Quality assurance system PSQ 6000
Short manual

Edition 101

PSQ 6000

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Short manual

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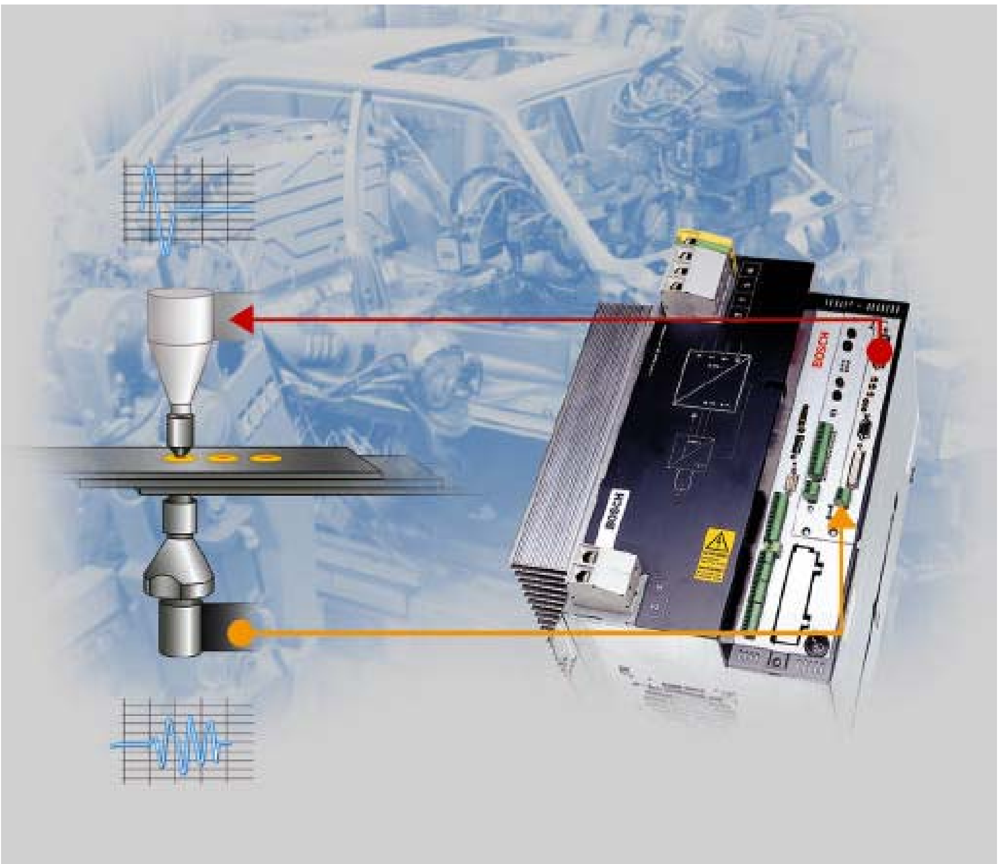
1 Advantages of ultrasonic method

1.1 Overview



1.2 Advantages of ultrasonic controller

- Ultrasound as independent measuring variable records the spot weld growth.
- Direct setpoint/actual value comparison during the welding process.
- Interference sources are eliminated by the integrated current adjustment.
- No cycle time increase - measurement is performed within the programmed weld time.
- Constant spot diameter.
- Adaptation to the changing electrode surfaces (wear).
- Online documentation of the measured values.

Notes:

2 General introduction into the ultrasonic measurement and control process

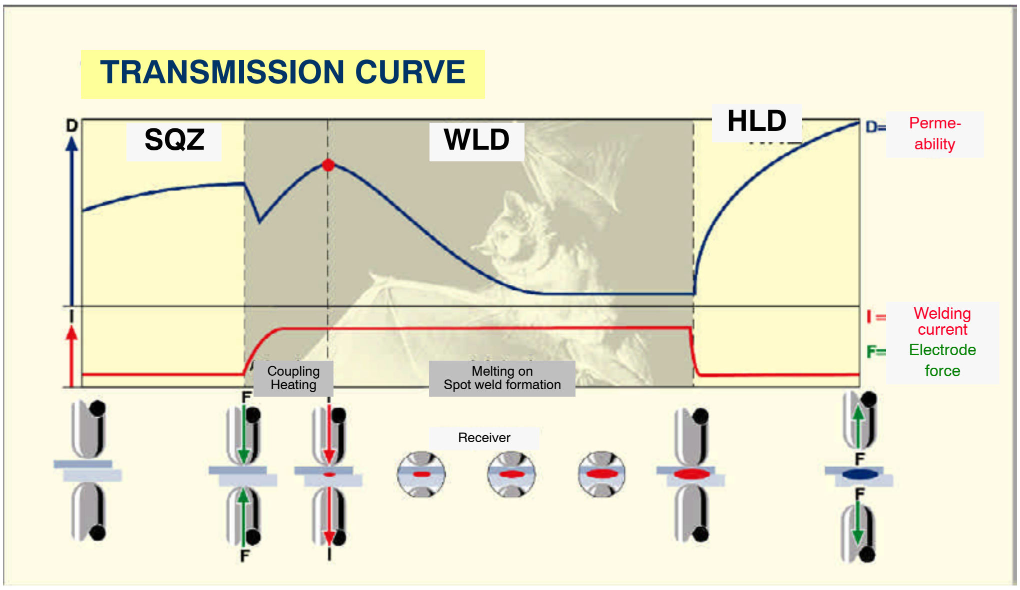
2.1 Ultrasonic measurement

The PSQ quality assurance system uses ultrasound as a physical variable that is independent of the welding process. This allows the intense observation of the melting down process in the weld spot, irrespective of the electrical variables resistance, voltage and current which supply the energy required for the melting down. Thus ultrasonic measurement is a measuring process that is largely independent of the fluctuations of the disturbance variables which occur in the welding process.

The ultrasound is generated using a piezo element which is integrated into one of the electrode shafts. For optimum sound spreading, the shaft is designed as a slim cone. The piezo element is energized with a short electrical impulse and subsequently emits ultrasonic waves which move in the direction of the electrode cap. These are transverse polarized ultrasonic waves, which are also called shear waves. The optimum frequency has been shown to be in the range of 100 kHz.

A piezo element serving as ultrasonic receiver has been attached in or at the mutual electrode shaft. Here, the received ultrasonic waves are converted into an electrical signal. The received signals are amplified and processed and provide the measuring information for the controller.

Ultrasonic measurements are performed at intervals between 3 and 10 ms during the welding schedule. The individual measurement results are combined to form a curve by entering them over the weld time on a diagram. This curve slope shows the ultrasound permeability of the transmission path shaft - part to be welded - shaft. The slopes of the ultrasound permeability curves - also called transmission slopes - provide characteristic curves which give information on the melting down of the material in the spot weld.



Transmission curve during a welding schedule

2.2 Characteristic curve slopes

It is a characteristic property of shear waves that they cannot pass through liquids. This means, the more material is molten down in the spot weld, the less ultrasonic signal arrives at the receiver.

Looking at the curve slopes, it is possible to detect the effect of the essential disturbance variables in the welding process.

The slope of the curve in Figure 1 should be interpreted as follows:
At the start of the weld time, the ultrasound permeability is determined by the cold and dry coupling of the ultrasound. The sheet are still cold and have not joined optimally. The surface roughness impairs the transition of the ultrasound. Coatings and layers, if present, also influence the start of the curve. Thus, the start value of the curve may vary.

As the weld time progresses, the sheets are heated and joined, gaps disappear. Coatings are partially burned off (zinc), glues are displaced by the electrode force. Ultrasound permeability improves because of these processes, i.e. the signal rises up to a relative peak.

After the peak, the melting down process starts in the spot weld. The material becomes soft to liquid - the ultrasonic signal is attenuated increasingly. In a good weld, the curve drops to approx. 20% of the maximum value.

Until the weld is completed, the curve remains on a low level or rises again.

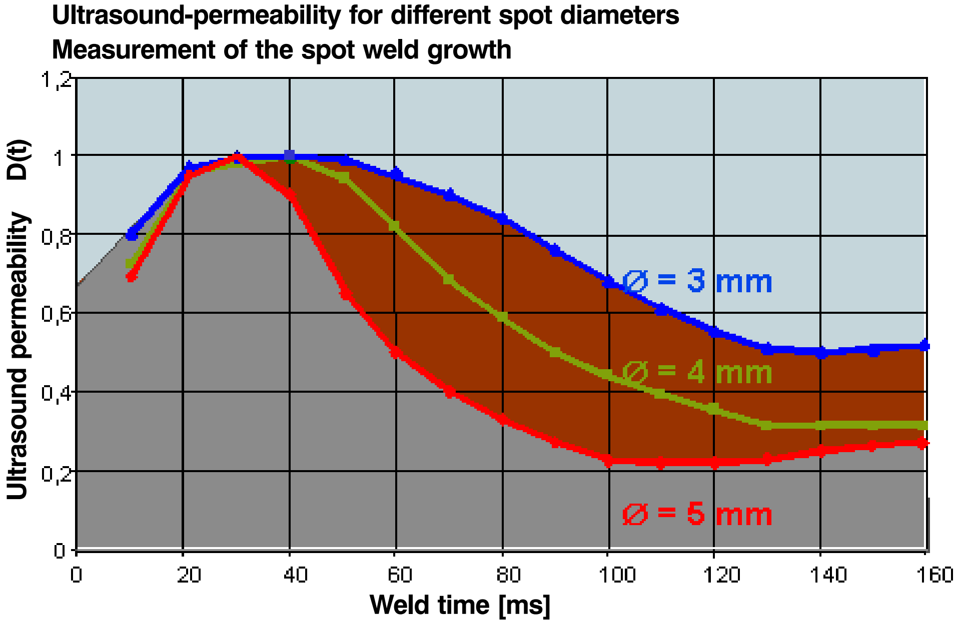


Fig. 1 Ultrasound permeability curve

A cold weld is recognized by the facts that the permeability starts to drop later and declines less strongly in comparison with a good weld. The ultrasonic signal is attenuated less because less material has been molten down. An example for a cold weld is the blue curve with the arrow symbols at the curve points in Figure 1.

In a hot weld, the melting down starts relatively early and more strongly which results in a clearly more steep drop of the ultrasonic signal. This is shown in the curve with the red rhombic symbols at the curve points in Figure 1.

Even spatters are clearly recognizable in the permeability curves. A spatter is liquid material that is hurled away, and depending on the re-sinking behavior of the welding device, more solid material is applied to electrode cap again. Because of this, the ultrasound permeability increases abruptly, so that the curve makes an upward jump.

The following 2 figures show how to optimize welds using ultrasonic measurement - with inactive controller. The first figure shows the state of a non-optimized system. The permeability curves of all points of an electrode gun on a component have been superimposed. A series of spatters are clearly recognizable. Following optimization by reducing the current, all spatters have been eliminated and identical strength of the spots achieved.

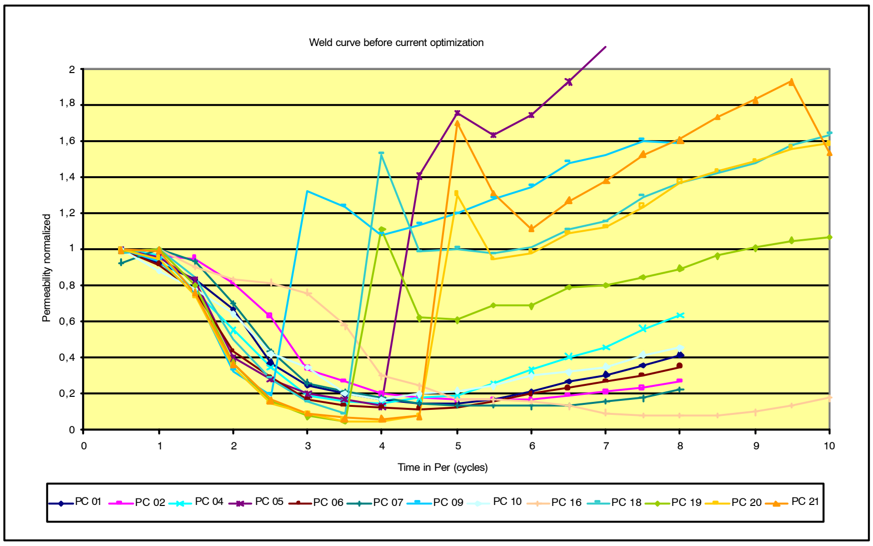


Fig. 2 Ultrasound curves before the optimization

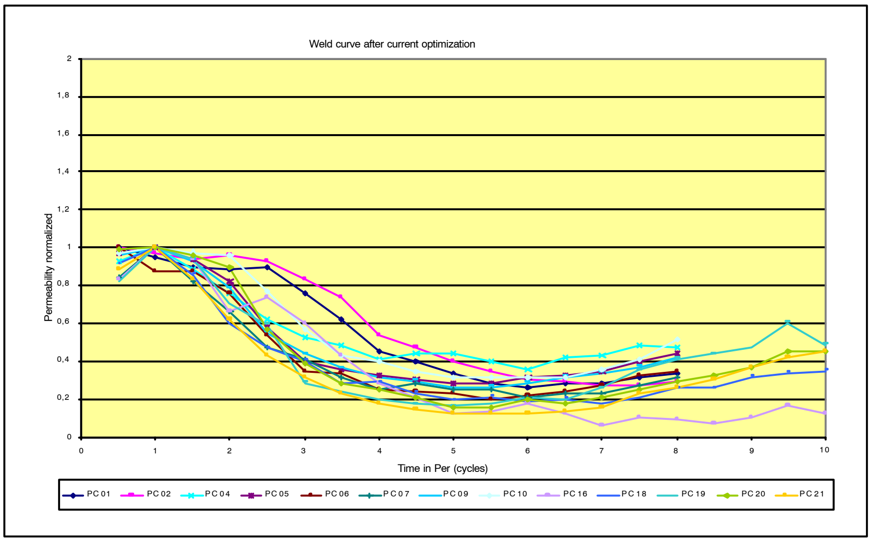


Fig. 3 Ultrasound curves after the optimization

Investigations and field tests have shown that the ultrasonic measurement is not impaired by different types of steel or coatings. The curve slopes are modified in a characteristic way in minor details but the basic slope remains. Interfering effects such as zinc evaporation are recognizable and can be suppressed. This also applies to the use of glues.

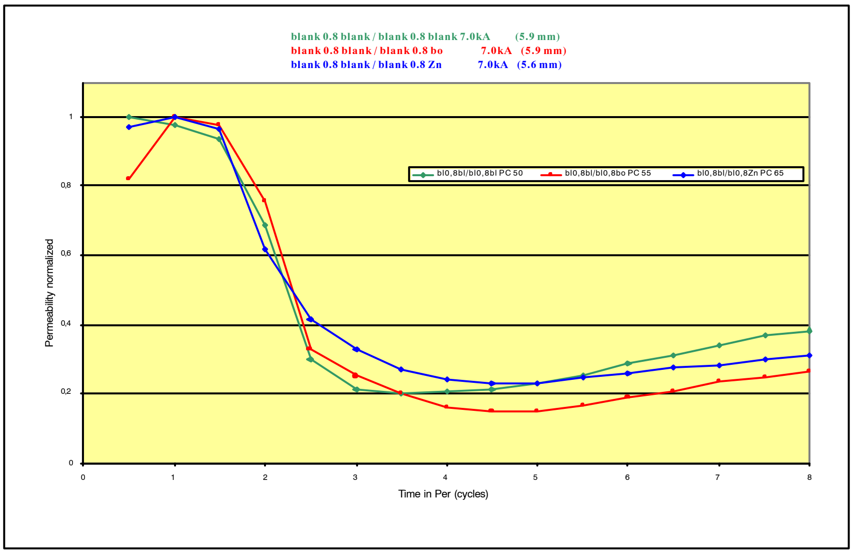


Fig.4. Curve slopes with different sheet coatings

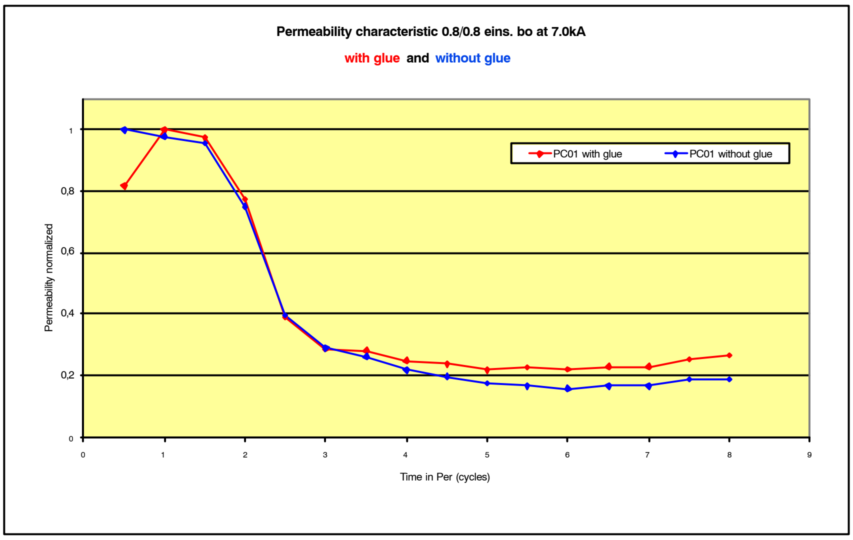


Fig.5. Curve slopes with / without glue

It is possible to insert a compensating line in the downward slope of the permeability curve. The position and ascent of the compensating line serves as a criterion to evaluate the spot weld. In future configurations it will be possible to derive the diameter of the spot weld, so that an essential feature of the strength of the welded joint becomes apparent.

2.3 Control

The ultrasound permeability curve is provided to the control as measurement variable (actual value) curve value per curve value. The setpoint value is the so-called sample curve, a permeability curve created with constant current regulation and integrated parallel to the welding parameters. The sample curve is the permeability curve of a weld which produced a good spot weld.

The controller continuously compares setpoint and actual values and adjusts the welding current depending on the deviation. Thus the correcting variable of the controller is the welding current. The aim of the controller is to approximate the current permeability curve to the sample curve.

The ultrasonic controller works closely together with the constant current controller. The constant current controller is active until the peak of the permeability curve is reached. Controlling is performed by the ultrasonic controller starting at the central phase of the melting down process (downward slope of the ultrasound permeability). In case of spatter, there is a switch to constant current regulation when the spatter is detected. However, the constant current controller receives the setpoint value from the ultrasonic controller.

On the example of a balanced shunt weld, the three figures below show how the controller works.

2.3.1 Creating a sample curve

The first of three spots is welded on the test sheet using constant current regulation. The recorded ultrasound permeability curve shows a good slope. Thus, it can be defined as sample curve, and the ultrasonic controller can be activated for the subsequent spots.

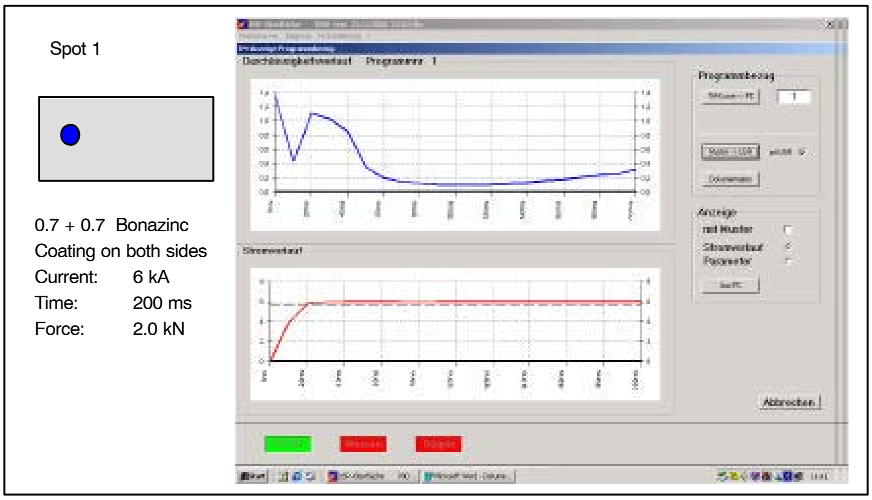


Fig. 6 Creating a sample curve

2.3.2 Welding the first shunt spot

The second spot is welded using the same welding parameters for current and weld time, the ultrasonic controller is active now. In the upper diagram, the sample curve is shown in black and the measured curve in blue. Since a part of the current flows out through the first spot weld and is thus not available to the new spot, the second welding is colder. As explained above, the melting down starts later and the downward slope is slightly less steep. The controller responds by setting the current higher until the current curve coincides with the sample curve again. The curve of the current is shown in the bottom diagram, where black is the sample current and red the current of present curve.

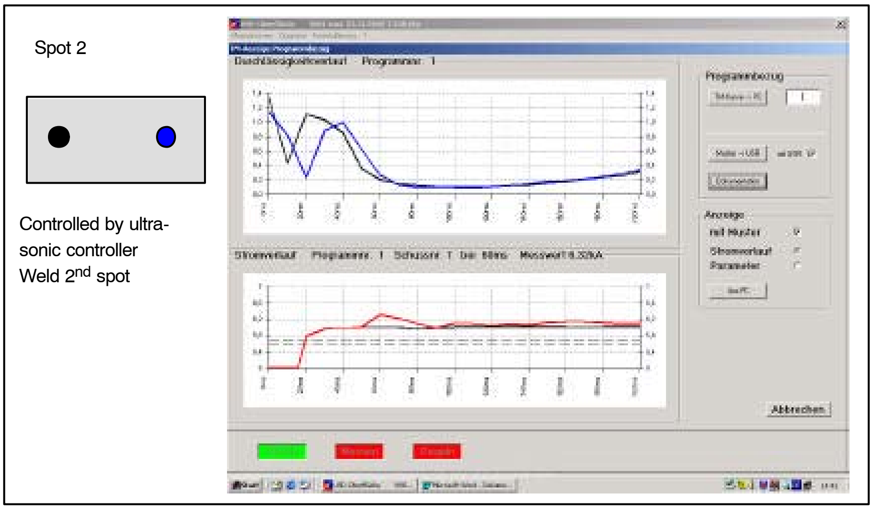


Fig. 7 First shunt spot

2.3.3 Welding the second shunt spot

Another spot is created between the existing spots using unmodified welding parameters. An even more distinct shunt behavior is expected because a stray current flows out via 2 neighboring spots. As can be seen in the bottom diagram, the controller compensates the shunt by setting the current still higher. By a subsequent shear test of the middle spot, it can be shown that the spot diameter has remained constant in spite of the shunt.

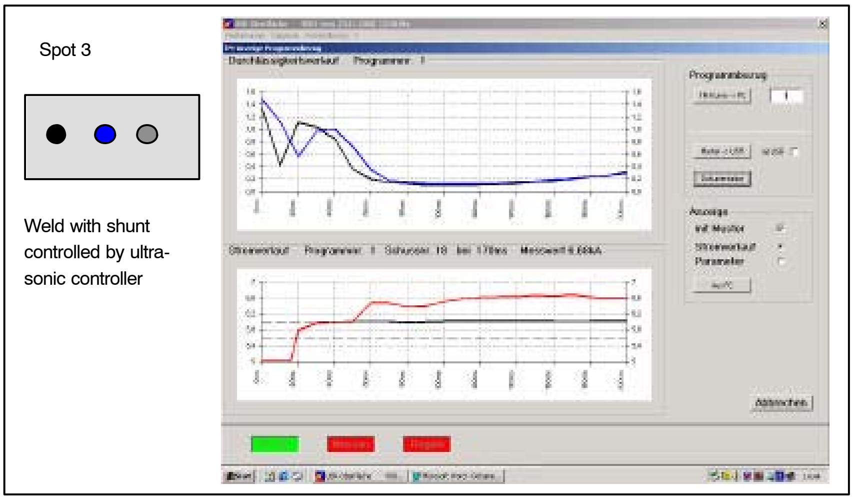


Fig. 8 Second shunt spot

2.4 Interpretation of the permeability curves

When reviewing permeability, the curve is divided into several sections or special points. Only the curve slope during the weld time is under review.

The first phase is the coupling and heating phase. It ends upon reaching the relative peak. This is followed by the downward slope which is due to the melting down of the sheet material. The last phase starts at the curve's lowest point, the relative minimum value, where the liquid material is joined in the fusion.

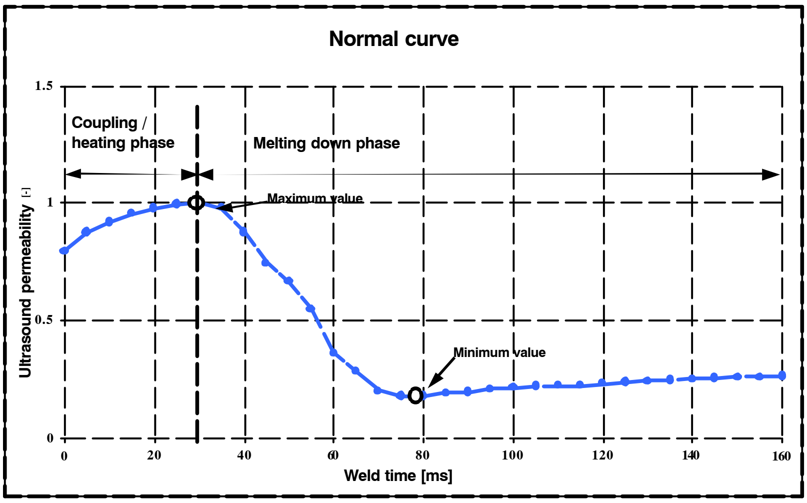


Fig. 9 Normal curve

2.4.1 Coupling and heating phase

At the beginning of the welding process, when the current has just started to flow, there is a superimposition of several physical effects. Depending on sheet coatings, component tension (fit) and material heating there will be different curves. This range of the permeability curve is not relevant to the control process. Some basic explanations are nevertheless provided for better understanding of the curves.

Zinc evaporation
In case of zinc-coated sheets, the zinc coating is burned away in the coupling and heating phase. This leads to extremely high and low values in the ultrasound permeability curve. This effect is especially pronounced in case of thick coatings, e.g. in connection with galvanization.

Bonazinc
Sheets which are coated with Bonazinc show almost no signal changes caused by the coating being burnt away. The zinc particles are embedded in an organic material which prevents the coating from being burnt away quickly.

Fitting problems
When fitting problems occur, the effect on the permeability curve is that it starts at a relatively low value (low permeability). As the fit improves, the sound impairment due to gaps and surface roughness decreases and the curve quickly approaches the peak.

2.4.2 Relative peak

The relative peak is determined when the permeability curve is recorded (curve value per curve value). For detection of the peak, the individual curve values are filtered and combined to form ”smooth” ranges. This determination of the peak is controlled with the parameters from the measurement parameter range. Correct determination of the relative peak is essential because the entire permeability curve is normalized to the value of the peak. The peak is assigned value 1.

2.4.3 Relative minimum value

The relative minimum value is the point on the permeability curve with the lowest value. It is used for the evaluation, see below.

2.4.4 End of the curve

After the minimum value, there are basically two types of curves. Either the curve stays approximately in the position of the minimum value or it rises again. This possible rise in the curve is explained by a pronounced sinking in when pointed cap shapes and fairly soft material is used.

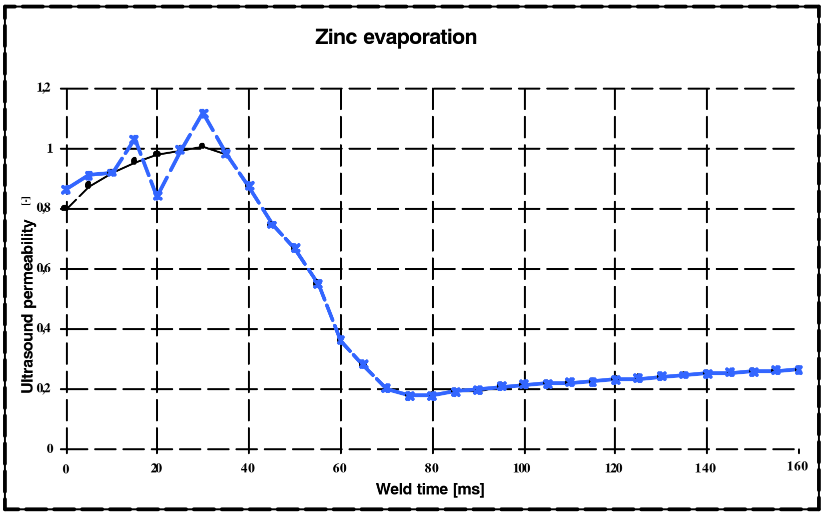


Fig. 10 Zinc evaporation

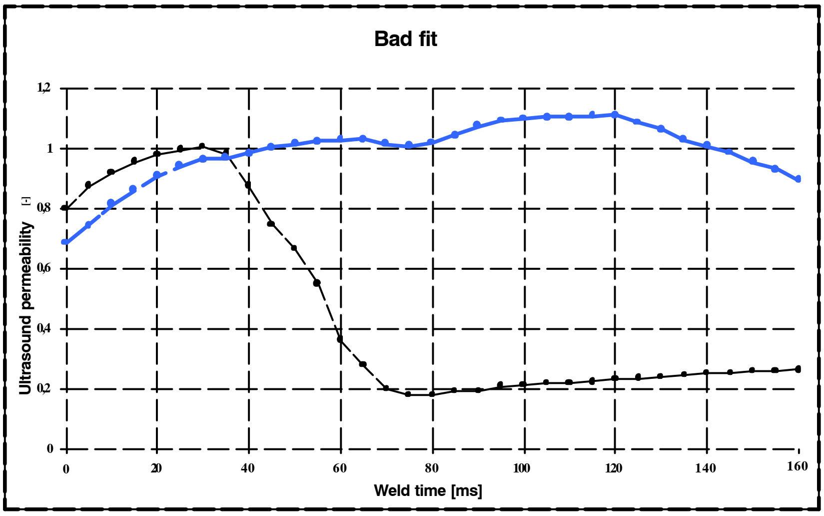


Fig. 11 Bad fit

2.4.5 ”Cold” welds

The melting down starts later in cold welds, i.e. the permeability drops after a longer weld time as compared to a good weld. Furthermore, the downward slope is less steep and the minimum value of the curve lies above that of a good weld. In extreme cases the amount of material fused is so little that the permeability curve drops to only 70-80% of the peak. In this case, the spot diameter is very small or a bonding has been created.

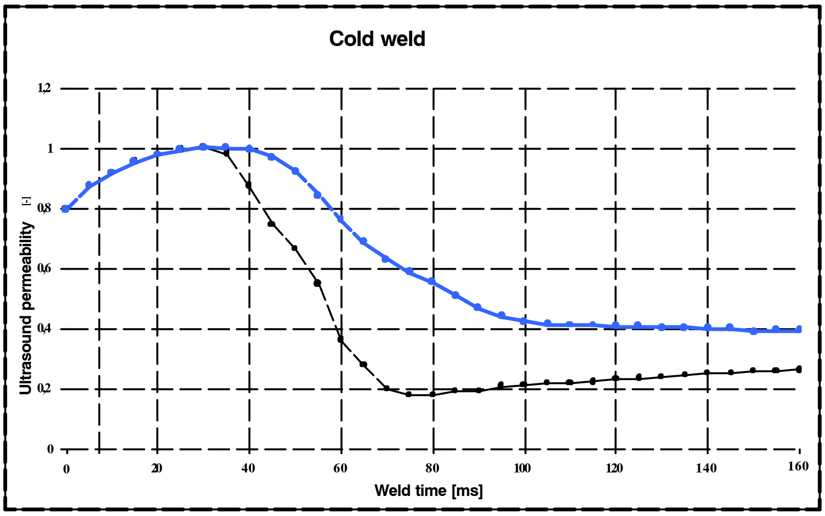


Fig. 12 Cold weld

2.4.6 ”Hot” welds

As opposed to cold welds, the permeability in hot welds drops very steeply directly following the peak. The minimum value ranges at 20% of the peak.

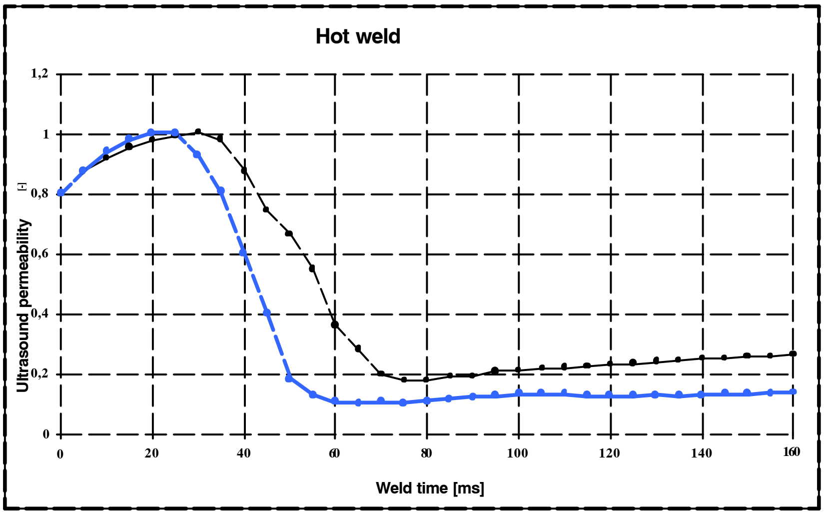
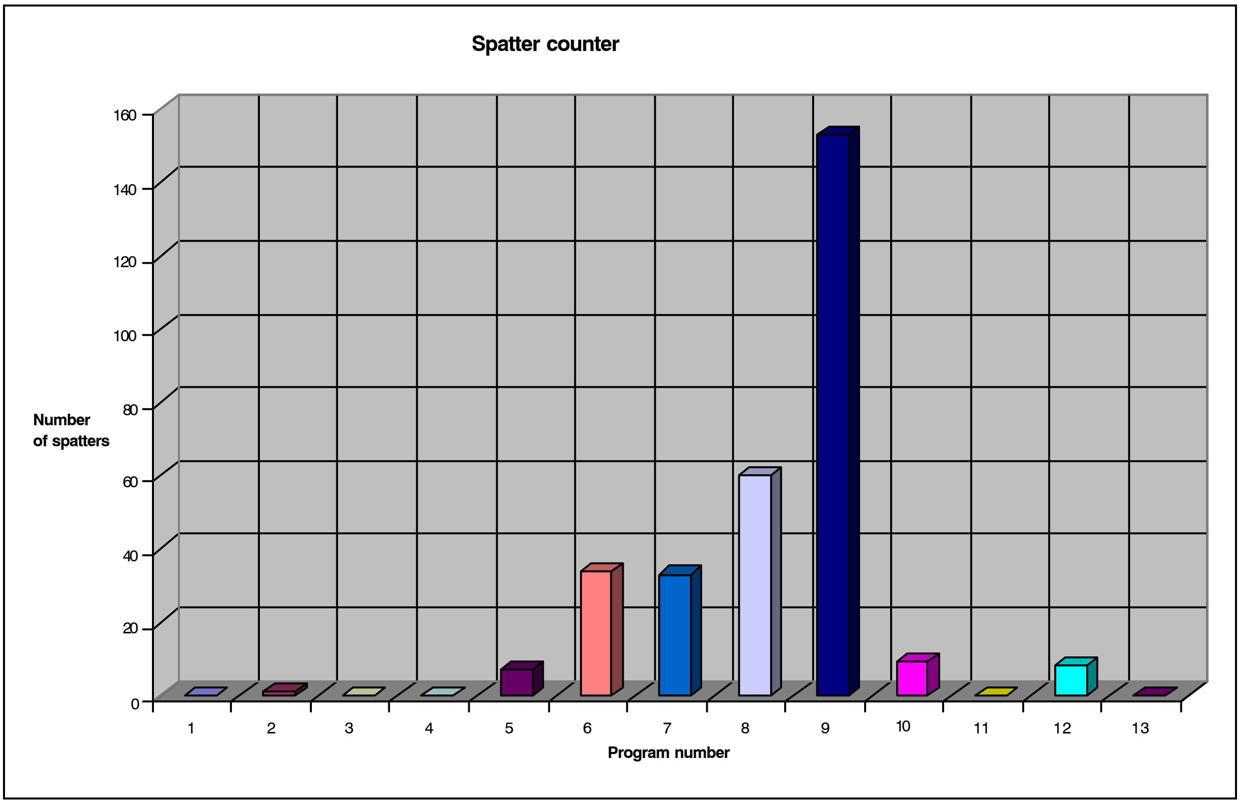


Fig. 13 Hot weld

2.4.7 Spatters

The observation of the transmission curves also allows the detection of spatters. Spatters result in a sudden rise in transmission curves which were counted in dependence on the program. The period of evaluation for spatter observation was 24 hours. The recording of the program-dependent spatter counter shows that welds carried out with program no. 9 have especially many spatters. In this case, the current has either been set too close to the spatter limit, the spot position is too close to an edge or the components have a bad fit. The programmed current values show that identical sheet combinations are welded using programs 8 to 13. However, the parameters weld time and current values are set higher in program 9 than in programs 8/10 to 13.



"Spatter counter"

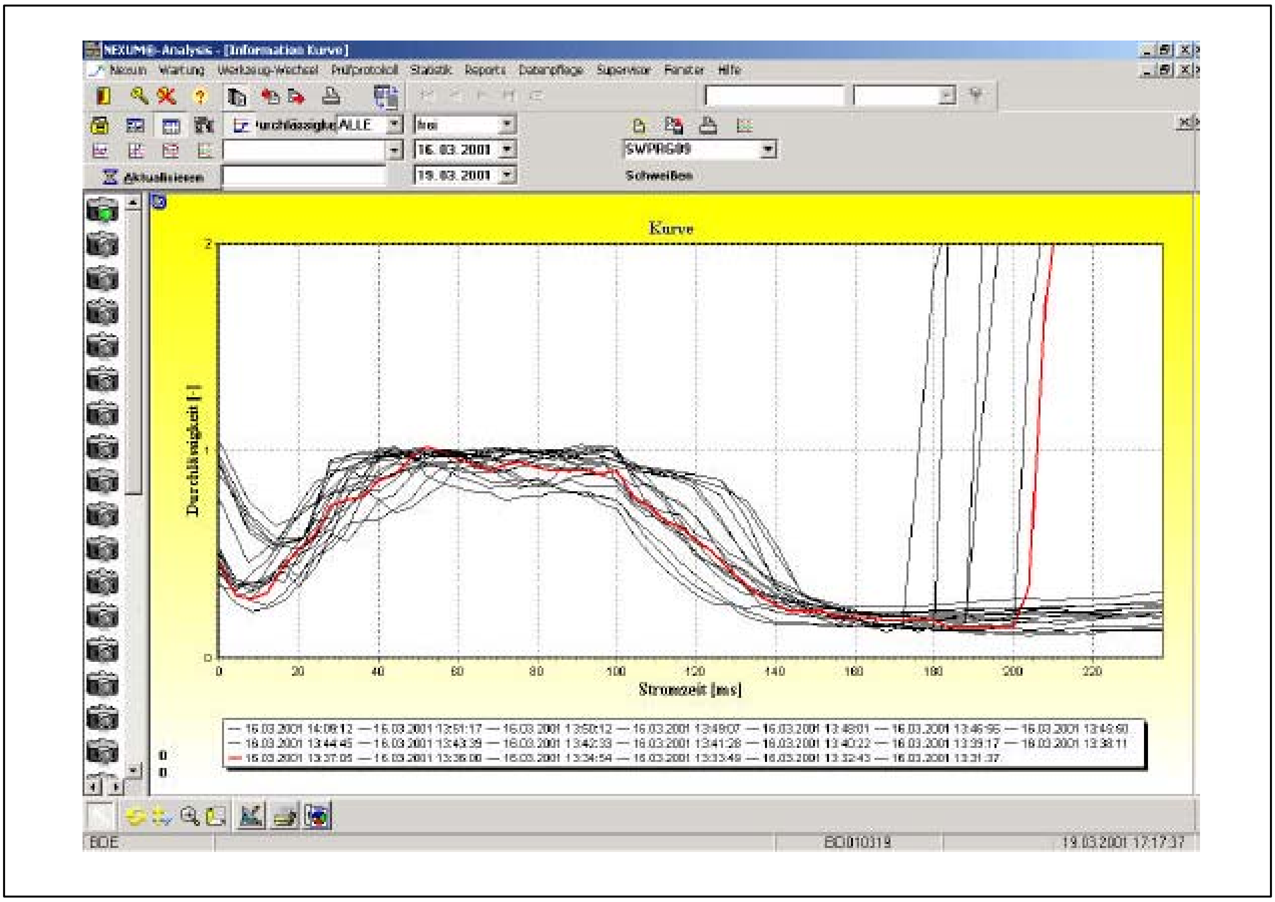
Spatter optimization

The spatter counter integrated in the ultrasonic systems furthermore gives an insight into the generation of spatter including the respective point in time. If this point in time is e.g. at the end of the weld time, it is possible to reduce the spatter formation by reducing the weld time. This new type of analysis optimizes the determination of parameters for the diverse welding tasks.

Advantages of spatter analysis

The integrated spatter analysis and its application to prevent spatters has decisive technical and economical advantages, e.g.

- reduction of the maintenance intervals
- subsequent processing steps become unnecessary
- such as e.g. complicated measures to remove spatters from shell parts prior to varnishing.



“Spatters in the program”

2.4.8 Multiple-sheet connections

Three-sheet welds display a tendency towards steeper slopes and lower minimum values in comparison with two-sheet connections. The explanation is the higher melt volume and thus the stronger attenuation of the ultrasound.

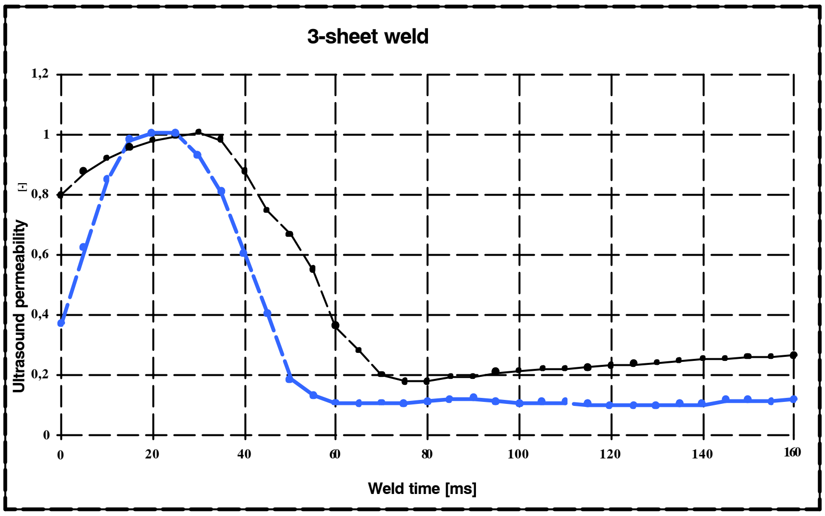


Fig. 16 Three-sheet weld

2.4.9 Extremely different sheet thickness

When sheets with greatly varying thickness are joined, there will be a ”double hump” in the permeability curve. The first peak occurs when the sheets are pressed together optimally. When the melting down starts in the thinner sheet, the permeability curve drops, but starts to rise again somewhat because the electrode sinks in until the thick sheet starts to melt down, too. Only then does the permeability curve drop to its minimum value.

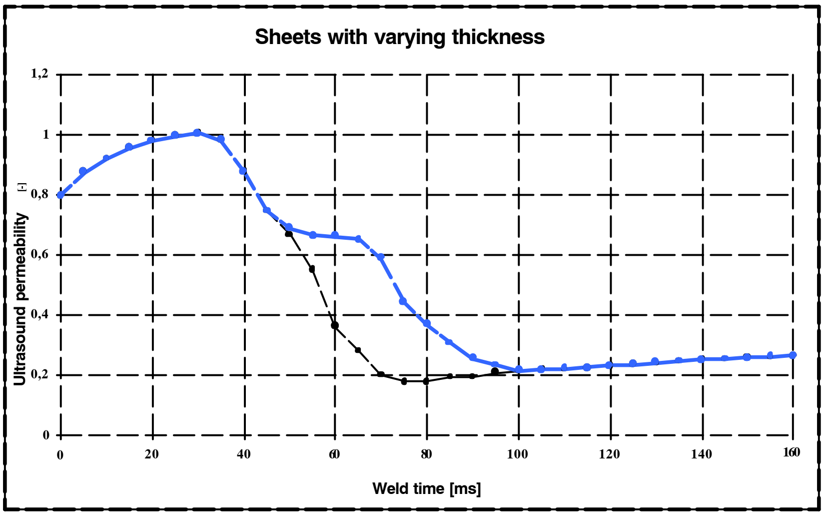


Fig.17 Sheets with varying thickness

2.4.10 Higher-strength steel

Higher-strength steel does not change the ultrasound permeability curve at all or not significantly.

2.4.11 Glue

Glue provides for smooth, regular curves. In the coupling phase, the curve starts at low values and rises.

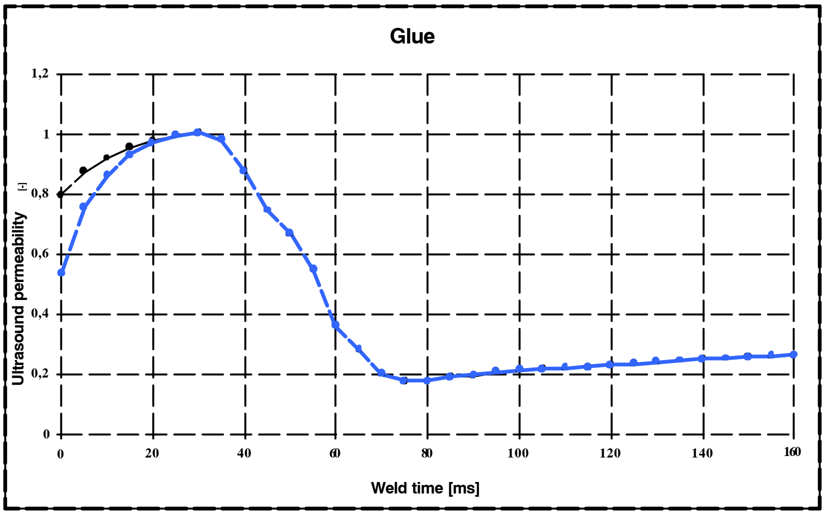


Fig. 18 Glue

2.4.12 Cap wear

With progressing cap wear, the contact surface of the electrode caps increases. This results in a lower current density, the weld has a tendency to become a cold weld. That is why the explanations given in the section on cold welds are applicable to wear in general.

2.4.13 Influence of milling

Milling corrects the contact surface of the electrode cap. This creates ambient conditions which correspond to those of new caps. However, there may also be interferences which are caused by milling. First of all, milling can create irregularities on the contact surface (e.g. "chatter marks"). Secondly, the plane of the contact surface may not coincide as well with the joining plane as in the used cap condition. It is a well-known effect that spatters frequently occur in the first 10 to 20 welds after the milling; this is caused by the above mentioned interferences.

The ultrasonic measurement is also impaired by these disturbances. That is why the measures and conditions for application mentioned in section 2 have to be complied with.

2.4.14 Border weld

Border welds are inclined to be hotter than welds with a greater distance from the edge. The reason is that little heat can flow off into the surrounding sheet on the side where the edge is. Therefore, the explanations given in the section on hot welds are applicable here.

2.4.15 Edge weld

An edge weld frequently results in spatter because only a part of the contact surface of the cap can be used for current transmission and the current density becomes very high on the surface in question. This situation has to be avoided. Edge welding is a difficult task for the ultrasonic controller as well. The weld has to be adjusted so that there is no spatter. Then the controller can proceed with its intended function.

3 System description

3.1 System components

The ultrasonic control system consists of the following components:

- Ultrasonic control board USR
- Ultrasonic signal processor USP
- Ultrasonic sensors USE
- User interface
- Measured values acquisition and evaluation USW

The ultrasonic control board is a switching device in the European double-card format which is plugged into the converter PSI or the weld timer PSS. It is closely connected to the weld timer via the bus coupling and is capable of exchanging information quickly. A 32-bit controller calculates the control algorithm and processes the communication to the weld timer, to the ultrasonic signal processor and to the user interface.

The ultrasonic signal processor is an electronic unit for rough ambient conditions (IP 65). It contains the impulse generator for the ultrasonic transmitter and the signal booster and processing for the ultrasonic receiver signal. This unit has to be mounted with the welding gun, so that the cables to the ultrasonic sensors remain short.

Control board and signal processor are linked to each other via CAN bus.

The ultrasonic sensors consist of the ultrasonic transmitter on the one hand and the ultrasonic receiver on the other. Both sensors are integrated in the electrode shaft or attached to it on the outside. The cable leading to the sensors has to be led along the arm of the gun and protected or placed in the respective groove, as agreed upon with the welding gun manufacturer. Prior to operation, the sensors have to be aligned one towards the other.

The user interface for the ultrasonic controller is a software which is installed on PCs. The link to the system is performed via an RS232 connection which is either connected to the control board or to the corresponding interface on the weld timer. This user interface is used to parametrize ultrasonic measuring and control devices, to inspect ultrasonic raw data and display permeability curves.

The acquisition and evaluation of measured values is also performed on a PC and communicates with the controller system via an RS232 connection, too. The task is to record permeability curves and other process parameters in an online data base over selected periods of time and later statistically evaluate these data. In this context, it is also possible to detect trends and perform monitoring tasks online.

Notes:

4 Connection and assembly

4.1 Structure

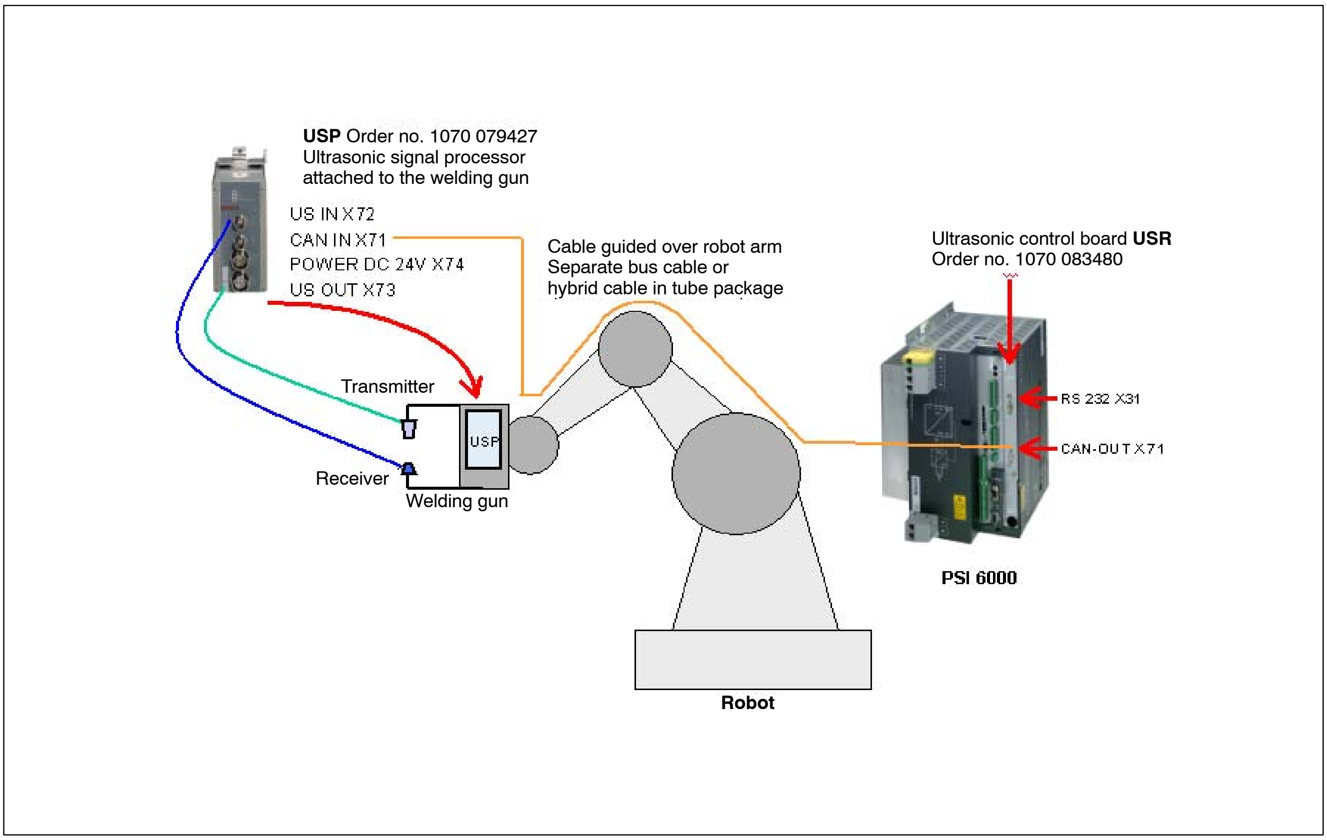


Fig. 1 Basic structure of the ultrasonic system PSQ 6000

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A Annex

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