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Detachable electrical connection of battery cells by press contacts

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A B S T R A C T

In battery applications, every electrical connection of battery cells is important because it influences functionality, efficiency, and safety. Increased contact resistances generate more heat at the affected terminals and if contact resistances of parallel-connected battery cells differ the current divides unequally.

Amongst different techniques, detachable connections are easy to handle and have advantages for service, repair and recycling. Usually, detachable electrical connections are based on the functional principle of press contacts. So, press contacts are frequently used for consumer batteries in electronic devices, for pouch battery cells in scientific tests, and for large battery cells with screw connections.

This paper focusses on the electrical contact resistance of press contacts for battery cells. A novel measuring method to assess the contact resistance itself is presented. Common terminal and connector metals for battery cells and the dependence of their contact resistances on the contact pressure, surface roughness, and contact area are investigated and compared with welding techniques. Only if these dependencies are considered, contact resistances as low as for welded connections are achieved. Furthermore, due to its hard passivating Al_2O_3 surface film, aluminum contacts need a certain surface roughness. The obtained results can serve for modeling and development of battery assemblies.

1. Introduction

Large battery assemblies are of particular interest, for example for the progressing electrification of mobility or the storage of intermittent renewable energy. But also for portable electronic devices, for example laptops, the battery is one of the key components. In all battery applications, every single electrical connection of a battery cell is of importance because it influences the functionality, efficiency, and safety. An increased electrical contact resistance generates more heat at the affected terminal of a battery cell [1,2]. Additionally, for battery cells connected in parallel, the total current is divided unequally if contact resistances differ significantly. These uneven loads may lead to inhomogeneous cell degradations, as discussed in [3,4]. What is more, defective cell connections are prone to fail suddenly if imposed to mechanical stress.

There are many options to electrically connect battery cells, such as welding, soldering, press contacts, and screwed joints. Because soldered connections can only be detached with significant effort, the most common detachable connection techniques are press contacts and screwed joints. The functional principal of the resulting electrical contact resistances for both techniques is the same and is based on the metallic contacts that are formed when two metal surfaces are pressed together.

Detachable connections have significant advantages when it comes to service, repair and recycling. Another advantage is that this connection technique does not need expensive machines and therefore can be handled by every specialist workshop or in certain cases also by the customer.

An illustrative selection of battery cells with terminals for press contacts is shown in Fig. 1. A common usage of press contacts is for consumer batteries in electronic devices, for example cell-phones or cameras. For this electronic applications, an example with brass springs is shown in Fig. 1 bottom left. To test battery cells of the pouch format, a press contact fixture can be used as shown in Fig. 1 bottom right. Such fixtures are quite common for scientific series of measurements. Furthermore, some large battery cells with high

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Fig. 1. Exemplary selection of battery cells with terminals for press contacts.

power capability exhibit screw connections. Especially for lead acid battery cells but also for some large lithium-ion battery cells, screw or clamp connections are quite common.

The most important parameter to evaluate an electrical connection is the electrical contact resistance. Although press contacts are frequently used to electrically connect battery cells, few scientific publications on contact resistances of press connections exist. As one of the few publications, Taheri et al. [5] investigated the electrical contact resistance losses in lithium-ion battery assemblies with screwed joints. Within that publication, the authors focused on 20 Ah lithium-ion pouch battery cells connected by copper bars with and without an additional interfacial electrically conductive material [5]. Taheri et al. showed that the pressure plays a key-role to reduce electrical contact losses and that additional conductive materials can help to reduce contact losses at lower contact pressures [5].

The present paper's focus is placed on the electrical contact resistance of press contacts at battery cells in general and lithium-ion battery cells in particular. The electrical contact resistance occurs as a result of the joint and not in the bulk material. Therefore, it is a criterion which may be transferred to any size of joint partners. Within this paper, a novel measuring and calculation method is applied to assess the electrical contact resistance itself.

For the series of measurements presented in this paper, the most common terminal and connector metals for battery cells are investigated. Because of their stability, the materials of primary current collectors within lithium-ion battery cells are aluminum at the cathode and copper at the anode [6]. By contrast, at the terminals of battery cells, joining of other metals can be required, for example a brass cell terminal with a nickel plated steel conductor [7,8]. For press contacts, mostly aluminum, copper, brass, and nickel-plated steel metals are used [7,8].

In the following sections, fundamentals of press contacts are presented first. Subsequently, the novel measurement and calculation method for the electrical contact resistance as well as the pneumatic test bench to apply defined pressure on the tested metal specimens are presented. Based on these fundamentals the results of the series of measurements are explained. For the series of measurements, the types of metals, the contact pressure, the surface roughness, and the contact area were varied systematically. The measured electrical contact resistances can serve as an important input for modeling and simulating battery assemblies.

At the end of this paper, the resulting electrical contact resistances are compared to the contact resistances obtained for spot, ultrasonic, and laser beam welding. Brass (CuZn37) test samples are used for the quantitative comparison of these four connection techniques, as this metal can be welded with all three welding techniques. In the conclusion, the suitability of press contacts for battery cells and its settings to achieve low electrical contact resistances are evaluated.

2. Fundamentals on the electrical connection of press contacts

In this section, the fundamentals of stationary electrical contacts between two solid metals are presented. Therefore, the

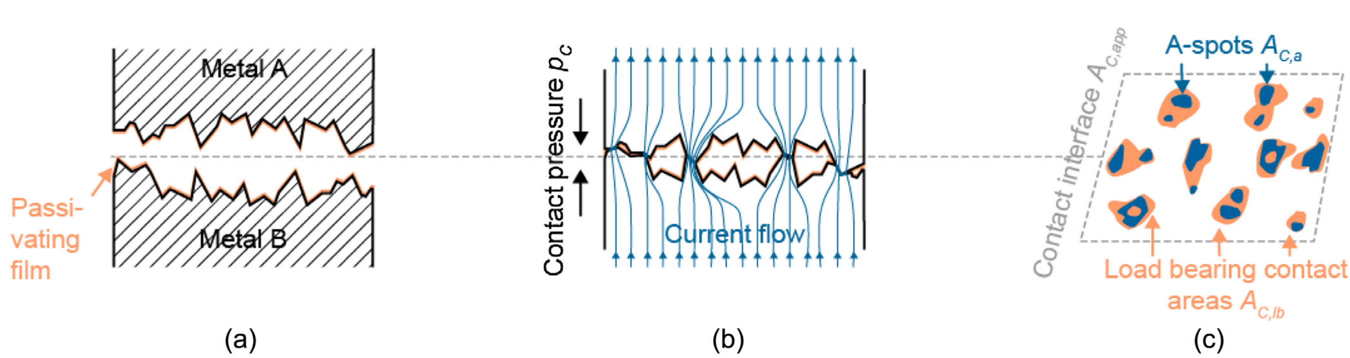

Fig. 2. Schematically (a) surface roughness including passivating surface films, (b) deformation when contact pressure p_C is applied including current paths, (c) load bearing areas $A_{C,lb}$ and a-spots $A_{C,a}$.