DESTRUCTIVE TESTING OF WELDED STEEL TUBULARS

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Steady evolution of Non-Destructive Testing equipment has dramatically reduced the number of weld defects being sent to customers. However, even the best NDT equipment does nothing to prevent those defects from occurring. Total reliance on NDT technology can lead to serious losses in productivity when inspection is used to replace prevention. Early detection of defects is essential to rectifying the problem in order to minimize the defective footage produced.

Because the interpretation of NDT results can be made in error, destructive methods are often used as verification. The destructive methods can also supply a “quick and dirty” evaluation for immediate use by production personnel. While destructive methods cannot evaluate an entire run of pipe as can NDT, they can give a fair evaluation of the mill setup, steel quality, and welding and normalizing practice.

The following is a brief review of destructive testing commonly used in the production of High Frequency Induction and Contact welded pipe and tube.

TRANSVERSE WELD AREA EVALUATION

One of the best tests for the weld setup is the TWA evaluation. This test is simple, quick and should be performed at every gage or setup change to ensure that the strip edges are coming together flat and parallel into weld rolls. A cutting torch is used to cut the Vee area out of the pipe (Fig 1). The Vee is split open and the section is viewed looking at the edge which is half welded and half unwelded. The welded portion will be bright and shiny and the unwelded edge will be dark from heat tinting. If the line between the light and dark areas (welded and unwelded) is vertical, the edges are meeting square and parallel. If the line is sloped, the edges are coming together peaked. Peaked edges are prone to create bond line defects such as entrapments as well as cold welds on the O.D. Additionally, welding with peaked edges takes more power than welding with parallel edges and the overheated inside corners may melt off and destroy impeder casings. The ID bead on peaked welds is usually larger than beads from welding with parallel edges so ID scarfing is more difficult and more metal

Transverse Weld Area Sample

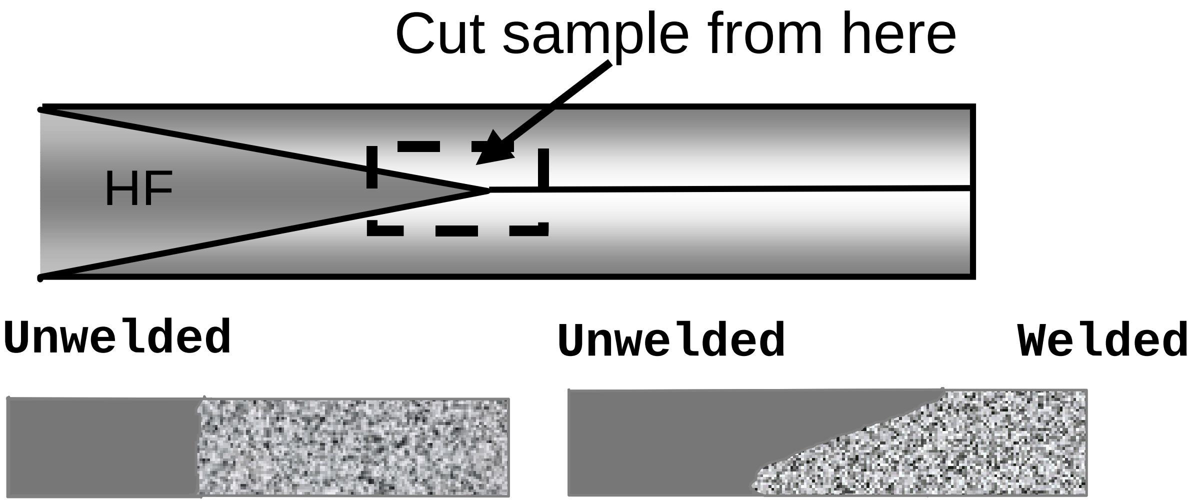

Fig 1

is wasted in squeeze out. Note that peaked edges can be the result of improper fin design or because of spring back of heavy or stiff strip. Edge forming is a significant help in preventing peaked edges.

Weld Area Microstructures

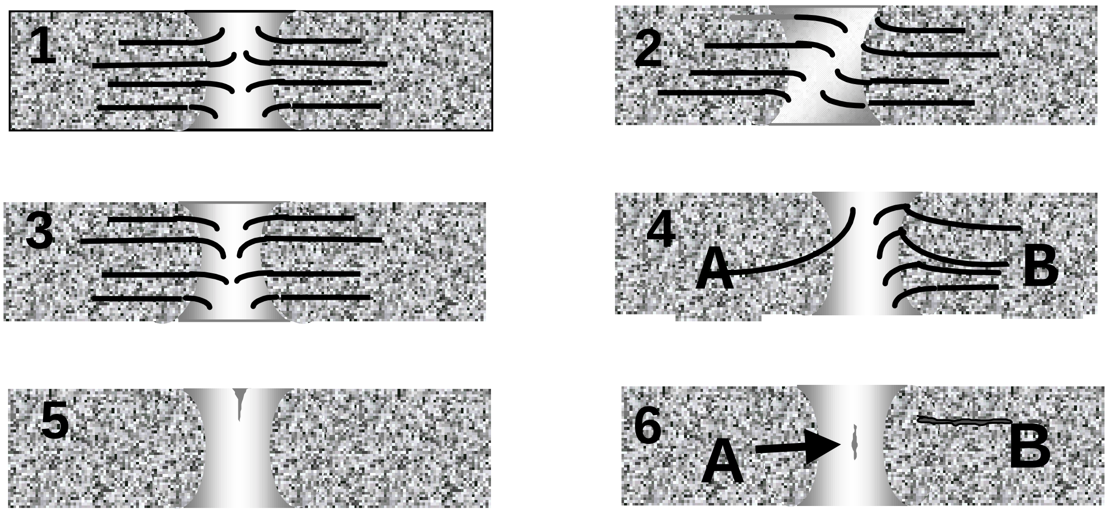

Fig 2

WELD AREA MICROSTRUCTURES

A weld area microstructure can provide a wealth of information on weld quality and edge presentation. The sample should be taken with care using a cutting torch. The sample should be large enough that the heat from the cut does not influence the microstructure. The degree of upset, the uniformity of the squeeze, flow angles and microstructural constituents can be determined using standard metallurgical preparation techniques and a metallurgical microscope. Figure 2 illustrates some of the basic conditions observable.

The most obvious structure to be observed is the flow angles. The lines or bands visible in the steel are the result of the rolling operation at the steel mill. These lines are usually straight, running parallel to the rolling direction, i.e., longitudinally. When the weld is made, the hot steel “bulges” (upsets) in the weld area. The angle and symmetry of the flow lines is an indication of the degree to which the edges are presented flat and parallel.

The specimens should be ground, polished and lightly etched to show the grain structure and flow angles. Viewing at low power, 50-100X is best. Volume 9 of the American Society for Metals and Materials Handbook Series presents clear descriptions of all preferred techniques for sample preparation and should be consulted if you are not thoroughly familiar with metallographic processes. If you still have questions, feel free to call Thermatool for assistance.

Figure 2-1 shows a normal HF weld area. The hourglass heat affected zone and flow lines are symmetrical around the bond line. Figure 2-2 shows a weld area resulting from non-parallel edges resulting in a skewed bond line and hourglass. Not shown is the undercutting of the ID and OD which results when off-set edges are scarfed. This undercutting may seriously reduce the wall thickness in the weld area. Figure 2-3 shows the weld area of a peaked weld. Because the inside edges are closer together than the outside edges as they pass through the vee, the ID gets hotter than the OD. The double vee created may also encourage entrapments on the bond plane. Figure 2-4 shows a typical hook crack and bond line defects such as penetrators or entrapments.

If the flow angles are very steep, i.e., approaching vertical, preferential corrosion may attack the upturned fibers, penetrating the wall along side the weld. If the flow lines turn up and then turn down, you may be seeing the result of edge deformation in slitting being compounded by the normal welding upsetting (Fig 2-4c)

If the hourglass is very narrow in the center, too much squeeze is being applied by the weld box. If the bond line shows a cast metal structure, too little squeeze is being applied. Both situations can result in a weak bond or brittle welds which can fail flattening and flare tests.

If your process includes seam normalizing, regular samples should be taken to evaluate the centering, penetration and heat effects. Samples for evaluation should be prepared with the same care as described above for weld area micros with special care taken not to overheat the specimen when cutting or grinding it. Figure 3 illustrates some common effects of seam normalizing.

Seam Normalized Weld Areas

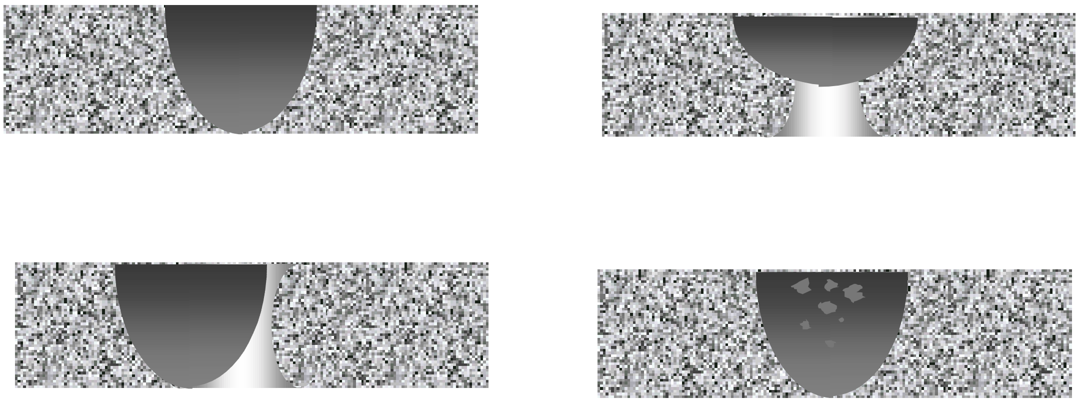

Fig 3

Figure 3-1 illustrates a properly centered seam normalizing heat affected zone. It penetrates the full wall thickness and is centered over the weld hourglass. If the proper temperature has been achieved, the grain structure after normalizing will be very similar to the parent metal. The ferrite bond line should be obliterated or signifi cantly reduced. Figure 3-2 shows insufficient depth of penetration of the seam normalizing heat. The top half of the weld hourglass has been normalized but the bottom half remains as welded. Figure 3-3 shows an off center HAZ caused by improper position of the weld line relative to the inductor bar. While the heat has penetrated full depth, it has not completely affected the entire weld area. Figure 3-4 shows the results of using a very high normalizing temperature. Above 1750 Deg F grain growth may occur which may weaken the weld area or lead to weld area corrosion.

FLATTENING TESTS

The flattening test is often performed on several or all pipe in each coil. While being a poor substitute for a full NDT inspection of the weld, it does give a good evaluation of the weld area ductility and can occasionally alert you to the presence of bond line defects. The flattening test can test both the ID and the OD by changing the orientation of the weld from the 12 o'clock position to the 3 o'clock position. Crushing the ring in the 12 o'clock position puts the ID in tension and the OD in compression; the 3 o'clock orientation does the opposite. In any case the sample should be at least as long as the pipe diameter up to a maximum of about 4" long. Rough edges and burrs can be removed prior to crushing. Figure 4 illustrates the two positions.

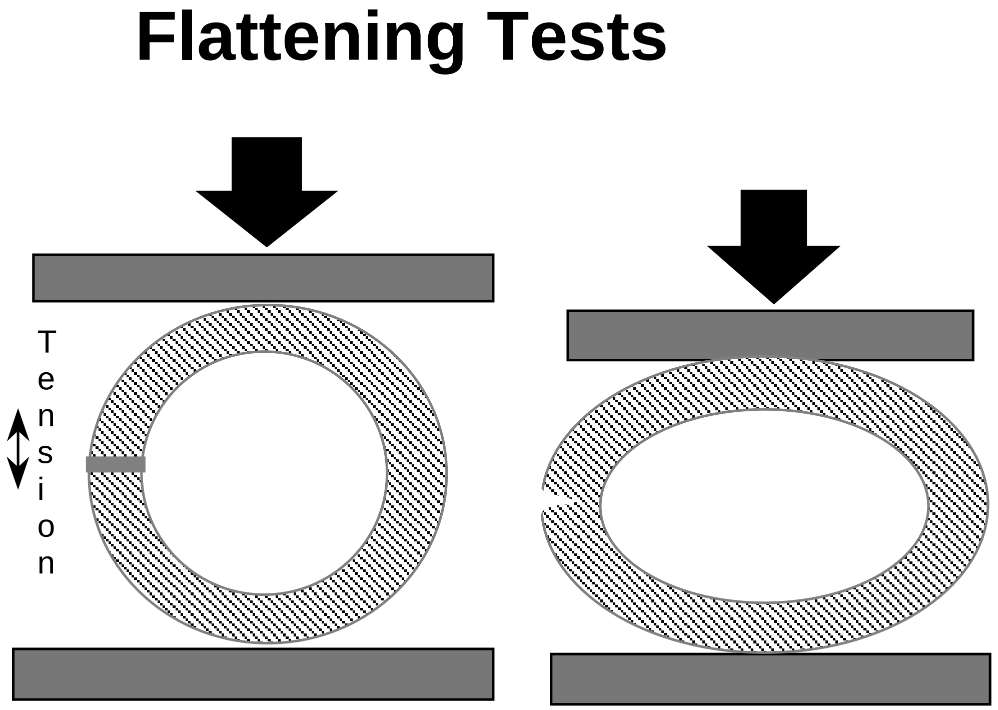

Fig 4

Any flattening test apparatus should be designed with operator safety in mind and interlocks incorporated into its operation that preclude actuation while the operators hands are in the press.

Typically, when specified by an organization such as ASTM or API, the pipe sample must be crushed to a specified height (expressed as a dimension or % of diameter) without fracture in the weld. Brittle welds due to improper normalizing or welding will usually fail before the minimum height is reached. The presence of bond line defects will also cause premature failure. Effort should be made to identify the cause of the failure and rectify the condition as soon as possible rather than continue running and making bad product, hoping you will “weld through it”.

For a more complete treatment of HF weld defects, refer to the publication “High Frequency Pipe and Tube Welding” available from Thermatool.

FLARE TESTS

One of the least valuable and most popular tests is the flare test. This test involves flaring one end of a short sample of tube by forcing it over a mandrel or expanding it. See Figure 5. In theory, the test looks like it closely resembles the manufacturing processes the tube will undergo and should be a valuable evaluation of the tube. However, several problems limit the usefulness of the test.

First, a small defect at the very end of the tube may fail while a larger one further in from the edge does not. Which defect is most critical? Deep scarfing may reduce the wall thickness causing a weld area failure. Conversely, high weld bead may reinforce a weak weld and allow it to pass. Also, if the bead is left in place during the test, the mandrel will force the bead into the body of the tube and may cause premature failure or possibly reinforce a bad weld and allow it to pass the test.

Flare, Flange and Expansion Tests

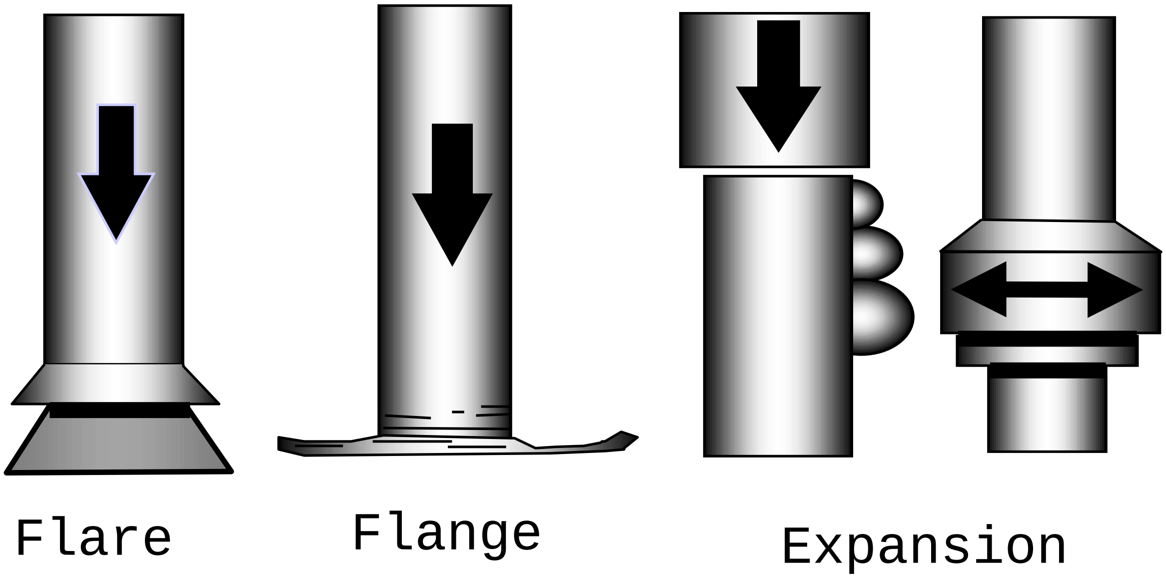

Fig 5

Even if done perfectly, the test is sensitive to the yield strength of the tube and may fail in a soft weld which is free of defects and pass on a hard weld with defects. Flange tests and expanding plug test suffer from similar limitations.

BEND TESTS

The most common bend test is the reverse bend. A short piece of pipe or tube is cut and then slit at 90 degrees to the weld (Fig 6). The section with the weld is flattened out and mounted in a vice and bent backward to put the ID in tension. It is used to evaluate ID defects and normalizing depth of penetration but the flattening test is easier, faster and just as useful.

NDT VERIFICATION

Defects found by NDT should regularly be evaluated destructively to aid in the interpretation of the NDT signal. A cutting torch can be used to cut out the sample containing the defect. The sample can be saw cut, ground, polished and viewed on a metallurgical microscope to evaluate defects like hook cracks. A nick-break test is better at evaluating defects such as penetrators, cold welds, and entrapments (Fig 7). The nick-break uses the same type of torch or saw cut sample but it is nicked on each end to create a stress riser on the weld, then broken open along the bond line. A flattening or crush test can do the same thing.

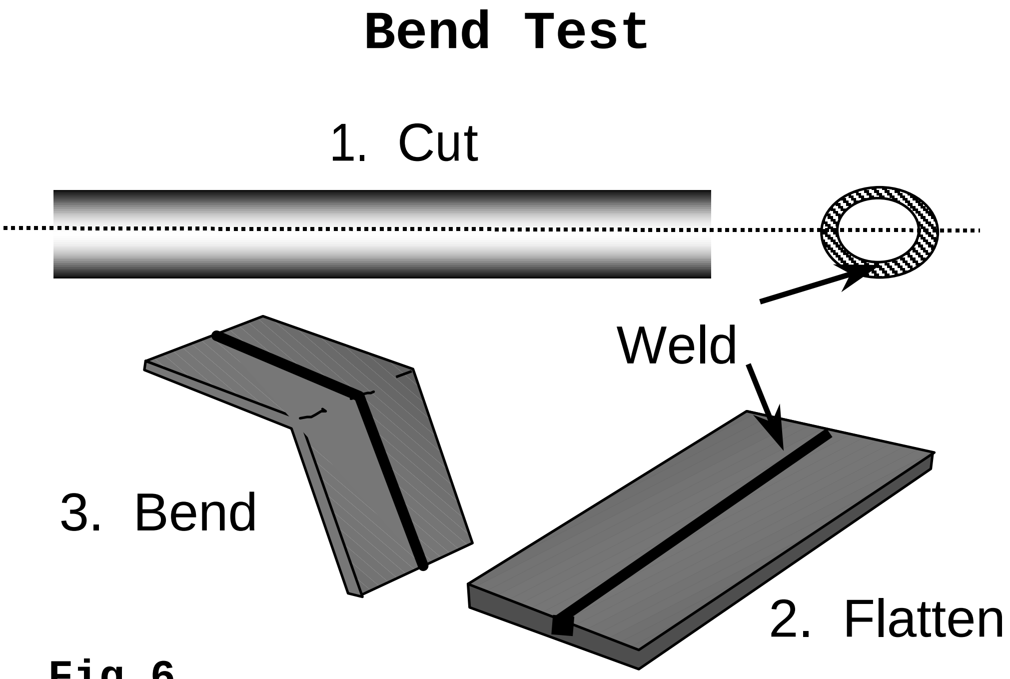

Fig 6

CONCLUSION

Destructive testing is a valuable tool when used in support of a defect prevention program and NDT systems. Operating personnel must have all necessary equipment at their work stations to conduct the tests quickly and efficiently. Proper training in the methodology is very important. The results should be documented so that statistical evaluations can be performed. All efforts to improve quality should start with the goal of PREVENTING the defect from occurring. Relying on finding the defects will invariably add cost and reduce productivity.