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Measurement System for the Monitoring of Laser + MAG Welding Parameters

Abstract: This paper presents the design, technical possibilities and the intended use of a multi-station measurement system for HLAW process monitoring. The system used at the production site allows the monitoring and recording of HLAW welding parameters in relation to various constructions and products. The use of an industrial fieldbus interface allows full integration with automation devices and systems found on typical production stations/sites.

Keywords: measurement system, monitoring of the HLAW process

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Introduction

The process of laser + MAG hybrid welding is one of the processes referred to in scientific publications as Hybrid Laser Arc Welding (HLAW) and involves the simultaneous use of two heat sources, i.e. a focused laser beam and MIG/MAG electric arc, which during welding form one common weld pool. The laser + MIG/MAG hybrid method is now intensively tested, developed and implemented. The interest in this hybrid method and its intense development result from the fact that laser + MAG/MIG hybrid welding is a highly efficient single-run welding method which can be used within a wide range of thicknesses of elements made of various steel grades [1, 2].

The design of hybrid welding (laser + MIG/MAG) stations include components made in large numbers by manufacturers of lasers, MIG/MAG semiautomatic welding machines, industrial robots and industrial automatics. Although the above-named stations constitute complex and sophisticated systems providing hybrid welding station functionalities, the present stage of development of the aforesaid welding technology is not supported by a complex system involving process parameter monitoring, control and quality documentation in batch production. The system mentioned above has been developed at Instytut Spawalnictwa (taking advantage of previously conducted research), where one of the primary assumptions involved the integration of the system controlling the manipulator operation and two heat sources operating at the same time within one hybrid method, i.e. a laser beam and electric arc [3, 4].

System Architecture

The computer-based control-measurement system has two layers, i.e. hardware and software. The hardware layer includes measurement transducers, measurement cards, communication interface cards, computer system elements and other elements as well as electronic devices and

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systems. The software layer includes software modules controlling the measurement system operation and communication with the welding station systems via an industrial IT network as well as software modules performing assumed system functionality [5].

The control-measurement system architecture is adjusted to the type of the welding station, i.e. robotic hybrid welding station, the primary components of which include a solid-state (disc or fibre) laser, MIG/MAG welding power source, industrial robot, industrial automation systems and a hybrid head (Fig. 1).

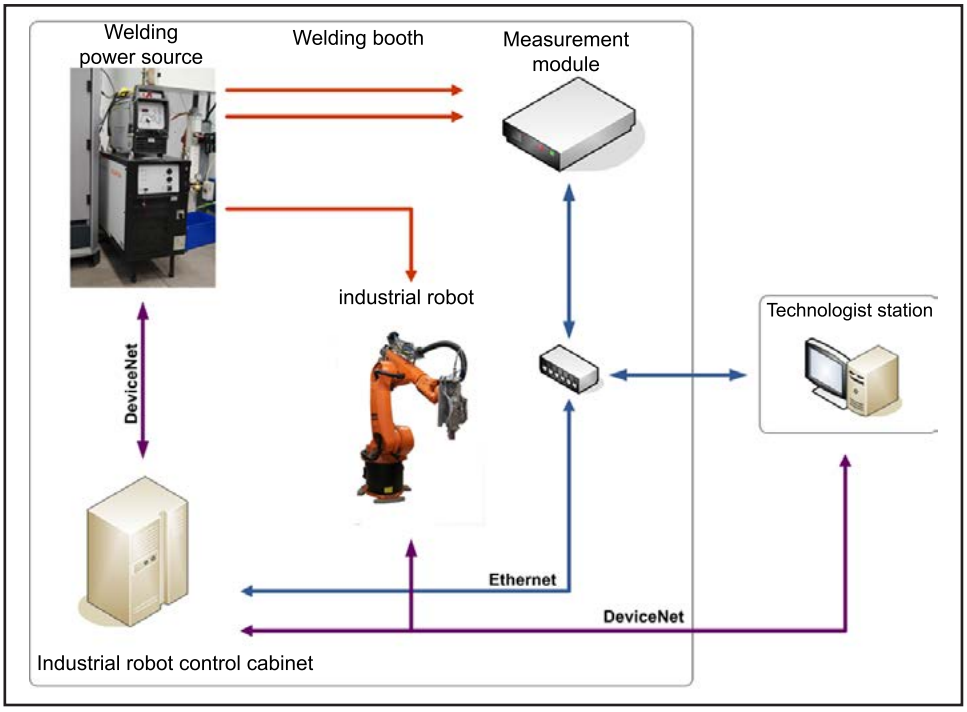
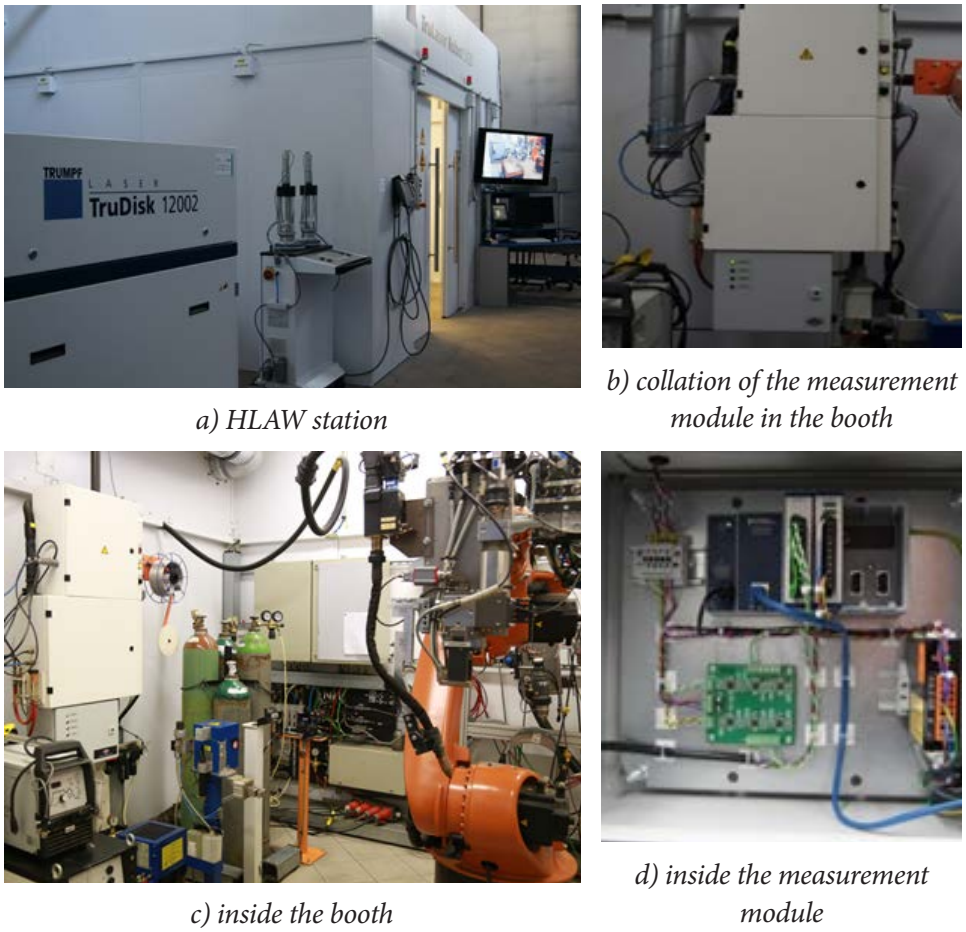


Fig. 1. Elements of the control-measurement system in the welding station structure

However, the use of modular architecture, both in terms of hardware and software, provides the possibility of incorporating successive welding stations to the system as well as enables the use of required system functions and the independent extension of individual software modules. As a result, it is possible to add new system software functions and adjust software to specific system users' needs.



a) HLAW station

b) collation of the measurement module in the booth

c) inside the booth

d) inside the measurement module

Fig. 2. Versatile HLAW station at Instytut Spawalnictwa

Because of the modular system architecture enabling a relatively unbounded configuration, in the case of the laboratory HLAW station at Instytut Spawalnictwa the measurement module (Fig. 2) is connected to a computer via the Ethernet, whereas communication with the robot control system is via the DeviceNet (industrial network) using a PCI card installed in the computer. Welding process parameters measured and controlled on the above-named station are the following:

– welding current and voltage,
– filler metal feeding rate,
– welding rate,
– laser power.

Optionally, the measurement system can control other parameters using additional measurement transducers, e.g. the flow rate of shielding gas. In addition, the system provides the possibility of adding a typical industrial controller, thus extending the system applications by controlling other devices and easier integration with other automation systems of typical production stations.

Control-Measurement System Software

Because of its complex functionality, the system software was divided into independent modules performing the following functions [6, 7]:

– **parameter recording module** – recording and saving of welding parameters, communication with the robot control system,
– **parameter control module** – control of parameters during welding,
– **technology editor module** – adding/deleting/modification of welding technologies,
– **reporting module** – creating reports after the welding of single elements or batches,
– **data visualisation module** – presentation of ongoing process parameters and data archiving.

The welding parameter recording module enables the recording and saving of the above-named waveforms of welding parameters in the database and data downloaded from a master system controlling the welding station, e.g. a welding programme number, a serial number of an element/welding being made, order number etc. The welding parameter recording module is supplemented by the welding parameter control module (Fig. 3) enabling the monitoring of preset welding parameters by verifying whether parameters are restricted within the ranges set by the operator.

In turn, the welding technology editor module (Fig. 4) makes it possible to enter (to the system) many important welding process-related technological parameters including data

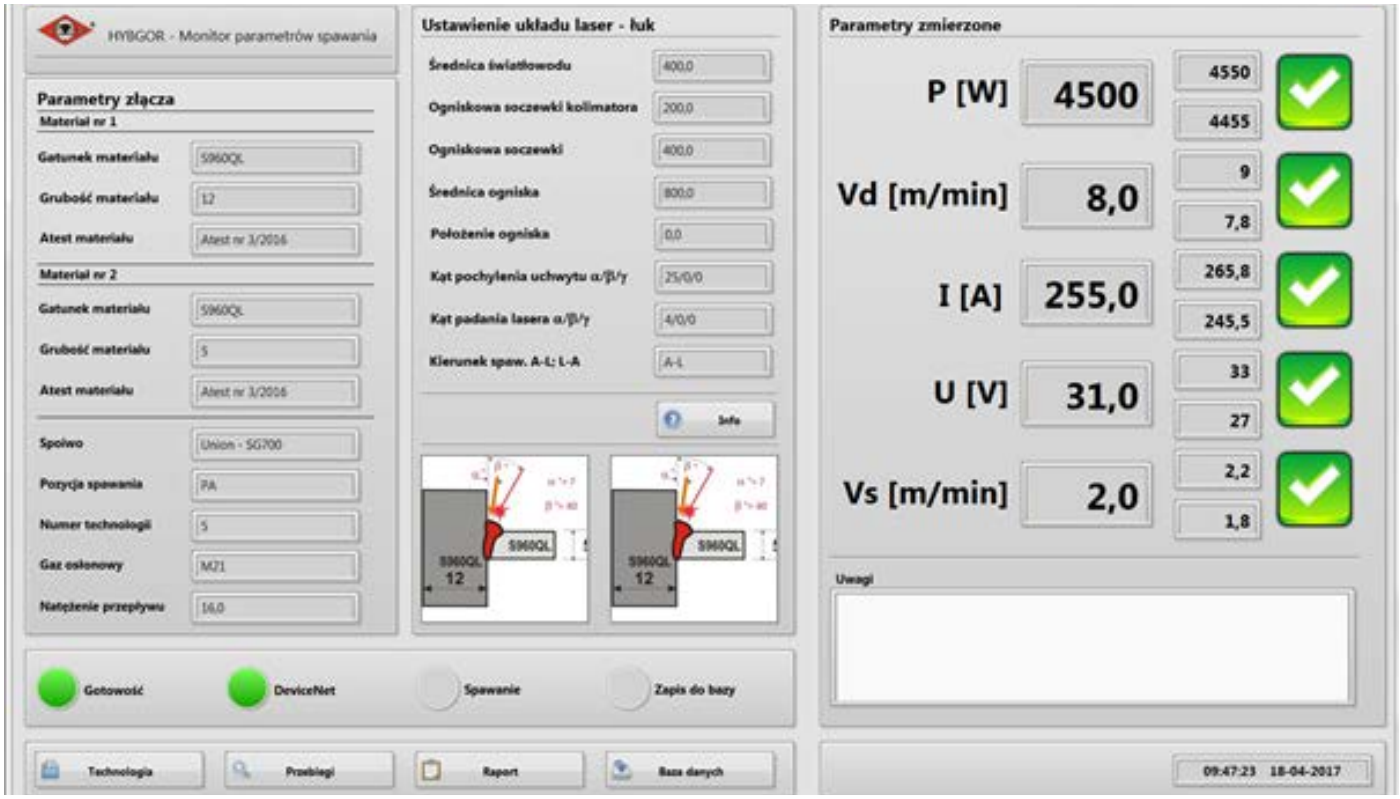


Fig. 3. Main window of the programme containing the ***Joint parameters/ Laser-arc system settings*** panel (data are downloaded from the database and entered in the technology editor module) and the ***Measured parameters*** panel presenting the operation of the module controlling welding parameters (mean parameter values and control limits)

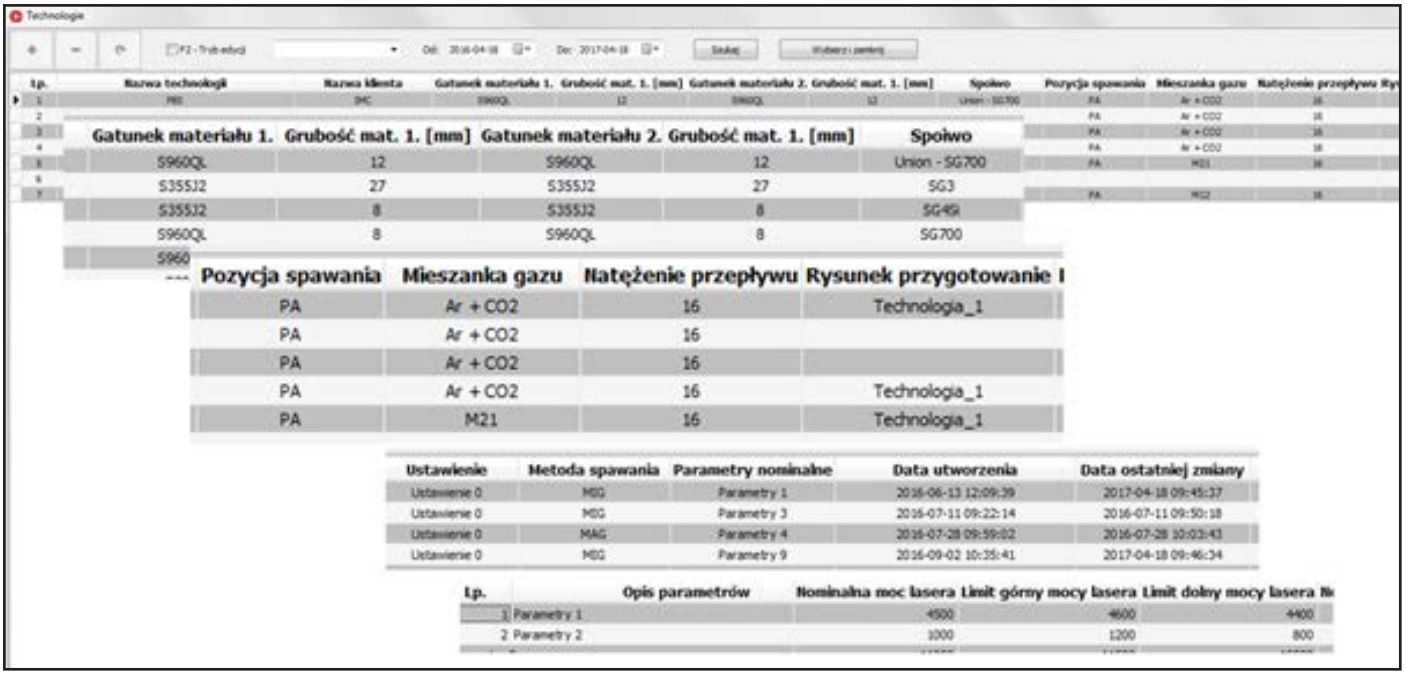


Fig. 4. Technology editing window (fragments of tables with technological parameters)

concerning materials being/to be welded (i.e. grade, thickness and conformity certificate of a material), filler metal type, welding position, the type of shielding gas and its flow rate, laser–welding arc system settings (e.g. optical fibre diameter, collimator lens focal length, the diameter and position of the beam focus, welding torch inclination angles and laser beam angle of incidence), the direction of welding and control limits of recorded parameters. In addition, the welding technology editor module enables the creation of a customer database.

The reporting module enables the generation of a report about a recently completed welding process or an archived process downloaded from the database. Reports are generated in the form of MS Word files. Because of the fact that the reporting module utilises the template of an MS Word programme, system users can adjust the form of the report to suit their own needs or those of their customers.

The report is composed of three pages, where the first page (Fig. 5) shows identification data, joint parameters, laser-arc configuration and average values of measured parameters and the second and third page contain generated diagrams presenting recorded welding parameters.

The data visualisation module operates in two modes, i.e. the mode of the visualisation of currently recorded waveforms (online mode) (Fig. 6) and the mode enabling the overviewing of archived waveforms (offline mode) (Fig. 7).

Monitor parametrów spawania HybGor - RAPORT

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Użytkownik	Data wykonania spoiny
Instytut Spawalnictwa ul. Bł. Czesława 16-18 44-100 Gliwice	2017-03-15 godz.10:59

Parametry złącza

Materiał nr 1		Materiał nr 2	
Gatunek materiału	S960QL	Gatunek materiału	S960QL
Grubość materiału	12	Grubość materiału	5
Atest materiału	Atest nr 3/2016	Atest materiału	Atest nr 3/2016
Spoiwo	Union - SG700	Pozycja spawania	PA
Numer technologii	5	Natężenie przepływu	16,0
Gaz osłonowy	M21		

Ustawienie układu laser - łuk

Średnica światłowodu [µm]	400,0	Położenie ogniska [°]	0,0
Ogniskowa soczewki kolimatora [mm]	200,0	Kąt pochylenia uchwytu α/β/γ [°]	25/0/0
Ogniskowa soczewki [mm]	400,0	Kąt padania lasera α/β/γ [°]	4/0/0
Średnica ogniska [µm]	800,0	Kierunek spawania A-L; L-A	A-L

Parametry zmierzone

Parametr	Wartość		Granice	Wartość poprawna
P [W]	4500,0	±	4550,0 4455,0	OK
V_s [m/min]	8,0	±	9,0 7,8	OK
I [A]	255,0	±	265,8 245,5	OK
U [V]	31,0	±	33,0 27,0	OK
V_t [m/min]	2,0	±	2,2 1,8	OK

Uwagi:

Strona 1 z 3

Fig. 5. First page of an exemplary welding report

In the offline mode, data are read out of the database constituting the central element of the system as regards the process of data collection and processing. The use of the database enables the archiving of all collected welding process-related data and provides the possibility of performing further analyses through the use of the data export function.

Summary

The primary advantage of the developed control-measurement system is the possibility of automatic and, at the same time, complex inspection, visualisation and archiving of all of the most important technological parameters of the HLAW process decisive for the quality of welding production on stations for the robotic hybrid laser + MAG welding method.

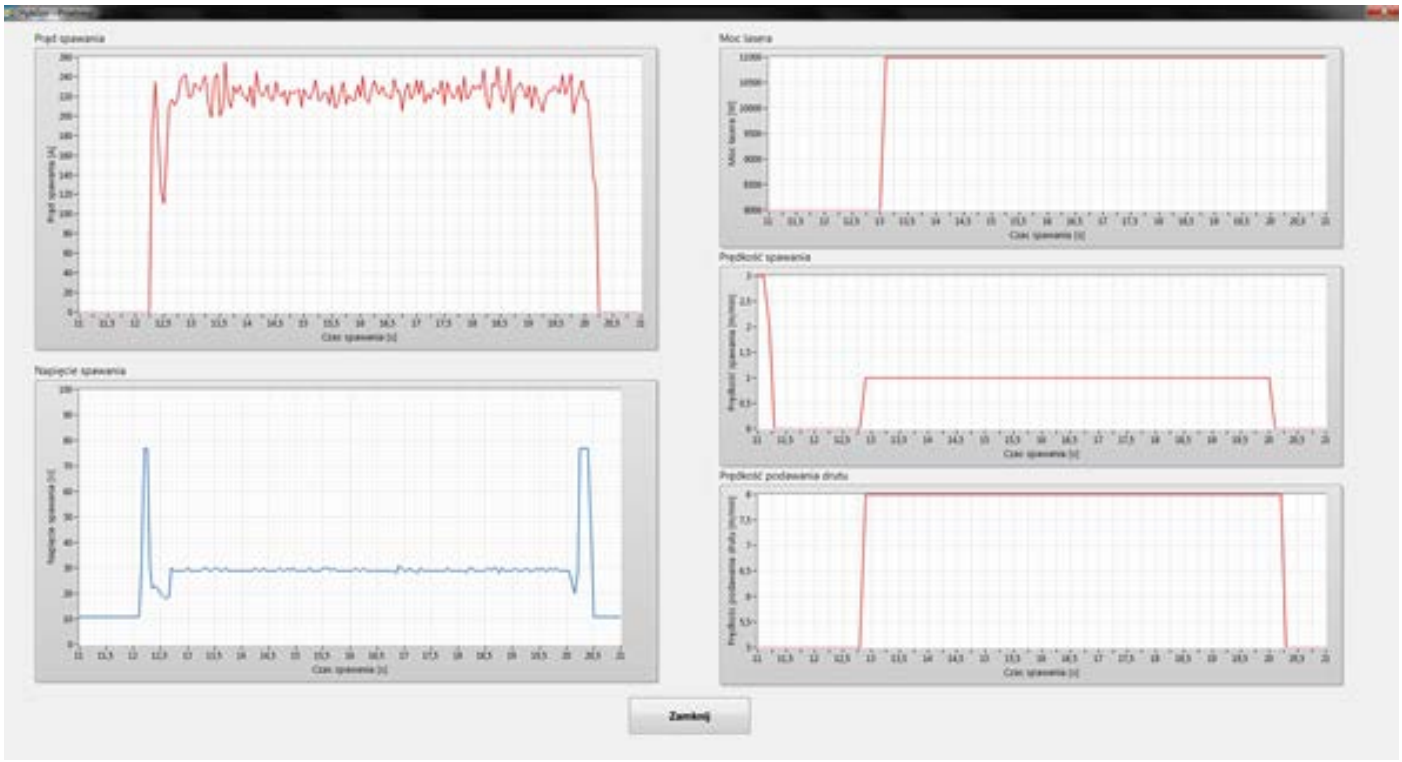

Fig. 6. Visualisation of recorded parameters (displayed on the online mode)

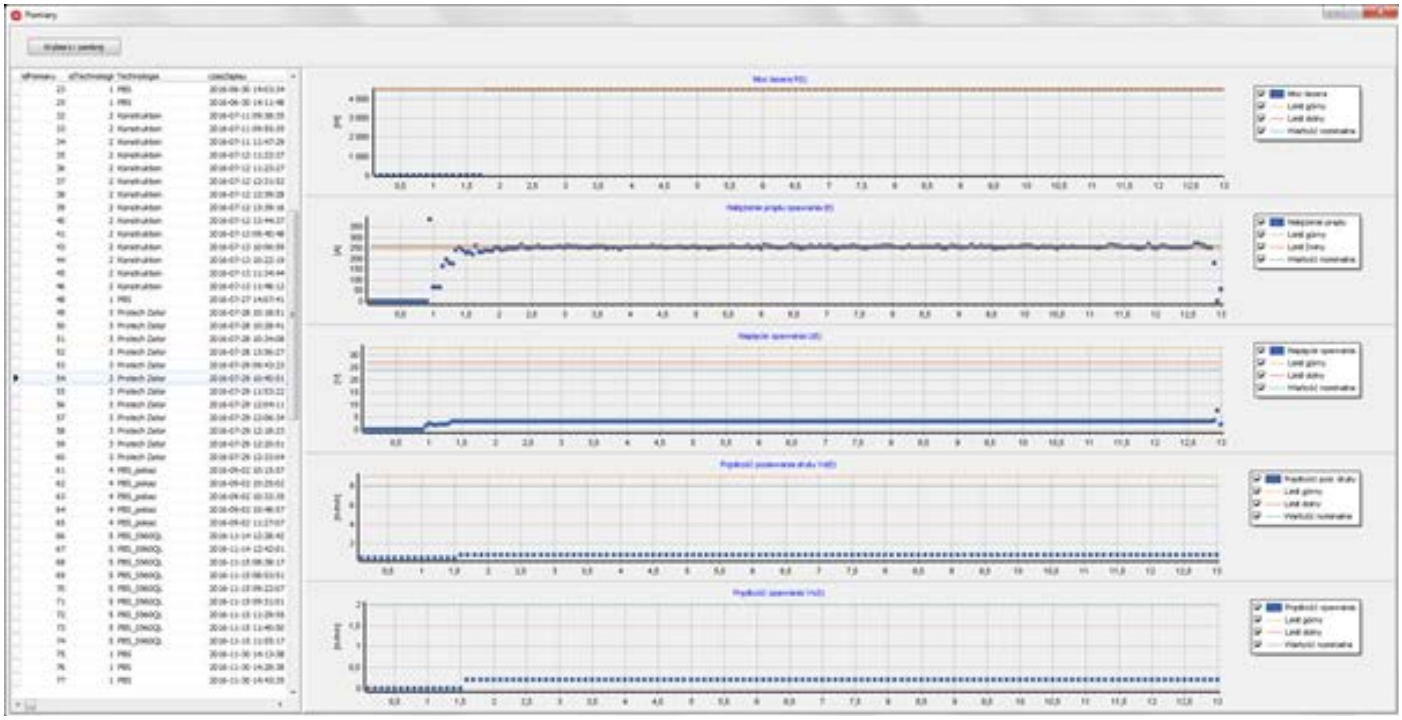

Fig. 7. Window of the software programme for overviewing archived parameter waveforms

The reporting module of the above-presented system facilitates the preparation and enables the generation of reports constituting the basis of welding process technological documentation.

The use of the control-measurement system may also lead to the obtainment of various additional advantages, e.g. when using it in the process of the optimisation of welding parameters, by limiting the number of tests necessary to adjust parameters, or, during production, by being able to stop the operation of a welding station in case of process disturbance (improper welding parameters) thus reducing the risk of making defective products.

The use of modular architecture, both in terms of hardware and software, provides the possibility of incorporating successive welding stations to the system and enables the independent extension of individual software modules. As a result, it is possible to add new system software functions and adjust software to specific system users' needs.

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