



High Temperature Corrosion Testing

Ultrasonic Thickness Testing up to 550 °C

Ultrasonic thickness measurement is a common industrial method used to measure the thickness of solid materials, with access only from one side of the test object. Its main field of application is to check the remaining wall thickness of objects which are subject to corrosion or erosion, like piping or vessels. Most measurements are made at temperatures up to 60 °C, where standard equipment and procedures can be used.

However, there are exceptions. In the refining and chemical industry, it is often necessary to check the wall thickness of plant components which may reach temperatures of 60 °C to 550 °C and cannot be cooled down during corrosion measurement. Temperature is also one of the factors that accelerates the corrosion process, so the measurement must be performed more frequently, compared to colder objects. Many refineries and chemical plants carry out regular spot checks of remaining wall thickness, in order to properly assess the corrosion rate and predict necessary replacements. These measurements are typically performed manually, using specially designed equipment and modified test techniques.

Measurement Method

Measurements at high temperatures are not easy to take. Therefore, special care is required not to expose yourself to burns. Operators are accustomed to wearing suitable protective clothing, while working under conditions of strong heat radiation, often in places that are difficult to access. To

ensure the safety of the operator and to prevent damage to equipment, measurements are taken at a duty cycle, not continuously.

Challenges

Ultrasonic probe

The ultrasonic probe is naturally the element of the measuring system most exposed to heat. The construction of a standard probe is based on piezoelectric materials and backing materials which cannot withstand a continuous temperature above 60 °C. Around the Curie temperature, piezoelectric material becomes depolarized and disbonding starts between the piezo element and the backing material (damper). Due to the varying shrinkage of the materials used to build the transducer under the influence of temperature, other damage (disbonding) may also occur. In all cases, the probe is permanently damaged, so special materials are required to build a high temperature probe. The most important factor in choosing the right ultrasonic probe is therefore the maximum operating time at the working temperature, which guarantees the safety of the probe.

Changes in examined materials under high temperatures

Correctly conducting measurements on hot objects also requires knowledge of the changes that occur

in the examined material under the influence of temperature. An important factor is the influence of temperature on ultrasonic waves. An increase in temperature causes an increase in the material's attenuation, and a decrease in the ultrasonic wave velocity. The molecules of the material begin to bounce rapidly in a random motion and as a result, the ultrasound signal is transmitted less and less effectively. In carbon steel, the decrease in sound velocity is about one percent for every 100 °F or 55 °C. Attenuation, or loss of energy, increases in high temperature materials for the same reason and it becomes more difficult to obtain a strong recognizable signal.

Ultrasonic couplant

Ultrasonic coupling also plays an important role in the measurement process, as it removes the air gap between face of the transducer and the test object. It ensures effective transmission of the ultrasonic wave to the test material. Standard low temperature couplant will fail in a high temperature environment, as it evaporates quickly, losing its properties. For this purpose, special coupling pastes are used, which, under the influence of high temperature, change their state into fluids and thus allow effective testing.

Due to the inability of the couplant to retain a viscous form at high temperatures, contact time for even the best couplant is very short. The signal appears briefly, then diminishes rapidly before disappearing completely. Therefore, a powerful A-scan display device with signal freezing function is required to evaluate the amplitude when contact with the material ceases.

Equipment

In view of the above challenges, the following selection criteria should be applied when selecting measuring equipment (in addition to the requirements for low temperature measurements):

Ultrasonic Probe

- **Lowest possible duty cycle for exact temperature for the application (maximum contact time plus cooling time before next use)**
- **Probe sensitivity at application temperature (many probes degrade in performance rapidly at high temperature, despite high temperature rating)**

Specialized ultrasonic probes offer the possibility of continuous operation up to 350 degrees Celsius,

as well as significantly extended operation cycles up to 550 degrees. The maximum cooling time between measurements is only 1 minute as the probe housing must only cool to 350 degrees Celsius, which means that the operator does not have to worry about long cooling. This translates to minimum pause between the measurements.

Ultrasonic gauge

Ultrasonic measurement at high temperatures is difficult due to many factors. Therefore, the thickness gauge should have the following features:

- **Powerful pulser: high power transmitter (400V rectangular transmitter which can provide enough energy to drive the probe to compensate for high attenuation losses)**
- **High gain and low noise device with digital filters: The received signal, which usually only appears for a short time, needs to be a decent quality for accurate evaluation. Devices which include digital filters have an advantage.**
- **Display & freeze function: Furthermore, a reasonable size of the display for A-scan evaluation as well as a freeze function which allows to adjust the gates while freeze are a big advantage.**
- **Maximum operation temperature: Since heat radiation will be an important factor, the maximum operating temperature of the device is also important, as many devices can suddenly switch off during measurements due to battery overheating.**
- **Dedicated software functions such as automatic zeroing of the probe in the air, i.e. compensation of the delay line, or compensation of the wave velocity in the material increase the accuracy of the measurements obtained.**

Ultrasonic Couplant

The working range of the couplant guarantees that it will not vaporize or boil before the actual measurement can be taken. It will also not solidify too fast (this would create a sound barrier), and when it finally melts, it doesn't emit dangerous or noxious vapors. Prior to using the couplant on the test object it is recommended to check the concentration of the crucial elements, to avoid causing local corrosion if residue is not cleaned.

The following factors should be considered when using coupling agents for ultrasonic testing:

- **Working range of the couplant**

- Chemical composition if local corrosion is an issue
- Stable transmission factor at high temperatures
- Vapor, smokes when melting
- Easy to clean and apply

Measurement procedure

To describe the measurement procedure, it is helpful to analyze possible sources of error during the measurement:

Reduction of the speed of the ultrasonic wave as the temperature increases

In carbon steel, it is estimated at around 1% per 55° Celsius. This means that the return time of the ultrasonic echo will increase and in the absence of speed correction the result will be artificially high. This error increases with the thickness of the test material and the temperature increase. To avoid this error, it is important to perform a calibration procedure using a test block of the same material and temperature as the tested material. The best practice is to heat the calibration block on the measurement spot until it reach the same temperature. If this is not possible, appropriate sound velocity correction should be applied. It is most convenient to do this in the software of the device because it provides immediate feedback to the operator for correct evaluation.

Increased material attenuation as the temperature increases

In carbon steel, it is estimated that attenuation of a 5MHz longitudinal wave at room temperature is 2dB per 100mm distance. This mean that for ultrasonic measurement, which is based on returned echo, a correction of 4dB per 100mm has to be done (round trip). At 500°C the attenuation is as much as 30dB (approximately 20 times higher). Significant gain adjustment is needed to obtain a decent signal.

Shifting of the probe zero with temperature change

When in contact with a hot object, the probe's delay line heats too. The time of flight of the ultrasonic wave between the piezoelectric material and the probe's face is longer. Thickness readings become artificially high. This error is difficult to correct due to the lack of precise information on the temperature of the delay line, as it does not heat up uniformly and immediately upon contact.

To avoid this error the best practice is to keep the probe on the test object until it reaches same temperature. With the TS5H probe this can be done up to 350°C; above this temperature, the error can be minimized by frequently performing the zero in air procedure in the device.

Applying the couplant

As mentioned earlier, the time of contact between the couplant and the object is usually short, so the correct procedure is to apply it directly to the probe's face before each measurement, instead of using it directly on hot object. When couplant is applied on the face it is recommended to press the probe firmly to the test object without grinding or twisting, in order to maintain a decent layer of couplant underneath the probe, thus guaranteeing a good transmission.



SONOSCAN TS5H for High Temperature UT

We offer a **Heavy Duty Working Kit** for high temperature corrosion UT.



High Temperature Thickness Measurement with SONOWALL 70 and ultrasonic probe SONOSCAN TS5H

Recommended equipment

SONOTEC offers a high temperature corrosion kit for the SONOWALL 70 A-/B-Scan thickness gauge.

The complete kit consists of the following components:

- SONOWALL 70 - High-End A-/B-scan thickness gauge with powerful pulser up to 400 V and 60°C ambient operating temperature
- Temperature compensation - Function for automatic adjustment of the sound velocity of hot test objects
- SONSOCAN TS5H ultrasonic probe – for precise high temperature measurements up to 550°C and 350°C with no duty cycle, including armored cable and handle extension
- SONOGRID Corrosion Management Software - for efficient collection of linear/2D/3D matrix data
- Heavy Duty impact protector set - for maximum protection against shocks and drops



High Temperature Corrosion Kit for SONOWALL 70

Contact and Support

SONOTEC GmbH
 Nauendorfer Str. 2
 06112 Halle (Saale)
 Germany

☎ +49 (0)345 / 133 17-0
 ✉ sonotec@sonotec.de
 🌐 www.sonotec.eu
 🏆 Certified according to ISO 9001

SONOTEC® is a registered trademark

Rev. 4