STATIC AND FREE VIBRATION ANALYSIS OF MULTI-COMPRESSOR PACKS BASE FRAME

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ABSTRACT

The requirement of light weight structural materials in industrial applications is increasing as the pressure for improvement in product to make it more efficient and reliable. Emerson launched new series of Multi Compressor Packs in the Accrex Exhibition-2015. In this Paper main focus is to optimize available base frame. Initially available design of frame is redesigned and layout is finalised in structural point of view. After these, CAD model is prepaired and Free vibration analysis and static analysis of same is carried out in ANSYS workbench 16. Results obtained will clearly indicate, whether Base frame is suitable or not for working frequency condition. To maintain its robust structure, further optimization of frame is carried out. After manufacturing of new base frame, FFT analyser is to be used for experimental validation of numerical results. Main objective of Paper is to construct Base frame that will sustain in all frequency range of product.

Keyword: - *Base frame optimization, Static Analysis, Modal analysis, Multi Compressor Packs*

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1. INTRODUCTION

Base Frame in the multi compressor packs serves as chassis which carries all components of refrigeration system. The compressor excitation forces arising from pulse and unbalanced forces are widely considered among the main vibration sources for flooded start condition. Correct geometry and positioning of the base frame ensures a good ride quality and performance. As compressor is mounted on base frame its basic tendency is to release vibrations, hence, dissipating the vibrational energy and keeping the stresses under a pre-described safety level should be achieved by careful designing and analysis of the mount bracket on a frame. A compressor mount must satisfy two essential but conflicting criteria. First, it should be stiff and highly damped to control the idle shake and compressor mounting resonance. Also, it must be able to control, similar to shock absorber, the motion resulting from load conditions such as running in flooded start condition. Second, for excitation of small amplitude over the higher frequency range, a compliant but lightly damped mount is required for vibration isolation. In this case support bracket provided for control panel and suction header acts as cantilever beam. Deformation of this beam for desired load and vibration condition also has to analyze.

H.N. Tang,et al [1] published paper Based on the characters that the piston rod of reciprocating compressors is supported by a guide bearing system in the direction of movement, simplified mechanical model of piston rod is established. The Analysis result is used for the optimization of the guide support system of piston rod, and good result is obtained.

Mr. Vijaykumar A. Patil et al. [2] studied the base frame (skid) which is generally made up of the standard I- beam or C -channel sections. The frame has to withstand various forces from the compressor during operation and dead loads of all bare compressor components during lifting the whole package. Due to lifting of the skid with dead loads of all bare compressor components, the skid tends to bend. The bending can results in damage of compressor component and piping. Hence compressor base frame should be strong enough to meet the deflection and stress criteria during lifting and also, withstand the loads during compressor running. At the same time, it should be light in weight. Hence, it is essential to carry out the analysis of compressor base frame to find out stresses in existing skid and modified skid.

Dr.Venugopal et al.[3] **,**Compressors are fitted with mounting plates and is welded to the compressor bottom and through the holes of this plate; the compressor gets mounted on to the A/C housing. The vibrations from the compressor get transferred to the A/C housing there by producing noise, which is undesirable. When the natural frequencies of the compressor, the mounting plate and the A/C housing coincide resulting in resonance. In this work the static analysis of the plate with three different PCDs are modelled and analysed.

Harper Chris et al [4] The majority of compressor packages are now mounted on steel skids or base plates. Designing a skid for a new machinery package can be challenging because of these factors .The skids must be designed to avoid resonance and vibration (from dynamic machinery forces and couples). The industry is looking for lower cost packages. This can drive suppliers to reduce the skid cost and associated stiffness, but an inappropriately designed skid will create vibration and reliability problems.

Erke Wang *et al* [5] presents some analytical results and some test results for different mechanical problems, which were then simulated using finite element analysis with tetrahedral and hexahedral shaped elements. The comparison was done for linear static problems, modal analysis and nonlinear analysis. According to results, it concluded that quadratic tetrahedron element are good and can always be used over hexahedral elements.

Eberle, et al [6] A growing number of reciprocating compressors are being used on Floating Production Storage and Offloading vessels (FPSO) for many applications. These compressors are significant sources of vibratory forces and can cause high vibrations of the compressors and FPSO module. Based on our experience with over 60 offshore reciprocating Papers, this paper discusses new analysis techniques to calculate the amplitude and location of high vibrations on the module deck and to optimize the topside module design. An example is included that reviews an integrated design approach, combining the topside module structural model with the mechanical model of the compressor packages.

Kishor Jadhav et al [7] **,**Now days, Compressors are widely used in gas gathering, gas processing, and gas storage, chemical and refining applications. Compressors are mounted on the Base frame to carry its weight, to maintain its alignment and to assist in carrying the dynamic loads. Compressors base frame needs an effective design technology to ensure its required performance and functions satisfactorily. This paper represents a case study of the compressor base frame on which high speed reciprocating compressors are mounted. Attemp ts are basically made to standardize base frame for all type of piston compressor.

In multi compressor packs, the compressor rests on brackets which are connected to the main-frame or the skeleton of the chassis. Hence, during its operation, the undesired vibrations generated by the compressor can get directly transmitted to the frame through the brackets. This may cause discomfort to the customer or might even damage the chassis. When the operating frequency or disturbance approaches the natural frequency of a body, the amplitude of Vibrations gets magnified. This phenomenon is called as resonance. If the brackets have their resonance frequencies close to the operating compressor frequencies, then the large amplitude of vibration may cause its fatigue failu re or breakage, thus reducing its estimated or desired life.FEA has been done to check the frequency and loading response of the brackets before finalizing the design. Mass optimization has been carried out to save material and reduce the weight. The modified designed has been re-analyzed using FEA before finalization.

2. LAYOUT OF MULTI-COMPRESSOR PACKS

2.1 Scope of Supply

It is divided into tree types as shown below.

- Standard Offering: Table I gives details of components and their scope. These are rh e basic features offered by compony to customers. These components are necessary to complete required functioning. Multy-Compressor packs mainly contains three compressor, detais of which given in following table.
- Optional Offerings: It contains, Step Capacity Control Kit, Stepless Control with Digital Kit/VFD, Head Cooling Fan, Electronic Oil Level control, Racks with more than 4 compressors available on special request, Condenser Sub Board.

Table -1: List of Components

Component	Scope
High Efficiency Copeland Semi-Hermetic or Scroll Compressor	2 To 4 Compressors , Crankcase Heater.
Adequately Sized Suction Header For Smooth Distribution	Suction Filters, Multiple Suction Stubs fitted with Ball Valves.
Heavy Gauged Discharge Header: Adequately Sized To Avoid Oiltraps	Vibration Eliminators.
Mechanical Oil Management System	Oil Level Regulator & Sight Glass fitted on each Compressor, Oil Reservoir & Oil Separator, Oil Sight Glasses & Filter in Oil Management System
Safety	Oil Pressure Switch (not applicable for Stream compressors), High Pressure /Low Pressure Adjustable Switches.
Liquid Line	Sight Glass, Ball Valve, Liquid Line Filter Drier
Liquid Receiver	Inlet & Outlet Valves for isolation, Sight Glass, Pressure Relief Valve.
Sturdy & Robust Mounting Frame	Lesser Noise & Vibration, Easy access to components, Suction & Discharge Service Valves.

- Adequately sized & ventilated electrical panel: Equipped with circuit breakers & Thermal overload Protection for individual compressors Includes phase failure & voltage protection. Electronic rack controller with display & complete wiring for compressor pack control & management. Electronic controller can be provided with multiple flexible options (alarms, additional i/o relays for safety & control, communication etc)

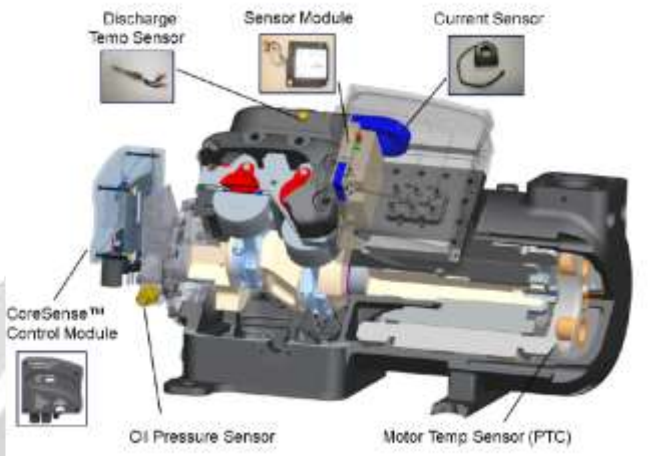

Fig-1: Semi Hermetic Compressor

3. DESIGN OF FRAME

For designining frame, considered dead load conditions are given in table II. This weights of standard offering and optional offerings are taken from compony manual.

Table -2: Weight of Components

Component	Weight (approximate)in Kg
Copeland Semi-Hermetic or Scroll Compressor	185*3 = 555
Adequately Sized Suction Header	25
Heavy Gauged Discharge Header	10
Mechanical Oil Management System	55
Oil Pressure Switches, High /Low Pressure Switches etc	15
Liquid Line	25
Liquid Receiver	90
Control Panel	95
Miscellaneous weight	250

From above table, approximate total weight of all components which are suppose to be mounted on frame is 1140Kg. In addition to this load, we assumed, dynamic load of 200kg is acting on frame. Thus frame which bears load of 1340 kg is supposed to be design. Europian frame model was considered while designing this frame. Here, we can use C section channel of Mild-Steel. From design data book, dimensions of C section channel are finelised for above loading condiations.

3.1 3D Model of Frame

By using NX 6.1of Simense 3D model of base frame is prepaired. Major dimentions of channel and frame are given in Table III and table IV respectively. 3D model shown in Fig.3.

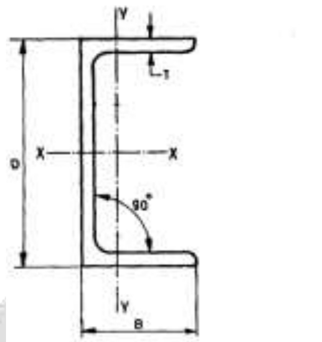

Fig- 2: Cross-section of Channel.

Table -3: Details of c-section

Channel	D	B	T
Channel 1	145	73	6.5
Channel 2	95	47.5	8.5

Table -4: Details of overall Dimension

Length	2700 mm
Width	850 mm
Height	1600 mm

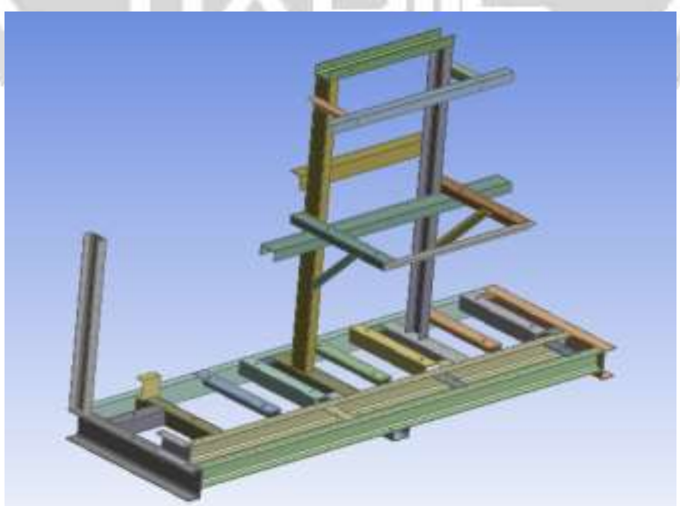

Fig-3: Isometric view of frame

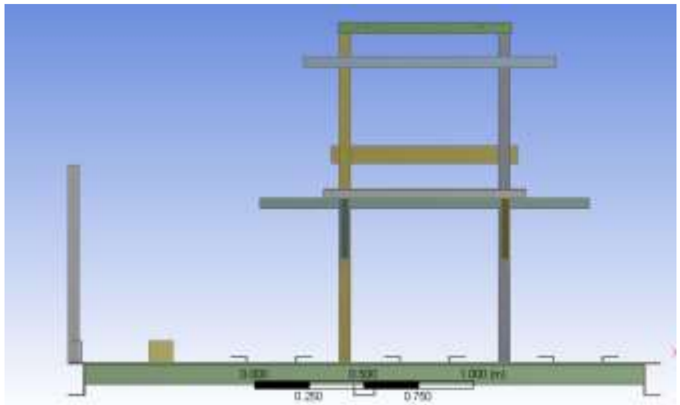

Fig-4: Front view of frame

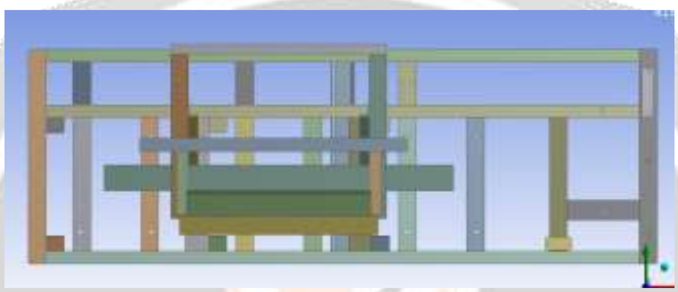

Fig- 5: Top view of frame

4. MODAL ANALYSIS OF FRAME

Modal analysis of frame is carried out in ANSYS Workbench 15. Analysis was required to check the values of natural frequencies and total deformation of frame. Each natural frequency sets up specific deformation pattern, i.e. mode shape. The same phenomenon may take place in a base frame during working condition. To avoid mechanical damage due to Resonance, the structure must checked for 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 compressors. It mainly consists of following steps as discussed below.

4.1 Preprocessing

Initially, material selection is carried out. The material used is structural steel cold-formed welded, structural hollow section. It has following properties as shown in Table V.

Table -5: Material Properties of Frame

Density of Frame	7850 Kg/m^3
Modulus of Elasticity, E	200 GPa
Shear Modulus, G	76.923GPa
Poisson ratio, υ	0.3
Bulk Modulus, K	166.7 GPa

After material selection geometry preparation is carried out in Workbench Design Modular. This is followed by different operations like, mid-surface extraction, Geometry Clean-up, Creation of weld surfaces, rigid support formation, Paperions of body, Formation of rigid structure. This is followed by meshing.

4.2 Meshing

Meshing for structure was done and details of meshing are given in Table VI. Mesh of frame is shown in Fig. 6 and Fig. 7.

Table -6: Details of Meshing

Meshing type	QUAD 4, Tri 3
Nodes	109233
Elements	105338

Fig-6: Complete body mesh

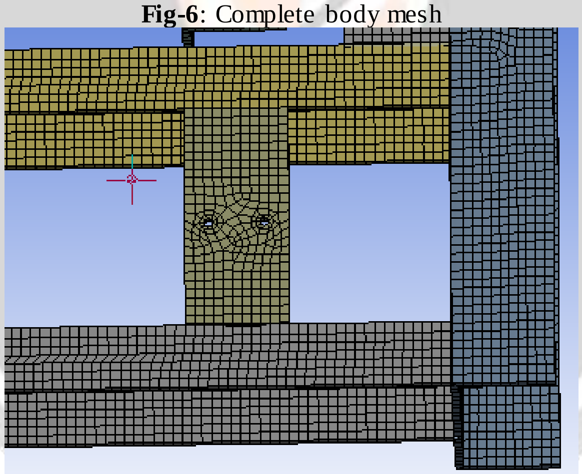

Fig-7: Mesh view

For Modal Analysis, the model should be kept free from all the loads and constrains. Hence, after mixed meshing was done, no constrains were applied.

4.3 Post-Processing

First six mode shapes were illustrated as shown in following Fig.8 to 13. Table VII shows natural frequencies associated with first six modes shapes

Table -7: Details of Meshing

Mode	Frequency (Hz)
1	99.335
2	111.38
3	144.93
4	148.25
5	153.15
6	158.11

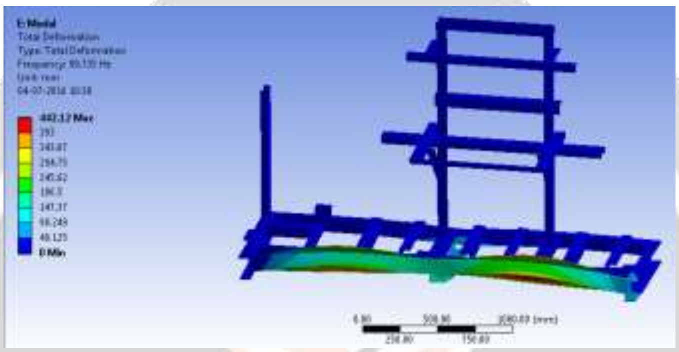

Fig- 8 :1st Mode Shape

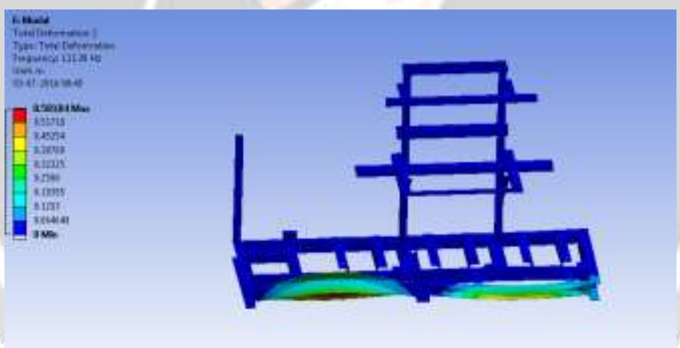

Fig- 9 :2nd Mode Shape

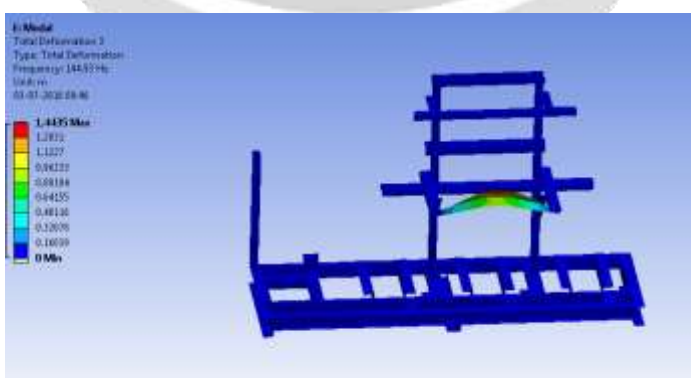

Fig- 10 :3rd Mode Shape

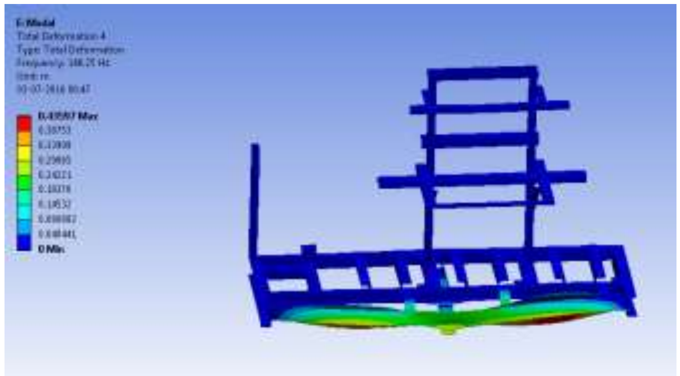

Fig- 11 :4th Mode Shape

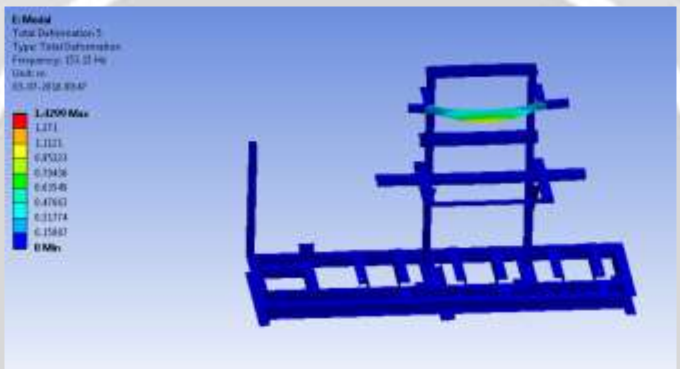

Fig- 12 :5th Mode Shape

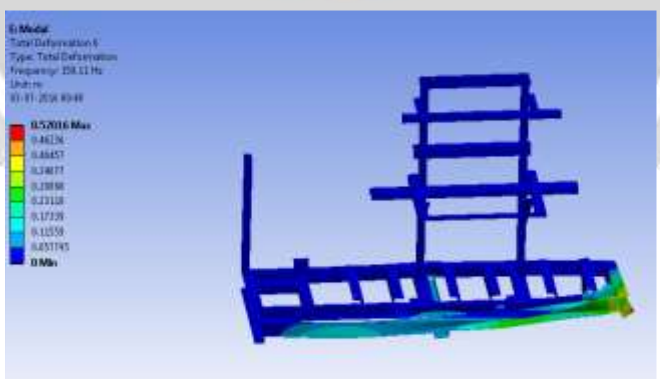

Fig- 13 :6th Mode Shape

For given natural frequency, mode shape defines the way in which the structure would deform. If excitation frequency matches with natural frequency then resonance occurs.

5. STATIC ANALYSIS OF FRAME

Load conditions and properties used for static analysis are shown in Table II and IV. Fig. 13 and fig 14 shows maximum deflection and stress plot respectively. Maximum stress induced in frame is 257.3 MPa and maximum deflection observed is 0.849 mm. These values are in permissible limit.

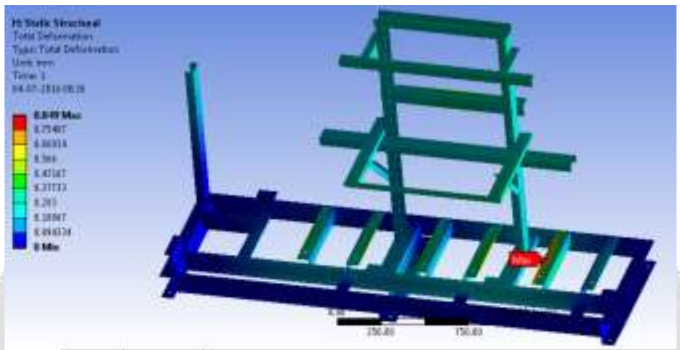

Fig- 14 : Total Deformation

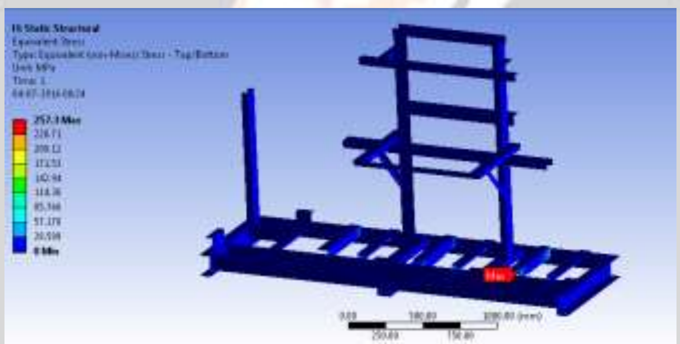

Fig- 15 : Stress Plot.

6 CONCLUSIONS

Main objective of Paper was to discuss about base frame that will sustain in all operating condition. In this study, base frame for Multi- compressor pack is designed and modeled. Two types of C shaped channel were used for manufacturing of frame. Further CAD drawing was prepared in NX 16.1. This model is analyzed in ANSYS workbench 15. Modal analysis is carried out to find natural frequency of frame up to six mode shapes. Its natural frequency varies from 99.335 Hz to 158.11 Hz. From compressor catalogue, compressor rotates at 1450 R.P.M., which implies that its forcing frequency is 24.66 Hz. Hence, Base frame manufactured is robust and sturdy. In static analysis it is observed that maximum stress induced and deformations are within permissible limit. Hence designed frame is safe. Also, stress induced is very less which indicates that, lot of scope is present for optimization.

5. ACKNOWLEDGEMENT

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