CURRENT DISTRIBUTION OVER THE ELECTRODE SURFACE IN A LEAD-ACID CELL DURING DISCHARGE

Petr Křivák, Petr Bača
Department of Electrotechnology, Technical University, 602 00 Brno, Czech Republic

Abstract

The current distribution over the plate surface in lead-acid cells in the course of discharge was determined mathematically by using the equivalent circuit method. The dependence of the internal cell resistance on the current and charge passed was determined by measurements on a laboratory cell. Three cell variants were considered differing by the location of tabs serving as current terminals. The results are presented in the form of 3-D diagrams at various states of discharge. To make the current distribution nearly uniform, extended current tabs located at opposite ends of the plate electrodes were proposed.

Results and discussion

The calculations were based on the electrical equivalent circuit (Fig. 1). However, the resistances, Rv_k, between the electrode elements were now considered as functions of the current, I, and charge passed, Q. To this end, the time course of the internal resistance of a laboratory cell was measured at various discharge currents. The values of Rv_k corresponding to a cell element were calculated from the measured data which involved the resistances of the electrolyte, interphase, active mass, and polarization resistance.The results were expressed by the following analytical function calculated by the least squares method:

$$Rv_k = 0.32 + 4.2 \cdot Q + 2.6 \times 10^{-5} \exp(730 \cdot Q + 100 \cdot I - 14) \quad (1)$$

With the positive plate, the active mass does not contribute significantly to the conductance of the grid members. However, with the negative, the grid member conductances must be corrected for the conductance of the active mass.

It was found in our earlier work that the conductance of the negative active mass decreases practically linearly with the time during constant-current discharge. Thus, the dependence of the resistances on the charge passed, Q, can be expressed by the following approximate equations:

$$R_x^- = 0.5/(376.67 - 1142.9 \cdot Q) \quad (2) \qquad R_y^- = 0.5/(1530 - 10286 \cdot Q) \quad (3)$$

The calculated current distributions over the plate electrode surface are presented in the form of 3-D diagrams in Figs. 2 – 4 for Q values corresponding to 0, 40, 60, 80, 90, and 100% discharge. This corresponds to discharge times of 0, 80, 120, 160, 180, and 200 minutes, discharge current $I = 2$ A, and discharge capacity $C = 6.66$ Ah.

It can be seen that the initial rate of discharge (*i.e.* the local current) is always more or less elevated in regions close to the tabs. This phenomenon is most pronounced in Fig. 2, where the tabs are located in the corners facing each other. Therefore, this region reaches the discharged state more rapidly. Since the total current is maintained constant, the current drop in one region causes the discharge rate in another one to increase, although not as much, as can be seen from the diagrams. In spite of this leveling effect, the situation at the end of discharge for most tab configurations (Figs. 2 – 3) does not look satisfactory. The best configuration seems to be the last one (with extended tabs on opposite ends of the plates) corresponding to Fig. 4. Here, the current distribution over the plate surface remains fairly uniform all the time, with a shallow extremum in the middle region of the plates.

This work was supported by the Grant Agency of the Czech Republic (Grant No. 102/02/0794).

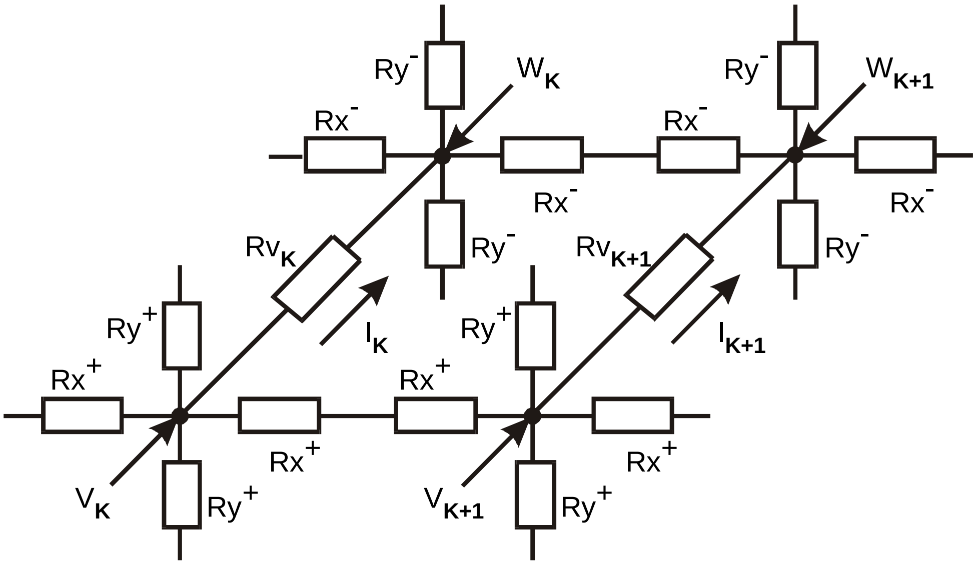

Fig. 1. Part of the equivalent circuit used for calculation of the current distribution over the electrode surface. Rv_k resistance between two electrode elements. Positive grid: $R_x^+ = 1.6125$ mΩ, $R_y^+ = 0.5375$ mΩ; negative grid (with active mass in the charged state): $R_x^- = 1.327$ mΩ, $R_y^- = 0.327$ mΩ; frame: $R_{x0} = 0.5375$ mΩ, $R_{y0} = 0.3583$ mΩ.

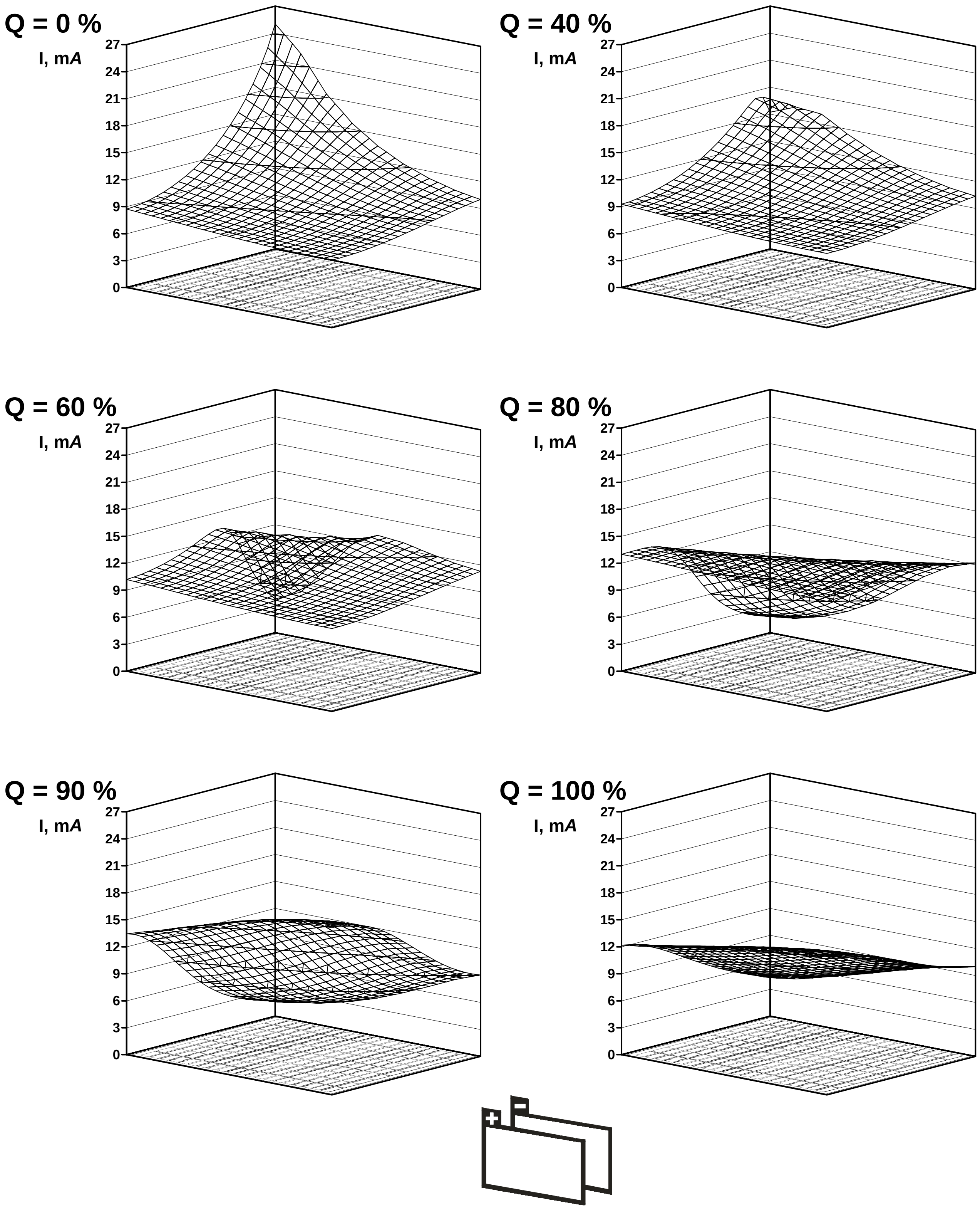

Fig. 2. Current distribution over the plate electrode surface at increasing state of discharge, Q, from 0 to 100% for the most unfavourable tab configuration.

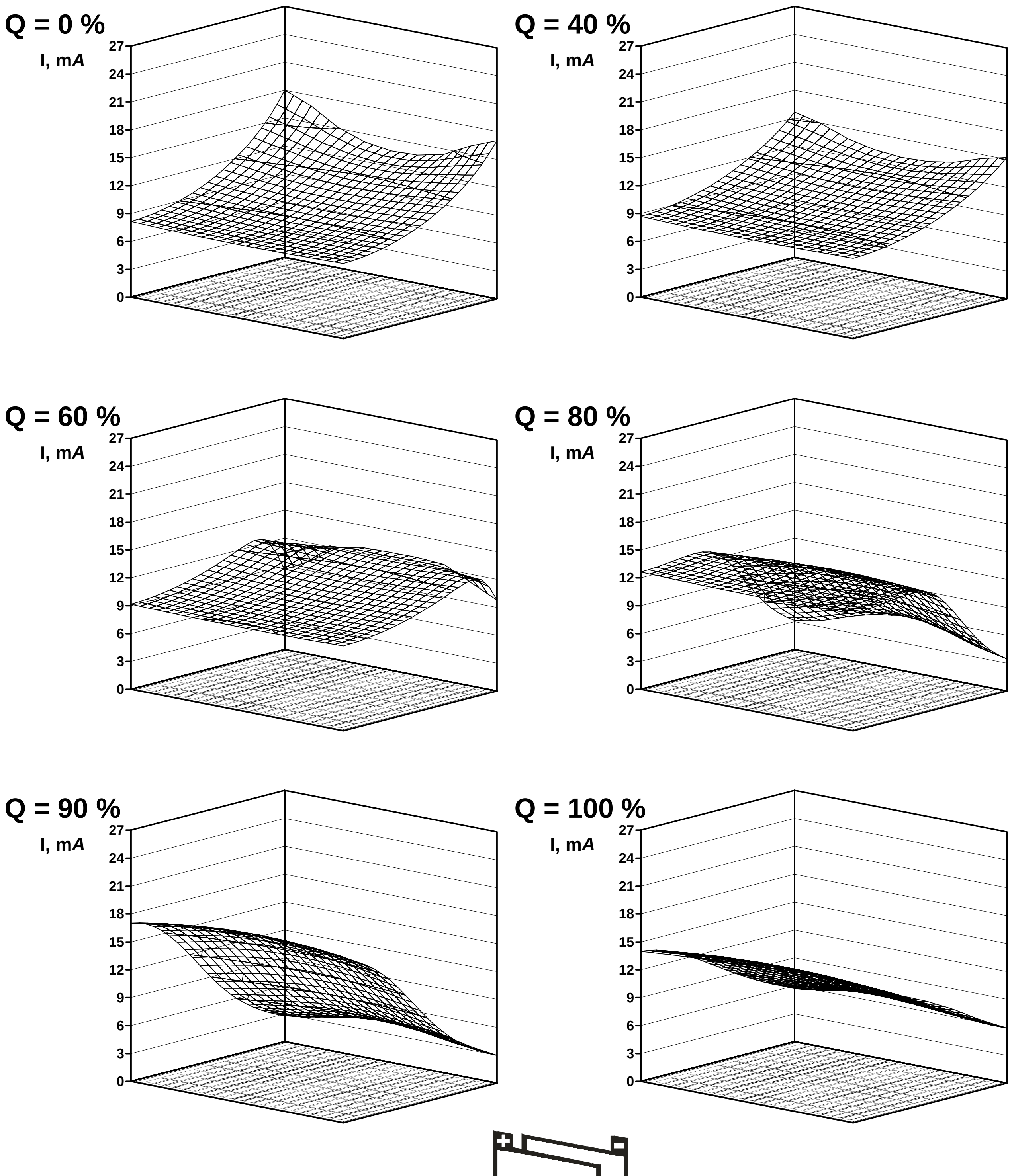

Fig. 3. Current distribution over the plate electrode surface at increasing state of discharge, Q, from 0 to 100% for the tab configuration used in practice.

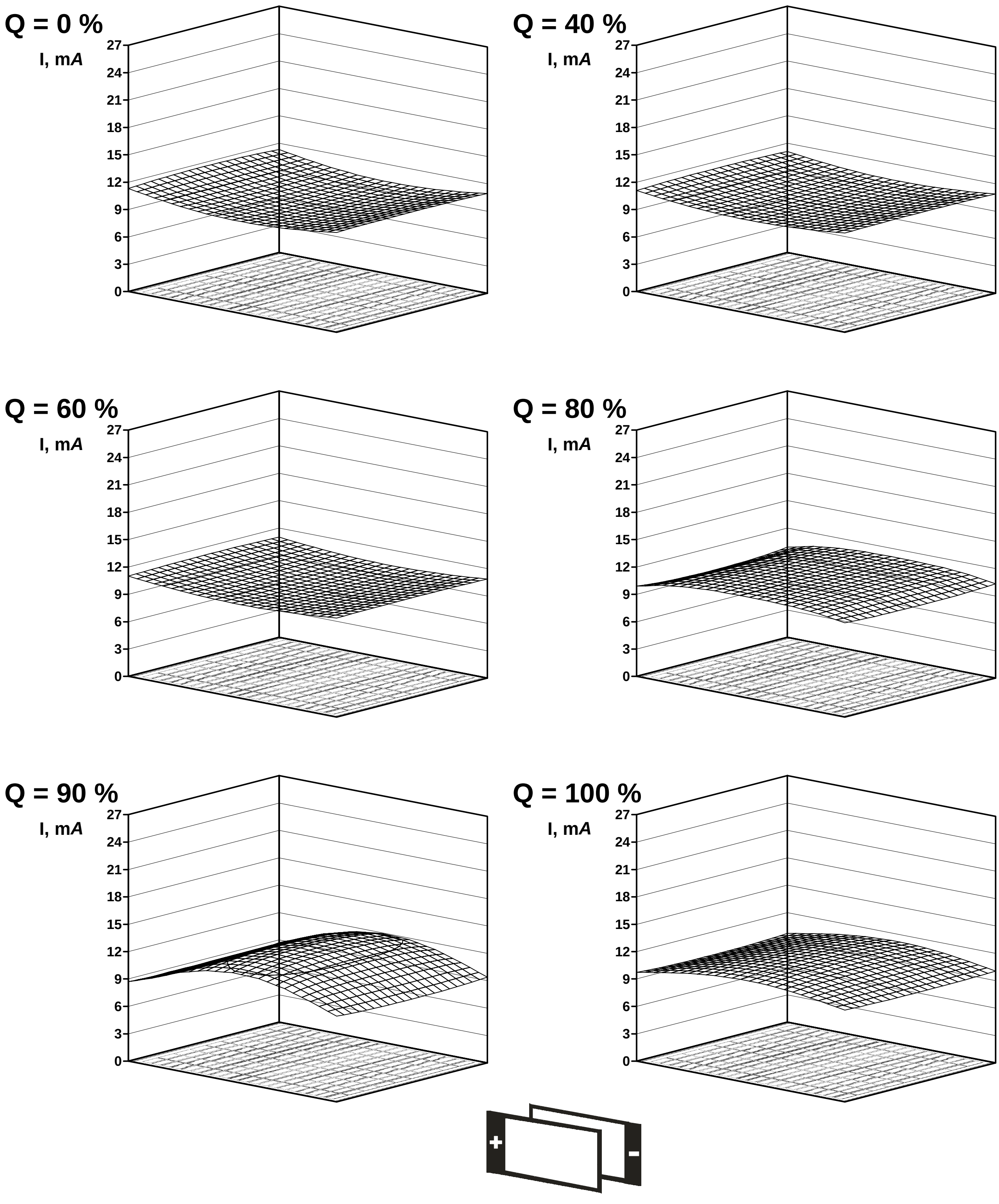

Fig. 4. Current distribution over the plate electrode surface at increasing state of discharge, Q, from 0 to 100% for the most favourable tab configuration.