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TECHNICAL NOTE

FINITE ELEMENT ANALYSIS OF CYLINDER-TO-CYLINDER SHELL STRUCTURES

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ABSTRACT

Intersecting cylindrical shells are frequently encountered in various types of engineering structures. Despite their common occurrence, reliable and accurate analytical methods have not been generally available, and consequently accurate design information for such configurations has also been generally lacking. To contribute to the understanding of the problem, a finite element analysis is carried out for two normally intersecting cylindrical shells. Two types of loading have been applied to the structure. Results of stresses are provided, of both the outside and the inside, for the two shells. The overall agreement between the finite element predictions and experimental results is a very good one. It has been shown that by using the finite element method together with a "mesh generation" technique, both computational efficiency and minimum user time can be retained.

Keywords: cylinder to cylinder intersections, finite element method, joints (structural components), nozzles, shells (structures), stress concentrations.

1. INTRODUCTION

Intersecting cylindrical shells are very common configurations in many industries. Applications of such structures are found in piping, power engineering, nuclear reactor systems, aerospace structures, off shore platforms, drilling towers, and pressure vessels. The main phenomenon observed in these structures is the existence of some local stresses in the neighbourhood of the intersection lines.

The theoretical treatment of the stress analysis of cylinder-to-cylinder intersections has only developed in recent years, and general solutions for some of these problems are still not available. Accordingly, and due to some difficulties, very few analytical

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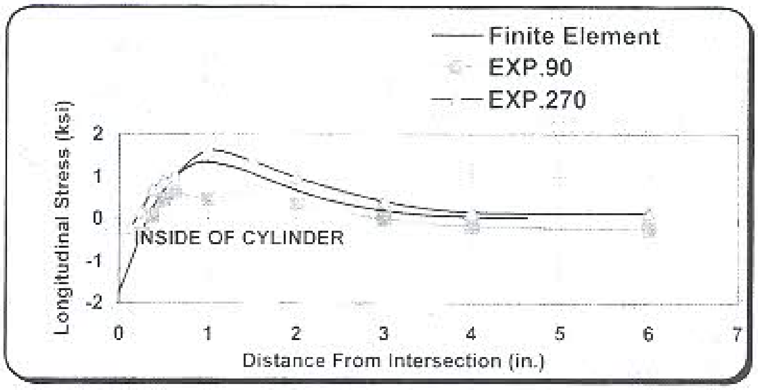

Figure 3 Measured and predicted stress distributions in the main cylinder for axial force of 5000lb on the main cylinder.

3.1 Axial force on cylinder

The axial force applied to the main cylinder had a value of 5000 lb. The results obtained indicate that stresses are changing rapidly at the intersection region and highly membrane and bending stress concentration factors (SCF) are obtained at the intersection line. The highest stresses have been observed along the 90° & 270° gage lines. Some of the results obtained along these lines are shown in figures 3 and 4. Taking in consideration the relatively low stresses in figure 3, the agreement between the finite element results and experimental ones are reasonably good. Furthermore, it is clear from the figures that there are some differences between the experimental stresses along the 90° gage lines and those along the 270° ones. From theoretical point of view, and due to symmetry of structures and loads, both sets of stresses are expected to coincide with each other. However, for some cases as shown in Figure 3, the differences are much higher. Both the experimentally determined and the finite element predicted maximum stress occurred on the outer surface of the nozzle, at the junction and on the 270° gage line.

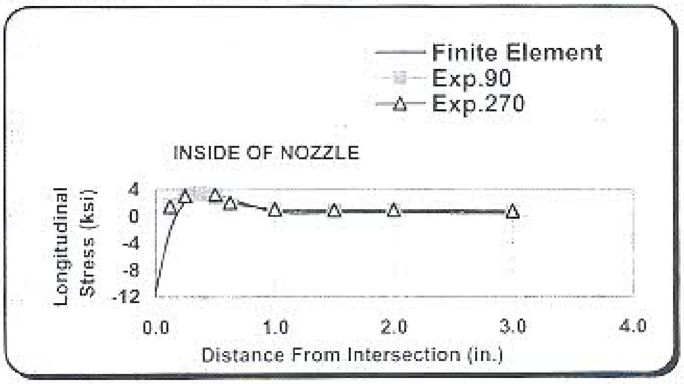

Figure 4 Measured and predicted stress distributions in the nozzle for axial force of 5000lb on the main cylinder.

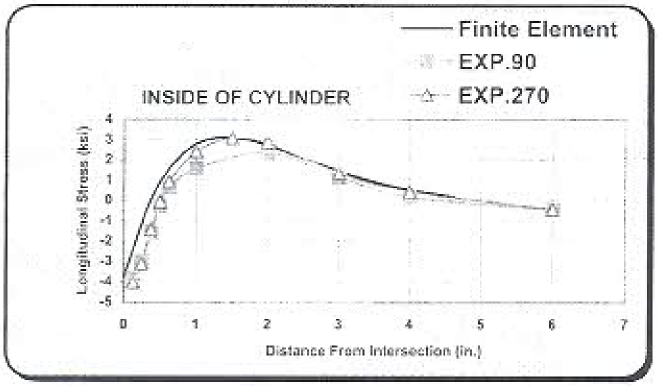

Figure 5 Measured and predicted stress distributions in the main cylinder for axial force of 300lb on the nozzle.

3.2 Axial force on nozzle

The axial force applied to the nozzle had a value of 300 lb. Again, the results obtained indicate that stresses are changing rapidly in the neighbourhood of the intersection line and highly SCF have been produced, at the line. For this loading, the highest stresses appear to occur along the 90° & 270° gage lines. The comparisons between the finite element and experiment for these lines are shown in Figures 5 and 6. The finite element results shown in Figure 6, in particular, show very good agreement with the experimental ones. However, it can be also concluded that a strain gage at a distance of (1/8) in., by no mean, is capable to predict correctly the stresses at the junction line. Generally, the overall agreement between the finite element and experiment is reasonably good for this loading. Again, the differences between the experimental stresses along the 90° gage lines and those along the 270° ones are noticeable but they are much smaller than the previous case and in the modest range of 5%. For this loading, both the experimentally determined and the finite element predicted maximum stress occurred on the outer surface of the nozzle, at the junction and on the 270° gage line.

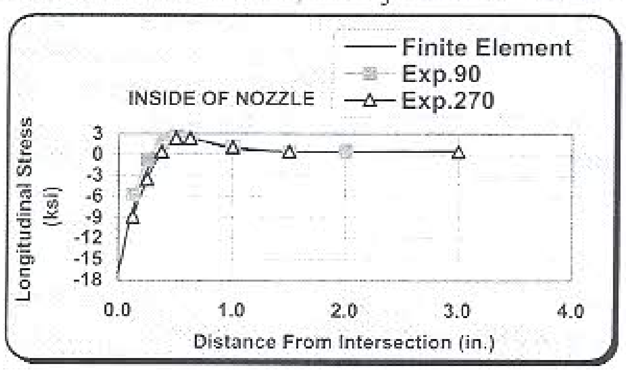

Figure 6 Measured and predicted stress distributions in the nozzle for axial force of 300lb on the nozzle.

4. CONCLUSIONS

It has been shown in this paper that the overall agreement between finite element and experiment is reasonably good. Nevertheless, and since the nearest strain gages used to measure the stresses experimentally are located (1/8) in. from the intersection lines, the experimental results can be used only qualitatively. The rapid changes of stresses in the neighbourhood of intersection lines; suggest the need for an efficient and accurate method that can yield detailed information on such changes. This can be achieved only by using a finite element scheme similar to that used in the present paper. Furthermore, the adaptability of the finite element method to different geometrical configurations makes it to a large extent more economical than the experimental schemes.

Perfect agreement between finite element and experiment, however, can never be expected. Small geometric variations and imperfections are inevitable, and these slight imperfections can, in a thin shell, markedly effect the measured stress distributions. From theoretical point of view, and due to symmetry of structures and loads, the measured stresses along the 90° and 270° gage lines are expected to coincide with each other. However, the differences between these two sets of results are in the range of 10%. Nevertheless, higher errors are also reported in Ref [6]. On the other hand, errors produced by the finite element method have been kept to minimum by adopting relatively fine meshes with elements approaching square shapes near the intersection lines. Therefore, it is expected that the finite element predictions are generally more accurate than the correspondent experimental ones. Furthermore, the adoption of a "mesh generation" technique makes the method more efficient and attractive.

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