NORDINKRAFT
The quality guard

SONAFLEX-FSW

Set of Test Electronics and Probes for Ultrasonic Examination of Friction Stir Welds

Reference Technical Specification (rev. 02.11.2020)

Remchingen
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CONTENT

1. SUMMARY

Friction Stir Welding (FSW) is a newer technique of metal joining whereas the materials being joined are fused using heat from friction rotation of the joining tool to create a new homogenous material at the fusing position without external weld fill material. FSW can join aluminium alloys, copper alloys, titanium alloys, mild steel, stainless steel and magnesium alloys. More recently, it was successfully used in welding of polymers. In addition, joining of dissimilar metals such as aluminium to magnesium alloys has been recently achieved by FSW. Application of FSW can be found in modern shipbuilding, trains, and aerospace applications.

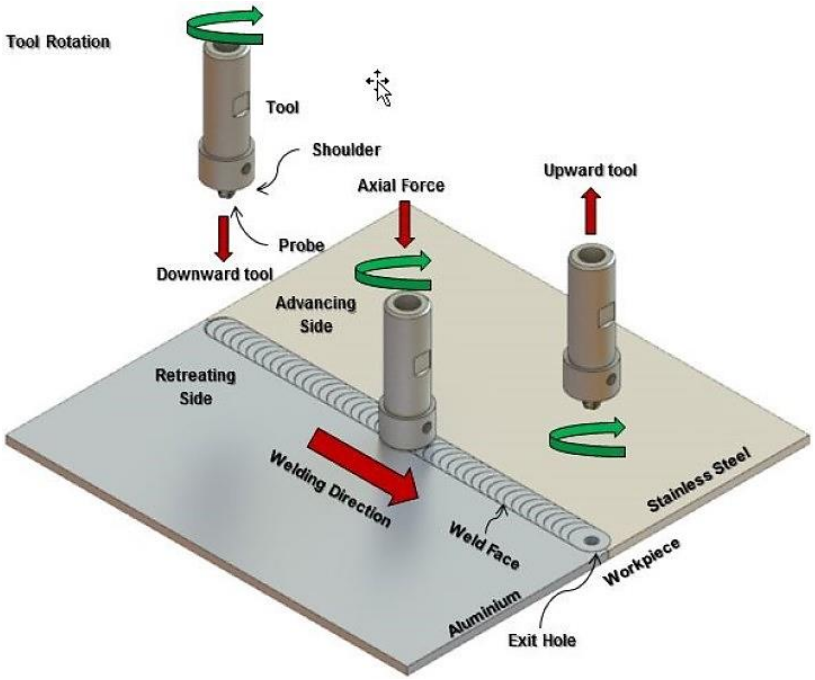


Fig. 1 – Friction Stir Welding Procedure

While a very useful process, inspection methods to accurately and repeatedly inspect and obtain valid results in highly regulated industries have not easily been adapted. Nordinkraft, working in conjunction with government laboratories and FSW specialists have designed a new State of the art method, using various ultrasonic (UT) inspection methods with customized first of a kind sensors to address the growing need of quality assurance and inspection of FSWs. The result of this effort is our SONAFLEX-FSW which allows suppliers of FSW equipment and services the ability to easily integrate the best-known method of FSW inspection in the industry.

SONAFLEX–FSW is an unique intelligent set of innovative test electronics and probes for ultrasonic examination of Friction Stir Welds.

SONAFLEX–FSW is designed to detect discontinuities and assure homogeneity of the material. It also determines the coordinates of defects (cracks, pores, and lack of penetration, inclusions, and other discontinuities, the dimensions of which exceed the maximum

permissible values). Friction stir welding welds from 4 to 40 mm can be inspected by scanning, using acoustic units, equipped with modern ultrasonic transducers.

Typical applications of SONAFLEX-FSW are (see also figures 1-3 below):

- Longitudinal and circular welded seams on flats
- Circular welded seams of tanks
- Meridian and circular bottom seams on tanks, vessels, etc.

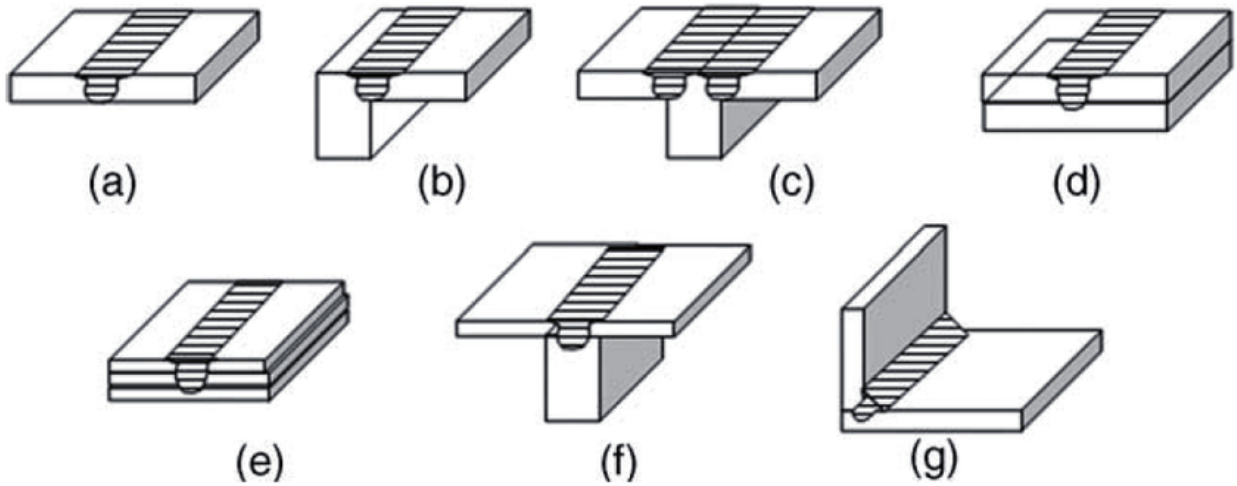


Fig. 2 – Joint configurations for friction stir welding: (a) square butt, (b) edge butt, (c) T butt joint, (d) lap joint, (e) multiple lap joints, (f) T lap joint, and (g) fillet joint

Typical defects to be detected are:

- Inadequate root penetration– absence of plastic deformation;
- Lack of penetration - severe plastic deformation;
- Lack of penetration on the face of the seam;
- Pores;
- Metallic inclusions;
- Accumulations of refractory oxides;
- Cracks of different orientations.

To detect the above described defects, the following ultrasonic testing methods are used:

Examination of weld seams by Shear Vertical (SV) waves transmitted/received by Phased Arrays
ATOFD is a variant of the classical TOFD method which we developed due to excellent performance for friction stir welds

The advanced design of SONAFLEX hardware and software based on the use of modern materials, technologies and components, in combination with powerful computing resources of the control computer complex, has significantly increased its performance and reliability especially in harsh industrial environments.

2. SONAFLEX-FSW CONFIGURATION AND APPLIED TECHNOLOGY

2.1 Summary

Basic set of SONAFLEX-FSW consist of the following mail components:

- Test Electronics Unit;
- Set of Phased Arrays and Angle Beam probes;
- Control Computing Unit (laptop) with pre-installed UT software.

Supplied set of equipment is sully prepared into integration of into welding systems of any complexity, scanning of the weld seam for imperfections is to be performed staring after welding.

2.2 Test Electronics Unit

Test electronics unit is the main part of the equipment. It is intended for generating of initial pulses, pre-amplification, amplification, processing, and filtering received signals.

All test electronics components are assembled in a well-protected, airtight aluminium housing. Depending on the customer request – different configurations of the Test Electronics Unit is available. Basic type of Test Electronics Unit is shown on the figure below:

a) *b)*

Fig. 3 – Test Electronics Unit. a) Overall view b) SONAFLEX-FSW as a part of friction stir welding machine

Test Electronics Unit is equipped with all needed plugs to connection of external devices, such as encoders, sound a d visual alarms, spray markets and etc. Besides it equipped with the LAN connections for performed the information exchange with the external data bases.

2.3 UT Probes

SONAFLEX-FSW is equipped with two types of probes, divided into two groups. General layout is shown in the figure 4 below:

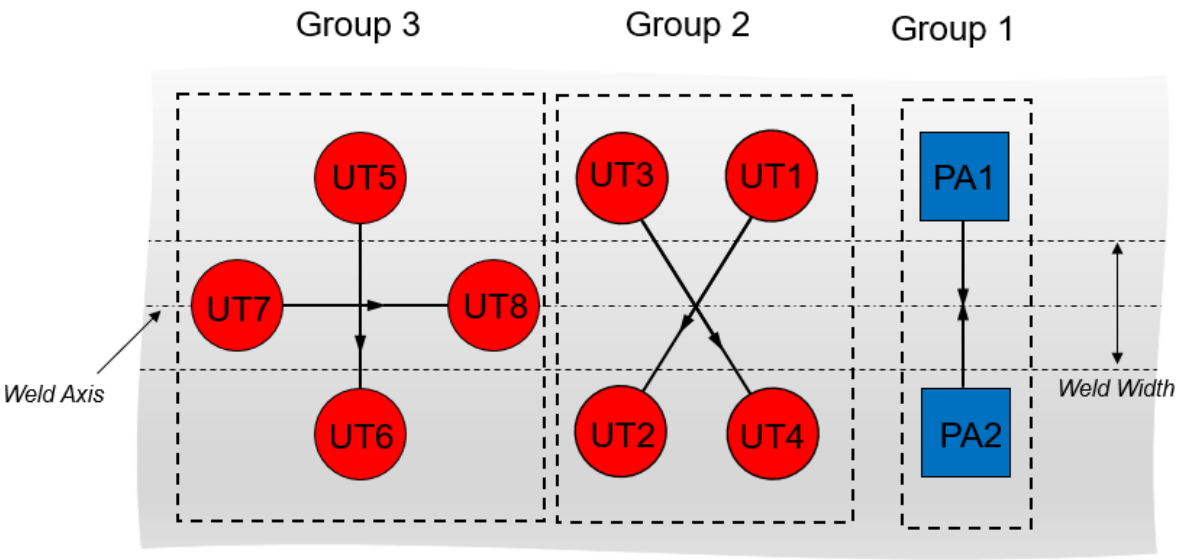


Fig. 4 – General Layout of the SONAFLEX-FSW probes. In Figure: Group 1 represented by two Phased Array Probes – PA 1 and PA 2, Groups 2 and 3 represented by eight angle beam assembling for performing TOFD/ATOFD configuration.

By means of the Phased Array probes it is possible to transmit/receive SV waves in the range of angles 35^0-75^0 for reliable detection of volumetric defects located in the thickness of welded joints and plane cracks it its surfaces.

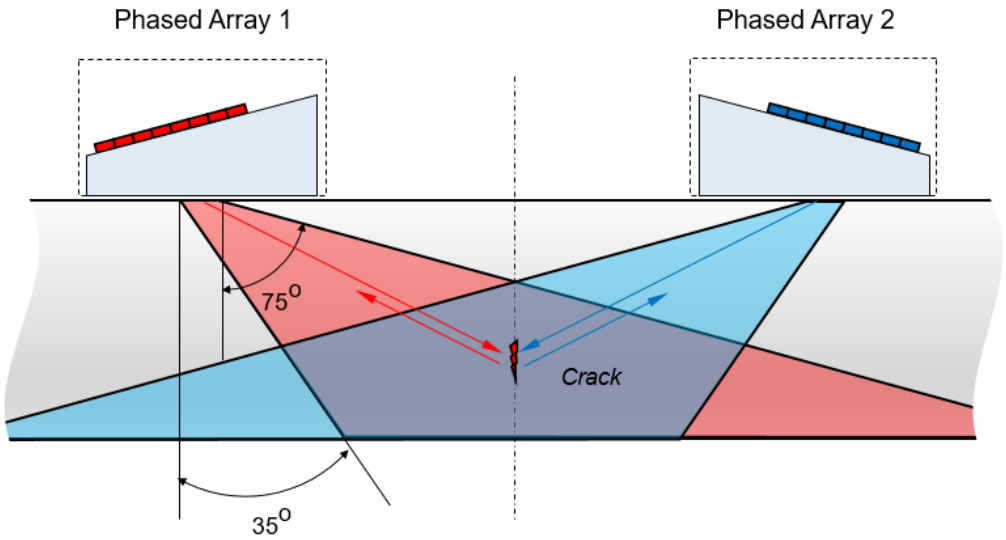


Fig. 5 – Applied Configuration Phased Array Probes and principles of defects detection

Specially designed angle beam probes are intended for realization of weld inspection based on diffraction methods. Application of diffraction methods has the following main advantages:

- Diffracted waves carry information about the place of their origin
- The amplitude of the diffracted waves depends on the acoustic impedance gradient

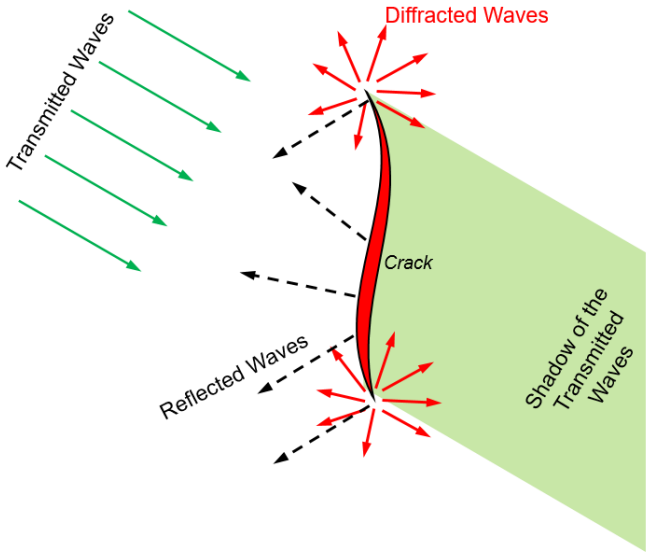


Fig. 6 – Physical basic of Diffraction Methods. Interaction of transmitted waves with crack

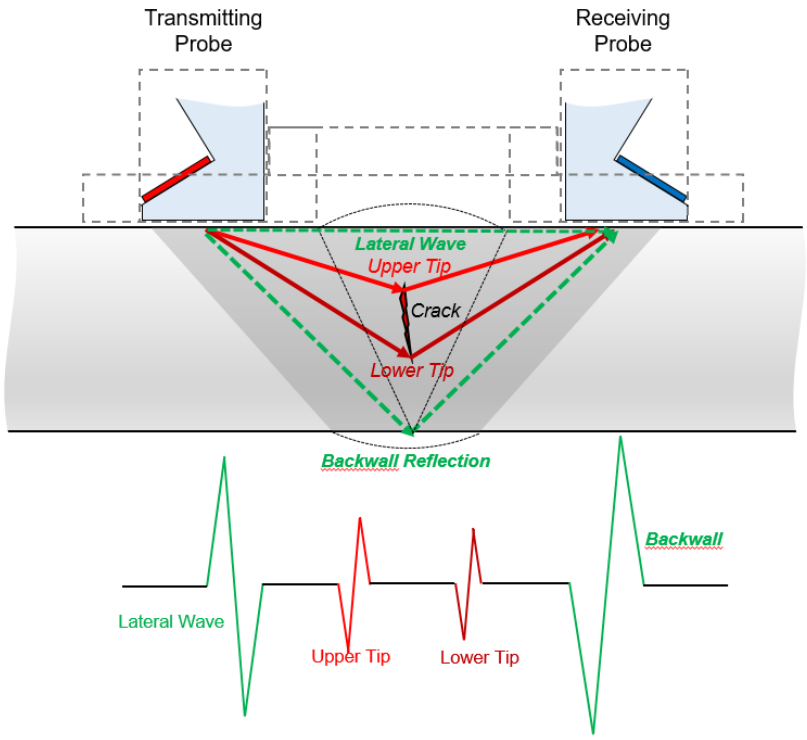
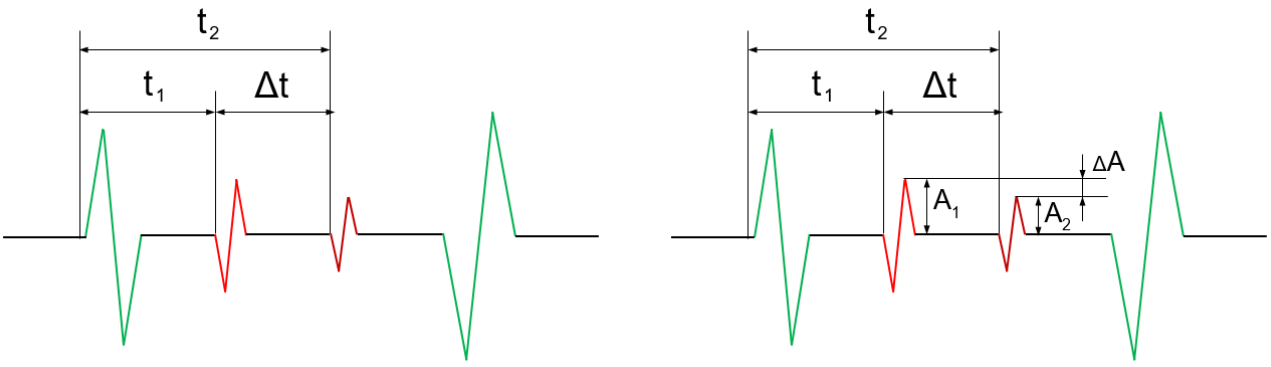


Fig.7 – Applied Configuration of Angle beam probes for realization of TOFD / ATOFD methods

There are two main varieties of the diffraction method (see figure 6):

- Time-of-Flight Diffraction method (see figure 6a), based on the reception and analysis of the diffracted wave propagation in time;
- Amplitude based Time-of-Flight Diffraction ATODF (see figure 6b), based on the reception and analysis of both the propagation time of diffracted waves and its amplitude.



a) *b)*

Fig. 8 – Informative parameters of the received signals for the Time-of-Flight diffraction Method (a) and Amplitude-and- Time-of-Flight diffraction Method (b)

ATODF is a more informative and, therefore, more reliable method for application which we developed for this purpose.

Overall view of the angle beam probes applied for realization for ATOFD configuration is shown in the figure (9) below:

Fig. 9 – Overall View of Angle Beam Probes (remark: PA probes has similar overall view)

2.4 Control Computing Unit with UT Software

The Control Computing Unit is intended for secondary signal processing and visualization of the measurement results, systems adjustments and communication with other external devises such as: test electronics, sensors, other computers, and portable devises.

The Control computing unit can be presented by:

- Industrial rack-mounted PC
- Industrial Laptop
- Panel or Desktop PC

Applied UT software is our HMI for operator interface for reliable and easy adjustment of the testing parameters.

Test results can be presented in your choice of A, B and C-scans, all being available.

- A-scan is to be applied mostly at the “static mode” for adjustment of the main testing parameters: gates position, gain, frequency, etc.

- B and C-scans are to be applied mostly at the dynamic mode for convenient displaying of the defects position through weld thickness (B-Scan) and long its length (C-Scan).

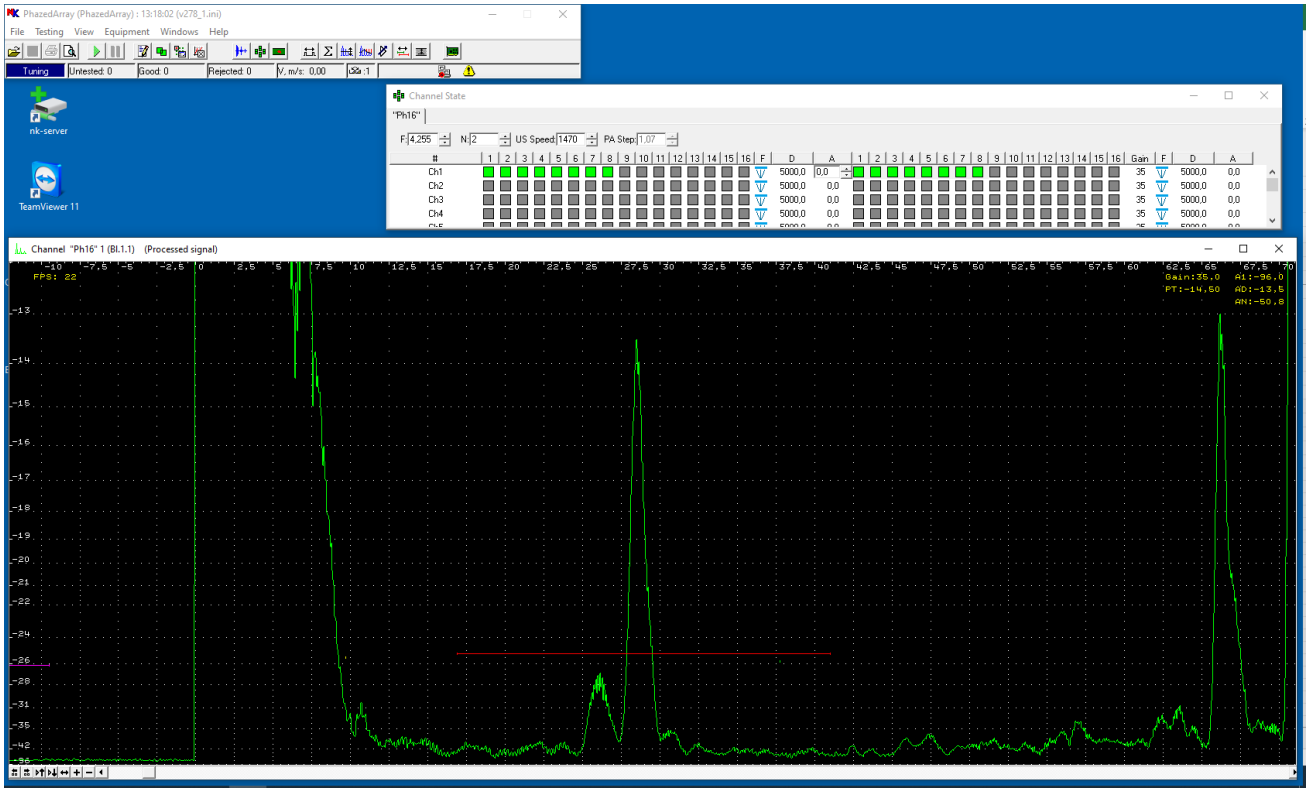
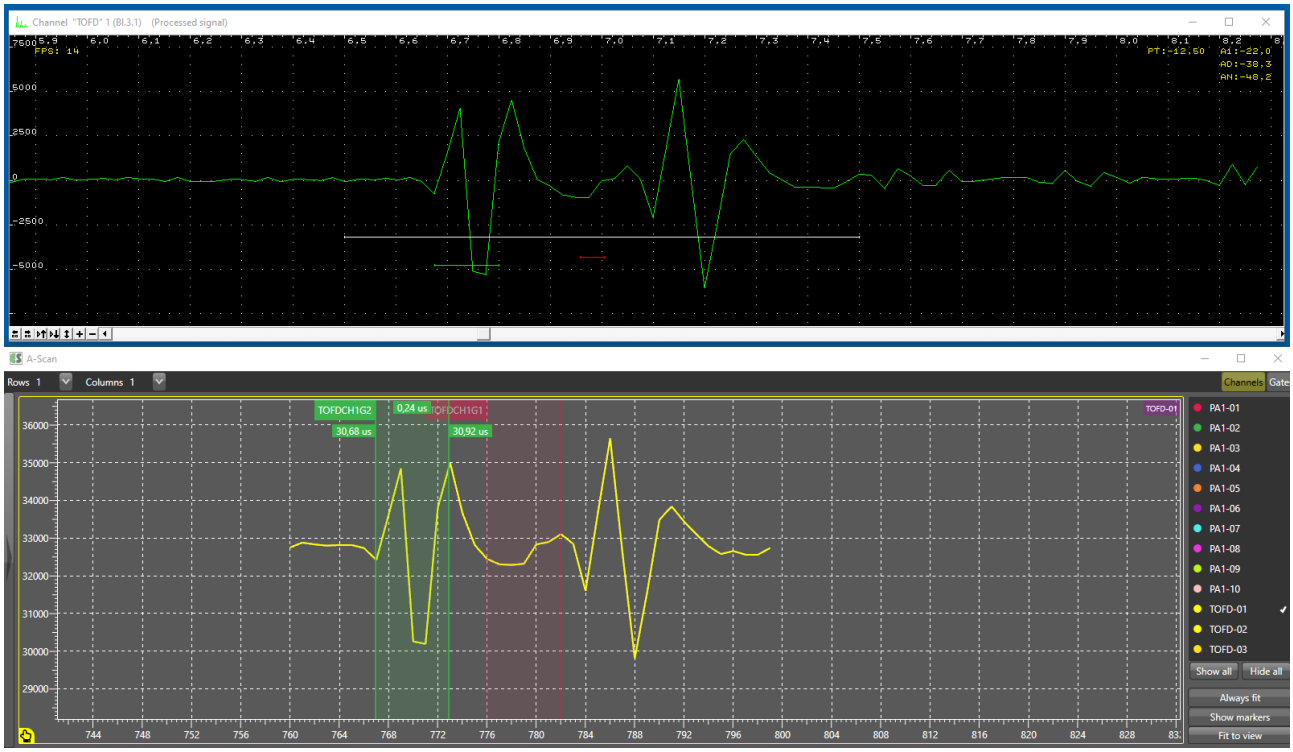
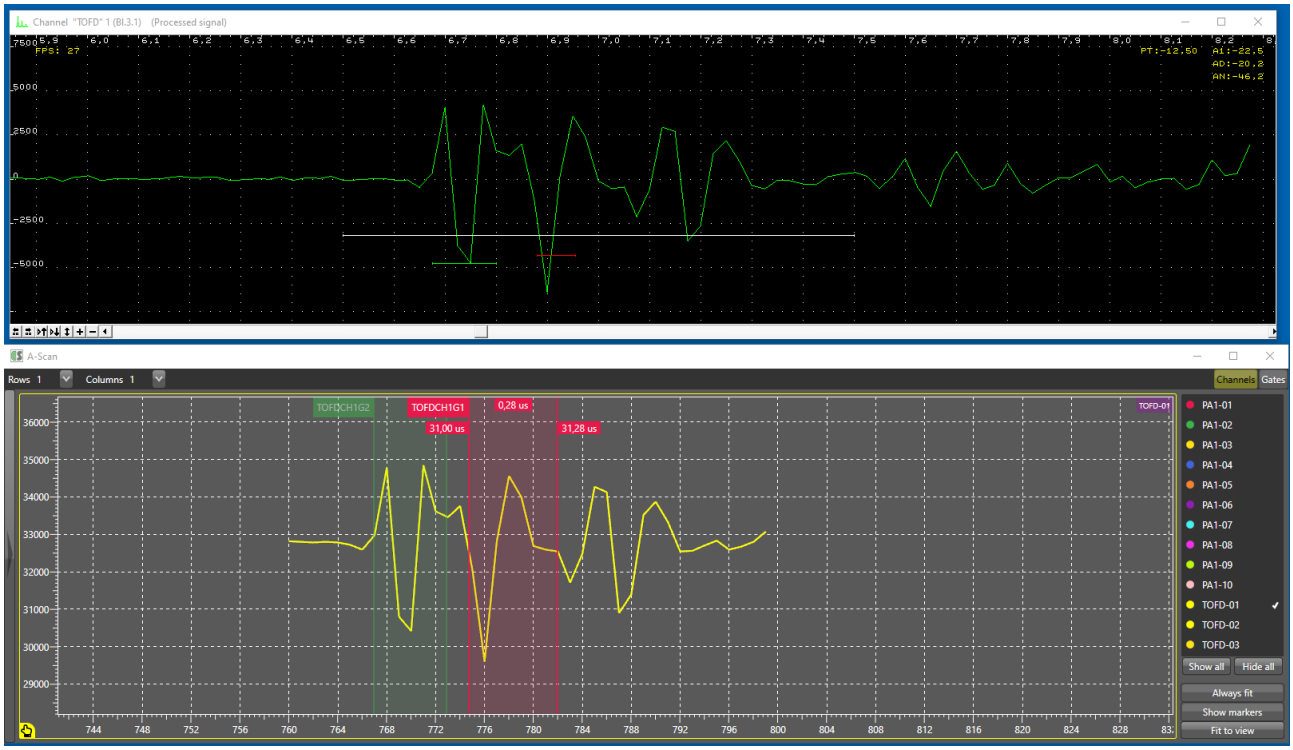


Fig. 10 – Example of SONAFLEX-FSW main Window, Channels Control Window and A-scan obtained for surface notch 0.2 mm deep



a)



b)

Fig. 11 – Example of SONAFLEX-FSW Presentation of A-Scan for TOFD system. Sample thickness 6 mm. In Figures a) Defect Free Area; b) Signals, obtained form side drilled hole 2 mm drilled in half of thickness

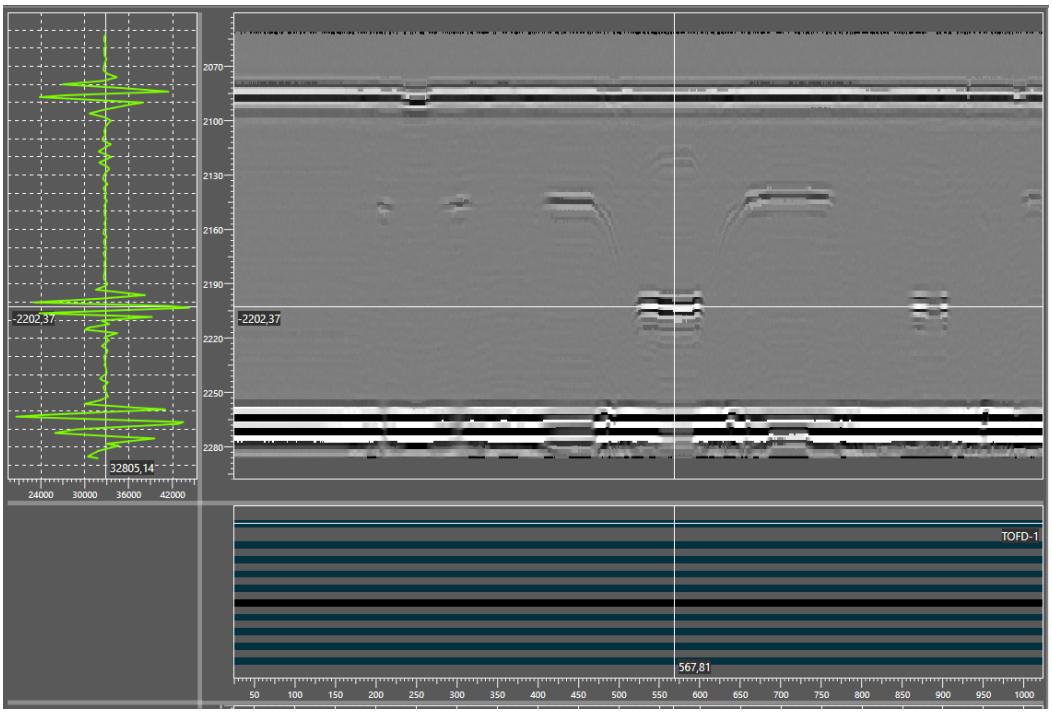


Fig. 12 – Example of SONAFLEX-FSW Presentation of A-Scan for TOFD system. Presentation of A, B and C-scans

In addition, UT software is able to safe the required data at the form of Test Report (see figure below) and (or) transferee it to the computer of higher level at that system software forms and processes the messages in in the form of XML information set.

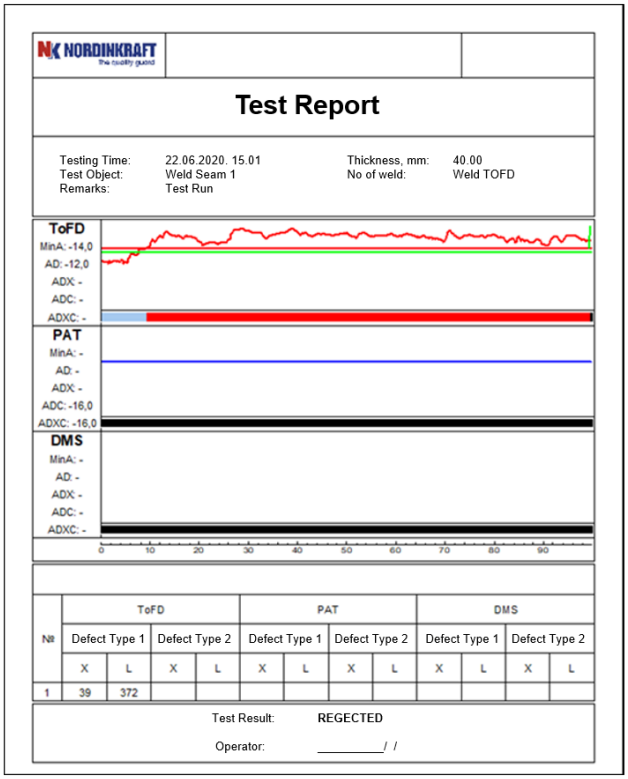


Fig. 13 – Example of the Test Report

2.5 Auxiliaries

The SONAFLEX-FSW can be provided with the required mechanical and automation design to be a stand-alone inspection system (off-line) or can be integrated into the FSW system to inspect in-situ, immediately after welding. Both scenarios assuring fast, reliable and fully automatic examination of welds. Weld equipment manufacturers will find value in adding an inspection station to the supplied welding equipment, whereas existing installations may find better value in an off-line inspection station.

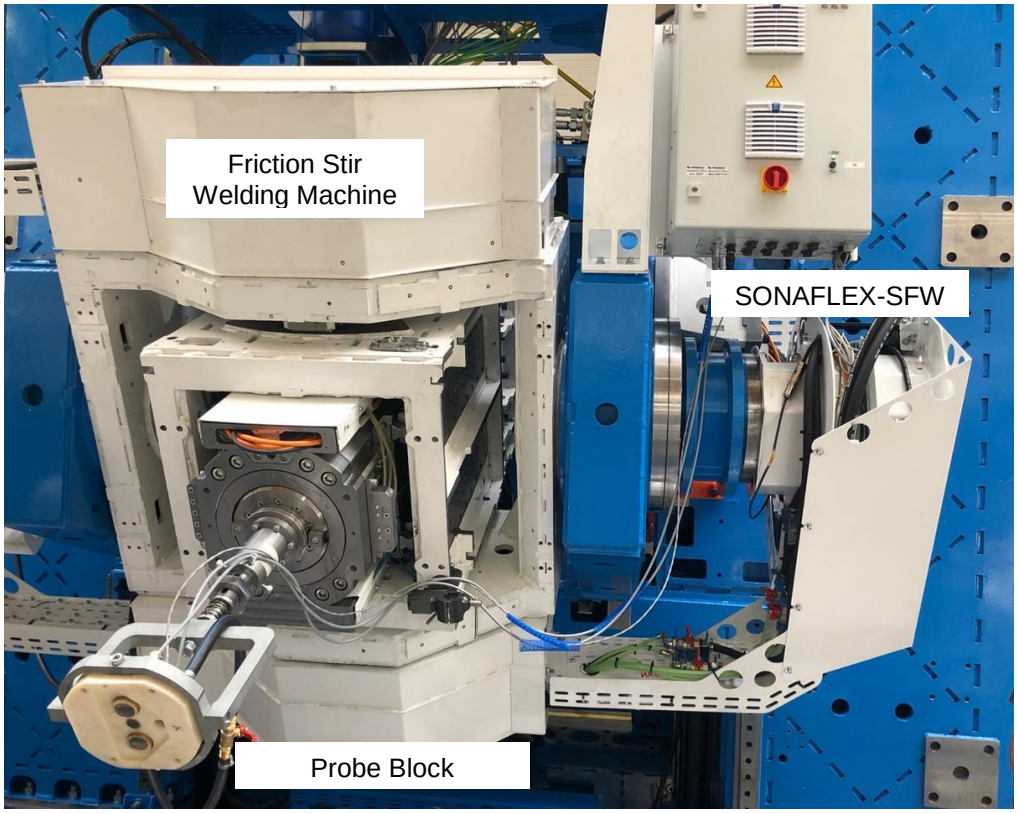


Fig. 14 – Example of SONAFLEX-SFW integrated with Friction Stir Welding Machine. In this example, the UT probe block is fastened directly to the Welding head

Fig. 15– Friction Stir Weld Examination Procedure

2.6 SONAFLEX-FSW Specification

No.	Parameters	Value
1	Overall Dimensions of the Test Electronics Cabinet	700mm x 500mm x250mm (LxWxH)
2	Weight of the Test Electronics Cabinet	30 Kg
3	Utility Consumption (for reference only)	**Power Supply:** a.c. 230 V, 50 Hz, 1 Phase, Power Consumption: 400W
		Coupling Water: suitable for UT coupling function:
4	Type of Welds To be Tested	▪ Longitudinal and circular welded seams of vessels/shells ▪ Circular welded seams of cylindrical tanks ▪ Meridian and circular bottom seams
5	Range of tested thicknesses	4 - 40 mm
6	Type of defects to be detected	▪ Inadequate root penetration– absence of plastic deformation; ▪ Lack of penetration - severe plastic deformation; ▪ Lack of penetration on the face of the seam; ▪ Pores; ▪ Metallic inclusions; ▪ Accumulations of refractory oxides; ▪ Cracks of different orientations.
7	Nominal working frequency	5-7 MHz (adjustable)
8	Frequency of the initial pulses repetition	Up to 5000 Hz
9	Total Number of UT probes	2 Phased Arrays (16 ch) 8 Angle Beam in ATOFD configuration
10	Number and Type of External Devices	By the discretion of Customer

3. SCOPE OF SUPPLY

3.1 Equipment

No.	DESCRIPTION	Q-ty.
1	Test Electronics Cabinet	1 set
2	Set of UT probes (Phased Arrays and Angle Beam) in assembly with the respective probe shoe	1 set
3	Control Computing Unit with Auxiliaries	1 set
4	UT software	1 license
5	Connection Cables, Hoses and Fittings	1 set
6	Technical Documentation	1 set

3.2 Services

№	Name
1	Test Electronics Customization
2	UT Software Customization
3	Assistance at Equipment Integration (optionally)
4	Equipment delivery (of FCA basis)
5	Training of Buyers personnel at Nordinkraft

4. CONTACTS

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