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BELLED-END PIPE FITTINGS ARE GAINING FAVOR

Abstract

"Belled end pipe fittings" is a term given to a design class of cold formed pipe fittings with tangent ends, which tangent ends are expanded, or belled, to form a socket. The fitting socket is slipped on to the pipe end and the joint is fillet welded. The resulting pipe fabrication is LEGGO-like in simplicity, stronger than the joining pipe in pressure applications and superior to any other standard commercial fitting design in fatigue applications. Moreover, the installed cost of the piping fabrication most likely will be lower in sizes larger than 2 NPS compared to the use of other Pressure Piping Code compliant fitting designs. The installed cost of belled end fittings in the smaller sizes will be cost competitive depending upon the performance attributes deemed most important.

This precision-formed socket weld pipe fitting design was standardized in 1996 in United States national standard, MSS SP-119 (Manufacturers Standardization Society, Standard Practice 119). Belled end fittings are now preferred for many piping system applications where forged socket weld fittings, cast socket weld fittings and, most notably, formed butt weld fittings were used. This fitting is made in several materials, in NPS pipe sizes 1/2 thru 12 and in standard and lighter pipe wall thicknesses.

This paper gives an overview of the design development and design testing of belled end fittings, the results of pipe joint fabrication studies, design standardization, pipe fitting applications and Piping Code recognition. In conclusion, a table of estimated cost savings is offered to give the reader an appreciation of which cost elements will profit most in his applications.

Design Development

MSS SP-119 belled end fittings are essentially an ASME B16.9 butt weld fitting with tangent ends, which are belled (a.k.a., expanded) to make a socket, which in turn are secured to the joining pipe end by a fillet weld. This fitting concept was first developed and marketed by Speedline Corporation and later by Bestweld Corporation, who figured prominently in the standardization of the fitting design. Before standardization, it was used for years in schedule 10 stainless steel, NPS pipe sizes 1/2 through 6, for on-site fabricated piping, notably in the pulp and paper industry, because it provided a strong and easily inspected welded joint with a wide range of tradesman skill levels. Moreover, welded joint preparation tooling requirements were minimal and, perhaps more significantly, leaking joints discovered upon system pre-activation pressure testing were very infrequent.

Pipe joint fabrication in Navy new ship construction has many of the same challenges as pulp and paper industry piping. Much of the piping is large (2-1/2 through 12 NPS), thin wall and before belled end fittings, it was joined with butt weld joints. Butt weld joints require considerable skill and time to prepare and weld. The internal surfaces of pipe and fitting are first machined in order that the diameters match, because, typically, they are different. The pipe end "V" groove for welding is machined at the same time. The butt joint may be either fitted with an internal or "backing" ring or not – as is the custom at each shipyard. A backing ring is an extra piece which both aligns the fitting with the pipe piece and serves as a backing on to which the first weld pass is deposited. If a backing ring is not used, the fitting and pipe are clamped in a jig, which aligns the two pieces – especially for out of roundness -- in preparation for tack welding. After tack welding – for those joints not using a backing ring, the first pass is fusion welded and the groove is filled with successive passes. If a backing ring is used, all welding passes are done with filler metal.

The welding groove preparation is similar in each process, backing ring or not. The machining process can be quite complex because there is not only a need to match both the differences in wall thickness but variations in the wall thickness around the perimeter. In addition, those joints using a backing ring must also be machined to accommodate the backing ring. Finally, it should be noted that often there is a need to accommodate a small misalignment between the pipe piece and fitting, which is very difficult to achieve in a butt welded joint with a backing ring and, essentially, is unachievable in a butt weld joint without a backing ring. Belled end fitting socket clearances will accommodate small misalignments (and are allowed by Piping Codes) with no degradation in pipe joint performance.

Most piping fabricated for surface Navy service (well over 90% of all footage) is inspection Class P-2 and, as such, does not get the high scrutiny quality control inspections imposed on pipe joints used in high pressure and high temperature services. For instance, there is no cost effective way to verify that a backing ring was properly installed, that the backing ring was fused in place with the first welding pass, that the welding bevel groove was properly machined, that the fitting was properly aligned to the pipe piece before welding or that the fusion pass on a butt without a ring was properly done. Moreover, joint record cards are not kept on P-2 system joints, which would identify a welder who had a habit of producing poor welds. The most generally used quality controls are to have the fitting and welding done by different people and to visually inspect the completed weld from the outside.

In 1994, there were a number of butt weld joint failures in installed piping in delivered ships. Senior military officers demanded a resolution to the problem by some change in process. At the same time a belled end fitting design was being proposed to the Navy for its fabrication efficiencies. As part of that proposal, one machinery space on a destroyer under construction was being estimated for a prototype belled end fitting installation. The military demands overrode the prototype installation and because there was no standard design belled end fitting -- either commercial or military, a much higher profile belled end fitting design development and testing program was initiated. The design of the belled end fittings used the B16.9 format for shapes because they allowed the continued use of manufacturing tooling, the resulting fittings required less changes to existing piping arrangement drawings and there was greater assurance that piping performance in fatigue applications would be similar.

Design Testing

The Navy uses thin wall stainless steel piping, but to an even greater extent – approximately, by a factor of 5, it uses more thin wall copper nickel piping. Accordingly, as part of the Navy sponsored belled end fitting program, Class 200 (very similar to schedule 10) copper nickel fittings and schedule 10 stainless steel fittings were tested for pressure performance and, in sizes larger than 2 NPS, for fatigue performance. As expected, the belled end fitting burst pressure performance was essentially the same as for the B16.9 fittings. Not expected however, was that the fitting bell contributed a reinforcement value to elbows, which was very apparent in fatigue tests. Specifically, an angular displacement large enough to produce B16.9 elbow fatigue failures in approximately 1000 cycles, would cause a failure in belled end fittings in 2000 to 4000 cycles.

Before a belled end fitting design was test proven and standardized, the Navy used many stainless steel B16.11 design forged fittings, which were socket welded to small diameter schedule 10 piping. Similarly, the Navy used cast or forged socket fittings to fabricate thin wall, Class 200, copper nickel piping fabrications. The cast fittings were most often silver brazed, but, more recently, also welded. The forged fittings were always welded. However, each of these fitting designs are much less flexible than the attached piping, which creates a “notch effect” at the joint and leads to a weakness in fatigue. Formed belled end fittings are flexible and will out perform either cast or forged fittings in a thin wall piping fabrication subjected to fatigue testing.

Pipe Joint Fabrication Studies

Pipe joint fabrication studies show both the expected and the surprising. Joint welding times are about the same for experienced welders but there are savings in welding time for less experienced welders. Welder skill levels are reduced for consistently good joints because the probability for success is greater on the first pass of a fillet weld. And, as expected, joint failures during pressure testing of installed piping are very infrequent.

The big surprise is in joint preparation times. In general, the preparation times are quartered because there are no on-site pipe or fitting end machining requirements for a socket joint. Pipe and fitting wall thickness differences, pipe wall thickness uniformity and pipe roundness issues do not affect either socket weld or joint quality. No backing rings preclude pipe flow turbulence and consequential erosion issues. The same level of quality control inspection, i.e., visual, is more meaningful with belled end fittings because there is no backing ring or joint machining hidden under a butt weld. Joint preparation for a belled end fitting is simply a matter of piece cleaning where the weld is to be deposited. Another benefit is that belled end fitting socket clearances will allow small angular compensations with no degradation in joint quality or performance. Finally, if there is an error in pipe piece fabrication, the belled end fitting can easily be cut out and reused.

Design Standardization

After the belled end fitting design was test proven and standardized, manufacturing specifications first appeared in Navy shipbuilding specifications. Very soon thereafter, the Navy sponsored the development of the Manufacturers Standardization Society Standard Practice, MSS SP-119. It was first published in 1996. The purposes of the commercial standard practice were to encourage greater quantities of scale in the new design through commercial applications and to promote competition among pipe fitting manufacturers for more cost effective Navy acquisition.

Fitting Applications and Code Recognition

The Navy of course, is using belled end fittings in the new construction and repair of piping for all surface ships in all non-nuclear systems using Class 200 copper nickel and Schedule 10 stainless materials. In addition, the Navy has started to use belled end fittings of the same materials in some nuclear piping system applications and in a few submarine systems. Recently, Naval engineers have started to use some belled end fittings in titanium, schedule 10, and heavier copper nickel materials, specifically Classes 700 and 1650. Accordingly, titanium material requirements are included in the new edition of MSS SP-119 published this year, 2003.

No mention of the superior performance attributes of belled end fittings in fatigue applications is contained in MSS SP-119, but those attributes have not gone unnoticed by commercial piping fabricators. Belled end fittings are being used in several types of tanker vehicle applications including fire fighting trucks, runway airplane refueling tankers, gasoline tankers, chemical carriers, contaminated chemical carriers and liquefied gas carriers. As requested by the manufacturers of liquefied gas carriers, aluminum material requirements are included in the new edition of MSS SP-119.

The first edition of MSS SP-119 limited the pressure rating of belled end fittings to 87-1/2% that of B16.9 fittings. That limitation is removed in the new edition. Belled end fittings now have the full service pressure rating of B16.9 fittings. And, belled end fittings now have Code recognition, MSS SP-119 being referenced by B31.3, Code for Chemical Piping.

Table of Cost Savings

The slightly higher acquisition costs of belled end fittings are offset several times over by their installation and operation economies. The costing engineer should expect that the extra acquisition cost is about 30%. However, the installed cost is the only true measure of relative costs. These savings result from the following fabrication advantages (the labor savings estimates are in comparison to butt weld fittings in piping sizes larger than 2 NPS, are from high volume shipbuilding pipe piece fabrication and will vary with specific application):

1. *Significantly less joint preparation time – as a result of no pipe end or fitting end machining (75 to 80% joint preparation labor savings),*
2. *Significantly lower joint preparation skills (20 to 30% fitter labor rate savings),*
3. *No backing rings (100% ring material savings, labor savings are included in joint preparation time savings),*
4. *Lower welder skill requirements for consistently high quality joints (10 to 20% welder labor rate savings),*
5. *Some savings in welding time (5 to 10% welder labor time savings),*
6. *Small angular corrections can be accommodated with no degradation of joint quality (5 to 10% installation labor time savings),*
7. *Fittings can be cut out from piping fabrication errors and reused (5 to 10% fitting material savings),*
8. *Almost zero rework from joint errors discovered during system pressure testing (5% installation labor savings and less schedule disruption),*
9. *Fewer fluid turbulence, vibration and erosion issues in installed piping,*
10. *Faster and easier inspection of weld quality and the possibility to visually verify weld size with a hand held gauge.*