IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
PP 42-48

Design and Analysis of Compressor Package Skid Frame

S. P. Mail[1], S. S. Sarawade[2],S. P. Gadewar[3]
[1, 2, 3](Mechanical Engineering Department, MES College of Engineering,, S.P.Pune University, India)

Abstract: *The Connected parts of the system used to support the Load is known as Structure. Compressor Package Skid Base Frame is an assembly of beams of Various Cross sections and dimensions. Base frame is subjected to gravitational stacking of the considerable number of segments mounted on Package Skid viz. Compressors, Nitrogen Generators Assembly and Electrical Control Unit. The frame is designed using INVENTOR and afterward analyzed using Finite Element Analysis software ANSYS. The structural loads considered during analysis phase resemble the actual loading case. The analysis is then carried out to determine the induced stress and the deformation at critical locations on proposed frame. The Lifting Lug of the frame is designed to ensure the safety of the frame. Compressor Package Skid Frame is designed for transporting assembled compressor with Lifting Cranes and spreader beams.*
Keywords –*Package Skid Base frames, INVENTOR, CAD Model, FEA Analysis, Lifting Lug.*

I. Introduction

Package Skid frame is structural assembly of beams used to carry weight and sustain the load of the various components mounted on it. The package unit includes Three Double Stage Air Cooled Screw Compressors, Nitrogen generator assembly and electrical control unit. The frame is madeof an I-beam of (American National Standard Institute (ANSI) standards). The positions of beam are designed in such that the impressions of the components are secured. The Skid haslifting arrangements. For designing the load of the components mounted on Package Skid Frame, the mass of the components is taken into consideration. Hardly any presumptions were made at the initial level of designing with a specific end goal to choose the cross section of the beam. Stress Analysis using FEM(Finite Element Method) is used to identify the critical points indicating the maximum stress on beams during loading. The purpose of the package skid is to support the Components mounted on it and sustain the load during transportation of frame from one location to another.

The scope is to check the strength of the package skid and Lifting lugs for twopoints loading. To perform strength analysis of skid and lifting lugs for compressor + Nitrogen generator+ Electrical control unit following load cases are considered.

- 1.0g Static (Operational load cases)
- 2.0g Lug Lifting load case for two-point lifting
- Lifting Lug proof Test.

Pandhare et al. [1] have given the idea about the skid base frame modeling, analysis for given conditions and optimization method to reduce its weight within safety limits. Writer concluded that the gradual reduction in the sectional dimensions gave significant reduction in weights.Aditi [3] Design of frame for Flow control system was generated and analyzed using Finite Element Analysis Software.Jadhav and Dhanvijay [6] have represented a Case Study and designed An Skid Frame for high speed reciprocating compressor. The design was to control the vibration on the deck surface and further analysis of it was done. A. J. Smalley [7] gave the idea of the number of loads affecting the compressor base frame.Shah et al. [9] represented the analytical and FEA results using staandprovi and Ansys. They optimized by changing the Dimensions of the cross section and performed DOE of the same.

II. Package Skid Base Frame Design

` The Material for Skid frame design given as input Parameter a **Mild Steel**. The Material Properties of Mild Steel is listed below in TableNo.1.
Assume, Factor of Safety: 1.2 for static load case
Allowable stress: Yield stress/ Factor of safety= 288/1.2 =240 MPa.

Table no 1:. Material Properties used for Skid Design

Sr. No	Physical Properties	Symbol	Magnitude	SI Units
1.	Tensile Strength	$\square_{\mathbf{Tensile}}$	360	MPa or N/mm^2
2.	Yield Strength	$\square_{\mathbf{yield}}$	288	MPa or N/mm^2
3.	Young's Modulus	**E**	210000	MPa or N/mm^2
4.	Poison's Ratio	**μ**	0.3	
5.	Density	□	7800	Kg/m^3
6.	Strain at Rupture		25	%

III. 3D Model of Frame

By using Autodesk INVENTOR 17.0 base frame is designed in frame generator. Skeleton of Skid is prepared and later on this Skeleton is converted in to 3D frame through selecting beams from content Centre. The Skid Dimensions of the package skid is 196in x 456in [49784 mm x11582.4 mm]. The most critical members in the structure are the beams and channels,hence their design should not only be economical but safe too. As the I-beams has excellent strength, efficient and economical in cost they are most commonly used for Skid. Selection of proper steel beam is all about selecting the correct beam with minimum weight that will sustain the load without surpassing the bending strength or shear quality of the material, and without surpassing the maximum allowable deflection of the beam. For this package Skid ANSI W 14x34 I beam is selected. Along with its Specification in Table No. 2.

Table no 2: I-beam ANSI W 14x34 Specification [4]

Parameters:	**Symbol**	**Values**	**Units**
Inner face height	H	332.486	Mm
Width	B	171.45	Mm
Flange thickness	H	11.557	Mm
Web Thickness	B	7.239	Mm
Density	P	7800	Kg/m^3

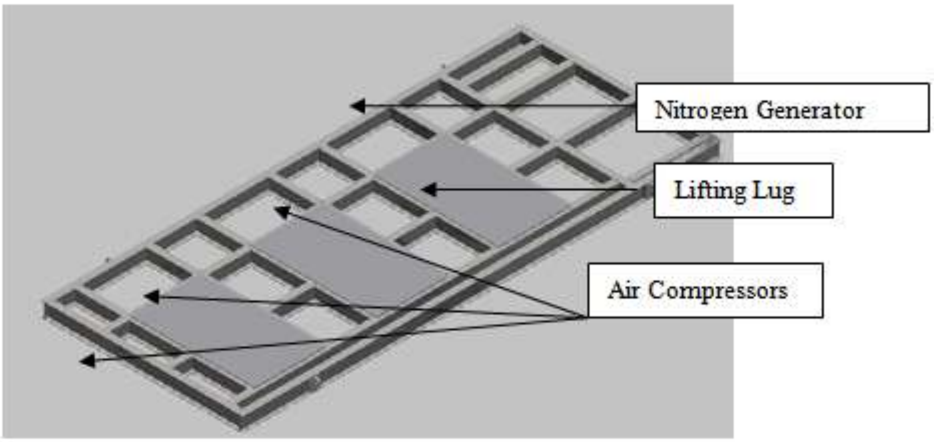


Fig.1. 3D Package Skid Model in INVENTORof 49784 mm x11582.4 mm

Table no 3: Package Skid Geometry

Sr No.	Component	Mass [Kg]	Centre of gravity [mm]			Representation
			X	Y	Z	
1	Air Compressor 1	2650	2349.52	602	1194.88	Lumped Mass
2	Air Compressor 2	2650	5294.65	602	1194.88	
3	Air Compressor 3	2650	8239.78	602	1194.88	
4	Nitrogen Generator	5292	10769.84	993.18	1565.10	
5	Electrical Unit 1	100	546	1981	4541.52	
6	Electrical Unit 2	100	3205.5	1981	4541.52	
7	Electrical Unit 3	100	6151.88	1981	4541.52	
8	SKID	4560				FE Mesh
9	Piping + Miscellaneous	550				FE Mesh
TOTAL		**18652**				

Static weight of the COMPONENTS AND PIPING = (3*2650) + (3*100) + (1*5292)+550
= 14092kg*9.81 m/s^2= 138242.52 N
Standard Acceleration is applied on the whole body = 9.81 m/s^2

Assumptions:

The welded joints will be assumed to have same strength as that of parent material and will be modeled by merging the interface nodes between the connections. Deformation and calculations are not calculated in pipes, lifting beams, spreader beams assuming that they are strong enough. Minimal constraints will be applied to avoid singularity error during simulation and it has negligible impact on the results.

IV. LUG PROOG Test Calculation

Lug proof test load factor consideration as per DNV 2.7-1. [2]

The Design of the Lifting Lug is designed in INVETOR and detail drawing along with its dimensions is shown in Figure No 2. The Load 'R' should be considered as being equally circulated between (n-1) pad eyes. Where n is the real number of Pad eyes. For estimation reason n might not surpass 4 or be under 2. To find resulting sling force on the pad eyes, the sling point must be considered. Thus, the Resulting Sling Load (RSL) on each Pad eye will be, the sling angle must be taken into account. Hence, the resulting Sling Load (RSL) on each Pad eye will be as shown in the Equation No. 1.

$RSL = \frac{3 * R * g}{(n-1) * \cos \theta}$…………… (1)

θ =Angle between horizontal and the sling leg is assumed to be 45º

RSL = (3*18652*9.81) / (4-1)*cos (45º)**RSL= 258767.31 N**

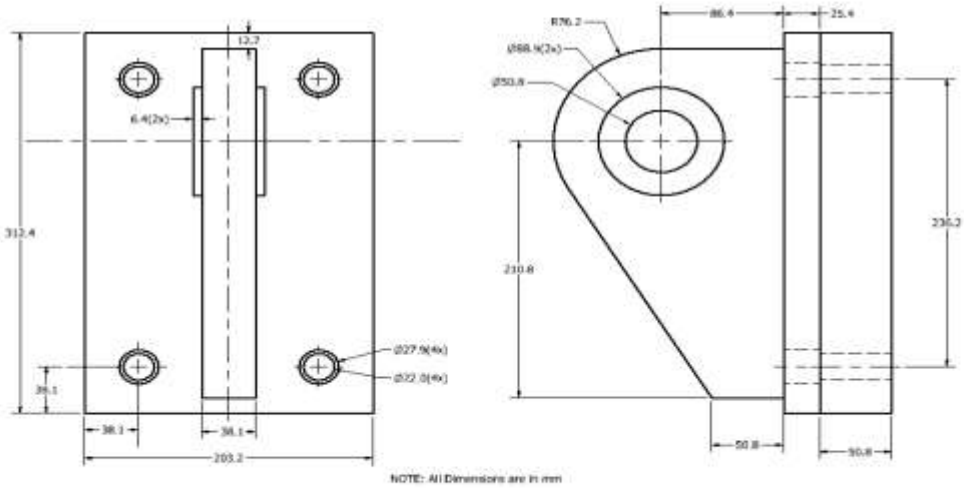


Fig2.Dimension Drawing of Lifting Lug

V. Analysis of Skid Frame

Here the base frame is modeled using 2D shell elements (Shell 181). The Air Compressors will be modeled as lumped mass using CONM 2 elements at its respective Centre of gravity (COG) and will be connected to their respective footprints on the frame using RBE3 element. Spreader beam will be modified using beam element and slings will be modeled using rod element. The bolt material is considered stiffer and stresses of high stiff elements will not be considered. The Modeling strategy of the frame is shown in Table 4.

Table no 4: Modeling Strategy

Load Case	Description	Analysis Type	Acceptance Criterion	Reference Value
I	Operating 1g Downward	Linear/	Von Mises	Yield Strength
II	Lug Lifting 2g			
III	Lifting Lug Proof Test			

The Frame is modeled and solved by Ansys Batch Method (Command Method).Batch method is useful if the product or component to be modeled remains same with minor variations in dimension as it saves time in preprocessing. It is easier to make changes and solve when the frame has same geometry/ shape with different dimensions. Once the macro is made it can be used for similar products thus reduces modeling and messing time by changing the variables. The frame is generated in Ansys by area or surfaces at mid-section of I beams. The Beams were glued to each other for connectivity. Quadrilateral 4 Node element shell-181 is used for meshing the area model. Shell Section properties were defined according to the thickness of the I Section. Linear material properties of mild steel were assigned to the model. Boundary condition as per the defined load cases were applied and the analysis was carried out.

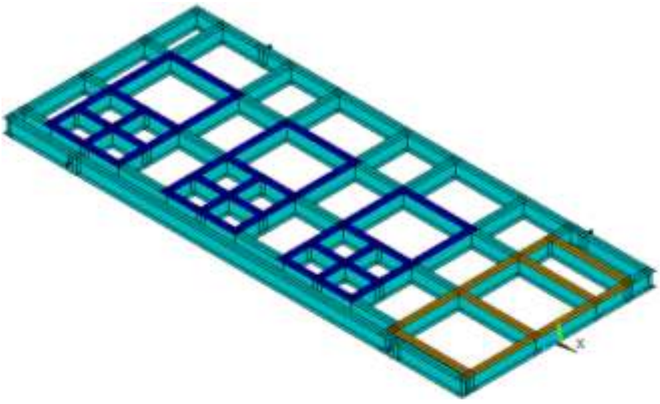


Fig. 3. Frame Generated &Meshed using Batch method

Load Case I: For 1.0g static (Operating load Case) the analysis type is Linear static Analysis. In this case 1.0 g acceleration will be applied in vertical downward direction (-Z direction). The bottom resting surface will be constrained in vertical direction as represented in Figure No.4.

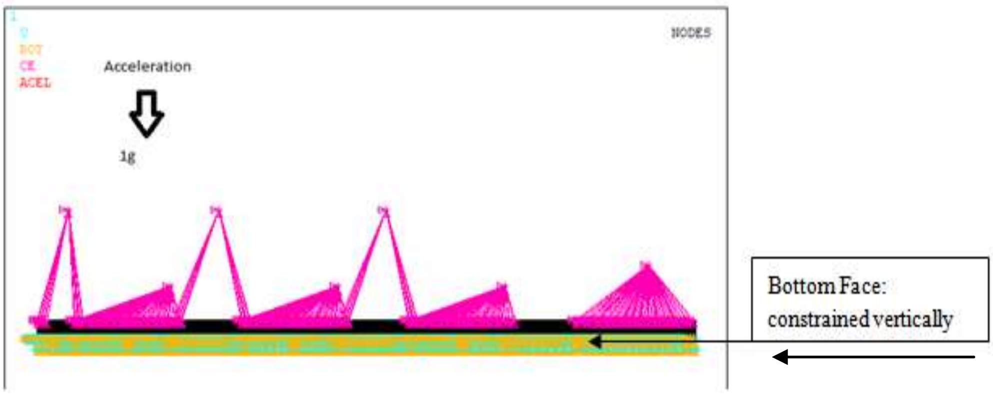


Fig.4.Loading and Boundary Conditions at Load Case I

Load Case II: For 2.0 g Lug Lifting Static Linear analysis is done. For lifting Lugs the 2.0 g acceleration is applied in vertical upward direction.Spreader beam ends are represented by mass element having negligible mass at a height of 5200 mm. The Lifting loads are connected to the mass elements by constrained equations. The nodes of mass element are fixed in all directions to simulate fixity. The sling makes an angle 60º with the horizontal. Lugs Location will be constrained in all degrees of freedom as shown in Figure No. 5.

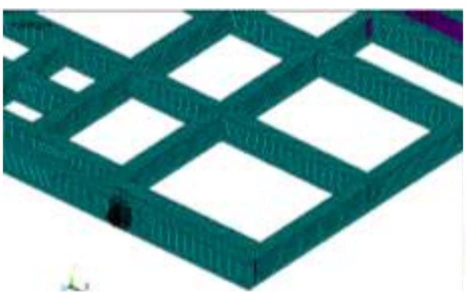


Fig.6. Meshing Details

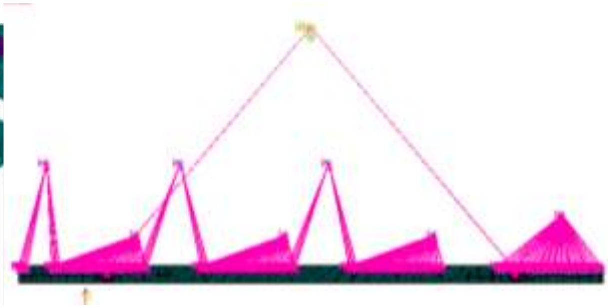


Fig.7. Lifting Arrangement of Package Skid

Δ

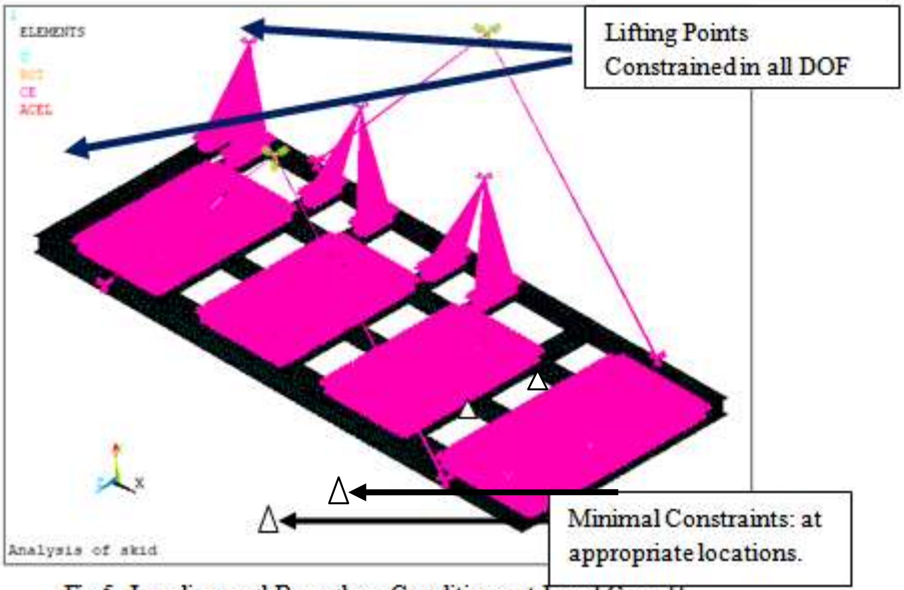
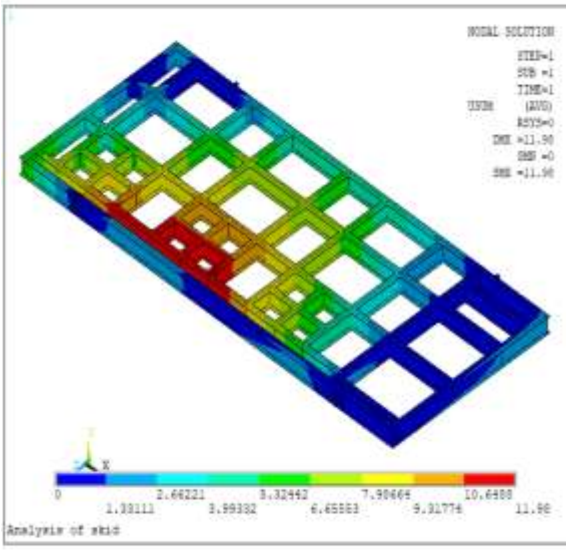


Fig.5. Loading and Boundary Conditions at Load Case II

Load Case III: Lifting Lug Proof Test is carried out and here the linear analysis is done. For Lifting Lug the sling Force of **258767.31N** is applied at Pad eye location with Sling angle.

VI. Results and Conclusion

Load Case I: The Maximum Stress Observed is 11.98 MPa at the End of Compressor 2 support. The Stress is less than Allowable Yield Stress limit of 240 MPa. The deflection in the beam is observed as 0.0018 mm at the Left end of Nitrogen assembly support.



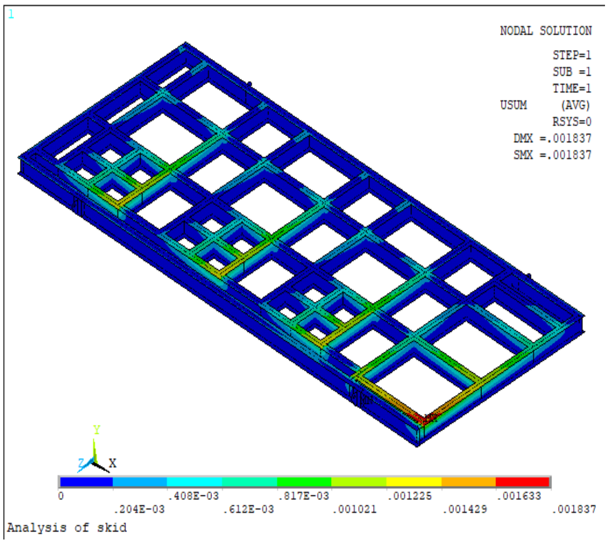


Fig 8(a) Von mises stress at Operating Load .**Fig 8(b)** Deflection at operating Load Condition.

Load Case II: The Maximum Stress Observed is 232.706 MPa at the Lug Supports. The stress is less than the Yield Limit of 240 MPa. The Maximum deflection observed in the frame due to lug lifting is 1.4011mm at the end of the frame.

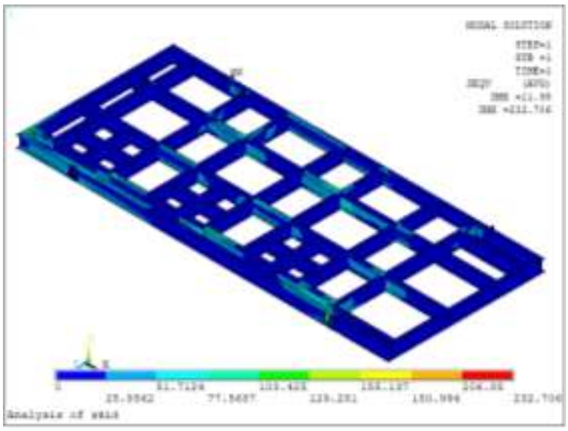


Fig 9(a) Von misses stress at Lug Lifting Condition

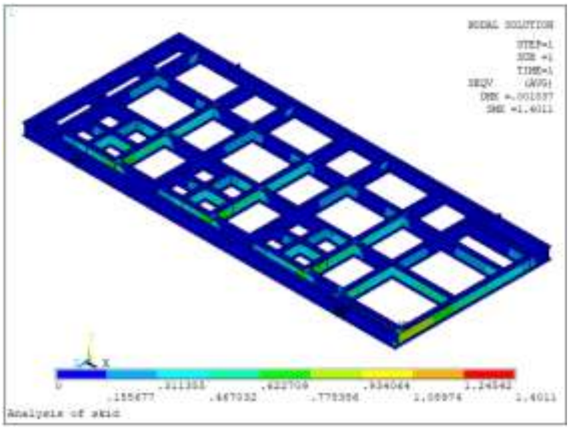


Fig 9(b) Deflection of Frame at case II

Load Case III: The Maximum Non Linear Stress observed is 102.9 MPa at the bolted location. Accountable stress is less than that of the Allowable Yield limit 240 MPa. The Maximum deflection observed is 0.067 mm in the lug eye location.

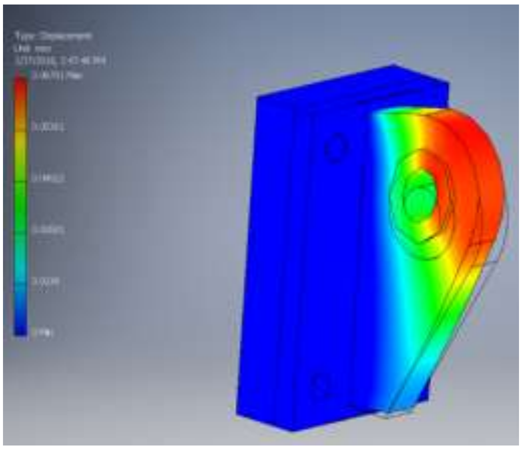
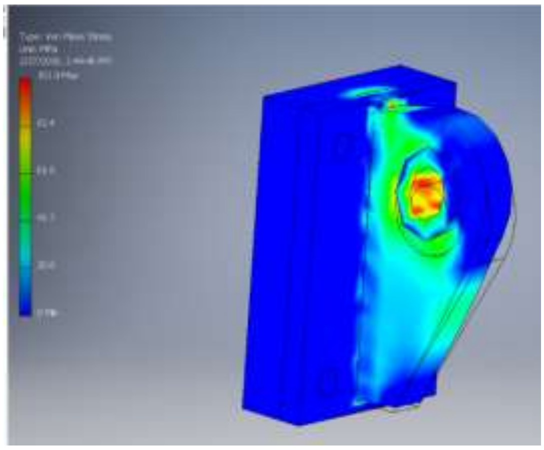


Fig 10(a) Von Mises Stress in lug at Load Case IIIFig



10(b) Deflection of Lug at Load Case III

Table no 5:Stress, deformation results

Load Case	**Description**	**Displacement (mm)/ Plastic strain**	**Stress [Mpa]**	
			Accountable stress	**Allowable Limit**
I	Operating Load	0.0018	11.98	240
II	Lug Lifting	1.4011	232.706	240
III	Lug Proof Test	0.067	102.9	240

The Package Skid frame is designed and Analyzed, parameters such as nodal displacement and stress distribution are analyzed in three load cases. The Study shows that the Von mises stresses in the Skid frame in all three load cases are 11.98 MPa at load case I, 232.706 MPa at case II and 102.9 MPa at Load case III are within the permissible limit 240 MPa. The deformations in the skid frame are observed and are in the acceptable range. From this results it can be concluded that the modeled and analyzed package Skid frame is Safe for Static as well as dynamic loading.

References

[1] Pandhare A. P., Chaskar S. T., et. al, Design Analysis and Optimization of Skid Base Frame, International Journal of Technology enhancement and Emerging Engineering Research, 2(7), 2014, 110-113.
[2] DNV 2.7-1 Standard "Standard For Certification, Offshore Containers", Certification No. 2.7-1, Section 4.2.3
[3] A. Godse, M. K. Wasekar, Design and Analysis of Skid Frame module for its strength & stiffness, International Journal of Engineering Technology Management and Applied science, 3(8), 2015, 59-64.
[4] ANSI/ API Standards 610, Centrifugal pumps for petroleum, Petrochemical and Natural Gas Industries,11th Edition ,2010.
[5] G. J. DeSalvo and J. A. Swanson. ANSYS Engineering Analysis System User's Manual. Houston, Pa. :Swanson Analysis Systems,2015.

[6] K. D. Jadhav and M. R. Dhanvijay, Design and Standardization of Base frame and anti-Vibration mounts for Balanced opposed Piston air compressor, International Journal of Applied Science in Mechanical Engineering ,2(2), 2012,71-78.

[7] A.J. Smalley, J.S. Mandke, et. al., Reciprocating compressor Foundation: Loading Design, Analysis and Mounting and Repair, GMRC,Mechanical and Fluid Engineering division, South West research Institute, TA, 1999.

[8] Naveena M, Naveen Kumar, et. al., Design and Analysis of skid frame for Pumping Station, International Journal of Engineering Research, 5(6), 2016, 1208-1212.

[9] H. R. Shah, A. K. Sahu, and M. Y. Patil, Structural analysis and design modification of the compressor skid of Helium Liquefier Plant, International Journal of Engineering Research and Technology, 2(11), 2013, 2567-2572.

[10] V. B. Bhandari, Design of Machine Elements (Mc Graw Hill Education, 2016).

[11] Chris Harper and Hongfa Wu, Optimized Skid Design for Compressor Packages, BETA Machinery Analysis - Gas Machinery Conference, Albuquerque, NM, 2013, 1-9.

[12] C.Rajendra, Design/Evaluation of overhead Lifting Lugs, PDH online Course S106, 2012, 1-7.

[13] T. R. Chandrupatla and A. D. Belegundu, Introduction to Finite element in Engineering, Third edition, 2007, pp.165-355.

[14] Ekhande and S. B. Naik, Study and FEA Analysis of Transportation Skid, International Journal of Engineering Development and Research, 5(2), 2017, 1335-1345

[15] M. Ramarutham, Strength of Material,(Dhanpatrai Publication, 2015).

[16] D. V. Hutton, Fundamentals of Finite Element Analysis, (McGraw Hill Publication,2016).