doi.org/10.15407/tpwj2018.01.08

INTERNET DATABASE OF ARC SURFACING PROCESS USING FLUX-CORED WIRES

V.G. SOLOVIOV
E.O. Paton Electric Welding Institute of the NAS of Ukraine
11 Kazimir Malevich Str., 03150, Kyiv, Ukraine. E-mail: office@paton.kiev.ua

A significant volume of work was performed on arc surfacing with application of self-shielded flux-cored wire on flat and cylindrical surfaces of workpieces by an open arc, submerged arc and in shielding gas atmosphere, in a wide range of voltages and currents of the arc, with different wire diameters and at different deposition rates, in order to use the experimental material to develop algorithms for automation of the technological process. The paper presents a solution on systematization of the data, obtained as a result of experiments, which allowed all the investigation participants to have remote access to the Internet database for its expansion, correction and analysis. 8 Ref., 3 Figures.

Keywords: *automation, database, arc surfacing, flux-cored wire*

Integrated automation of nonlinear multifactorial technological process of arc surfacing of metals requires involvement of considerable mathematical and computational resources on modeling relations of a large number of parameters, part of which can be obtained using sensors, and the other part by indirect method, using the apparatus of regression analysis, neural network technologies, fuzzy logic, etc. In addition to that, optimization of the process is contemplated, and in this case optimization will be multicriterial, that greatly complicates system synthesis. Recently, the synergetic principles of synthesis [1] are ever more often used for automation of «dissipative systems», to which the arc process belongs. These principles allow stabilizing the relationships between the variable states of the process. The consequence of this fact is degeneracy of the equations of dynamics of arc surfacing process and presence of integral invariants of manifolds in the space of its states. Invariant manifolds represent «certain functions which do not change during movement» [2]. Such approaches to automation of nonlinear objects greatly simplify the system synthesis and can be used for reaching the ultimate automation goals, i.e. improving the manufactured product quality with maximum energy saving. However, they require conducting a considerable number of experiments for analysis. A large scope of experimental arc surfacing with flux-cored wire of flat and cylindrical surfaces of products has been performed to obtain data characterizing the arc surfacing process, which furtheron will be used for analysis and synthesis of an automation system. Open-arc, submerged-arc and gas-shielded arc surfacing was performed in a broad range of voltages and currents of the arc with different diameters of flux-cored wire and at different deposition rates. Quality characteristics of the deposits and deposited beads were obtained, which are particularly significant for process automation.

The objective of this work is compiling an Internet database of the results of experimental arc surfacing with flux-cored wires for remote sharing during development of a system of automatic regulation of arc surfacing process.

Figure 1 shows a list of input and output data of the process of arc surfacing. The following process parameters are input data for the process: kind of surfacing (open-arc, submerged-arc or gas-shielded surfacing), flux-cored wire grade and its diameter, electrode extension, deviation from the item equator (for surfacing on cylindrical surface), etc. Controlling parameters are the position of manual device for setting power source voltage, position of manual device for setting electrode wire feed and position of manual device for setting the deposition rate on the unit control panel.

During preparation for experiment performance, software was developed within the framework of automated acquisition of statistical data [3], which provided monitoring and digital recording of the following parameters of arc surfacing process:

- instantaneous values of power source voltage $U_{p.s}(t)$;
- instantaneous values of surfacing current $I_s(t)$;
- $U_{p.s}(t)$ and $I_s(t)$ values average over surfacing time;
- instantaneous values of arc voltage $U_a(t)$ and arc current $I_a(t)$; here $U_a(t)$ and $I_a(t)$ values were determined by excluding from $U_{p.s}(t)$ and $I_s(t)$ values the voltage and current values in the time intervals of appearance of short-circuits (ShC) and arc breaks;
- arc voltage and arc current values average over surfacing time;
- manual entering and recording of settings of arc voltage and current voltage;

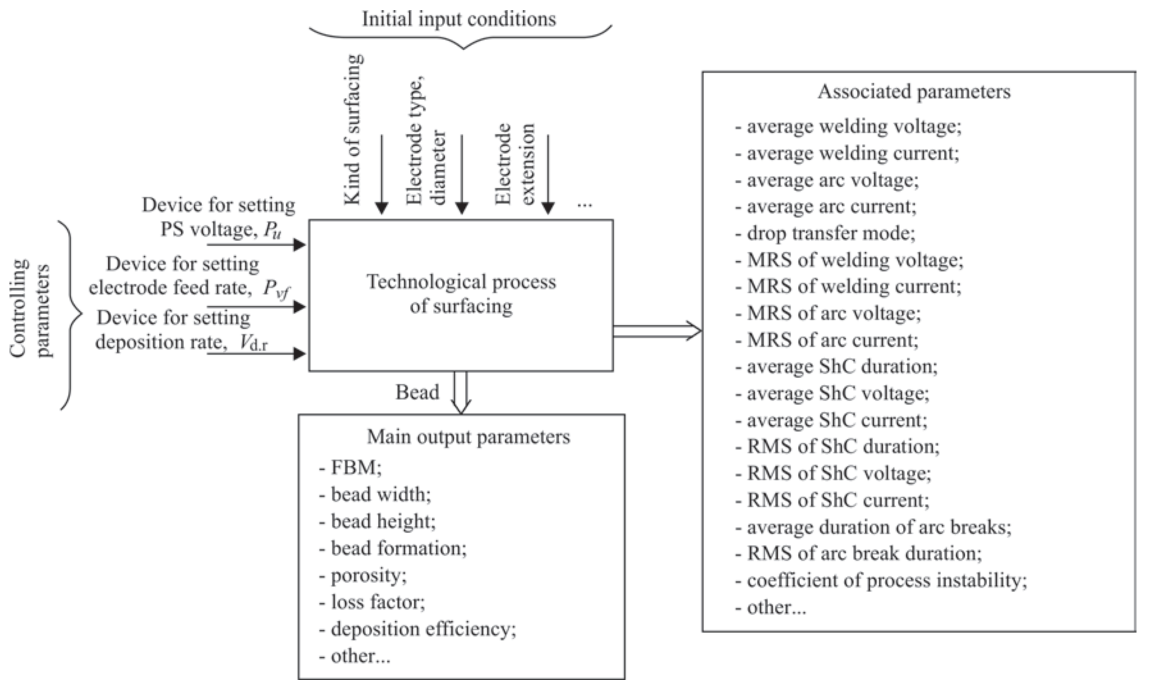

Figure 1. List of input and output data of the technological process of arc surfacing

- manual entering and recording of values of the position of manual device for setting power source voltage P_u, position of manual device for setting electrode wire feed rate P_{vf} and deposition rate $V_{d.r}$;
- ShC duration average over surfacing time;
- ShC voltage average over surfacing time;
- ShC current average over surfacing time;
- duration of arc breaks average over surfacing time;
- calculation and recording of such statistical parameters as MRS (mean-root-square error) value of welding voltage and arc voltage; MRS value of welding current and arc current; MRS value of ShC duration, voltage and current; MRS value of arc break duration;
- coefficient of instability of electric parameters of surfacing;
- type of metal drop transfer: globular, drop, fine-drop or spray;
- calculation and recording of evaluation by average duration of arc breaks. The following states were determined: «no breaks», «allowable number of breaks», «considerable number of breaks», «many breaks», «a great number of breaks» or «process is unstable».

During experiments, surfacing time, kind of surfacing, flux-cored wire grade, wire diameter, electrode extension, kind of workpiece surface, deviation from zenith of a cylindrical billet were recorded. Deposited beads were photographed, and time chart entries were recorded by such parameters as instantaneous welding voltage and welding current, instantaneous arc voltage and arc current.

At the end of each surfacing operation surfacing protocol was automatically generated in the form of a text file.

Results of expert evaluation of the deposited beads were used to determine the quality of bead formation as: «poor», «satisfactory» or «good»; presence of pores: «no pores», «individual pores» or «numerous pores».

Processing macrosections yielded such parameters as: «fraction of base metal in the deposited metal» (FBM); bead cross-sectional area, bead width, bead height and penetration.

Analysis and processing of experimental results yielded a lot of data on interconnection of various parameters, regularities of their change, depending on initial input conditions. This was recorded [3, 4] in the form of various graphs, figures and tables.

It resulted in obtaining data on arc surfacing of about 250 experimental beads, each of which is characterized by about 50 values of the above parameters unique for each bead, i.e. approximately 12500 data points [3]. By their structuredness, these data completely correspond to the definition of normalized relational database [5, 6], i.e. these data can be placed in a two-dimensional table, in which the relationships between information are fully defined. Marking the deposited bead is the primary KEY for such a table. Unique parameters, inherent to just this bead, are placed in the table rows in the corresponding cell. Markings are stamped on the item near the bead with shock markers for metal so that the marks did not disappear at further cutting and processing of the items. The database has the following structure: OBJECT is the bead; ATTRIBUTES are all the above-listed parameters, characterizing the deposited bead. In the Table the number of rows (entries) corresponds to the number of deposited beads, and the number of columns (fields) corresponds to the number of attributes.

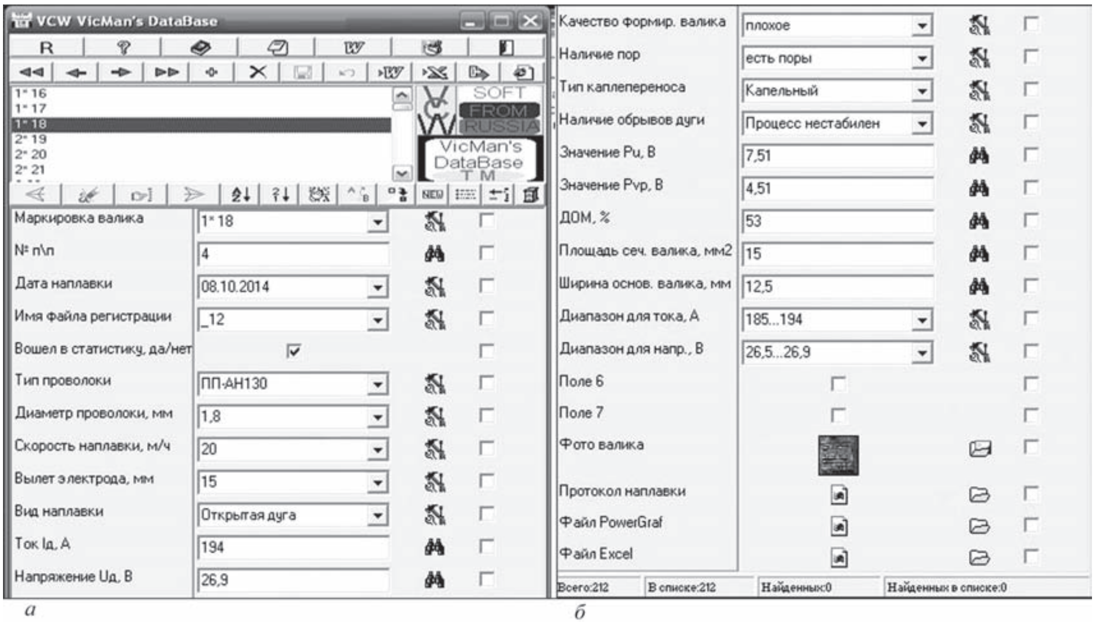

Figure 2. Arc surfacing database created using VCW VicMan's DataBase

Known are examples of databases of the modes of CO_2 arc welding, submerged-arc and inert-gas arc welding [7], which were developed on the basis of specialized software, suitable for application for the range of products, characteristic for this machine-building plant, and only within this plant. This software, however, is not suitable for collective study of the technology of self-shielded flux-cored wire arc surfacing with the purpose of process automation. Figure 2 shows the main form of the control system of VCW VicMan's DataBase (further on DBCS) which we used initially for systematizing and integrating (in the form of surfacing database) all the data derived as a result of experiments. DBCS is simple and very flexible for creation of small relational databases. It allows creating up to seven types of fields (text, graphic file of any format, in the form of a list, in the form of a flag, etc.). It allows editing the database, exporting it into a file and importing it from a file. It searches the text fields and sorts the entries in the required order; exports the database into Microsoft Word, Excel, into DBF and HTML format files. It, however, has a limitation by the number of fields — up to 30 ones (in this case about 50 or more are required). Here, as shown by practical work with the surfacing database, it is very often necessary to perform computations, using the data in the tables, for instance, determine the sum of the selected data, determine the value of autocorrelation or cross-correlation coefficients. However, this DBCS does not have such a capability. Therefore, it is necessary to export data into Excel program, which has a sufficient arsenal of tools for analysis, computation and visualization, and to perform the required computations in this program. Moreover, VCW VicMan's DataBase cannot be placed in the cloud Internet resource, and without it, under the present conditions, it is impossible to organize efficient collective research on the defined problem. For its filling and analysis the arc surfacing database requires participation of different groups of experts, specializing in certain areas of the work on the defined problem. And this work should be performed from different workplaces.

Internet database (cloud database, web-database) is the electronic distributed database, accessible through the Internet, unlike the lumped databases, accessible only in an individual computer or on the storage device connected to it, for instance, compact disc. Such databases are located on servers, fitted with a web-interface that allows access to them using widely accepted software through one of the public web-browsers. Intensive introduction of services for cloud computations by providers, led to Internet-databases becoming increasingly in demand. Such services, as Amazon Web Services (AWS), Google Cloud SQL, Microsoft Azure, SAP, Oracle, etc, operate in the cloud database market. They are attractive for customers with bases having a large distributed volume of data, for whom such cooperation is cost-effective.

A relational database can also be created in Microsoft Excel software package. In this case, Excel will perform, in some sense, the role of DBCS uncharacteristic for it, but, nonetheless the one it often plays [8]. If the relational database created in Excel, is not normalized, i.e. has several values in one cell of the table, then an additional table has to be compiled, which is linked to the first one, that complicates working with Excel as the database control system. Now in

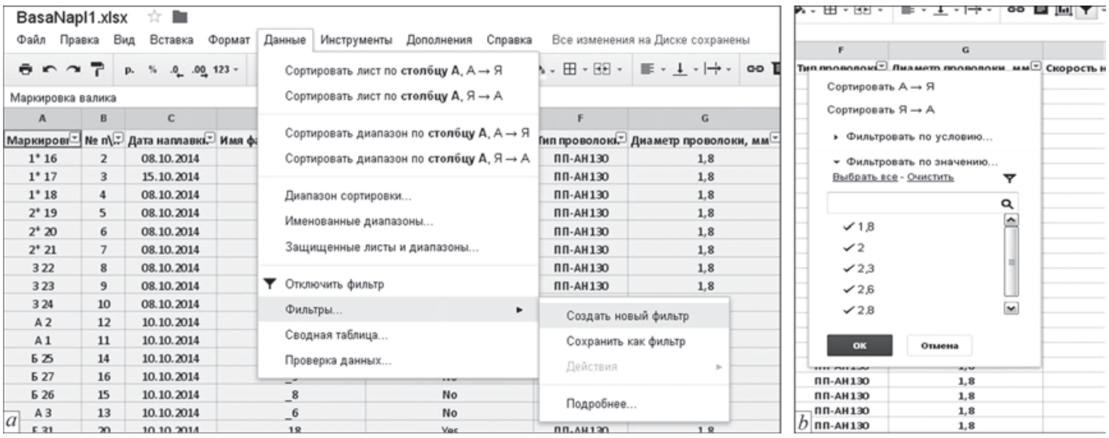

Figure 3. Some database functions, realized in Google Tables: *a* — sorting function; *b* — filtering function

our case, the surfacing database is normalized, and it can be placed in one table. Moreover, if required, hyperlinks to a graphic, text or other document, as well as the executed file, can be entered in the table fields that is very convenient, but searching by these fields is impossible in Excel.

At present Google Drive cloud resource provides for free use of more than 15 GB of cloud memory for secure file storage, including Microsoft Word, Excel documents, photos and videos. Thus, it enables other users looking through, editing and copying the documents. Google Tables application allows working with Excel files quite comfortably, practically no worse than in Microsoft Office Excel. It is possible to work not only on-line, but also off-line with subsequent synchronizing with Google Tables, when you turn on the Internet, as well as to work on the smartphone, with installed OS Android 4.0 and later versions. Moreover, Google Tables supports simultaneous joint work with tables of an unlimited number of employees, who received the right of access from the administrator.

Cloud database of arc surfacing results, created in Google Tables, allows editing, managing, and sorting the data (Figure 3, *a*), filtering it by columns (Figure 3, *b*), as well as generating reports based on data stored in spreadsheets. Results can be manually entered into the database, or imported into the Google Tables. If the data pertain to other programs, then before importing, they should be saved in Excel format, and after that imported into Google Tables. Google Tables application allows computing the result by the most diverse criteria:

- sum — data is summed;
- count — number of cells in the numerical range is counted;
- average value — mean arithmetic value is calculated for the selected data range;
- minimum and maximum values — shows the lowest and the highest values in the selected range;
- product — calculates data product;
- standard deviation — assesses the standard deviation in a sample;
- dispersion — assesses the dispersion in a sample, etc.

Conclusions

1. Capabilities of Google Tables Internet resource for creation of a fully functional cost-effective database of arc surfacing process for shared use were studied and confirmed.

2. An Internet database of the results of the process of experimental arc surfacing with flux-cored wires was created for its remote sharing in order to develop an automatic system of regulation of arc surfacing process.

1. Kolesnikov, A.A. (1994) *Synergic control theory*. Taganr. TRTU. Moscow, Energoatomizdat [in Russian].
2. Vladimirsky, E.I., Ismajlov, B.I. (2011) *Synergic methods of chaotic system control*. Baku, ELM [in Russian].
3. Ryabtsev, I.A., Lankin, Yu.N., Soloviov, V.G. et al. (2015) Computer information-and-measuring system for investigation of arc surfacing processes. *The Paton Welding J.*, **9**, 32–35.
4. Lankin, Yu.N., Ryabtsev, I.A., Soloviov, V.G. et al. (2014) Effect of electric parameters of arc surfacing using flux-cored wire on process stability and base metal penetration. *Ibid*., **9**, 25–29.
5. Connolly, T., Begg, C., Strachan, A. (2001) *Databases: Design, implementation and management. Theory and practice*. Moscow; St.-Petersburg; Kiev, Williams [in Russian].
6. Redmond, E., Wilson, J.P. (2013) *Seven databases in seven weeks. Introduction in current databases and NoSQL ideology*. Ed. by J. Carter. Moscow, DMK Press [in Russian].
7. Demchenko, V.F., Kozlitina, S.S. (2010) Database of modes of CO_2-, flux-cored and inert gas arc welding. *Izvestiya TulGU. Tekhnicheskie Nauki*, 4, 1 [in Russian].
8. Dolzhenkov, V.A., Stuchenkov, F.B. (2007) *Microsoft Office Excel 2007*. St.-Petersburg, BKhV-Petersburg [in Russian].

Received 21.11.2017