Recent Investigations on Structural Performance Improvement of Compressor Base Frame (Skid): A Review

Rohit Vishwakarma[1] Gourav Beohar[2]
[1,2]Department of Mechanical Engineering
[1,2]Shri Ram Institute of Technology, Jabalpur (M.P.), India

Abstract— To help maintain its alignment and carry dynamic loads, the compressor is placed on the base frame, namely 'skid'. Compressors base frame requires an effective design technique to ensure that the base frame completes the designed work, and maintains its integrity. In this review article, some recent investigations on structural performance improvement of compressor base frame are thoroughly discussed. After studying various research articles of different authors we have found out these parameters and factors which can be further optimized for improving the structural strength of compressor base frame (skid). Material of construction, optimization methods, stress concentration, geometrical dimensions and mechanical construction, finite element analysis meshing methods, weight reduction and life cycle were found out to be the major factors that influences the performances of compressor base frame (skid).

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].

Fig. 1: Compressor Base Frame (Skid) [1].

II. FACTORS AFFECTING PERFORMANCE OF COMPRESSOR BASE FRAME (SKID):

After studying various investigations on compressor base frame skid, we have concluded that the following factors primarily affect the structural performance.

A. *Material of Construction*

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. Hence, the work is focused on design and analysis of compressor base frame to reduce the weight. The weight of existing skid is 4100 Kg and weight of the assembly mounted on it is 9420 kg. The frame has been modified in four different way like I-beams have been replaced by C-channels, removed the C-channels at some places if not required, reduced the thickness of the plates used to mount the motor etc. The free vibration analysis has been carried out to check the occurrence of the resonance and also determined the natural frequencies experimentally using FFT analyzer to validate the results. Similarly, the stress analysis has been carried out and observed that all the modified frames are safe under the various loads acting on it. The weight upto 19 % would have been reduced. 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. A large amount of research has been conducted for CBF systems in order to maximize their performance in regions exhibiting a very significant seismicity level. Indeed, current code previsions are quite advanced for high-ductility design of CBF structures. However, although these systems are also very popular in low-to-moderate seismic regions, there is not a clear distinction for their detailing requirements between high-seismic and moderate-seismic design. Since the strict application of the high-seismic design principles in regions of low to moderate seismicity leads to solutions with a significant increase of the building costs, designers usually choose "non-dissipative" design, neglecting any detailing provisions that enhance the seismic performance. This approach may lead to unsafe solutions with significant life-safety and economic consequences. This situation gives rise to the need of an optimized design (both in terms of safety and economy), with specific design rules more compatible with the buildings located in areas susceptible to low-to-moderate earthquakes. Ongoing research project MEAKADO (RFSR-CT-2013-00022) aims to develop specific design methodologies for steel and steel-concrete composite structures in regions characterized by a low to moderate seismic activity, with an appropriate reliability level. The present paper presents the preliminary results of the full scale testing program realized in this research project. Tests focus on the contribution of the compression diagonal, assessment of the parts of the horizontal loads that are effectively resisted by the bracing system and the part that is actually taken by the frame, and investigate the inherent ductility provided by "non-dissipative" bracing connections. Thanks to the observations obtained from these tests, possibilities to improve seismic performance of concentrically braced frames built in moderate seismic have been discussed. Y Raju and V Narsinha Rao [4], concluded that in today's industries, material handling system is unitary of the significant system. Skids have a massive impact on logistics, packaging and also on the transportation systems. Skids are used in different industries for different resolutions. But mostly, the purpose of skid is in material storage, material handling of heavy parts and transporting cargoes. Reason for using skid is to ensure safe material handling and storage of the material. If the skid is not properly designed then it will fail to handling and storage. This makes the designer to be more cautious about designing of the skids. A skid is a single-deck loading platform which lacks a bottom deck. Designing is a field of making a part to be sustained in particular condition. In this project, design of skid for fuel tank bracket of a heavy truck is done precisely.So, the skid for fuel tank bracket discussed in this Project was designed with conventional CAD design practices and then analyzed statically with FEA software having gravitational loading of fuel tank brackets. Initially, the design of skid is developed based on the design of fuel tank bracket using NX- CAD software. Two types of skids are developed with same dimensions but with different sections.ie. Solid section and L section skid. The designed skid is later imported into Ansys to perform structural analysis. The analysis was carried out to determine the induced stresses and deflections at various locations on proposed skids. The project also includes the analysis of skid by comparing different materials. Based on the results the best skid is proposed and finally the fabrication drawing of the skid is created and documented in the report. Ying Zhao, et. al. [5], concluded thatThe low-order vibration modes of a reciprocating compressor were studied by means of numerical simulation and experimental validation. A shell element model, a beam element model, and two solid element models were established to investigate the effects of bolted joints and element types on low-order vibration modes of the compressor. Three typical cases were compared to check the effect of locations of moving parts on the vibration modes of the compressor. A forced modal test with the MRIT (Multiple References Impact Test) technique was conducted to validate the simulation results. Among four numerical models, the solid element model with the bolt-pretension method showed the best accuracy compared with experimental data but the worst computational efficiency. The shell element model is recommended to predict the low-order vibration modes of the compressor with regard to effectiveness and usefulness. The sparsely distributed bolted joints with a small bonded region on the contact surface were key bolted joints that had greater impacts on the low-order vibration modes of the compressor than the densely distributed bolted joints. The positions of the moving parts had little effect on the low-order vibration modes of the compressor.

B. Optimization Methods

Vivek Dhand ,et. al.[6], concluded that a recent increase in the use of ecofriendly, natural fibers as reinforcement for the fabrication of lightweight, low cost polymer composites can be seen globally. One such material of interest currently being extensively used is basalt fiber, which is cost-effective and offers exceptional properties over glass fibers. The prominent advantages of these composites include high specific mechano-physico-chemical properties, biodegradability, and non-abrasive qualities to name a few. This article presents a short review on basalt fibers used as a reinforcement material for composites and discusses them as an alternative to the use of glass fibers. K. K. Saxena, R. Das & E. P. Calius [7], concluded thatauxetic materials possess an interesting property of negative Poisson's ratio. By virtue of this negative Poisson's ratio, several other mechanical properties can be enhanced. This review presents briefl y the current state of the art and progress in the auxetics research made in the past three decades. The review attractively covers most of the aspects of auxetic materials such as classifi cation, structure, properties, applications, design, and modeling. Arie Borenstein,et. al. [8], concluded that Electrochemical capacitors, so-called supercapacitors, play an important role in energy storage and conversion systems. In the last decade, with the increasing volume of scientific activity and publications in this field, researchers have developed better tools to improve electrode materials. Although carbonaceous materials seem the most suitable for supercapacitor applications, a large diversity of materials has been proposed and studied. Yet, in order to accomplish performance beyond the limitations of each material, mainly in terms of energy density and durability, composite materials have been implemented, most of them being the combinations of carbon-based materials and other components. In this review, we present the recent advances in the field of composite materials that include at least one carbon-based component for supercapacitor electrodes. James J. Kingman, Konstantinos Daniel Tsavdaridis and Vassili V. Toropov[9], introduced applications of structural topology optimisation to buildings and civil engineering structures. Topology optimisation problems utilize the firmest mathematical basis, to account for improved weight-to-stiffness ratio and perceived aesthetic appeal of specific structural forms, enabling the solid isotropic material with penalization (SIMP) technique. Structural topology optimisation is a technique for finding the boundary conditions. Aerospace and automotive engineers routinely employ topology optimisation and have reported significant structural performance gains as a result. Recently designers of buildings and structures have also started investigating the use of topology optimisation, for the design of efficient and aesthetically pleasing developments.. Hector Delgado-Garibay, et. al. [10], concluded that common testing practices at the factory vary depending on the type of the compressor. This chapter is focused on providing general and practical considerations related to compressor performance and dynamic testing at the factory or actual site. Other types of tests such as hydrostatic and gas leakage, overspeed, sound level, etc., may also be agreed to be carried out by compressor original equipment manufacturers (OEMs), but details are not covered in this chapter. N. Domun, et. al. [11] The incorporated nanomaterials in the polymer matrix is considered to be a highly effective technique to improve the mechanical properties of resins. In this paper the effects of the addition of different nanoparticles such as single-walled CNT (SWCNT), double-walled CNT (DWCNT), multi-walled CNT (MWCNT), graphene, nanoclay and nanosilica on fracture toughness, strength and stiffness of the epoxy matrix have been reviewed. The Young's modulus (E), ultimate tensile strength (UTS), mode I (GIC) and mode II (GIIC) fracture toughness of the various nanocomposites at different nanoparticle loadings are compared. The review shows that, depending on the type of nanoparticles, the integration of the nanoparticles has a substantial effect on mode I and mode II fracture toughness, strength and stiffness.

C. Stress Concentration

Kishan Anand &AnadiMisra[12], analyzed thatthe optimization technique for structural topology can be done by two methods, analytically and by using numerical technique. These days, FEA software packages are used for various analysis of designs which are purely based on numerical methods. In this paper ANSYS is used for structural analysis and topological optimization of a simple column fixed at bottom edge and central point load applied on upper edge, two point and three points supported pressurized short beams. This paper presents compliance, optimized shape, deformed and undeformedshape, displacements and stresses of the linearly elastic isotropic structures by using ANSYS software based on optimality criterion. V Kacani[13], presented the influence of modelling on the mechanical natural frequencies, the effect of inertia loads on the structure vibration, the impact of the crank gear damping on speed fluctuation to ensure a safe operation and increasing the reliability of reciprocating compressors. In this paper it is shown, that conventional way of modelling is not sufficient. For best results it is required to include the whole system (bare block, frame, coupling, main driver, vessels, pipe work, etc.) in the model (see results in Table 1). Sunpreet Singha, Seeram Ramakrishna & Rupinder Singh[14], concluded that additive manufacturing (AM) is a well known technology for making real three dimensional object, with metal or ceramic or plastic or thereby combination, which may be subjected to various applications. Additive bio-manufacturing (ABM) techniques are highly in demand and researches have been going on for making these safer and more versatile. For more utilization and versatility, special attention is required to develop new materials which can help in increasing the service life, bioactivity, cell growth along with the desired mechanical properties.. Marina Cerpinska, Martins Irbe&RihardsElmanis-Helmanis[15], concluded that vibration of the foundations for rotary screw compressors used for gas compression for thermo power plant installed on skid mounting. To evaluate the compressor vibration according to the industry standard VDI 3836, the user should decide whether the foundation is rigid or resilient. The foundation is rigid, if the vertical natural frequency of the foundation is at least 25 % higher than the excitation frequency. The excitation frequency, compressor running speed in Hz is normally known, while the natural frequency is usually not known. S. Budhea, et. al. [16], analyzed that continuing interest and more developments in recent years indicated that it would be useful to update Banea and da Silva paper entitled “Adhesively bonded joints in composite materials: an overview”. This paper presents an updated review of adhesively bonded joints in composite materials, which covers articles published from 2009 to 2016. The main parameters that affect the performance of bonded joints such as surface treatment, joint configuration, geometric and material parameters, failure mode etc. are discussed.

D. Geometrical Dimensions and Mechanical Construction

Sarah Simons, et. al. [17], concluded that compressor systems must be designed and evaluated according to industry standards for safety and reliability reasons. This chapter will cover various compressor arrangements and station layouts as well as a detailed description of different analyses that can be performed to sufficiently design and evaluate problems in the station piping. In the following description of each analysis will be a reference to each relevant standard or guideline that provides the parameters that determine the acceptability of the design for operation. Sameer Agrawal, Nitin Sherje& Ashish Umbarkar[18], 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. Hence, the work is focused on design and analysis of compressor base frame to reduce the weight. The weight of existing skid is 4100 Kg and weight of the assembly mounted on it is 9420 kg. Gordon Hart [19], studied that combination skid for Supporting a plurality of skid-Supported loads comprises a base having a longitudinal axis and a plurality of docking stations, each to receive a skid-Supported load along a loading directional axis. The loading directional axis of the plurality of docking stations is oriented substantially perpendicular to the longitudinal axis of the base. In a system aspect, a system for supporting one or more loads is provided. The system comprises a base having a longitudinal axis, at least one skid for Supporting the one or more loads and at least one docking station to receive the at least one skid along a loading directional axis. The each of the loading directional axis is oriented Substantially perpendicu lar to the longitudinal axis of the base. James B. Edwards [20], described a system and method for maintenance and inspection of a rotor and exhaust assembly that includes a maintenance skid. The maintenance skid includes an exhaust portion that holds an exhaust and a rotor portion that holds a rotor. A pair of movable stands are part of the exhaust portion, where the movable stands move along tracks. At least two stands are part of the rotor portion, where the stands include rollers that allow the rotor to be turned. Additional features of the present invention will become apparent from the following description and appended claims, taken in conjunction with the accompanying drawings. Jess Daniel Wilson, [21], described a skid structure for a power train includes a pair of longitudinally extending members disposed about a central axis and in a mutually spaced apart relationship with one another. Each of the members includes a top wall; a bottom wall disposed in a spaced apart relation with the top wall; and a side wall connected at corresponding edges of the top and bottom walls to define a pocket there between. Curtis Roys [22], concluded an object of the invention is to provide protection against excessive pressure in a high pressure, low volume fluid distribution system. The current invention provides a pressure relief system that allows fluid in a system using a positive displacement pump to flow to a safe location if the pressure in the system exceeds predetermined value. In preferred applications, when a lubrication system is over pressurized, the lubricated equipment is shut down, directly or indirectly, by a protection device and cannot be restarted until the problem is corrected.

E. Finite Element Analysis Meshing Methods

Alessandro Del Bono [23] studied a base plate comprised a central elongate torsion and bending resisting member and at least a first load bearing cross - member, which extends transversely to the elongate torsion and bending resisting member. At least one machinery support platform is rigidly connected to the elongate torsion and bending resisting member and to the first load bearing cross - member. The elongate torsion and bending resisting member comprises vertically extending longitudinal lateral walls, where along auxiliaries of the rotating machinery are supported. The machinery support platform projects sideways beyond the longitudinal lateral walls of the elongate torsion and bending resisting member. Pascal Lardy, et. al. [24], concluded that Apparatus and a method for supporting one or more turbomachines , with the apparatus including a first package module including a first frame and a fluid – handling machinery mount coupled to the first frame , the fluid handling machinery mount being configured to support one or more fluid - handling machines. The apparatus also includes a second package module including a second frame and a heat exchanger mount coupled to the second frame, the heat exchanger mount being configured to support one or more process fluid coolers, and the second package module being coupled to the first package module. The apparatus further includes an access passage extending between the first and second modules and configured to enable personnel to proceed there through. OshimichiTaketomi&Masafumi Hara[25], studied an electric motor support structure includes: a base that has a cantilever Support unit and a mount unit the cantilever Support unit Supporting an electric motor main unit with a first end part thereof in an axial direction being fixed and a second end part thereof being free, and the mount unit having a Support Surface that supports the second end part of the electric motor main unit and a support member that restricts relative movement between the electric motor main unit and the mount unit in an orthogonal direction parallel to the Support Surface and also orthogonal to the axial direction and makes possible a relative movement between the electric motor main unit and the mount unit in a direction vertical to the support surface. With this electric motor Support structure , it is possible to suppress vibration of the electric motor without applying an undue force to the cantilever support unit.

F. Weight Reduction and Life Cycle

Domenico Zaffino, et. al. [26], concluded that a mounting system for supporting rotating machinery is described. The system comprises a base frame having an upper side for mounting the rotating machinery, and a lower side. A set of main supporting members are arranged according to a triangular arrangement and forming a three – point mounting arrangement defining a mounting plane. Moreover , a set of auxiliary supporting members , having a variable stiffness in at least one direction , are provided and are configured and arranged such as to increase the stiffness thereof when the base frame is subject to an overload , thus reducing load on the main supporting members . Y Zhao, et. al. [27], concluded that reciprocating compressor packages are key equipment for the offshore platforms which are used for the pressurization and transportation of natural gas. Dynamic analyses of high-speed and flexible supported offshore compressor packages are more complex than that of compressors on land. The dynamic analysis techniques of the offshore reciprocating compressor package were studied including numerical modelling, excitation forces calculation, support boundary determination of the compressor package and load transmission between the compressor package and the offshore platform.

III. CONCLUSION

In this review article, we have studied various recent investigations done for improving the structural performances of compressor base frame (Skid). We have concluded that the structural performances of compressor base frmame couold be enhanced using different composite materials. Further, the topology optimization of compressor base frame could be done for reducing its weight. Moreover, it is observed that material of construction, optimization methods, stress concentration geometrical dimensions and mechanical construction, finite element analysis meshing methods, weight reduction and life cycle plays a crucial role in improvement of its performances. These factors could be optimized for further improvement in performances of compressor base frame (skid).

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