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Nugget diameter in resistance spot welding: a comparison between a dynamic resistance based approach and ultrasound C-scan

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Abstract

Automakers today are challenged with improving the quality of spot welded structures, while reducing the costs associated with quality control. While ultrasonic C-scan testing has become a mainstay of quality control programs, it is not suitable for inspection of every weld in a high volume production due to the considerable operator skill required, and the requirement to take parts off-line for inspection. The dynamic resistance curve of a weld is known to contain information about the development of a weld, however there is not always a clear way to relate that directly back to the quality of a weld and exactly how a system may have arrived at that decision. Because the dynamic resistance data is available inline for every weld, developing a method of determining weld quality from the dynamic resistance would allow for process faults to be diagnosed sooner than would be possible with periodic off-line inspection.

In this paper we present a method of estimating nugget diameter directly from the dynamic resistance obtained during welding, by means of Principal Component Analysis (PCA), autocorrelation and multilinear regression. The accuracy of estimated nugget diameters is compared to ultrasound inspection in a production environment. The nugget diameter estimated by the dynamic resistance was found to be more accurate than ultrasound, with Mean Squared Error values of 2.26 for Ultrasound and 0.33 for the Dynamic Resistance Method. For welds with misaligned electrodes, the effectiveness of Ultrasound dropped significantly when the probe was unable to sit flat on the weld surface. The method presented in this paper is suitable for inspection of every weld in a high-volume production, and has been shown to outperform ultrasonic inspection in estimation accuracy.

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Keywords: Resistance Spot Welding, Ultrasonic C-scan, Dynamic Resistance Signature

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1. Introduction

Resistance spot welding (RSW) is a ubiquitous sheet metal joining technique in the automotive industry due to its low cost and quick cycle time. To monitor the quality of spot welds in industry, regular inspection (both destructive and non-destructive) is required to ensure the quality of welds produced in a high volume environment such as auto production. Though resistance spot welding is well established in industry, maintaining consistent, high quality weld production remains a challenge due to sensitivity to small process changes that uncontrollably drift and can be difficult to detect. Effective quality monitoring techniques rely on information about weld quality that is both; accurate (so that small changes can be reliably detected), and frequent (so that process changes can be detected and addressed quickly).

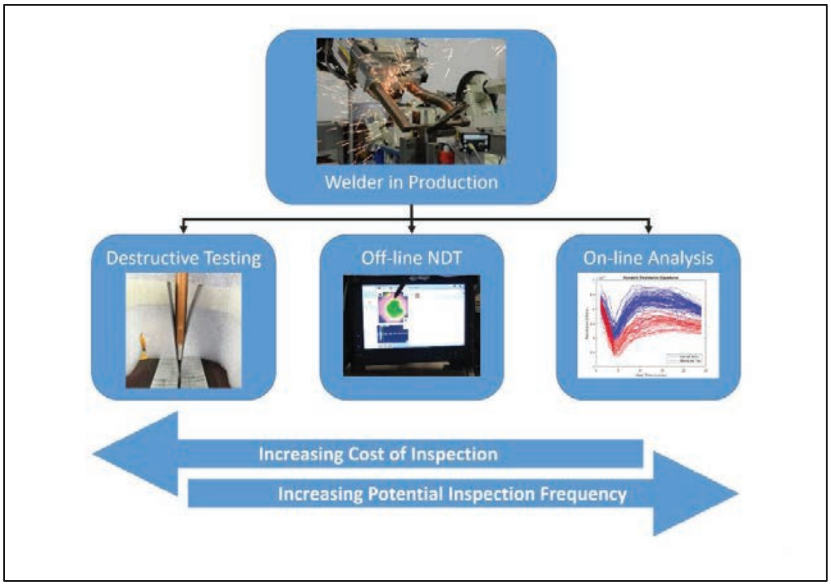

Figure 1: Inspection techniques have varying accuracy, frequency and cost

Given that weld nugget diameter is the output variable that is frequently monitored in most manufacturing settings, determining nugget diameter for as many welds as possible should be the priority, without requiring parts to be taken off the production line. The most common non-destructive testing method used in industry is ultrasonic C-scan, which uses an array of ultrasound transducers to produce a 2D image of the fused area in the faying surface [1]. From the 2D image the nugget diameter is measured and often compared to a benchmark that determines whether the nugget passes or fails quality control testing. Despite its popularity, ultrasound still currently requires a skilled operator, while the setup and scanning time make it unsuitable for inspection of every weld in a high-volume production.

Given the issues with Ultrasonic testing, alternative methods using information from the signals collected during welding have been investigated. The dynamic resistance signature (DRS) has long been known to contain information about the growth of the weld nugget and presence of expulsion [2], and for that reason is frequently used in monitoring and control systems [3]–[7]. Several attempts have been made to directly estimate the nugget diameter or strength from the dynamic resistance signature [8]–[10] resulting in an alternative form of non-destructive testing.

In this paper, the relative performance of two non-destructive nugget diameter assessment methods is compared: ultrasound C-scan and inference from the DRS. As is highlighted schematically in Figure 1, the methods being compared allow for varying frequency, accuracy and cost. The DRS nugget size estimation method offers the potential to be suitable for automated quality assurance of every weld in production, greatly increasing the chance of