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Influence of product characteristics of prismatic lithium-ion battery cells on the production processes and plant technology for cell finishing

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Abstract

The increasing demand for electric vehicles and, consequently, battery cells will result in a significant surge in production capacity in the upcoming years. Product, factory, and production are being planned simultaneously. Processes must be designed even though not all product specifications have been defined yet. This paper examines the impact of product characteristics of prismatic battery cells on the processes and production technology for cell finishing. Understanding these dynamics facilitates early-stage integration of product effects into innovative process and product developments, mitigating uncertainties and reducing development risks. In summary, this paper provides a comprehensive understanding of how product characteristics influence the production technology of battery cells.

Keywords: Battery Cell Production; Cell Finishing; Product Design; Production Technology; Formation; Trays; Manufacturing System; Cell Conditioning

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1. Introduction

The global ambitions to reduce greenhouse gases result in a rising demand for electrical energy storage systems. The market for battery cells and the need for battery factories is growing, particularly due to the increasing number of battery electric vehicle [1]. For the battery factories currently being planned worldwide, studies predict an electricity demand of 130,000 GWh by the year 2040. Savings of up to 66 % are possible with innovative process and product technologies. [2] The production of lithium-ion battery cells is divided into three stages: electrode production, cell assembly and cell finishing [3]. With a throughput time of up to three weeks and an energy consumption of over 10 kWh per kWh cell capacity, cell finishing has a major influence on costs, electricity demand and factory requirements [4, 5, 6]. The production technology for cell finishing is determined by product characteristics such as cell format, dimensions, tab position as well as the electrochemical cell specifications such as chemistry and capacity. The trend in the development of battery cells is currently moving towards large-format cells with higher capacities [7]. This trend is accompanied by challenges in process and plant design and may lead to longer development times for product, production technology and factory, which is associated with higher costs.

Practical system design at the Fraunhofer FFB has shown that even minor changes to product specifications can have an impact on system technology and thus factory requirements. From this, the problem is derived that the influence of the product characteristics of prismatic battery cells on the production resources of cell finishing has not yet been scientifically investigated and published.

This paper addresses this problem and gives an overview about the influence of product characteristics of prismatic lithium-ion battery cells on the production processes and plant technology of cell finishing. First, the state of research and

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basics of prismatic battery cells, the production process chain of cell finishing, and the core components of the respective technology are presented.

The aim of this paper is to illustrate the chain of effects of product characteristics on the cell finishing manufacturing technology and to work out the cause-effect relationships on specific system components. This investigation and presentation represents a novelty in the research field of battery cell production. It is hypothesized that product characteristics directly influence plant design and that there are interdependencies between manufacturing resources. A systematic analysis of the influence of product characteristics of prismatic battery cells on the production technology for cell finishing and publication of the results is not yet known.

This paper offers scientists and industry representatives an insight into the influence of product characteristics on the production process chain of battery cells. This insight makes it possible to incorporate the effects of product features on production into the development process of innovative product and production innovations at an early stage. This could lead to fewer uncertainties in the development process and thus to a lower cost and time risk.

2. State of Research

The following section describe the state of research. First, the product characteristics of battery cells are explained, followed by the production process chain with a focus on cell finishing. On the basis of the state of the art, product features and the core components of the necessary production processes are selected and presented in this chapter.

2.1. Product Characteristics of a Battery Cell

The product characteristics of a battery cell are attributed to the cell design of internal and external features. While the electrochemical properties of a battery cell are defined by the internal features, regardless of the cell format, external features are decisive for the dimensioning, geometry, and configuration of a battery cell and, in this regard, are product specific. In the following, the internal product characteristics are therefore regarded as general and the external characteristics as product specific.

The cell chemistry of a battery cell is mainly determined by the electrode design and material selection of the anode, cathode, separator and electrolyte from the material and component perspective. The cell chemistry design, especially the design of the active materials, is responsible for its electrochemical properties and thus the performance characteristics. The electrode materials for the anode are commonly based on carbon and consist of graphite. Metal oxides are used for the cathode, such as lithium iron phosphate and lithium nickel manganese cobalt oxides. [8, 9, 10] For the current transport between the anode and cathode a conductive electrolyte can be selected, such as dimethyl carbonate and lithium hexafluorophosphate [8]. Through electrolyte additives, electrochemical cell properties can be further optimized [11]. Between the two electrodes, a separator made of polymer membranes or non-woven materials can be determined to prevent electrical short circuits [11]. Specific design decisions regarding the cell chemistry and the internal cell components have significant impact on cell performance characteristics, such as internal resistance of the battery cell, specific cell power and energy, and cell capacity. [7, 12]

The external characteristics of the battery cell depend on the features like connection terminals, electrolyte filling hole and the cell housing, which also depend on the specific cell format (cylindrical, pouch or prismatic). The dimensioning, configuration and positioning of these features are determined by product design decisions. The specification of these product features must be considered when enabling the interface to the production machines in battery cell production. [13, 14] Using the prismatic format as an example, the design of its housing is determined by the geometric parameters length, height, and thickness, whereas the ratio of the longest versus shortest side could range from 1:1 to 4:1 [12]. The lid assembly could be positioned on different sides of the prismatic cell and depends on the design of the connection terminals and electrolyte filling hole, which may vary by the design parameters orientation, position, form (design) and dimension [13]. Fig. 1 shows the most important cell characteristics for cell finishing of one-sided-tab (OST) and counter-sided-tab (CT) versions of prismatic cells. The lid assembly orientation summarizes that the filling hole is in the lid assembly together with the terminals. During handling it is important that the filling hole point upwards to prevent electrolyte leakage because the cell is eventually not finally sealed.

Selected prismatic cell characteristics: electrochemical properties, terminal orientation, filling hole orientation, lid assembly orientation, terminal position, terminal design, height, length, thickness, filling hole position, filling hole diameter

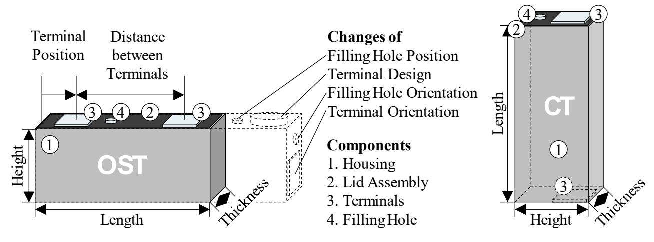


Fig. 1. Prismatic battery cells and their characteristics

2.2. Production Process Chain

Battery cell production is split into electrode production, cell assembly, and cell finishing. Electrode production features two lines: one for the cathode and one for the anode. Assembly and finishing varies for round, pouch, and prismatic cell formats. This paper concentrates on cell finishing for prismatic cells, detailing the production process chain and plant technology as well as selected core components for analysis. [15]

2.2.1. Cell Finishing Production Processes

The plant technology for cell finishing includes all processes from electrolyte filling to sorting and packaging. Typically, cell finishing begins after the initial electrolyte filling process. With prismatic cells, this step is increasingly integrated into cell finishing. Therefore, electrolyte filling is included in the process steps describete in this chapter. [3, 16] Fig. 2 shows the production process chain for prismatic battery cells focusing the cell finishing.

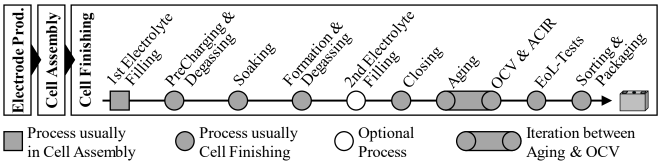


Fig. 2. Production process chain of cell finishing for prismatic cells

Electrolyte Filling: Electrolyte filling is a critical step in lithium-ion battery production, as it aims to ensure the ionic conductivity of the battery cell components. The initial filling process is usually part of the cell assembly and begins with a vacuum pre-treatment to remove air and moisture from the cell, improving the wettability of the cell components and facilitating electrolyte absorption. Precision pumps and automated nozzles or mask systems are used to dispense the electrolyte, ensuring thorough saturation without overflow or air bubble formation. After a rest period to allow for complete electrolyte diffusion, the cell is either temporarily sealed with a vacuum mask or plug if a second electrolyte filling is planned, or permanently sealed. The second filling has similar specifications and is part of the cell finishing. A safety vent is incorporated for pressure regulation. The equipment used for the filling process includes vacuum chambers or masks, precision dispensing systems, and controlled temperature and flow rate mechanisms for the electrolyte. The setup also maintains a carefully managed ambient atmosphere and utilizes cell holders of various sizes. For the second filling process, similar equipment is used, allowing for the possibility of using the same machinery or a separate station with reduced specifications. [13, 16, 17, 18]

Selected core components of electrolyte filling: workpiece carrier dimensions, filling position, filling system, electrolyte supply

Soaking: The aim of soaking is to ensure an even distribution of the electrolyte. Cells are stored at an elevated temperature between 30 to 50 °C to reduce viscosity and shorten the wetting process. Two system alternatives can be used: temperature-controlled cabinets operated by a stacker crane, or high racks in a conditioned enclosure. In the second variant, the Stacker Crane moves through airlocks and places the trays in high-bay areas. [19, 20]

Selected core components of soaking: dimensions tray space, temperature control

Pre-Charging, Formation & Degassing: The primary aim of the pre-charging & formation process is to electrically activate the cell and form crucial passivation layers on the electrodes through the formation of the solid electrolyte interphase (SEI), enhancing stability and preventing unwanted reactions. Gas evolution from side reactions is tackled using a degassing system to remove gases and maintain optimal cell conditions, reducing safety risks. Formation lines in production facilities feature towers with climate-controlled chambers built to handle events like thermal runaway from faulty cells, safeguarding surrounding equipment and infrastructure. Cells in trays are placed in climate chambers for formation and degassing; an automated system connects them to power electronics, which are tailored to the cell type, for customized current-voltage profiling. Valves may be integrated into cells with openings to expel gases during degassing. [19, 21, 22, 23]

Selected core components for formation & degassing: dimensions tray space, temperature control, contacting orientation, contacting position, distance between contacts, contacting design, specifications power electronics (PE), channel number, degassing system

Closing: The closing process is a crucial step that completes the assembly of prismatic cells. During this stage, the cell cover is positioned and securely fastened using selected joining technologies like laser welding. This hermetic seal prevents electrolyte leakage and safeguards the cell against external contaminants. To ensure the integrity of the seal, precise leak testing is conducted, adhering to high safety and longevity standards. [16, 24]

*Selected core components for closing: w*orkpiece carrier dimensions, positioning laser, leakage test

Aging: Aging refers to storing battery cells at a constant temperature for several days to weeks for quality assurance. The self-discharge rate is determined through Open Circuit Voltage (OCV) measurements, which are not conducted in the aging sections but rather at a separate station. An automated system stores the cells in aging trays within high racks in a typically temperature-controlled room. [3, 18, 19, 25]

Selected core components of aging: dimensions tray space, temperature control

OCV & ACIR: During and after aging, OCV and the Alternating Current Internal Resistance (ACIR) at 1 kHz are measured at a dedicated station. Cells are transported in aging trays by automation and contacted similarly to the formation process. The objective is to assess self-discharge rates and detect defects. Core components resemble those in formation but with less critical system impact, as adjustments are cheaper due to the brief duration of measurements, which necessitate limited system parallelization. [19, 26]

Selected core components of OCV & ACIR: dimensions tray space, contacting orientation, contacting positions, distance between contacts, contacting design, measurement technology, channel number

End-of-Line Tests: The End-of-Line (EoL) inspection includes electrical and non-electrical tests of the cells. The electrical tests are mostly carried out in trays during the previous process steps. For the dimensional, optical and weight check, the cells are automatically removed from the trays and individually fed to the measuring stations. Based on these evaluations the cells are graded into different quality levels for sorting, ensuring that cells within a battery pack perform consistently. [3, 18, 20, 24]

Selected core components of EoL-Tests: weight measurement, dimensions measurement, optical control

Sorting & Packaging (S&P): Once graded, cells are organized and sorted accordingly. Following the grading and sorting, the cells are then discharged to a specified state of charge for shipping, aligning with safety regulations and ensuring optimal conditions upon arrival. [24] The equipment utilized in the grading, sorting, and packaging stages incorporates testing and automation technology like conveyor belts, roboter arms and automated guided vehicles. Packaging units then securely encapsulate the cells, using materials and designs that comply with shipping and handling standards.

Selected core components of S&P: shipping box

2.2.2. Plant Concept for Cell Finishing

In large-scale production, cell finishing pants are fully automated. Cells are either open or temporarily sealed when fed from the assembly line. The subsequent sections delve deeper into the tray-based automation system, which is tailored to the cell design and thus affects the layout of the production stations.

During cell finishing, battery cells are batch-processed in trays. Tray capacity varies with factors like configuration and cell size, reaching up to 80 cells per tray. Individual trays can weigh several hundred kilograms. Process requirements dictate separate trays for formation and degassing (F&D) as well as for aging (Aging trays). Fig. 3 shows a F&D tray with the core specifications. Until the final sealing, prismatic cells remain open and are typically connected to a degassing system through proprietary solutions. For formation, cells in these trays are pressurized using integrated spindles or equivalent methods. Contact orientation depends on whether cell terminals emerge from the top or side, with each cell allocated a specific compartment designed for its dimensions. As cells are open during this stage, the filling hole must be positioned upward, dictating the contact orientation. With aging tray, cells are sealed, sharing core features with the F&D tray but lacking pressurization and degassing capabilities. [3]

Selected core components for trays: Contacting orientation, cell contacting position, tray dimensions, dimensions cell positions, number of cell rows, cells per row, cells per tray; additionally F&D tray: pressurization, degassing design, degassing position

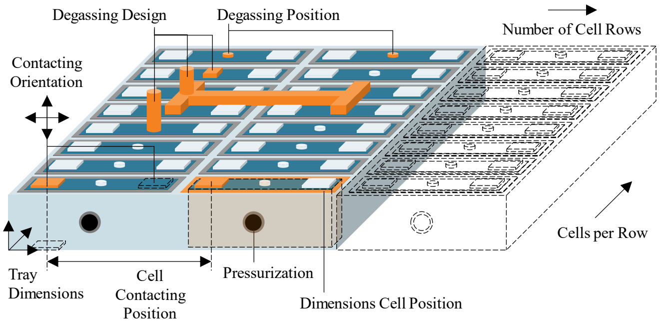


Fig. 3. Tray specifications in cell finishing

The individual production sections may be linked by conveyor belts. Due to the extended durations of soaking, formation, and aging processes in cell finishing, these are conducted in high-bay storage areas where stacker cranes feed trays to the stations, resulting in substantial space requirements. For processes like electrolyte filling, welding, and parts of EoL testing, cells are removed from the trays for individual handling. Consequently, there are automation systems for trays, single cells, and the degassing system. [3]

3. Methodology of the cause-effect analysis and case study of the prismatic cell finishing

The following procedure is used to analyse the cause-and-effect relationships between product characteristics and cell finishing plant technology. In the first step, core elements of the plant technology of all production process steps within cell finishing are selected on the basis of the state of the art. The focus is placed on those system components that need to be specified as part of production process planning, particularly in specifications for system procurement. The results are already assigned to the respective production processes in chapter 2. In the second step, the chain of effects from the cell design via the trays to the system technology is worked out so that a clustering of production processes without and with the respective trays is possible and the chain of effects from the cell design via the trays to the production resources becomes apparent. This is followed by an analysis of the cause-and-effect relationships between the product features of prismatic battery cells and the system components. Since trays represent both a system component and an intermediate product, the influence of the tray characteristics on the system technology is analyzed in particular for processes in which the cells are handled in trays. This approach makes it possible to assess both the influence of the product characteristics and the tray design on the system technology independently of each other.

The presentation method chosen in the following chapter in the form of harvey balls allows a clear classification of whether there is an influence as well as a qualitative classification of what influence the product feature has on the different system components. Figure 4 shows the legend of the results presented in the following chapter. This approach to analysis and presentation allows the influence of the product features on the system components to be considered independently of each other. If, as a result of the change to one characteristic, another is also inevitably subject to changes during the development process, at least the maximum of the respective influences must be selected. The mentioned flexibility corridor describes the range of various product features to be defined, for which the manufacturing system is already designed in the initial equipment. This is especially common with several product variants

Degree of influence	
No direct influence on the component	○
Change included in the flexibility corridor of the manufacturing system or by minor adjustments	◔
Change of the specification is possible through additional automation or customized adjustments	◑
Converting of the production technology with other tool sets or permanent adjustments necessary	◕
New design or fundamental change of the production technology necessary	●

Fig. 4. Classification of the cause-effect relationships analysis

The cell designs used are the variants of prismatic battery cells introduced in Chapter 2, which represent both current industrial product variants and the variants that will be manufactured at Fraunhofer FFB in the future. In addition, the production process chain shown in Figure 2 is considered. The analysis is based on the production process and plant planning of Fraunhofer FFB, which is carried out by an interdisciplinary scientific team. This use case is comparable to industrial battery cell production. Previous studies have shown that there may also be interdependencies between production resources in battery cell production [27]. However, this is outside the scope of this study.

4. Influence of Product Characteristics on the Plant Technology for Cell finishing in Battery Cell Production

In the following chapter, the cause-and-effect relationship of the cell design on the plant components is first presented and then the influence of the cell design on the trays and the selected core components of a cell finishing plant is analyzed using the expertise of the scientific planning team.

4.1. Dependency relationships between product specifications and overarching plant components for cell finishing

As the cells are processed in trays during certain production steps, both the cell design and the design of the aging and F&D trays have an impact on the plant components. Fig. 5 shows the chain of effects of the mechanical cell design on the production resources. The chain of effects initially occurs through the trays. For this reason, both the influence of the cell design on the trays and the individual processes are analyzed. The components of the automation system can potentially interact directly with all components and intermediate products and are adapted to the trays and production processes accordingly. The consideration of potential interactions between the cell design, the production processes, and trays with the components of the automation system is not part of this research.

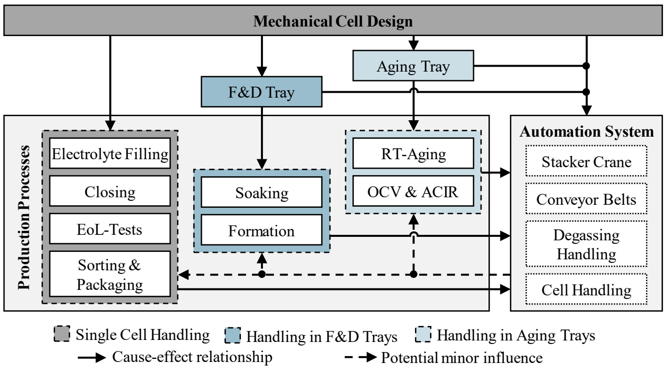


Fig. 5. Cause-effect chain for the production technology in cell finishing

4.2. Cause-effect Relationships of Product Features on the Tray Specifications for Prismatic Battery Cells

Fig. 6 shows the influence of the product specification on the core features of the F&D trays and aging trays. The harvey balls indicate the presence and qualitative magnitude of a significant influence based on the technical design. The influence of the cell design on the tray variants is largely the same. However, as the aging trays have lower requirements, no pressurization and no degassing system, the influence is lower in some cases. The influence of the lid assembly orientation is determined by the maximum of the terminal orientation and filling hole orientation, as these features are typically found together in the lid assembly. With OST type cells, the contacts extend from the top of the trays. In contrast, with CT type cells that have a filling hole on the side of a terminal, the cells are handled upright, and the terminals protrude from the top and bottom with the F&D trays. This results in fundamentally different designs for F&D trays depending on the lid assembly orientation.

This figure shows the influence of the product characteristics of a prismatic battery cell on the selected core components of the F&S trays and aging trays in a cell finishing plant. *Degree of influence* ○ ◔ ◑ ◕ ●		F&D Tray										Aging Tray						
		Contacting Orientation	Cell Contacting Positions	Tray Dimensions	Dimensions Cell Position	Number of Cell Rows	Cells per Row	Cells per Tray	Pressurization	Degassing Design	Degassing Position	Contacting Orientation	Cell Contacting Positions	Tray Dimensions	Dimensions Cell Position	Number of Cell Rows	Cells per Row	Cells per Tray
Prismatic Battery Cell	Terminal Orientation	●	●	◑	◔	◕	○	◕	◑	◔	◑	●	●	◑	◑	◕	○	◕
	Filling Hole Orientation	●	●	◕	◕	◕	○	◕	◕	◔	◕	○	○	○	○	○	○	○
	Lid Assembly Orientation	●	●	◕	◕	◕	○	◕	◕	◔	◕	●	●	◑	◑	◕	○	◕
	Terminal Position	○	◕	○	○	○	○	○	◔	◔	◔	○	◕	○	○	○	○	○
	Terminal Design	○	○	○	○	○	○	○	○	◔	○	○	○	○	○	○	○	○
	Height	○	◔	◔	◕	◔	○	◔	◕	◔	◑	◔	◔	◑	◔	◔	○	◔
	Length	○	◔	◑	◕	◕	○	◕	◕	◔	◔	◔	◔	◑	◑	◑	○	◑
	Thickness	○	◑	◔	◑	○	◕	◕	◑	◑	◑	○	◑	◔	◑	○	◕	◕
	Filling Hole Position	○	○	○	○	○	○	○	○	◔	◕	○	○	○	○	○	○	○
	Filling Hole Diameter	○	○	○	○	○	○	○	○	◕	◔	○	○	○	○	○	○	○
	Electrochemical Properties	○	○	○	○	○	○	○	◕	◑	○	○	○	○	○	○	○	○

Fig. 6. Influence of prismatic cells on the trays

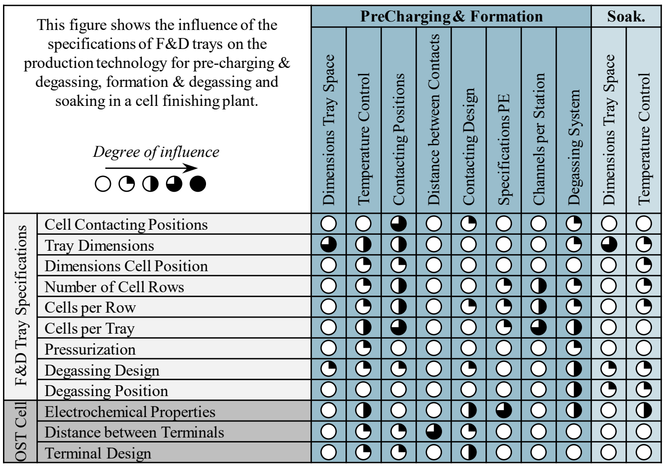
Other important features are that the terminal position of individual cells only has an influence on the subsequent contacting of the trays, as the terminals are exposed, and cells are contacted directly in formation, OCV and ACIR measurement. However, the relative position of the terminals and cells against each other can also be changed by the cell and tray dimensions. Features such as the filling hole only have an influence on the degassing system and are therefore irrelevant for the aging trays. The electrochemical properties of the cell define the necessity and characteristics of pressurization and gas formation. Cells with the same dimensions but different chemistries and capacities can usually be processed with the same trays. The number of cells per tray is defined by the thickness and length of the cells. The height of the cells, on the other hand, has an influence on the dimensioning of the cell position and therefore the height of the trays.

4.3. Cause-effect Relationships of Product and Tray Features of Cells with OST Configuration on the Plant Components

In processes with electrical contacting, in particular formation, all contacts of OST cells are on top. To establish the electrical contact, either the trays can be supplied for contacting on the system side or the spring contact pins can be supplied to the cell. With CT cells, the cells are contacted from above and below. Different configurations can therefore lead to a different number of channels in the electrical process steps with contacting due to a different number of cells per tray. In processes with single cell handling, in particular electrolyte filling and closing, the cells must be handled horizontally with OST and vertically with CT. This places different requirements on the workpiece holders. Therefore, different cause-and-effect relationships exist for CT cells than for OST cells. Due to these technical differences, the market relevance, and the application in the Fraunhofer FFB research project, only the cause-and-effect relationships for OST cells are considered in the following subchapters.

4.3.1. Cause Interaction of the Processes with F&D Trays

In this chapter, the influence of the F&D trays and product specification of prismatic battery cells of the OST type, which have a direct influence on the production technology, are analyzed. Fig. 7 shows the cause-and-effect relationships for formation and soaking. The dimensioning of a formation station depends on the dimensions of the trays or interacting accordingly. The temperature control of the process environment is dependent on the process parameters, which are designed based on the electrochemical cell characteristics. Furthermore, all mechanical components of the tray, degassing system and the cells can have a influence due to the air circulation on the temperature control. The aim is to achieve uniform temperature control for all cells. As soaking only involves temperature-controlled storage of the trays, the influences remain predominantly the same. Important features for formation are the contacting, the power electronics, and the number of channels per station. The number of cells per tray has a influence on the formation technology as these changes the positions of the contacts, the required number of channels and therefore also the power electronics. The specifications of the power electronics, for example the maximum charging or discharging current, is based on the formation protocol and thus based on the mechanical cell properties of the cell in combination with the electrochemical properties. The decisive factor here is the C-rate, which is the charge rate related to the cell capacity. When designing the formation process, it is important to ensure that the production technology is designed according to the expected current-voltage curves to find the best solution in terms of both measurement accuracy and investment costs.



This figure shows the influence of the specifications of F&D trays on the production technology for pre-charging & degassing, formation & degassing and soaking in a cell finishing plant.

Degree of influence ○ ◔ ◑ ◕ ●

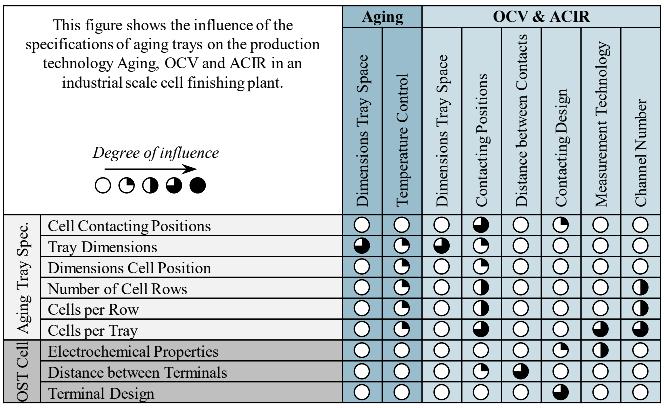
		PreCharging & Formation								Soak.	
		Dimensions Tray Space	Temperature Control	Contacting Positions	Distance between Contacts	Contacting Design	Specifications PE	Channels per Station	Degassing System	Dimensions Tray Space	Temperature Control
F&D Tray Specifications	Cell Contacting Positions	○	○	◕	○	◔	○	○	◔	○	○
	Tray Dimensions	◕	◑	◑	○	○	○	○	◔	◕	◔
	Dimensions Cell Position	○	◔	◔	○	○	○	○	○	○	◔
	Number of Cell Rows	○	◔	◑	○	○	◔	◑	◔	○	◔
	Cells per Row	○	◔	◑	○	◔	◔	◑	◔	○	◔
	Cells per Tray	○	◑	◕	○	○	◔	◕	◑	○	○
	Pressurization	○	◔	○	○	○	○	○	◔	○	○
	Degassing Design	◔	◔	◔	○	◔	○	○	◑	◔	◔
	Degassing Position	○	○	○	○	○	○	○	◑	◔	◔
OST Cell	Electrochemical Properties	○	◑	○	○	◑	◕	○	◑	○	◑
	Distance between Terminals	○	◔	◔	◕	◔	○	○	○	○	○
	Terminal Design	○	◔	◔	○	◑	○	○	○	○	○

Fig. 7. Influence of F&D trays and OST cells on formation and soaking

Minor changes to the cell design do not necessarily have a impact on the production technology. It is possible that these can be processed without changes or flexibly designed F&D trays. In that case, the contacting positions, and the number of cells per tray should remain the same. Essential changes in cell characteristics can lead to suboptimal utilization of production potential, cost-intensive adjustments to production technology and even new system concepts due to different power electronics. However, subsequent adaptation is associated with a conversion effort and reengineering. The results in this chapter show that the production technology for formation and soaking is directly and indirectly influenced by the cell design. A high level of system flexibility could be achieved by keeping the distance between the terminals of a cell and the number of cells in the tray constant.

4.3.2. Cause Interaction of the Processes with Aging Trays

In the following section, the influence of the tray and cell specifications on the aging and OCV & ACIR processes is analyzed analogously to chapter 4.3.1. Fig. 8 shows the results of this analysis. The production technology for aging is similar to soaking and influenced by the dimensions of the aging trays. All mechanical characteristics of the tray and the cell can potentially influence the temperature control. As aging is examined in this publication at room temperature, the influence on temperature control is mentioned for completeness, but it is unlikely to have a relevant effect in practice. The requirements for OCV & ACIR must be considered in the same way as for formation, although the influence of the degassing system does not apply. As the cells are closed during this processes, it makes it easier and more cost-effective to achieve conversion and system flexibility through different or more flexible contacts.



This figure shows the influence of the specifications of aging trays on the production technology Aging, OCV and ACIR in an industrial scale cell finishing plant.

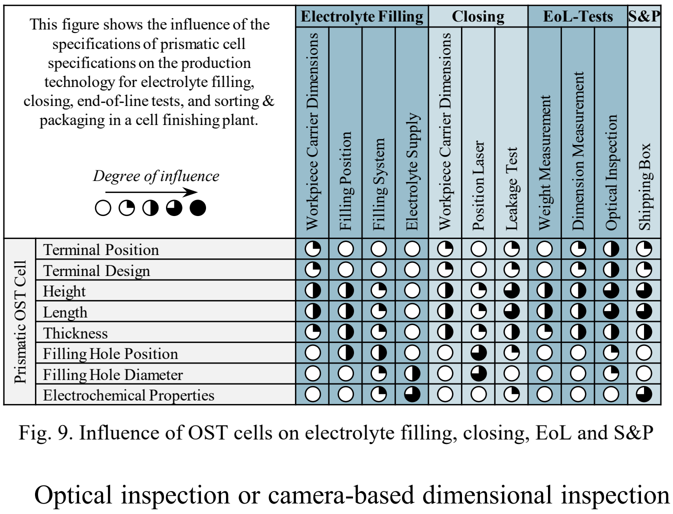
Degree of influence ○ ◔ ◑ ◕ ●

		Aging		OCV & ACIR					
		Dimensions Tray Space	Temperature Control	Dimensions Tray Space	Contacting Positions	Distance between Contacts	Contacting Design	Measurement Technology	Channel Number
Aging Tray Spec.	Cell Contacting Positions	○	○	○	◕	○	◔	○	○
	Tray Dimensions	◕	◔	◕	◔	○	○	○	○
	Dimensions Cell Position	○	◔	○	◔	○	○	○	○
	Number of Cell Rows	○	◔	○	◑	○	○	○	◑
	Cells per Row	○	◔	○	◑	○	○	○	◑
	Cells per Tray	○	◔	○	◕	○	○	◕	◕
OST Cell	Electrochemical Properties	○	○	○	○	○	◔	◑	○
	Distance between Terminals	○	○	○	◔	◕	○	○	○
	Terminal Design	○	○	○	○	○	◕	○	○

Fig. 8. Influence of aging trays and OST cells on aging, OCV & ACIR

4.3.3. Cause Interaction of the Processes with single Cell Candling

Fig. 9 shows the influence of the cell design on processes with single cell handling. For electrolyte filling this is caused by specific workpiece carriers. Depending on the technical solution, either the vacuum chamber must be provided in the appropriate dimensions, or the workpiece holder must be adapted to the cell dimensions. Position and diameter of the filling hole influence the positioning and design of the filling system, as well as the positioning of the laser optics in closing.



This figure shows the influence of the specifications of prismatic cell specifications on the production technology for electrolyte filling, closing, end-of-line tests, and sorting & packaging in a cell finishing plant.

Degree of influence ○ ◔ ◑ ◕ ●

		Electrolyte Filling				Closing			EoL-Tests			S&P
		Workpiece Carrier Dimensions	Filling Position	Filling System	Electrolyte Supply	Workpiece Carrier Dimensions	Position Laser	Leakage Test	Weight Measurement	Dimension Measurement	Optical Inspection	Shipping Box
Prismatic OST Cell	Terminal Position	◔	○	○	○	◔	○	◔	○	◔	◑	◔
	Terminal Design	◔	○	○	○	◔	○	◔	○	◔	◑	◔
	Height	◑	◑	◔	○	◑	◔	◕	◑	◑	◕	◕
	Length	◑	◑	◔	○	◑	◔	◕	◑	◑	◕	◕
	Thickness	◔	◑	◔	○	◑	◔	◑	◔	◑	◑	◑
	Filling Hole Position	○	◑	◑	○	○	◕	◔	○	○	◔	○
	Filling Hole Diameter	○	○	◔	◑	○	◕	○	○	○	◔	○
	Electrochemical Properties	○	○	◔	◕	○	○	◔	○	○	○	◕

Fig. 9. Influence of OST cells on electrolyte filling, closing, EoL and S&P

Optical inspection or camera-based dimensional inspection must be adapted to the cell variants. As the cells are closed yet, the handling differs. The design of the shipping boxes for battery cells is subject to various legal framework conditions. Each cell position in the boxes has to be separated from each other. These positions must be adapted to the cell dimensions. Furthermore, when designing the shipping box, it is important to observe the applicable legal regulations with regard to safety when transporting battery cells.

5. Conclusion and Outlook

In this paper, the influence of the product characteristics of prismatic battery cells on the production technology of cell finishing were analyzed. The chain of effects initially runs through the tray variants, influencing the selected core components of the processes, as well as directly impacting the plant technology from the cell. The orientation of the lid assembly has a great influence on the trays. Minor changes to individual product features can be realized by the definition of flexibility corridors, whereas a change in the lid assembly orientation requires a fundamental technical change. In this case, the convertibility or adaptability of cell finishing is associated with high technical expenses and therefore financial costs. This results in changing factory requirements. For this reason, only one configuration, the OST variant, was considered in detail. These influences and the consideration of the cause-and-effect relationships between cell design and automation system as well as an analogous consideration for CT cells should be the subject of further research work. Follow-up scientific studies should also analyze the influence of the characteristics of prismatic CT cells, pouch cells and cylindrical cells on the production technology. The results of this paper are subject to the limitations that manufacturers pursue different concepts for the implementation of product variance and flexibility and that these insights are not publicly available. In addition, only the core components, which are significantly designed in the production process planning, were analyzed so that further relevant system components can exist beyond the described use case for different products or process chains. This paper offers for the first time a detailed insight into the cause-and-effect relationships in the system design of cell finishing as a function of specific product characteristics of prismatic battery cells. This knowledge can help to reduce uncertainties in the early phases of product, plant and factory planning.

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