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FEA Of Catalyst Bed Reactor Vessel and its Optimization

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ABSTRACT

A Catalyst Bed Reactor (CBR) is a type of reactor device that can be used to carry out a variety of multiphase chemical reactions. In this type of reactor, a fluid (gas or liquid) is passed through a granular solid material (usually a catalyst possibly shaped as tiny spheres) at high enough velocities to suspend the solid and cause it to behave as though it were a fluid.

Catalyst bed is a popular technique to speed up chemical processes. However current designs of a bed are stagnant designs where the chemical reaction occurs while the fluid is stationary, as if in a storage vessel. This process is time expensive and hence there is need of speeding up the process in which the fluid flow is present. This can be achieved in a reactor vessel where the Catalyst bed is embedded in the design.

This design has its own challenges, because as the reaction takes place, some quantity of the catalyst stagnates, and this stagnation has to be removed, which is done using inclined nozzles. These inclined nozzles are a design headache as they create a lot of stress zones. Thus our objective is find out the best solution out for this problem so as to enhance the process and to get the best results doing actual analysis for the vessel under consideration.

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I. INTRODUCTION

A pressure vessel is a closed container designed to hold gases or liquids at a pressure substantially different from the ambient pressure. In pressure vessels, nozzles are required for inlet and outlet of fluid.Pressure vessels find wide applications in thermal and nuclear power plants, process and chemical industries, in space and ocean depths, and fluid supply systems in industries. Due to practical requirements, pressure vessels are often equipped with nozzles of various shapes, sizes and positions, at various angles.

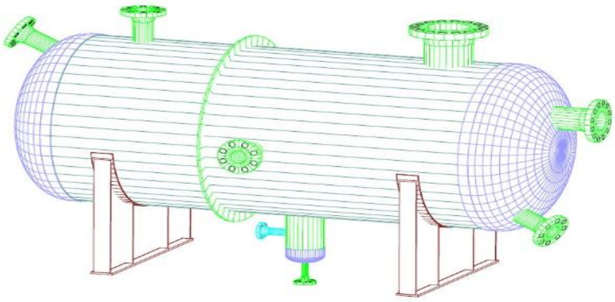

Figure 1: Pressure vessel with nozzles on the periphery

A nozzle is a cylindrical component that penetrates the shell or heads of a pressure vessel. The nozzle ends are usually flanged to allow for the necessary connections and to permit easy disassembly for maintenance or access.However sometimes process requirements dictate that some nozzles be

placed on the periphery of the pressure vessel.Nozzle is a device designed to control the direction or characteristics of fluid (especially to increase velocity) as it exits (or enters) an enclosed chamber or pipe. Under different loading conditions, the stress will occur at the nozzle to head or shell junction area. Thus reliable and accurate design calculation for head or shell to nozzle junction is necessary. The calculation for nozzle design gives the information whether the design is adequate for given parameters.

A **Catalytic bed reactor** (CBR) is a type of reactor device that can be used to carry out a variety of multiphase chemical reactions. Catalyst bed is a popular technique to speed up chemical processes. However current designs of a bed are stagnant designs where the chemical reaction occurs while the fluid is stationary, as if in a storage vessel. This process is time expensive and hence there is need of speeding up the process in which the fluid flow is present. This can be achieved in a reactor vessel where the catalyst bed is embedded in the design. As the reaction takes place, some quantity of the catalyst stagnates, and this stagnation has to be removed, which is done using inclined nozzles. In this subject, these inclined nozzles are of primary interest for their angular inclinations and locations in the vessel as we have to look after the symmetry and stresses generated in the vessel because of them.

So, we will be dealing with FEA (Finite element analysis method):-

1. to get the feasible angular position of the nozzles with respect to the vessel enhancing/speeding up the reaction
2. to conduct stress analysis of the nozzles at varying angular positions
3. to find out the loads acting on them

Finite element analysis

Finite element analysis (FEA) is a fairly recent discipline crossing the boundaries ofmathematics,physics, engineering, and computer science. The method has wide application and enjoys extensive utilization in the structural, thermal and fluid analysis areas.

The following paragraph show the relevant result and the studies conducted on the performance and analysis done by them are describe in below paragraph of the literature.

II. METHODOLOGY

1 Design

Instead of directly starting with modeling, first the dimensions are provided by company are to be calculated as company design guideline (Reference no. A-2209) and ASME code too. Now calculate all necessary dimensions to design the pressure vessel. After verifying the all dimensions starts modeling and this will be carried out by using Ansys software and in Ansys software for modeling workbench 14.5.7 are used as per dimensions which are calculated. (Refer figure 2: modelling). Material used for the vessel is ‘SA 516 Grade 70’

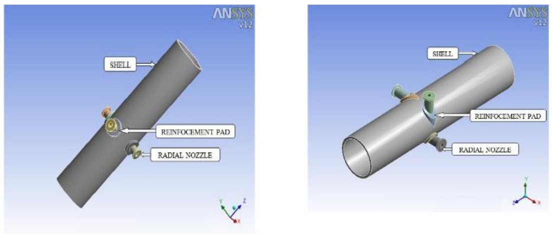

Figure 2: geometry of generalized nozzles [4]

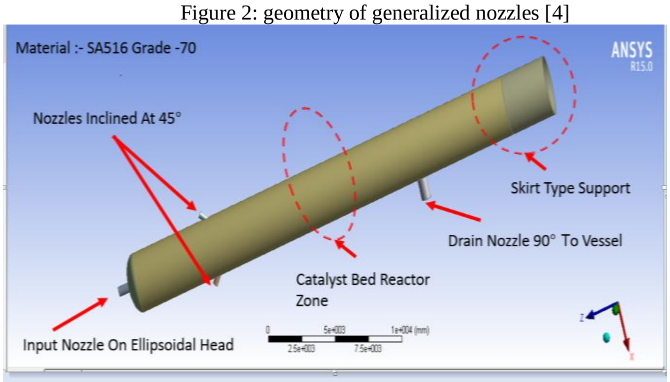

Figure 3: Model of the Catalytic bed reactor vessel

For model creation we have the following inputs from the company:-

Number of nozzles: 2, Drain nozzle diameter: 0.1m, Drain location: Head, Head type: ellipsoidal, Support: Skirt type, Support height: 2.5 m, Vessel radius: 1.5 m, Process volume (Vp): 176 cum, Expected stagnant volume (Vs): 5.5 cum, Buffer volume requirement (Vb): 3.2 cum, Internal pressure (P): 0.14 Mpa, External pressure (Po): Atm, nozzle diameter: 0.1 m, Both nozzles inclined at 45 degrees.

2 Analysis

The 3-D model of pressure vessel with nozzles which is structurally analyzed for determining the stresses in the model at working boundary conditions. But before applying the boundary conditions first the meshing of the mode is done. In analysis if stresses are identified, then taking remedial action and modification can be done at the weak point. And again analysis starts the modified model at working boundary conditions.

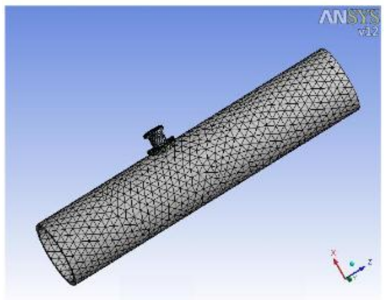

Figure 4: Meshing of the model

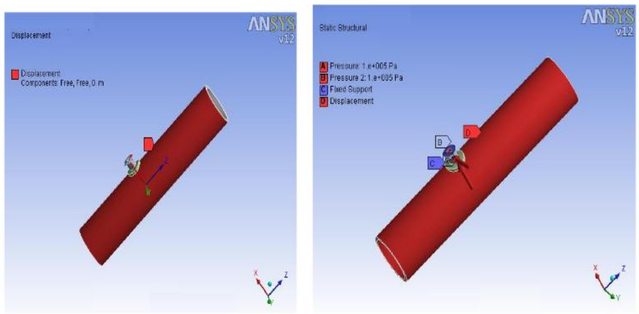

Figure 5: Boundary conditions [4]

3 Experimental

For the validation of result obtained by the Ansys software, Experimentation is to be carried out on the actual model. Using strain gauge and ultrasonic Test Equipment for experimental testing and then the results of this work are used for the validation of results obtained from analysis software.

3.1 Strain Gauge

Strain gauges are intended for measure of strain. The results of such measurements may be used for statements for concerning the material stresses in the specimen, the nature and amount of forces acting on the specimen etc. However a strain gauge can only perform its task properly if the strain to be measure is transferred faultlessly and free of loss. For that purpose, an intimate connection required between strain gauge and object to be measured. The required intimate, plane connection between specimen and the strain gauge is performed by special adhesive. Other bonding agents and methods are limited to special application area, e.g. ceramic bonding agent for high temperature installation and spot welding for applications on steel construction.

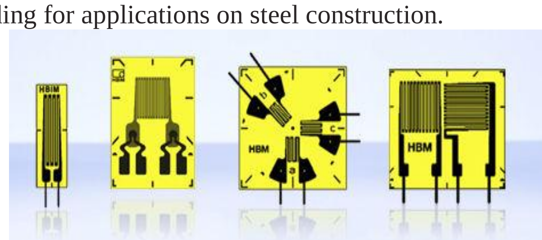

Figure 6: HBM Strain Gauge [13]

Procedure

The procedure of surface preparation, clamping and curing is similar to working with classic hot-curing adhesives. Gauge positioning is simple as the strain gage is dry and not sticky. Gauge fixing is accomplished using a small piece of heat-resistant tape.

Benefits

Strain gauges with the stick-on option have a thin, consistent adhesive layer. This facilitates high-quality bonding which is one of the reasons for the excellent measurement properties of the gauge.

3.2 Ultra sonic Test

In ultrasonic testing (UT), very short ultrasonic pulse-waves with center frequencies ranging from 0.1-15 MHz and occasionally up to 50 MHz are transmitted into materials to detect internal flaws or to characterize materials.

In ultrasonic testing, an ultrasound transducer connected to a diagnostic machine is passed over the object being inspected. The transducer is typically separated from the test object by a coolant (such as oil) or by water, as in immersion testing. However, when ultrasonic testing is conducted with an Electromagnetic Acoustic Transducer (EMAT) the use of coolant is not required.

There are two methods of receiving the ultrasound waveform reflection and attenuation. In reflection (or pulse-echo) mode, the transducer performs both the sending and the receiving of the pulsed waves as the "sound" is reflected back to the device. Reflected ultrasound comes from an interface, such as the back wall of the object or from an imperfection within the object.The diagnostic machine displays these results in the form of a signal with amplitude representing the intensity of the reflection and the distance, representing the arrival time of the reflection. In attenuation (or through-transmission) mode, a transmitter sends ultrasound through one surface, and a separate receiver detects the amount that has reached it on another surface after traveling through the medium. Imperfections or other conditions in the space between the transmitter and receiver reduce the amount of sound transmitted, thus revealing their presence.


Figure 7: Ultra sonic Test Machine

III. RESULTS

The results obtained till now are the dimensions of the nozzle and pressure vessel model following the inputs given under the figure 3.

In nozzle design, we have diameter of nozzle as 0.1 m, also considering the corrosion allowance as 6mm, we get the nozzle thickness as 6.1496 and hence nominal wall thickness of nozzle will be 9mm. Exterior projection of nozzle (Lp) is found to be 150mm, nozzle to nozzle distance (NTD) is 26209mm, height of vessel found is 29271mm, thickness of shell 10.23mm and hence nominal thickness as 12mm, thickness of reinforcement pad 9mm. Using these values we can construct the pressure vessel as shown in figure 3. Incorporation of catalyst bed into this vessel will complete the model required.

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