Analysis and Optimization of Reactant Column by using FEA

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Abstract
A reactant column is typically a vertical duct, from which reactant at high pressure is pushed from top to bottom. At the bottom of the column there are holes allowing the reactant to flow out, and mix with the other reactant and chemical process is underway. The advantage of such a design is that the rate of reaction is directly controlled by the pressure in the column, as this indirectly controls the mass flow rate. So more the number of holes more will be efficiency of the process. The project focuses on optimizing the location of these holes for maximum structural safety.

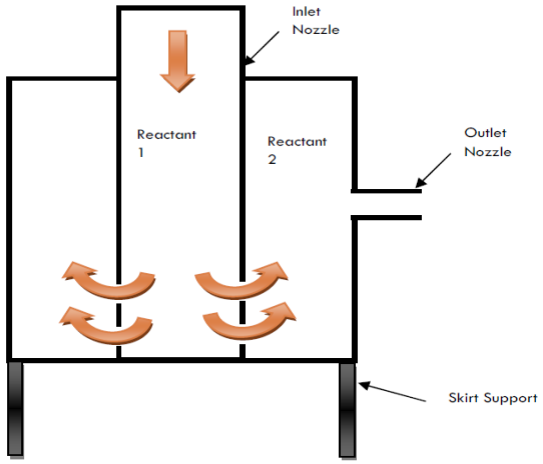

Fig. Block diagram of Reactant Column

Introduction
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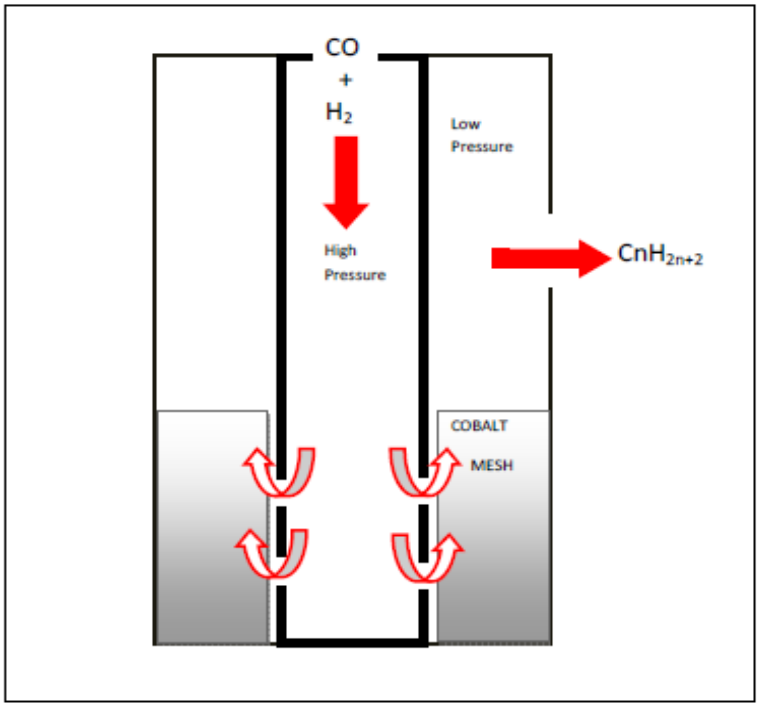
Reactant Column is used in many industries (e.g., hydrocarbon processing, chemical, power, pharmaceutical, food and beverage). The prospect of sustained high oil prices, the heavy dependence of the US on imports for meeting its oil needs, and Middle East turmoil have together catalyzed intense interest 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. It involves some chemical process.

Fischer–Tropsch process
Fischer–Tropsch synthesis is a collection of chemical reactions that converts a mixture of carbon monoxide and hydrogen into liquid hydrocarbons. The process, a key component of gas to liquids technology, produces a synthetic lubrication oil and synthetic fuel, typically from coal, natural gas, or biomass

Process Chemistry
The Fischer–Tropsch process involves a series of chemical reactions that lead to a variety of hydrocarbons ($C_nH_{(2n+2)}$). Useful reactions give alkenes.

$(2n+1)\ H_2 + n\ CO \rightarrow C_nH_{(2n+2)} + n\ H_2O$

where 'n' is a positive integer



BRIEF OVERVIEW OF SOME RESEARCH

[1] E. O. Bergman, Alhambra, Calif, 1995, "The Design of Vertical Pressure Vessels Subjected To Applied Forces"
This paper discusses some design principles that are not covered in the codes. It deals with vessels that are subjected to various applied forces acting in combination with internal or external pressure. The type of vessels considered is limited to cylindrical shells with the longitudinal axis vertical

[2].David Heckman, University of California, Davis Mentor: Gene Masson, Mark Greise Summer 1998, "Finite Element Analysis of Pressure Vessels"
Pressure vessels are a commonly used device in marine engineering. Until recently the primary analysis method had been hand calculations and empirical curves. New computer advances have made finite element analysis (FEA) a practical tool in the study of pressure vessels, especially in determining stresses in local areas such as penetrations, O-ring

[3]. Rick P. Willard son , David L. Gray ,Thomas K. Delay Dassault Systems Simulia Corp , Nasa Marshall Space Flight Centre, Lewisville,2009," Improvements In FEA Of Composite Overwrapped Pressure Vessels"
The original FEA over predicted the vessel's burst strength by 7.6%. This is respectable accuracy, but it is concerning for other reasons. The primary reason for concern is that the prediction was not conservative, which resulted in a lower than expected burst pressure

[4] Thomas G. Kreutz, Eric D. Larson, Guangjian Liu, Robert H. Williams in Fischer-Tropsch Fuels from Coal and Biomass

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. Biomass has long been a focus of development efforts that have focused on using food crops for making bio fuels (primarily corn-based ethanol but also biodiesel derived from soybeans and canola)

[5] Dennis. R. Moss: Pressure Design Manual

The designer must familiarize himself with the various types of stress and loadings in order to accurately apply the results of analysis. The designer must also consider some adequate stress or failure theory in order to combine stresses and set allowable stress limits

Material Selection for Reactant Column

SA516 Grade 70:-

High quality carbon steel used for boiler and pressure vessel fabrication which is ideally suited to the high standards set by the oil, gas and petrochemical industry. The material is normalized steel with excellent weld ability and improved notch toughness i.e. the materials ability to absorb energy when a flaw is present.

A. 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

B. 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%

NEED OF ANALYSIS

In industry the component produced may be of different sizes, from flat plates of very simple shape to complex 3 dimensional solid bodies. During operation they may be subjected to various types of applied loading conditions which include centrifugal force, pressure and temperature loading and prescribed boundary conditions

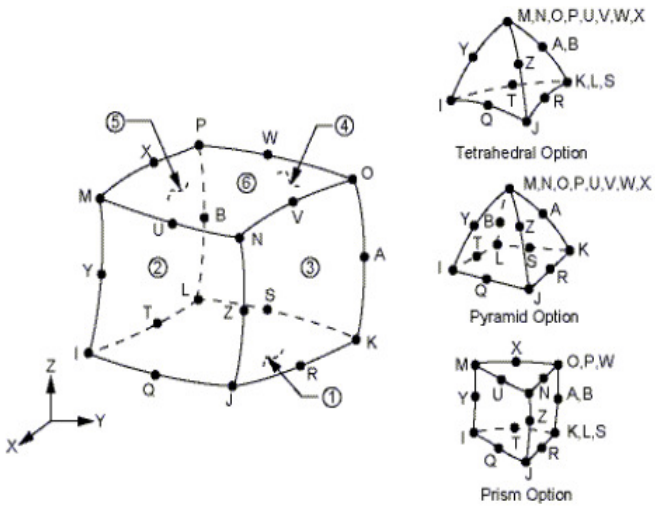
FINITE ELEMENT ANALYSIS

Finite Element Analysis (FEA) is a computer based numerical technique for calculating the strength and behaviour of engineering structures. It can be used to calculate deflection, stress, vibration, buckling behaviour and many other phenomena. It also can be used to analyze either small or large scale deflection under loading and applied displacement. It uses numerical technique called the Finite Element Analysis. In finite element method, the actual continuum is represented by the finite elements. These elements are considered to be joined at specific points called nodes or nodal points.

MESHING

The Reactant column assembly model is meshed with 20 node hexahedron SOLID186 element. 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.

Also the Reactant column assembly model is meshed with SOLID187 element is a higher order 3-D, 10-node element. SOLID187 has a quadratic displacement behavior and is well suited to modeling irregular meshes (such as those produced from various CAD/CAM systems). The element is defined by 10 nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions.



SCOPE OF PROJECT

The 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
• Optimize the vertical reactant column in the form of thickness.

References

[1] The Design Of Vertical Pressure Vessels Subjected To Applied Forces By E. 0. Bergman, Alhambra, Calif
[2] Finite Element Analysis of Pressure Vessels by David Heckman, University of California, Davis
[3] On Using Finite Element Analysis for Pressure Vessel Design by Pedro Marcal, Dennis H. Martens, Michael A. Porter
[4] Improvements In FEA Of Composite Overwrapped Pressure Vessels Rick P. Willardson , David L. Gray ,Thomas K. Delay Dassault Systemes Simulia Corp , Nasa Marshall Space Flight Center
[5] Annual International Pittsburgh Coal Conference Fischer-Tropsch Fuels from Coal and Biomass Thomas G. Kreutz, Eric D. Larson, Guangjian Liu, Robert H. Williams
[6] Dennis. R. Moss: Pressure Design Manual
[7] www.en.wikipedia.org/wiki/Fischer–Tropsch_process
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[10] "Introduction to the Finite Element Method" – by Evgeny Barkanov, Institute of Materials and Structures, Riga Technical University.