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APPLICATION OF ULTRASOUND FOR DIFFERENT PURPOSES WITH EXAMPLES

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Abstract. *In the last decade application of ultrasound has been increasing. The reason for this is that a wide range of frequencies can be utilized for various purposes. Different scientific fields describe ultrasound in their own way, and from an engineering point of view, the use of ultrasound is quite interesting. The purpose of this paper is to provide an overview of how ultrasound can be applied in diagnostics and welding, including practical examples. Also, during this research dependency between the measured echo of ultrasound wave and depth of founded irregularity is given.*

Key words: *ultrasound, ultrasound diagnostics, ultrasound welding, echo, depth, wires and welded joint*

1. INTRODUCTION

Ultrasonic represents vibrations of frequencies greater than the upper limit of audible range for humans, greater than 20 kHz. Ultrasound waves of very high amplitudes define the term sonic, which is applied to ultrasound [1]. Ultrasound is used in many different fields in order to detect objects and measure distances and more. The first article on the history of ultrasound was written in 1948 [2]. In ordinary daily communication, people are

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familiar with the fact that ultrasound is mostly used in medicine but this powerful method is used in a variety of different fields. Non-destructive testing (NDT) or Ultrasonic diagnostics (UD) represent a way to inspect and monitor the conditions of parts or equipment ensuring that cannot be damaging of components or materials. The application of ultrasound can be in many different fields such as: medicine, industrial processing, robotics, bioacoustics, etc. In the field of industrial processing can be used for cutting, welding, drilling, monitoring liquid flows, etc. In the field of welding, UD has a huge purpose as a method that can ensure the quality and integrity of weld joints. This means that this method allows the detection of defects and irregularities with welds mostly in order to prevent potential failures that could have serious consequences during exploitation. Inside defects of welded joints or defects somewhere near the weld zone must be inspected, and it's often used in practice for different types of industries. The main principles of UD are introduced, including air-coupled ultrasonic testing, electromagnetic ultrasonic testing, laser ultrasonic testing and so on in [3]. NDT can detect defects inside industrial materials, such as cracks, corrosion and voids by analyzing the characteristics of the signal, such as amplitude, time delay and frequency [4,5,6,7]. A group of authors in [8] present research about the propagation of ultrasonic waves in ultrasonically welded thermoplastics composite joints. One part of this paper will represent an ultrasonic diagnostic of welded joints. In the paper [9], a method for evaluating spot-welded joints using ultrasonic surface waves was proposed. The study employed ultrasonic transducers operating at a frequency of 10 MHz, along with a specialized testing setup, to analyze a range of spot-welded samples with different welding process parameters. The macrostructure from the defect indication site was evaluated and assigned using ultrasound indication [10], where the aim of the article was to check the internal defects in the butt welded joints. An ultrasonic detection method for weld defects based on neural network (NN) architecture is presented in [11], where including NN new scientific field is open.

The second part of this paper will be dedicated to showing the usage of ultrasound in the field of ultrasonic welding. Following the new standard in the solderless connection part of IEC 60352-9 [12] covers ultrasonically welded connections and includes requirements, tests and practical guidance information. This presents the modern way how to use ultrasound. A central focus in [13] was to investigate the weldability of Al-wires and flat flexible copper cables using ultrasonic welding. In the manufacturing industry, ultrasonic welding can be used on many different materials including plastics, rubbers, metals, textiles and components. It has become a very popular manufacturing process such as the automotive industry, electronics industry, medical device production and even the production of furniture. The authors of this paper want to explain how sound, as one of the basic physical units, can have huge practical usage in different industries and different methods of how to use sound, in this case, ultrasound. It's very important to mention that two big industries, the automotive industry and electronic industry, have deeply integrated the use of ultrasound in their manufacturing processes. Advances in technology, rapid technological development, low cost, and practical usage are some of the top targets in the future in mentioning industry. This means that ultrasonic welding will continue to be used, and we can expect many more innovations in this field, along with new standards set by leaders in the industry.

2. Overview of the Application of Ultrasound with Examples

2.1. Application of ultrasound in diagnostic

The basic principle of the ultrasonic method involves the transitions of ultrasonic pulses generated by a piezoelectric transducer through the material. When the waves encounter a region with an acoustic impedance value different than the host material, they are reflected and scattered [14]. Simply said UD is a technique that sends ultrasonic waves through an object or material. High-frequency of sound waves are transmitted into materials. The frequency range of 0.1 ÷ 15 MHz represents a range for short pulse waves, in some cases frequencies above 50 MHz also can be used. The basic methods of ultrasonic diagnostics can be carried out using the pulse-echo technique, although through transmission is also an available option. If ultrasonic diagnostic equipment (ultrasonic defectoscope for example) uses pulse-echo testing this means that the ultrasonic defectoscope produces short electrical impulses of pointed or square shape. These electrical impulses travel from the ultrasonic defectoscope, through the probe and finally to the transducer. Transducer are mostly piezo-electrical and convert electrical impulses to mechanical oscillations. The frequency of the transducer is above 20 kHz. Oscillation from the transducer, with the help of ultrasonic gel, travels through material like ultrasonic waves. Ultrasonic waves that travel through the object have a start value of acoustic (sound) pressure. During the propagation of ultrasound waves, through the material, sound pressure decreases with increasing traveled path of ultrasonic waves. After the emission of ultrasonic waves, the ultrasonic defectoscope starts to measure how much time is necessary for ultrasonic waves to come to some irregularities in the materials. Those irregularities can be named “reflectors” because they have acoustic features to reflect ultrasonic waves. Reflected ultrasonic waves represent echo. Reflected ultrasonic waves that return to the probe trigger the transducer's oscillations, which are then converted into low-voltage impulses. Those electric voltages travel through to defectoscope where can be filtered, processed and amplified. Signals on the screen of the ultrasonic defectoscope represent indications of reflections in material [15]. There are two types of ultrasound waves; it can be longitudinal waves or transverse waves. In the first part, authors will give practical examples of ultrasonic diagnostics (UD).

In this paper examinations that were performed were related to the ultrasonic testing of the welded joints of the supports of the harbor pontoon access bridge. For this testing, four pieces of the supports were inspected. This paper will present the results of one study to demonstrate the applicability of ultrasonic testing (UT) as a technique for inspecting welded joints. The material from which the supports are made is steel. Dimensions of the supports are 900 × 300 × 10 mm. The type of welded joint is angle T welded joint with K weld. Welding procedure was done with CO_2. Figure 1 shows one of the four inspected supports, labeled as number 4.

Fig. 1 Steel support No.4 of the harbor pontoon access bridge

The scope of this investigation was completed at 100 %, with a surface temperature of 26°C, which was also the ambient temperature. The used device for the UD of material is USM 36 GE and the ultrasound probe is MWB 70 4 MHz, as shown in Fig. 2. Amplification was 48,3 dB, type of ultrasonic waves was transverse. Ultrasonic gel was used as a contact medium. Acceptance criteria are defined by the level of quality described in SRPS EN ISO 5817 “B” and the level of acceptability is defined in SRPS EN ISO 11666 “2”.

Fig. 2 USM 36 GE Devices

The supports of the access bridge are located on the port side deck of the port pontoon; the supports are numbered 1 to 4 running from bow to stern. A drawing of support No.4 with found irregularities is shown in Fig. 3. In this case 5 irregularities were found on support No. 4.

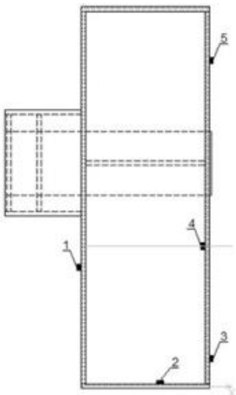


Fig. 3 Drawing of support No. 4 with irregularities

Repairs and re-testing were carried out in places where, during the first test pass, irregularities greater than those allowed by the standard defining the levels of acceptance of welded joints (SRPS EN ISO 11666) were measured. All tested welded joints are of the prescribed quality level. Table 1 gives the measuring results from support No. 4 with all detected irregularities. During this examination, the dependency between the echo of ultrasound waves and the depth of detected irregularity was found. Figure 4 shows that with the increase of depth, echo sound is decreasing. Inversely proportional dependency between the echo of ultrasound wave and depth of found defect exists. The overall conclusion from this practical example is that ultrasonic diagnostics were used to inspect the welded joints, and all of them exhibited a high level of quality.

Table 1 The measured results and important data of welded joint

Type of welded joint	Number of findings	Parameters of detected findings					Status OK	Status NOK
		Echo Height*)	Distance from "zero point"**)	Length	Depth	Position		
		dB	mm	mm	mm	***)		
T	1	4.5	X= 0 Y=280	1	4.6	MWJ	X	-
T	2	5	X= 180 Y=0	1	3	MWJ	X	-
T	3	0.8	X= 300 Y=65	6	8.7	RW	X	-
T	4	5	X= 300 Y=330	1	2	MWJ	X	-
T	5	0.4	X= 300 Y=378	10	9.3	RW	X	-

*) Above the reference level
**) „Zero point" and direction of detection
***) BM – Base Material, MWJ – Metal Welded Joint, HAZ – Heat Affected Zone, RW – Root of the weld, N – Welded layer

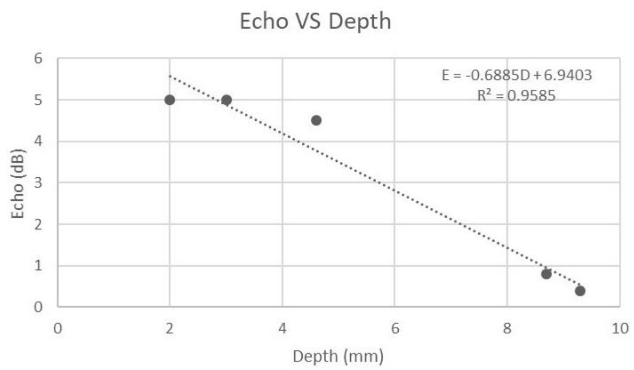
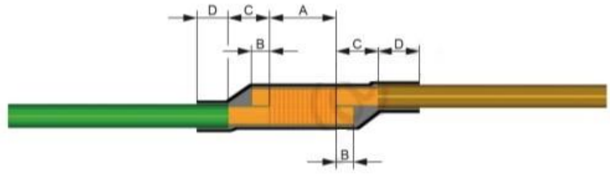


Fig. 4 Dependency between the echo of ultrasound waves and depth of detected irregularity in welded joint

2.2. Application of ultrasound in welding

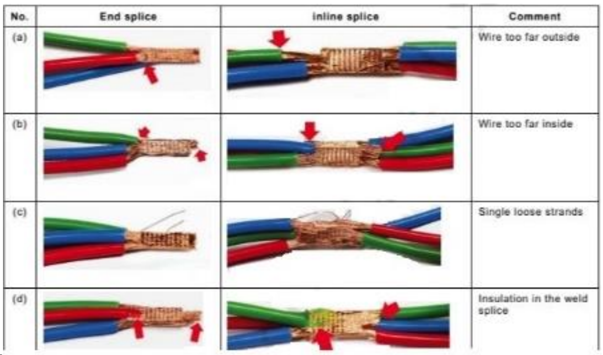
Ultrasonic welding (USW) represents currently the fastest known welding technique. Speaking about ultrasonic metal welding (USMW) this technology receives widespread attention because of its advantages of environmental protection, high efficiency, etc. The core of the USMW is ultrasonic vibration. This process uses vibrations to the acoustic softening of materials during welding. High frequencies somewhere between 15 ÷ 70 kHz generate vibrations. These vibrations generate enough heat which melts the material and welds two parts together creating a strong bond. In the second part of this paper main goal is to show how ultrasound is used in wiring technology (for example, automobile industry). In general, the wires and cables industry rests on ultrasonic welding. The goal of this method is to connect the conductors between themselves or to connect them with the contactors. Figure 5 shows an ultrasonic welded splice between two wires protected with a shrink tube as an example of ultrasonic welding. Here, A represents the length of the splice, B is the wire overhang at the splice's end, C is the distance between the insulation and the splice, and D is the overlapping length of the shrink tube and wire insulation. [12].



[12]

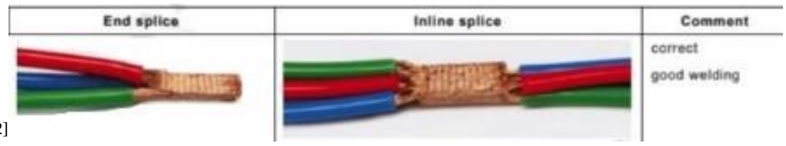
Fig. 5 Ultrasonic welded splice of two wires protected by a shrink tube

Figure 6 shows visual inspection of each ultrasonic splice weld (inline or end splice). These examples are done with error and splices in that condition cannot be accepted. In row (a) wires are too far outside, (b) wires are too far inside position, (c) single loose strands are detected and (d) insulation is in the weld splice. These examples of ultrasonic welding are unacceptable and those splices must be returned to rework. In Fig 7 a good example of correct ultrasonic welding is shown. Visually both splices are done perfectly [12].



[12]

Fig. 6 Error characteristics for end splices and inline splices



[12]

Fig. 7 Good welds for end splice and inline splice

It is familiar that ultrasound is above the human hearing range, greater than 20 kHz. When it comes to comparing the range between those two ultrasound applications, it can be said that the range of frequency for USW (or USMW) is below the range of UD. USW

(USMW) vibrations work on a lower frequency and it overlaps with the human hearing area. In the range of frequency for UD propagation of waves through the material space is on higher frequency. Figure 8 shows a diagram of the frequency range for USW, UD and hearing range.

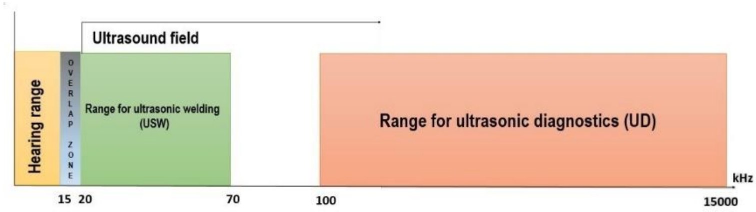


Fig. 8 Diagram of the frequency range for USW, UD and hearing range

3. Conclusion

In this paper, the focus was to show two different ways to use the ultrasound field. One way shows how ultrasonic diagnostics is a necessary tool in measuring all irregularities, which is unavoidable in the welding process. Ultrasonic diagnostic is a non-destructive type of examination, becoming a more and more popular method in the field of engineering. UD advantages can be described through the following conclusion: Modern devices enable the visual display of results, signal recording, and real-time monitoring and UD devices are mostly portable. Handling this type of weld testing equipment is safe for the user. Also, the UD technique can detect surface and subsurface defects and provide instant results. UD can detect more than 50 % of irregularity, for some new equipment on the market, that number is over 85 %, in some cases even 90 %. The disadvantages of UD techniques are that information about materials and parts must be known in order to have reference to calibrate equipment set-up, difficult to use on thin materials and most important above all disadvantages is expensive training for UD which implicates the high price of the UD service. This example demonstrates the use of ultrasonic diagnostics (UD) and explains how the ultrasonic equipment operates. The most important conclusion from this paper is that with the increase of measured echo of ultrasonic waves, the depth of detected irregularity is decreasing. The used UD on the welded joint confirmed a good level of quality. The second example of the usage of ultrasound is ultrasonic welding. A new standard from IEC 60352 covers this topic where ultrasound can connect wires of copper or copper alloy, as well as aluminum or aluminum alloy. There are many reasons why ultrasonic welding may be preferable as compared to other welding and joining techniques. Some of these advantages of ultrasonic welding: Safety - USW (USMW) equipment is extremely safe compared to other welding techniques. The ultrasonic energy is highly targeted, reducing the risk of dangers due to excess electrical energy the heat produced is minimal, localized and quickly dissipated, minimizing the thermal impact on the material and human also; Speed - it is an fast process, the welding process takes a few seconds at most, high-frequency ultrasonic acoustic vibrations allows the material to heat, weld and cool very quickly; Joint quality - Ultrasonic welding equipment produces no deformation, resulting in a clean, nearly invisible seam that requires no touch-up work, ultrasonic welding produces a very clean and precise joint; Reliability **-** The process can even be automated so that thousands of parts can be welded reliably with minimal human intervention; Flexibility - Ultrasonic welding can be applied to a variety of materials and parts; Reduced material costs - USW is very cost-effective in terms of material usage, because of the highly precise and high-quality joints, part scrapping is kept to a minimum. Ultrasonic welding is not an ideal welding technique and has some negativity such as: Joint type limitations- this type of welding can only be used on specifically designed joints, called lap joints, where parts directly overlap one another with a flat surface (Corner, butt, tee, and edge joints cannot be effectively welded using this technique); Material limitations - Materials with high moisture content require vibration welding, which is an entirely different technique; Size limitations **-** ultrasonic welding is highly useful for many thermoplastics and specific types of metals, it is not appropriate for all applications involving these materials (ultrasonic energy is not enough to produce large joints greater than 250 mm in length); High investment - ultrasonic welding equipment is significantly more expensive than traditional welding equipment, and the costs only increase with the introduction of automation [13]. In the Republic of Serbia, there are several manufacturing facilities of large companies from the automotive industry. All of these companies use ultrasonic welding (USW or USMW) in their production for renowned customers who have very strict standards. A lot of people are trained to work on ultrasound machines, and in the future accent must be on ultrasound welding. Future research will focus on developing new procedures, methods, and methodologies for applying ultrasound in this field. Automotive industries are moving fast into electromobility and ultrasound will be a topic of interest in many different fields.

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