AlPrg: a software tool for aluminium smelting

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AlPrg is a collection of computer programmes (modules) for PCs using interactive graphics to display the results of calculations concerning aluminium production by electrolysis. The user applies these modules among other things to visualise how varying the parameters will affect pot operation. He can then choose the best values to operate the electrolytic cells of a potroom so as to optimise the most important technical and economic results. This paper reports on the use of one of these modules, namely the Electrolyte Properties Module. This module calculates the physical and chemical properties of the cryolite electrolyte as a function of its composition and temperature. The Electrolyte Properties Diagram Pane shows plots of these bath properties in function of the electrolyte parameters. This plot predicts the behaviour of the bath after a parameter change, and so identifies the optimal bath composition and bath temperature to operate the electrolytic cells.

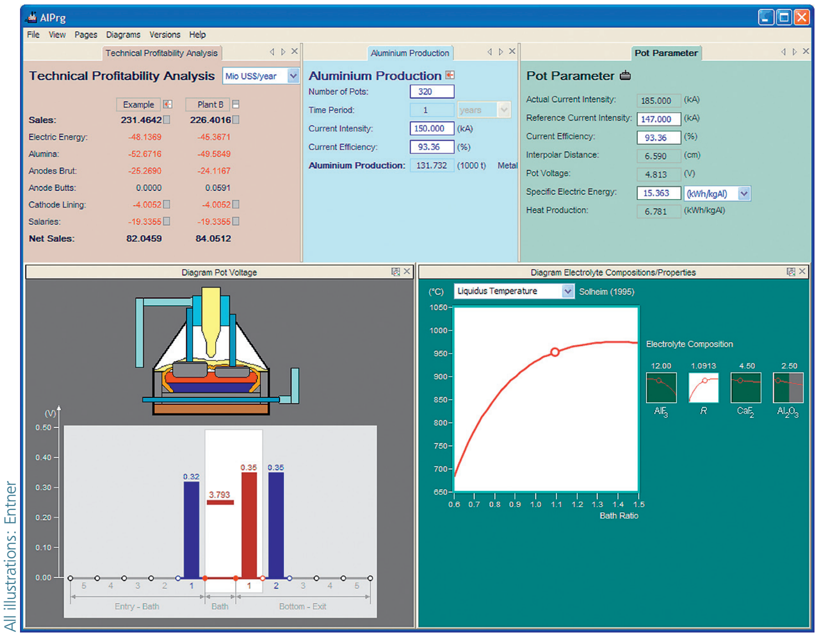

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Fig. 1: Layout of the User Interface of AlPrg. The figure shows 3 tab groups with the calculation pages Technical Profitability Analysis, Aluminium Production and Pot Parameters being selected. Two diagram panes namely the Pot Voltage Diagram Pane and the Electrolyte Composition/Properties Diagrams Pane are docked on the programme user interface.

AlPrg was developed with the aim of helping people occupied with aluminium production by electrolysis. AlPrg contains several modules that the user selects depending on the tasks he wants to study. For instance, if he wants to know how much aluminium a potroom is producing in one month, then he uses the aluminium production module. If he needs to find the set value of the pot voltage, the alumina feeder setting or how much aluminium fluoride to add, he will apply the corresponding, obviously more complex, modules of AlPrg. Finally if the user wants to improve the economic performance of the aluminium smelting plant, the profitability analysis modules will help him to determine those operational parameters to run the plant in a better way.

This paper deals with the electrolyte properties module of AlPrg. This module shows the physical and chemical properties of the cryolite electrolyte, like the liquidus temperature or electrical conductivity. AlPrg determines these values in relation to the chemical composition and the temperature of the electrolytic bath.

The electrolyte properties diagram pane shows diagrams of these bath properties in function of various plots. These plots predict the behaviour of the bath after a parameter change and so help to determine the optimal bath composition and bath temperature.

Programme layout

When the author of this paper worked with Alusuisse and later with Alcan he developed ElysePrg [1] a precursor of AlPrg. AlPrg is, however, a completely new concept for this application, especially regarding the program features and program layout. AlPrg consists of pages and diagram panes. In the windows the user changes numerical values in input fields, and then AlPrg calculates the corresponding results. The diagrams (plots) show graphical representation of properties depending on various parameters. Formed as graphical user interfaces (GUIs), the plots allow the user to change values on the plot by dragging their size representation with the mouse pointer. AlPrg calculates the corresponding new resulting values and updates the relevant pages and plot panes.

The user selects pages or plot panes by clicking on the corresponding menu or tab items. He can arrange several pages on the programme user interface and see them simultaneously so as to study the calculation results. The diagram panes can float on the computer screen or they can be docked, i.e. added on the AlPrg user interface. The next figure (Fig. 1) depicts an example of the AlPrg user interface containing three tab groups and two diagram panes. From the tab groups the user has selected the technical profitability analysis page, the aluminium production page and the pot parameter page. In addition he has docked the pot voltage diagram pane and the electrolyte composition/properties pane on the user interface.

The user finds more information about AlPrg in the conventional accompanying help system. He may also consult the corresponding website [2] that contains practically the same user's guide and theoretical background information.

The Electrolyte Composition/ Properties Page

Fig. 2 shows the electrolyte composition/properties page. In the upper part of the page the user changes the concentration values of the electrolyte components of aluminium fluoride (AlF_3), calcium fluoride (CaF_2), aluminium oxide (alumina Al_2O_3), lithi-

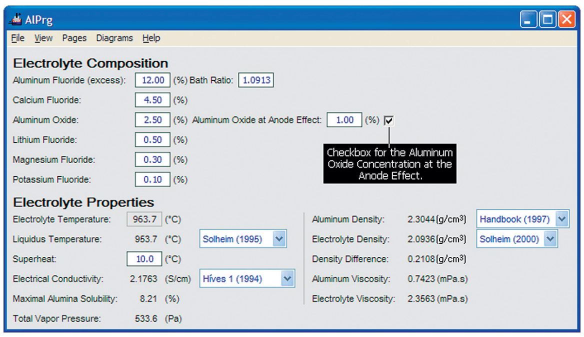

Fig. 2: Electrolyte Composition/Properties Page. In the upper part of the page the user may change the concentration values in the input fields. The lower part contains the property values. The user may select the authors of the corresponding equations that AlPrg uses to calculate the properties.

um fluoride (LiF), magnesium fluoride (MgF_2) and potassium fluoride (KF). The bath ratio is the weight ratio of sodium fluoride over aluminium fluoride. Aluminium oxide at anode effect is the alumina concentration when the anode effect occurs. The user can suppress this parameter by inactivating the check box.

The lower part of the page contains the values of the electrolyte properties, namely the liquidus temperature, the electrical conductivity, the maximum alumina solubility, the total vapour pressure, the densities and viscosities of the electrolytic bath and of the aluminium metal.

The bath temperature can be expressed as the liquidus temperature plus the superheat. The user selects as input value either the superheat (as shown in Fig. 2) or the electrolyte temperature. Selecting a value as input means that it is constant for the following calculations (the superheat in Fig. 2) and the other depending value (the bath temperature in Fig. 2) is calculated correspondingly.

To determine the liquidus temperature, the electrical conductivity or the densities the user can choose between several relationships published by different authors. Fig. 2 shows a Drop Down Combo Box where the user has selected the equations of Solheim [3]. He could alternatively also click on the names of Røstum [4], Peterson [5], Bullard [6], Lee [7] or Dewing [8] to choose the corresponding relations.

The theoretical part of the AlPrg website [9] contains all the relations and equations that AlPrg uses for its calculations.

The Electrolyte Composition/ Properties Plot

Fig. 4 shows the electrolyte composition/properties plot pane together with the electrolyte composition/ properties page.

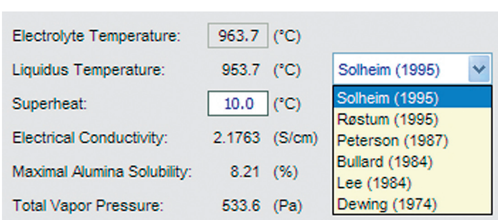

Fig. 3: Drop Down Combo Box to select the authors of the relations that AlPrg uses to calculate the liquidus temperature. The user has chosen the equation of Solheim [3] by clicking on the name with the mouse pointer.

Icon plots

The idea of this plot pane is to show a property of the electrolytic bath in dependence of the bath composition and the bath temperature. The plot pane of Fig. 4 consists of small icon-like plots of the liquidus temperature against the concentrations of aluminium fluoride, calcium fluoride, aluminium oxide etc. From these plots the user can visualise how

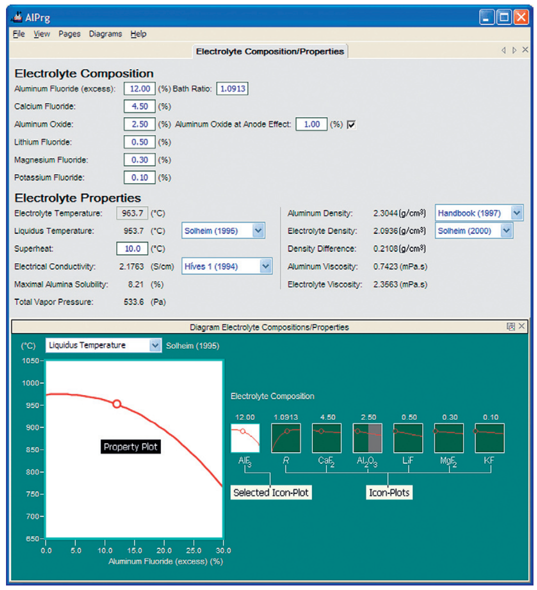

Fig. 4: The Electrolyte Composition/Properties Diagram Pane docked on the AlPrg user interface. Small icon-like plots represent the selected electrolyte property (the liquidus temperature in this figure) in function of the electrolyte components. The user has selected the liquidus temperature vs. aluminium fluoride content to be shown in the larger property plot. The circles represent the current values of the electrolyte composition.

the liquidus temperature depends on these variables, the other parameters staying constant. The small circles represent these constant concentration values shown on the electrolyte composition/properties page.

Property plot

If the user wants to study an icon-plot more profoundly he clicks on the icon-plot with the mouse pointer and the icon-plot expands to replace the larger property plot. In Fig. 4 the

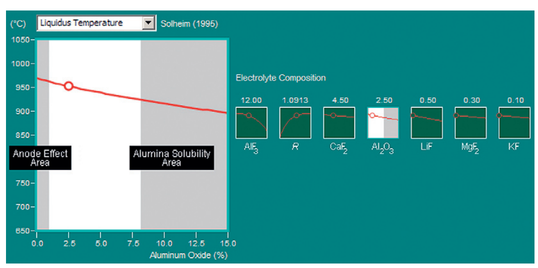

Fig. 5: Liquidus temperature vs. Alumina Concentration Property Plot. The user has clicked on the Al_2O_3 icon-plot and the property plot shows the liquidus temperature vs. the alumina concentration. The gray areas are the regions where the alumina concentration is lower than anode effect concentration (on the left side) or higher than the maximum alumina solubility (right side).

user has clicked on the aluminium fluoride concentration icon-plot, and consequently the property plot shows the liquidus temperature in dependence of the aluminium fluoride con- →

centration between 0 and 30 weight %. The circle represents the liquidus temperature of 953.7 °C at the aluminium fluoride concentration of 12 weight %.

Gray areas in the icon or property plots are regions where values are not available or not possible. Fig. 5 shows the property plot of the liquidus temperature vs. the alumina content. The grey regions show where the alumina concentration is smaller than the anode effect concentration (on the left side) or greater than the maximum solubility of alumina in the electrolyte.

Electrolyte and aluminium densities

As an example the following chapter discusses the densities of the electrolyte and of the liquid aluminium metal. In the electrolytic production of aluminium the density values es-

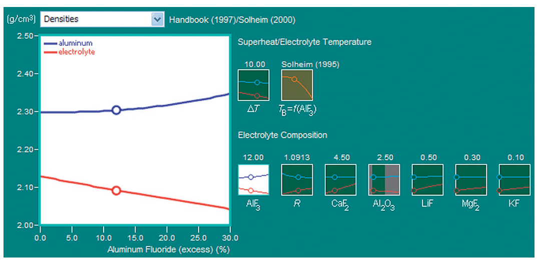

Fig. 6: Aluminium and Electrolyte Densities Plot Pane. The user has clicked on the aluminium fluoride icon-plot, so that the property plot shows the aluminium and electrolyte density vs. the aluminium fluoride concentration.

pecially the density difference between aluminium and electrolyte affects the separation of the produced aluminium metal from the bath. This difference should be larger than 0.2 g/cm³ in order to prevent mixing and to maintain good separation between the metal pad and the electrolyte layer. In the electrolyte and aluminium density plot pane AlPrg shows simultaneously the densities of the liquid aluminium metal and the liquid electrolyte. In this way the user sees immediately the influence of parameter changes on the density difference.

Dragging

If the mouse pointer is over the property plot and the user presses the right mouse button a so-called value line

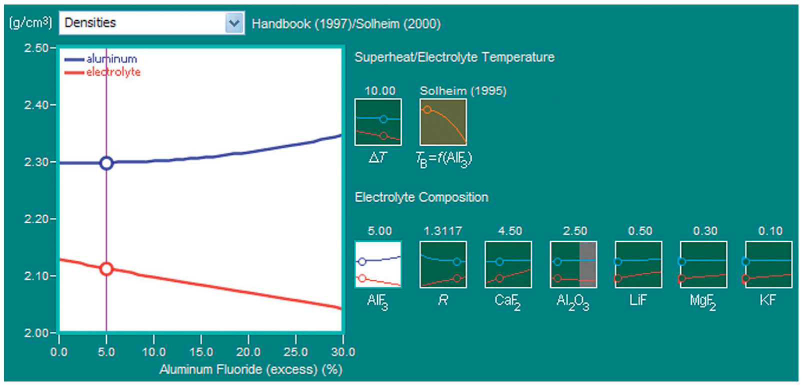

Fig. 7: Dragging of the Value Line. When the user holds down the right mouse button AlPrg draws the so-called value line. When the user drags this line by moving the mouse, AlPrg registers a new input value and plots new density values in the property and icon plots.

is drawn. When the user displaces the mouse (dragging) the value line follows this motion on the property plot. AlPrg registers this new concentration input value (5% aluminium fluoride in Fig. 7) and calculates the corresponding new density values in the icon and property plots (and electrolyte composition/properties page).

If the user wants to change another parameter, the lithium fluoride concentration, the procedure is the same. The user clicks on the lithium fluoride icon plot. This icon plot is then selected, i.e. AlPrg shows this plot in the main property plot. By again dragging the value line with the mouse pointer, the user changes then the lithium fluoride concentration, and AlPrg calculates the corresponding density values.

Temperature plots

The superheat, i.e. the temperature difference between the electrolyte temperature and the liquidus temperature, is a very important value for everyday pot operation. Sometimes some quite puzzling events are observed, namely that the superheat might be negative (the electrolytic bath should be solid) even for a rather long time period. This effect is called the liquidus enigma [10].

If the superheat (ΔT) is selected as input value on the electrolyte composition/properties page (see Fig. 2, 3 and 4), then the electrolyte composition/properties diagram pane shows two icon-plots, namely the superheat plot (densities vs. superheat on Fig. 6, 7) and the electrolyte temperature plot (bath temperature vs. aluminium fluoride on Fig. 6, 7).

Clicking on the superheat icon-plot (ΔT) AlPrg draws the corresponding property plot, namely aluminium and electrolyte density vs. superheat. By dragging the value circles, the user can modify the input value of the superheat.

Since the last selected composition icon plot was the densities vs. aluminium fluoride icon-plot, AlPrg shows in the bath temperature icon plot how the electrolyte temperature depends on aluminium fluoride concentration.

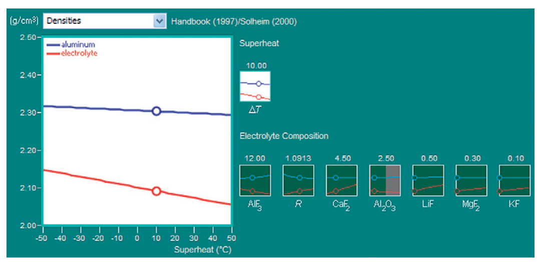

Fig. 9: Property Plot of Densities vs. Superheat. The user has selected the superheat icon-plot of Fig. 6 and so AlPrg draws the corresponding property plot densities vs. superheat.

If the electrolyte temperature is selected as input value on the electrolyte composition/properties page (see Fig. 2, 3 and 4), then the electrolyte composition/properties diagram pane shows the densities vs. electrolyte temperature icon-plot (Fig. 11). By clicking on this icon plot, the user instructs AlPrg to show the corresponding aluminium and electrolyte density vs. bath temperature property plot, as well as the electrolyte temperature plot (bath temperature vs. aluminium fluoride on Fig. 6, 7).

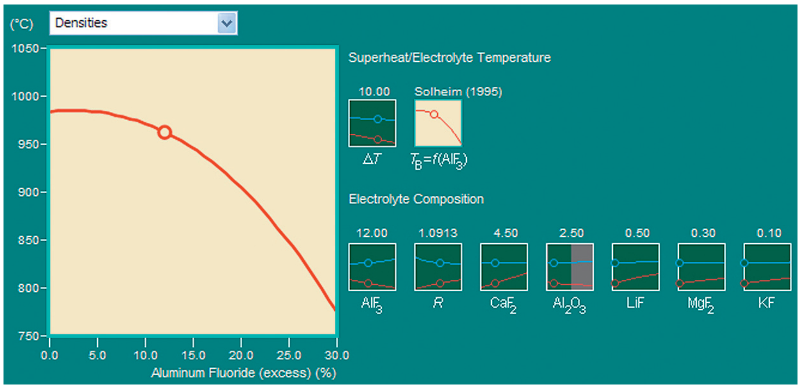

Fig. 10: Property Plot of Bath Temperature vs. Aluminium Fluoride Concentration. The user has selected the bath temperature icon-plot of Fig. 6, and so AlPrg draws the corresponding property plot bath temperature vs. aluminium fluoride concentration.

Conclusions

This paper describes the calculation page and the diagram pane of the electrolyte properties module of AlPrg. In the calculation page the user enters or modifies in a rather conventional way values in the corresponding input fields, and AlPrg then determines the corresponding electrolyte properties, like liquidus temperature, electrical conductivity etc. The diagram pane shows graphical representations, i.e. small icon-plots, of how a selected property (the liquidus temperature, for instance) depends on the electrolyte composition values and the bath temperature. The user selects an icon-plot to be drawn in the larger and more precise property plot. This plot is a graphical user interface, i.e. the user can change input values by dragging the so called values line with the mouse pointer to a new position and value.

The user investigates in this way the behaviour not only of those electrolyte properties already described in this paper (liquidus temperature and densities), but also the electrical conductivity (interesting for pot voltage settings), maximal alumina solubility (used for point feeder setting), vapour pressure (necessary for environmental issues) and the viscosities of the liquid aluminium pad and electrolyte (used for hydrodynamic studies).

This paper describes the electrolyte properties module as a standalone programme. This module is however also incorporated into other modules where it is needed, for instance into pot voltage or the profitability module. It works there in the same interactive way as described in this paper; this means the user can change an input value either from the key board on the electrolyte property page, or else by dragging on the corresponding property plot. AlPrg then recalculates other parameters and updates the corresponding pages or plot panes.

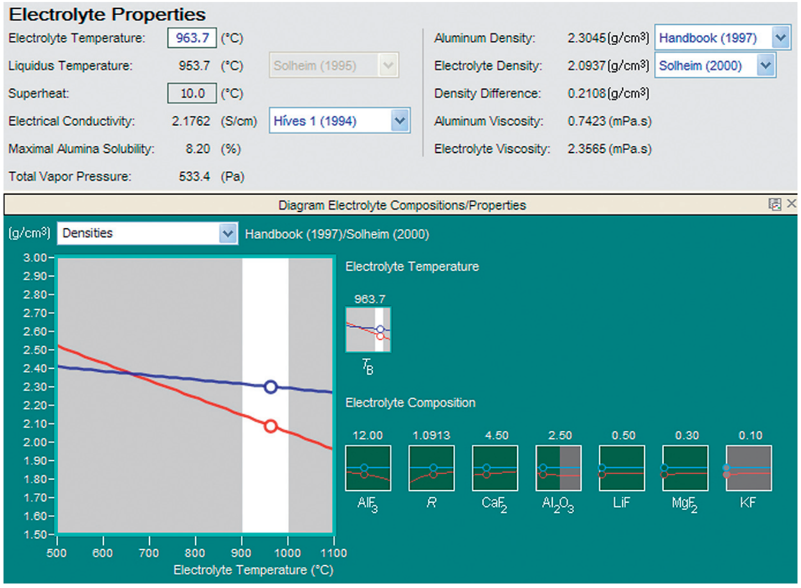

Fig. 11: Densities vs. Electrolyte Temperature Property Plot. The user has selected the electrolyte temperature as input value on the electrolyte composition/properties page. AlPrg then shows the densities vs. electrolyte temperature icon- and property plot after appropriate selection by the user. The shaded area is the region where the bath temperature is lower or higher than the liquidus temperature +/- the maximum superheat (±50 °C).

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