Real-Time Integrated Weld Analyzer

Institute For Diagnostic Imaging And Research

THE INSTITUTE FOR DIAGNOSTIC IMAGING RESEARCH

University of Windsor

Introduction

Real-Time Integrated Weld Analyzer (RIWA) is a combination of an advanced non-destructive ultrasonic system which provides a solution to evaluate resistance spot welds in real-time. The hardware of the system consists of a high frequency ultrasonic transducer that is integrated into the welding electrode, which generates ultrasonic waves that pass through the electrode cap into the welded plates. Further, the final goal of the RIWA project is to create a predictive system using machine learning algorithms.

What is Resistance Spot Welding?

Resistance spot welding is a process in which metal plates at contact are joined by the heat obtained from resistance to electric current.

Figure 1.1
Welding electrode and RIWA system

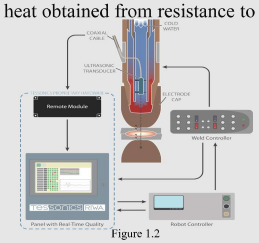

Figure 1.2
Full System Diagram

My Role and Responsibilities

I have been involved in various aspects of RIWA project for my eight months Co-op. Two of my major tasks were:

1. Labeling B-Scans to prepare large training data sets for machine learning model.
2. Assembling and testing ultrasonic equipment

Labeling of B-Scans

Labeling is the most integral part towards the goal of the RIWA project. In order to train the machine learning model, we must manually rate the welds based on features mentioned below. This is done using Machine Learning Database Manager.

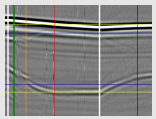

Figure 2.1
Labeled B Scan

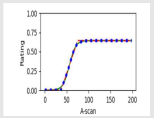

Figure 2.2
Sigmoid Fitting

Features labeled:

1. Melting Onset
2. Steel-Steel Interface Disappearance (SSID)
3. Saturation point
4. Nugget Top and Nugget Bottom interface
5. Front and Back interface
6. Expulsions
7. Nugget Closure

Melting Onset

The identification of melting onset is one of the most critical aspect in order to label a B-scan. The melting point (green line in the figures 3.1 and 3.2) indicates that the nugget has started forming. Its position can be estimated by analyzing the shape of the nugget, back wall etc. Usually, the initial forking of weld nugget is marked as the melting onset of the weld nugget.

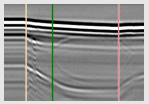

Figure 3.1
Melting Onset for 0.8 mm-1.4 mm plates

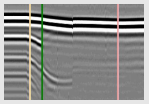

Figure 3.2
Melting Onset for 0.9 mm-0.8 mm plates

Steel-Steel Interface Disappearance (SSID)

The SSID (orange line in the figures 4.1 and 4.2) is a point when the weld nugget breaches the thinnest outer sheet. Often, this feature is confused with the melting point. However, it is found out that melting point and SSID occur concurrently for the symmetrical welds. But as the weld gets more asymmetrical, the SSID is more offset from the melting point.

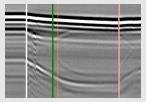

Figure 4.1
SSID for more asymmetrical welds

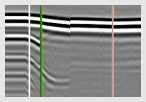

Figure 4.2
SSID for less asymmetrical welds

Saturation Point

The saturation point (red line in the figures 5.1 and 5.2) is defined as a point of deepest vertical penetration of the weld nugget. It is an important feature as the coordinates of the bounding boxes (feature detection technique in AI) rely on its position and its intersection with other interfaces.

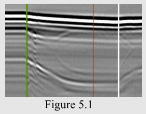

Figure 5.1
Saturation point for 0.8 mm-1.4 mm plates

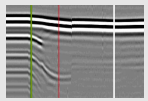

Figure 5.2
Saturation point for 0.9 mm-0.8 mm plates

Nugget top and bottom interface

Nugget top (bottom) interface (blue lines in the figures 6.1 and 6.2) is marked at the point of intersection of saturation line and nugget top (bottom).

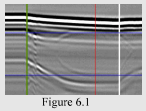

Figure 6.1
Nugget Interfaces for 0.8 mm-1.4 mm plates

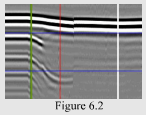

Figure 6.2
Nugget Interfaces for 0.9 mm-0.8 mm plates

Front and Back interface

Front (back) interface (yellow line in the figures 7.1 and 7.2) is marked at the point of intersection of the saturation line and the front (back wall) wall .

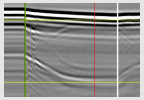

Figure 7.1
Outer Interfaces for 0.8 mm-1.4 mm plates

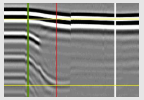

Figure 7.2
Outer Interfaces for 0.9 mm-0.8 mm plates

Expulsions

Expulsion is an event during the resistance spot welding. It is the ejection of the molten metal from the weld nugget when high current is applied for short duration of time. It is an important feature in determining the weld quality. Expulsions are labeled by a cyan (magenta) colored box (figure 8.2) with its crosshair positioned at the intersection of expulsion and front (back) wall.

Figure 8.1
Event of Expulsion

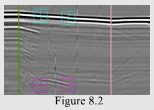

Figure 8.2
Multiple Expulsions for 1.0 mm-1.4 mm plates

Nugget Closure

Nugget closure (black line in the figures 9.1 and 9.2) is marked at the position where the molten liquid completely solidifies. It is estimated by the convergence of nugget top and bottom interfaces.

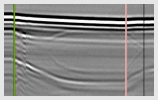

Figure 9.1
Nugget Closure of 0.8 mm-1.4 mm plates

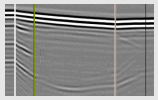

Figure 9.2
Nugget Closure of 0.6 mm-1.0 mm plates

Assembling and Testing Ultrasonic Equipment

F2 Platform:-. F2 is an ultrasonic device designed for NDE and quality control for various applications, including resistance spot welds, and adhesive joints. Various components of F2 such as battery backs, touch-screen stylus, back stand, handles, motherboard heatsink, and other electronics were assembled. In addition, motherboards were flashed with the appropriate firmware.

Figure 10.1
F2 Platform

Figure 10.2
F1 Platform

Communication Modules:-. REX (Remote Extender) and LEX (Local Extender) are two integral communication modules in generating the B scan image of a weld. REX gathers the ultrasonic data from the transducer and sends it to the LEX which further transfers the data to the computer and aids in the visualization of a B scan of the weld nugget.

LEX and REX were assembled, programmed, and the system was tested by observing the A scan signal in the oscillograph.

Figure 11.1
Local Extender

Figure 11.2
Remote Extender

Results and Future Work

From figures 12.1, 12.2 and 12.3, we can note that we have a huge bias in our training datasets based on weld duration, stack thickness, vertical saturation, respectively. Due to this, the machine learning model overestimates the rating of poor-quality welds. In order to train the machine learning model accurately, we need to prepare the datasets with weld duration greater than 300 ms and poor vertical saturation for different stack combinations.

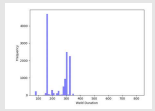

Figure 12.1

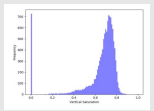

Figure 12.2

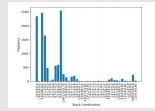

Figure 12.3

Acknowledgements

Special thanks to Dr. Roman Maev and Dr. Andriy Chertov (Project Supervisor) for giving me the opportunity to work at IDIR and gain experience in the field of Applied Physics. I am also thankful to Mr. Danilo Stocco for giving me insights into weld science, Dr. Ryan Scott for helping me in labeling of B scans, Mrs. Sarah Beneteau for the co-operation and support.

Shubham Kukreja (kukrejas@uwindsor.ca)
Program: BSc. Physics (Hon.) With Co-op, Fourth year Undergraduate
Co-op work term: Winter 2020 and Summer 2020
Employer: IDIR Supervisor: Dr Andriy Chertov