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Analysis And Weight Optimization Of Butane Separator Using Finite Element Analysis

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***Abstract*— Butane -1/Butene-2 mixture is used as a raw material for the production of methyl ethyl ketene (MEK). MEK is used as a solvent for polymer compounds, paints and adhesives. Besides, it is used as a high-performance solvent in the magnetic tape manufacturing industry in recent years. Butane is obtained by cracking of crude oil. Cracking produces a mixture of products and the butane is extracted from this by fractional distillation. Fractional distillation is a process than hinges upon usage of temperature and pressure in a manner that yields the desired product from the mixture at hand.**

For a structural engineer the stresses produced by this combination of pressure and Temperatures are crucial, as is the fact that any distillation equipment will need lots of closely placed nozzles that will act as separation points.

***Keywords*— Pressure Vessel Design, Nozzles, Stress Analysis.**

I. INTRODUCTION

Methyl ethyl ketene (MEK) is a solvent that used in paint coatings and is, for instance, used widely in the auto industry. MEK is obtained from Butane. Butane traditionally was a waste product used in crude oil supply.

Crude oil is too heavy to flow down pipelines, so Butane is injected in the pipeline to facilitate flow by making it lighter. Traditionally, there has been no way to recapture the Butane, and was considered a cost of pushing crude oil through pipelines. With the Gas Recapture Systems process, the Butane can now be recaptured, and used again. A typical $1-3 million dollar monthly budget of Butane cost, can now recover 75% savings using, Gas Recapture Systems. This recaptured Butane can thus be utilized in producing MEK. This will be useful in preventing damage to environment. This process is termed as “Gas Recapture Process”. This process of separation is unique, as this separation occurs at extremely low temperatures.

To cool off Butane vapour gases to as low a temperature as feasible, using refrigerated – 25 °C chillers and Plate heat exchangers.

Note that the Butane component flow is assumed to be equal to min 6.0 m3/h to a max of 8.0 m3/h.

Liquid butane at standard conditions (Iso-Butane: -11.7°C N-Butane: -0.5°C) This requires cooling up to -25 deg C, at such low temperature Butane will separate from the flow. Separators are rated for a maximum of 285 psig (1965 kPa), and -25°C.

The objective is to

1. Analyse the current separator design using FEA.
2. To understand the complex interaction of low temperature and pressure.
3. Establish safety norms for the vessel, and determine critical areas for inspection.

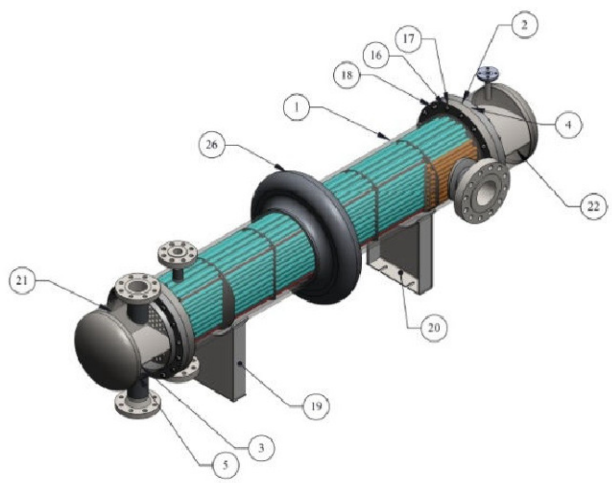

Fig1. Butane Separator

II. METHODOLOGY

A. GEOMETRY

The modelling of Butane separator and its components- flanges, expansion joints, saddles, repad and main body is done using CATIA V5R19. This can be viewed in Fig.2

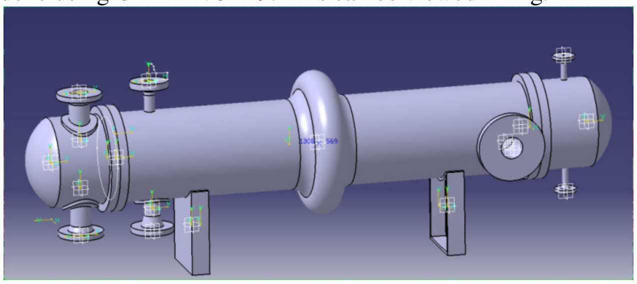

Fig2. CAD Model Butane Separator

The vessel and S.E head are modelled with thickness of 0.75 inch. RFWN flanges are of class 300 and 900. The diameter of Butane separator is 18.5 inch and length of this vessel is 131.13 inch. Repad are modelled with thickness of 0.625 inch.

The assembly of the Butane separator is also done in CATIA V5. Then this separator model is export in ANSYS workbench.

B. FINITE ELEMENTS

The meshing is done with mesh size such that the mesh is not over fined and with no ram problem. Also Map faced meshing is done on flanges for removing non regularity in meshing which affects the end results. This can be viewed in Fig.3

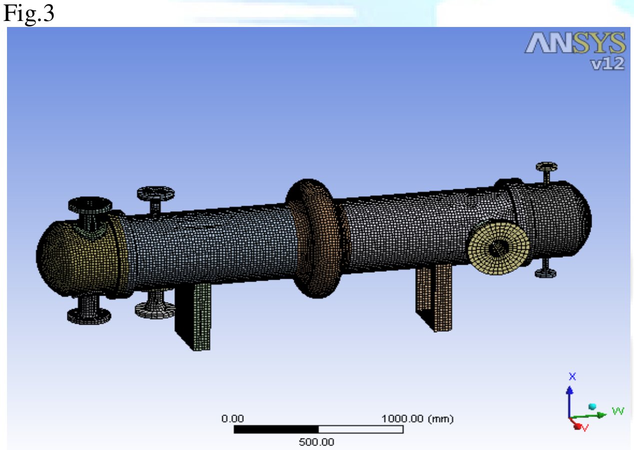

Fig3. Finite Element Mesh

Various sizes and locations of Butane Separator were analysed for stress distribution with three different element sizes using ANSYS. Also, using modal analysis, corresponding natural frequencies of defect components were determined. The ANSYS finite element package is used to evaluate the stress distributions in Butane Separator. Hex Dominant method was selected to mesh the model, Butane Separator. The Hex dominant approach can have very fast transitions at the core of the volume. To get the uniform mesh Mapped Face meshing is used on the surfaces of flanges. The mapped mesh is usually more uniform, has less distorted elements, no triangles, and usually has fewer nodes.

C. LOADING

The vessel was analysed using internal pressure loads only. A pressure of 9.6526 MPa was applied to all internal surfaces of the pressurised section. Also Acceleration of 9810 mm/s² was applied in the upward direction. Also remote forces and moments are applied on flanges. This can be viewed in Fig.4

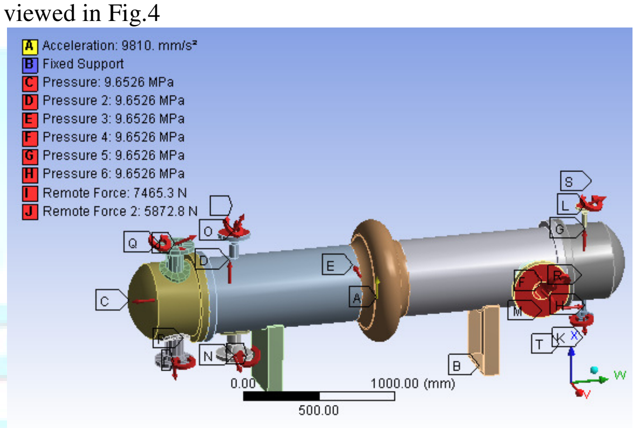

Fig4. Boundary Conditions

D. MATERIAL PROPERTIES

The material is assumed to be isotropic and linear elastic. For the purposes of the analysis, a Young's modulus of 210,000N/mm^2 was assumed together with a Poisson's ratio of 0.3 corresponding to standard boiler plate material.

TABLE I

Property	Value
Density	7.85e-6 kg mm^-^{3}
Tensile Strength	485-620 Mpa
Yield Strength	260 Mpa
Coefficient of thermal expansion	1.17e-5
Thermal conductivity	22.92 Btu/hr-ft-°F

E. DESIGN ALLOWABLE STRESSES

According ASME Code, Section VIII, Division 1, 2010, 2011a

1. Maximum allowable total deformation is = 2.975mm.
2. Shell axial membrane allowable stress due to joint interaction = 260 MPa
3. Maximum allowable Linearized equivalent stress= 324 MPa

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III. INITE ELEMENT RESULT

The following results are presented for the three different element sizes 17mm, 18mm and 19 mm respectively.

1) Element size=17mm

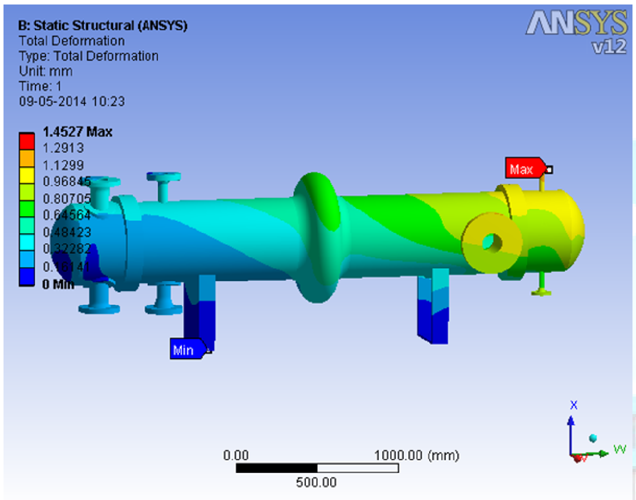

Fig.5 Total deformation result for 17mm element size

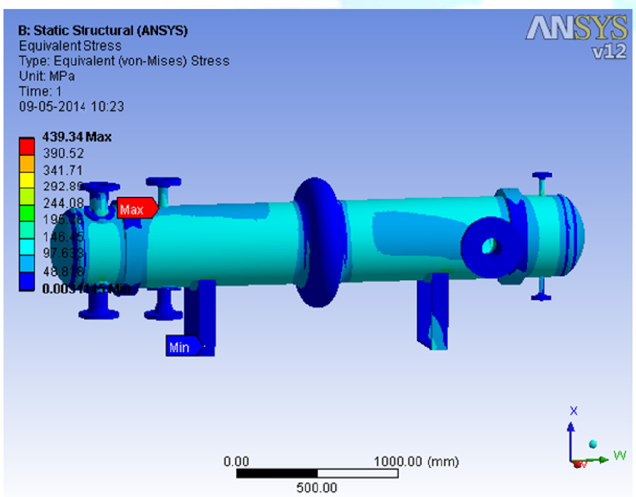

Fig.6 Von-mises stress result for 17mm element size

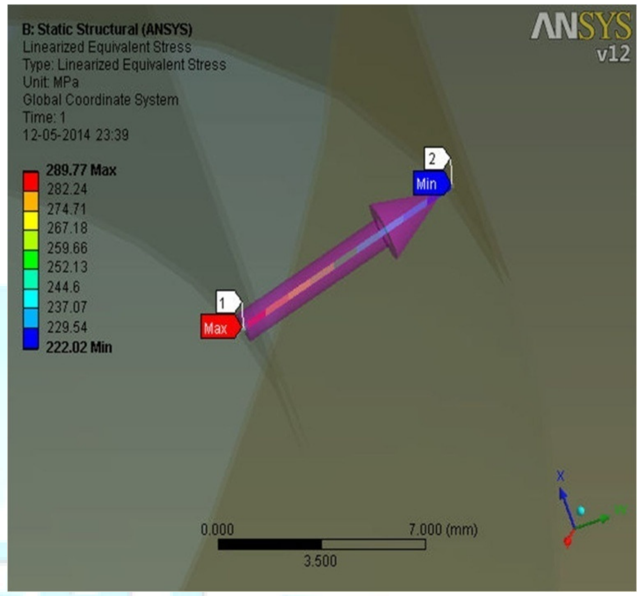

Fig.7 Liner zed equivalent test result for 17mm element size

2) Element size=18mm

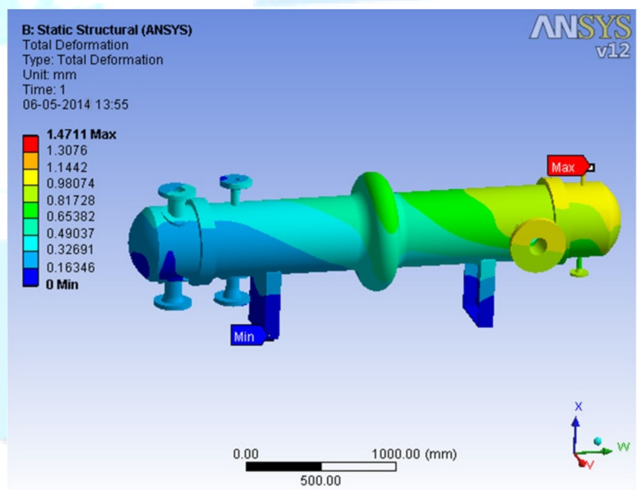

Fig.8 Total deformation result for 18mm element size

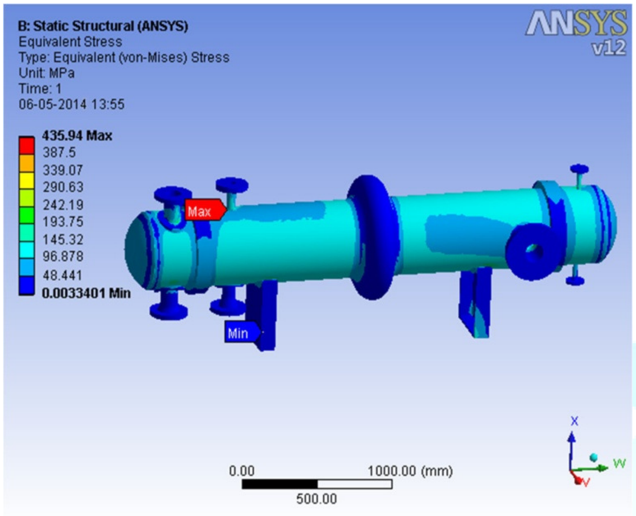

Fig.9 Von-mises stress result for 18mm element size

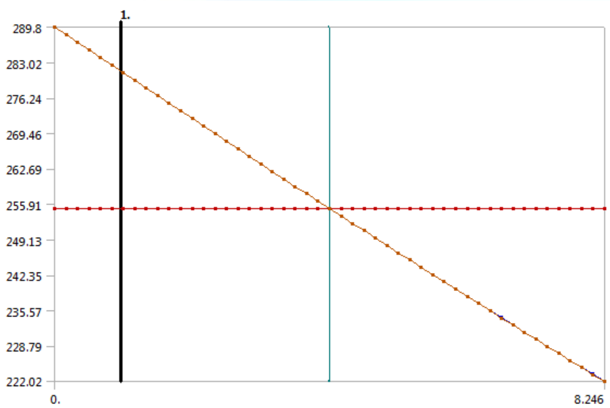

Fig.10 Linearized stress Vs. Length graph

3) Element size= 19mm

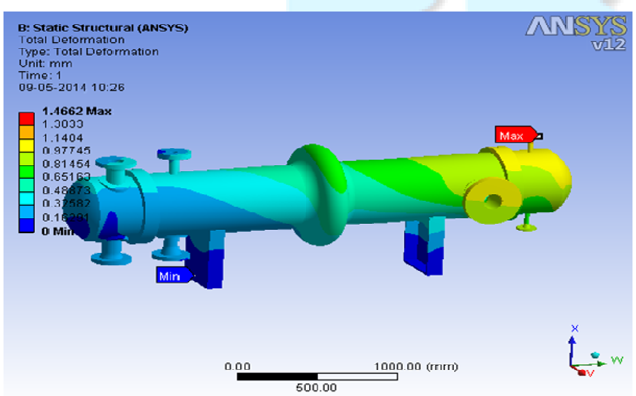

Fig.11 Total deformation result for 19mm element size

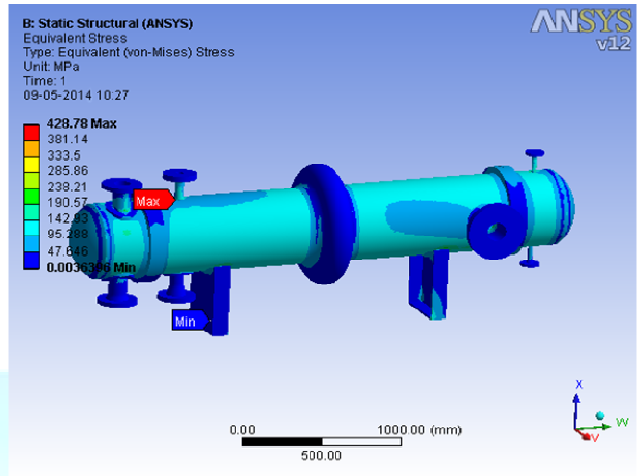

Fig.12 Von-mises stress result for 19mm element size

From the resulting finite element stress analysis output, the maximum total deformation occurs at flange T4, and its value is less than the maximum allowable total deformation 2.975mm.

From the results it is found that the maximum Equivalent von-mises stress occurs on flange S3 whereas minimum occurs on left saddle.

Also it is found that value of Linear zed equivalent stress is well within allowable limit, its maximum value is found when 17mm element size is used.

It is found that shell axial membrane stress is also less than the allowable value i.e. 260 Mpa.

TABLE III

Element Size	Max. Total deformation	Max. von-mises stress	Max. Membrane stress
17 mm	1.4527 mm	439.34 Mpa	257.76 Mpa
18 mm	1.4711 mm	435.95 Mpa	255.05 Mpa
19 mm	1.4662 mm	428.78 Mpa	254.45 Mpa

IV. RESULT AND CONCLUSION

The butane separator vessel separated by expansion joint and supported with saddle support and consisted of flanges, repads has analyzed. The model was analyzed at MAWP of 9.6526 Mpa.

General stresses are well within code allowable. The stresses induced by applying given boundary condition in all three cases are less than the permissible membrane stress value which is 260 Mpa.

Also the deformations occurs in the separator vessel is less than allowable Total deformation which is 2.975. Stress concentration had analyzed.

All the cases exhibits stress generated is less than allowable or design stress. After carrying out structural analysis it is proved that the given model is safe from strength and rigidity point of view.

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