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Ultrasonic test of resistance spot welds based on wavelet package analysis

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ABSTRACT

In this paper, ultrasonic test of spot welds for stainless steel sheets has been studied. It is indicated that traditional ultrasonic signal analysis in either time domain or frequency domain remains inadequate to evaluate the nugget diameter of spot welds. However, the method based on wavelet package analysis in time–frequency domain can easily distinguish the nugget from the corona bond by extracting high-frequency signals in different positions of spot welds, thereby quantitatively evaluating the nugget diameter. The results of ultrasonic test fit the actual measured value well. Mean value of normal distribution of error statistics is 0.00187, and the standard deviation is 0.1392. Furthermore, the quality of spot welds was evaluated, and it is showed ultrasonic nondestructive test based on wavelet packet analysis can be used to evaluate the quality of spot welds, and it is more reliable than single tensile destructive test.

1. Introduction

Resistance spot welding is an effective and economical welding method joining sheet metal. It has been widely used in modern manufacturing industry [1,2]. The structure's reliability even the whole product's usability are directly influenced by the quality of spot welds. However, in the process of spot welding, the formation of nugget and its growth, which are both in closed state, cannot be observed. Besides, nucleation time is extremely short. Thus, the fluctuation of welding parameter may result in serious defects like splash, stick welds and deficient dimension. So it is significant to evaluate the quality of spot welds.

At present, in actual production, most industries mainly use destructive testing. However, this method is low efficiency and wastes materials as well. Therefore, in recent years, many scholars focused on nondestructive testing [3–5]. Comparing with other nondestructive testing methods, ultrasonic test is much concerned by scholars in various countries for greater convenience, high sensitivity, wide test range, high test speed, good safety performance and easy for site operation [6].

Ultrasonic test of spot welds usually adopts the pulse-echo method by using high frequency contact probe with water film latency [7–9]. The testing effect relies on the operator's experience. It can only test spot welds within certain range according to the probe's diameter [5,8–10]. Although Shi et al. [11] used an immersing ultrasonic C-scan to test the nugget diameter, the result showed that the dimension of the nugget is relatively large due to the influence of the corona bond, i.e. high temperature solid metal around the nugget, where plastic deformation and recrystallization of the metal occurs under the action of gravity electrode. Yet, the test error can be adjusted through changing the threshold value. Zhang et al. [12] used an immersing ultrasonic transmission to test the spot welds of stainless steel. The nugget diameter is evaluated by signal analysis in time domain and frequency domain. Although the result is larger than the actual metallographic measured value, the estimation of diameter using frequency spectrum is feasible. Actually, water immersion ultrasonic test is slow-speed, and high-cost, which is not suitable for real working test. Chen et al. [9] used the wavelet packet transform to process the echo signal of resistance spot welding for galvanized high strong sheets. He connected the gross power of the signal which can evaluate the quality of spot welds with the nugget diameter and mechanical properties, and made evaluation on the quality of spot welds. However, whether the nugget diameter include corona bond in testing result was not mentioned. The corona bond is the weak zone of spot welds. Its size directly affects the quality of spot welds. Therefore, the reliability of ultrasonic nondestructive testing results can be effectively improved by distinguishing the nugget from the corona bond.

This paper makes signal analysis of ultrasonic A-echo in time domain, frequency domain and time–frequency domain. In this

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Table 1
Chemical composition of SUS304 austenitic stainless steel (wt.%).

C	Si	Cr	Ni	N	Mn	P	S	Fe
⩽0.07	⩽1.00	18.00–20.00	8.00–11.00	0.01–0.25	⩽2.50	⩽0.035	⩽0.030	Allowance

Table 2
Mechanical properties of SUS304 austenitic stainless steel.

Yield strength (N/mm^2)	Tensile strength (N/mm^2)	Elongation %	Hardness HV
⩾205	⩾520	⩾40	⩽200

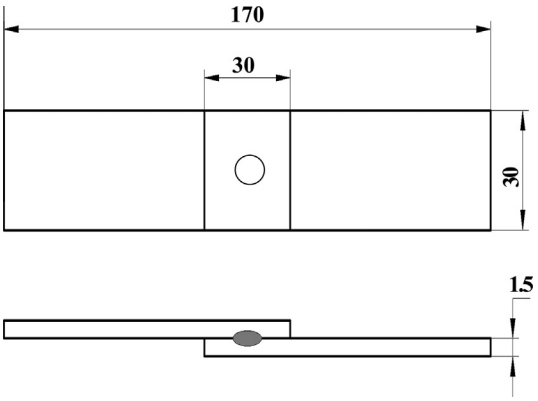

Fig. 1. Geometry and dimension of specimen (in mm).

Table 3
Welding parameters used for the stainless steel.

Group	Current (kA)	Cycles (cyc)	Pulse	Pressure (kN)
1	6	20	2	10
2	7.5	18	2	10
3	9.5	16	2	10
4	11	13	2	10

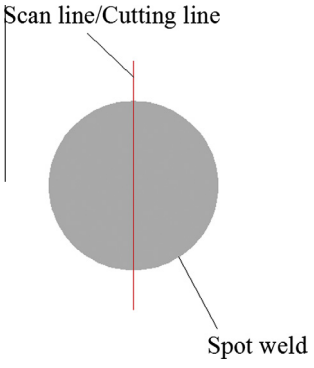

Fig. 2. The probe scanning path schematic diagram.

study, we extract the characteristic signal in the spot weld, and use wavelet packet transform to separate the high-frequency echo signal. Then, we effectively identify the nugget and corona bond according to the spectrum characteristic. The results of ultrasonic test are compared with the actual metallographic measured value, and the quality of spot welds is finally evaluated.

2. Materials and experiments

2.1. Specimen preparation

SUS304 stainless steel (0Cr18Ni9) is used in this study, with the chemical composition and mechanical properties shown in Tables 1 and 2, respectively. The specification of specimen is shown in Fig. 1. The thickness of the specimen is 1.5 mm, width is 30 mm, and length is 170 mm. Four groups of specimens with different welding quality are prepared using different welding parameters (see Table 3). There are eight specimens in each group. Four specimens are used to measure nugget diameter, and the rest to test shear performance.

2.2. Testing device

The ultrasonic testing device used in the experiment is comprised of 15 MHz ultrasonic focusing probe, card with sampling rate of 100 MHz, scanning platform and portable industrial computer. The probe is driven by linear motor scanning platform, which moves automatically according to the set program. Scanning precision is up to 0.02 mm. Ultrasonic probe conducts data acquisition at every step-type spot in the process. After a sub-regional scanning, the regional data matrix can be obtained. Computer makes a comprehensive process with the data matrix. The result will be shown intuitively in the output end.

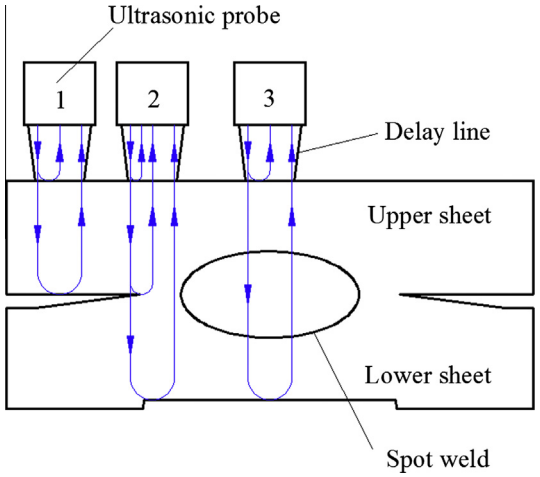

Fig. 3. The ultrasonic propagation path in different locations of spot weld.