International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2015): 6.391

Finite Element Analysis of Girder Pin Connection

Thavamani Charles[1], P. A. Krishnan[2], V. Ramachandran[3]

[1]MS Scholar, Department of Civil Engineering, NIT, Tiruchirappalli, India

[2]Professor, Department of Civil Engineering, NIT, Tiruchirappalli ,India

[3]Sr.DGM, PCPS, BHEL, Tiruchirappalli, India

Abstract: ***The aim of the research in the present article is to access the working of Girder Pin connection when placed between bottom of fully loaded Girder and top of column in Boiler Supporting Structure. The analysis is doneusing ANSYS analytical software. The deflections and end reactions of various girder sizes with appropriate span length used in boiler structure are considered and the results are obtained. The end reactions obtained are further applied on girder pin.Current paper presents the contact stresses and deflection developed at the Girder pin due to the compressive loads from Girder. Further using stress values obtained it is compared with maximum allowable stress of plate and thereby selecting appropriate plate and rod thickness i.e optimising the components used in Girder pin connection.***

Keywords: Boiler supporting structure, girder, girder pin connection, deflection, stresses, analysisetc

1. Introduction

Boiler structure is top supported predominantly steel used mainly to support boiler components in a power plant. All pressure part components including drum are suspended from the ceiling structure.Boiler components include furnace (water wall tubes), back pass, ducts and other major components are hung vertically to allow downward expansion in a boiler. All loads from pressure and non-pressure parts of boiler components are taken to ceilingstructure and then transferred to main columns. Hence,ceiling structure plays a vital role in transferring the loads in boiler structure.

Ceiling structure comprises of main ceiling girder beams, cross girders, intermediate beams both welded beams and rolled sections, which together holds the entire boiler components.Ceiling girder beams are generally I section beam with web and flange plates with intermediate stiffeners and bearing stiffeners to avoid web buckling and to transfer concentrated load between web and flange respectively.

The intermediate beams at ceiling which are generally back to back I section or channel section which are used to suspend the pressure hangers. These intermediate beams transfer the pressure parts load further to cross girders, which in turn transfer the load to main girder. The main girders, which are supported on column top further, transfer the load to column cap plate through girder pin connection and column further to ground.Ceiling girder beams are major beams, which takes load from all primary and secondary beams. Both girder and welded beams are plate formed structure.

Ceiling structure also comprises of horizontal bracing trusses, which ensures stability of boiler structure at roof level against horizontal loads due to wind and seismic forces.

They are two types of main ceiling girders.
1. Conventional girders
2. Hybrid girders

Conventional girders are the ones in which the web and flange plate are made of same steel, normally carbon steel conforming to IS2062. They are used mostly for lower capacity boilers.

Hybrid girders are those in which flanges are made high strength steel (IS 8500 Fe540) and web is made of carbon steel (IS2062). They are used for higher capacities to achieve overall economy by weight of the girder.

A structure is only as strong as its weakest link. Unless properly designed and detailed, the connections may become weaker than the members being joined. Generally, a connection failure is not as ductile as that of steel member failure. It may lead to catastrophic failure of whole structure, which should be avoided by adopting higher safety factor for the joints than its members. Connections between different members of steel structurenot only facilitate the flow of forces and moments from one member to another but also allow the transfer of forces up to the foundation level. The behaviour of joints is very complex due to various factors, which influence them, such as geometric imperfections, lack of fit, residual stresses and slipping. Hence, connection from girder and column is considered critical for any steel structure and needs to be ensured for structural stability. These girder beams transfer loads to column or other girder through an arrangement called Girder Pin connection in boiler supporting structure.

A. Constituents of the girder and pin connection:

The ceiling girder is erected and placed on top of the girder pin assembly above the column top ensuring only axial compressive loads are transmitted to column with less or no moments to column.The girder pin assembly is provided with an end plate on one side with holes whichis used to hold the girder while erecting the girder. These rods connecting both girder and girder pin are cut offafter erecting ceiling horizontal bracings. It is done so to allow the girder to deflect freely. A typical arrangement of girder and its assembly resting on columnis shown in Fig 1.

International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2015): 6.391

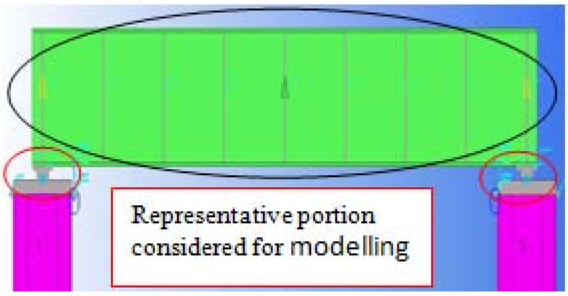
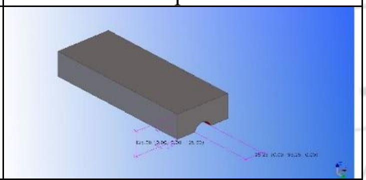
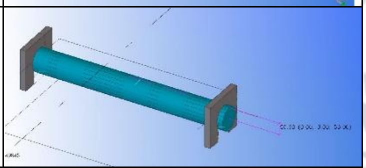
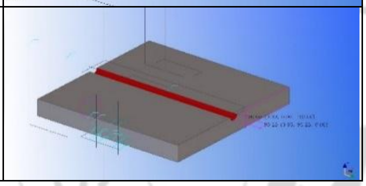


Figure 1: Duct burner Arrangement

Girder Pin connection is an arrangement which comprises of the following components.

1) Top Plate
2) Rod or Pin arrangement

Table 1: Pictorial representation of different components of pin connection

S. No	Description	Pictorial representation
1.	Top plate with bottom groove	
2.	Girder pin rod With clamps	
3.	Bottom plate with top groove	

Top Plate

Top Plate of a girder pin connection isa plate with high thickness, which is placed below the flange of girder and has groove at the bottom with radius equivalent to rod. The thickness of top plate is 125 mm.

Pin arrangement

Pin arrangement is rod, which is placed between top and bottom plate, which rotates due to moments transferred from girder.

Bottom Plate

Bottom Plate of a girder pin connection is placed above the column plate having groove at the top with radius equivalent to that of rod.

2. Geometry

The portions of the elements, which are marked in Fig [1], are considered and analysisare carried out using ANSYS v14.5. The analysis is donein two different models for different ratings of boiler. First part of analysis in which girder deflection and support reactionsareobtained when ceiling loads are applied. Second part of analysis includes superimposing the results inferred in previous analysis and applying it on girder pin assembly. Second part includes multi body contact analysis between its components, it is marked in red color circle in Fig [1]. First part of analysis is marked in black circle in Fig [1]. It was so done because the geometry of girder when compared to pin is very large and meshing and developing contact between girder and its corresponding pin connection would be very tediousand may provide singular non-linearity..

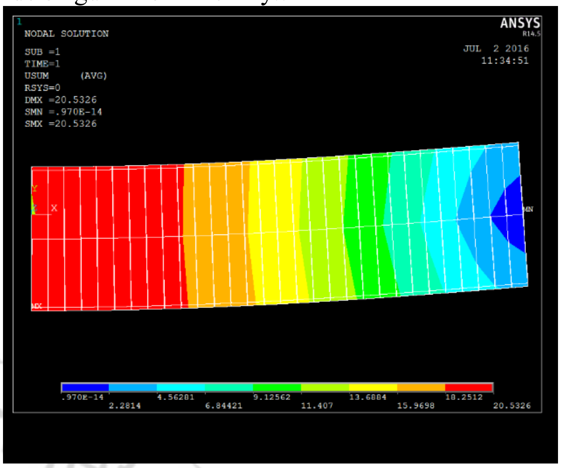


Figure 2: Simulation of one of the case

Girder Analysis:

A. Model

Models for different boiler capacities ranging from 125 MW to 800 MW are analyzed. Various girder sizes and span are considered for each boiler capacities as tabulated is Table [2]. For each range of capacity three girder sizes are taken with corresponding span and loading details to arrive at accurate results. A total of 21 such girders are modelled and analyzed and results of the same are tabulated in Table [3]. Loading details on ceiling girder are considered confidential and hence not revealed. The advantage of symmetricityis used for all girders i.e only half of length of the girder is modelled and analyzed as shown in fig [2]

3. Modelling and Meshing

A. Elements& Meshing

The model uses BEAM 188 element, which is based on Timeshenko beam theory which includes shear deformation effects. The element provide both unrestrained and restrained warping of cross-sections. The elementhas seven degrees of freedom at each node. These include displacement in the x, y, and z directions and rotations about the x, y, and z directions. The element provided stress-stiffness terms, which enables the elements to analyse flexural, lateral, and torsional stability.The finite elemental mesh are maintained uniformly along length of the girder. The model contains about 50 elements and 51 nodes when half the girder length is modelled.

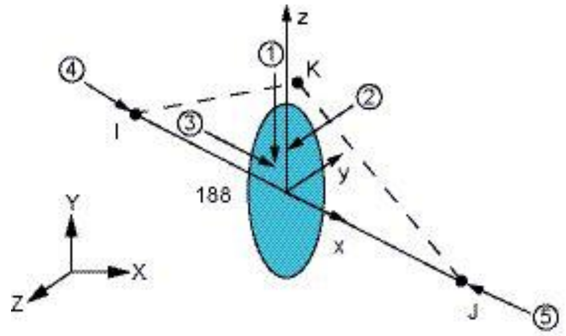


Figure 3: Representation of beam188 Element

B. Material properties and loading:

Table 2: Table consisting of various girder sizes

Modulus of elasticity (MPa)	Poisson Ratio	Unit mass of Steel (Kg/m^3)
2.0 X10^5	0.3	7850

Structural and physical properties of the beam are considered based on IS800:2007 Section 2.2.4.1.and are tabulated in table 3

Table 3: Physical properties of ceiling girder

Boiler Rating	Case	Girder Sizes				Span of Girder
		Depth	Width	Flange Th.	Web Th.	(mm)
1		(mm)	(mm)	(mm)	(mm)	
125 MW	1	2750	700	63	40	18800
	2	3250	600	63	20	14500
	3	3764	900	32	20	18720
2						
150 MW	1	3200	800	63	63	20110
	2	3200	800	63	50	20110
	3	3200	800	63	63	20110
3						
250 MW	1	3200	800	63	63	20110
	2	3770	950	100	32	11900
	3	2500	500	75	40	9700
4						
500 MW	1	3800	1400	115	25	31710
	2	3800	1400	115	25	31710
	3	3800	1400	115	25	31710
5						
600 MW	1	3800	1400	155	25	31500
	2	3800	1550	155	32	31500
	3	3800	1550	155	32	31500
6						
660 MW	1	4000	1000	115	50	28600
	2	4000	1100	115	63	30300
	3	4000	1200	115	50	30300
7						
800 MW	1	4500	1300	115	40	31160
	2	4500	1400	115	40	31160
	3	4500	1500	115	32	33300

A combination of the following loads are considered for the analysis of girder arrangement:

1) Pressure part (Drum, super-heated coils, water walls, economiser coils) and non-pressure part (ducts)loads
2) Roof deck and vertical loads from lining and insulation of boiler furnace.
3) Critical pipe support loads like main steam line pipe and other pipe loads
4) Safety valve silencer loads
5) Loads due to roof structure

Grid independency test is performed for four girders to check the accuracy of the results obtained. When elementsare meshedfiner, the results obtained are found to be same. The plot showing accuracy of the model is shown in Fig [4]

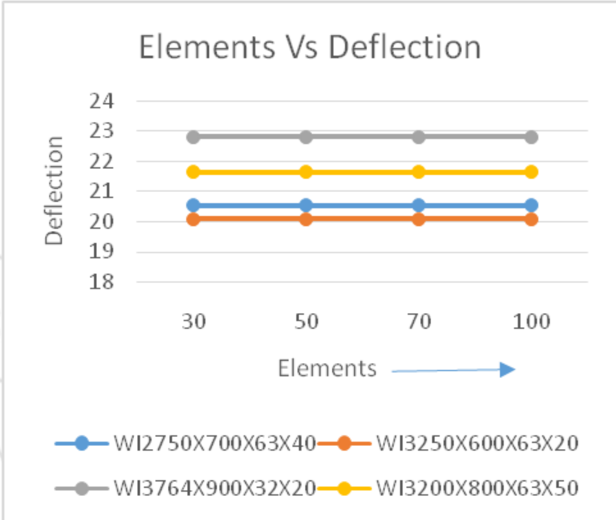


Figure 4: Grid independency test (Elements Vs Deflection)

C. BoundaryConditions:

Since girder rests upon column top, the following boundary conditions are applied to stimulate exact working condition. The beam is allowed only to displace along longitudinal axis on one end and at the midpoint, it is allowed to deflect along Y-direction.Therefore, at the mid node is symmetric boundary condition is selected which allows movement about along X direction.For other end both moment and rotation along Y and Z directions are constrained.

4. Comparative Study Between Analytical And Numerical Results

A. Analytical Results

The model is processed in ANSYS 14.5.The solver mainly utilizes Timoshenko beam theory, a first order shear deformation theory.Shear strain in transverse direction is constant through the cross-section i.e. cross-sections remain plane and undistorted after deformation. It is more superior in producing accurate deflection results than Euler-Bernoulli's Equation. Timoshenko theory holds good for slender and stout beams. The results obtained using analysis are given in Fig [5]The transverse-shear distribution calculation ignores the effects of Poisson's ratio.

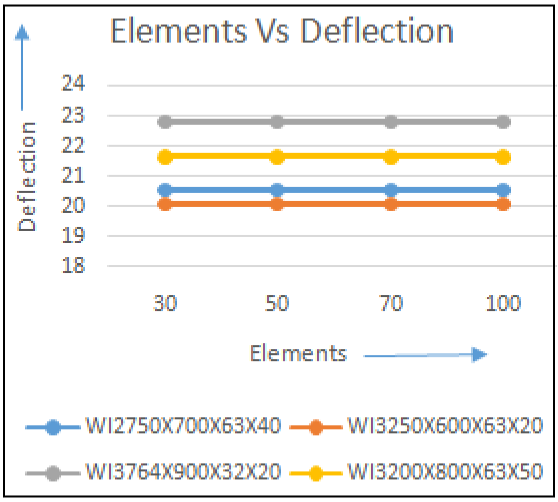


Figure 5: Deflection obtained from ANSYS analysis

B. Numerical Calculation

The Deflection of beam when loadis distributed along its length is given by simple bending theory of beams. The equation is based on Euler Bernoulli's and is given by

$$EI\,\frac{d^4 w(x)}{dx^4} = q(x)$$

Where
E is the Young's Modulus
I is the moment of Inertia
Q is the distributed load

The equation gives a relation between load applied to deflection of the beam. The deflection is calculated for various beam cases as in analytic models and are furnished in Fig [6]. It is found the boiler capacities with both lower and higher the deflections are kept very low when compared mid capacities boiler. If the shear modulus of the beam material approaches infinity, the beam becomes rigid in shear and if rotational inertia effects are neglected, Timoshenko beam theory converges towards ordinary beam theory.

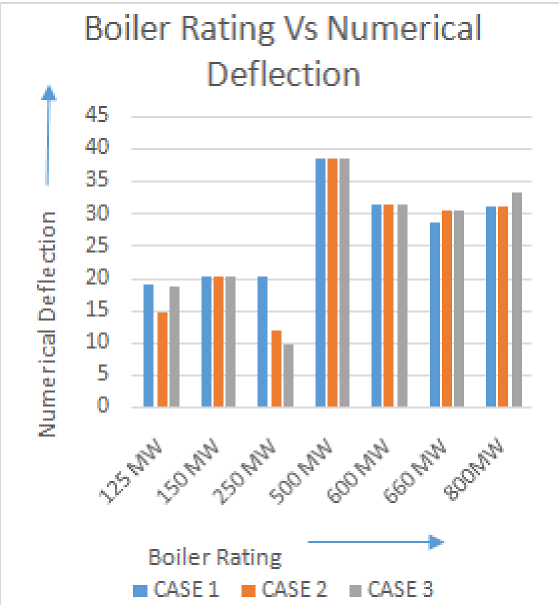


Figure 6: Deflection obtained from numerical calculationModel

C. Comparison between Analytical and Numerical Deflections

Analytical results obtained from ANSYS model are compared with numerical calculation and show satisfactory results. The deflection obtained by analytical and numerical values are plotted in Fig [7].The results show good accuracy of about 85 percent.

5. Girder Pin Analysis

Girder pin of different sizes based on boiler capacities are considered and analysed using ANSYS 14.5. Models for different boiler capacities ranging from 125 MW to 800 MW are considered.The girder pin dimensions, which includes top plate, bottom plate and pin dimensions are tabulated in table [4] which are in practise. A total number of 16 models were devolved and results are obtained. When analysed the existing girder pin it is found that the stress values are far below the allowable stress of the plate. After analysing fordifferent iterations an optimised pin dimensions are concluded for different ratings of boiler capacities. Multi body contact is developed between three elements while performing analysis.

A. Elements & Meshing

The model uses SOLID185, whichis usedfor modellingthree-dimensional element. It is eight nodal element having three degrees of freedom at each node withorthotropic material properties.The element geometry and nodal locations are shown Fig 8.The element uses enhanced strain formulation which prevents shear locking in bending and volume locking in nearly incompressible cases.The model consists of 5457 elements and 4867 elements per case.

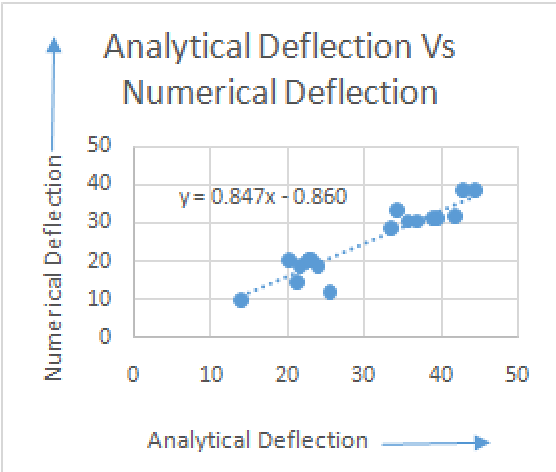


Figure 7: Result comparison from Analytical and Numerical Deflections.

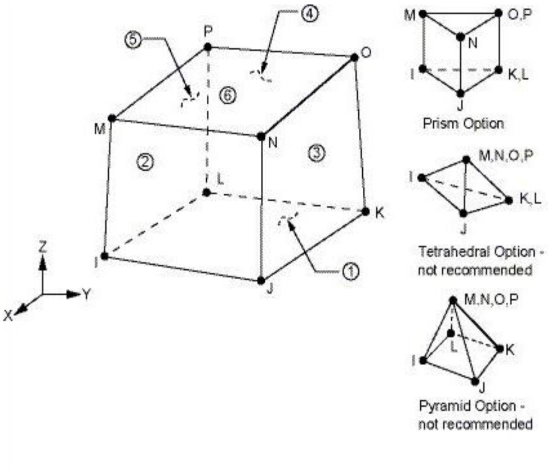


Figure 8: Representation of Solid 185 Element

B. Loading on Girder pin connection

Load is uniformly distributed along the top surface of the plate of pin connection. Thereaction at girder end being point load is loaded throughout the area. Load to be applied is calculated based on girder reaction obtained from girder analysis.

Table 4: Table consisting of various girder pin sizes in practise and maximum contact stresses

Boiler Rating	Case	Top Plate Size			Bottom Plate Size			Pin or Rod		Contact Stress
		Length	Breadth	Thickness	Length	Breadth	Thickness	Diameter	Length	
1		(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(N/mm2)
125 MW	1	700	300	130	700	600	155	110	802	89.34
	2	600	300	125	600	600	150	100	704	112.57
2										
150 MW	3	800	300	130	800	500	155	100	902	115.67
	4	800	300	125	800	500	150	100	902	121.31
3										
250 MW	5	800	300	125	800	800	150	100	904	101.85
	6	1000	300	130	1000	1000	155	110	1104	115.64
4										
500 MW	7	1600	300	130	1600	900	150	100	1702	135.89
	8	1600	300	125	1600	900	125	90	1702	137.45
5										
600 MW	9	1500	300	130	1500	1000	155	100	1602	140.52
	10	1500	300	125	1500	1000	150	100	1602	142.35
6										
660 MW	11	1100	300	125	1100	1100	150	100	1202	130.32
	12	1200	300	125	1200	1200	150	100	1302	137.51
7										
800 MW	13	1300	300	130	1300	1300	150	100	1402	141.35
	14	1500	300	125	1500	1500	150	100	1552	147.57

C. Boundary conditions

Boundary conditions are applied based on actual working condition of girder pin arrangement. Top plate is allowed to rotate with the pin using multi body contact. Bottom plate is considered fixed at the bottom surface and allowed to rotate when in contact with pin. Top and bottom plates are taken as "target surface" and pin is taken as "contact surface "while developing contact analysis between the surfaces.

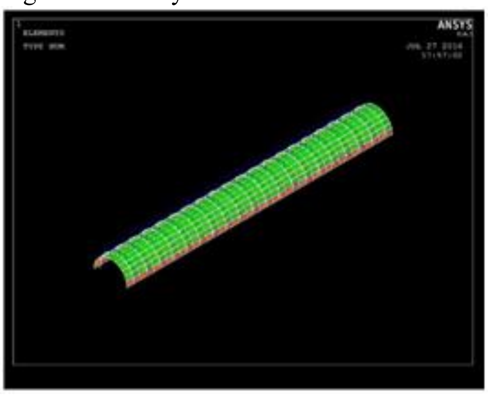


Figure 9: Representation of area in contact with top plates

Fig 9 shows the contact developed for top plate with pin top and Fig 10 represemts are in contact bottom plate with pin bottom. It is observered the contact is developed along the circumferential length of the pin.The coeffient of friction betwwen the elements are taken as 0.15.

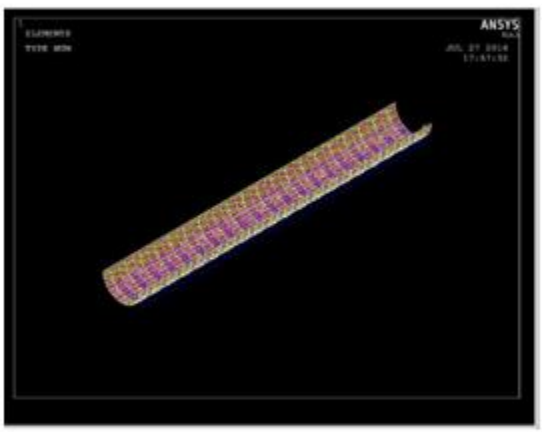


Figure 10: Representation of area in contact with bottom plates

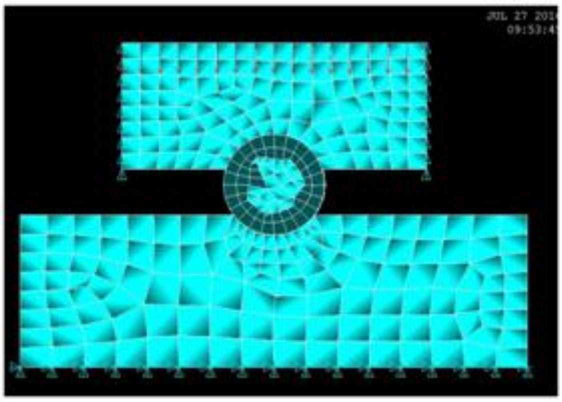


Figure 11: Representation of mesh and element model of Pin for case 1

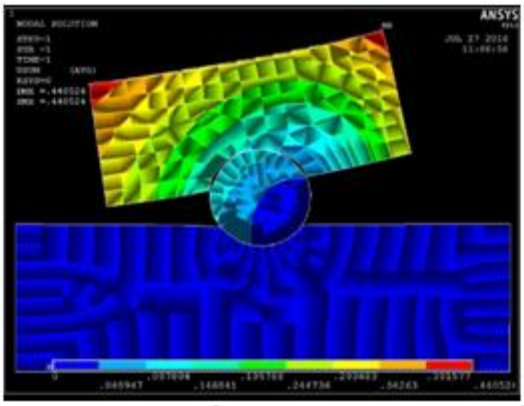


Figure 12: Deflection plot for case 1

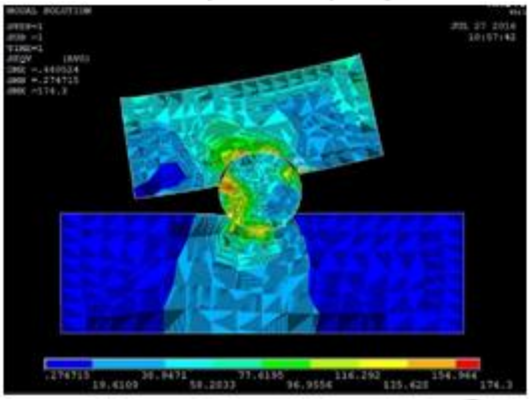


Figure 13: Representation of Von misses stress plot for case 1

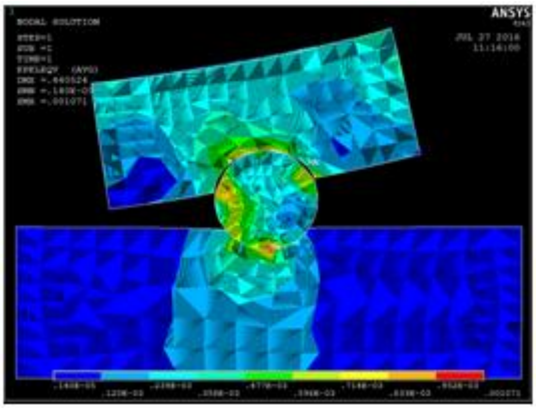


Figure 14: Strain plot for case 1

6. Results, Discussions and Conclusions

The following are inferences from analysis carried out.Girder pin arrangement being adopted for lower capacity boilers are found to be very uneconomical and for higher capacity boilers large scope for optimising the components of girder pin.Therefore by adopting different plate and rod thickness available in market the arrangement is optimised and tabulated in table[5].

Stresses between the pin and top plate is observed high due to relatively high stress concnetration.Stresses at the corners of bottom plate is found to be considerably low when comapared to mid sectionas shown in Fig [10]. Stress concentration at mid section ensures only axial loads are transferred to column thereby reducing column weight. Stress values are inferred less for bottom plate when compared to top plate which concludes the bottom plate thickness can be furthur optimised.

Deflection of top plate is observed high when compared to pin and bottom plate due to bending in girder beam. It is noted that bottom plate deflection is minimum when compared to pin and top plate.Deflection for higher capcities boiler are found to be high when as compared to lower capacities.

The strain values as shown in Fig [14] is concentrated only around pin and top plate. It decreases along the depth of the bottom plate. Strain values are found large for higher capacities boiler when compares to low capacities boiler. The future scope includes adopting only bearing plates rather than using girder pin connection. Hence, it can be concluded my adopting girder pin sizes furnished below table it is economical and the load can be transferred safely from girder to column top.

Table 5: Table consisting of optimised girder pin sizes for different rating of boiler capacities.

Boiler Rating	Case	Top Plate Size			Bottom Plate Size			Pin or Rod		Contact Stress
		Length	Breadth	Thickness	Length	Breadth	Thickness	Diameter	Length	
1		(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(N/mm2)
125 MW	1	700	300	63	700	600	100	63	802	157.34
2										
150 MW	2	800	300	63	800	500	100	75	902	151.68
3										
250 MW	3	800	300	63	800	800	115	75	904	157.64
4										
500 MW	4	1600	300	100	1600	900	125	90	1702	152.75
5										
600 MW	5	1500	300	100	1500	1000	125	100	1602	154.65
6										
660 MW	6	1100	300	100	1100	1100	150	125	1202	160.52
7										
800 MW	7	1300	300	125	1300	1300	150	100	1402	163.45

7. Acknowledgment

The authors are grateful for the encouragement, support, guidance and facilities extended for the research by National Institute of Technology (NIT), Tiruchirappalli, India and Bharat Heavy Electricals Ltd (BHEL), Tiruchirappalli, India

References

[1] In-plane behaviour of beam-to-column connections of corrugated web I-sections by R.Aydin,E.Yuksel ,N.Yardimci, M.HasimKısa, T. Gokce
[2] Generalised component-based model for beam-to-column connections including axial versus moment interaction byA.A. Del Savio, D.A. Nethercot, P.C.G.S.Vellasco, S.A.L.Andradec,L.F. Marthaa
[3] Modelling of CFRT through-diaphragm connections with H-beams subjected to axial load byYing Qin , Zhihua Chen, Bin Rong
[4] Experimental investigation of CFT column to steel beam connections under cyclic loading byIkhlas S. Sheet, UmaraniGunasekaran,Gregory A. MacRae
[5] Experimental and numerical analysis of the crushing behaviour of stiffened web girders by Bin Liu, C. GuedesSoares
[6] ANSYS 14.5 help guide

Author Profile

Thavamani Charles had completed his under graduation in the year 2011, from College of Engineering, Guindy, Chennai, Tamilnadu, India; in the field of civil engineering. He is presently pursuing his MS (by research) National Institute of Technology (NIT), Tiruchirappalli, Tamilnadu, India. He is working as Senior Engineer in Process and Captive Power Systems group of Bharat Heavy Electricals Ltd (BHEL), Tiruchirappalli, India since July 2011. He is involved in the design and analysis of boiler supporting structure of pulverized fuel fired boilers, circulating fluidized bed combustion boilers as well as heat recovery steam generators. He provides field engineering support to resolve problems on boiler supporting structures at power plant sites.