Calibrating the Ultrasonics

In any piece of measurement equipment, proper calibration is essential. Calibration of an ultrasonic bolt load measurement is a very complex subject, but it is important to understand.

For many application, the default factors are completely adequate, and no further calibration work is required. For the highest precision, however, individual bolts must be calibrated.

There is a lot of confusion over proper calibration of ultrasonic bolt measurement. Hopefully, this section will explain what all these different factors are and what their effect on the measurement is.

This page does not address calibration for load measurement. If you want to convert the reading into load you can read about load calibration.

Transducer Calibration

Transducer calibration is sometimes called artificial zero calibration. The point is to establish what is essentially the y-intercept of the time versus length graph.

When converting from time to length, we use the equation D=RxT (distance equals rate times time), however things are not quite so simple. Transducers vary slightly because of the thickness of the crystals and the wear plates. The length of the cable slightly effects the reading. Delays in the electronics of the instrument also contribute. Thus the correct equation is D=Rx(T-To). We have to subtract (or add) a small amount of time to compensate for fixed delays in the instrument and transducer.

In practice, transducer calibration is usually accomplished by measuring a test sample of known length and sound velocity. The delay time is then adjusted to make the test piece read the same as the known length of the block.

This delay time is arbitrary and does not effect the accuracy of an elongation measurement as long as it is consistent from unloaded length measurement to loaded length measurement. Why is this? Because when the two measurements are subtracted to get the difference, the delay times are subtracted and cancel. This is why it is a bad idea to constantly readjust your delay value. The operator may frequently check the delay value (called SYSTEM ZERO in the USM-1), but it is not advisable to change the value unless the instrument or transducer are damaged and must be replaced.

A perfectly suitable means for setting up a delay factor is to make a master bolt. Take a bolt that is representative of the ones you are measuring. Make sure to pick one that gives a good, strong, repeatable signal and length. Set the SYSTEM ZERO to a value of zero, and the velocity to the default velocity. Measure the unloaded length of the bolt and mark it on the size of the bolt.

During the job, perhaps at the shift, recheck the length and verify that is hasn't changed. If you do have a problem with either the instrument or the transducer, use this master bolt as a reference standard - place that transducer on the bolt and adjust the SYSTEM ZERO until it measures the length correctly.

Velocity Calibration

Sometimes velocity calibration is included in transducer calibration. It's important to realize the difference between these two items.

Modern bolt measurement systems utilize quartz crystal clocks and are very stable and accurate, even over a wide range of temperature. Trying to use measurements of a block to calibrate the quartz oscillator is like trying to use a sundial to set your wristwatch. The wristwatch is far more accurate that the sundial could ever hope to be. Still if there is something wrong with the wristwatch (the batteries are dead!) then the sundial might be more accurate.

So, its not a bad idea to use calibration blocks to check and verify that the velocity of the blocks is within tolerance, but don't adjust the velocity to match your blocks! The next time you measure them, and the temperature has changed by a degree, you will find yourself setting the velocity back to what it was!

Velocity doesn't vary much in steel, but it is enough to cause problems with calibration blocks. A rule of thumb for steel is that the sound velocity is usually within plus or minus 0.2 percent. This means that on a ten inch calibration bar, the length could be off by 0.02 inch - and remember that even if you adjust this velocity to read the exact length, the next bar you check might be 0.020 inch the other way!

Having the wrong velocity has very little effect on the elongation reading. If you change the velocity by 0.2 percent you effect the length of our ten inch bar by 0.02 inch, and you effect the load reading by 0.2 percent. If the total elongation was 0.010 inch, you would change this by 0.00002

Stress Factor Calibration

The stress factor is the ratio of the mechanical length change divided by the ultrasonic length change. Another confusing area, but one which is very important to understand.

When we apply load to a bolt, it stretches mechanically. The sound velocity also drops due to density changes. This causes the apparent ultrasonic length to change more rapidly that the physical length change.

For example, suppose we stretch a bolt 0.010 inch mechanically. If we take the ultrasonic length of that bolt when it is tight, and then subtract the ultrasonic length of the bolt when it loose, we don't get 0.010 inch! In fact, we get almost three times that length. This is what the stress factor does, then, it compensates for the velocity change as stress is applied to the bolt.

The stress factor is almost constant for steel. There are other materials which have some different stress factors, and for extremely exacting work, the stress factor should be calibrated on a sample of the actual bolts being used.

Temperature Factor Calibration

If the temperature of the bolt stays the same from when the unloaded length is measured to when the elongation is measured, there is no need for temperature compensation. Often, however, this temperature changes, and it must be compensated for.

A change in temperature of the bolt effects its length, both physically as well as ultrasonically. By saving the temperature of the unloaded length measurement, and measuring the current temperature, the elongation can be corrected.

The needed temperature is the average temperature of the bolt. This can be very difficult to obtain in some circumstances. Often it is best to simply make a measurement of the super structure or body that the bolts are being assembled into to prevent error from handling the bolts or temperature sensor.

Small changes in temperature are not important for all but the most critical applications. It is easy to get an idea of the effect temperature has on the measurement. Take the bolt that you want to know about, measure an unloaded length and then place the measuring instrument into elongation mode. The display should indicate an elongation of zero. Now change the temperature by a small amount, say five degrees fahrenheight. Now return to measuring elongation. You will see the effect of 5 degrees of temperature change on the elongation. Typically errors of less than five degrees will not have a large effect on the elongation. They will be a problem when the bolt is much longer that the grip length, in other words when the area under stress is a small fraction of the total length of the bolt.

The temperature factor can be calibrated by placing a transducer on a bolt, slowly and carefully varying the temperature of the bolt, and adjusting the temperature factor such that the bolt remains a constant length. It is not easy to do this. Insufficient time for the bolt to reach a constant temperature can cause large errors. It is best to make several runs and then plot the ultrasonic length versus temperature. If you do not get a straight line, something is wrong with the measurement process.

In practice, temperature calibration is only attempted when extreme ranges of temperature are used, such as measuring bolts on a cold engine and then after it has been running and heated up. For other applications that are not so demanding, standard temperature coefficients can be obtained from the operating manual.

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