Digitalization in Battery Cell Manufacturing

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Abstract: Environmental sustainability begins with the eco-efficient product design, continues with operation of energy- and material-efficient production systems and factories and concludes with forward looking end-of-life strategies.

Digitalization offers important tools for a life cycle-oriented evaluation and optimization of the environmental compliance of energy storage systems. Digital twins (DTs) can be used to improve product quality and increase resource efficiency in production.

This paper includes current results of the projects DigiBattPro 4.0 BW (digitalization of battery production) and DeMoBat (industrial disassembly of battery modules).

Keywords: Battery manufacturing, battery production, digital twin, digitalization, battery recycling

1 Introduction: Battery Cell Manufacturing and Industry 4.0

The lithium-ion battery has become a core component within a wide variety of applications and products.

This change does affect both industry and consumer products ranging from machine tools to storage systems and electric vehicles. Besides, new applications using lithium-ion battery technology such as air-taxis promise continuously growing demand for high-performance lithium-ion cells in the near future [1].

Developing highly flexible battery manufacturing lines that produce superior product quality is an important step to establish a competitive and economically viable cell manufacturing industry in Germany and Europe (ref. Figure 1). In order to derive this competitive advantages, all steps within the value chain of lithium-ion battery cell manufacturing need to be optimized using the tools of digitalization.

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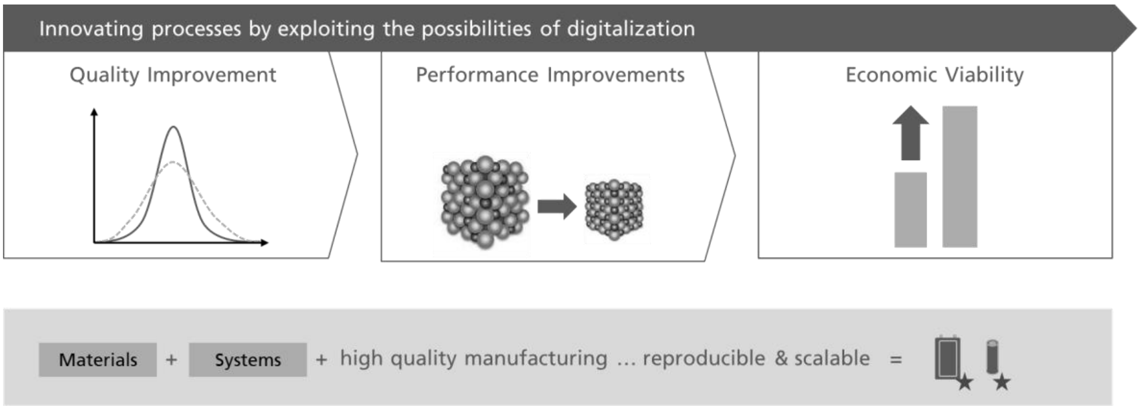

Figure 1: Overall objectives of digitalized battery production

As the term Industry 4.0 first came up during Hannover Fair it describes the evolution of mass production from mechanization and automation to “digitalization”. The new production concepts of Industry 4.0 encompass “Smart Factories” with an interconnected production environment, that is part of the “Internet of Things (IoT)” and uses “Cloud Services” (Figure 2: The evolution of industry 1.0 to 4.0 (Image: From Momentum 02.08.2019) [1, 2].

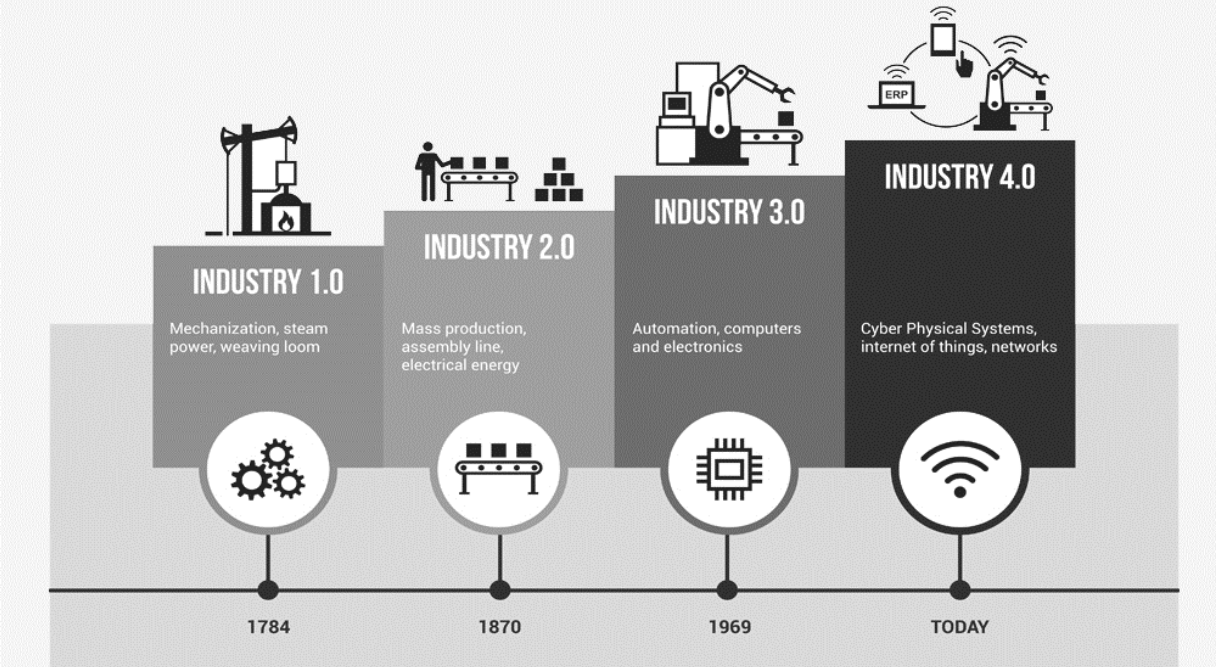

Figure 2: The evolution of industry 1.0 to 4.0 (Image: From Momentum 02.08.2019)

2 Problem and objective

2.1 Description of the problem and solutions

The European battery cell manufacturing industry is on its rise. However, there are several challenges associated with the development of competitive, high quality battery cell manufacturing capacities in prospective GigaFactories.

In total, there is an estimation of global demand of 1.200 GWh battery capacity in the year 2030, which increases, to 3.500 GWh by 2050 [3]. The rapid growth may lead to temporary shortages of lithium, nickel and cobalt under certain circumstances. Especially for Europe, the recycling of lithium-ion batteries is a strategic necessity to reduce raw material dependencies.

Additionally, production scrap is another problem. Taking into account that 5% rejects may occur due to inadequate product quality, it would result in 18 GWh/year battery cells, which is equivalent to 70.000 tons of cells.

In order to reduce battery scrap and increase production efficiency, it is indispensable to optimize and improve the manufacturing process chain. With the tools of digitalization like digital twins (DTs) and traceability, battery manufacturers and other industrial companies have the opportunity to optimize their product quality and improve the resource efficiency and consequently the economic viability of battery cell manufacturing. The benefits of these key elements are presented in Figure 3.

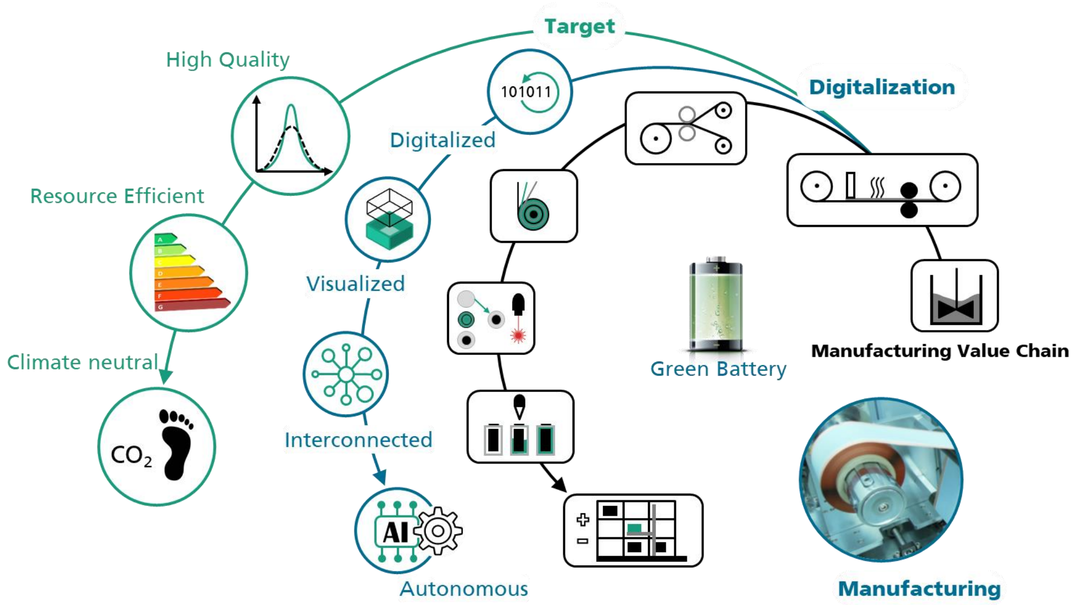

Figure 3: Key benefits of digitalization in battery cell manufacturing

3 Solutions

3.1.1 Concept for the integration of traceability systems in battery cell manufacturing

Traceability is the ability to track all processes including raw materials during incoming goods inspection to end product characteristics across the entire value chain. The purpose is to answer questions "when, where and under which conditions the product was manufactured”.

Every manufacturing step can be recorded and tracked by using built-in sensors and cameras (Real-time tracking, Figure 4).

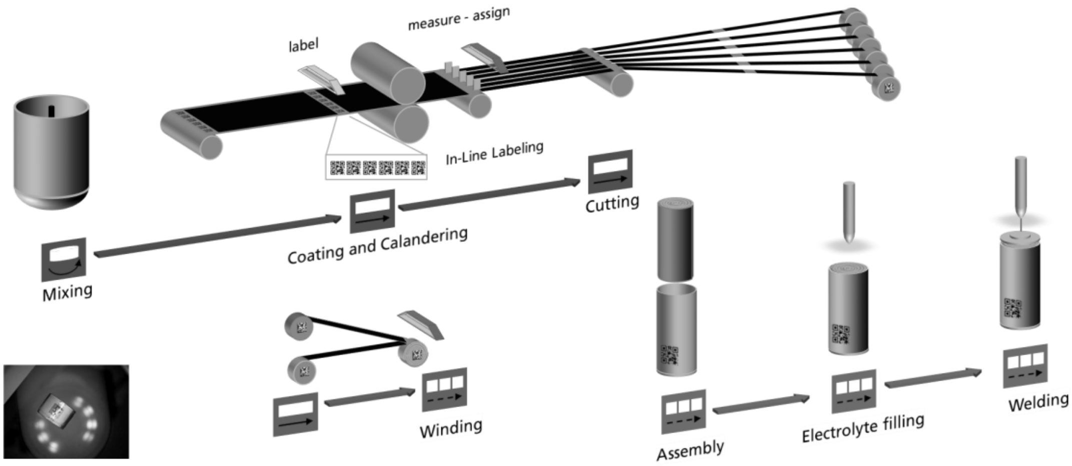

Figure 4: Concept for the integration of traceability systems in battery cell manufacture

All these traceability tools receive and save data. In the end there will be a large spectrum of data collection, which allow engineers to analyze the performance of the processes like coating, cutting, winding, electrolyte filling and packing. If these data are coherent, the digital twin of the product can be created.

Establishing a coherent traceability system within battery cell manufacturing requires that the following points are considered:

- Process speed and time
- Availability and accessibility of sensor information
- Missing information on process parameters and product characteristics and possibilities to integrate further sensors
- Sampling rates
- Performance of data collection and handling

3.1.2 Digital Twin

The digital twin can be described as an intelligent digital prototype of a real product, system or process [4–7].

After enough data has been captured by traceability, a digital twin (DT), (a virtual representation of the battery cell or system) can be created that reflects the characteristics of the physical product. The creation of DTs can be a continuous process which serves as a long-standing, self-adaptive learning approach (Figure 5).

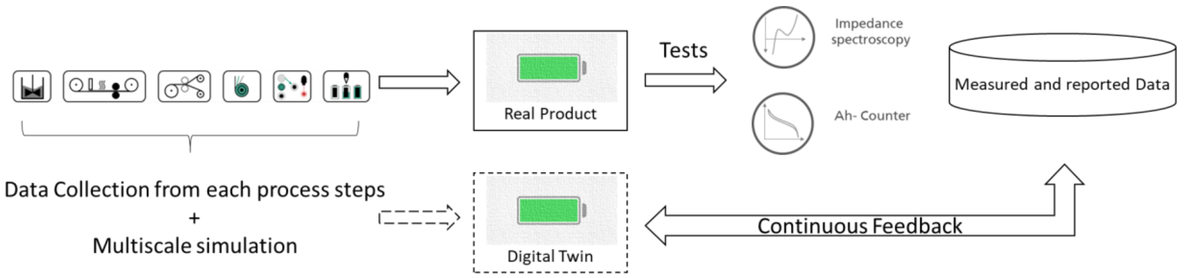

Figure 5: Digital Twin engineering at cell level

This virtual representation of the end product offers an opportunity to establish predictive maintenance as services for products and systems. Besides, it can be used to predict and control production quality, machine availability and end product characteristics.

4 Use Cases

4.1 Ageing prediction

Determining the battery states with high accurarcy depends on the amount and quality of the measured data and the right selection of methods for extrapolation.

Neural networks can be implemented which select the production data and the appropriate measurement methods (such as impedance spectroscopy, cycle tests, etc.) as a function of cell chemistry, cell age and the history of the cells. After selecting the appropriate data and the required amount of data, the most appropriate method can be chosen for an optimal aging prediction.

4.2 End-of-Life (EoL) prediction

Currently there are only few projects which consider the use of EV batteries after their EoL in second life applications. Second life and repurposing require State-of-Health (SoH) analysis, around 100 hours of testing during a week for each cell, which is expensive for providers and second users.

Here the digital twin can providethe information about the current state of the battery cell and /or system one can predict further aging. Exact determination of battery condition also enables certification of batteries (via decision support system) after EoL without further costs (Fig. 6)

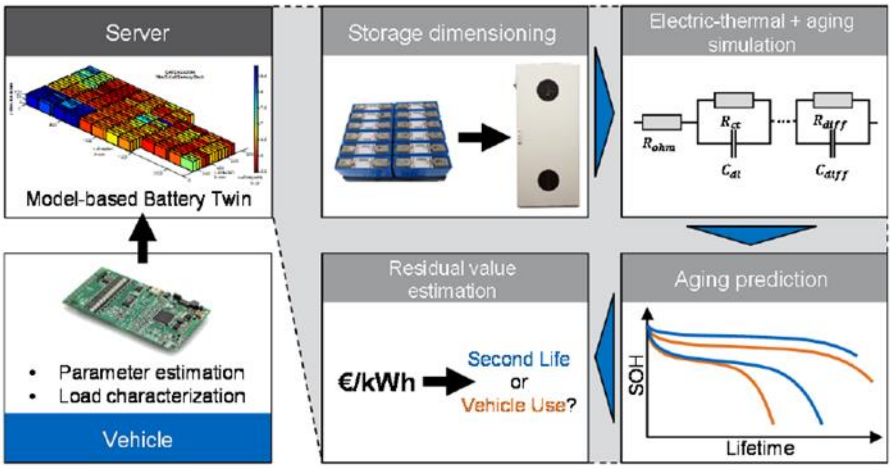

Figure 6: Cloud-connected battery management approach to estimate the residual value of vehicle batteries in respect to various potential Second-Life applications [8].

5 Conclusion

The modeling of a real product means that great amounts of information have to be captured and associated with the final product along the entire value chain, in order to get full traceability. This paper has summarized how digital twin implementation can be realized through traceability. Even though the DT concept is viable, challenges like massive amounts data, data encryption and data management need to be overcome in order to reach the accurate results.

Since DTs have become one of the popular topics used to digitalize products and manufacturing, engineers and scientists continuously work on optimizing the concepts and implementations of DT technologies. Once this virtual representation of a product or system is available, they can be used to continuously optimize costs and resource efficiency in battery cell manufacturing as well as the quality of the manufactured battery cells.

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