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Measurement and Data Processing System for Welding Parameters and Noise Level during Manufacturing Process of Welded Structures

Abstract: This paper presents the design, technical possibilities and the intended use of a multi-station measurement system for assessing welding process parameters and noise levels. The system is an innovative solution as regards the measurement technique related to welding process parameters and acoustic pressure in production floors. Once implemented industrially, the system enables the monitoring and recording of noise levels in individual work centres as well as the monitoring and recording of technological conditions accompanying the welding of various structures and products.

Keywords: measurement system, monitoring of welding processes, monitoring of noise levels

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Introduction

The use of welding technologies in industrial practice entails the necessity of testing and determining conditions related to health and safety at work. Welding processes used when joining metals belong to manufacturing processes significantly and unfavourably affecting the work environment. Presently, welding, along with allied techniques, constitute the most developed and established joining technology used when making structures and products of diverse materials and sizes in many industrial sectors. Welding processes generate excessive noise, being a physical factor having a definitely destructive effect on the worker's physical health and significantly deteriorating work conditions

The exposure of individual welding shop workers to noise depends on numerous factors, particularly including concurrent work performed in individual production centres, welding process current-voltage parameters and the intensity of post-weld mechanical treatment. The acoustic environment of a process room where welded structures are made is hazardous to the worker's health and affects the efficiency of production. According to Instytut Spawalnictwa's research and experience, in many companies the excessive noise accompanying the making of welded structures constitutes a very urgent and important issue.

Having in view the foregoing, Instytut Spawalnictwa has developed an innovative

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measurement and data-processing system for measuring and analysing welding process parameters and noise levels in process rooms [1]. The combination of measuring and recording functions of the system with analytical modules related to the making of welded structures and concerning acoustic conditions is an innovative solution enabling the control of manufacturing (welding) processes and that of the acoustic environment of work.

A Glance at the System

In strict terms, the system is by definition a computer-based control-measurement and analytical-advisory system. The measurement system is an appropriately organised set of elements constituting a certain whole dedicated to obtaining measurement information from an object being tested and providing the user with this information in a usable form. The control system is tasked with verifying whether a measurement result is restricted within a certain range of boundary values. In turn, the role of the analytical system is to analyse collected information and enable the user to draw rational and practical conclusions. The advisory (expert) system, on the basis of collected information and using an appropriate algorithm, provides the user with a solution to a given problem. The term computer-based means that all of the above-presented functions are performed using a computer system. The system is composed of two layers, i.e. hardware and software. The hardware layer includes measuring transducers, measurement cards, communication interface cards, computer system elements as well as the remaining elements, systems and electronic devices. The software layer includes software modules controlling the operation of the measurement system as well as software modules implementing the adopted functionality of the control-measurement system and the assumed functionality of the expert system.

According to previously adopted assumptions, the system is not dedicated to a specific type of a welding station. It has been assumed that the system should be usable with many different types of welding stations. For this reason, the system architecture is sufficiently open and versatile so that the system could be adapted to various conditions. The multi-station character of the system means that system functions are implemented on many welding stations at the same time. The system is experimental in nature and constitutes an innovative approach to the assessment of sounds emitted when welded structures are made in a production shop. The system incorporates the control-measurement functions of the system with analytical functions related to the making of welded structures and to acoustic conditions as well as advisory functions aimed to reduce the level of sound by changing welding process parameters.

Description of the System

The system is relatively complex and its functionalities can be viewed in various ways [1]. The most general level involves the following functions:

- **measuring / recording** – recording of parameters connected with welding processes and parameters related to noise generated and emitted during production,
- **storing** (archiving) – transfer of recorded data from welding stations and data collected during acoustic measurements to the central storage unit (database sever), where these data are stored and secured,
- **analysis and processing** – calculating derivative quantities, analysis of collected data, the evaluation of welding processes and the assessment of noise levels,
- **advisory** – changes of technological parameters aimed to reduce noise levels,
- **visualising** – presentation of collected data.

The detailed description and characteristics of system functions are presented in Table 1.

Table 1. Description of system functions [1]

FUNCTION	DESCRIPTION	ADVANTAGES
Recording of welding parameters	The measurement of quantities related to electric arc welding processes (MIG/MAG), i.e. welding current, welding arc voltage and filler metal wire feeding rate.	The possibility of obtaining detailed technological information about welding processes.
Recording of noise parameters	The recording of acoustic pressure levels using correction A and C.	The possibility of obtaining detailed information about noise present at selected production stations.
Archiving of recorded parameters	The saving of recorded parameters in the database.	The possibility of using data for further analysis and the documentation of production processes.
Automated information collection process	The recording, saving and processing of selected parameters are performed automatically by the measurement system.	The unattended gathering of information concerning production processes.
Visualisation and reporting of collected data	The presentation of collected information, recorded waveforms/courses, calculated derivative quantities in various timeframes (shift-based, daily, monthly etc.) enables the system user to assess the process production in a bigger picture. The generation of daily, weekly etc. reports.	The assessment and detection of trends and untypical changes of parameters.
Advisory function for the correlation of welding parameters and sound levels	On the basis of defined technological welding parameters, it is possible to select/adjust an alternative set of parameters leading to the reduction of noise generated and emitted during production processes.	The reduction of noise improving work conditions.
System scalability	The universal modular design of the system makes it possible to add more stations to the system and to add new functions connected with the analysis of collected data without the necessity of system reorganisation.	The modular architecture of the system enabling its easy extension.
Access via a computer network	The use of Ethernet for data transmission. The possibility of incorporating the system into the network infrastructure of a production facility. As a result, collected data are available to all authorised workers using the computer network.	The availability of the system.

System Architecture

The system can be characterised as a scattered multi-station measurement system connected (via a computer network) with the central computer (server) storing recorded parameters and data created on the basis of these parameters (Fig. 1). The data can be accessed by users connected to the computer network and provided with appropriate software applications enabling the users to visualise and analyse collected information [2].

The system represents a typical example of client/server network architecture, where the central computer with the database (server) is the receiver of data generated by measurement modules installed at production stations and analytical software programmes (clients) used by the main system users, i.e. welding technologists, Health and Safety Inspectors and other personnel managing production processes. The measurement system is composed of modules for measuring welding parameters (Fig. 2),

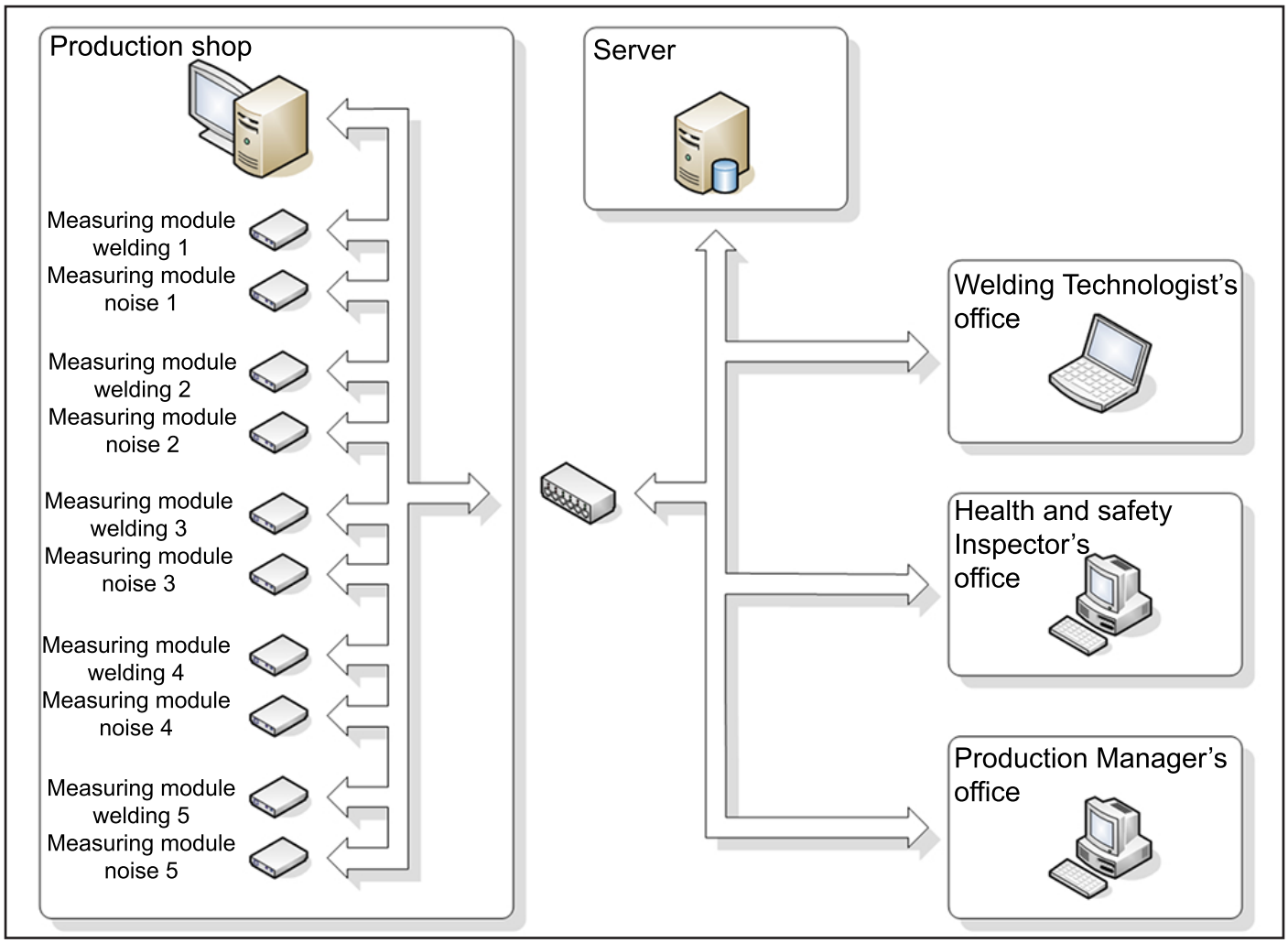


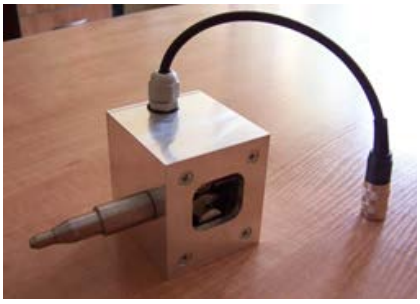
Fig. 1. Measurement System Architecture [1]

provided with three measurement channels, i.e. for measuring welding current, electric arc voltage and filler metal wire feeding rates. The modules have been provided with appropriate measuring transducers, measurement cards and an industrial controller controlling the operation of the measurement module provided with an output for communication via Ethernet.

The operation of the measurement module is entirely autonomous. The measurement module software programme automatically detects the commencement of a welding process and afterwards, on the basis of momentary values, systematically calculates

a) module connected to the welding power source

b) measurement module



c) transducer for measurements of filler metal wire feeding rates installed in the filler metal wire feeder

Fig. 2. Module for measuring technological parameters of welding processes [1,5,6]

the average and root-mean-square values of recorded waveforms/courses and sends this information to the server via the computer network.

The module for measuring acoustic pressure is presented in Figure 3. The system includes a DSA-50 noise meter manufactured by Sonopan, provided with a special software programme adapted to the welding measurement system. The meter is equipped with a special RS 232 digital output for communication with the master system. For this reason, the module is equipped with an RS232/Ethernet converter to enable communication between the meter and the server via the computer network.

Microphones for measuring sound levels combined with a DSA-50 noise meter were fixed in a welding shop, 2-2.5 m above the floor and a minimum of 0.5 m from a wall. The microphone location provides necessary access to adjust positions of the microphones, perform calibration and check a measurement channel (Fig. 4).

Fig. 3. Noise meter in the production shop

System Software

Because of the complex functionality of the system and due to the fact that the system has been created by many developers using various IT and measurement technologies, the system software has been divided into the following independent modules (applications) [3,4]:

- **Monitor of parameters in the production shop** – software for the visualisation of welding parameters and noise levels currently recorded at monitored production stations available in the production shop,
- **Software for the visualisation of collected data** – presentation of collected data and calculated derivative quantities saved in the database, activated remotely by any computer connected to the computer network (e.g. from the office of a welding technologist/Health and Safety Inspector),
- A**dvisory (expert) module** for the correlation of welding conditions and noise levels (activated remotely, e.g. from the office of a welding technologist/Health and Safety Inspector),
- **Reporting software** – generation of periodical reports on the basis of collected data stored in the database,
- **Software of recorders** – software of measurement modules for recording welding

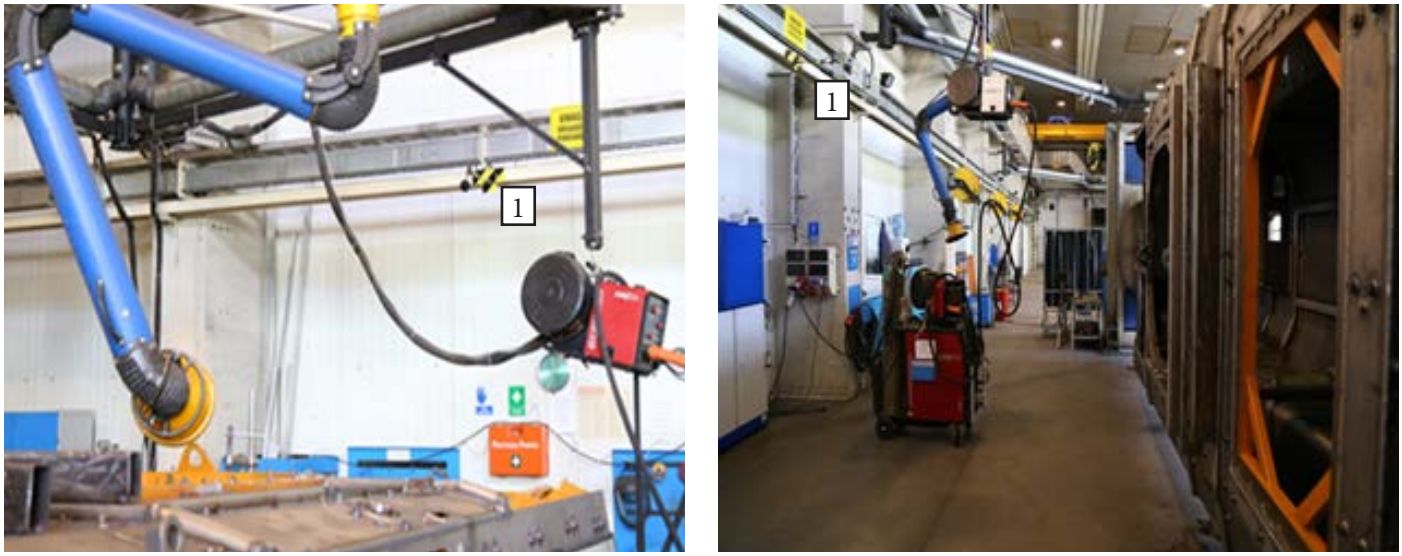


Fig. 4. System measurement microphones located at various production areas; 1 – microphone

parameters and the software of noise meters for recording acoustic pressure levels.

The module structure has made it possible to implement required functions of the system, independently in individual modules, using the computer network for the exchange of data and the database as the element integrating the system in one whole.

The graphic interface of the application monitoring noise parameters (used in the production shop) is presented in Figures 5-6. The software programme window contains numbered bookmarks related to each noise meter (bookmarks ***Meter 1÷5***), bookmark ***List*** and the bookmark ***Diagnostics*** for controlling the application operation and communication between the application and noise meters.

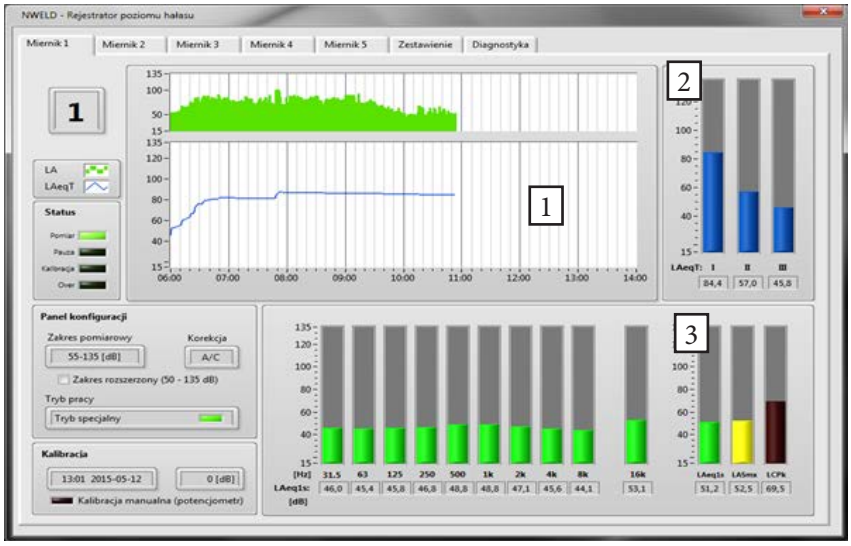


Fig. 5. Main window – monitor of acoustic pressure levels (1 – panel of acoustic pressure diagrams, 2 – panel presenting working changes, 3 – panel of the analyser)

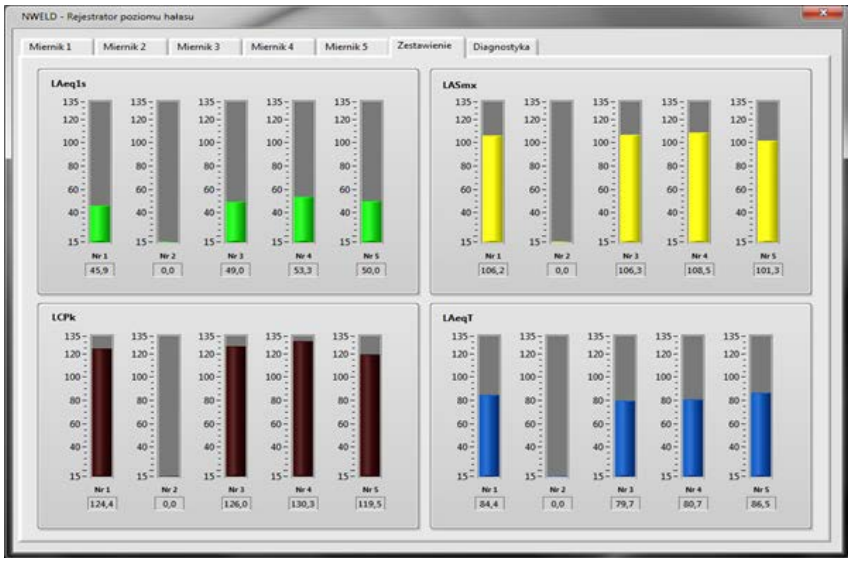


Fig. 6. Bookmark *List* of the acoustic pressure level monitor software programme

The panel presenting the diagram of noise levels (1) displays equivalent one-minute levels of acoustic pressure (in green) according to frequency characteristic A and changes of acoustic pressure equivalent to an 8-hour working day (in blue). The panel showing working changes (2) displays values for each working change of equivalent 8-hour acoustic pressure corrected according to characteristic A. The panel of the analyser (3) displays equivalent one-second levels of acoustic pressure A for individual octaves. In addition to the above-presented panels, the bookmark also contains the panel of configuration presenting the current configuration of a noise meter and the panel of calibration presenting the information about the timing of the recent calibration of the meter.

The bookmark List is used for the simultaneous comparison of noise level values indicated by all five meters:

- $\boldsymbol{L_{Aeq1s}}$ – equivalent one-second level of acoustic pressure corrected according to frequency characteristic A,
- L_{ASmx} – one-second root-mean-square value of acoustic pressure corrected according to frequency characteristic A with the time constant slow,
- L_{Cpk} – maximum momentary value (at the last second) of acoustic pressure corrected according to frequency characteristic C,
- $\boldsymbol{L_{AeqT}}$ – equivalent 8 hour level of acoustic pressure corrected according to frequency characteristic A (calculated since the start of the shift until the present moment).

The welding parameter monitor interface of a selected meter is presented in Figure 7. The programme window contains the panel of graphs presenting waveforms of welding current and welding arc voltage (also root-mean-square current and root-means-square voltage) as well as the filler metal wire feeding rate recorded during a welding process. The control lights in the panel of parameters provide the following information during welding (on an ongoing basis): root-mean-square values of welding current and voltage, the average filler metal wire feeding rate, welding process start time and welding process duration.

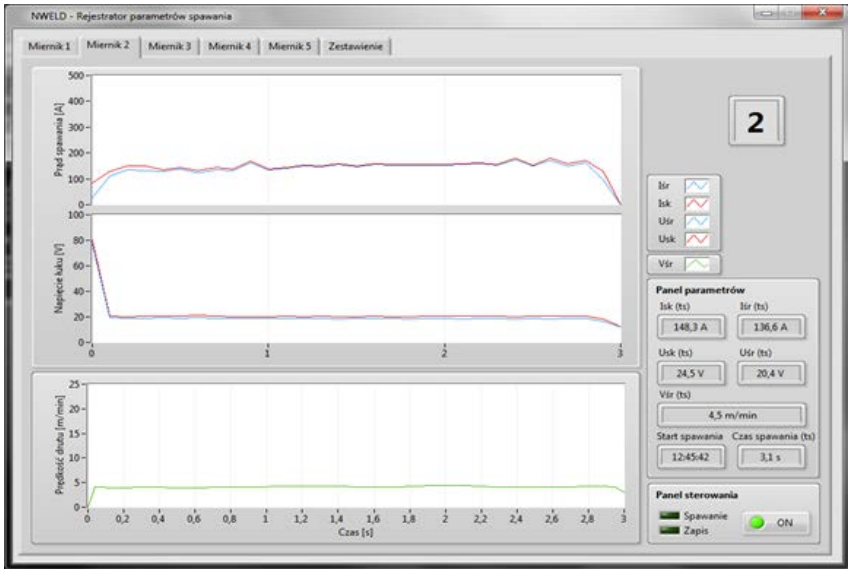


Fig. 7. Main window of the welding parameter monitors software programme

The bookmark ***List*** contains a simple welding log in the form of a table displaying the number of recently made welds. The log contains the following fields: meter number, welding process start time, welding process duration, average welding current, root-mean-square welding current, average electric arc voltage, root-mean-square electric arc voltage and the average filler metal wire feeding rate.

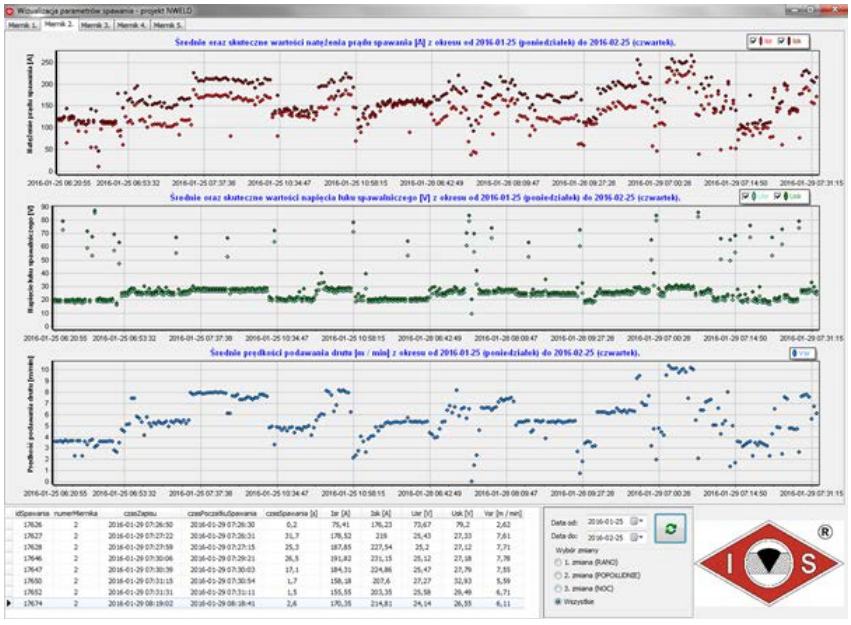


Fig. 8. Main window of the software programme for the visualisation of welding process-related data

The primary function of the programme is to preview present measurement results and archived data (Fig. 8). The programme window contains three graphs, i.e. welding current, welding voltage and a filler metal wire feeding rate (average). In addition, the window contains a panel allowing the selection of a work shift and of a measurement date as well as a table containing information related to a selected measurement such as the date when a given weld was made, recording date, welding process duration and values of individual quantities being measured. In the graphs presented below, successive points correspond to average values of successively made welds. Clicking on any point opens a window containing time courses of recorded parameters related to a selected weld.

Figure 9 presents the programme window for the visualisation of acoustic pressure measurement results. The window contains graphs showing changes of acoustic pressure for each work shift, a table containing measurement results in the form of numeric values and a panel for selecting measurement dates. The window displays the following acoustic pressure values:

– $L_{Aeq,1m}$ – equivalent one-minute level of acoustic pressure corrected according to frequency characteristic A,

– $L_{ASmx,1m}$ – maximum 1-minute root-mean-square value of acoustic pressure,
– $L_{Cpk,\ 1m}$ – maximum momentary value of acoustic pressure, recorded in a 1-minute period, corrected according to frequency characteristic C.

An exemplary window of the advisory module for the correlation of noise levels and welding parameters is presented in Figure 10. The primary function of the module is to provide the possibility of forecasting acoustic pressure values on the basis of the developed statistical model. The model is based on multiple regression and describes the dependence of noise generated during the welding of sheets/plates on factors having a statistically significant effect on the level of noise. On the basis of the research-related tests, the factors recognised as statistically significant are the following [7,8]:

– welding method,
– sheet/plate grade and thickness,
– welding current,
– filler metal wire diameter,
– oxygen and carbon dioxide contents in a shielding gas mixture.

An additional function of the module is the diagram-based presentation of comparative test results for various configurations of welding process parameters. It is possible to select the precise configuration of the above named welding parameters.

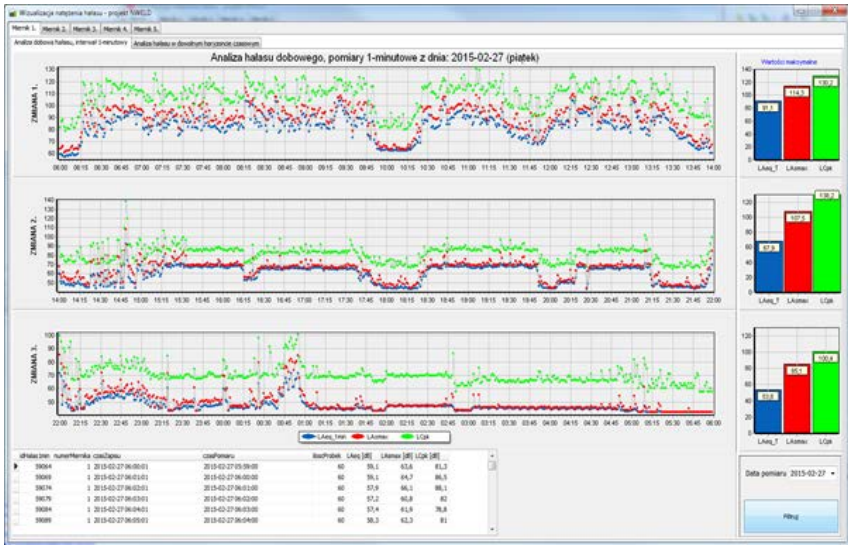


Fig. 9. Main window of the programme for the visualisation of noise-related data

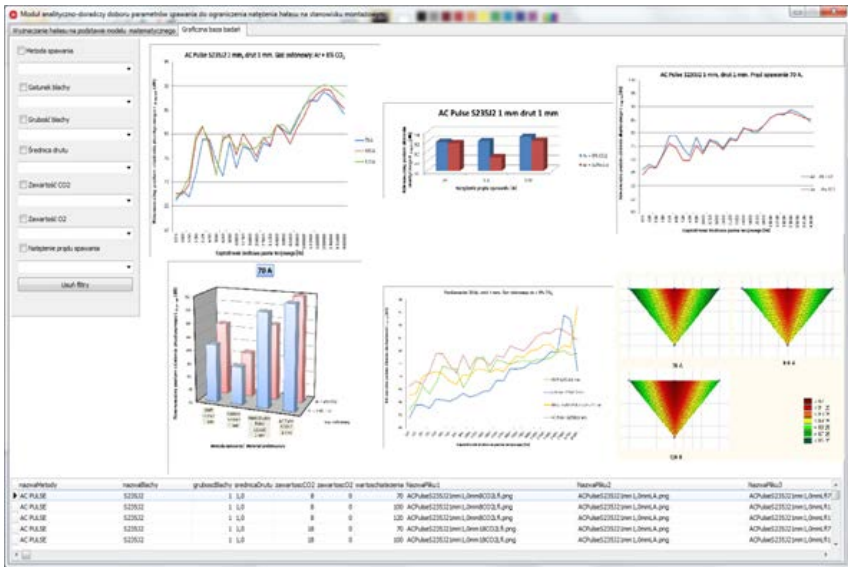


Fig. 10. Advisory (expert) module for correlating welding parameters and noise levels [1,7,8]

Summary

The measurement and data processing system for assessing noise emitted when making welded structures enables the monitoring and recording of acoustic pressure levels in individual production centres (work stations) as well as the monitoring and recording of technological welding conditions. The system is provided with the advisory module for correlating welding conditions and noise levels. The combination of measuring and recording functions of the system with the advisory (expert) functionality concerning the making of welded structures and acoustic conditions enables the control of manufacturing processes (welding processes, mechanical processes) as well as the acoustic control of the work environment aimed to comply with noise-related hygienic standards. The system was provided with the universal (in terms of welding process applications in various sectors) and entirely innovative

database of acoustic pressure levels for various welding methods. The base was developed for selected welding methods and current-voltage parameters commonly used industrial practice. The database used in the advisory module is based on test results focused on acoustic pressure levels for numerous combinations of welding method – base material – filler metal – shielding gas - current-voltage parameters – filler metal wire feeding rate [9].

The measurement system is a solution enabling the technological and acoustic monitoring of individual production steps as well as making it possible to implement modifications of technological conditions aimed to reduce the exposure of workers to noise. The use of the system when making welded structures is an important move aimed at the prevention of hazards affecting workers' health. In future, such an initiative is bound to improve work conditions and increase work efficiency.

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