Parametric Modeling of 'C' Class Boiler- A case study

Abhinav A Kherkar[#1], Girish M Dhote[*2], Dr.V.H.Tatwawadi[*3]

[#]CADMA Mechanical Department, RTMNU University, Nagpur (Maharashtra, INDIA)

[1]abhinavkherkar@yahoo.com, [2]girishdhote@gmail.com

Abstract—In order to reduce the pressures of reading drawings and dimensional analysis on engineering staffs, the use of CATIA to build 3D models by 2D drawings with the given information is suggested. Through the application of 3D modelling, the overall situation of the time consuming design can be avoided. The research focuses on the case of the 'C' Class boiler owned by renowned company. 3D model is constructed by using information of 2D drawings to calculate the design parameters of boilers concerned with the project. It managed to shorten the design time, reduce the construction difficulties and ensure that the requirements on equipment, human resource and materials are all satisfied.

Keywords— Parametric modelling , CATIA, 3D Model, boiler, 'C' class boiler, 2D drawing, KBE, Design parameters, Design time.

INTRODUCTION

C Class boilers mainly used in Marine ships for the purpose of hot water supply, cooking and other basic purpose. These boilers need to be designed frequently as per change in dimensions for different types of marine ships. In the phase of multidisciplinary design optimization of boilers, according to the changes of the design parameters, structure and the shape need to be continuously adjusted. The parametric modeling can avoid the disadvantages of 3D modeling, such as long time consuming, low efficient, and poor interaction, and it will be the important method of multidisciplinary design optimization.

A model of a Boiler by using the parametric modeling in CATIA software which will be the base of design and analysis using a Knowledge Based Engineering (KBE) as a parametric tool.

1.2 .Introduction to Boilers

Steam boilers: It is a closed vessel made of steel. Its function is to transfer heat produced by combustion of fuel (solid, liquid or gaseous) to water and ultimately to generate steam. For producing hot water which can be used for heating installation at much lower pressure.

1.2.1 Classification of Pressure Vessels

The pressure vessels may be classified as follows:

1. According to the dimensions.

If the wall thickness of the shell (t) is less than 1/10 of the diameter of the shell (d), then it is called a **thin shell.**

Ex: boilers, tanks and pipes.

If the wall thickness of the shell is greater than 1/10 of the diameter of the shell, then it is said to be a **thick shell.**

Ex: high pressure cylinders, tanks, gun barrels etc.

2. According to the end construction.

A simple cylinder with a piston, such as cylinder of a press is an example of an open end vessel,

In case of vessels having open ends, the circumferential or hoop stresses are induced by the fluid pressure, whereas a tank is an example of a closed end vessel. In case of closed ends, longitudinal stresses in addition to circumferential stresses are induced.

1.3 Problem Identification

Boilers which were designed are produced as standard assembly and designed using traditional design methodology. According to this methodology the boilers design were tedious and time consuming Class boilers mainly used in Marine ships for the purpose of hot water supply, cooking and other basic purpose. These boilers need to be designed frequently as per change in dimensions for different types of marine ships.

1.4 Aim

Design of C-Class Boiler by using a parametric modelling technique (A case study approach)

1.5 Objective

To use parametric modelling technique to minimize the efforts of design engineer for designing similar objects with varying capacity.

To reduce design time for repetitive jobs.

1.6 Challenges in typical design

Due to change in dimensions redesign of boiler was tedious.

Analysis was time consuming and end results were not satisfactory.

1.7 Concept used

Basic concept of Knowledge Base Engineering (KBE) has been the approach for case study. The use of CATIA to build 3D models by 2D drawings with the given information is suggested. Through the application of 3D modelling, the overall situation of the time consuming design can be avoided. The research focuses on the case of the 'C' Class boiler .3D model is constructed by using information of 2D drawings to calculate the design parameters of boilers concerned with the project.

1.8 Why CATIA for parametric modelling?

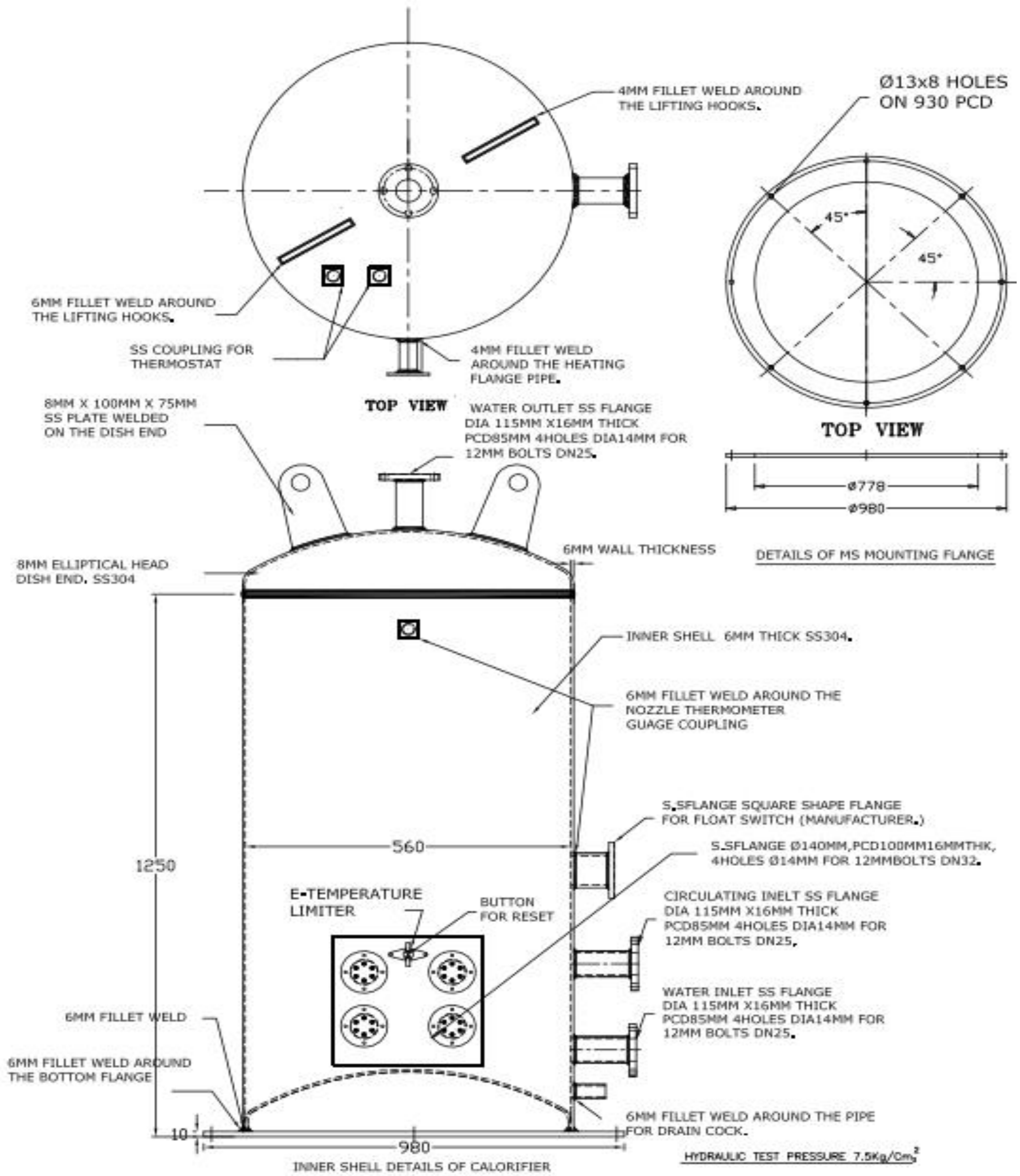
The parametric modelling approach has elevated computer-aided design technology to the level of a very powerful design tool. Parametric modelling automates the design and revision procedures by the use of parametric features. Parametric features control the model geometry by the use of design variables. The word parametric means that the geometric definitions of the design, such as dimensions, can be varied at any time in the design process.

Parametric Modelling is an approach to CAD that leaves the traditional 2 dimensional approach. Parametric modelling represents a different approach to CAD compared to 2D drafting. It is often called Feature Based modeling. Parts are composed of features of positive or negative space. A positive space can be an extruded boss, a negative space can be a hole or segment that is cut away. Often the feature is sketched 2 dimensionally and extruded, revolved or swept into a 3 dimensional object.

2. WORK DONE

2.1 Input data.

ADCC Infocad ltd. Nagpur has been source for obtaining a 2D diagram of a boiler which has become a base for the start of case study. A knowledge based engineering approach is followed. From this figure we studied total number of parts, material of boiler, specification, dimensions and other dimensional attributes.



2.2 Design Formulae

2.2.1 Boiler Tubes up to and including 5 inches O.D. (125 mm):

a) The minimum required thickness, according to ASME paragraph PG-27.2.1, use equation below:

$$t = \frac{PD}{2S + P} + 0.005D + e \qquad 1.1$$

b) To calculate the Maximum Allowable Working Pressure (MAWP):

$$P = S\left[\frac{2t - 0.01D - 2e}{D - (t - 0.005D - e)}\right] \qquad 1.2$$

Where:

t = Minimum Design Wall Thickness (in)

P = Design Pressure (psi)

D = Tube Outside Diameter (in)

e = Thickness Factor (0.04 for expanded tubes; 0 = for strength welded tubes)

S = Maximum Allowable Stress According to ASME Section II, Table 1A

2.2.2 Piping, Drums, and Headers

a) Using the outside diameter

$$t = \frac{PD}{2SE + 2yP} + C \quad 2.1$$

$$P = \frac{2SE(t - C)}{D - (2y)(t - C)} \quad 2.2$$

b) Using the inside radius

$$t = \frac{PR}{SE - (1 - y)P} + C \quad 2.3$$

$$P = \frac{SE(t - C)}{R + (1 - y)(t - C)} \quad 2.4$$

Where:

t = Minimum Design Wall Thickness (in)

P = Design Pressure (psi)

D = Tube Outside Diameter (in)

R = Tube Radius (in)

E = Tube Welding Factor (1.0 for seamless pipe; 0.85 = for welded pipe)

y = Wall Thickness Welding Factor (0.4 for 900°F & lower; 0.7 for 950°F & up)

C = Corrosion Allowance (0 for no corrosion; 0.0625 in. commonly used; 0.125 in. maximum)

S = Maximum Allowable Stress According to ASME Section II, Table 1A

2.2.3 - Thin Cylindrical Shells:

The formulae in ASME Section VIII, Division 1, paragraph UG-27, used for calculating the wall thickness and design pressure of pressure vessels, are:

a) Circumferential Stress (longitudinal welds):

When, P < 0.385SE:

$$t = \frac{PR}{(SE - 0.6P)} \quad 1.3$$

Or

$$P = \frac{SEt}{(R + 0.6t)} \quad 1.4$$

(R = Internal Radius)

b) Longitudinal Stress (circumferential welds):

When, P < 1.25SE

$$t = \frac{PR}{(2SE + 0.4P)} \quad 1.5$$

Or

$$P = \frac{2SEt}{(R - 0.4t)} \quad 1.6$$

2.2.4 Thick Cylindrical Shells:

For internal pressures higher than 3,000 psi, special considerations as specified in paragraph U-1 (d).

As the ratio of t/R increases beyond 0.5, an accurate equation is required to determine the thickness. The formulae in ASME Appendix 1, Supplementary Design Formulas used for calculating thick wall and design pressure, are:

a) For longitudinal welds:

When, P > 0.385SE:

$$t = R\left(Z^{\frac{1}{2}} - 1\right) \quad \text{Where} \quad Z = \frac{(SE + P)}{(SE - P)} \quad 1.7$$

And

$$P = SE\left[\frac{(Z - 1)}{(Z + 1)}\right] \quad \text{Where} \quad Z = \left[\frac{(R + t)}{R}\right]^2 \quad 1.8$$

b) For circumferential welds:

When, P > 1.25SE:

$$t = R\left(Z^{\frac{1}{2}} - 1\right) \quad \text{Where} \quad Z = \left(\frac{P}{SE}\right) + 1 \quad 1.9$$

And

$$P = SE(Z - 1) \quad \text{Where} \quad Z = \left[\frac{(R + t)}{R}\right]^2 \quad 1.10$$

Where:

R = Design Radius (in.)

Z = Dimensionless Factor

2.2.5 Pressure Piping - Minimum Wall Thickness:

$$t = \frac{PD}{2SE + 2yP} + C \qquad 1.12$$

Where:

t(min)= Minimum wall thickness required (in)

P = Design pressure (psig)

D = Outside diameter of pipe (in)

S = Allowable stress in pipe material (psi)

E = Longitudinal joint factor - E = 1.0 for seamless pipe, E = 0.85 for ERW pipe

C = Corrosion allowance, typically 0.05 in.

y = Wall thickness coefficient in ASME Table 304.1.1 for ferritic steels, is:

y = 0.4 for T<= 900 ºF

y = 0.5 for 900< T <= 950 ºF

y = 0.7 for 950 < T <= 1000 ºF

2.2.6 Reinforcement Wall Thickness Plate:

The standard design method uses an increased wall thickness plate at the equator line of the vessel to support the additional stresses caused by the attachment of the legs. The formula for calculation the wall thickness of a segmented plate of to be welded in a vessel or spherical shell is:

t = (P x L) / (2xSxE – 0.2xP) + C

Where L = Di/2

Where:

t = Minimum Design Wall Thickness (in)

P = Design Pressure (psi)

Di = Inside Diameter of Sphere (in)

L = Sphere Radius (in)

E = Tube Welding Factor (1.0 for seamless pipe; 0.85 = for welded pipe)

C = Corrosion Allowance (0 for no corrosion; 0.0625 in. commonly used; 0.125 in. maximum)

S = Maximum Allowable Stress According to ASME Section II, Table 1A

2.2.7 Dished Heads Formulae

a) Blank, Unstayed Dished Heads:

$$t = \frac{5PL}{4.8S} \qquad 1.11$$

Where:

t = Minimum thickness of head (in)

P = maximum allowable working pressure (psi)

L = Concave side radius (in)

S = Maximum Allowable Working Stress (psi)

b) Seamless or Full-Hemispherical Head

$$t = \frac{PL}{2S - 0.2P} \qquad 1.13$$

t = Minimum thickness of head (in)

P = Maximum Allowable Working Pressure (psi)

L = Radius to which the head was formed (in)

S = Maximum Allowable Working Stress (psi)

Note: The above formula shall not be used when the required thickness of the head given by the formula exceeds 35.6% of the inside radius. Instead, use the following formula:

$$t = L\left(Y^{\frac{1}{3}} - 1\right) \quad \text{where} \quad Y = \frac{2(S + P)}{2S - P} \qquad 1.14$$

c) Spherical or Hemispherical Heads:

i) When t < 0.356R or P < 0.665SE - (Thin Spherical or Hemispherical Heads):

$$t = \frac{PR}{2SE - 0.2P} \qquad 2.1$$

and

$$P = \frac{2SEt}{R + 0.2t} \qquad 2.2$$

ii)When t > 0.356R or P > 0.665SE – (Thick Spherical or Hemispherical Heads):

$$t = R\left(Y^{\frac{1}{3}} - 1\right) \quad where \quad Y = \frac{2(SE+P)}{2SE - P} \qquad 2.3$$

$$P = 2SE\left(\frac{Y-1}{Y+2}\right) \quad \text{where} \quad Y = \left(\frac{R+t}{R}\right)^3 \qquad 2.4$$

d) Elliptical or Ellipsoidal Heads - Semi-Elliptical or Semi-Ellipsoidal Heads – 2:1:

$$t = \frac{PD}{2SE - 0.2P} \qquad 2.5$$

or

$$P = \frac{2SEt}{D + 0.2t} \qquad 2.6$$

e)Torispherical Heads:

i)Flanged & Dished Head (F&D heads):

$$t = \frac{0.885PL}{SE - 0.1P} \qquad 2.7$$

$$P = \frac{SEt}{0.885L + 0.1t} \qquad 2.8$$

Where:

P = Pressure on the concave side of the head

S = Allowable stress

t = Thickness of the head

L = Inside spherical radius

E = Joint efficiency factor

2.4 Preparing input database.

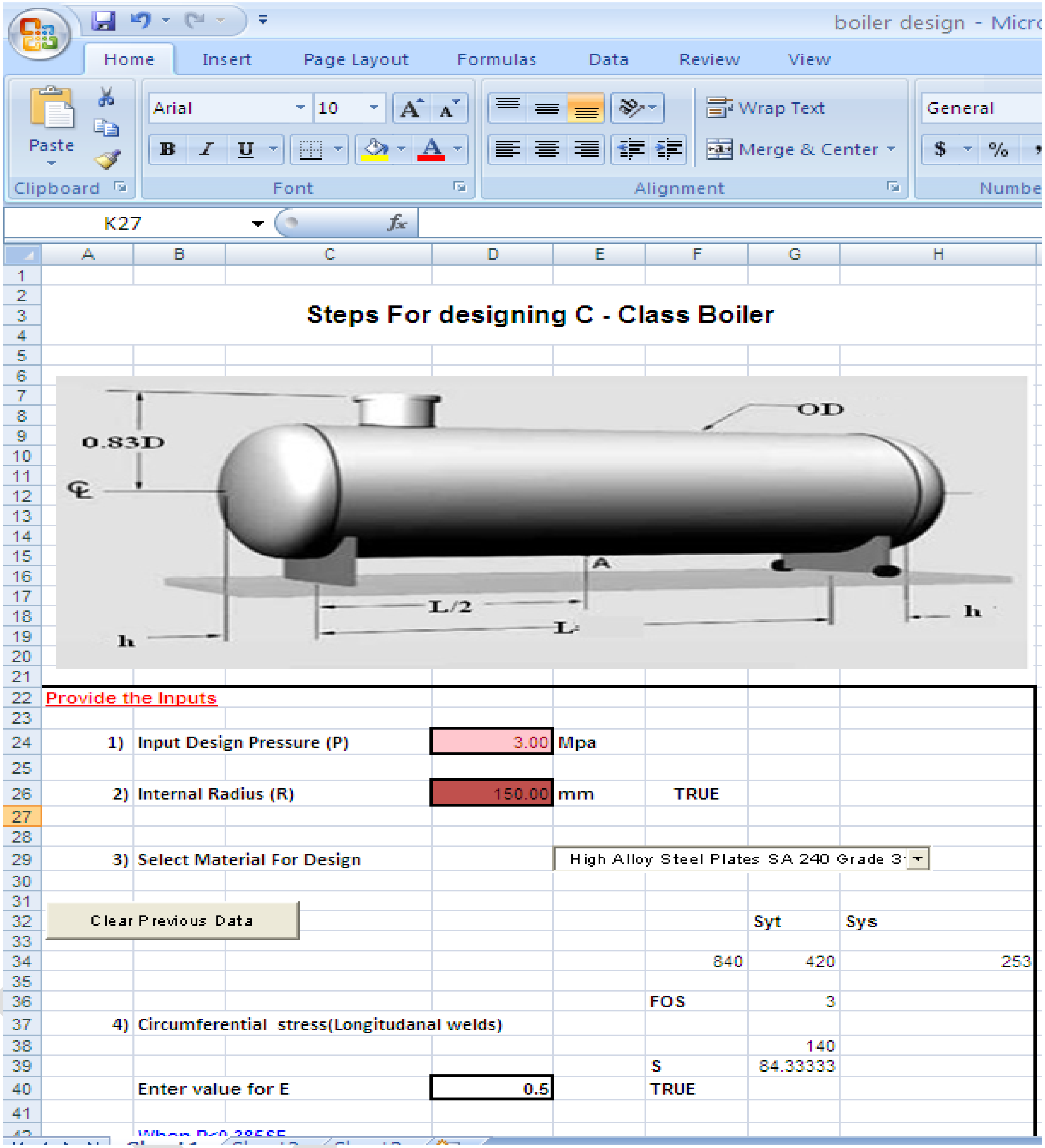
An input data base is prepared in MS excel sheet, incorporating all the design parameters. Based on the above boiler design formulae integrated tool in VB is prepared with in the form of design software which gives design of each part of boiler. Steps for using this software.

1. Input the working pressure required in MPA.

2. Select the internal radius of boiler in mm.

3. Select the appropriate material as per the table of material from ASME handbook.

These following parameters are to be entered before going to the calculation step.


boiler design - Micr
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Provide the Inputs
1) Input Design Pressure (P)
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Mpa
2) Internal Radius (R)
150.00
mm
TRUE
3) Select Material For Design
High Alloy Steel Plates SA 240 Grade 3
Clear Previous Data
Syt
Sys
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253
FOS
3
4) Circumferential stress(Longitudanal welds)
140
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84.33333
Enter value for E
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TRUE

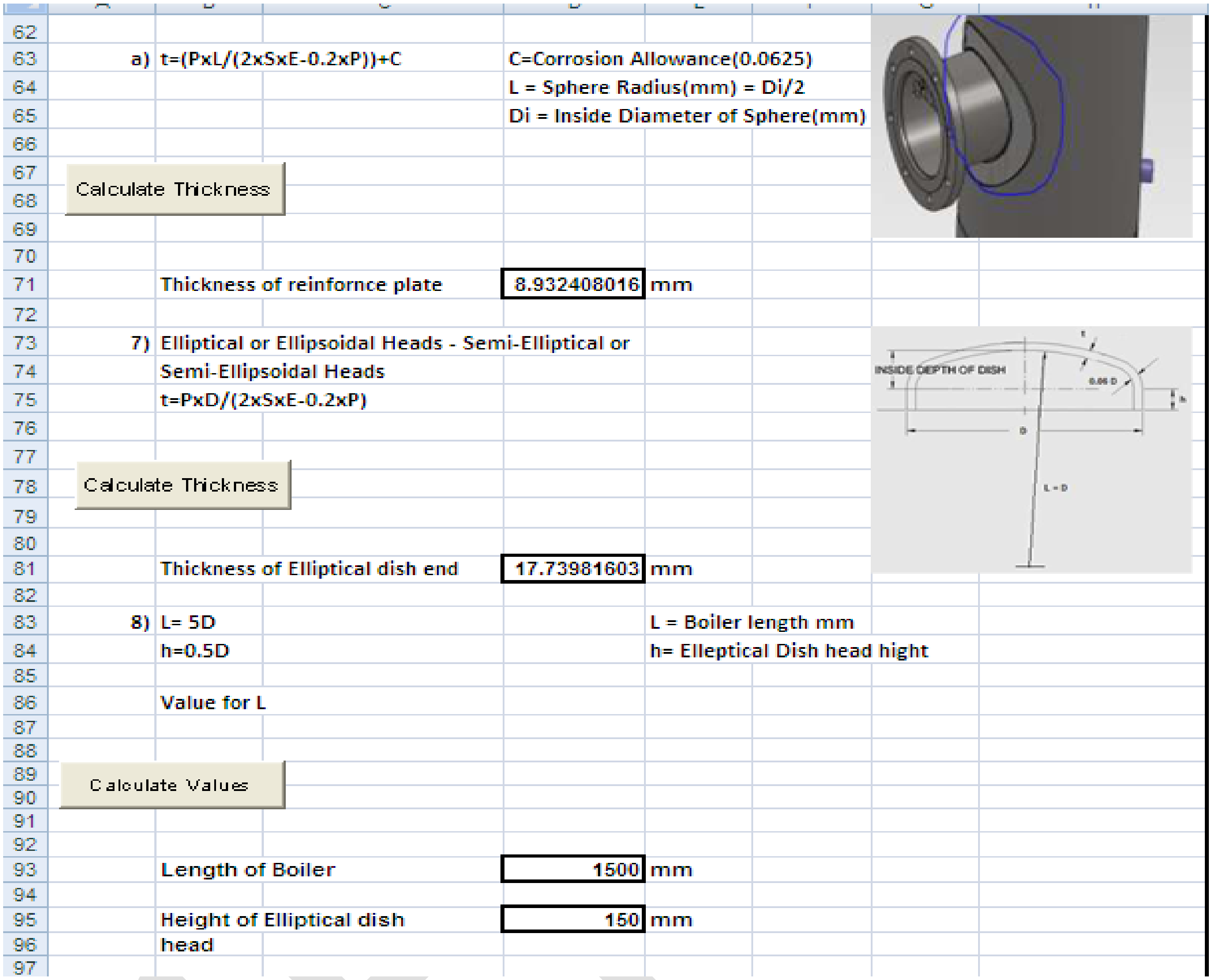

Fig 2 Database in MS Excel

2.5 3D Model in CATIA

After the calculation of the above data a 3D model is generated based on the calculation from the design.

All the parameters are linked with the CATIA software to incorporate frequent the design changes. A 3D model is generated as shown in figure based upon the sample calculation for 400 mm internal radius.

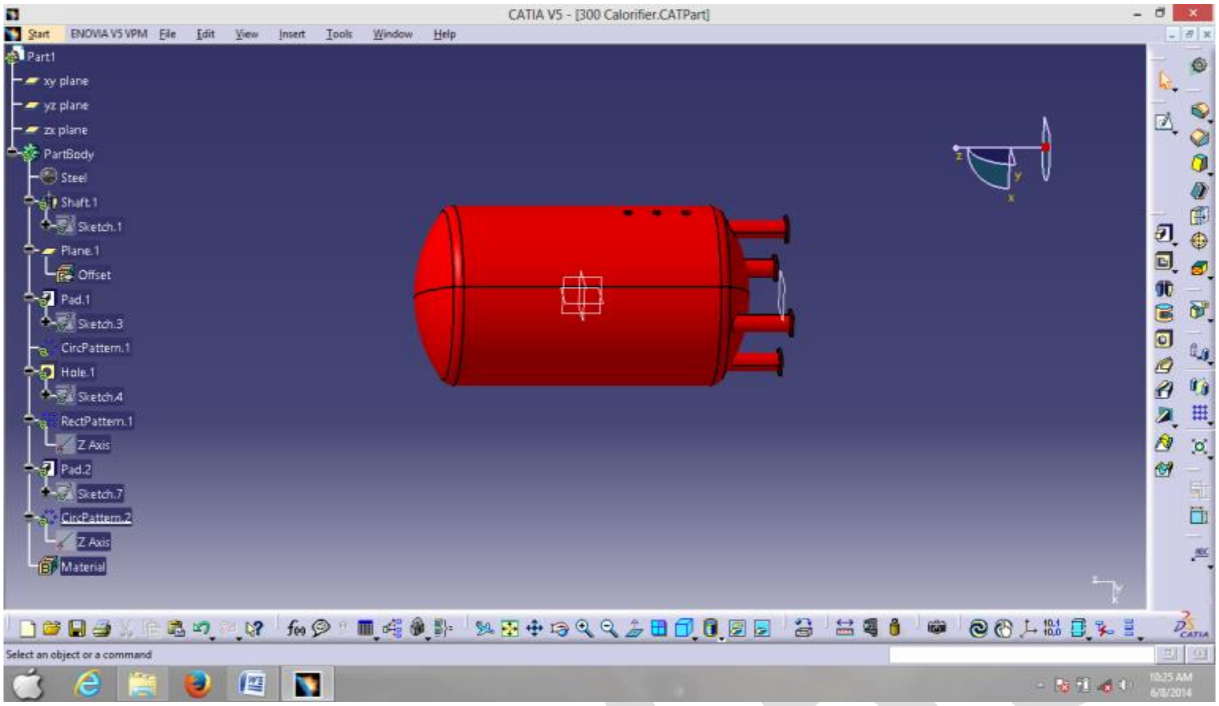

Fig. 3 3D Modelling in CATIA

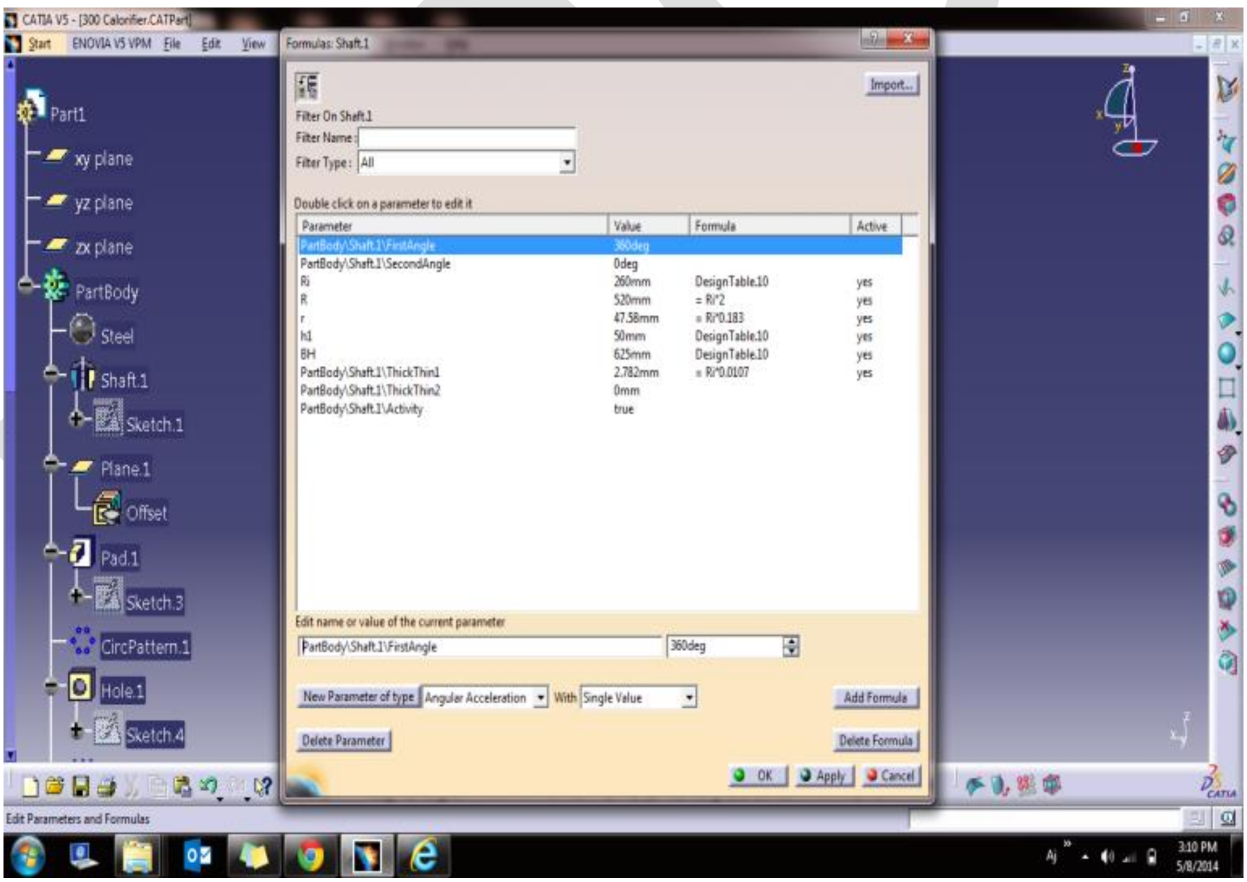

FIG 4. FORMULA FOR PART

3. ANALYSIS

Based on the calculation and 3D model an analysis report is generated with the help of analysis tool in CATIA. Each part is analysed based on the input parameters and results are formulated in a report. This report is generated by analysis tool in CATIA which gives details about stresses, deformation and other factors which affect the design because of the change in parameters or dimensions.

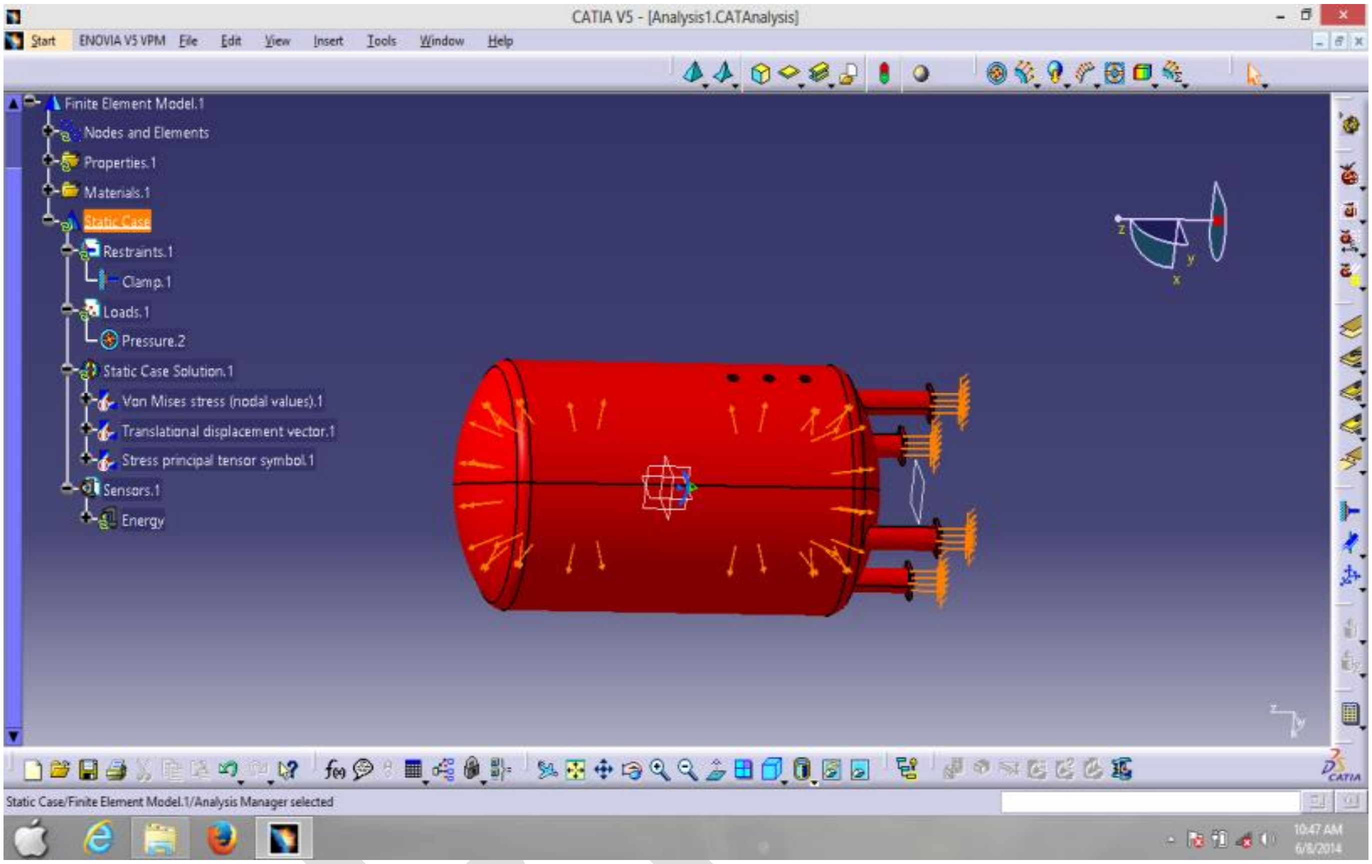

Fig 5. Analysis Model

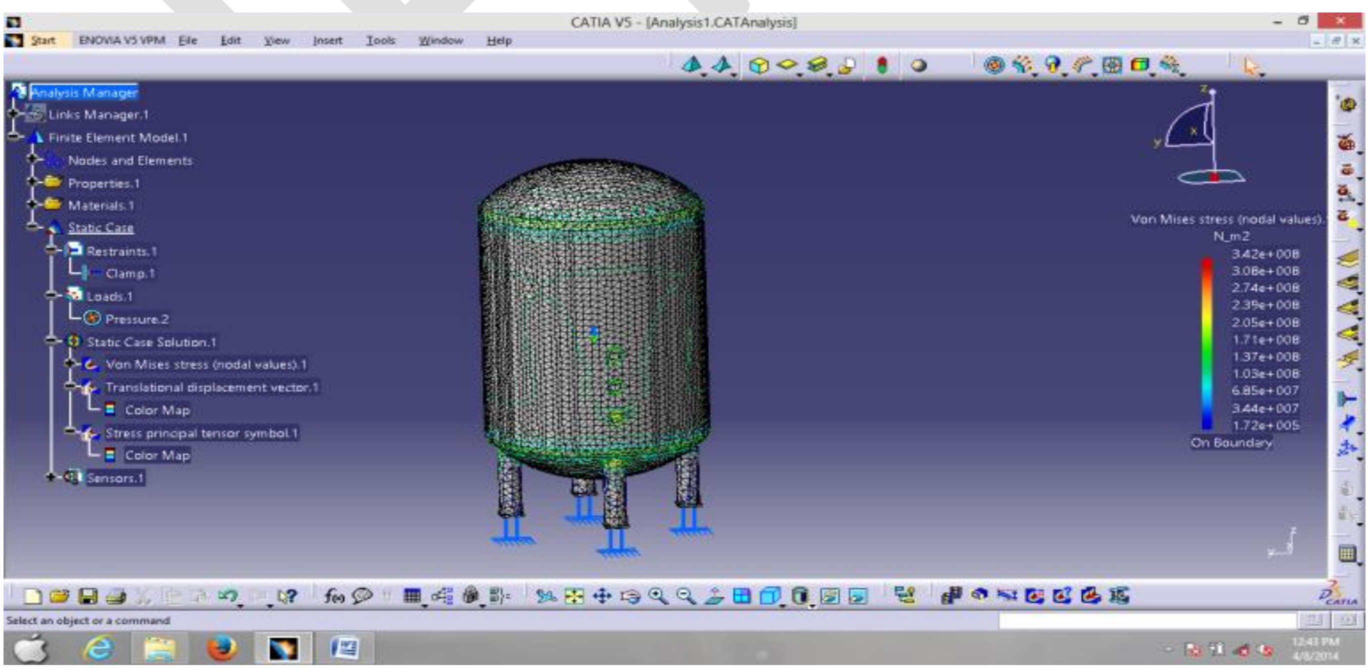

Fig6.Static Case Solution.1 - Von Mises stress

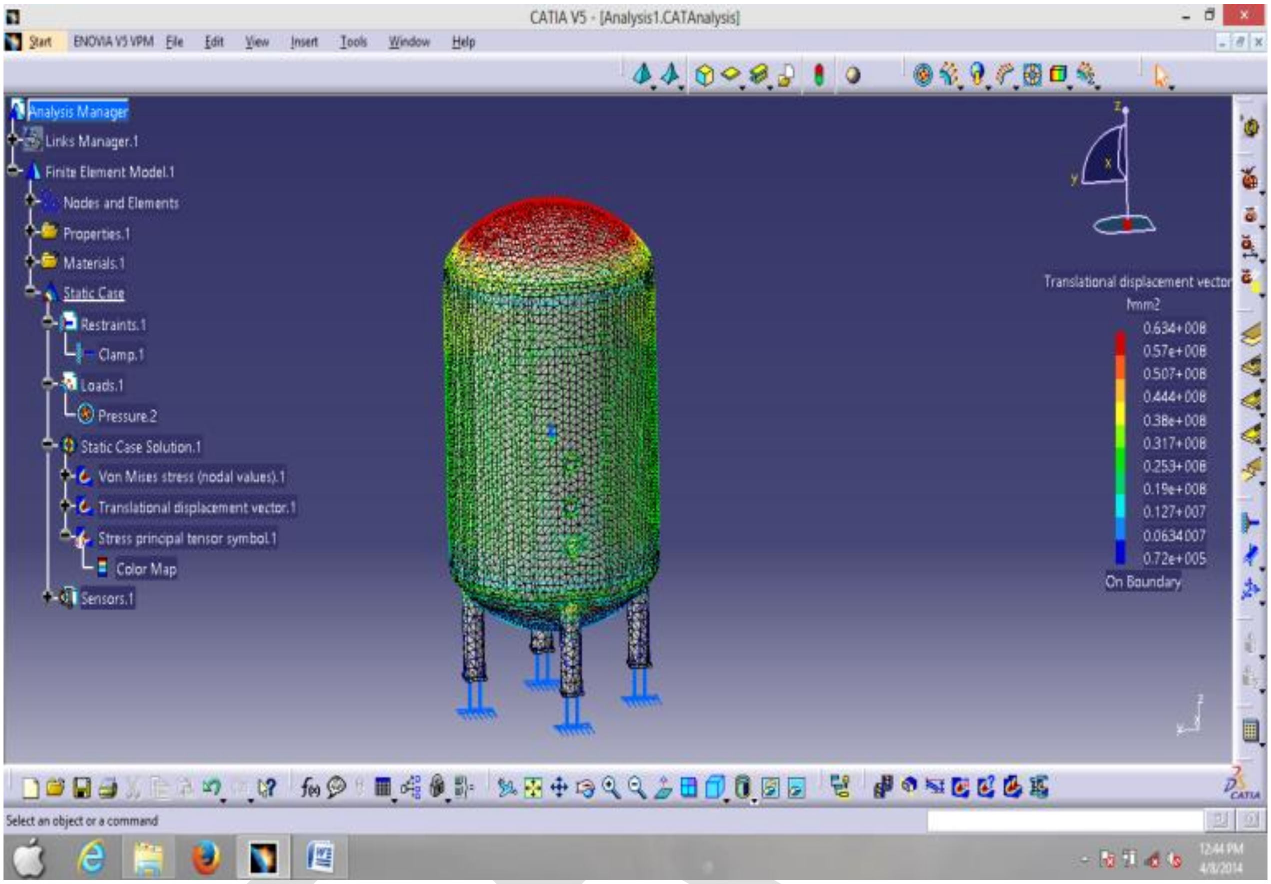

FIG7. **STATIC CASE SOLUTION.1 - TRANSLATIONAL DISPLACEMENT VECTOR**

4. RESULT

KBE is the key technology at the base of any design development. In the current design approach, too much time is wasted in lengthy and repetitive activities; not enough time remains available for investigating more product configurations and exploiting designers' skills and creativity. In this case study, it is demonstrated how KBE can be a suitable technology to help designers reducing time and cost for engineering applications by automating repetitive design tasks and supporting the systematic application of design best practices with the use of parametric modelling as a tool.

3D modelling is tool which help to save time in regards the capturing the design intent of particular equipment. The process is known as Knowledge base engineering. In this process all design intent of object is captured & save in term of relational formulas & on this basis the 3D object is prepared. Once the design requirement is change some parameters will require modifying. All other parameters are depended on the driving parameters. One driving parameter get updated, all relevant parameters will update automatically & relevant production drawings will update automatically. This helps to reduce time, which is the prime motive of this case study.

It managed to shorten the project preparation time, reduce the construction difficulties and ensure that the requirements on equipment, human recourse and materials are all satisfied

5. ACKNOWLEDGMENT

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6 CONCLUSION.

In this study, in particular it is shown how, using KBE, it is possible to win one of the greatest design challenges at date: automate the generation and modification of boiler models, from geometry definition to the launch final design. Entire models of boiler & components can be generated in software and independently from the specific topology of the parameters.

7. FUTURE SCOPE

Future developments will include the creation of a tooling module to be linked to the movable modeland a cost module, which will provide a smooth link to a cost calculation program.

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