A Study of Stress Distribution in Elbows Mounted on Stanchions

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ABSTRACT

It is a common practice, both in the nuclear and power piping industry, to have integral attachments on piping to either form a restraint or an anchor. For small attachments, such as lugs, one can use the readily available methods (eg., ASME Code Case N-318) to evaluate the local stresses at these attachments. For elbows or curved pipes mounted on stanchions, the evaluation of local stresses is more complex.

In the present analysis, a 3D finite element model was implemented to determine the stress intensification factor that can be applied to piping stress under internal pressure and in-plane bending type of loads. The analysis indicates that, for an internal pressure load, in-plane bending is generated. For such supports, a stress intensification factor should be used to account for the increased loads. The results also indicate that there is an optimum elbow to stanchion post radius ratio which should be used in designing such supports.

1.0 Introduction

It is a common practice to have integral attachments on piping to either form a restraint or an anchor. For small attachments, such as lugs, one can use the readily available methods [1][2][3][4] to evaluate the local stresses at these attachments. However, for large attachments, a number of assumptions have to be made to use the above procedure. The practice in the past has been to provide welded stanchions as anchor points to restrain the piping systems. These types of attachments do change the flexibility of the piping component and, hence, the local stresses. A common practice that exists for stanchion on straight pipe, at the present time, is to use the stress intensification factor of a "tee" provided in ASME Section III, Section NC and ND, or ANSI B31.1 Codes. For stanchion on elbows or curved pipe, a stress intensification factor obtained by the product of individual stress intensification factors of the "elbow" and "tee" is recommended. However, this conservative approach has been found to be extremely uneconomical in the piping industry.

A survey of approximately one hundred twenty-five piping drawings, ranging from 2 1/2" to 6" nominal pipe size diameters used in the Beaver Valley Power Station, Unit No. 1, indicated that the ratio of mean diameters of the stanchion post to the main pipe size vary from 0.672 to 1.00. The value of 1.00 is not recommended by the manufacturers and, hence, the range 0.42 to 0.84 has been considered in the analysis.

With this in the background, and due to the finesse of stress analysis required in nuclear piping, an attempt has been made to study the local stresses in the elbows mounted on stanchions. Rodabaugh and George [5] have experimentally shown that the stress intensification for in-plane bending of elbows is slightly higher than the out-of-plane bending, and, for simplicity, the higher value can be used for both in-plane and out-of-plane bending. Based on their conclusion, only internal pressure and in-plane bending types of loading has been considered in this analysis.

It is generally known that the curved piping subjected to bending and internal pressures have higher stresses than would be indicated by the normal bending theory. The stress intensification factors for elbows and pipe bends are given in ASME and ANSI B31.1 Codes as:

$$i = \frac{0.9}{h^{2/3}} \qquad \text{Eq. (1)}$$

where the flexibility characteristic is:

$$h = \frac{tR}{r^2} \qquad \text{Eq. (2)}$$

The above equations are based on tests without internal pressure. However, Rodabaugh and George [5] have conclusively shown that the internal pressure has a pronounced effect on the flexibility and stress intensification factors.

Any attachments to the piping components will change the flexibility and, hence, the stress intensification factors. Dodge [2] and Rodabaugh, et.al [3] have provided the stress indices for straight piping with lug attachments. However, their theoretical evaluation is based on thin-shell theory and local stresses in piping due to small lug attachments.

2.0 Finite Element Analysis

In order to study the local stress distribution on elbows mounted on stanchions, a finite element model was developed. The ANSYS [6] computer program was used. The elbow and stanchion is idealized as a mesh of 3D isoparametric elements (STIF45) connected at the corners or the node points. Only one half (1/2) of the structure was considered to take advantage of the symmetry.

A six inch (6") elbow, (40 sch) with different size pipe (40 sch) attachments were modeled in the present analysis. Figures 1 and 2, respectively, show the finite element model and the coordinate system used in the analysis.

Internal pressure and in-plane bending type of loadings were considered. The pressure loading causes an unsymmetrical stress field due to the type of attachment. To account for the resulting three-dimensional stress field, the maximum equivalent stress was considered and compared with that for a straight pipe to obtain a stress factor. The equivalent stress for the straight pipe being $pr/4t$, where p, r and t are, respectively, pressure, radius and thickness of the pipe. The in-plane moment was applied by a force couple acting at the ends of the elbow, and the stress factor was obtained by taking the ratio of the maximum equivalent stress to the bending stress M/z, where M and z are, respectively, the in-plane moment and section modulus of the pipe.

3.0 Discussion of Results

Figures 3 and 4 show typical contours of stress factors on the outside and inside surface of the elbow, respectively, due to in-plane bending. As one would expect, the stresses are highly localized in the attachment area. Also, the maximum stress occurs near the attachment where the free stress flow is considerably obstructed. Figures 5 and 6 show similar contours for pressure loading. Since the attachment is unsymmetrical, the pressure loading induces an in-plane bending moment. This can be easily seen by comparing the stress pattern for the two types of loading considered in the analysis.

Figure 7 is a plot of stress factor versus r^1/r, which is the size parameter for stanchions on elbows. The size parameter r^1/r was chosen because of the influence of the stanchion diameter that restricts the force stress flow pattern in the elbow. The results indicate that a stress intensification factor of an unreinforced tee could be used in the stress analysis to yield conservative results. However, this factor should also be used in stresses resulting from pressure type loading. Also, it can be seen that the stress intensification factor is a minimum at r^1/r around 0.65, which helps in optimizing the stanchion design.

References

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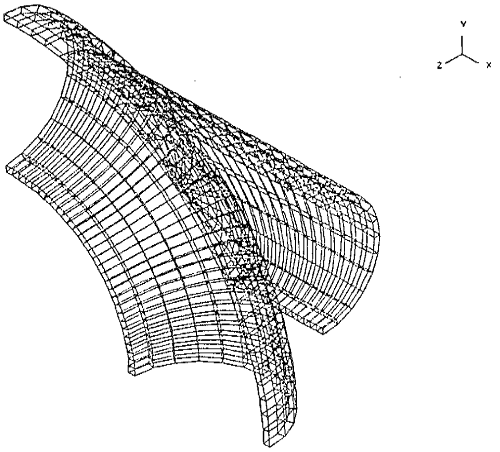
[2] W. G. DODGE, "Secondary Stress Indices for Integral Structural Attachments to Straight Pipe", WRC Bulletin 198, (September, 1974).

[3] E. C. RODABAUGH, et.al., "Stress Indices at Lug Supports on Piping Systems", WRC Bulletin 198, (September, 1974).

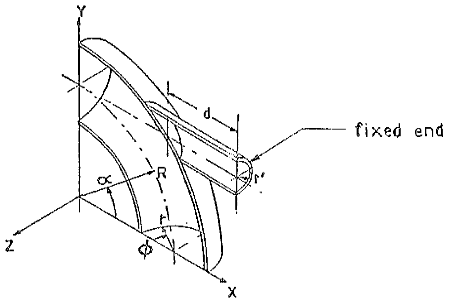
[4] ASME Boiler and Pressure Vessel Code, Case N-318, (May, 1981).

[5] E. C. RODABAUGH, H. H. GEORGE, "Effect of Internal Pressure on Flexibility and Stress Intensification Factors of Curved Pipe or Welding Elbows", Paper No. 56-SA-50, Transaction of the ASME, (May, 1957).

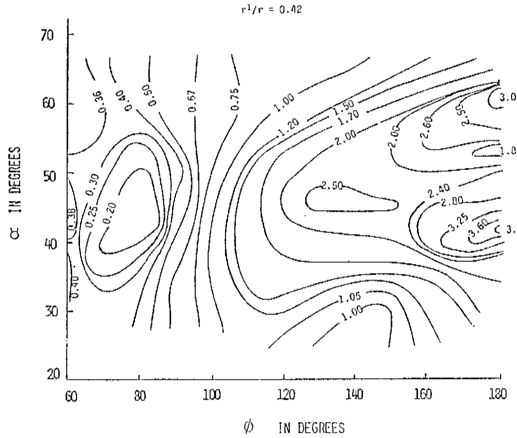
[6] ANSYS Engineering Analysis System, Computer Program by Swanson Analysis Systems, Houston, Pennsylvania, (1979).



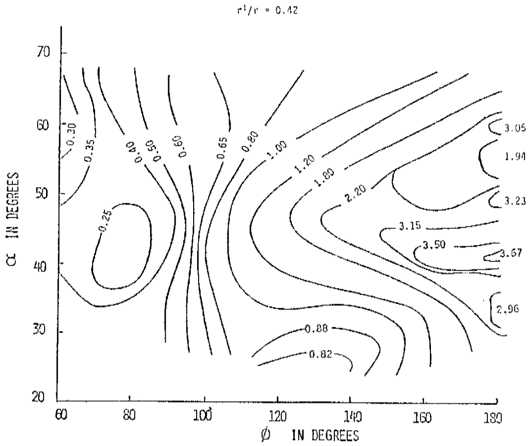
1. Finite Element Model



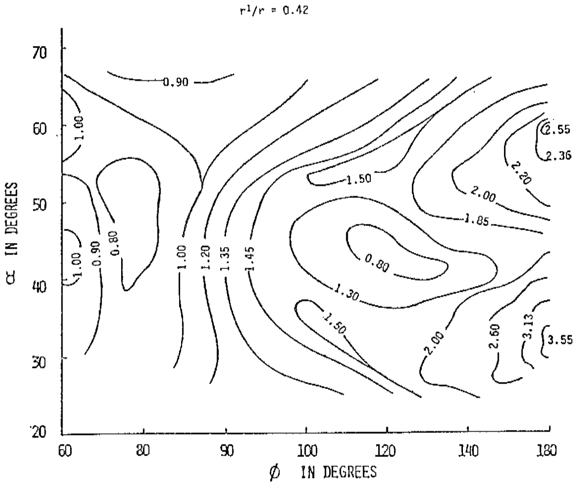
2. Co-ordinate System Used in the Analysis



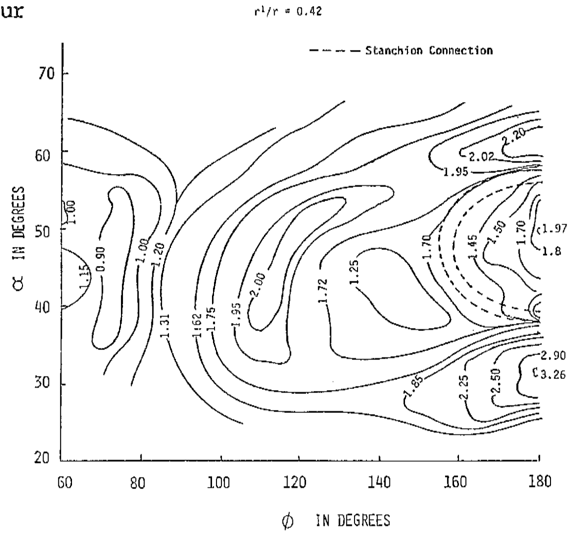
3. Typical Normalized Equivalent Stress Contour Due to In-Plane Bending (Outside Surface of Elbow)



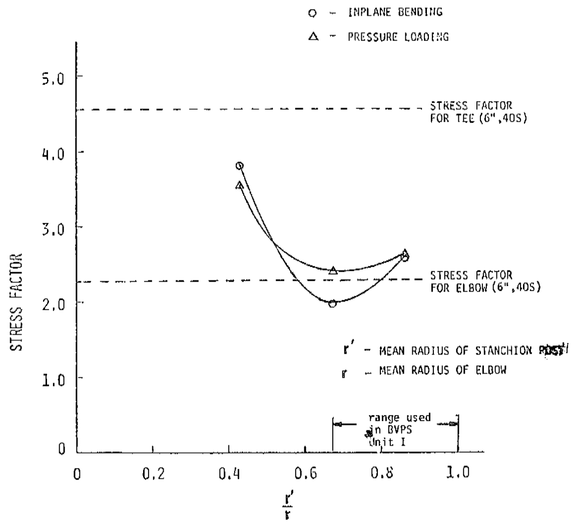
4. Typical Normalized Equivalent Stress Contour Due to In-Plane Bending (Inside Surface of Elbow)



5. Typical Normalized Equivalent Stress Contour Due to Pressure Loading (Outside Surface of Elbow)



6. Typical Normalized Equivalent Stress Contour Due to Pressure Loading (Inside Surface of Elbow)



7. Stress Factor Versus Size Parameter for Elbows Mounted on Stanchions