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Parametric Optimization of Belt Conveyor Supporting Structure Using FEA-DOE Hybrid Modeling

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Abstract: *The supporting structure use in track mounted convoyer. It should be rigid enough to withstand the vibration and other stresses. Along with strength, an important consideration in structure design is to have adequate bending. The main objective of the research is to obtain the minimum weight of supporting structure. The structure model is to be developed in Solid works 2012 and analyzed using Ansys14.5. Since the no. of parameters and levels are more, the probable models are too many. So, to select optimum parameters among them large no of modeling and analysis work is involved which consumes more time. To overcome this problem TAGUCHI method along with FEA is use. The weight reduction of the side bar is achieved by changing the Parameters using orthogonal array. Then FEA is performed on those models to get the best solution. This method can save material used, production cost and time.*

Keywords - *Parametric optimization, belt conveyor supporting structure, FE analysis, FEA-DOE hybrid modeling, Weight reduction*

I. INTRODUCTION

Material handling is a necessary and significant component of any productive activity. It is something that goes on in every plant all the time. Material handling means providing the right amount of the right material, in the right condition, at the right place, at the right time, in the right position and for the right cost, by using the right method. It is simply picking up, moving, and lying down of materials through manufacture. It applies to the movement of raw materials, parts in process, finished goods, packing materials, and disposal of scraps. In general, hundreds and thousands tons of materials are handled daily requiring the use of large amount of manpower while the movement of materials takes place from one processing area to another or from one department to another department of the plant. The cost of material handling contributes significantly to the total cost of manufacturing.

Fig.1 structure

II. Literature Review

The chassis serves as a backbone for supporting the body and different parts of the automobile. It should be rigid enough to withstand the shock, twist, vibration and other stresses. Along with strength, an important consideration in chassis design is to have adequate bending stiffness. The main objective of the research is to obtain the minimum weight of Eicher 11.10 chassis frame. The chassis frame is made of two side members joined with a series of cross members. The number of cross members, their locations, cross-section and the sizes of the side and the cross members becomes the design variables. The chassis frame model is to be developed in Solid works and analyzed using Ansys. Since the no. of parameters and levels are more, the probable models are too many. So, to select optimum parameters among them large no of modeling and analysis work is involved which consumes more time. To overcome this problem TAGUCHI method along with FEA is use. The weight reduction of the side bar is achieved by changing the Parameters using orthogonal array. Then FEA is performed on those models to get the best solution. This method can save material used, production cost and time. [1] Bappa Acherjee et al. (2012) carried out a systematic investigation on laser transmission contour welding process using finite element analysis (FEA) and design of experiments (DOE) techniques. A three dimensional thermal model was developed to simulate the laser transmission contour welding process with a moving heat source. Design of experiments was employed to plan the experiments and to develop mathematical models based on simulation results [2].

III. Material of model

Structural steel A36 is widely used in track mounted conveyor. The material properties are shown in Table 1

Table 1 Material property [3]

Material	Structure steel (A36)
Modulus of Elasticity E	2×10^5MPa
Poisson's Ratio	0.3
density	7850Kg/m^3
Yield Strength	250Mpa

IV. Methodology

As an important subject in the statistical design of experiments, 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 quantitative experimental variables or factors.

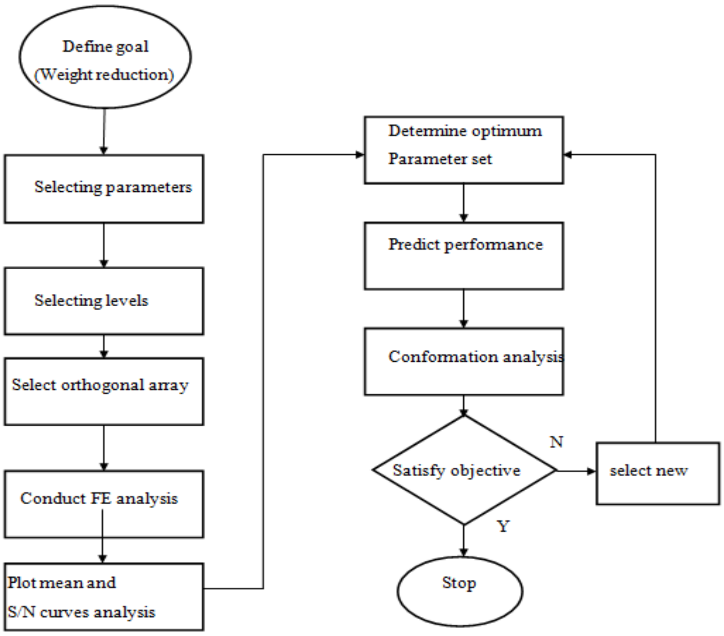

Fig. 1 Flow chart of experiment [4]

- Steps for the Experiment
- Formulation of the problem – the success of any experiment is dependent on a full understanding of the nature 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

V. Experimental Method

Experiments are planned according to Taguchi's L16 orthogonal array for plate, L-angle, rectangular tube, lower weldment, side weldment as shown in fig.2. It has 16 rows corresponding to the number of testes with 4 columns at four levels and 5 parameters as shown in Table 2. This orthogonal array is chosen due to its capability to check the interactions among factors.

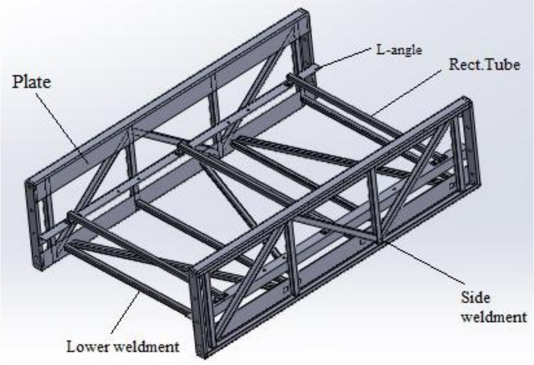

Fig.2 structure

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

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

Where,
$\mathrm{S/N}$=signal to noise ratio
n = Number of repetitions of experiment
Yi = Measured value of quality characteristic

Table 2 Factors and their levels

SR.NO	FACTOR	Level-1	Level-2	Level-3	Level-4
1	PLATE	7	6	5	4
2	SIDE WELDMENT	4	3.6	3.2	2.6
3	L-ANGLE	10	8	6	5
4	RECT.TUBE	4	3.6	3.2	2.6
5	LOWER WELDMENT	4	3.6	3.2	2.6

VI. Result And Discussion

The shear stress and deflection are measured for each set of parameter using FEA in Ansys, and the Results of FEA are analyzed using Minitab 17. Minitab offers four types of designed experiments: factorial, response surface, mixture, and Taguchi (robust). The steps follows in Minitab to create, analyze, and graph an experimental 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 17 is used for the analysis of result obtained by Finite element analysis. The S/N ratio for minimum shear stress and deflection are coming under “Smaller-is-better” characteristic, which can be calculated as logarithmic transformation 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 142.43MPa obtained at the experiment no 9 having values of plate, L-angle, rectangular tube, lower weldment, side weldment thickness of 5mm, 4mm, 6mm, 2.6mm and 3.6mm respectively.

Table 3 Experimental results

Sr. No.	Plate	Side weldment	L- angle	Rectangular tube	Lower weldment	Weight (kg)	Stress (Mpa)	Displacement (mm)
1	7	4	10	4	4	340.49	160.01	3.06
2	7	3.6	8	3.6	3.6	329.86	176.69	3.33
3	7	3.2	6	3.2	3.2	308.16	167.22	3.75
4	7	2.6	5	2.6	2.6	288.41	172.47	4.08
5	6	4	8	3.2	2.6	302.28	158.79	3.39
6	6	3.6	10	2.6	3.2	312.64	154.42	3.51
7	6	3.2	5	4	3.6	292.7	166.36	4.08
8	6	2.6	6	3.6	4	291.99	173.32	4.21
9	5	4	6	2.6	3.6	282.13	142.43	4.18
10	5	3.6	5	3.2	4	279.65	146.73	4.40
11	5	3.2	10	3.6	2.6	286.94	159.74	4.05
12	5	2.6	8	4	3.2	278.57	206.43	4.31
13	4	4	5	3.6	3.2	260.44	210.82	4.52
14	4	3.6	6	4	2.6	253.3	179.49	4.63
15	4	3.2	8	2.6	4	264.23	174.51	4.74
16	4	2.6	10	3.2	3.6	271.15	309.22	4.9

Main Effects Plot for Mean data and S/N ratio data are shown in Fig.3,4,5,6,7 and 8 that shows effect of thickness of plate, side weldment, L-angle, rectangular tube, lower weldment on weight, shear stress and deflection. In table 3 weight calculate by software.

I. The effects of thickness of plate, side weldment, L-angle, rectangular tube, lower weldment on weight of structure are shown in Fig.3 and Fig.4.

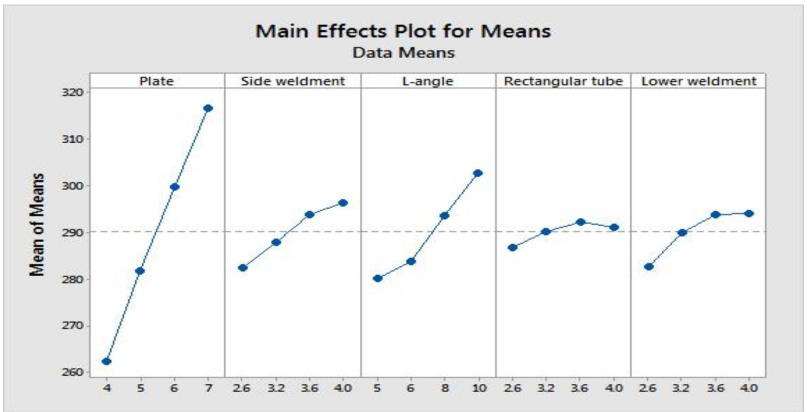

Fig. 3 Main effects plot for mean data: weight

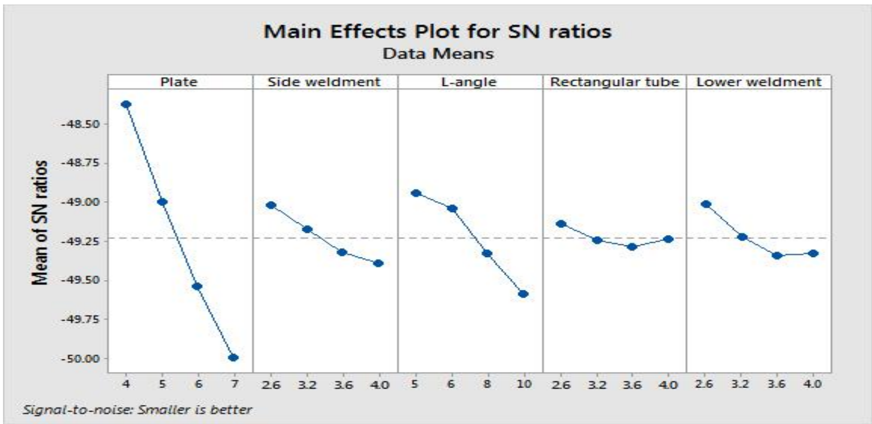

Fig. 4 Main effects plot for S/N ratio data: weight

In the investigation, it has been found that as the values of plate, side weldment, L-angle, rectangular tube, lower weldment thickness are increased, the weight is increased and when these values are decreased the weight is also decreased as shown in Fig.3 and Fig.4.

II. The effects of thickness of plate, side weldment, L-angle, rectangular tube, lower weldment on shear stress of structure are shown in Fig.5 and Fig.6.

The FEA done on structure and generated shear stress values are given in Table 3.The permissible value of shear stress for material is $\frac{250}{1.3} = 192.30\text{MPa}$(considering factor of safety is 1.3 for design).[3]

$$\text{Design stress} = \frac{\text{yield strength}}{\text{factor of safety}}$$
$$= \frac{250}{1.3}$$
$$= 192.30\text{MPa}$$

The corresponding value of S/N ratio is -45 for smaller is better characteristics.

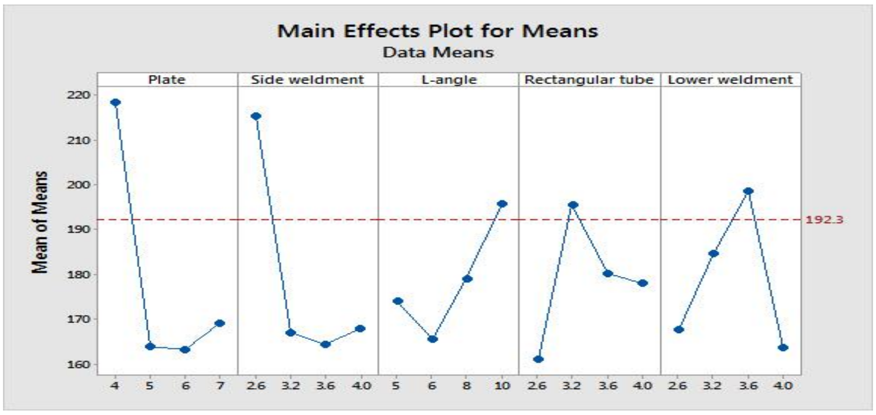

Fig.5 Main effects plot for mean data: shear stress

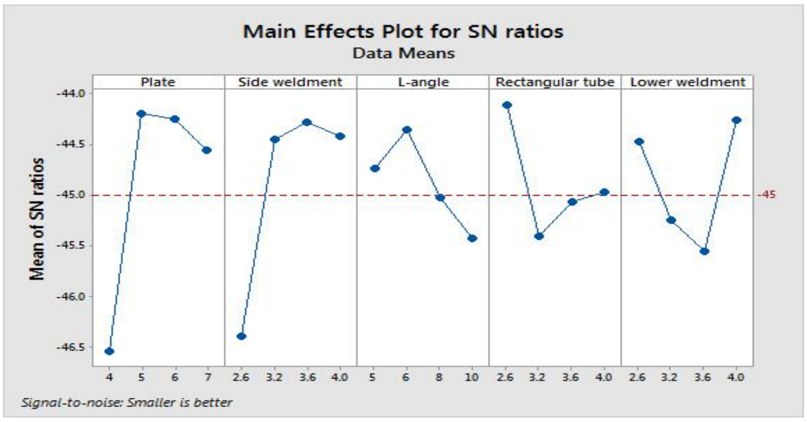

Fig.6 Main effects plot for S/N ratio data: shear stress

Results of Main Effects Plot for Mean data for shear stress (Fig.4) and Main Effects Plot for S/N ratio data for shear stress (Fig.5) analysis are given in Table 4. As per the results structure with 5mm plate thickness, 3.2 mm side weldment thickness,5 mm L-angle thickness 2.6 mm rectangular tube thickness and 2.6 mm lower weldment thickness is having optimum weight.

Table 4 Analysis of shear stress

	Plate	Side weldment	L-angle	Rectangular tube	Lower weldment
Generated Stress >192.30 For Size	4	2.6	10	3.2	3.6
Generated Stress <192.30 For Size	5 6 7	3.2 3.6 4	5 6 8	2.6 3.6 4	2.6 3.2 4
Optimum Size	5	3.2	5	2.6	2.6

III. The effects of thickness of web plate, side weldment, L-angle, rectangular tube, lower weldment on deflection of structure are shown in Fig. 7 and Fig. 8.

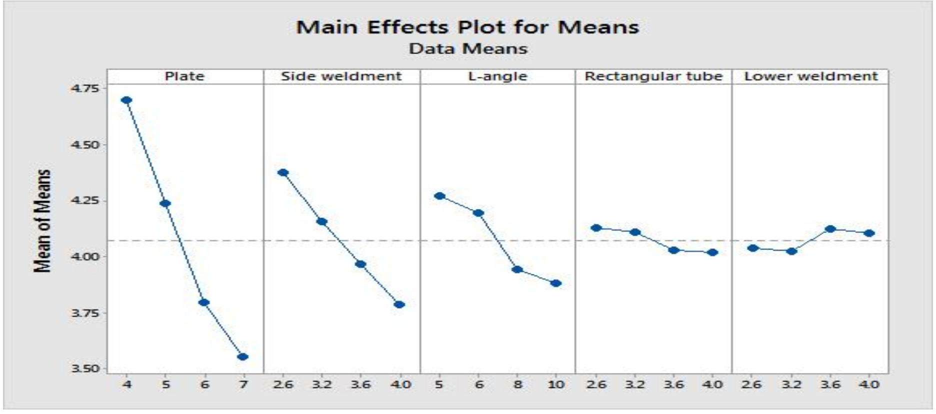

Fig.7 Main effects plot for mean data: deflection

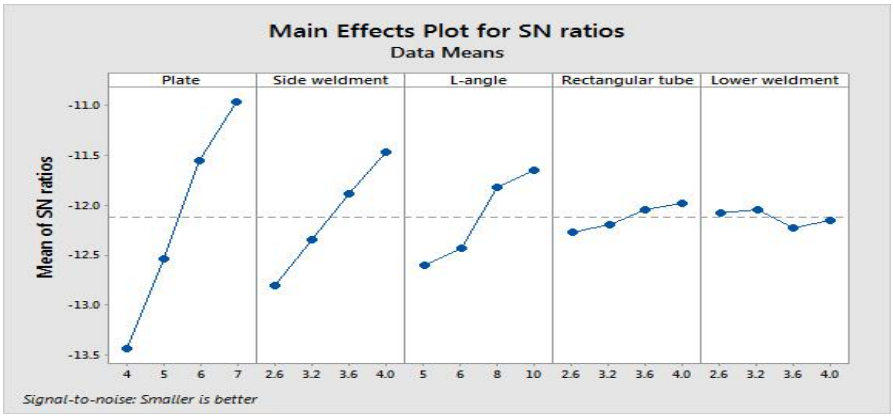

Fig. 8 Main effects plot for S/N ratio data: deflection

The deflections for all the value of plate, side weldment, L-angle, rectangular tube, lower weldment are within the safe limit.

Table 5 Optimum set of parameter

Plate	Side weldment	L-angle	Rectangular tube	Lower weldment
5	3.2	5	2.6	2.6

VII. Validation of Taguchi result

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

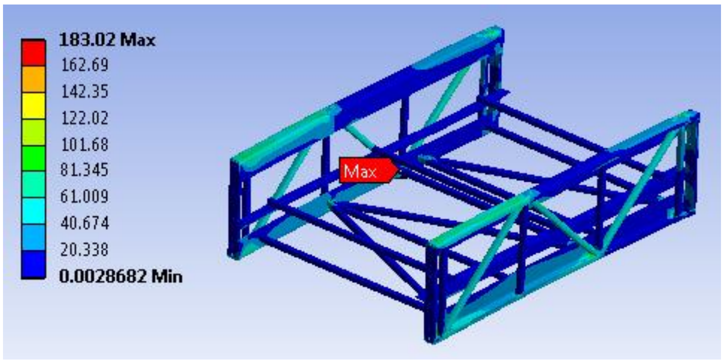

Fig. 9 Shear stress in optimize structure

The generated shear stresses (183.02 MPa) are less than the permissible value (192.30 MPa) so the design is safe. The shear stress is as shown in Fig.9

Table 6 Result compression

Name	**Use of parts no.**	**Existing structure**	**Optimize structure**	**Total existing structure weight**	**Total optimize structure weight**
Plate	4	29.9	24.99	119.6	99.96
Side weldment	2	23.7	20.03	47.4	40.06
L-angle	2	16.8	14.23	33.6	28.46
Rect.tube	3	6.08	3.95	18.24	11.85
Lower weldment	1	49.24	36.4	49.24	36.4
Total				268.08	217.27

In the result shows comparison of all parts in table 8.6. In this table only calculate of five main parts and other parts are same in existing and optimize structure. Difference between two structures is 268.08-217.27= 50.81kg and total 18.95% weights reduce.

VIII. CONCLUSION

The FEM-based Taguchi methods have effectively decreased the time and efforts required for evaluating the design variables of implants.

The optimal parameter combination for the minimum weight with permissible value of stress is obtained by using the analysis of S/N ratio. According to the results 5mm plate , 3.2mm side weldment, 5mm L-angle, 2.6mm rectangular tube, 2.6mm lower weldment thickness are the optimal parameters for permissible stress.

FEA results obtained from the confirmation analysis using optimum combination are shown excellent agreement with the predicated result. Weight reduction achieved by FEA-DOE hybrid modeling is 18.95% as shown in Table 6.

REFERENCES

Journal Papers:

[1] Tushar M. Patel, Dr. M. G. Bhatt , Harshad K. Patel Parametric Optimization of Eicher 11.10 Chassis Frame for Weight Reduction Using FEA-DOE Hybrid Modeling IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 6, Issue 2 (Mar. - Apr. 2013), PP 92-100

[2] Bappa Acherjee, Arunanshu S. Kuar, Souren Mitra, Dipten Misra, Modeling of laser transmission contour welding process using FEA and DoE, Optics & Laser Technology 44-5, 2012 1281-1289

Books:

[3] PSG Design Data Book for Standard Data (Kalaikathir Achchagam, Coimbatore2004).

Thesis:

[4] Brian J. Auer, Size and shape optimization of frame and truss *structures through evolutionary methods*, University of Idaho, 2005