Structural Performance Enhancement of Compressor Base Frame (Skid) Utilizing Alumina Saffil

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Abstract— In this study, an attempt was made to enhance the structural performance of compressor base frame (skid) using finite element analysis. A 3d geometry of compressor base frame was modeled in Catia v5 and performed static structural analysis on Ansys 14.0. A comparative analysis with original material of compressor base frame i.e. structural steel and replacement material which is alumina saffil which is a composite material was performed. It was found out by static solution of the analysis that alumina saffil is suitable for manufacturing of compressor base frame since less total deformation for alumina saffil when compared with the conventional material of compressor base frame i.e. structural steel was observed. The values of stresses and strains were found to be optimum as well. The weight was also observed to to reduced applying alumina saffil as replacement material. These all contributed to increase the structural performance of compressor base frame.

Keywords: Compressor Base Frame (Skid), Structural Performance, Finite Element Analysis, Stress-Strain Behavior, Weight Optimization

I. Introduction

Compressors are widely used in industries to transport fluids. It is a mechanical device that compresses a gas. There are many types of compressors, thus a proper selection is needed to fulfill the typical necessity of each industry. Generally, the compression of gases may be accomplished in device with rotating blades or in cylinders with reciprocating pistons. Rotary equipment is used for high volume flow where the discharge pressure is not too high, while the reciprocating compressors are required for high pressures. Besides volumetric flow rate, there are also many parameters to be considered, includes the valid standards to be used.

Most of the larger high speed compressor models are mounted on Base frames. Compressors are mounted on the Base frame to carry its weight, to maintain its alignment and to assist in carrying the dynamic loads which every compressor generates. Compressors base frame needs an effective design technology to ensure that the base frame as designed performs the required functions, and maintains its integrity. There is also a need to maximize the life of the compressor base frame under the loads to which it is exposed. The base frame (skid) is generally made up of the standard beam or channel sections [1]. 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. Different types of sections are used for skid frames [2]. The sections can be of IS standard dimension or custom made. The base frame is subjected to gravitational loading of all the components mounted viz. Compressor, Air Receiver vessel, flow control system etc. Depending on the type of loading, the optimum design is made considering material properties and type of welding. The Skid frame is required to support various components that have been designed by conventional design procedure. The weights of the components mounted on the frame are considered as static loads for designing. Some simplifying assumptions are made at the initial stages in order to decide the cross sections used for various beams. This frame is to be designed for flow control system which is used to control and regulate the flow, pressure, and temperature for fluids. These systems mainly include piping, pumps, valves, and gauges. The flow control application is mainly required for process industries like sugar plants, cement plants, power plants etc. Many times these systems are locally operated & hence their elevation should be designed in such a way that it will reduce the hardship of the operator [3]. Sameer Agrawal, Nitin Sherje& Ashish Umbarkar[1], concluded that the compressor base frame also known, as skid is required to carry its weight and the forces to which it is exposed. The work undertaken is for the compressor base frame (skid). The weight of existing base frame is much higher than the required, which means it is over designed. It was essential to reduce the weight ultimately reducing the cost of it. S.Gholizadeh [2], reviewed about non-destructive testing (NDT) methods for the evaluation of composites. The review considers the capabilities of most common methods in composite NDT applications such as Visual Testing (VT or VI), Ultrasonic Testing (UT), Thermography, Radiographic Testing (RT), Electromagnetic Testing (ET), Acoustic Emission (AE), and Shearography Testing with respect to advantages and disadvantages of these methods. Then, methods categorized based on their intrinsic characteristics and their applications. A. Kanyilmaz, C.A. Castiglioni & H. Degee [3], concluded that concentrically braced frames (CBF) represent a very effective structural form against horizontal loading, providing high lateral resistance at the same time limiting lateral displacements. Global cyclic behavior of these structures is determined by several phenomena acting together such as yielding of tension bracings, buckling and post-buckling of compression bracings, slip of bolts, and frame action provided by semi-rigid joints.

It was observed from the various investigations on compressor base frame (skid), that no investigations was done using alumina saffil as the compressor base frame material. Many studies reported the performance improvement in structural performance using alumina saffil. Hence in this study, an attempt was made to replace the structural streel (conventional material) of skid by alumina saffil (Novel material).

II. Methodology

This section discusses the modeling of geometry, meshing, applying boundary conditions, support and loads working on compressor base frame.

A. Geometry

The geometry was modeled in Catia v5 as shown below in the figure 1. The geometry was modeled same for both the material i.e. structural steel and alumina saffil.

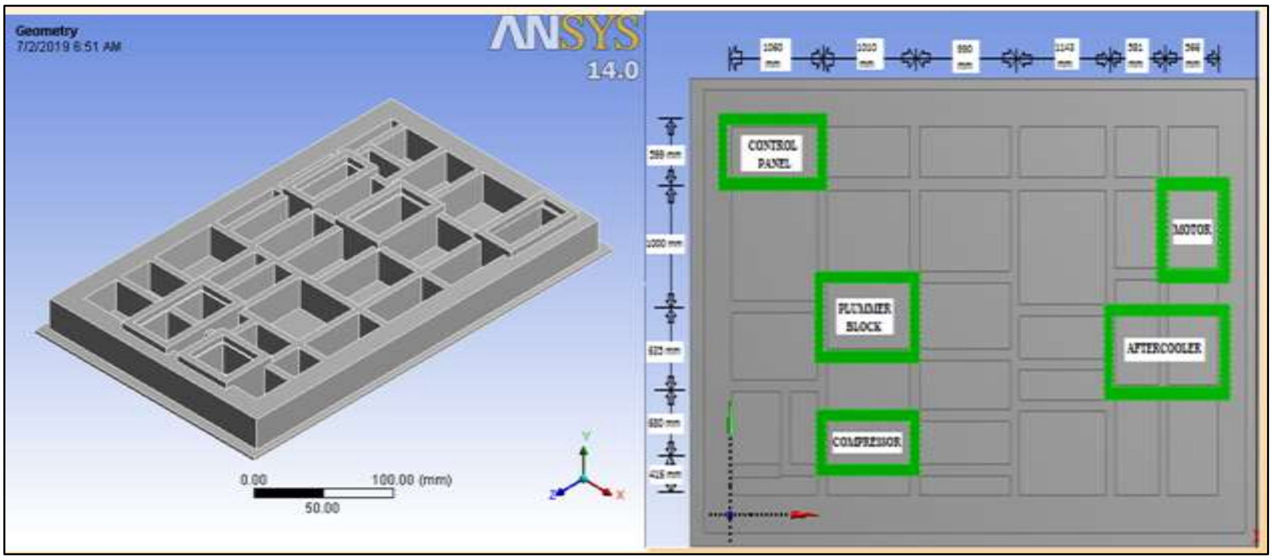

Fig. 1: a) 3D geometry of compressor base frame, b) various components on compressor base frame.

B. Meshing

The meshing was done in Ansys workbench14.0. The meshing was done using tetrahedral type elements. The meshing details are shown in below table 1.

Meshing details	
Elemnt size	1mm
Advanced Size Function	On
Curvature Relevance Center	Medium
Initial Size Feed	Active Assembly
Smoothing	Medium
Transition	Slow
Nodes	22437
Elements	12528

Table 1: Details of meshing parameters.

The below shown Fig. 2 shows the meshing of compressor base frame modeled in Catia v5. The same meshing conditions were adopted for meshing compressor base frame for structural steel and alumina saffil material.

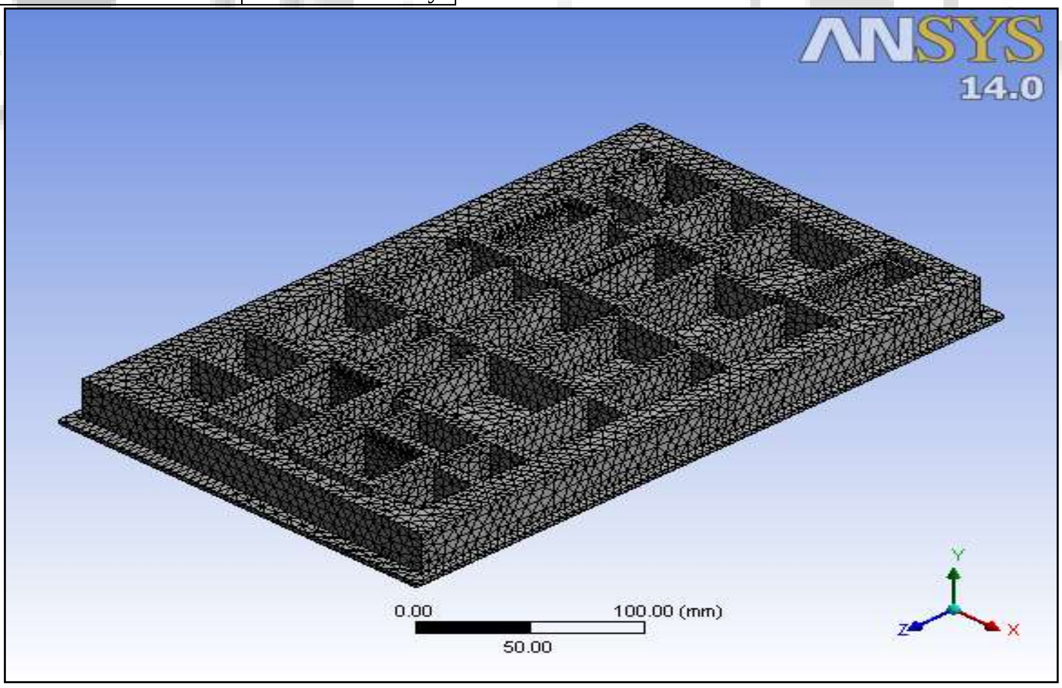

Fig. 2: Meshing of the 3D geometry of compressor base frame.

C. Boundary conditions

The fixed support and various forces were applied on different components of compressor base frame (skid). The details of support and forces are shown in below Fig. 3.

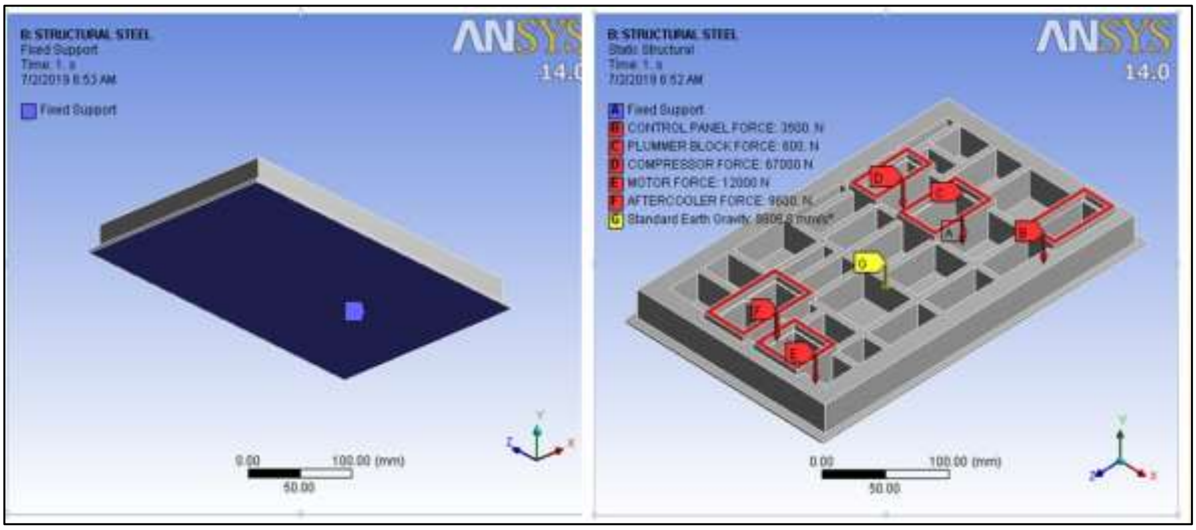

Fig. 3: a) Fixed support at bottom of compressor base frame, b) Forces acting on various components of compressor base frame.

D. Material properties

The study incorporated structural steel and alumina saffil materials for comparative study of mechaniucal strength. The properties of both the materials are given in table 2.

Material Name → Properties↓	Structural steel	Alumina Saffil
Density (kg/ m^3)	7830	3300
Modulus of elasticity (GPa)	210	300
Modulus of rigidity (GPa)	76.923	125
Poisson ratio	0.30	0.20
Bulk modulus(GPa)	166.67	166.67
Yield Tensile strength(MPa)	250	1200
Ultimate tensile strength(MPa)	460	1500
Compressive strength(MPa)	250	14700

Table 2: Details of Material Properties.

III. RESULTS AND DISCUSSIONS

After modeling the geometry, meshing and applying the boundary conditions, the mechanical strength was analysed in Ansys mechanical 14.0 in terms of equivalent von mises stresses, total deformation and equivalent elastic strain.

The results of equivalent von-mises stresses for structural steel and alumina saffil are shown in below Fig. 4.

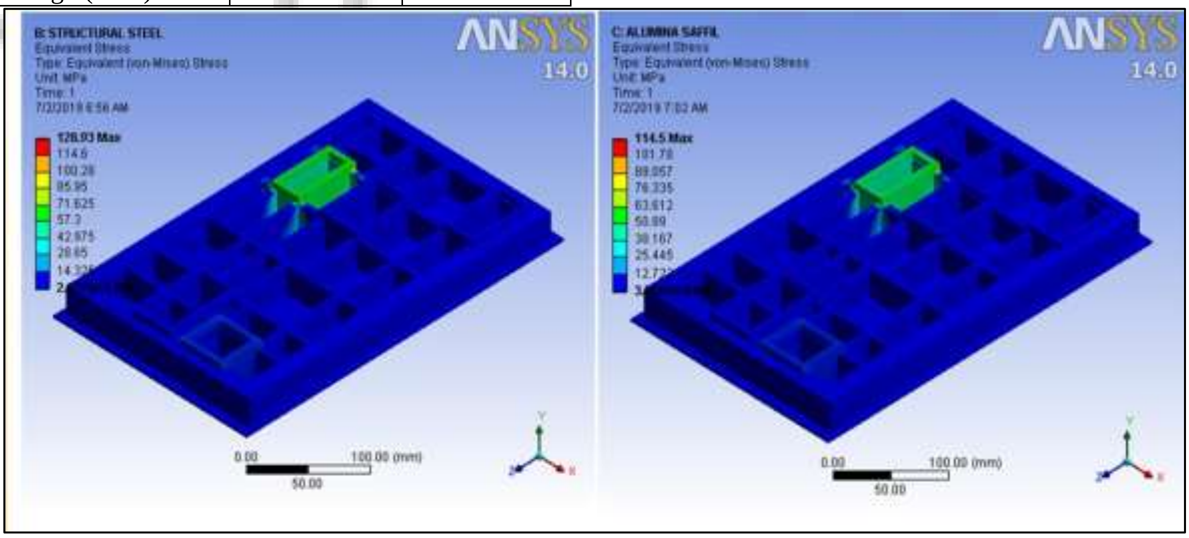

Fig. 4: Results of equivalent von-mises stresses for a) structural steel, b) Alumina saffil.

The results of total deformations for structural steel and alumina saffil are shown in below Fig. 5.

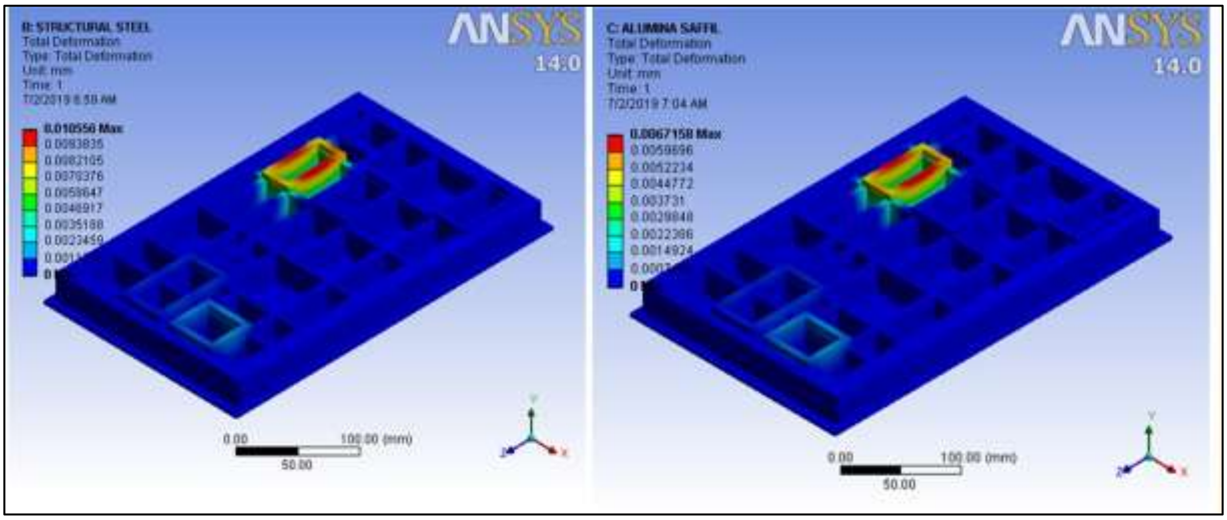

Fig. 5: Results of total deformation for a) structural steel, b) Alumina saffil.

The results of equivalent elastic strain for structural steel and alumina saffil are shown in below Fig. 6.

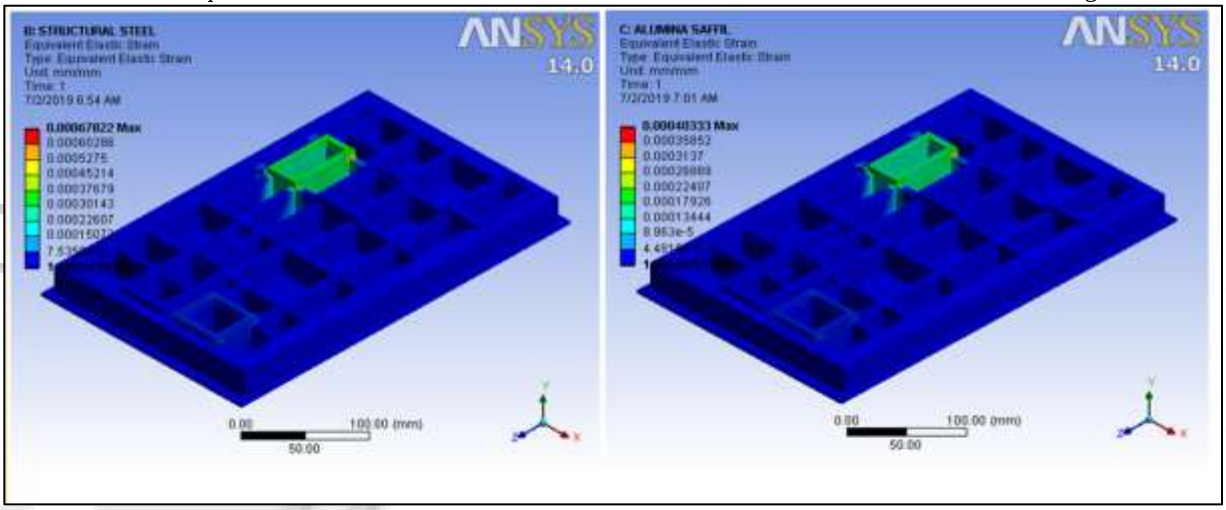

Fig. 6: Results of equivalent elastic strain for a) structural steel, b) Alumina saffil.

All the results of the analysis of compressor base frame 3d geometry with the help of Ansys 14.0 are summarized in the following table 3.

Name of material→ solution↓	Structural Steel	Alumina (Saffil)
Equivalent stress (MPa)	128.93	114.5
Maximum principal stress(MPa)	38.825	27.903
Minimum principal stress(MPa)	3.1757	2.1942
Maximum shear stress(MPa)	70.574	63.301
Normal stress(MPa)	36.515	22.001
Shear elastic strain (mm/mm)	0.00050691	0.0003506
Equivalent elastic strain(mm/mm)	0.00067822	0.00040333
Maximum principal elastic strain(mm/mm)	0.00025328	0.00011347
Maximum shear elastic strain(mm/mm)	0.00091746	0.00050641
Minimum principal elastic strain(mm/mm)	1.3527e-7	9.9534e-7
Normal elastic strain(mm/mm)	0.00023827	0.00010748
Directional deformation(mm)	0.010556	0.00085844
Total deformation(mm)	0.010556	0.0067158
Strain energy (mJ)	0.49522	0.31545
Volume (m^3)	5.4371	5.4371
Mass (kg)	9420.4	3960.2
Weight (KN)	92.414124	38.849562
Price (Rupees/kg)	150	720
Manufacturing cost (Rupees)	1413060	2851344

Table 3: Summary of all the results obtained from the finite element analysis.

IV. Conclusion

The structural performance of compressor base frame was analyzed by a comparative study using conventional material of compressor base frame structural steel and composite material alumina (Saffil). The structural analysis was done using Ansys fluent 14.0. It is concluded that composite material alumina (Saffil) have lower value of total deformation when compared to conventional material of compressor base frame which leads to high structural strength of compressor base frame. It is also concluded that the values of equivalent stresses and equivalent strains are also optimum for alumina (Saffil). The weight is reduced by 57.96 % for new material alumina saffil while the manufacturing cost is increased by 101.78 % for alumina saffil. The long life of alumina saffil compressor base frame will compensate for its high manufacturing cost. So, the enhancement of structural strength of compressor base frame is achieved using alumina Saffil.

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