Optimum Design and Analysis of Weld Attachment in Pressure Vessel

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Abstract—**Pressure vessels have a wide range of engineering applications. In the design of pressure vessels, it is common practice to provide a variety of attachments such as weld pads, pressure ports and reinforcements. These attachments create discontinuity regions in the pressure vessel where it gets subjected to additional bending stresses leading to stress concentration.**

In this work, the authors have made a detailed analysis of discontinuity stress caused by wear pad in a pressure vessel using the ANSYS parametric design language. The effect of weld pad size, thickness, weld footprints are studied. Also this paper propose the optimum weld footprint that gives the minimum discontinuity stress.

Keywords — Component; formatting; style; styling; insert

I. INTRODUCTION

Pressure vessels are containers fabricated and designed to hold liquids or gases under pressure. Pressure vessels contain discontinuities that can be described as: Abrupt changes in shell geometry, thickness, material properties, loads, temperatures, Openings or cut-outs in the pressure vessel surface, Geometric irregularities resulting from variations in the manufacture of structural parts. These discontinuities alter the membrane stress field of the pressure vessel and cause high local stresses, which in turn can cause pressure vessels to fail. The consequences of discontinuity stress failures may range from leakage, bursting, and detrimental deformation to catastrophic failure of the vessel.

II. PROBLEM DEFINITION

The pressure vessel attachments, like weld pads locally stiffen the vessel shell and alter the membrane stress field due to internal pressure in the vicinity of the attachment. Depending on the type of weld and geometry of the weld footprint, the local stress field in the vessel shell at the attachment boundary can increase significantly. This will lead to the failure of the pressure vessel resulting in leakage and bursting of the pressure vessel.

Hence for a given design, a detailed analysis of the discontinuity stresses generated due to weld pad footprints, weld pad size and thickness are made and verified for the optimum design.

III. ANALYSIS METHODOLOGY

Three dimensional finite element analyses of pressure vessels with weld pads have been attempted to get a more realistic behaviour of the stress fields. Combined Material and geometric nonlinear analysis of the cylindrical shells with weld pads will be carried out for internal pressure loading. SOLSH 190 is used for simulating shell structures with a wide range of thickness (from thin to moderately thick). The element possesses the continuum solid element topology and features eight-node connectivity with three degrees of freedom at each node: translations in the nodal x, y, and z directions. Thus, connecting SOLSH190 with other continuum elements requires no extra efforts. A degenerate prism option is available, but should only be used as filler elements in mesh generation. The element has plasticity, hyper elasticity, stress stiffening, creep, large deflection, and large strain capabilities. It also has mixed U-P formulation capability for simulating deformations of nearly incompressible elastoplastic materials, and fully incompressible hyper elastic materials. The element formulation is based on logarithmic strain and true stress measures. SOLSH 190 can be used for layered applications such as modelling laminated shells or sandwich construction. The layered section definition is given by section commands. Accuracy in modelling composite shells is governed by the first-order shear-deformation theory (also known as Mindlin-Reissner shell theory).

IV. THE FINITE ELEMENT MODEL

The pressure vessel being symmetric, a half cylinder is modelled with a weld pad attached on its centre. Any other discontinuities are considered to be remote to the weld pad location so that the bending stresses developed near the attachment locations are due to that attachment only. The model is developed using the ANSYS parametric design language (APDL) by which different configurations can be modelled by suitably changing the dimensions in the APDL codes. The pressure vessel and the weld pad have been modelled with SOLSH190 elements. The Fig.9.3 shows the finite element model of cylindrical shell with a weld pad attached on to it.

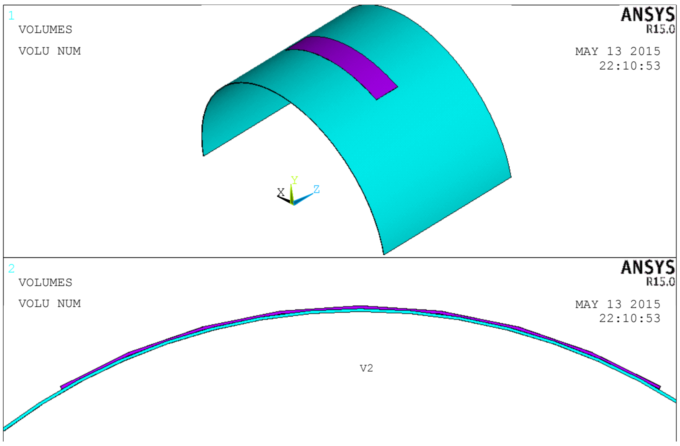

Fig 1. Solid model with 600 weld pad.

1. SIMULATION OF WELD

The pad is attached on to the cylindrical shell by welding. Welding is usually done one the four sides of the pad. So the weld conditions can be simulated on the boundaries of the bond pad by coupling the translational degrees of freedom of coincident nodes at the boundaries. For this purpose, the nodes on the weld pad and on the cylindrical shell which coincides at the same location are selected and coupled in all translational degrees of freedom.

2. LOAD AND BOUNDARY CONDITIONS

Out of plane displacements are arrested on the symmetric plane of the cylindrical shell by enabling symmetry boundary condition along the X-Z plane . Axial translation in the Z direction of the shell is arrested. Internal pressure is applied on the inner surface of the cylindrical shell and end pressure is applied in the Z direction at one of the free end of the cylindrical shell to simulate the closed end boundary condition due to the cylinder head. One of the node is arrested in the X translation to avoid rigid body motion and prevent the singularity of stiffness matrix to obtain a nonlinear static solution.

V. PARAMETRIC STUDY ON PRESSURE VESSELS WITH WELD PADS

To study the effect of attachments like weld pads on the stress field of pressure vessels, different configurations of pressure vessels and weld pads have been selected. A general analysis program using ANSYS Parametric Design Language (APDL) has been generated. This program is capable of modelling the basic configuration, analysing it, and also studying the impact of varying different parameters.

The following are the studies conducted on the pressure vessels with weld pad attachments:

1. Effect of weld pad dimensions
2. Effect of weld pad thickness
3. Effect of weld foot prints

The stress concentration factor is calculated as the ratio of the peak stress occurring due to discontinuity to the nominal stress.

1. EFFECT OF WELD PAD DIMENSIONS

Weld pads with different dimensions which are attached to the cylindrical shell have been analysed to study their effect on the stress field of pressure vessels. The following tables and figures show the variation of Stress concentration factor and peak effective stress with respect to pressure for different model configurations.

Table 1. Variation of effective stress and Stress concentration factor with respect to weld pad thickness for different weld pad dimensions

Radius = 1209mm, thickness= 6mm, Material- 15CDV6, 4 sides welded				
Weld pad dimensions $(\theta \times a \times t_1)$	Thickness of weld pad, t_1	Nominal Effective Stress	Peak Effective Stress	SCF
	mm	MPa	MPa	--
60° x 200mm x 2-10mm	2	83.4	118.22	1.417
	4	78.4	128.24	1.638
	6	86.84	143.35	1.65
	8	79.35	153.276	1.93
	10	83.69	159.42	1.90
30° x 200mm x 2-10mm	2	83.11	118.28	1.42
	4	78.497	128.205	1.633
	6	86.90	143.442	1.65
	8	79.364	153.37	1.93
	10	83.317	158.84	1.906
60° x 150mm x 2-10mm	2	85.788	119.657	1.394
	4	79.6388	128.087	1.608
	6	77.1623	142.84	1.85
	8	83.4015	152.548	1.82
	10	83.559	158.923	1.90

2. EFFECT OF WELD PAD THICKNESS

Weld pads with different thickness have been analysed to study their effect on the stress field of pressure vessels.. The pad thickness has been increased and analysed. The variation in stress concentration factors and peak effective stresses obtained from the analysis of different configurations. From the analysis, it can be inferred that as the weld pad thickness increase, the stress concentration factor also increase.

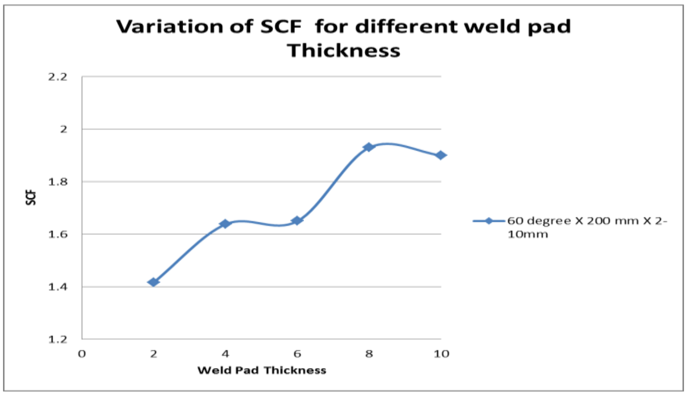

Fig 2. Variation of SCF with different weld pad thickness.

3. EFFECT OF WELD FOOT PRINT

Different model configurations were analysed with different weld footprints. The following three weld foot prints have been used for analysis:

1. All the four sides welded
2. Circseam welded
3. Long seam welded

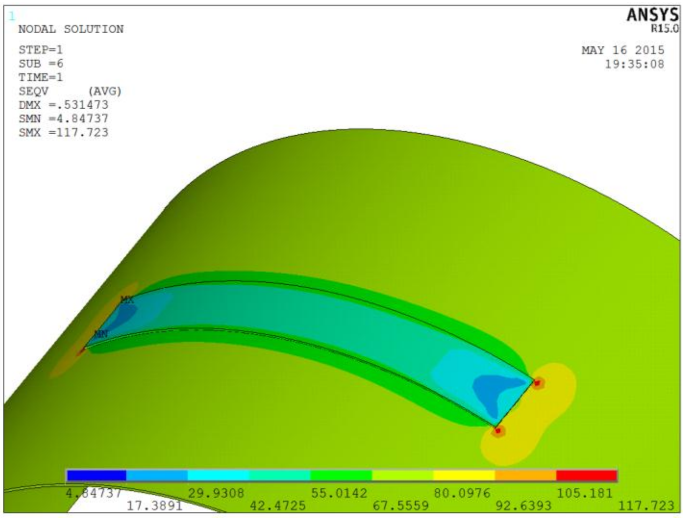

Figure 9.14: Variation of SCF for Circseam Welding

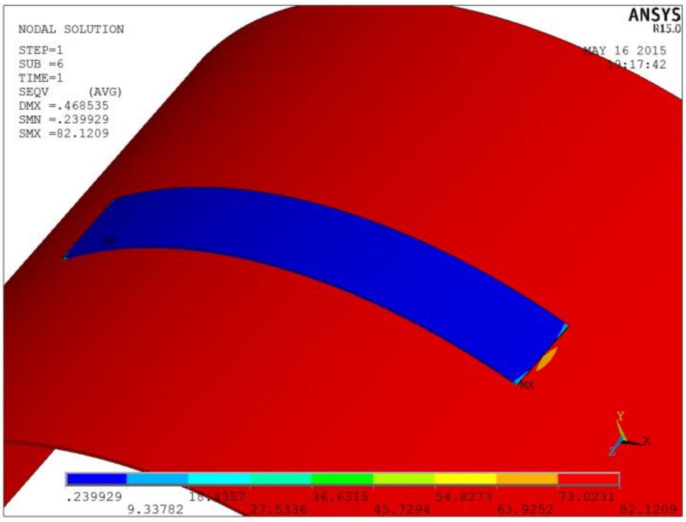

Figure 9.15: Variation of SCF for Long seam Welding

V. CONCLUSION

Based on the parametric study conducted on the pressure vessel, Weld foot print was found to have a huge influence on the Stress concentration factor. Weld pad thickness also created changes in the Stress concentration factor. Long seam welding was found to be creating the optimum stress concentration factor. Hence Long Seam welding can be recommended as the best welding practice for weld attachments in pressure vessel. Also, weld thickness should be the minimum thickness obtained from design calculation. Increase in thickness will lead to higher stress concentration factor and can result in the failure of the pressure vessel.

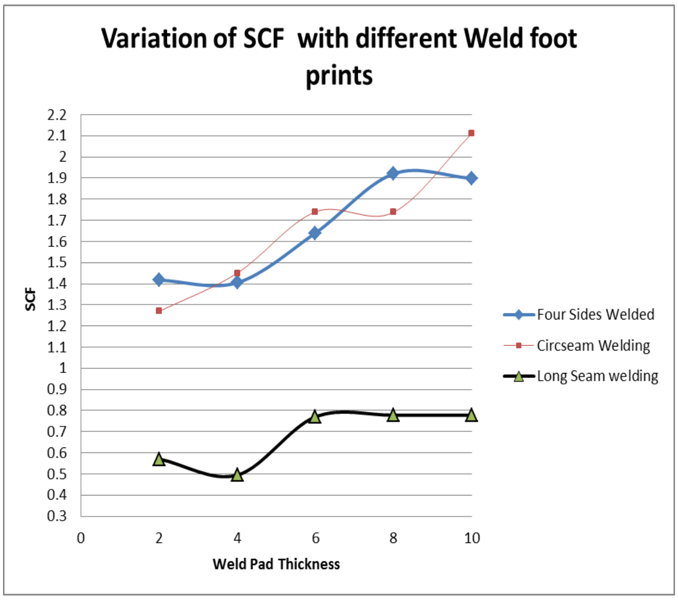

Figure 3. Variation of SCF with different weld Foot Prints.

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