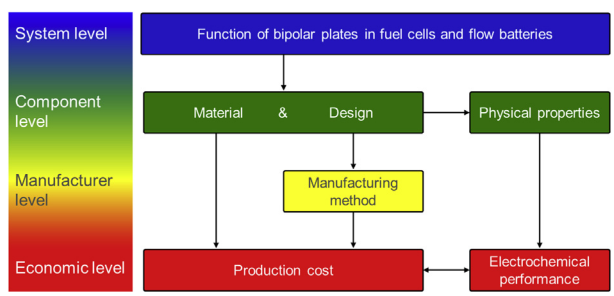
HIGHLIGHTS

- Integrated materials and cost analysis for carbon–polymer-composite bipolar plates.
- Investigation of forming methods considering electrochemical conductivity of product.
- Production cost model for compression and injection molded plates.
- Cost prospects based on sensitivity analysis of production parameters.

GRAPHICAL ABSTRACT



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ABSTRACT

Carbon–polymer-composite bipolar plates (BPP) are suitable for fuel cell and flow battery applications. The advantages of both components are combined in a product with high electrical conductivity and good processability in convenient polymer forming processes. In a comprehensive techno-economic analysis of materials and production processes cost factors are quantified. For the first time a technical cost model for BPP is set up with tight integration of material characterization measurements.

1. Introduction

The bipolar plate (BPP) is one of the key components of a redox flow battery (RFB) providing multiple functions in the cell stack. It is the electrical connection between adjacent cells and at the same time a separator for the different electrolytes. Furthermore, the homogeneous distribution of electrolyte can be achieved by an optimizes surface design (flow fields). These functions result in a set of complex technical requirements [1]. A high electrical conductivity and chemical resistance against corrosive electrolytes are indispensable. In regard to transport, handling and total system

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weight a low density should be combined with a high mechanical stability. Production should be possible at low cost and high quantities.

BPP made of carbon–polymer-composites combine the electrical conductivity of carbon and the good processability of polymers. The graphite loading is usually around 80wt.-%, while the isolating polymer is the smaller component. A variety of additives improving electrical conductivity or flowability of the composite material may be added in small amounts below 4wt.-%. Composite materials may be processed in conventional polymer processing methods like extruding, compression molding and injection molding with a potential for low price mass production [2].

The present paper provides a comprehensive approach to quantify cost potentials of composite BPP. Three commercial composite materials with different polymer binders are analyzed, namely Sigracet® PPG86, BBP4 and BMA5. In a technical cost model material and production cost are assessed for a standard plate of 625 cm^2. The economic methodology is described in Section 2 in detail. The presented approach is based on the identification of influencing factors and limitations coming from the material side. Therefore an in-depth analysis of physical graphite and binder characteristics with regard to raw material pricing and processability is given in Section 3.1. Results from the analysis and modeling of the manufacturing processes compression and injection molding are discussed in Section 3.2. Considering current technical limitations and different degrees of plant automation advanced production models are applied in a set of manufacturing cases.

2. Methodology

2.1. Economic methods

The overall techno-economic approach has been described in a former article on economics of membranes in RFB [3]. It is based on the simple definition of production cost as the sum of raw material and manufacturing cost.

Profound analyses of raw materials and manufacturing processes for composite BPP form the basis for economic modeling and evaluation. As illustrated in Fig. 1 the material analysis reveals a material balance of the ingredients. These raw materials follow high quality requirements, including purity, particle size distribution and particle morphology, that are directly influencing the material prices. Due to the fact that RFB are a relatively young technology using specialty materials, production cost are subject to many complex influences, such as customer relationship and market shares. Therefore statistical data is prepared (Section 2.1.1) for a Monte Carlo approach, which allows to calculate probability distributions of different material costs (Section 2.1.2). The selection of an appropriate manufacturing process is determined by material properties, as well as plate design and lot size. These data go into a complex production cost model, where different case settings are calculated (Section 2.1.3).

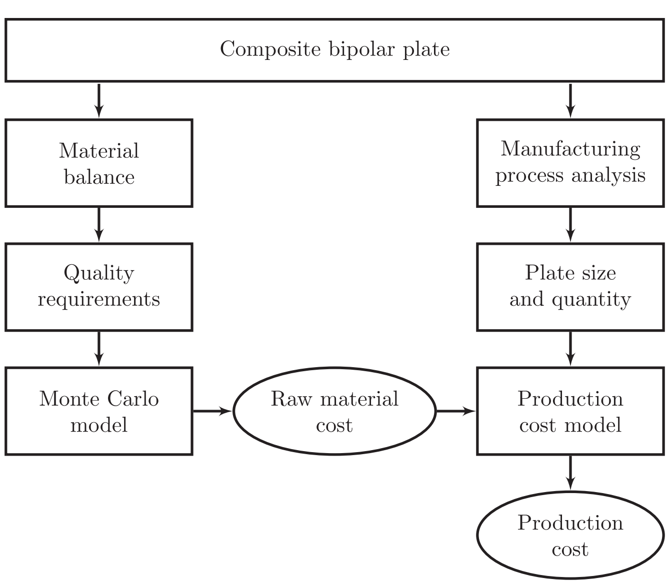

Fig. 1. Methodology for calculating production cost.

2.1.1. Preparation of statistical data

Prices of specialty carbon materials are influenced by a variety of factors, e.g. primary cost, purchase quantity and customer relationship. Statistical price data are independent from these direct determinants. As input for the cost model two kinds of statistical data are used; general price data from the €pean Commission mark the bottom limit, whereas modeled price ranges involve current quality and market requirements.

General price data on raw materials are retrieved from the PRODCOM database of the statistical office of the €pean Commission €STAT [4]. Data collected from the PRODCOM database include information from the EU-27 member states. The time period considered ranges from 2007 to 2012. The database provides six balance sheet values: quantity of imported, exported and produced goods and the monetary value of those. Required information about the price per kilo gram of a substance only results in case of a corresponding pair of quantity and value of goods. Considering these three balance sheet figures in 27 states and six periods of time, the theoretical data set contains 486 data points. The derived statistical data is checked for consistency and documented in a histogram. The corresponding cumulative distribution function (CDF) contains complete information about the spread of values and is used as input for the analytical cost model. Price data on artificial graphite are given as an example in Fig. 2 (top plot).

For further processing characteristic quantiles are determined

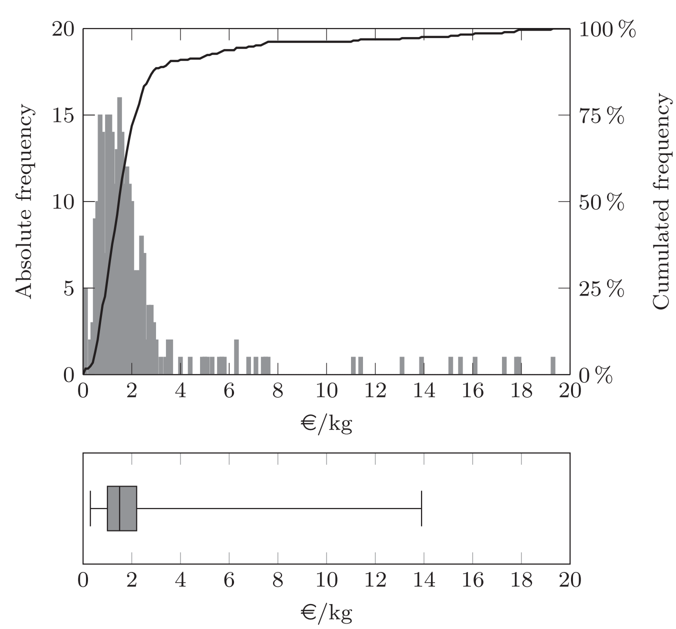

Fig. 2. Probability distribution (top) and box plot (bottom) of prices for artificial graphite based on statistical data of EU member states. 288 datapoints after consistency check (Data: [4]).