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Ultrasonic Calibration Details

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Abstract

The present paper is a short explanation related to what happen in ultrasonic calibration process. The *material velocity* and *zero offset* functions are related with the two known distance peaks classical requirement for setup. The *autocalibration* function is also explored and explained. The aim is to help beginners to understand the foundations of ultrasonic setup.

1. Introduction

Ultrasonic equipments used to develop weld or material flaw detection and sizing, need to be calibrated prior to the inspection, so one of the mandatory calibrations is the well known *time base* calibration that can be defined as the process developed to establish a correspondence between the time spend by the wave to *go and come* (time of flight) from a known reflector and the distance traveled.

Practically all the commercial equipments can be calibrated using iteratively the functions ***Zero Offset(ZO)*** and ***Material Velocity (MatVel)*** applied over reference signals using a reference block. Another very practical way to develop the time base calibration is using the ***Autocalibration*** function.

The present paper is a short explanation of the details of the calibration process using the mentioned functions and the algorithm that in a non conscious form we develop in the calibration routine.

2. The Ultrasonic Velocity (Material Velocity)

In general ultrasonic velocity is considered as a constant value relative to the material. This assumption is made supported in a set of conditions that can be resumed in the next tips [1]:

- The material is elastic.
- The material is non dispersive.
- The frequency is enough high to produce a wave length very much lesser that the test piece dimensions.
- Atmospheric pressure and constant temperature.

The ultrasonic velocity is always a temperature dependent variable [2].

Ultrasonic velocity is one of the time base calibration variables that the operator need to set to perform the calibration. Usually, the ultrasonic velocity is named ***Material Velocity (MatVel)*** in the equipment panel.

3. The Zero Offset

The ***Zero Offset*** is the numeric value of time spends by the wave before entering the material of interest as shown bellow in the **Figure 1**, this is the time used by the wave to travel trough the matching layer and the wedge material, identified as t_o (the matching layer is usually lesser than $\frac{\lambda}{4}$ and is not represented in the **Figure 1**).

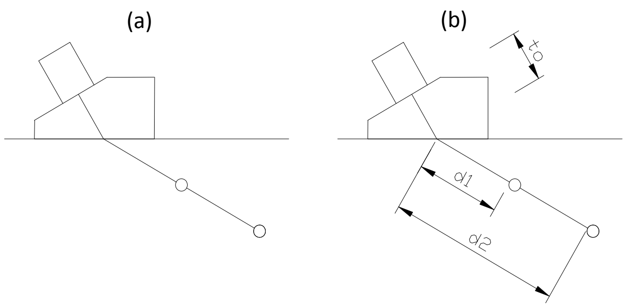

Figure1. (a) Scheme representing the time spends by the wave to travel trough matching layer and wedge material and the distances to two different reflectors. In (b) the nomenclature is presented.

4. Classical Digital Calibration

The standard calibration process requires the use of two reference signals coming from two similar reflectors at different distances. Before the calibration begins, is a very good practice to fix the ***Zero Offset*** and ***Delay*** values to cero. It is also recommended to input the ***material velocity*** value as close as possible to the actual value, using ultrasonic velocity tables.

Setting a ***range*** a little bit more than d_2 in the **Figure 1**, with the right refracted angle selected in the equipment panel and appropriate ***gain*** value, the display should shown a presentation similar to **Figure 2**.

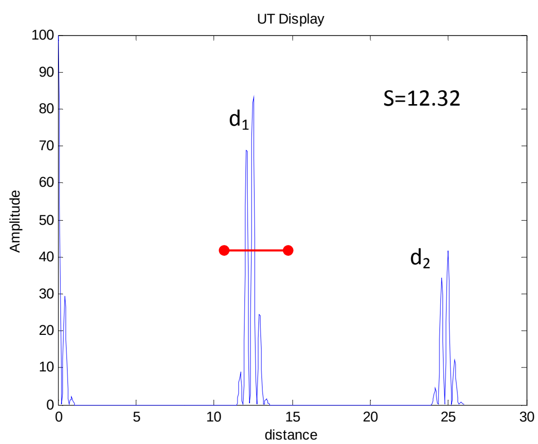

Figure2. Representation of a generic equipment display showing two indications coming from reflectors at d_1 and d_2 distances.

When the first peak is selected, setting the gate as in **Figure 2**, the ultrasonic unit compute the following value:

$s_e = c_e t_h$ (Eq. 1)

Where s_e is the sound path showed in the display, c_e is the ultrasonic velocity (***material velocity)*** manually introduced by the UT operator, and t_h is the time measured from the instant where the excitation pulse was emitted to the arrival of the first peak enclosed by the gate as shown in **Figure 2**. **Figure 3** is a schematic explanation of the situation. The time t_h is decomposed in two parts:

$t_h = t_o + t_1$ (Eq. 2)

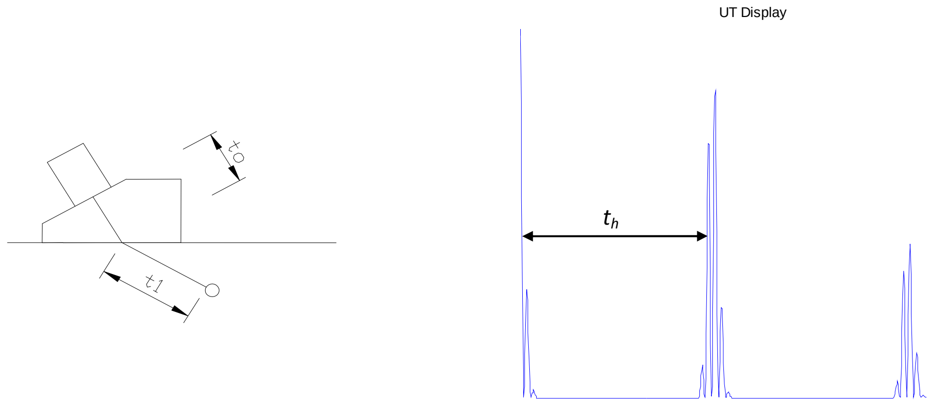

Figure 3. Graphic representation of the time counted from the start of the record up to the first peak.

Where t_1 is the actual time of flight from the transducer exit point at material surface to the reflector placed at d_1 in accordance with **Figure 1** and **3**.

At this point, It is necessary to use the ***Zero Offset*** function to correct the error introduced by the time t_o, which the equipment alone cannot separate from the measured time t_h.

When the operator introduces a ***Zero Offset*** value, the new time value will be:

$t_n = t_h - t_{Off}$ (Eq. 3)

Where t_n is the time used for the calculation in Eq. 1 (a new time value) and t_{Off} is the ***Zero Offset*** value.

If the ***material velocity*** manually introduced by the operator match with the actual material velocity, the calibration should be perfect as the operator can verify enclosing the second peak with the gate, and cheeking the coincidence between the displayed sound path and the actual distance d_2. Nevertheless, it is possible that the sound path showed differ from the actual d_2 distance. The reason is that the ***material velocity*** selected originally from an ultrasonic table, is not exactly the actual ***material velocity*** of the test block**.** This fact make the ***Zero Offset*** value, previously adjusted, an inexact value since the calculation made for the equipment by the Eq. 1 and corrected with the new time t_n:

$s_e = c_e t_n$ (Eq. 4)

Is affected by the wrong velocity value c_e.

At this point the recommendation is to correct the value of ***material velocity*** c_e and come back to the first peak and cheek that the sound path showed match with the distance d_1 adjusting the ***Zero Offset*** value (t_{Off}) if necessary.

For the first peak the sound path showed will be:

$s_{e1} = c_e(t_o - t_{Off} + t_1)$ (Eq. 5)

The condition that allows the correct adjustment of ***Zero Offset*** *(t_{Off}) is:*

$s_{e1} = d_1$ (Eq. 6)

For the second peak the sound path showed will be:

$s_{e2} = c_e(t_2 + t_1 + t_o - t_{Off})$ (Eq.7)

The condition that allows the correct adjustment of ***material velocity*** *(c_e) is:*

$s_{e2} = d_2$ (Eq. 8)

As $t_{Off} \to t_o$ and $c_e \to c_{er}$, where c_{er} is the actual material velocity in the test block the condition expressed in Eq. 6 and Eq. 8, gone be satisfied and the calibration done.

5. Autocalibration

The ***Autocalibration*** function is included by most of the last generations of commercial flaw detection ultrasonic equipments [3-4] and the idea is so easy that is difficult to understand why was not included in the first digital versions of most common ultrasonic flaw detection units (surely the habit of always doing things the same way). In the ***Autocalibration*** mode, the first step recommended is to input in the equipment panel the exact values d_1 and d_2, as showed in the **Figure 1** for angle beam case (the same rule applies for straight beam). The equipment can develop the calculation:

$d_p = d_2 - d_1$ (Eq. 8)

The time difference between the two indications, as shown **Figure 4**, is easily measured, using the following equation:

$t_p = t_{1h} - t_{2h}$ (Eq. 9)

Where $\boldsymbol{t_{1h}}$ is the time measured from the instant where the excitation pulse was emitted to the arrival of the first indication and $\boldsymbol{t_{2h}}$ is the same but referred to the second indication.

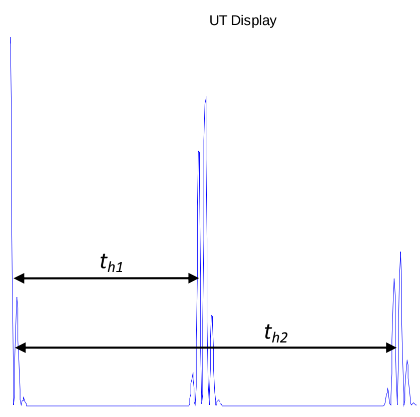

Figure 4. Schematic representation of the UT display showing the first two indications.

At this point is convenient to indicate that the measured value of time $\boldsymbol{t_{1h}}$ and $\boldsymbol{t_{2h}}$ depends on what point of the vertical position of the indication is selected to make the measurement. This is the reason why the flaw detection UT has the modes peak and flank. By experience, a better calibration is obtained in the flank mode, with the gate placed at 10% threshold. It is recommended to maintain the gate at the same threshold until the calibration has finished.

The actual ***material velocity*** is calculated and automatically updated using the following expression:

$c_{er} = \frac{d_p}{t_p}$ (Eq. 10)

Knowing the actual ***material velocity***, the time $\boldsymbol{t_1}$ showed in **Figure 3**, can be calculated: $t_1 = \frac{d_1}{c_{er}}$ (Eq. 11)

The ***Zero Offset*** value is fixed using: $t_{Off} = t_{1h} - t_1$ (Eq. 12)

The time base calibration is done.

6. Bibliography

[1] Cheeke D., Fundamentals and Applications of Ultrasonic Waves, CRC Press 2002. FL, USA ISBN 0-8493-0130-0.

[2] Ginzel E.A., Automated Ultrasonic Testing For Pipeline Girth Welds, Olympus NDT, MA, USA. ISBN 0-9735933-2-6.

[3] Krautkramer Branson USN 60 Operator Manual

[4] Olympus Epoch 4 plus Manual