Research Paper

THERMAL-STRUCTURAL ANALYSIS &OPTIMIZATION OF PRESSURE VESSEL USING FINITE ELEMENT ANALYSIS

Viraj H. Barge[1], Dr. Prof. S.S.Gawade[1], Mr. Vinaay Patil[2]

Address for Correspondence

[1, 2] Mechanical Engineering Dept., Rajarambapu Institute of Technology, Sakharale, Islampur, Maharashtra, India;

[2]FEA (Finite Element Analysis) Dept, Vaftsy CAE, Pune, Maharashtra, India

ABSTRACT

Cylindrical pressure vessels or vertical reactant column are commonly used in industry to carry both liquids and gases under high pressure & temperature. Pressure vessels are used in a variety of applications in both industry and the private sector. Examples of pressure vessels are diving cylinder, distillation towers, autoclaves, and many other vessels in oil refineries and petrochemical plants. The design problem in the pressure vessel is that the holes at the bottom of pressure vessel which controls the mass flow rate are the weak regions structurally & thermally. The project focuses on optimizing the location of these holes for maximum structural safety.

KEYWORDS: Pressure vessel, Non-Linear, Thermo-structural, Optimization

1. INTRODUCTION

The prospect of sustained high oil prices, the heavy dependence of the US on imports for meeting its oil needs, and Middle East turmoil have together catalyzed intense interest in secure domestic alternatives to oil for satisfying US transportation energy needs. Also, it is now highly likely that the US will soon put into place a serious carbon mitigation policy—in which the transportation sector, accounting for 1/3 of US GHG emissions from fossil fuel burning, is likely to get focused attention. The two most significant domestic supplies that might be mobilized to address these challenges are biomass and coal.

The production of Fischer-Tropsch liquids (FTL) from biomass has been given considerable attention.FTL offers as advantages over cellulosic ethanol the prospects that:

- No significant transportation fuel infrastructure changes would be required for widespread use.
- The technology could plausibly come into widespread use more quickly than cellulosic ethanol, which needs considerably more development before it can be widely deployed.
- It can probably accommodate more easily the wide range of biomass feed stocks that are likely to characterize the lignocelluloses biomass supply—because gasification-based processes tend to more tolerant of feedstock heterogeneity than biochemical processes.

1.1 Fischer–Tropsch process

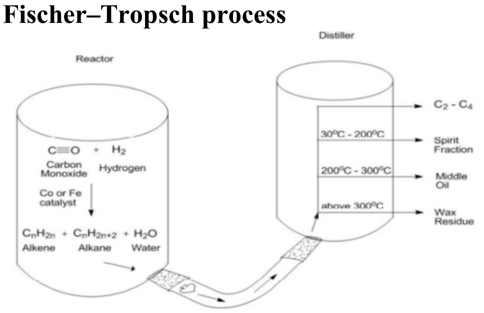

Fig1. Process Description of the Fischer-Tropsch process

The petrol obtained artificially from coal as a mixture of alkanes resemblin petroleum like aliphatic hydrocarbon fuels is called synthetic petrol. Two important methods for producing synthetic petrol are the Fischer-Tropsch process and the Bergius process.These processes have once again drawn much attention due to the existing uncertainties in the world oil markets.

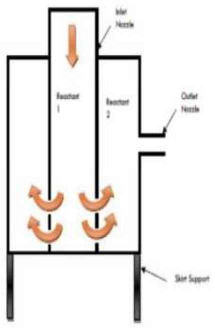

Figure2.Block Diagram of Reactant Column

In the high temperature system, iron based catalysts are used to produce lower carbon chains, C1 - C15, mainly used for liquid fuel purposes. A mixture of water gas and hydrogen under pressure (5-10 atm) is passed over a cobalt catalyst at 450 - 475 K. The water gas required is obtained by passing steam over redhot coke. The product so obtained is fractionally distilled to obtain petrol, middle oil and heavy oil. Further hydrogenation of the middle oil fraction then produces petrol.

3. PRESENT THEORIES AND PRACTICES

3.1 Muhammad A. Al-Arfaj, William L. Luyben [1] studied that the design and control of a reactive distillation column in which one reactant is consumed and two products are formed. The reactant is intermediate boiling between the two products. Three designs are considered: the base case (low-conversion=low-pressure), a low conversion=high-pressure case and a high-conversion= high-pressure case. The base design is obtained from the literature, and the other two steady-state designs are optimized with respect to the total annual cost. All the designs are found to be open loop stable. Five control structures are studied for the base design. Then the best two structures are applied to the remaining two designs.

3.2 Mariano Asteasuain, Adriana Brandolin [2] has shown that the complex relationship existing between design and operating conditions, optimization studies are very useful tools for improving the performance of the reactor in terms of productivity and capability of tailoring the polymer molecular structure. Moreover, it was demonstrated that it is possible to produce new polymer grades with the high pressure tubular reactor. Polyethylene manufacturers may consider using the optimization approach presented in this paper not only to increase the process productivity but also to design novel polymer grades to satisfy specific market requirements.

7. SCOPE OF PROJECT-

This project aims at design and analysis of the proposed model of the vertical reactant column to find out stress and deflection in its various components using FEA and then optimizing the thickness of vertical reactant column. The complete project runs through the following steps:

- Study of working conditions in Vertical reactant Column like pressure, temperature & weight of cobalt mesh
- Optimize the vertical reactant column in the form of thickness.
- FEA of existing vertical reactant column from the nonlinear static structural & thermal analysis of existing Vertical Reactant Column & the area of maximum and minimum stress have been located.

8. DETAILS OF REACTANT COLUMN ASSEMBLY

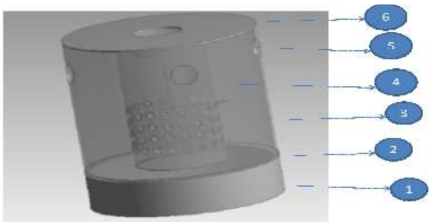

Figure 3- Drawings of reactant column

1. Skirt Support, 2.Base Plate, 3.Shell, 4.Inner Reactant Column, 5.Nozzle, 6. Top Plate

Steps involved in analysis of Vertical Reactant Column-

- Creating CAD geometry in CATIA
- Importing CAD geometry in ANSYS 12.0
- Meshing of Vertical reactant Column
- Applying boundary conditions
- Solving for result in terms of stress & deformation

9. MODELLING AND MESHING

Fig.03 shows the 3-D model of partitioned vertical column. It is created in modelling software CATIA then exported to ANSYS Workbench, which is required for the purpose of further analysis. ANSYS Workbench provides a highly integrated engineering simulation platform, supports multi-physics engineering solutions and provides bi-directional parametric association with most available CAD systems

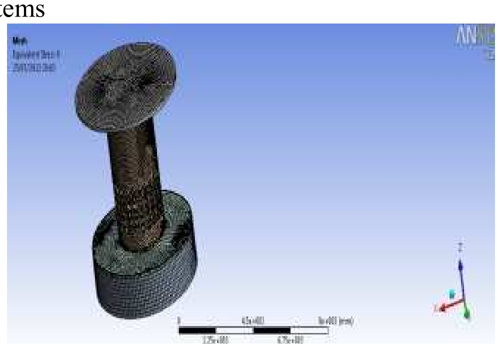

Figure 4.Reactant Column Assembly

The partitioned vertical column assembly model is meshed with 20 Node Hex-Dominant SOLID 186 elements. It is a higher order 3-D 20-node solid element that exhibits quadratic displacement behaviour. The element is defined by 20 nodes having three degrees of freedom per node: translations in the nodal x, y, and z directions. The element supports plasticity, hyper elasticity, creep, stress stiffening, large deflection, and large strain capabilities. It also has mixed formulation capability for simulating deformations of nearly incompressible elasto - plastic materials, fully incompressible elastic materials.

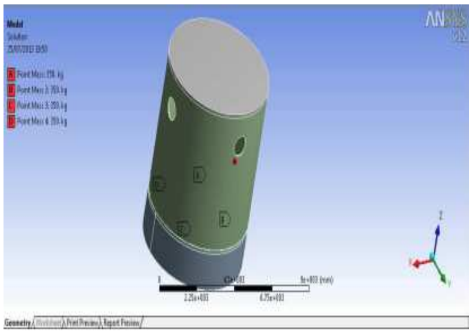

Figure5. Fine Hexahedron Meshed Model of Reactant Column

High quality carbon steel used for boiler & pressure vessel fabrication which is ideally

Suited to the high standards set by the oil, gas & petrochemical industry. The material is normalized steel with excellent weld ability and improved notch toughness i.e. materials ability to absorb energy when a flow is present.

Material properties SA516 Grade 70 applied to the body-Contains:

9.1 Mechanical properties

Table I. Mechanical property of material SA516 Grade 70

Yield Strength	240 MPa
Ultimate Strength	460 MPa
Thermal Conductivity	60.5 W/mk
Poisson's Ratio	0.3

9.2. Chemical Composition

Table II. Chemical Composition of material SA516 Grade 70

Carbon(c)	0.30%
Manganese (Mn)	0.80-1.3%
Phosphorous (p)	0.035%
Sulphur (s)	0.035%
Silicon (si)	0.13-0.45%

9.3 Boundary Conditions

Boundary Conditions are as follows:

1. Skirt support which is considered as Fixed.
2. Process Temperature 500k.
3. Internal pressure 0.2 MPA apply on top & bottom plate also on shell faces.
4. Weight of cobalt meshing 1400 kg Applies on the base plate.
5. Standard earth gravity 9.81 m/s2.

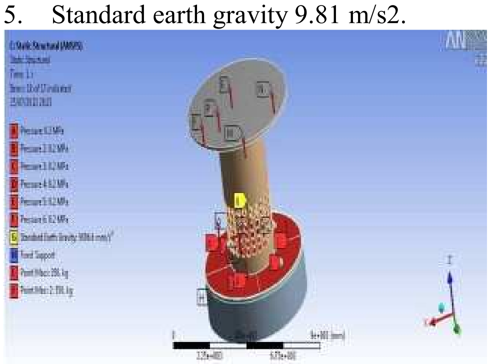

Figure 6.Reactant Column with Boundary Condition

10. RESULT AND DISCUSSION

The stress and the deformation colour counters plots for considering above all boundary conditions by changing meshing size & sub steps. Maximum von-misses Stress &deformation colour counters plotted as shown below in fig.

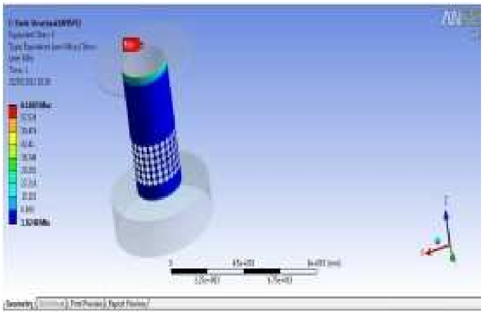

Figure 7.Von-Mises Stress Plot on Inner Reactant Column having rectangular pattern.

We are concentrated on inner reactant column of pressure vessel. From this analysis we can say that comparatively very low stress introduce on inner reactant column. Maximum von-misses stress is found on top portion inner reactant column as shown as red colour contour plot above fig.7. This is also less than that of the yield point of that material.

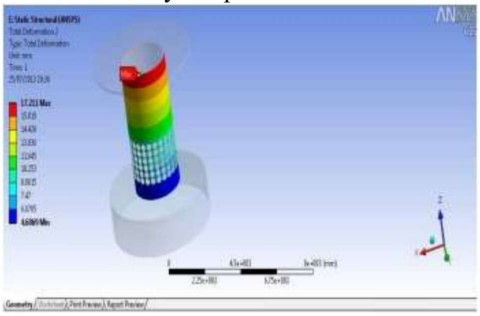

Figure 8. Total Deformation Plot on Inner Reactant Column having Rectangular Pattern.

Table III. Analysis Results of Rectangular Pattern

Analysis of inner reactant column	No of Elements	Maximum von-misses Stress in Mpa	Maximum von-misses deformation in mm
1	60390	64.603	17.211
2	72518	67.641	17.199
3	97462	63.951	17.198
4	107823	61.763	17.203

11. CONCLUSION AND FUTURE SCOPE

Structural optimization for components of vertical reactant column is achieved in the form of thickness. The basic objective of this project is to optimization and analysis of proposed model of vertical reactant column assembly using FEA. However the inner reactant column becomes a critical component in design, if it is gets subjected to a high pressure & temperature. As future work in the design of pressure vessels, we can perform above analysis using other patterns. We can also vary the distance between the holes of the pattern and check effect on the stress & deformation.

REFERENCES

1. Devrim B. Kaymak1, William L. Luyben "Quantitative comparison of dynamic controllability between a reactive distillation column and a conventional multi-unit process" Published in Computers and Chemical Engineering 32 (2008) page no.1456-1470.
2. Mariano Asteasuain, Adriana Brandolin "Modelling and optimization of a high-pressure ethylene polymerization reactorusing gPROMS" Published in Computers and Chemical Engineering 32 (2008) page no.396-408.
3. Bilal Alatas ACROA "Artificial Chemical Reaction Optimization Algorithm for global optimization" Published in Expert System with Applications 38 (2011) page no. 13170-13180.
4. Yuri Avramenko, Lars Nystrom, Andrzej Kraslawski "Selection of internals for reactive distillation column case-based reasoning approach" Published in Computers and Chemical Engineering 28(2004) page no.37-44.
5. Muhammad A. Al-Arfaj, William L. Luyben "Design and control ofan ole!n metathesis reactive distillation column" Published in Chemical Engineering Science 57 (2007) page no.715-733