Stephan Falter, Baker Hughes, a GE company, Germany, details how innovations can enhance confidence in the operational integrity of seamless tube and pipe.

Seamless tube and pipe is widely used throughout the oil and gas sector, as it offers significant advantages over longitudinally welded pipe in terms of better torsional and axial strength, as well as higher burst pressure. However, seamless pipe can also carry intrinsic flaws and defects, which can affect its operational integrity. As a result, stringent inspection procedures are performed by pipe manufacturers. To date, these procedures have been unable to identify specific flaws with absolute certainty, but with the introduction of a new inspection technique from Baker Hughes, a GE company (BHGE), it is now possible for pipe mills to carry out 360° gapless inspection of seamless tube and pipe.

Typical applications for seamless pipe in the oil and gas sector include: drill strings, thick walled pipe with good torsional strength used for drilling, well casings, to line wells after drilling, needing good axial strength and high burst pressure; and line pipe, which is attached to the well head and is used for gathering lines to connect several wells. Offshore, line pipe can be called riser.
pipe and it needs to have good axial strength and fatigue resistance.

All metals, and all pipes, contain defects. These can range from defects on an atomic scale, to larger defects that are induced during processing. The detection and identification of these defects is the primary purpose of pipe inspection. Typically, quality assurance procedures and standards are intended to assess any defects in terms of size, sharpness, orientation and location, in order to determine whether those defects will compromise integrity during a pipe's operational life. To understand this more completely, it is worthwhile to have a look at the way in which seamless pipes are manufactured.

**Defects in seamless pipe**
The majority of seamless pipe begins life as a hot steel billet or ingot. The casting or forging of billet can introduce a range of defects, including holes and porosity, as gas dissolved in the molten metal is ejected or trapped on solidification. Inclusions can also be present and these can be in the form of indigenous inclusions, which are small particles such as sulfides, oxides or silicates, formed by chemical reactions between the various constituents of the alloy and with the atmosphere. There can also be exogenous inclusions, which result from the accidental inclusion of foreign matter, such as bits of refractory lining into the casting.

However, defects are not only introduced during the casting stage, but can also appear as a result of the pipe-forming process itself. Seamless tube is produced by first introducing a piercing mandrel, which is forced through the length of the cylindrical, hot metal billet to create a pipe. As the mandrel passes through the billet, rollers act on its outside circumference so that the tube length is extruded and the final outside diameter of the tube or pipe can be established. Using this technique, known as the Mannesmann process, it is possible to produce pipes with outside diameters from 60 - 660 mm and wall thicknesses from 3 - 125 mm. Single pipe lengths can be up to 28 m.

However, the tube manufacturing process itself can also create defects. Small surface cracks in the original ingot can be further developed by rolling, poor mandrel lubrication can cause cracks or tears, and scratches can be caused by rough dies and mandrels.

**Inspection techniques**
There is a range of techniques for the nondestructive testing of metals. Eddy current technology and magnetic particle inspection are often applied in the field to detect near surface or surface breaking cracks. Radiography is often used for in-depth weld inspection. Hydrostatic testing can also be used in some cases. But, perhaps the most widely applied technology is ultrasonic testing (UT) inspection. This
is used widely for in-service inspection, as well as for the inspection of pipes and tubes in pipe mills.

As mentioned earlier, all metals contain defects and the acceptance criteria embodied in inspection standards, such as BS EN 13445, relating to UTs specify identification of planar indications based on the height, length and amplitude.

Seamless tubes are tested for various flaw types in the pipe wall, over the entire circumference and length. Because of the manufacturing process, longitudinal flaws, which are parallel to the length axis of the pipe, are the most common in seamless tube and pipe. But, historically, inspection has also covered transverse flaws, which are at right angles to the longitudinal axis, wall thickness measurement, eccentricity, ovality and testing for lamination type flaws. High specification, hot finished seamless tubes for the oil sector are also tested with differing degrees of success, for oblique flaws. But more of this later.

**Conventional UT seamless pipe inspection**

UT pipe inspection is usually carried out inline. A UT inspection machine consists generally of four parts: a mechanical system to rotate or convey the tube to be tested or to rotate the probe carriage; a carriage that contains the UT scanning probes, the probe couplant delivery system and the mechanics to raise or lower the probes into contact with the pipe; the front end electronics, which operates and controls the probes, ultrasonically and mechanically; and the back end electronics for evaluation of the inspection data. Basically, three types of tube or pipe inspection are possible. The tube can be transported linearly, in which case the probe carriage rotates, or the tube can be transported helically, when the probes are stationary. If the tube is stationary but rotated, then the probes are guided along the tube length. In all three cases, the probe track is helical.

**Developments in inspection**

Historically, probe carriages carried two kinds of probes: longitudinal (compression) probes to identify and size longitudinal flaws; and transverse (shear) probes, which are fired at various angles to identify and size transverse flaws (Figure 3). Shear wave probes are fired at various angles and need to be adjusted to cover a wide dimension range to capture the flaws. This meant that a probe carriage would carry a number of individual shear wave probes.

**Phased array probes**

The introduction of phased array probes introduced a paradigm shift in inspection. Phased array systems rely on the computer-controlled excitation of each element in a linear multi element probe in terms of the element’s amplitude and the delay between the energising of consecutive elements. In this way, the small wavefronts created can be time delayed and synchronised for phase and amplitude such that a focused, steerable beam is produced. As a result, a single phased array probe can perform those inspection tasks normally requiring large numbers of conventional probes or multiple scanning passes. This means that inspections are faster, inspection equipment is more flexible as setup change over can be
achieved very quickly and there is no need to use different sets of probes for different inspection tasks.

**High end electronics platforms**

With the development of phased array came the need to create electronics platforms capable of operating and controlling the more complex probe systems and of handling the increased data from inspections. One such platform is the USIP|xx from BHGE. The USIP|xx is today’s most powerful electronics platform for UT testing machines. While earlier platforms were capable of operating all the UT functions in up to 60 channels, the USIP|xx has the capability to handle up to 768 parallel phased array channels per rack. This offers better flaw knowledge and allows more comprehensive inspection coverage, such as that provided by the paint brush technique.

The paint brush technique permits the detection of oblique flaws, aligned at angles of up to 45˚ to the tube longitudinal axis, as well as longitudinal and transverse flaws. With this technique, all elements of a phased array probe are fired simultaneously. The received signals are stored and then evaluated in a special pattern (sub cycles), related to the different sound transmission angles, with time delayed receiving of the sound energy. The high speed signal processing of USIP|xx combined with the ability to transmit and receive the entire angle scan pattern in a single evaluation cycle then allows an inspection for oblique defects, as well as longitudinal and transverse defects at high pulse repetition frequencies, using the same array probe.

Powerful electronics platforms have also allowed the exploitation of 2D array scans to provide even more comprehensive inspection coverage. Conventional phased array probes are arranged linearly, but 2D probes have elements arranged on both the x and y-axis so that the pipe wall can be flooded with ultrasound. Electronics platforms such as the USIP|xx have the capability to handle this huge amount of inspection data. These recent developments have now been combined with a unique algorithm to create ShapeUT.

**ShapeUT**

By combining sophisticated existing technology with a technique to produce an acoustic hologram, ShapeUT provides industry’s first gapless oblique inspection method for seamless tube and pipe.

Specifically, ShapeUT uses the USIP|xx electronics platform with 2D matrix array transducers to acquire panoramic information on anomalies in a pipe. This vast amount of data is then mathematically processed by a specially developed algorithm. It provides a clear indication of all the flaws in the pipe wall, regardless of orientation, by creating real UT holograms and producing soundfields with superior properties.

Online at the pipe mill, the results can then be shown as simple indicators, identifying where in the pipe wall all flaws occur, to allow reliable Go-NoGo sentencing of the pipe. Alternatively, attention can be focused on particular sections of the pipe, which require further investigation and, here, a C-scan type inspection image is created. Consequently, for the first time, the pipe manufacturer can now be certain of the actual integrity of the pipe he supplies to end users.

**Conclusion**

Plant integrity is essential in the oil and gas sector, both to ensure safety to employees and the environment, and to avoid any financial losses that result from unanticipated plant shutdown or product leakage, catastrophic or otherwise. In addition, consideration must also be given to the impact of pipeline failure on a company's reputation.

All oil and gas companies operate strict, in-service inspection regimes. However, sometimes, pipe or tube failure can be due to faults in the supplied materials, which are exacerbated during normal operations. Manufacturing quality standards exist to mitigate these failures but these standards are based on sentencing flaws that can be identified. To date, no inspection system has been able to provide 360˚ gapless inspection for oblique flaws in seamless tube and pipe. ShapeUT fulfills this long-standing need and ensures that end users can now have greatly enhanced confidence in the integrity of supplied seamless tube and pipe.