ABSTRACT

The use of cold field bends is not practical for some pipeline construction applications, particularly for large diameter pipelines built with restricted work space. For many reasons, the use of segmented induction bends and long-radius elbows becomes a necessary part of normal construction practice.

This paper describes the results of the first phase of a recently-completed joint industry project pertaining to welding of field segmented induction bends and elbows for pipeline construction. In this phase, manufacturing methods, capabilities, and limitations of induction bend and elbow manufacturers were evaluated during visits to manufacturing facilities. Pertinent industry standards and related pipeline company specifications were reviewed. The information was summarized and used to develop examples of generic purchasing specifications for both segmentable induction bends and manufactured elbows. Annotations in the specifications describe the source of key content and highlight content specifically related to segmentability.

INTRODUCTION

Until recently, inadequate guidance was available regarding the use of segmented induction bends and elbows for pipeline construction, and in particular 30-inch diameter pipe and larger. This included a lack of consistency regarding the purchase of “segmentable” elbows and bends, the dimensional characteristics of segmentable fittings, field cutting/beveling/transitioning practices for these fittings, and verification methods to insure adequate girth weld fit-up. When fit-up (internal alignment) is not within specified limits, improved guidance was lacking with respect to pipe wall transitioning and backwelding.

Recognizing the need to develop guidelines for the use of field segmented induction bends and elbows for pipeline construction, Spectra Energy organized a joint industry project (JIP) that was conducted by Det Norske Veritas (U.S.A.), Inc. (DNV). Participation in this project included:

- Alliance Pipeline
- Centerpoint Energy
- El Paso
- Kinder Morgan
- NiSource
- Panhandle Energy
- Spectra Energy
- TransCanada
- Williams

This paper describes the development of guidance for the specification and purchase of segmentable induction bends and elbows. Guidance for field segmentation and related construction practices is addressed separately.

Development of the guidance for specification and purchase of segmentable induction bends and elbows resulted from three main activities:

- Review of current industry codes and standards
- Review of existing company specifications
- Review of manufacturing practices including procedure qualifications and testing, heat treatment, and quality assurance/documentation. An industry survey was conducted to determine current capabilities of various manufacturers of induction bends and elbows with respect to segmentability. Visits to three induction bend manufacturers and one elbow manufacturer were also made.

The deliverable from this first phase of work included a report and companion examples of purchase specifications for...
induction bends and for elbows. Each of the example specifications included comments in the margins describing the sources for and explanation of specific content so that users can decide for themselves if the content is optimized for their own pipeline construction, operating, and maintenance practices. Instructions for downloading the reports for this project, which contain much more technical content, are provided near the end of this paper.

DESCRIPTION OF MANUFACTURING PROCESSES

Induction bends are manufactured by pushing the pipe through an induction coil that heats a narrow band of the pipe to the desired temperature. As the pipe is pushed, the opposite end is swung through an arc having a radius that is the same as the desired bend radius. The locally heated band is quenched by a water spray immediately downstream of the point where the pipe is bending. The process is illustrated in Fig. 1.

Elbows are typically manufactured using either the forged and welded process (two longitudinal weld seams) or the “bend over mandrel” process. In the mandrel process pipe material is heated and bent while a mandrel is drawn through the inside. The mandrel prevents ovalization and maintains a constant inside diameter throughout the length of the elbow.

The elbow manufacturer who was visited prefers to use the forged and welded process to make segmentable elbows. An example of a forged and welded elbow manufacturing process flow chart is illustrated in Fig. 3. The OD is controlled by controlling the circumference during seam preparation, tacking, and welding. The forged and welded method involves the use of plate material that is heated and forged into two halves (clam shells) using a press and a die that will produce the desired radius and diameter as illustrated in Fig. 4. The edges of each half are trimmed and the two halves are then assembled and welded together using two submerged-arc welds (one along the intrados and the other along the extrados). Heat treatment is then performed to obtain the required mechanical properties, as shown in Fig. 5.
REVIEW OF INDUSTRY STANDARDS AND COMPANY SPECIFICATIONS

Several industry standards were identified that specifically address the manufacturing and use of bends and elbows. Each of the standards listed in Table 1 was reviewed with specific note made of content related to dimensional limits that relate to segmentability. Some differences were noted in the way that different standards address dimensional tolerances. Not only are the quantitative tolerances different in some cases, but in some cases, even the definition of the controlled dimension is different. An example is the emphasis on “ovality” versus “out of round” summarized in Table 2.

In addition to the industry standards, nine Company specifications were reviewed. Comparable sections from each specification were copied into a master table so that the contents could be more easily compared. A subjective assessment of what represented the probable “best practice” for each topic was then developed (or copied) and assembled into new example specifications including one for induction bends and one for manufactured elbows.

**Table 1 – Reviewed Standards**

<table>
<thead>
<tr>
<th>Source</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASME</td>
<td>B16.49 – 2007 Factory-Made, Wrought Steel, Butt-welding Induction Bends for Transportation and Distribution Systems</td>
</tr>
<tr>
<td>ASME</td>
<td>B16.9 – 2007 Factory-Made Wrought Butt-welding Fittings</td>
</tr>
<tr>
<td>ASME</td>
<td>B31.11 – 2002 Slurry Transportation Piping Systems</td>
</tr>
<tr>
<td>CSA</td>
<td>Z245.11 – 2009 Steel Fittings</td>
</tr>
<tr>
<td>ISO</td>
<td>15590-1 – 2009 Petroleum and natural gas industries -- Induction bends, fittings and flanges for pipeline transportation systems -- Part 1: Induction bends</td>
</tr>
<tr>
<td>MSS</td>
<td>SP-75-2008 Specification for High-Test, Wrought, Butt-Welding Fittings</td>
</tr>
<tr>
<td>Tube and Pipe Assoc. Int’l</td>
<td>1998 Recommended Standards for Induction Bending of Pipe and Tube</td>
</tr>
<tr>
<td>Offshore std.</td>
<td>DNV-OS-F101 Submarine Pipeline Systems, October 2002</td>
</tr>
<tr>
<td>NORSOK</td>
<td>Std. M-630 Material Data Sheets and Element Data Sheets for Piping</td>
</tr>
<tr>
<td></td>
<td>EDS NBE2 MDS C11</td>
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<tr>
<td></td>
<td>MDS C01 MDS C23</td>
</tr>
</tbody>
</table>

**Table 2 – Examples of Descriptors for “Roundness”**

<table>
<thead>
<tr>
<th>Standard</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO 15590</td>
<td>% ovality: 100 x (Max. OD – Min. OD) / Nominal OD</td>
</tr>
<tr>
<td>MSS SP-75</td>
<td></td>
</tr>
<tr>
<td>ASME B16.49</td>
<td>Out of round: the sum of the absolute values of plus and minus tolerance</td>
</tr>
<tr>
<td>ASME B16.9:</td>
<td></td>
</tr>
</tbody>
</table>
SUMMARY OF KEY OBSERVATIONS

Definition of “Segmentable”:
The most common definition of “segmentable” consisted of a requirement that the ovality not exceed 1% throughout the length of the bend. Some manufacturers supplement the definition of “segmentable” with a requirement that the inside diameter be constant within specified tolerances.

Starting Material:
The use of spiral weld pipe (helical seam pipe) is not recommended for use in the manufacture of segmentable induction bends. The helical orientation makes it impossible to orient the seam along the neutral axis.

Tight limits on steel composition (for example carbon equivalent limits to enhance weldability) may interfere with the ability of manufacturers to achieve the specified mechanical properties within the limits of the available heat treating practices.

Dimensional Tolerances:
For induction bends, it is common for the diameter to shrink by an average of ½% during the induction bending process. This diametrical shrinkage can influence the extent of misalignment at the root of the weld joint (high-low condition) when the bend is joined to adjacent pipe. Because of the nature of the manufacturing process, elbows do not experience diameter shrinkage.

Ovality in bends is influenced by the diameter to thickness ratio (D/t), bending temperature, and bending speed. Higher bending temperatures (sometimes used for higher strength pipe) can reduce ovality but will increase diametrical shrinkage. Larger radius bends result in less ovality and less thinning along the intrados. Slower bending can reduce ovality. One manufacturer noted that ovality typically increases from the start to the end of the bend.

During induction bending, a “bump” is commonly formed at the transition from the tangent end to the bend section where the induction coil starts or stops. The bump can be problematic in the field when trying to determine exactly where the end of the tangent length is located. Some manufacturers can push the tangents though the induction coil, thus avoiding the formation of the bump. For other manufacturers, the severity of the bump can be minimized by altering the bending parameters.

Dimensional Stability:
Some manufacturers, including all of those visited, require some type of heat treatment after induction bending to improve dimensional stability. The reason typically cited for requiring heat treatment for a segmentable induction bend is to relieve residual stresses introduced during the manufacturing process. These residual stresses may result in changes in roundness cutting in the field. The magnitude of the dimensional changes is a function of the bend type and heat treatment condition. This phenomenon however has not been quantified and there is currently no consensus as to whether heat treatment helps control the dimensional stability of an induction bend after it has been segmented.

Elbows can be quenched and tempered or normalized and tempered and then re-rounded to meet out of roundness specifications. Re-rounding without subsequent stress relief heat treatment is expected to reduce the dimensional stability and some elastic rebound or “spring” is expected to occur when the bend is segmented. No consensus exists regarding a practical limit to re-rounding that balances the ability to produce a “round” fitting, with the desire to limit deformation upon subsequent segmentation.

Manufacturers generally prefer performance-based specifications, rather than prescriptive specifications that limit options for heat treatment and starting material.

Quality Assurance and Inspection:
A diverse range of inspection and documentation requirements was found among the various Company specifications and manufacturer practices with regard to the types, numbers, and locations of inspections and measurements. Purchasers should diligently review manufacturing records and certifications to ensure that the inspection and testing requirements of the purchase specification have been met, particularly if the requirements differ from or supplement the manufacturer’s “typical” practices.

One recommendation is to include a requirement that each bend or elbow be assigned and marked with a unique alpha-numeric designation that is traceable to all manufacturing steps and related documentation. The unique number allows the exact manufacturing history for each bend or fitting (e.g., as opposed to an entire lot) to be retrieved and reviewed if needed.

Figure 6 – Measurement of diameter and ovality
Facilitating Easier Field Construction:

Field segmentation is a slow, time consuming process when done correctly. Factory-marked lines at various angles (i.e., 5 degree increments) could speed the process of field segmentation. Some manufacturers will segment bends and elbows to specific angles prior to shipping.

The manufacturers interviewed provide elbows that are taper bored to match the adjoining pipe so that thickness mismatch in the root of the weld joint is minimized.

Some manufacturers can weld pups to the ends of the tangent ends. Pups can be sized to minimize wall thickness mismatch at the ends of adjacent pipe so that fit-up is improved at the root of the weld joint. The use of pups having a thickness between the thickness of the pipe and the fitting reduced the severity of the thickness change at the bend.

DEVELOPMENT OF EXAMPLE PURCHASE SPECIFICATIONS FOR SEGMENTABLE INDUCTION BENDS AND ELBOWS

The development of the purchase specifications started with an identification and review of relevant industry standards and pipeline operator specifications as previously described. The development of the specification content focused on the following topics:

- Material Requirements
- Manufacturing methods and related qualification requirements
- Type and location of dimensional measurements and related acceptable tolerances
- Type and location of mechanical property measurements and related acceptance criteria
- Type and location of nondestructive examinations and related acceptance criteria
- Limitations on repair
- Marking, certification and documentation requirements

After the draft specifications were completed, particular attention was given to identifying content that related exclusively to segmentable induction bends and fittings. That content was highlighted so that it could be easily identified by readers and extracted for addition to existing Company specifications, or deleted for cases in which segmentability is not required. The example specifications are contained in an appendix to the report for this phase of the project. The reports for both phases of the project can be downloaded free of cost here:

http://www.dnvusa.com/resources/reports/WeldingofFieldSegmentedInduction.asp

Content related specifically to segmentability in each of the example purchase specifications is summarized below:

**Segmentable induction Bends**

- Helical seam line pipe shall not be used to produce a segmentable induction bend
- The induction bends shall be manufactured to maintain a maximum ovality of 1% through the arc section. Percent ovality is as calculated as 100 x (Max. OD – Min. OD) / Nominal OD. Ovality shall be measured in the bend within 2 inches (50 mm) of each bevel end, within 6 inches (150 mm) of the start of the bend, center and within 6 inches (150 mm) of the end of the arc, and at approximately X° increments in between. [“X” is a value to be specified by the purchaser.] No measured points may exceed 1%. These measurements shall be recorded and provided with each completed induction bend.
- Circumferential shrinkage throughout the induction bend shall be limited to 0.5%. This shall be measured along the bend within 6 inches (150 mm) of the start of the bend, center of the bend and within 6 inches (150 mm) of the end of the arc, and at approximately X° increments in between. No measured points may exceed the limits of inside diameter specified by the purchaser. These measurements shall be recorded and provided with each completed induction bend.
- In addition to the information listed in ASME B16.49, the bend shall be marked “SEGMENTABLE”
- All segmentable induction bends shall be post-bend heat treated.

**Segmentable Elbows**

- The ovality for segmentable elbows shall be no greater than 1% throughout the body of the elbow. Out of roundness shall be measured in the elbow within 6 inches (150 mm) of the start, center and within 6 inches (150 mm) of the end of the arc, and at approximate X° increments in between. No measured points may exceed 1%. These measurements shall be recorded and provided with each completed elbow.

- The minimum inside circumference of segmentable elbows shall be no less than \(\pi x \) (nominal ID -3/16 inch [4.8 mm])

- Alternative Specification Content for “Roundness” Tolerances: When an elbow is ordered as segmentable, the difference between maximum and minimum diameters at any cross-section throughout the elbow shall be limited to +0.5% of the nominal outside diameter.

- The elbow shall be marked “SEGMENTABLE”
CONCLUSIONS
Input obtained from manufacturers of induction bends and forged elbows and purchase specifications contributed by several major pipeline operators were used to develop example purchase specifications for induction bends and elbows. Since this work was part of a larger project aimed at improving the field fit-up and welding of segmentable induction bends and elbows, the emphasis was on manufacturer capability and specification content related to segmentability. However, segmentability-related requirements are addressed as a subset of more comprehensive and general example specifications so that purchasers can choose to adopt either the more general specification or only the content related to segmentability.

REFERENCES