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Design, Analysis And Optimization Of Skid Base Frame

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ABSTRACT: Skid Base Frame is a structural assembly consisting of beams of various cross sections and dimensions. The base frame is subjected to gravitational loading of all the components mounted viz. Compressor, Air Receiver vessel etc. The frame discussed in this report was designed with conventional CAD design practices and then analyzed statically with FEA software. The acceleration loads considered during analysis phase resembled the actual loading cases. The analysis was carried out to determine the induced stresses and the deflections at various locations on proposed frame. The structure was optimized to reduce weight.

Keywords-Skid Base frame, CAD model, FEA loading, static analysis, weight optimization

1 INTRODUCTION

SKID Frame is a structural assembly consisting of beams of various cross sections and dimensions. The sections used may be of equal dimensions and cross sections, or a combination can be used for optimum strength and weight. The sections can be of IS standard dimensions or custom made. Placement of beams is done in such a way that all the footprints of the components are covered. Different arrangements for assembly lifting (for e.g. hook lifting lugs, forklifting insertion passages) are provided in the skid frame. The frame was designed and analyzed for 3g loading under both hook lifting and forklifting process. For sufficiently lower values of deflection (< 2.5 mm), and higher value of FOS(> 1.15), the structure was redesigned using thinner and smaller IS standard sections. The repetitive iterations with smaller sections gave final optimum solution.

2 DESIGN OF SKID FRAME

The Skid frame required to support various components has been designed by conventional design procedure. The weights of the components mounted on the frame were considered as loads for designing. Some simplifying assumptions were made at the initial stages in order to decide the cross sections of various beams. The forces from Footprints were transferred directly to the main structural beams. Shear Force and Bending Moment diagrams were drawn for the beams carrying maximum portions of weights. Flexural equation was used to obtain Moment of Inertia of required section.Formula applied: $\delta_{max} = ML^2/ 8EI$ For Iteration I, Beams of MB 225 I-section, MCP 225 Channel section of adequate lengths were modeled as CATparts. The beams were assembled to generate a structure, or CATproduct. This was later converted into STEP for analysis.

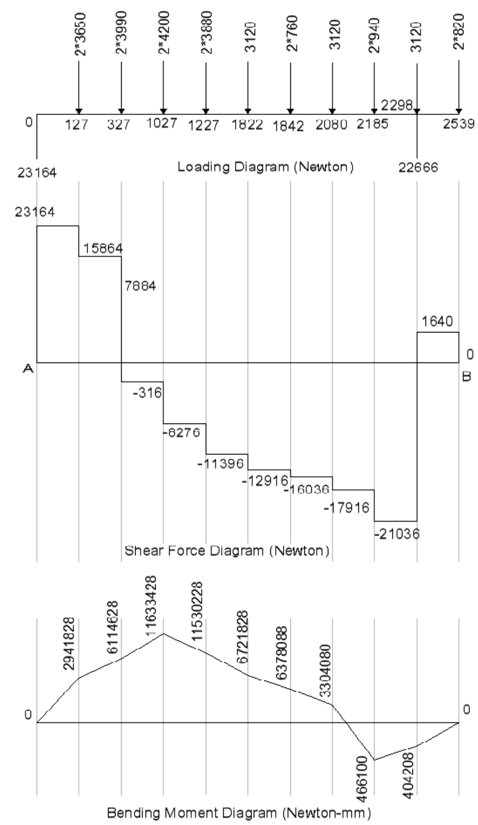

Fig. 1: *S.F.D. and B.M.D.*

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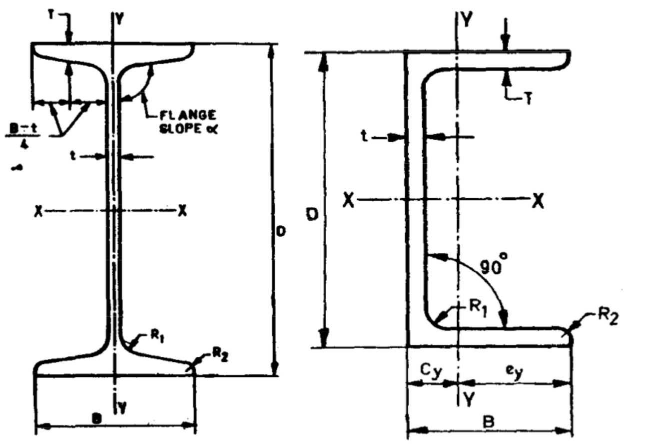
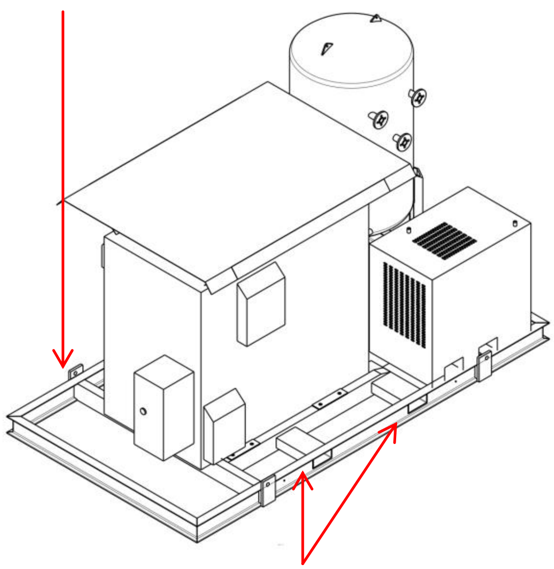


Fig. 2: *I (MB) and Channel (MCP) sections*

SECTION NAME	D	B	t	T
MB 225	225	110	6.5	11.8
MCP 225	225	83	9.0	12.4

Table 1 *Sectional Dimensions (Iteration II)*

Arrangement for lifting hook insertion (4 lugs)



Arrangement for fork insertion

Fig. 2 *Assembled Skid Frame (Iteration I)*

3. ANALYSIS

The designed frame was analyzed with Finite Element Method. The analysis was required to check the values of induced stresses and deflections caused due to the weights of components. The STEP file structure was meshed and analyzed using ANSYS Workbench 14.5 for stresses and displacements during various loading conditions.

3.1 Static Analysis

The static analysis is applied when the value of any load acting on frame does not change with time. Generally linear behaving materials are used for manufacturing of frames. Thus the Skid Frame structure was subjected to linear static analysis. The material used is structural steel cold-formed welded, structural hollow section. The literature regarding Skid frames being rare, their hypothetical similarity with automotive chassis gives aid in referring the chassis analysis methods. Meshing for Iteration I structure was done and later Remote Forces and respective constrains were applied. Weight of the body is always assumed to be acting from its CG, hence applied as a Remote Force. The forces behave rigidly, i.e. as if the whole body is mounted on the frame.

	Hook Lifting Analysis	Forklifting Analysis
Meshing Type	Hexagonal	Hexagonal
Nodes	883,952	31,24,552
Elements	240,882	472,446

Table 1*- Meshing Details (Iteration I)*

Component Name	CG Co-ordinates			Remote Force (N) (3g)
	X	Y	Z	
Compressor	740	373	13	31550
Air Receiver	1218	-1145	-366	10000
Dryer	460	-1065	620	5002

Table 2*- Loading Details (Iteration I)*

For hook lifting analysis, nodes of every hook, which were at 70^{o} w. r. t. vertical (along the direction of lifting rope), were constrained. Whereas, for forklifting, the rectangular section up to length 1500 mm was constrained in vertical direction. Dummy constrains (along horizontal axes) were also given in both cases. They help in solving FEM equations correctly without affecting stress distribution.

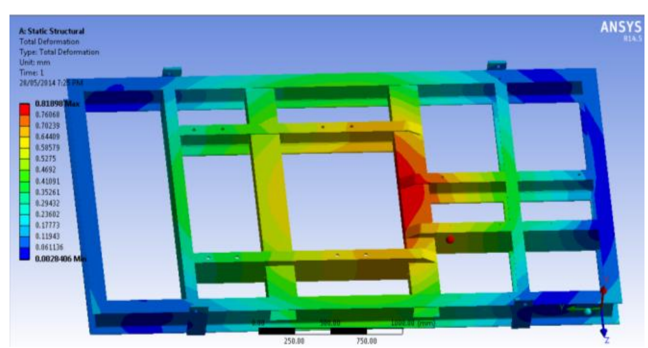


Fig. 3 *Total Deflection for hook lifting*

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Maximum total deflection= 0.8189 mm

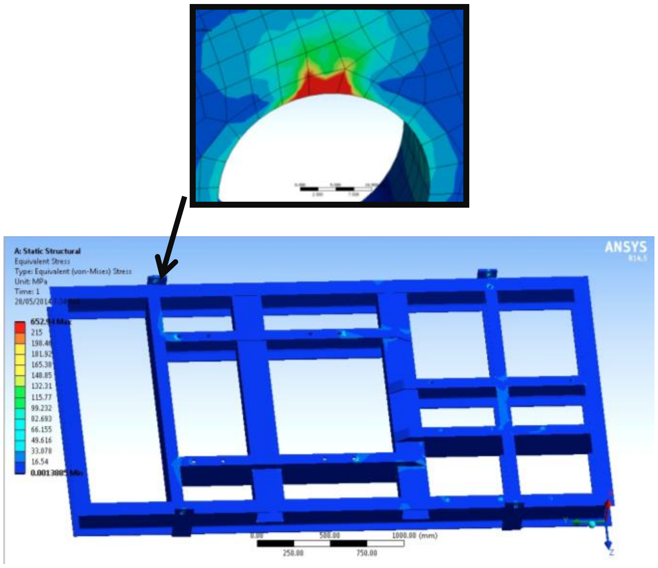

Fig. 4 *Equivalent Stresses (von Mises)*

Maximum stress out of hook lifting and forklifting analyses was observed in hook region. Maximum Localized stress (corrected to second node)= 132 N/mm^2
Material selected for modeling was having tensile strength S_{yt}= 250 N/mm^2
∴ FOS= 250/ 132= 1.89
The values were way safer than the limit values (deflection= 2.5 mm, FOS= 1.15)
Thus, there was need of obtaining a model lighter in weight by varying (reducing) sections' dimensions to smaller standard values.

3.2 Iterations for Optimization

The structure was remodeled and reanalyzed under same loads. Following tables show IS Standard sections used in every Iteration-

Table 3: *Beam sections for Iteration II*

Section Name	D	B	t	T
MB 200	200	100	5.7	10
MCP 200	200	76	7.5	11.4

Table 4: *Beam sections for Iteration III*

Section Name	D	B	t	T
MB 175	175	85	5.8	9
MCP 175	175	77	7.5	10.2

Table 5: *Beam sections for Iteration IV*

Section Name	D	B	t	T
MB 150	150	75	5	8
MCP 150	150	76	6.5	9

Table 6: *Beam sections for Iteration V*

Section Name	D	B	t	T
MB 125	125	70	5	8
MCP 125	125	66	6	8.1

Frame structures assembled using these sections were analyzed one by one for hook lifting and forklifting. Results for maximum deformation and maximum stress were obtained. The graphs below integrate most significant values of deflection and FOS for all the Iterations.

Fig. 5 *Maximum Deflection values*

Deflection up to 2.5 mm is allowed in general practice. Hence, Iterations showing deflections less than this value are considered safe.

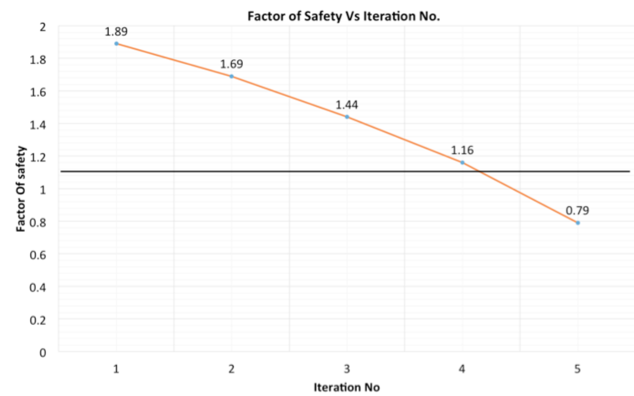

Fig. 6 *Minimum FOS values*

As per British Standards, FOS of 1.15 is sufficient for a stationary application skid frame. Thus, Iteration IV comes out to be the most optimum design, with FOS= 1.16.

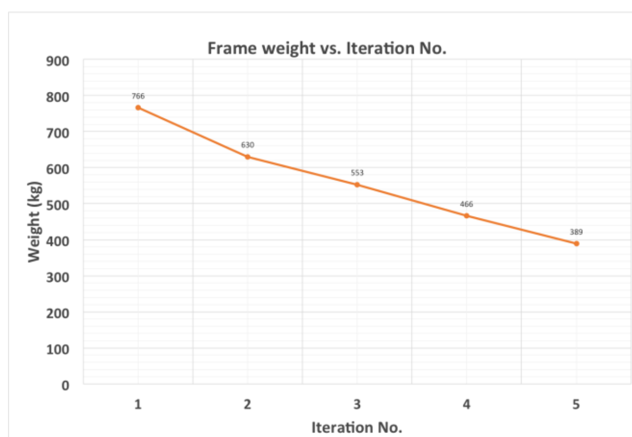

Fig. 7 *Weights of Frames*

Weight of the material required for every Iteration no. goes on reducing due to use of thinner/ smaller sections. This

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shows the gradual reduction in weight of the Skid Frame. With reference to the deflection and FOS results, weight reduction up to Iteration IV was taken as safe. Thus, the frame with 150 mm IS sections was the optimized solution for given loading.

3.3 Modal Analysis

Modal Analysis determines natural frequencies and mode shapes of a structure. Each natural frequency sets up specific deformation pattern, i.e. mode shape. The same phenomenon can occur in a Skid frame during working condition. To avoid mechanical damage due to Resonance, the structure must undergo Modal Analysis and it should be verified that the frequencies don't lie in the vicinity of the frequency of oscillatory forces being applied by the rotating components in assembly. For Modal Analysis, the model should be kept free from all the loads and constrains. Hence, after Tetrahedral meshing was done, no constrains were applied. First six frequencies were supposed to be zero, as they represent translational and rotational vibrations about X, Y, Z axes. Seventh frequency, or the First Resonant Natural Frequency should be greater than 20 for compressor applications. This is illustrated by following table-

Tabular Data

	Mode	Frequency [Hz]
1	1.	0.
2	2.	0.
3	3.	7.3625e-004
4	4.	8.8975e-004
5	5.	2.4781e-003
6	6.	2.6767e-003
7	7.	20.273
8	8.	49.577
9	9.	55.974
10	10.	62.736

Fig. 8: *Natural Frequencies for Iteration IV*

For given natural frequency, mode shape defines the way in which the structure would deform. Mode shape for first resonant frequency was as follows-

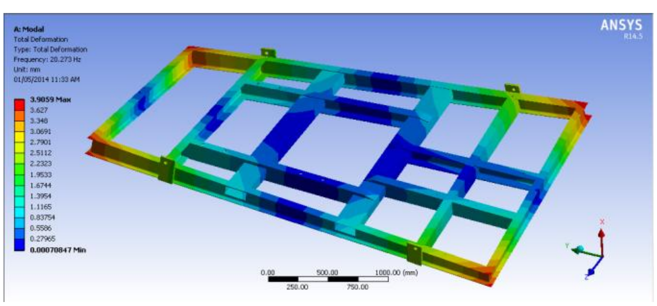

Fig. 9: *Mode shape for 20.273 Hz*

4 CONCLUSION

The project developed an illustration of Skid Frame modeling, analysis for given operating conditions and optimize its weight, within safety limits. Gradual reduction in the sectional dimensions gave significant reduction in weight. Also, values of stress, FOS and deflections lie within the permissible limits of yield for the given loading conditions. Modal Analysis verified that the frame would operate safely under working conditions due to distant value of First Resonating Frequency.

The Flexural formula gives required value of I (Moment of Inertia) for given deflection δ, under known static loading. However, the general procedure is to test the model for Equivalent von Mises Stresses, and not for deflections. Thus, this method needs to be developed further, to get I value of beam used in terms of maximum stress value. This work development will lead to invention of a direct method to design a Skid Frame.

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