Transient Dynamic Stress Analysis of Mixing Chamber Applied for Chemical Industry

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Abstract - *Pressure vessels are the container used for storing, receiving or carrying fluid under pressure. Pressure vessels are used for various purposes such as chemical industry, nuclear reactor vessels, pneumatic reservoirs, processing fluid, etc. In chemical industry pressure vessel act as mixing chamber where the mixing of reagent with the chemical take place. Due to high pressure and temperature of reagent and chemical creates deformation and distorsion. It reduces the fatigue life of mixing chamber. This paper deals with transient dynamic stress analysis and evaluation of fatigue life of mixing chamber. Thermal analysis of mixing chamber modified the design.*

Key Words: *finite element method, mixing chamber, saddle support. Transient dynamic analysis.*

1. INTRODUCTION

Several types of equipment are used in chemical industry, Petrochemical industry, Power plant and fertilizer industry are pressure vessel, storage vessel, heat exchanger, In all these equipment Pressure vessel is basic and generally used in all industries. Pressure vessels are used for various purposes such as nuclear reactor vessels, pneumatic reservoirs, and storage vessel of liquefied gases. From last few decades as increased in demand of alternative fuels, need of pressure and temperature vessel for petroleum refineries, chemical plant gave rise to the development in pressure vessel technology [2]. Many advanced development in the field of pressure vessel engineering such as

Fracture mechanics, fatigue and creep understanding, new material grade, composite materials and welding techniques such as explosion welding. Finite element analysis is a simulation technique which is used to find out the behavior of a component and structure for various loading condition such as force, pressure and temperature. Complex engineering problem with unusual shape can be solved by finite element method [1].

About finite element modelling and analysis of product By using CAE like ANSYS 17.0 software we can design all types of concept parameter required for the

In chemical industry mixing of liquid state of chemical take place with the help of baffle in enclosed chamber such as pressure vessel. In this mixing chamber it may combine with other reagents hence these reagents mix into mixing chamber at different pressure and different time which creates deformation distortion. It result high local stress developed in mixing chamber. These stresses reduce the fatigue life of mixing chamber. For deeper understanding of stress can be achieved by transient dynamic stress analysis. It is used to determine the structure under the action of any time dependent load. In this paper author will developed optimized design of mixing chamber.

1.1 literature review

The work focused on this area is reviewed with the help of standard journal papers. After studying the literature it can be observed that some work has been done in the field of mixing chamber as pressure vessel.

Khan studied the stress distribution in a horizontal pressure vessel and saddle supports by Finite element analysis. The analysis show that the stress distribution different part of the saddle separately. The effect of changing the load and various geometrical parameters was investigated. From result the optimum valves of ratio of distance of support from the end of the vessel to the length of the vessel and the ratio of length of the vessel to radius of the vessel. To find out the minimum stresses in pressure vessel and saddle structure.

Patil et al. [2] did the transient finite element analysis of balanced stiffness valve. In transient analysis the load is divided into steps. As pressure at pressure plate side is increases plate moves forward against the spring force and hence at particular time "t" each step is having different pressure. Hence the maximum stress developed within the permissible safety limit.

A computational fluid dynamics was carried out by Kong et al., [4] to simulate the transient flow of vacuum ejector system.

For understanding mixing phenomena and to find the time required for mixing is employed by CFD. A parametric sensitivity analysis is done varying various parameter to know how mixing phenomenon is affected.

Nicolas et al., did the study of mixing performance of three geometries of Hartridge Roghton mixers with similar dimension and identical inlet. The performance of the mixer is compared by segregation index. Computational fluid dynamics did the simulation of the flow to develop zonal model to convert segregation into mixing time. hence use the mixing chamber of conical narrowing which has high mixing efficiency.

Mixing is one of the common operations used in chemical industry. Kailas et al.,did the Computational fluid dynamics employed to study the mixing phenomenon and the time required for mixing in a jet mix tank. It predicated the accurate design jet mixing systems.

Quadir and Redekop [3] carried out finite element analysis of pressurized vessel and nozzle interaction with wall thinning damage. The largest force found at crotch corner for tee joint without wall thinning damage.

Pande et al.,[4] conducted transient dynamic analysis on the tube sheet. It is used as filter in filter tube. Maximum stress and deformation obtained from analysis which is used to calculate infinite fatigue life of tube sheet.

1.2 problem statement

Mixing is one of the common unit operations employed in chemical industries. It is used for blending of liquids, homogenization of mixtures, heat transfer operation, mass transfer operation, prevention of deposition of solid particles, etc. In this mixing chamber during operation additives added through the nozzle at different time interval and pressure varies in a cycle from 0 to.14Mpa, 0-0.16MPa and temperature of fluid changes from 0 to 200 degree Celsius. Hence it creates continuous deformation & distortion in mixing chamber. A stress induced in mixing chamber which causing failure of chamber and reduces the fatigue life. Component is fail before the expected life. It is need to find out failure reason of mixing chamber and also flow engineer wants input nozzles incline up to 30 deg angle which angle is suitable with FEA validation.

2. ANALYSIS SETUP

Modeling of mixing chamber as per given dimension in ANSYS workbench 17.0. Analysis of mixing chamber is done to obtain maximum stress and deformation. Optimize the design of product.

2.1 Material and operating parameter

The material used is SA516-grade70, (ASME –Sec-2 part D) it is good choice. It is ideally suited for oil gas and petrochemical industry.

Young's modulus, E = 180Gpa

Poisons ratios, μ= 0.23
Ultimate stress = 485MPa
Yield stress = 262MPa
Working pressure: 0-0.14Mpa, 0-0.16MPa.
Maximum Temperature: 200 deg.celsius

2.2 Modeling and meshing of mixing chamber

Modeling of mixing chamber is done in ANSYS Workbench. It is a common platform for solving engineering problems. For creating the geometry used the design modeler.

Meshing is the internal part of computer aided engineering simulation process. It improves the accuracy and speed of the solution.

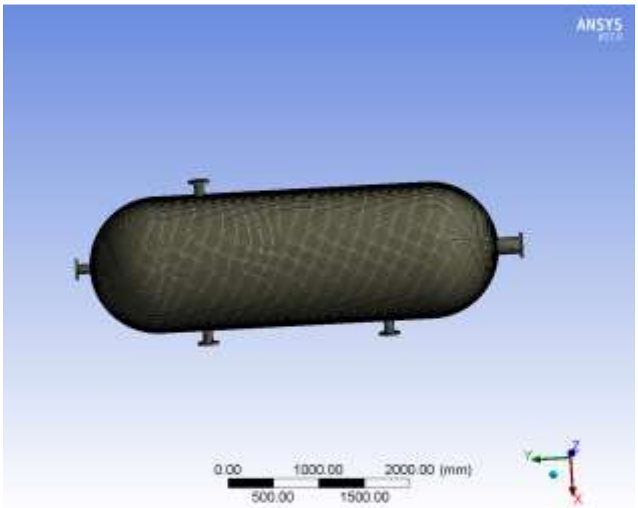

Fig -1: Mesh model of mixing chamber

2.3 Nozzle position optimization

With the help of conventional design it in not possible to calculate stresses and deformations at different position of nozzle on the shell periphery. Location of nozzle is not considered in the conventional design process[5]. According to FEA as the distance between two nozzle changes stresses and deformation generate in the mixing chamber changes. So by fixing two nozzle positions at the periphery of mixing shell varies the one nozzle radially along the mixing shell with 2 degree interval in the opposite plane of fixed nozzle. Calculate the all stresses and deformation in that plane.

Optimum angle position calculation procedure-

Maximum stress relative value =1

Other stresses RV=(stress at angle/max stress)*1

Maximum deformation Relative value =1

Other deflection RV= (deformation at angle/max. deformation)*1

Importance equation= 80%stress + 20% deformation

So from this analysis optimum nozzle position get at 30 deg angles that is final position of two input nozzle is at opposite to each other as shown in figure.

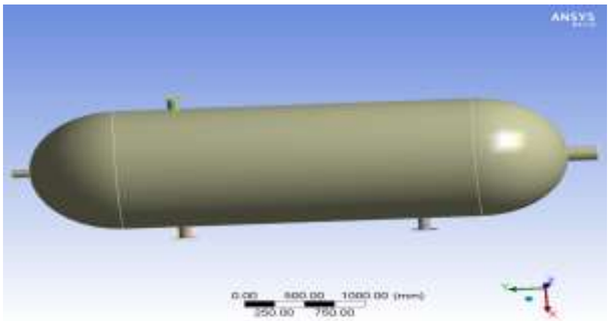

Fig -2: nozzle positioning of mixing chamber

2.4 Structural analysis

It is most common application of finite element method. Static structural analysis is used to determine stress and displacement. One end of flange is fixed.

As maximum stress generated in mixing chamber is less than allowable stress

(81.18 < 131Mpa)

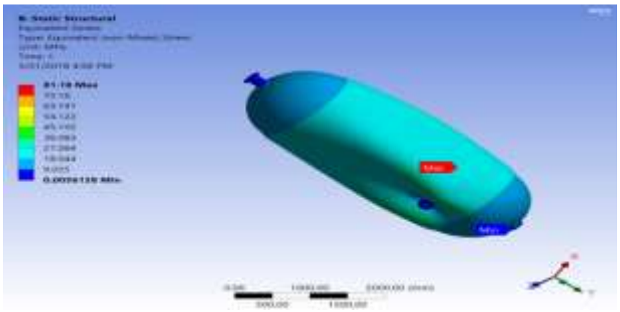

Fig -3: static structural analysis of model

2.4 Gravity analysis

Consider the geometry given below. Gravity analysis is also called self-weight analysis. Model with Young's modulus of 180 Gpa and Poisons ratio 0.23.Mixing chamber model is subjected to standard earth gravity. As stress generated in model is below allowable stress.

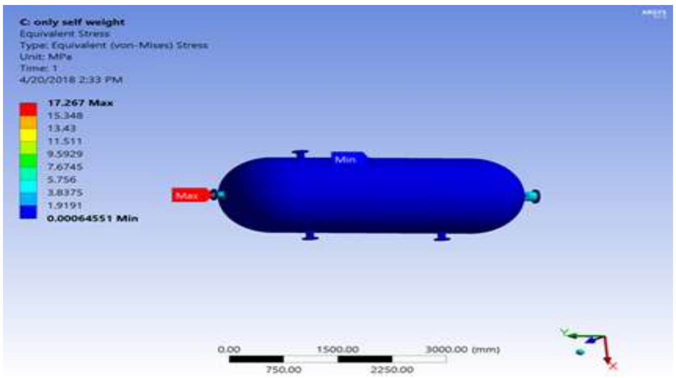

Fig -4: Gravity analysis of model

2.5 Thermal analysis

A steady state thermal analysis calculates the effect of temperature on the component. Model having thermal coefficient of expansion 1.3e-5/c, Temperature, T = 200 deg c. Stress generated is very high is which about 1843.4 Mpa. Hence there is no space for thermal expansion. So that instead of fixing nozzle flange provide the saddle support for mixing chamber.

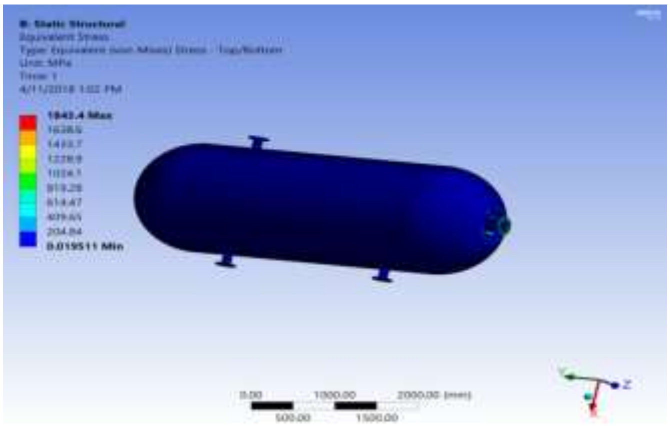

Fig -5: Thermal analysis of model

2.6 Nozzle incline validation

Consider the geometry given below. Two input nozzle are incline at 30 deg with horizontal axis. Structural analysis is done to check stress concentration at incline nozzle area. Stresses generated are within the allowable limit.

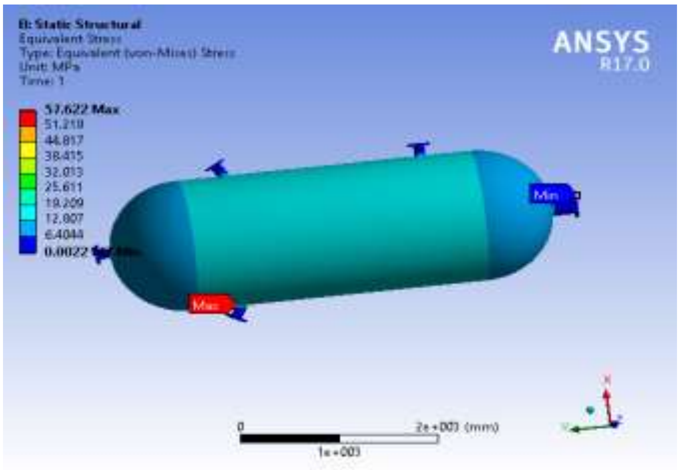

Fig -6: static structural analysis of incline nozzle model

3. RESULT

Horizontal cylinder is supported by saddle. The selection of type of support depends upon diameter and height of the vessel, available space, location, operating temperature and material [7]. These attachments of support of vessel welded by fillet welds it should transfer load from vessel to support.

Table -1: Welded saddle for vessel

Dia.	A	B	C	D	E	F	G	H	Max load
1.5m	1350	950	130	160	330	580	200	140	7100kg

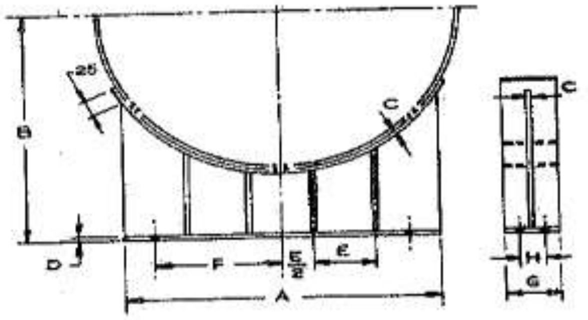

Fig -7: saddle

- Analysis of mixing chamber with saddle support -

Mixing chamber with saddle support in which one saddle is fixed. Structural analysis of mixing chamber where the stresses induced is below the allowable stress. (68.445 < 131Mpa.) Hence design is safe

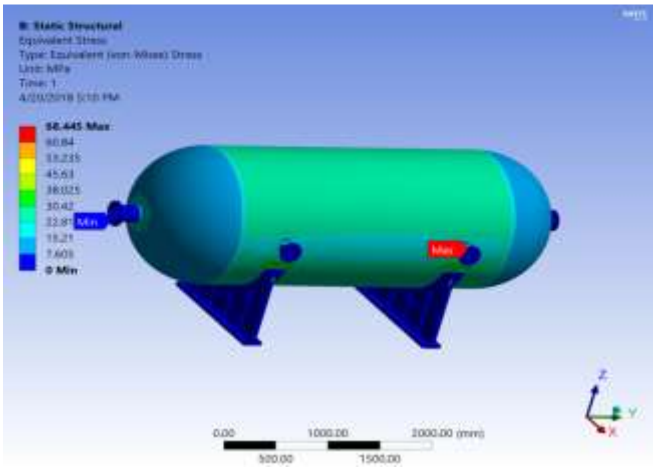

Fig-8: structural analysis of mixing chamber with saddle support.

3.1 Transient dynamic analysis-Thermal condition

Vibration in the mixing chamber generate due sudden incoming fluid and also some time from the earthquake. In Transient dynamic analysis effect of vibration, temperature, force is consider w.r.t. time. In thermal condition vibration effect is consider with temperature.

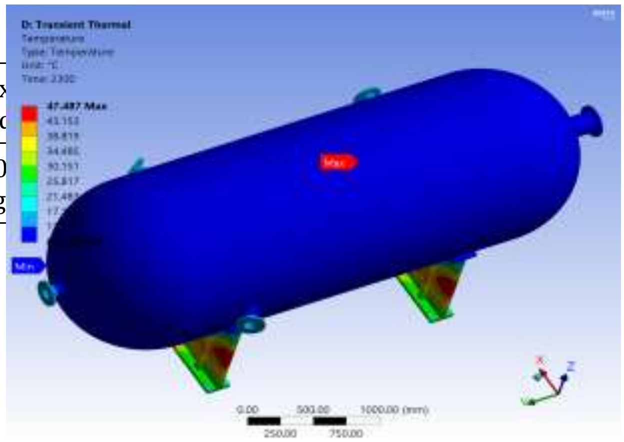

Fig-9: Transient dynamic analysis of mixing chamber with saddle support.

3.1 Transient dynamic analysis- pressure condition

In this transient dynamic analysis there are two cycles of pressure changes with respect to time. In operating cycle pressure changes from 0 to 0.14MPa and in cleaning cycle pressure changes from 0 to 0.16MPa. Effect of vibration is considered with pressure condition.

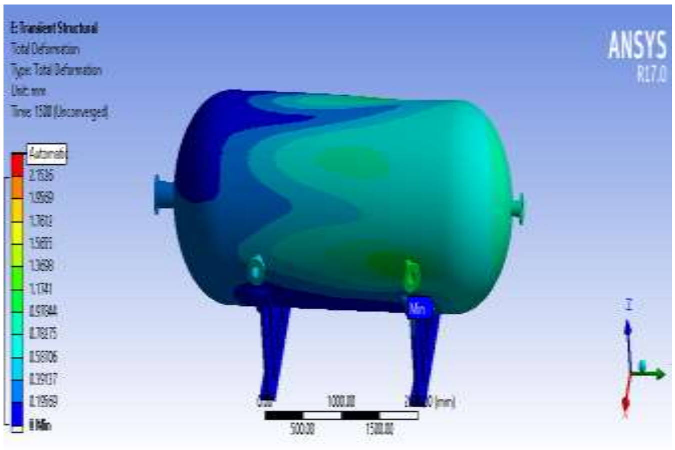

Fig-9: Transient dynamic analysis of mixing chamber with saddle support.

4. CONCLUSIONS

Structural analysis of mixing chamber is done with different boundary conditions. Stresses and deformation obtained is below the allowable limits. Failure of mixing chamber is found out which is due to the no space for thermal expansion which is solve by providing saddle support with sliding contact of on saddle.

The transient dynamic stress analysis of mixing chamber is done to check the effect of maximum stress and deformation at various instant of time during load cycle.

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