Scientific Journal of Impact Factor (SJIF): 4.72
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 4, Issue 9, September -2017

Study Of The Effect Of Various Factors On The Stress Generation Of Large Horizontal Pressure Vessel By Taguchi Approach.

Hirenkumar I Joshi [1], Ghanshyam D Acharya [2]

[1]*Kadi Sarva Vishvavidyalaya, Gandhinagar and Dept. of Mech. Engineering, Government Engineering College, Rajkot.*
[2]*Principal,Atmiya Institute of Technology & Science, Rajkot*

Abstract —*Large Horizontal pressure vessels are required to be supported with more than two saddles.teh vessel and saddle are subject to combined state of stresses due to longitudinal, circumferential stress due to pressure and axial, compressive and bending stresses due to loading conditions. The precise prediction of the stresses is very important due to complicated state of stress. This research article looks for the study of effect of various design factors on the stress distributions in vessel and saddle parts of large horizontal pressure vessel supported by more than two supports. The numerical method has been applied by performing simulation in ANSYS 15.0.Design of experiment method has been applied by Taguchi method.L9 orthogonal array has been selected with 4 factors and 3 levels. Number of saddle, wrap angle, distance from head and wear plate extension has been shortlisted for the design of experiementaion.The regression analysis, Main effect plot and SN Ration plots have been obtained. The prediction model has been derived by regression analysis and can be used for suggest of stresses and influence of various design factors on the stress.*

Keywords-*Multi saddle supported vessels, Finite Element Analysis, Taguchi experimental design, L09 orthogonal Array, Regression Equation*

I. INTRODUCTION

Industrial pressure vessels are usually structures with complex geometry containing numerous geometrical discontinuities and are often required to perform under complex loading conditions (internal pressure, external forces, thermal loads, etc.)The ASME Section VIII vessels that are in general use throughout the refinery and chemical industries have demonstrated an excellent safety record. However, as these industries mature, there is an ongoing need to reduce the capital and facility maintenance costs, including the cost of pressure vessels, related piping and infrastructure. This cost control requirement is manifested in the increase in the allowable design stress utilized in ASME Section VIII Division 1. To this end, design engineers must use their experience and the latest design tools to maintain reasonable safety levels while providing the most cost effect design. One tool being used on an ever increasing basis is Finite Element (FE) analysis software. Fly Ash brick is the product which is having tremendous potential in the construction industries. FEA and Design of Experiments can be efficiently applied to design components with a concern about cost and safety. [14].

Horizontal pressure vessels are generally supported with twin supports, which cause bending stresses in the pressure vessel along with the stresses produced by the internal pressure in the vessel. The saddle structure is also subjected to high stress. So the design of a saddle and evaluation of the stresses in saddle is critical in the horizontal pressure vessel design. The ASME code [9] pressure vessel code does not suggest design procedure for the design of and the produced stresses. The present scenario is to use the semi empirical method developed by Zick which is based on the beam theory and various assumptions to simplify the problem. Due to these assumptions, Zick's method may not produce accurate results. The finite element method is well developed and a very popular technique for the computer solution of complex problems in solid mechanics. With FEM analysis we found out that the horizontal pressure vessel with two saddle supports at the ends does not act as a beam for most the cases considered [3].Under the beam assumption the zick analysis can predict the maximum tensile and shear stresses as s function of wall thickness quite well [3].But there are large differences between the results from two methods when the length and diameters of vessels are varies.

A precise study of the membrane and bending stresses and deformations of the vessel and saddle is critical and has obtained the attention to researchers. Ong [2] studied the horizontal storage vessel for circumferential stress for various configurations. Nash et al. [10] investigated the plastic collapse of horizontal saddle supported storage vessels along with parametric study. FEM has been applied effectively for finding stress distribution in saddle supported pressure vessel along with effect of individual parameters by Shafique M.A.Khan [13].Parametric analysis for horizontal vessel was performed by Finite element method and further results were compared with experimentation on small scale model by L.yang et al. [7]. Widera et al. [1] and K.Magnucki et al. [8] also performed study of horizontal pressure vessel for different range of various parameters with the help of finite element method.

With a consideration of above literature reviews that saddle supports have not been studied in great detail and also more weightage has been given on the stress in the vessel. Further all the work has been carried out to evaluate condition related to twin supported vessels only. There is a huge gap for the research to be carried out for more than two support vessels.

The present study looks to check the combined effect of various design factors. The design of experiment approach has been selected for this purpose and Taguchi robust design has been selected. The L-09 orthogonal array has been selected for the 4 factors and 3 levels and simulations have been carried out. The Industrial case study has been taken of the Fly Ash Brick autoclave from Metalfab Engineers, Surat. To find out the stress values the Finite Element Method has been applied in the software package ANSYS 15.0.The CAD model has been developed in the Creo Parametric Software package.

II. PROBLEM SETUP

2.1 CAD MODEL

The case study has been taken with MetalFab Engineers Surat. The vessel has been designed as per code ASME SECTION VIII DIV. 1 [3] .The total length of the vessel is 21 meter and 1.6 meter in diameter. The vessel is subjected to the pressure of 1.85 Mpa. The thick of the shell obtained is 12 mm for both head and shell. The material of the vessel is SA 526 Grade 70 and that for the saddle is IS 2062 GR.02.The dimension of the saddle have been obtained bas per the Deniss Moss.

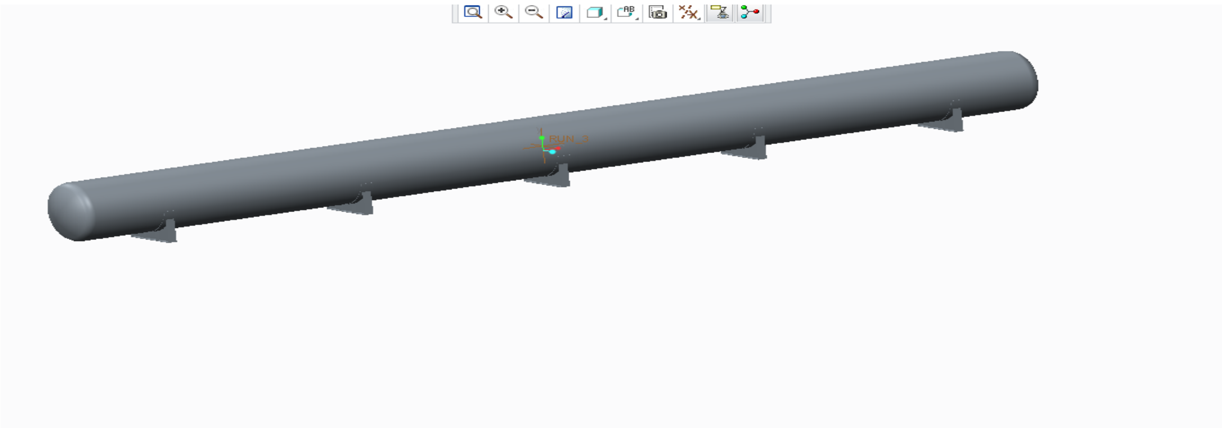

Figure 1. Vessel Geometry

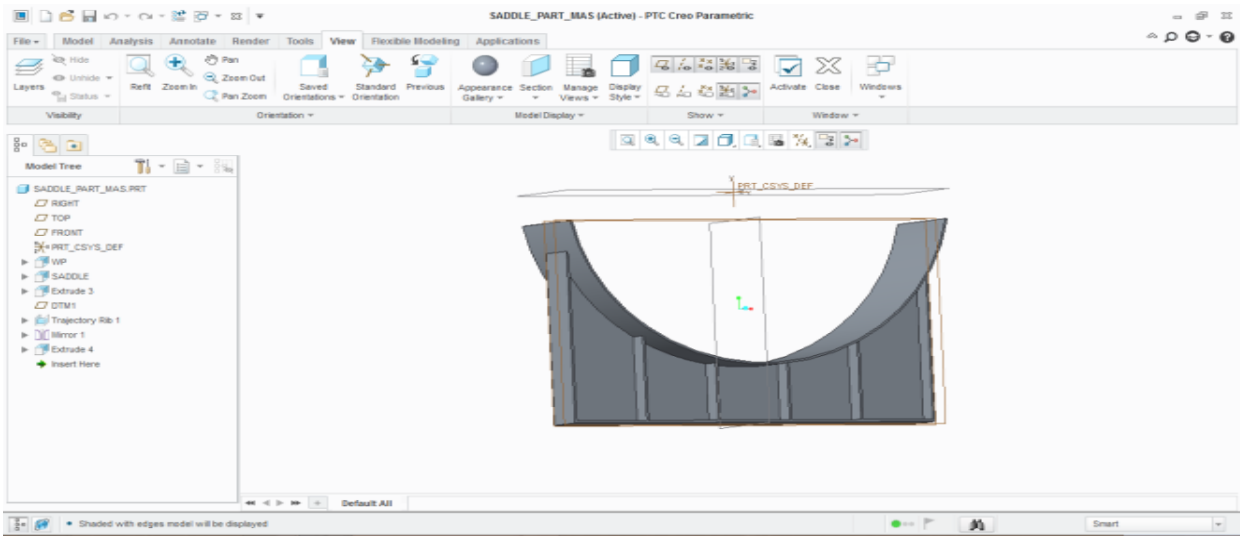

Figure 2. CAD Model of saddle

2.2 Finite element analysis

The geometry has been created in Creo parametric and further exported to ANSYS 15.0 for finite element analysis. The element type selected for the FEA is 8 node brick elements for ANSYS Library. The vessel has been applied boundary condition as shown in figure 4 as per the design data by applying internal and hydrostatic pressure. Both the saddles have been considered as fixed support. The weight of vessel is considered also for the analysis purpose.

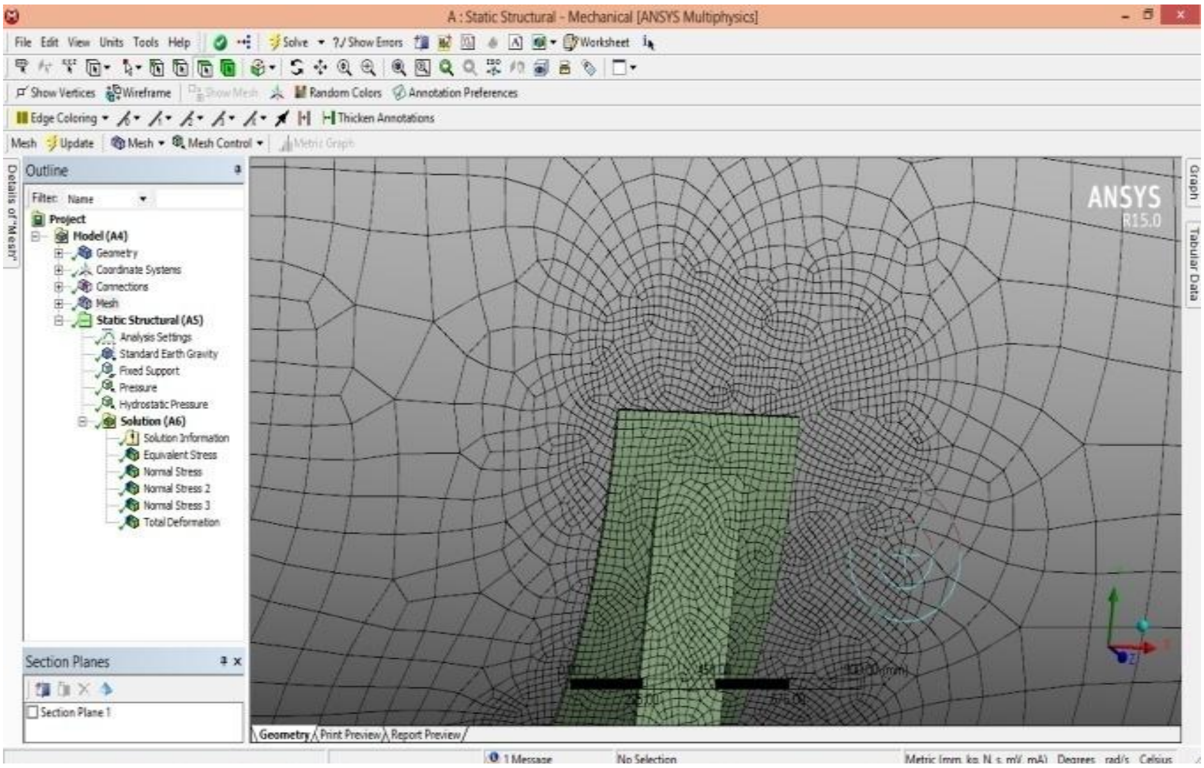

Figure 3. Meshing

The vessel has been simulated as shown in figure 4 for the boundary condition of internal pressure of 1.85 Mpa and hydrostatic pressure of the fluid along with the self weight of the vessel. Further mesh convergence has been done before achieving the element size for all the simulation as shown in the figure 3. The solver converges to a less than 5 % error for all the solutions so the results are reliable from prediction point of view.

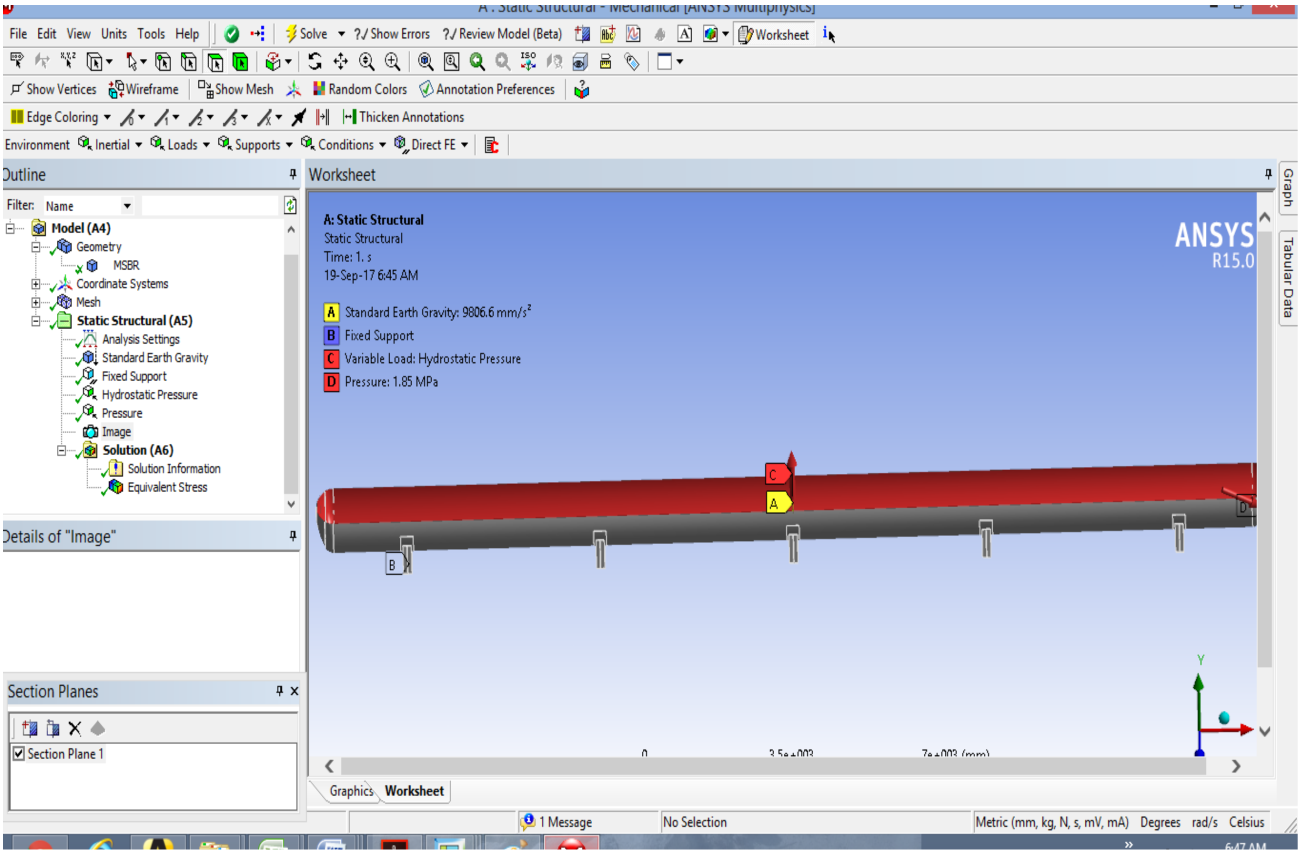

Figure 4.Boundary conditions and Convergence

III. DESIGN OF EXPERIMENTATION

Design of experiments (DOE) is a systematic, rigorous approach to engineering problem-solving that applies principles and techniques at the data collection stage so as to ensure the generation of valid, defensible, and supportable engineering conclusions. DOE is more efficient that a standard approach of changing "one variable at a time" in order to observe the variable's impact on a given response. DOE is a formal mathematical method for systematically planning and conducting scientific studies that change experimental variables together in order to determine their effect of a given response. The Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with only a small number of experiments. The TAGUCHI method has been for finding the influence of and its significance. To carry out Designing following parameters were considered as discussed previous with its range as mentioned in table.

3.1. Factors

The factors as shown in table 2 have been shortlisted to evaluate the effect and the range has been selected from the references Ong [2], tooth [6], Abbasi [9], Nash [10] and in consultation with industry experts so as to make the study more effective.

Table 2. Design Factors

Sr	Parameter		Level I	Level II	Level III
1	Saddle angle(degree)	Θ	120	140	160
2	Extension of wear plate(degree)	ϕ	6	12	18
3	Distance of saddle from head(mm)	a	400	1000	1600
4	Number of Saddle	N	3	4	5

3.2. Experimental Design

As per Taguchi method the following L09 orthogonal array has been designed to carry out experimentation. The response 1 is the equivalent stress at the rib portion at the base of the saddle for the inside rib. The response 2 is the equivalent stress at the outside rib at the saddle base. The response 3 is the equivalent stress at the saddle vessel interface area.

Table 3. Taguchi L09 orthogonal array with results

Exp. No.	Saddle angle (degree)	Extension of wear plate (degree)	Dist of saddle from head (mm)	Number of saddle	Response 1 Sri Mpa	Response 2 Sro Mpa	Response 3 Srm Mpa
1	120	6	400	3	135.45	302.21	187.7
2	120	12	1000	4	126.21	269.39	167.39
3	120	18	1600	5	134.06	230.48	156.48
4	140	6	1000	5	148.39	259.43	138.29
5	140	12	1600	3	131.2	251.82	143.63
6	140	18	400	4	141.21	266.97	143.97
7	160	6	1600	4	137.82	243.12	115.51
8	160	12	400	5	142.28	261.34	120.98
9	160	18	1000	3	127.72	258.85	131

IV.RESULTS AND DISCUSSIONS

The regression analysis has been carried out and the prediction equation has been obtained for various stresses. The regression equation for the stress at inner rib Sri = 392 - 0.323 wrap angle - 1.35 wpe - 0.0292 head distance-10.3 saddle number and the R-Sq = 99.1% R-Sq(adj) = 98.2% values of the regression model.

Table4. Regression Analysis of Response Sri

Predictor	Coef	SE Coef	T	P
Constant	392.067	9.152	42.84	0.000
wrap angle	-0.32308	0.05377	-6.01	0.004
wpe	-1.3461	0.1792	-7.51	0.002
head distance	-0.029194	0.001792	-16.29	0.000
saddle number	-10.272	1.075	-9.55	0.001

The main effect plots and regression analysis of are obtained as in figure 5 and the table 4.The R-Sq value of the model is 79.87 % which implies that model is significant.

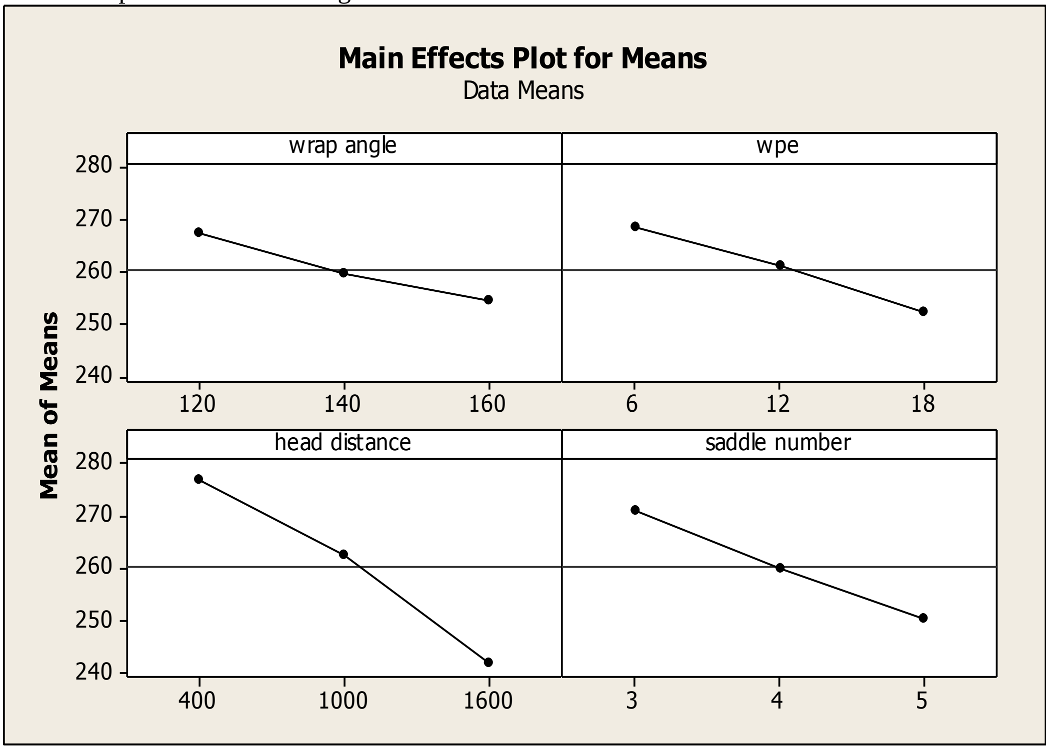

Figure 5. Main effect plot for Response 1.

The main effect plots and for Response 2 (stress at outside rib of saddle)are obtained as in figure 6 and the table 5.The R-Sq value of the model is 98.1 2 % which implies that model is significant. The regression equation is obtained as follows.

SRO = 358 - 1.20 wrap angle - 0.279 wpe - 0.0103 head distance - 7.76 saddle number

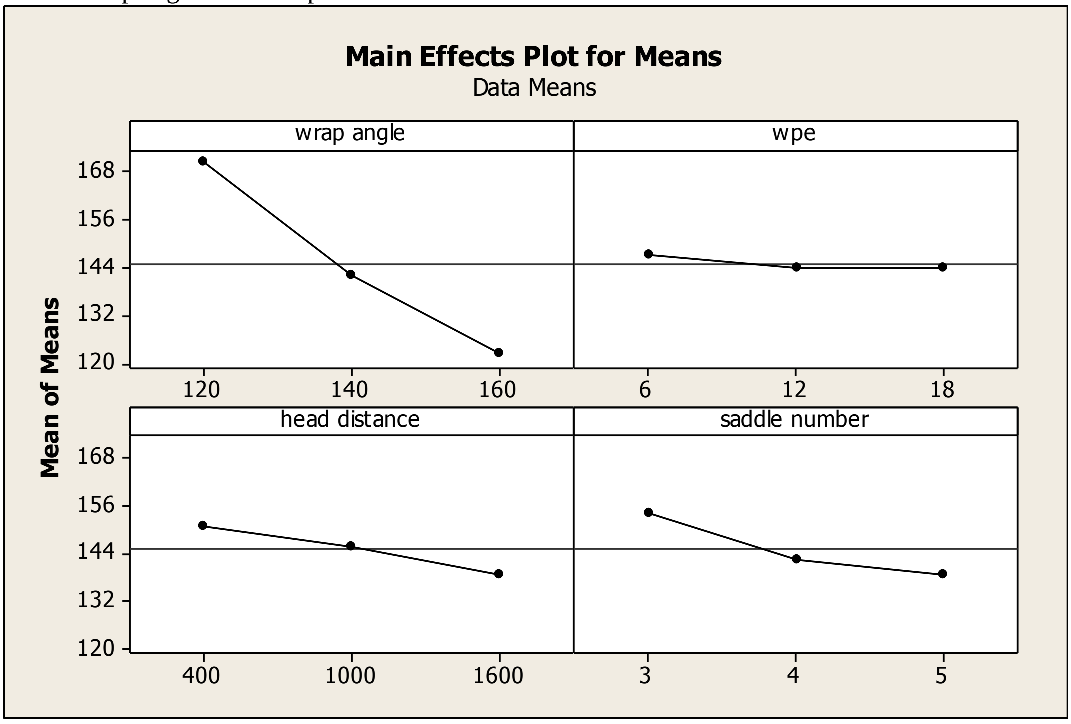

Figure 6. Main effect plots for Response 2.

The main effect plots and for Response 3 (stress at midsaddle in vessel)are obtained as in figure 7.The R-Sq value of the model is 92.6% which implies that model is significant. The regression equation is obtained as follows.

SRM = 166 - 0.103 wrap angle - 1.83 wpe + 0.00201 head distance+ 1.62 saddle number

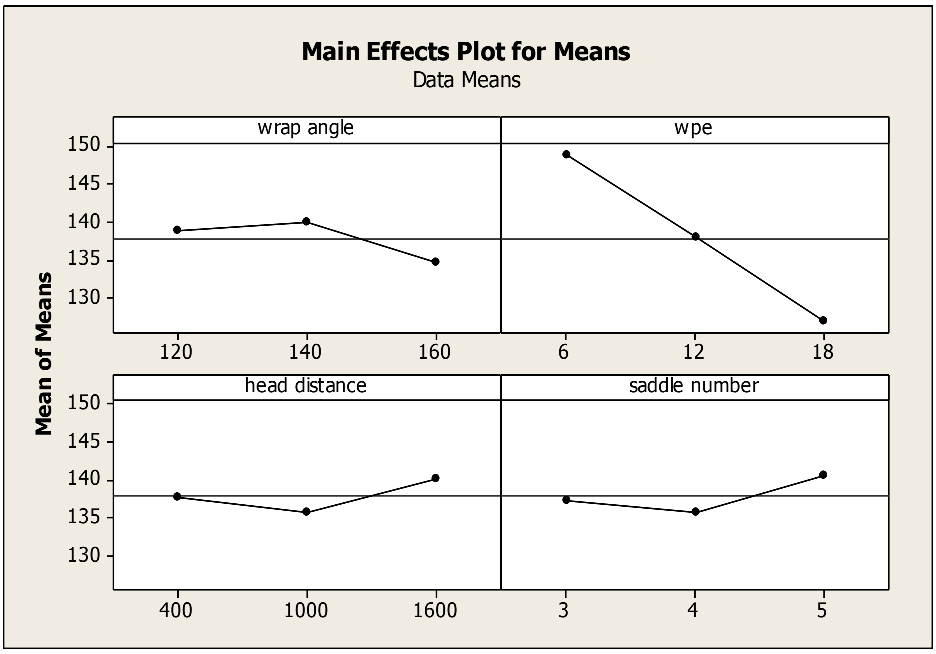

Figure 7. Main effect plots for Response 3.

V. CONCLUSIONS

The regression equations of the response suggests that number of saddle and wear plate extension plays critical role in controlling the stress distribution in both vessel and saddle. The wear plate extension plays moderate role for stress distribution in The Taguchi method can be effectively used along with finite element method to investigate the stress distribution in the pressure vessel. Further one can use these models for selection of various design parameters to minimize the stress distribution in pressure vessel and saddle.

REFERENCES

[1].G.E.O.Widera, Z.F.Sang, R.Natarajan, “On the Design of Horizontal Pressure Vessels”, Journal of Pressure Vessel Technology, ASME-1998.

[2].Ong, “Parametric Study of peak circumferential stress at the saddle support”, International Journal of Pressure Vessel and Piping, 48, pp.183-207, 1991.

[3]. ASME SECTIONVIII DIV I, EDITION 2010.

[4].Montgomery, D.C. “Design and Analysis of Experiments”, 5th ed.John Wiley & sons Inc., 2001.

[5].Tooth A.S.,Chan,G.C.M. and Spence,and Nash,d.h. “Horizontal Saddle Supported Storage Vessels: A Parametric Study of Plastic Loads. In: Pressure Equipment Technology: theory and Practice”. Professional Engineering Publishing Ltd.,London and Bury St. Edmonds,Uk, 2003 ISBN 978-1-86058-401-5

[6]. Nash D H,Spence J, “Parametric plastic loads and their validation for horizontal saddle supported storage vessels”. In: International conference on Design, Inspection, Maintenance and operation of cylindrical steel tanks and pipelines, 2003,10-08-2003-10-11, Kralupy, Czech Republic.

[7]. L.yang,C.Weinberger and Y.T.Shah, “Finite Element Analysis on horizontal vessels with saddle supports”. Journal of computers & structures, Elsevier Science Ltd, 52, pp.387-395, 1994.

[8].K.Magnucki,P.Stasiewicz,W.Szyc, “Flexible saddle support of a horizontal cylindrical Pressure vessel”, International Journal of Pressure Vessel and Piping, 80, pp205-201, 2003.

[9]. N.El-Abbasi,S.A.Meguid,A.Czekanski, “Three dimensional finite element analysis of saddle supported pressure vessels”. International Journal of Mechanical Sciences, 43, pp1229-1242, 2001.

[10]. Nash,Spence, “On the plastic collapse of horizontal saddle supported storage vessels”, Proceedings ICPVT-10, July7-10, 2003, Austria.

[11]. L.P.Zick, “Stresses in large horizontal cylindrical pressure vessels on two saddle support”. Weld J Res Suppl, 30, pp 435-445, 1951.

[12].L.S.Ong, J.S.T. Cheung, H.W.Ng, A.S.Tooth, “Parametric equations for maximum stress in cylindrical vessel subjected to thermal expansion loading”. International Journal of Pressure Vessel and Piping, 75, pp255-262, 1998.

[13]. Shafique M.A.Khan, “Stress distributions in a horizontal pressure vessel and the saddle supports”, International Journal of pressure vessel and piping, 87, pp239-244, 2010.

[14]Joshi H.I., Acharya G.D,” Design of experiment approach for stress assessment in saddle supported pressure vessels”, International Journal of Advance Engineering and Research Development,4 ,pp375-380,2017

