Optimization of Diverter car belt conveyor supporting structure to Reduce dead weight

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Abstract-Over the years a lot of work has done and is still continuing with great effort to save weight and cost of applications. The current trend is to provide weight/cost effective products which meet the stringent requirements. The belt conveyor is an endless belt moving over two end pulleys at fixed positions and used for transporting material horizontally or at an incline up or down. Allow quick and efficient transportation for a wide variety of materials. Diverter car belt conveyors are used to transfer concrete horizontally and limited distance vertically. They are particularly useful in areas such as dam slabs where it is difficulty to put concrete at mid side of the river at specific point, bridge, tunnels where space is limited and where it is difficulty to put concrete at specific point, Bridge grader making. A 25 meter cantilever belt conveyor is used in the diverter car belt conveyor system. The supporting the belt conveyor system is called *belt conveyor supporting structure*. Structure that supports and maintains the alignments of the idlers and pulleys and support the driving machinery. Goal of the project is to study existing conveyor system and optimize dead weight, structures optimize to minimize the overall weight of assembly and material saving can withstand such loads. The design of supporting structure can be make safe. With the help of SOLIDWORK for modeling and ANSYS 14.5 for analysis we analyzed the whole system.

Key words- SOLIDWORK 2012, ANSYS 14.5, Weight reduction, Optimized design, material handling systems.

I. INTRODUCTION

Conveyor is used in many industries to transport goods and materials between stages of a process. Using conveyor systems is a good way to reduce the risks of musculoskeletal injury in tasks or processes that involve manual handling, as they reduce the need for repetitive lifting and carrying. Conveyors are a powerful material handling tool. They offer the opportunity to boost productivity, reduce product handling and damage, and minimize labour content in a manufacturing or distribution facility. Conveyors are generally classified as either Unit Load Conveyors that are designed to handle specific uniform units such as cartons or pallets, and Process Conveyors that are designed to handle loose product such as sand, gravel, coffee, cookies, etc. which are fed to machinery for further operations or mixing. It is quite common for manufacturing plants to combine both Process and Unit Load conveyors in its operations. Roller conveyor is not subjected to complex state of loading still we found that it is designed with higher factor of safety. If we redesigned critical parts eg. Roller, Shaft, Bearing& Frame etc. then it is possible to minimize the overall weight of the assembly. Powered belt conveyors are considerable long (9000 meter to 10000 meter) as compared to roller conveyor. So we can achieve considerable amount of material saving if we apply above study related to roller conveyor to this belt conveyor ‘Finite Element Method’ is a mathematical technique used to carry out the stress analysis. In this method the solid model of the component is subdivided into smaller elements. Constraints and loads are applied to the model at specified locations. Various properties are assigned to the model like material, thickness, etc. The model is then analysed in FE solver. The results are plotted in the post processor. The scalar plot shows us the stresses and deformations over entire span.

II. LITERATURE REVIEW

Structural optimization using computational tools has become a major research field in recent years.Methods commonly used in structural analysis and optimization may demand considerable computational cost, depending on the problem complexity. Among these various techniques of DOE may be combined with classicanalysis, to reduce the computational effort without affecting the final solution quality. AjaykumarMenon et al.(2005) proposed an automation process in MATLAB that incorporates a response surface approximating toolcalled MQR. The results obtained from the proposed method were compared with ANSYS Design Xplorergoaldriven optimization which was based on DOE and ANSYS First order optimization technique [6]. D. M.Chauhan et al. (2006) Optimized weight of the HMT (Hydraulic Modular Trailer) to have higher pay loadcapacity. Frame was optimized using design optimization module available in ANSYS using first orderoptimization method. They have concluded that frame was optimized and feasible design was obtained with 52% reduction in mass. This reduction in mass of the frame increases the payload capacity by 4.900 tonesapproximately. During optimization of frame, it was found that web thicknesses value should be kept more thanthe flange thicknesses value for side long member [8]. Wen-Hsien Hsu et al. (2009) has been used a FEM-basedTaguchi method to investigate the effects of various factors to find the robust design of the body cage. TheFEM-based Taguchi methods have effectively decreased the time and efforts required for evaluating the designvariables of implants and had fairly assessed the contribution of each design variable [1]. BappaAcherjee et al.(2012) carried out a systematic investigation on laser transmission contour welding process using finite elementanalysis (FEA) and design of experiments (DOE) techniques. A three dimensional thermal model was developedto simulate the laser transmission contour welding process with a moving heat source. Design of experimentswas employed to plan the experiments and to develop mathematical models based on simulation results [2].

III. MATERIAL OF MODEL

The material for the structure is defined A 36 which is widely used material for the structure. The material properties are as shown in Table 1.

Table 1: Material properties of chassis [5]

Material	Structural Steel A 36
Poisson's Ratio	0.260
Tensile Strength	410 N/mm^2
Yield Strength	250 N/mm^2
Shear modulus	79.3 GPa (11,500,000 psi)
Young's modulus E	200 GPa (29,000,000 psi)
Density	7.85 gm/cm^3 , 7,800 kg/m^3 (0.28 lb/cu in)

IV. METHODOLOGY

As an important subject in the statistical design of experiment, the Taguchi method is a collection of mathematical and statistical techniques useful for the parametric optimization and analysis of problems in which
a response of interest is influenced by several variables and the objective is to optimize this response.
Taguchi method is used to examine the relationship between a response and a set of quantitativeexperimental variables or factors.

Steps for the Experiment:

- Formulation of the problem – the success of any experiment is dependent on a full understanding of thenature of the problem.
- Selection of the output performance characteristics most relevant to the problem.
- Selection of parameters.

- Selection of factor levels.
- Design of an appropriate Orthogonal Array (OA).
- To Perform FEA with appropriate set of parameters.
- Statistical analysis and interpretation of experimental results.
- Modeling and FEA with optimum parameter set for validation

Flow chart of experiment is given in Figure 1.

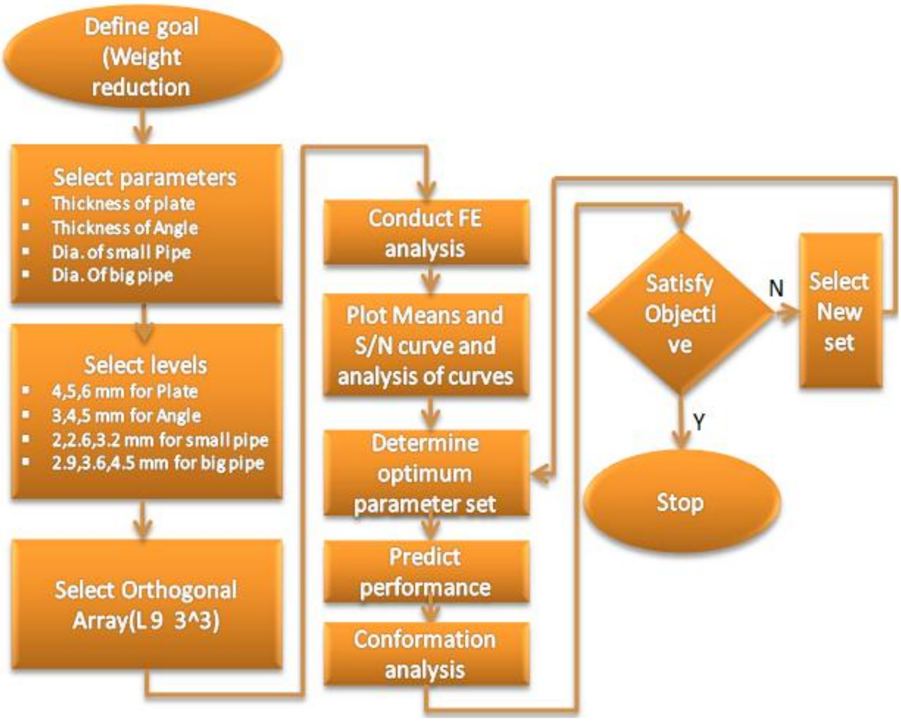

Figure 1: Flow chart of experiment [7]

V. EXPERIMENTAL METHOD

Experiments are planned according to Taguchi's L9 orthogonal array for band plate, L-angle, big pipe weldment, small pipe weldmentshown in fig. It has 9 rows corresponding to the number of testes with 3 columns at three levels and 4 parameters as shown in Table 2. This orthogonal array is chosen due to its capability to check the interactions among factors.

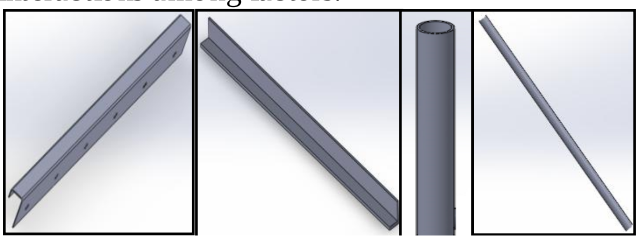

Figure 2: Band Plate, L-angle, Big pipe weldment, Small pipe weldment

The experimental results are then transferred in to a Signal to Noise (S/N) ratio. There are threecategories of quality characteristic in the analysis of the S/N ratio, (i) the-lower-the-better, (ii) the-higher-thebetterand (iii) the-nominal-the better. Regardless of the category of the quality characteristic, process parametersettings with the highest S/N ratio always yield the optimum quality with minimum variance. The category thelower-the-better was used to calculate the S/N ratio for both quality characteristics stress and deflection,according to the equation (1):

$$S/N = -10\log_{10}[\frac{1}{N}\sum_{i=1}^{n} Yi^2]$$

Where,
S/N = Signal to noise ratio
N = Number of repetitions of experiment
Yi= Measure value of quality characteristic

Table 2: Factors and their levels

No.	Factor	Level 1	Level 2	Level 3
A	Thickness of band Plate(mm)	4	5	6
B	Thickness of Angle(mm)	3	4	5
C	Thickness of Pipe(mm)	2	2.6	3.2
D	Thickness of Pipe(mm)	2.9	3.6	4.5

For finding out optimum thickness of Band Plate, L-angle, Big pipe weldment, Small pipe weldmentthe value of shear stress,deflection and weight is measured using ANSYS. Series of analysis is conducted to obtain the optimum weightfor allowable stress and deflection condition. Taguchi method is being applied to select the control factors levels(thickness of Band Plate, L-angle, Big pipe weldment, Small pipe weldment) to come up with optimal response value (weight, shear stressand deflection).

VI. RESULT AND DISCUSSION

The shear stress and deflection are measured for each set of parameter using FEA in Ansys, and theResults of FEA are analysed using Minitab 16. Minitab offers four types of designed experiments: factorial,response surface, mixture, and Taguchi (robust). The steps follows in Minitab to create, analyse, and graph anexperimental design are similar for all design types. After conducting the analysis and entering the results,Minitab provides several analytical and graphing tools to help understand the results. Minitab version 16 is usedfor the analysis of result obtained by Finite element analysis. The S/N ratio for minimum shear stress anddeflection are coming under "Smaller-is-better" characteristic, which can be calculated as logarithmictransformation of the loss function.
Taguchi designs experiments using especially constructed tables known as "orthogonal arrays" (OA).The use of these tables makes the design of experiments very easy and consistent.
From the Table 3 it is identified that minimum shear stress value 105.97MPa and minimum deflectionvalue 9.19 mm are obtained at the experiment no 9 having values of thickness of band Plate, L-angle, Big pipe weldment, Small pipe weldmentweb 6 mm , 5 mm,2.6 mm and 2.9 mm respectively.

Table 3: Experimental results table

No.	Thickness of band Plate	Thickness of Angle	Thickness of Small Pipe	Thickness of Big Pipe	weight	stress	displace ment
1	4	3	2	2.9	222.19	327.99	11.75
2	4	4	2.6	3.6	236.63	165.13	14.09
3	4	5	3.2	4.5	251.6	168.46	12.97
4	5	3	2.6	4.5	273.31	191.33	9.34
5	5	4	3.2	2.9	275.64	137.77	9.73
6	5	5	2	3.6	284.06	115.43	10.19
7	6	3	3.2	3.6	304.47	270.84	9.2
8	6	4	2	4.5	314	133.39	9.8
9	6	5	2.6	2.9	316	105.97	9.19

Main Effects Plot for Mean data and S/N ratio data are shown in Fig. 3, 4, 5 , 6, 7 and 8 that showseffect of thickness of web , thickness of Band Plate, L-angle, Big pipe weldment, Small pipe weldment on weight, shear stress anddeflection.

The effects of thickness of Band Plate, L-angle, Big pipe weldment, Small pipe weldmenton weight ofstructure frame are shown in Fig. 3 and Fig. 4.

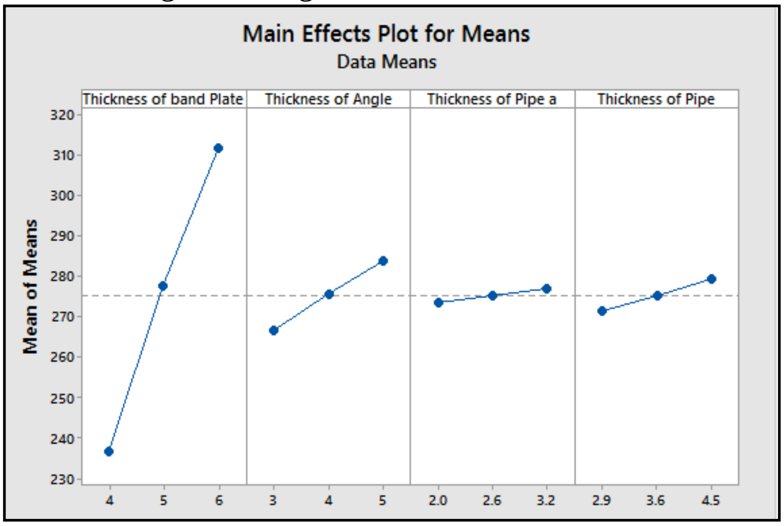

Figure 3: Main effect plot for mean data – weight

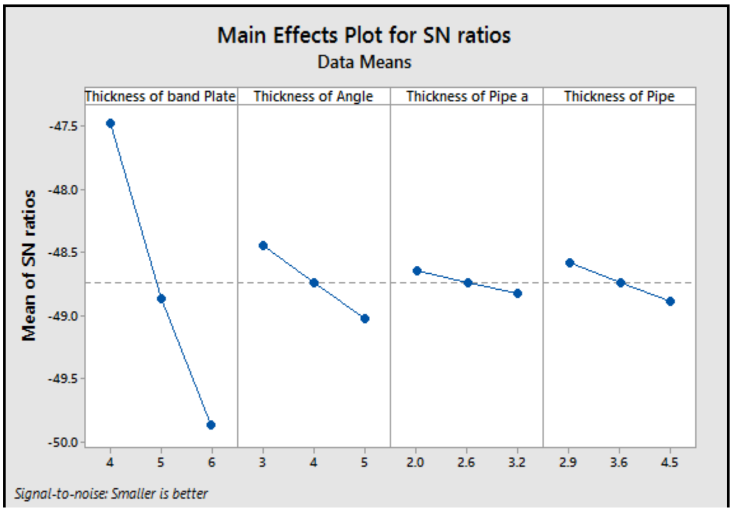

Figure 4: Main effect plot for S/N ratio data – weight

In the investigation, it has been found that as the values of Band Plate, L-angle, Big pipe weldment, Small pipe weldment thickness are increased, the weight is increased and when these values are decreased the weight isalso decreased as shown in Fig. 3 and Fig. 4.

The effects of thickness of Band Plate, L-angle, Big pipe weldment, Small pipe weldmenton shear stressof chassis frame are shown in Fig. 5 and Fig. 6.

The FEA done on the chassis model and generated shear stress values are given in Table 3. Based onstatic safety factor theory, the magnitude of safety factor for this structure is 1.43. J. P. Vidosic recommendssome value of safety factor for various condition of loading and material of structures. The value of 1.5 to 2 for well-known materials under reasonably environmental condition, subjected to loads and stresses that can bedetermined readily [4]. It is necessary to reduce the stress magnitude of critical point in order to get the satisfySF value of truck chassis. The structure can be modified to increase the value of SF especially at criticalpoint area. The permissible value of shear stress for material A 36 is 250/1.3 = 192.30Mpa (considering factor ofsafety is 1.3 for design). The formula of Safety Factor (SF) is defined by [5]

Design stress = yield strength / safety factor
= 250 /1. 3
= 192.30MPa

The corresponding value of S/N ratio is -44.58 for smaller is better characteristics.

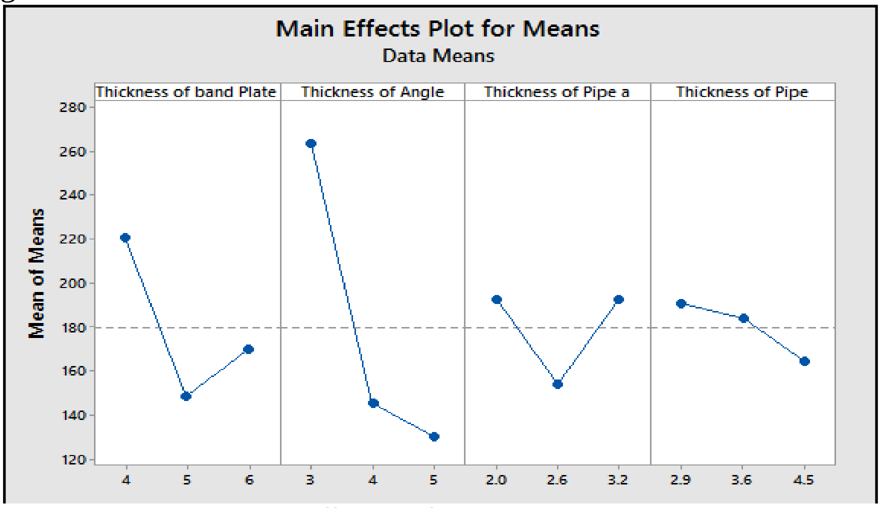

Figure 5 Main effect plot for mean data – shear stress

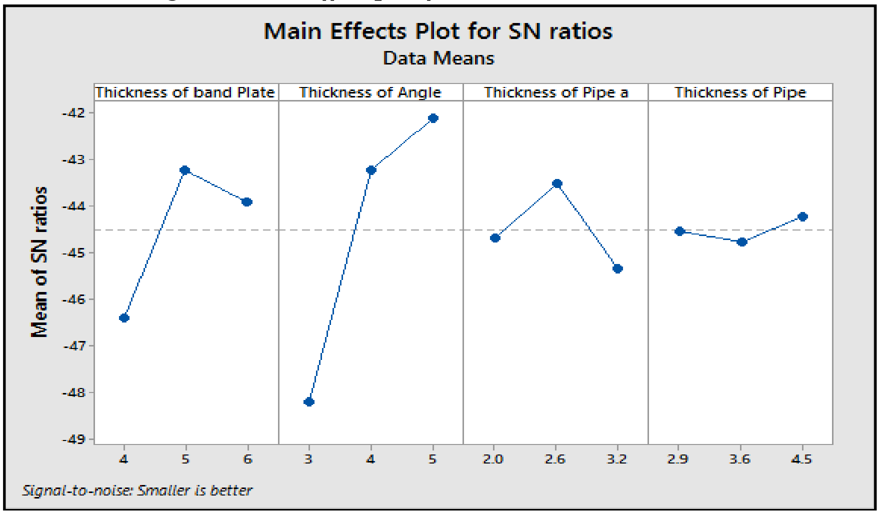

Figure 6 Main effect plot for S/N ratio data – shear stress

Results of Main Effects Plot for Mean data for weight (Fig. 7) and Main Effects Plot for S/N ratio datafor weight (Fig. 8) analysis are given in Table 4. As per the results structure with 5mm band pipe thickness, 4 mm L-angle, 2.6 mm big pipe thickness, 3.6 mm small pipe thickness is having optimum weight.

Table 4: Analysis of shear stress

	Band Plate	L-Angle	Big Pipe weldment	Small Pipe weldment
Generated Stress > 192.30 For size	4	3	2 3.2	2.9
Generated Stress < 192.30 For size	5 6	4 5	2.6	3.6 4.5
Optimum Size	5	4	2.6	3.6

The effects of thickness of band plate, L-angle, Big pipe weldment, small pipe weldment on deflectionof structure frame are shown in Fig. 7 and Fig. 8.

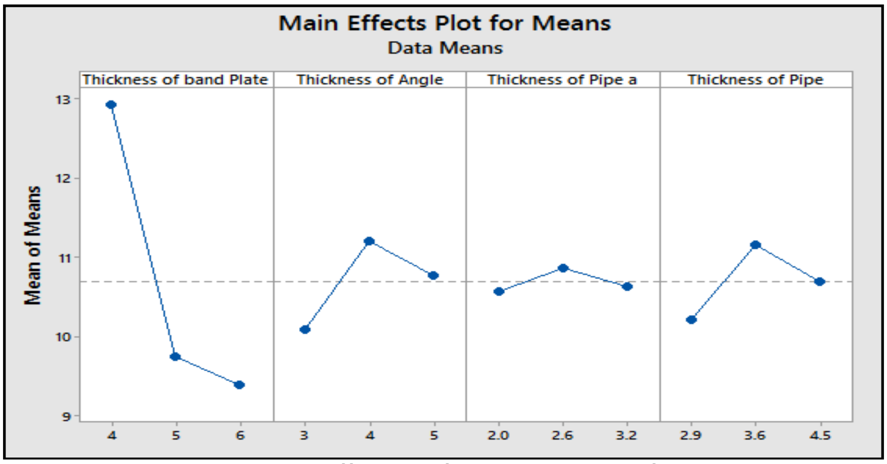

Figure 7 Main effect plot for mean data – deflection

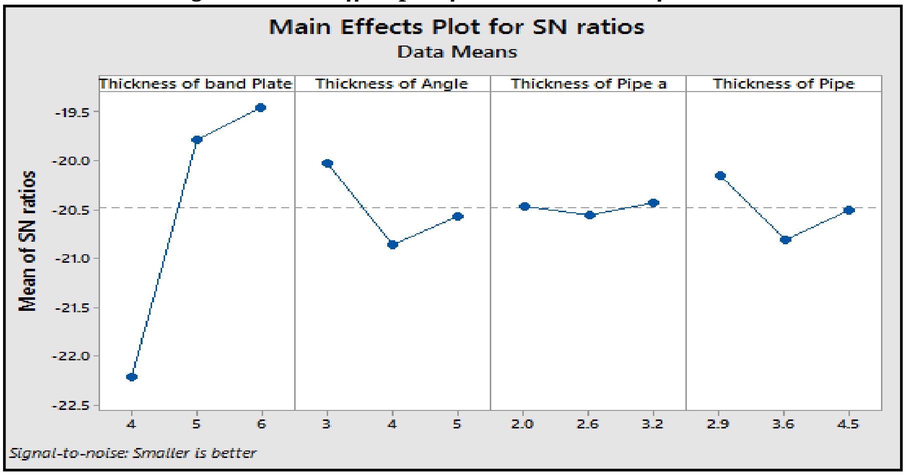

Figure 8 Main effect plot for S/N ratio data – deflection

According to deflection span ratio allowable deflection for overhanging beam is l / 300. So for6355mm length allowable deflection for simply supported beam is 21.18 mm. Fig. 7 and Fig. 8 shows followingeffects:

- As the band plate thickness of structure frame is varied from 4 mm to 6 mm, the deflection developed in structure decreased from 3.97194 mm to 3.02162 mm.
- As the L-angle thickness of structure frame is varied from 3 mm to 7 mm, the deflection developedin chassis decreased from 4.03764 mm to 3.13928 mm.
- As the Big pipe weldment thickness of structure frame is varied from 3 mm to 7 mm, the deflection developedin chassis decreased from 3.75288 mm to 3.17506 mm.
- As the small pipe weldment thickness of structure frame is varied from 3 mm to 7 mm, the deflection developed in structure decreased from 3.68252 mm to 3.0535

The deflections for all the value of band plate, L-angle, Big pipe weldment, Small pipe weldment thickness are within the safelimit.

From the above analysis the Optimum set of parameters which is having the minimum weight is givenin Table 5.

Table 5: Optimum set of parameter and value of stress

Band Plate Thickness(mm)	**L- Angle Thickness(mm)**	**Big pipe weldment Thickness(mm)**	**Small pipe Weldment Thickness(mm)**	**Predicated value of stress MPa**
5	4	2.6	3.6	183.02

VII. VALIDATION OF TAGUCHI RESULT

The model of modified structure as per the dimension given in Table 5 is created in solid works 2012 asshown on Fig. 9.The model is then saved in IGES format which can be directly imported into ANSYSworkbench.

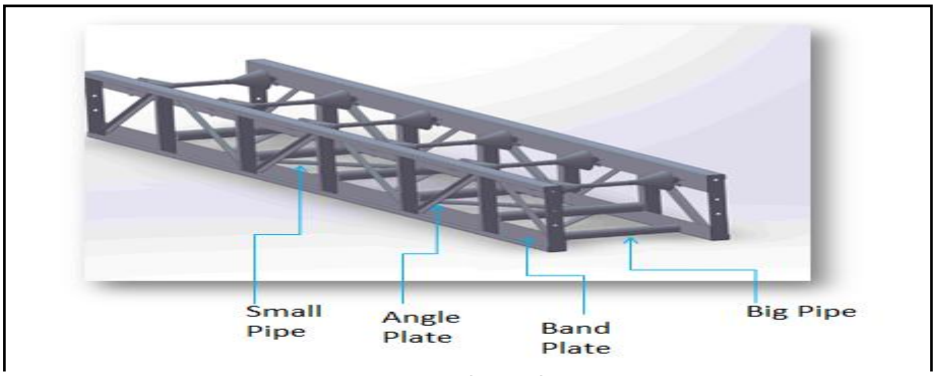

Figure 9: Modeling of modified all section

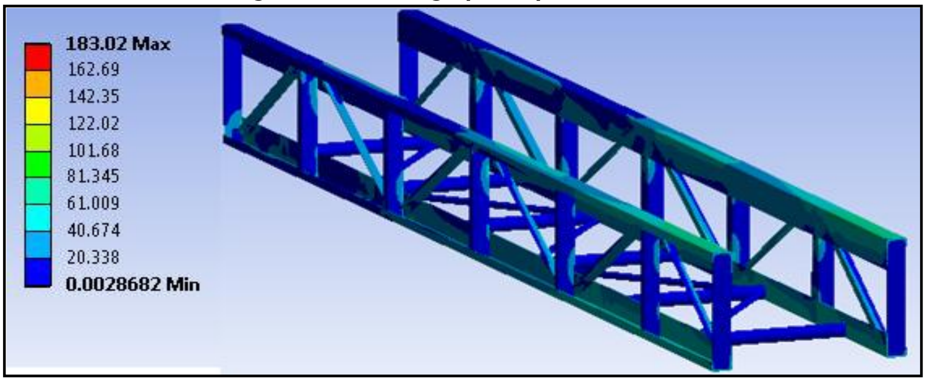

Figure 10: Shear stress in modified section

The generated shear stresses (183.20MPa) are less than the permissible value (192.30MPa) so thedesign is safe. The shear stress is as shown in Fig. 10.

Table 6: variation in results of Taguchi and FEA

Predication value of stress MPa	FEA Result of stress MPa	% Variation
183.9483	183.020	0.9283

Table 7: Reduction in results of Taguchi and FEA

Weight of Actual structure in Kg	Weight of Modified structure in Kg	Weight Reduction in %
255.14	217.14	14.76

The generated shear stresses are less than the permissible value so the design is safe. The analysis givesmaximum shear stress which is within desired limit and it is also nearer to Taguchi's prediction as shown inTable 6.

This percentage variation is caused by uncertainties of Taguchi Prediction and accuracy of FEA.

VIII. CONCLUSION

The FEM-based Taguchi methods have effectively decreased the time and efforts required forevaluating the design variables of implants.The optimal parameter combination for the minimum weight with permissible value of stress isobtained by using the analysis of S/N ratio. According to the results 5 mm band plate thickness, 4 mm L-angle thickness and 2.6 mm big pipe weldment thickness and 3.6 mm small pipe weldment thickness are the optimal parameters for permissible stress.

FEA results obtained from the confirmation analysis using optimum combination are shown excellentagreement with the predicated result. Weight reduction achieved by FEA modelling is 14.76% asshown in Table 7.

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