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Finite Element Analysis of Skid (Base Frame) for Screw Compressor

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Abstract: A base frame, commonly referred to as a skid frame, is a rigid structural platform designed to support machinery and its associated components by providing a uniform mounting surface. These frames are typically composed of structural members with varying cross-sections and are essential in applications where stability, alignment, and structural integrity are critical. In the context of screw compressors especially those enclosed within a canopy for noise reduction, safety, and transportation base frames play a crucial role in maintaining operational efficiency and equipment longevity.

This paper presents the design and validation of a base frame tailored for a screw compressor operating under known power and load conditions. A three-dimensional CAD model was created using Autodesk Inventor 2023, followed by finite element analysis (FEA) in ANSYS to ensure structural safety. Additionally, an optimization study was carried out using a nature-inspired Artificial Intelligence (AI) algorithm implemented in MATLAB to minimize the weight of the frame without compromising performance. The core objective of this work is to design a base frame with structurally efficient members optimized according to the load distribution on each component.

Keywords: Screw Compressor Skid, Finite Element Analysis (FEA), Weight Optimization, Nature-Inspired Algorithm, MATLAB Simulation, Structural Validation, Cohort Intelligence, Sheet Metal Design

I. INTRODUCTION

In electric screw compressors, the base frame plays a vital role in supporting and bearing the load of key components such as the drive assembly (including the motor, air end, adaptor, and coupling), cooling system, separation system (air-oil separator tank and piping), canopy, and electrical enclosures. It ensures proper alignment of all subsystems and sustains both static and dynamic loads generated during operation. To maintain the performance and durability of the compressor system, the base frame must be designed with structural integrity and robustness. Its design should also accommodate long-term operational stresses to maximize the service life of the compressor. Functionally, the base frame can be likened to a shock absorber, helping to dampen vibrations induced by rotating components like the motor, air end, and separator tank during active operation. The screw compressor package is mounted on a robust base frame that accommodates all major subsystems, as shown in Fig. 1.

Fig. 1 Screw compressor Package

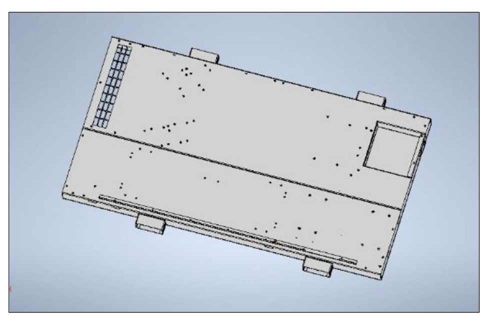


Fig. 2 Base Frame used for the previous model

This study focuses on the design and optimization of a base frame intended for an oil-injected electric screw compressor. The compressor model in question has a rated power of 315 kW and a total system weight of approximately 6.5 tons. Designing a base frame for such a heavy-duty machine requires careful consideration of multiple design factors to ensure optimal performance under all operational conditions. Key characteristics of an effective base frame include a compact and portable layout, ease of access for maintenance, minimal spatial footprint, controlled assembly procedures, provision for process connections, and compatibility with factory acceptance testing protocols. The base frame of the previous model provided the fundamental support for integrating compressor components, as shown in Fig. 2.

A. *Functional Requirements of the Base Frame*

The functional requirements of the base frame are categorized into three levels based on their role in structural integrity, operational efficiency, and serviceability:

1) *Primary Functions*
- Provide rigid support and sustain the load of all critical components—including the drive system, air-oil separator tank, coolers, electrical cubicle, and canopy—while ensuring operational safety and structural reliability.
- Effectively absorb and dampen vibrations generated during compressor operation.

2) *Secondary Functions*
- Facilitate easy alignment and accessibility for servicing and component fitment.
- Enable safe and efficient mobility of the assembly throughout its lifecycle without disturbing the overall setup.
- Support handling, transportation, and lifting without causing structural damage.

3) *Tertiary Functions*
- Establish a stable foundation with a level mounting surface in contact with the ground.
- Offer surface protection against rust and environmental degradation to ensure long-term durability.
- Provide adequate support for routing and securing piping and accessory components.

B. *Material and Design Selection*

Traditionally, base frames are fabricated using standard structural members such as C-channels or I-beams, in accordance with Indian Standards (IS 808). These components are known for providing excellent structural rigidity at a reasonable cost. However, a significant drawback of these profiles is their high weight due to the dense material and standard cross-sectional geometry, which results in elevated weight-to-length ratios.

To address this limitation, the present design adopts an alternative approach using sheet metal—specifically, Cold Rolled Carbon Steel (CRCS) and Hot Rolled Carbon Steel (HRCS)—which is formed into C-channel-like structures. These sheets are readily available in the market in a wide range of dimensions and thicknesses. For this study, the maximum sheet size considered is 6 meters by 2 meters, with a maximum thickness of 6 mm. This constraint is based on manufacturing capabilities such as laser cutting and marking limitations at the supplier end.

The use of bent sheet metal not only reduces the overall weight of the frame but also allows for greater flexibility in design and orientation. CRCS sheets conform to IS 513 in terms of material composition and manufacturing specifications. According to Indian standards, sheets with thicknesses of 4 mm and above are categorized as HRCS, governed by IS 1079. These materials are typically processed using compressive forming techniques such as rolling and metal extrusion, making them suitable for custom fabrication while maintaining mechanical strength. Sheetmetal sections are bent into different shapes suitable for structural applications as shown in Fig 3 and 4.

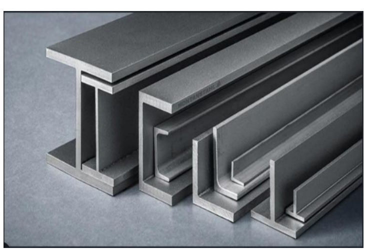


Fig. 3

Fig. 4

In many practical engineering applications, structural designs are often derived from legacy data or empirical reference values rather than detailed analytical calculations. This practice can lead to over-designed components, which unnecessarily increase the weight and cost of the final product. To address this inefficiency, a computational approach leveraging Artificial Intelligence (AI) techniques has been adopted in this study to optimize the weight of the base frame. The goal is to achieve an optimum or reduced-weight configuration without compromising the structural integrity and functionality of the compressor system.

The proposed optimization strategy utilizes numerical algorithms executed in MATLAB, which evaluate each structural member of the base frame based on the load it experiences. This method enables precise dimensional tuning of individual components to achieve a lighter, more cost-effective design. Similar approaches have been extensively applied in the domain of civil engineering, where optimization of steel frames focuses on minimizing structural weight while maintaining required strength and deflection criteria.

Several nature-inspired algorithms—such as Genetic Algorithms (GA), Particle Swarm Optimization (PSO), and Ant Colony Optimization (ACO)—have been previously explored for structural weight reduction. In this study, the Cohort Intelligence (CI) algorithm is employed, which draws inspiration from the natural and social learning behavior of individuals within a group. This AI-based technique enables iterative learning and decision-making, allowing structural parameters to converge toward an optimal solution based on defined performance objectives.

C. Literature Review

Some of the literature studied for this research by different researchers are mentioned below.

Sr. No	Author (Year)	Study/Method/Approach	Remarks
1.	Abhay. C. Suke, B. P. Londhe (2015)	One study focused on the structural behavior of a base frame used in a centrifugal compressor by applying both Finite Element Analysis (FEA) and experimental testing under static loading conditions. The comparison between simulation and physical test results showed strong agreement, indicating that the 3D FEA model accurately represents the real-world performance of the base frame. Initially, the design featured H-channels for interconnections, which were later replaced with two C-channels after analysis. This modification resulted in a lighter structure without compromising structural safety.	A comparative analysis of two base frame models revealed a weight reduction of approximately 400 kg in the optimized design. This decrease in material mass directly translated to substantial cost savings, demonstrating the economic benefits of structural optimization in compressor base frames. The study highlights how even minor design modifications, when guided by analytical validation, can significantly enhance both performance and cost-efficiency.
2.	S. P. Mali, S. S. Sarawade, S. P. Gadewar (2018)	A study on a compressor package skid frame evaluated the structural behavior under three distinct loading scenarios. The analysis focused on key parameters such as nodal displacement and stress distribution across the frame. The results showed that the von Mises stresses and resulting deformations in all load conditions remained within the allowable limits, thereby confirming the structural safety and robustness of the skid frame under both static and dynamic loads.	These findings confirm that the modeled compressor package skid frame maintains structural integrity and operates safely under both static and dynamic loading conditions.
3.	Sameer Agrawala, Nitin Sherje, Ashish Umbarkar (2019)	The natural frequencies of a base frame were evaluated using Finite Element Analysis (FEA) and validated against experimental data obtained through Frequency Time Testing (FTT). The finite element model showed a high level of correlation with the experimental results, confirming the accuracy of the modal analysis. The study also employed analytical techniques to reinforce the findings and assessed the dynamic response of the frame under different boundary conditions, demonstrating the reliability of the simulation approach for vibrational behavior prediction.	In each loading scenario, the maximum von Mises stress was found to be within the permissible limit, indicating that both the original and modified base frame designs were structurally safe. Furthermore, the deviation between the finite element and experimental results was observed to be less than 9%, underscoring the accuracy and reliability of the simulation approach.

4.	Prajakta P. Kachare, Aditya R. Wankhede, Vishal C. Momale (2019)	This study presents a fundamental structural analysis of a compressor base frame, incorporating both static structural and modal analysis. The modal analysis specifically determined the natural frequencies corresponding to the first six vibration modes of the base frame, providing insights into its dynamic characteristics and potential resonance behavior.	The study found that the excitation frequency of the system was significantly higher than the identified natural frequencies, thereby eliminating the possibility of resonance. Additionally, the static analysis confirmed that the base frame operated safely under applied loads, validating its structural adequacy in static conditions.
5.	J. Willie, W. Asal, R. Sachs, (2017)	This research investigates torsional vibrations in oil-free screw compressors designed for continuous year-round operation on mobile platforms such as trucks. The study develops detailed free and forced torsional vibration models, which are validated through experimental measurements. The Holzer method is employed to evaluate both system configurations, taking into account torsional characteristics. Sensitivity analyses are conducted on inertia and stiffness parameters to assess their impact, ultimately identifying the weakest link within the compressor's drivetrain.	The results indicate that the nature and magnitude of excitation significantly influence the system's dynamic response. It was observed that torsional effects—rather than structural deformations—were primarily responsible for the increased peak torque in the drivetrain. Furthermore, the relative angular deflection within the system was found to be largely governed by the inertia of the male and female rotors, emphasizing the importance of rotor mass properties in torsional behavior analysis.
6.	Marina Cerpinska, Martins Irbe, Rihards Elmanis-Helmanis (2020)	This study focuses on the vibrational behavior of rotary screw compressor foundations used in gas compression applications at thermal power plants, specifically those mounted on skid structures. A key aspect of the investigation involves evaluating whether the foundation behaves as rigid or flexible, in accordance with industry-standard vibration assessment criteria. To this end, the natural frequencies of the skid were determined using a combination of analytical calculations, computational modeling, and empirical "bump testing" conducted under real-world operating conditions.	The findings reveal that, in screw compressors, axial vibrations tend to be more pronounced than radial vibrations. Additionally, the study concludes that on-site bump testing is relatively ineffective for accurately identifying the natural frequencies of compressor foundation structures, suggesting the need for more reliable analytical or simulation-based methods in such evaluations.
7.	Mohammad Farshchin, Mohsen Maniat, Charles V. Camp, Shahram Pezeshk (2018)	This study applies the School-Based Optimization (SBO) technique to the structural design of steel frames with the objective of minimizing total frame weight while adhering to the Load Resistance Factor Design (LRFD) criteria established by the American Institute of Steel Construction (AISC). The SBO method is evaluated against other well-established optimization algorithms to assess its effectiveness in	The results demonstrate that SBO significantly improves computational efficiency in handling discrete variable structural optimization problems. Moreover, it outperforms several conventional methods by generating lighter and structurally

		meeting strength and displacement requirements. Comparative analysis reveals SBO's potential as a viable and efficient tool for discrete structural optimization problems.	sound frame designs, reinforcing its suitability for complex engineering applications.
8.	T. Balogh & L.G. Vigh (2018)	This study presents the development of a numerical optimization algorithm aimed at improving the structural design of typical steel buildings subjected to seismic loading. The algorithm, based on genetic optimization techniques, is rigorously validated for stability and convergence. Additionally, a detailed parametric investigation is conducted to test and calibrate various control parameters of the algorithm, ensuring its robustness and reliability in earthquake-prone structural applications.	The study concludes that the evolutionary algorithm is capable of optimizing not only the bracing configuration but also the overall structural layout. Furthermore, the use of a multi-population (competitive) approach enhances the algorithm's effectiveness in addressing both topology and layout optimization challenges in seismic design scenarios.
9.	Soumya Meti, Mamta Mogali (2022)	This study focuses on the analysis of two-dimensional structural components using MATLAB software. Addressing a gap identified in previous literature—where research has predominantly emphasized space (3D) structures—the authors develop customized MATLAB scripts to analyze three different 2D frame configurations. The implementation offers a simplified and efficient approach for evaluating the structural performance of planar elements.	The use of MATLAB significantly streamlines the computational process, making the analysis of frame structures more efficient and less labor-intensive. The developed program achieves an accuracy level of approximately 95% when compared to conventional methods. Additionally, it offers flexibility by allowing individual or combined analysis of multiple structural components, producing a unified output for effective evaluation.
10.	Osman Shallan1, Hassan M. Maaly2, and Osman Hamdy (2020)	This study investigates the optimization of flat steel frames incorporating semi-rigid beam-to-column connections using both Biogeography-Based Optimization (BBO) and Genetic Algorithm (GA) techniques. The nonlinear structural model accounts for multiple types of base connections—fixed, semi-rigid, and hinged—while capturing all relevant deformations within connection components to accurately compute relative spring rotation and base rotational stiffness. The analysis also integrates geometric nonlinearity and the P-Δ effect to enhance the realism and accuracy of the optimization process.	The findings clearly indicate that the Genetic Algorithm consistently outperforms the Biogeography-Based Optimization method across all analyzed frame configurations and boundary condition scenarios, demonstrating superior efficiency and accuracy in optimizing nonlinear structural systems.
11.	P. A. Salunkhe, Gayatr Kulkarni, Manish Begad (2016)	The primary objective of this research is to optimize the existing base frame design of an electric screw compressor. The initial frame configuration undergoes iterative structural revisions to arrive at a finalized arrangement that satisfies mechanical and operational requirements. A detailed 3D CAD model	The results of the static structural analysis indicate that both the maximum induced stress and overall deformation remain well within the permissible design limits, confirming the structural

		is developed, and both static and modal analyses are conducted using ANSYS Workbench 16 to evaluate the frame's structural performance. The overarching goal is to ensure that the base frame remains stable and robust across the entire frequency spectrum relevant to the compressor's operating conditions.	safety of the frame. Moreover, the relatively low stress levels observed suggest potential opportunities for further material optimization and weight reduction without compromising structural integrity.
12.	Amit V. Chavan, S.S Gawade (2011)	Rigidity tests involving real-world measurements under various loading conditions were conducted to evaluate the stiffness of a standard base frame design. These tests aimed to verify compliance with the stiffness criteria specified in API 610. The results indicated that the existing design fell short of the required stiffness benchmarks. Consequently, several potential design modifications were proposed to improve structural rigidity. These revised configurations were subsequently modeled and analyzed using Finite Element Analysis (FEA) techniques to assess their effectiveness in meeting the qualification standards.	The modified base frame design is identified as the most effective configuration that meets the stiffness requirements outlined in API 610. The addition of structural ribs—particularly larger slant ribs—significantly contributes to enhanced stiffness. However, these enhancements also introduce spatial constraints that must be considered during integration. From a structural safety perspective, the von Mises stress levels in the modified design are well below the material's yield strength, confirming that the frame remains safe under operating conditions.

D. Summary

The reviewed literature presents a wide range of methodologies for the design, analysis, and optimization of steel and skid-based structural systems. A common approach across studies involves the use of standard structural members for base frame construction, with performance validation conducted via static and dynamic analysis techniques. Optimization of such structures is frequently achieved through the application of nature-inspired algorithms, leveraging artificial intelligence to refine design parameters for improved efficiency. These algorithms—ranging from genetic algorithms to cohort intelligence—enable lightweight, cost-effective solutions without compromising structural integrity. The comparison between conventional design practices and algorithm-based optimization reveals a high degree of accuracy and consistency in results, reinforcing the value of intelligent computational techniques in modern structural engineering.

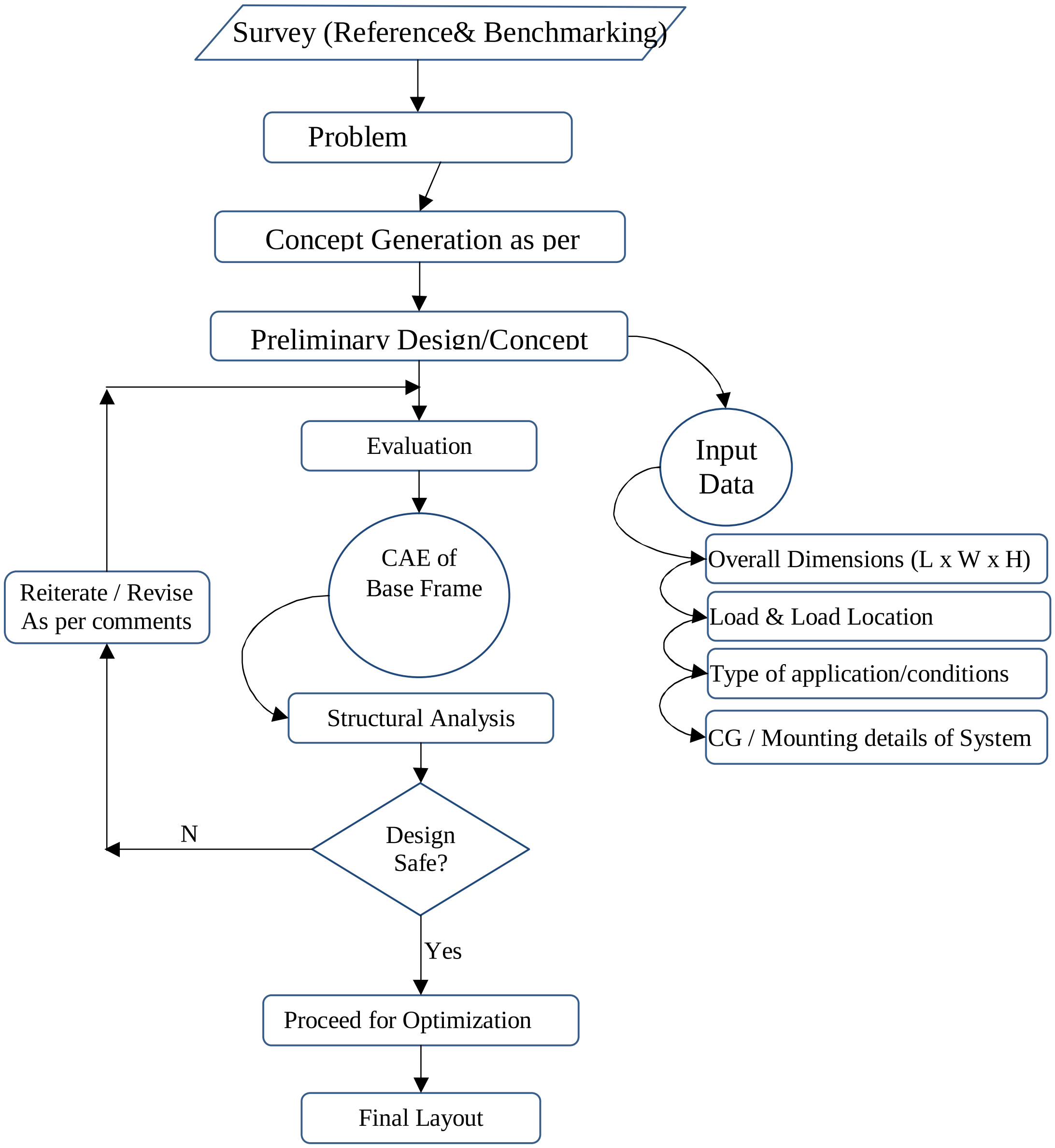
E. Gap Identification

Most base frame designs rely on standard structural members such as channels and I-beams, which, while offering strength and availability, contribute significantly to the overall weight due to their fixed geometry and high weight-per-meter ratio. This results in overdesigned and heavier frames that may not be optimal in terms of material usage and cost. To address this issue, there is an opportunity to explore alternative materials—such as formed sheet metal sections—that offer comparable strength while enhancing design flexibility and manufacturability.

Furthermore, while previous studies have employed optimization techniques such as Genetic Algorithms, Ant Colony Optimization, and School-Based Optimization, there remains a gap in the application of less explored or emerging optimization methods to base frame design. Investigating new or hybrid algorithms and validating their results through analytical or numerical methods presents a promising research direction for achieving lightweight, cost-effective, and structurally sound base frame configurations.

II. DESIGN METHOD USED:

A. Flowchart for Base Frame Design



B. Methodology

Objective

- To perform static structural analysis of the base frame using Finite Element Analysis (FEA) techniques.
- To verify that the induced stresses remain within allowable material limits under operational and lifting conditions.
- To assess the stress distribution and deformation characteristics of the base frame in both mounted and lifting scenarios.
- To compare the structural analysis results of the modified design with those of the conventional base frame.
- To identify and evaluate the superior design alternative based on analytical results and structural performance.

C. Material Properties:

Material Properties: (CRCS Sheet as per IS: 513)
Modulus of elasticity = 2.01E5 Mpa
Poisson's ratio = 0.3
F.O.S =1.5 (66% of Yield Strength) (Refer IS 800CL.6.2.1)
Hence Allowable stress = 200 Mpa for IS 2062

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D. Verification

Design verification serves as the confirmation of the base frame's structural safety and is conducted through simulation-based methods for both models considered in this study. As detailed in the analysis section, the earlier model is used for a screw compressor with a lower power rating, whereas the newly developed model supports a higher power-rated compressor.

From the provided figures, it is evident that the previous model is constructed using Cold Rolled Carbon Steel (CRCS) sheet metal, fully enclosed in a continuous sheet configuration. The latest design follows a similar concept but incorporates bent CRCS sheets formed into C-channel-like profiles. This modification enhances rigidity and provides localized support only where required, effectively reducing weight while maintaining structural integrity.

The skeletal structure of the new model significantly lowers the overall mass compared to a solid sheet-based design, offering improved efficiency. Additionally, the modular nature of the bent sheet design enhances manufacturability and supports customization in high-stress regions.

Two primary loading scenarios are considered in the analysis:

- Lifting Condition: Simulates the behavior of the base frame during hoisting and transportation.
- Mounted Condition: Represents the frame in a stationary position under operational loads during regular working conditions.

The results of both simulations are detailed in the subsequent analysis section.

III. ANALYSIS OF BASE FRAME:

A. Previous Model

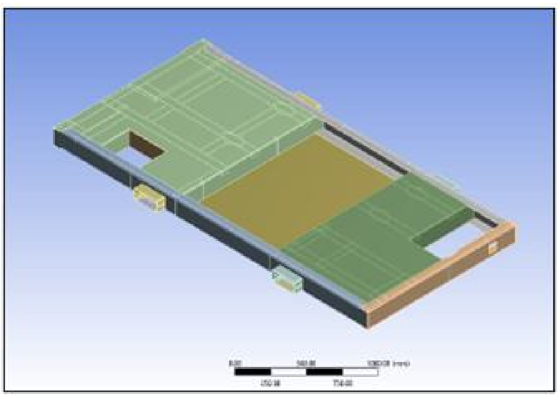

Fig. 5 Base frame Geometry

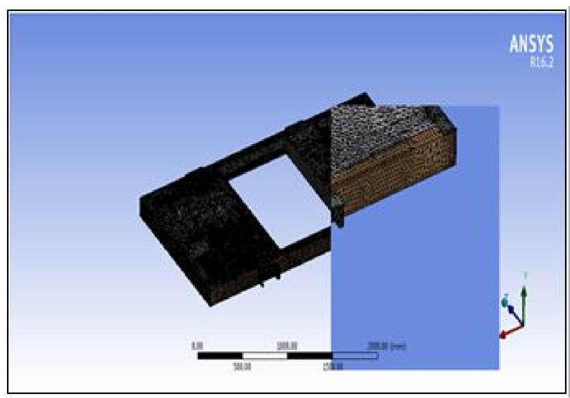

Fig. 6 Meshing of Base Frame

Case 1: Analysis of base frame while lifting

Sr. No.	Component Name	Dead Weight for analysis(kg)	Actual Dead Weight(kg)
1	Drive Assembly	2580	2090
2	Cooling assembly	549	457
3	Canopy Assembly	345	287
4	Air Oil Separator Tank	261	217
5	PDB	124	103

Table 1 Dead weight considered for base frame lifting case

The geometric configuration of the previous base frame is illustrated, as shown in Fig. 5, while the meshed model prepared for finite element analysis is presented in Fig. 6. The corresponding dead weight values of major components considered for the lifting case are summarized in Table 1.

Note: In lifting case loads are considered 1.5 times actual loads.

1) Constraints

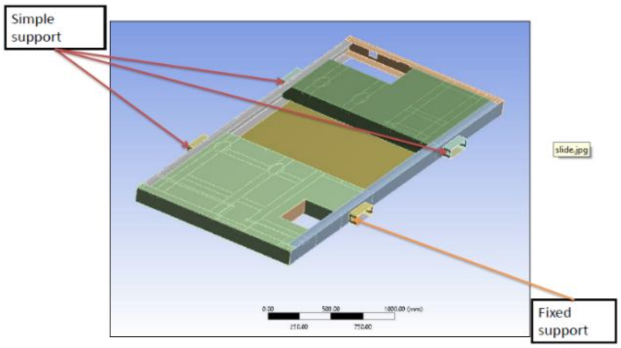

Fig. 7 Boundary Condition

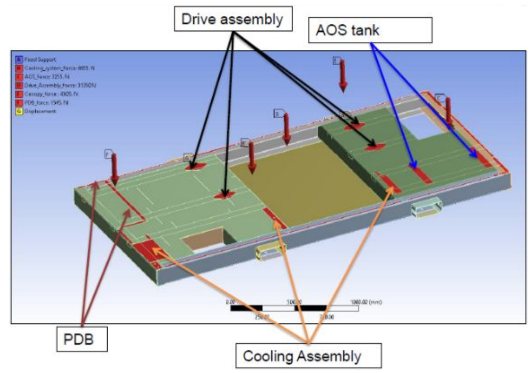

Fig. 8 Load

Case 2: Analysis of mounted base

Sr. No.	Component Name	Dead Weight for analysis(kg)	Actual Dead Weight(kg)
1	Drive Assembly	2508	2090
2	Cooling assembly	685.5	457
3	Canopy Assembly	430.5	287
4	Air Oil Separator Tank	325.5	217
5	PDB	154.5	103

Table 2 Dead Weight considered for mounted case (previous model)

The boundary conditions applied to the base frame in the mounted case are illustrated, as shown in Fig. 7, while loading configuration is shown in Fig. 8. The corresponding dead weight values of the main components considered in this mounted case are summarized in Table 2.

Note: In mounted case loads are considered 1.2 times actual loads.

2) Constraints

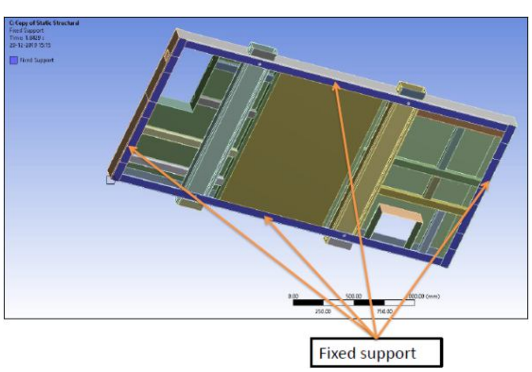

Fig. 9 Boundary Conditions

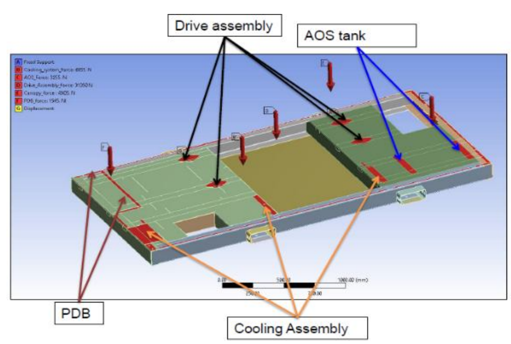

Fig. 10 Loads

The boundary conditions applied to the base frame in the mounted case are illustrated, as shown in Fig. 9.
The loading configuration considered for the mounted case is presented as shown in Fig. 10.

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B. New Model

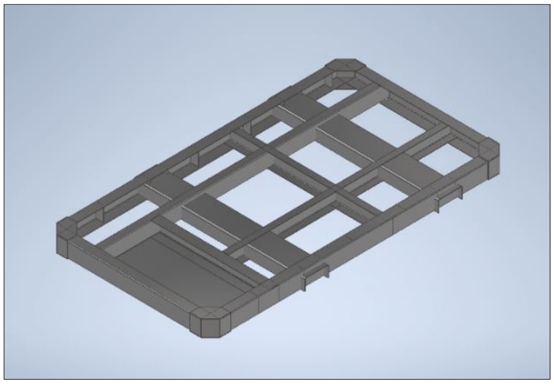

Fig. 11 Geometry

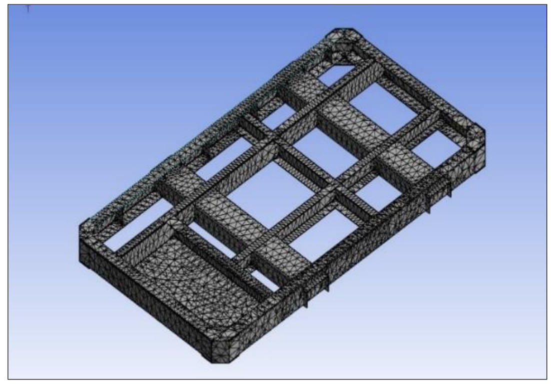

Fig. 12 Meshing

Case 1: Analysis of base frame while lifting

Sr. No.	Component Name	Dead Weight for analysis(kg)	Actual Dead Weight(kg)
1	Drive Assembly	2800	2333
2	Cooling assembly	571.2	476
3	Canopy Assembly	870	580
4	Air Oil Separator Tank	319	266
5	PDB	40	33.33

Table 3 Dead weight considered for lifting case (new model)

The geometric configuration of the newly designed base frame is illustrated, as shown in Fig. 11 and the meshed model used for the finite element analysis is presented in Fig. 12. The dead weight values of critical components considered for the lifting case are summarized in Table 3.

Note: In lifting case loads are considered 1.5 times actual loads.

1) Constraints

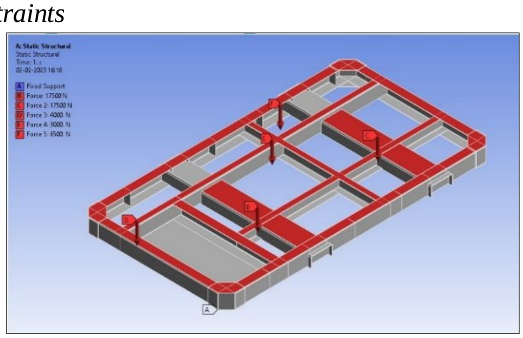

Fig. 13 Loads

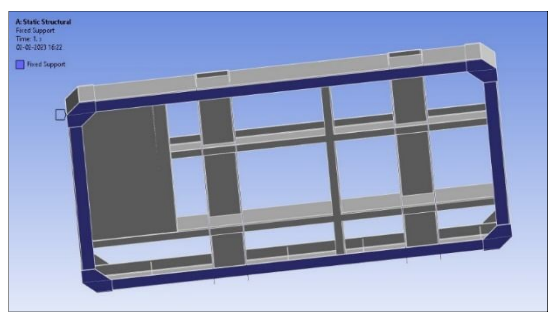

Fig. 14 Boundary Conditions

Case 2: Analysis of mounted base

Sr. No.	Component Name	Dead Weight for analysis(kg)	Actual Dead Weight(kg)
1	Drive Assembly	3500	2333
2	Cooling assembly	715	476
3	Canopy Assembly	870	580
4	Air Oil Separator Tank	400	266
5	PDB	50	33.33

Table 4 Dead weight considered for mounted case (new model)

The applied loading conditions for the new model in the mounted case are depicted, as shown in Fig. 13, while the corresponding boundary conditions are illustrated in Fig. 14. The associated dead weight distribution of the components considered for this case is summarized in Table 4.

Note: In mounted case loads are considered 1.2 times actual loads.

2) Constraints

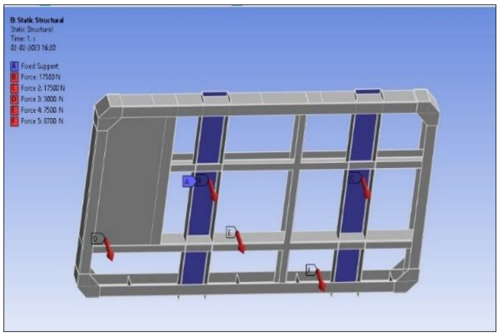

Fig. 15 Boundary Conditions

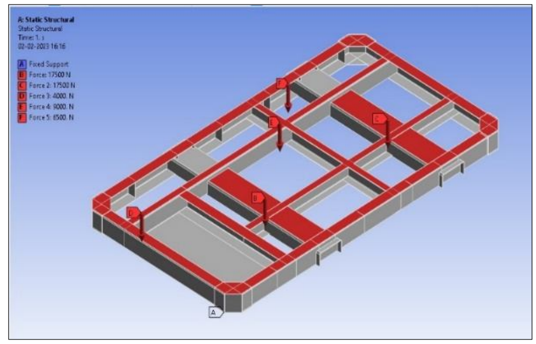

Fig. 16 Loads

The boundary conditions of the mounted cases are shown in Fig. 15.

The load configuration of the mounted case is shown in Fig. 16.

C. CAE of both Models of Base frame

1) Previous Model Analysis Results

Case 1: Analysis of base frame while lifting

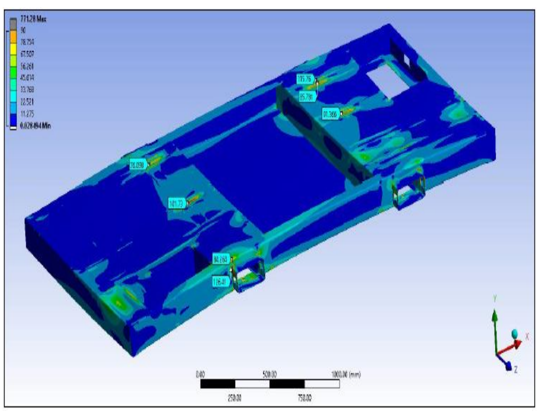

Fig. 17 Equivalent (von-Mises) Stress (127 MPa)

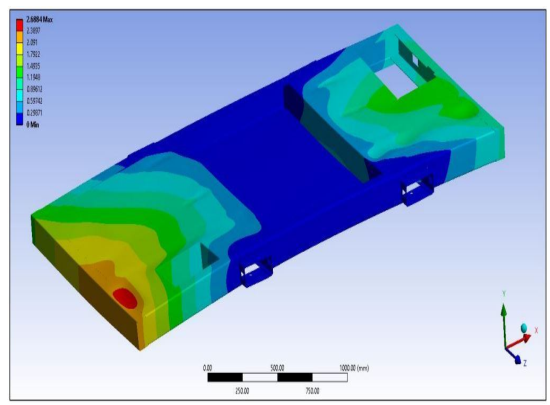

Fig. 18 Total Deformation (2.688 mm)

The equivalent stress distribution of Case 1 as shown in Fig. 17.

The total deformation observed in Case 1 is shown in Fig. 18.

Case 2: Analysis of mounted base

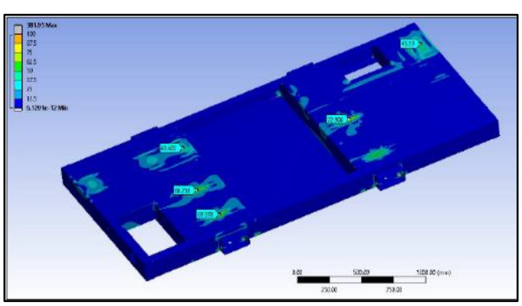

Fig. 19 Equivalent (von-Mises) Stress (73 MPa)

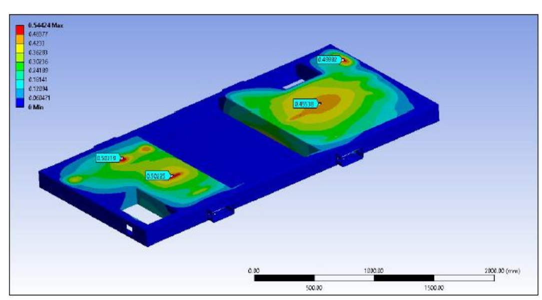

Fig. 20 Total Deformation (0.502 mm)

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The equivalent stress distribution for the mounted case is shown in Fig. 19.
The total deformation in the mounted case is shown in Fig. 20.

2) Observation Table

Cases	Von Mises Stress	Total Deformation
Analysis of base frame while lifting	127	2.866
Analysis of mounted base	73	0.502

Table 5 Observation table for previous model

The results obtained for the previous base frame model under both lifting and mounted cases are consolidated in Table 5.

3) New Model Analysis Results
Case 1: Analysis of base frame while lifting

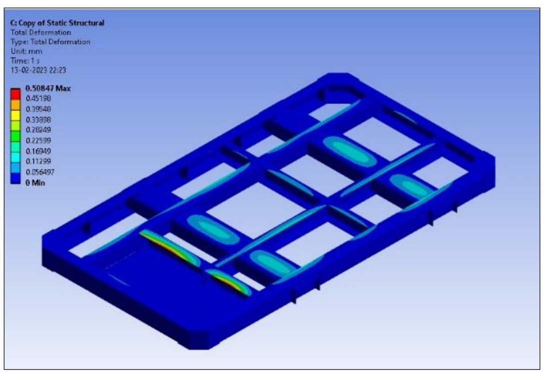

Fig. 21 Equivalent (von-Mises) Stress (128 MPa)

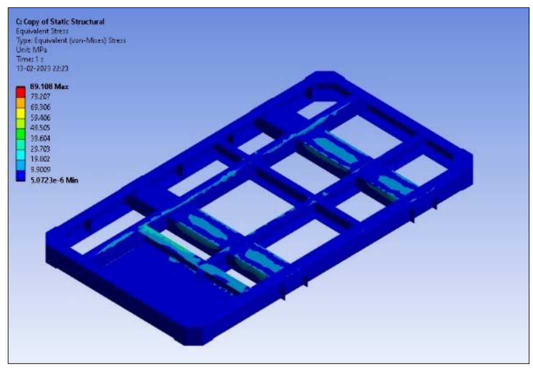

Fig. 22 Total Deformation (2.544 mm)

The equivalent stress of the new model in the lifting case is shown in Fig. 21.
The total deformation of the new model in the lifting case is shown in Fig. 22.

Case 2: Analysis of mounted base

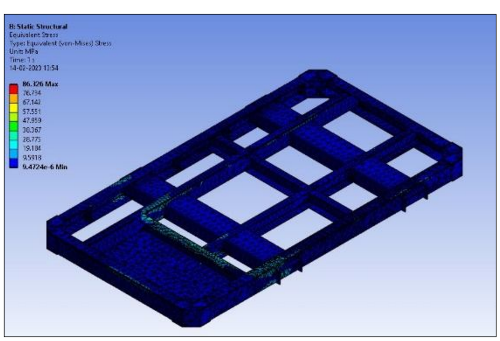

Fig. 23 Equivalent (von-Mises) Stress (73 MPa)

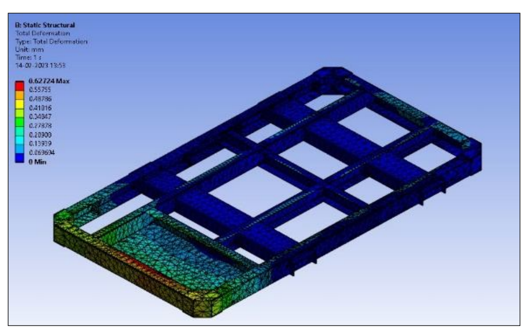

Fig. 24 Total Deformation (0.502 mm)

The equivalent stress of the new model in the mounted case is shown in Fig. 23.
The total deformation of the new model in the mounted case is shown in Fig. 24.

4) Observation Table

Cases	Von Mises Stress	Total Deformation
Analysis of base frame while lifting	128	2.544
Analysis of mounted base	73	0.627

Table 6 Observation table for new model

The summarized results of the new base frame model for lifting and mounted cases are presented in Table 6.

IV. ANALYTICAL APPROACH FOR OPTIMIZATION

Optimization is the process of identifying the most efficient solution within a given set of constraints, with the goal of maximizing performance or minimizing cost, weight, or other parameters. In the context of this study, mathematical optimization is employed to reduce the overall weight of the base frame. The primary objective is to achieve a lightweight yet structurally sound design, thereby reducing material usage and lowering the total cost of the compressor assembly.

This paper adopts a nature-inspired Artificial Intelligence (AI) algorithm for weight optimization. Such algorithms are increasingly prevalent across various disciplines—including mechanical design, manufacturing systems, and operations management—due to their ability to handle complex, multi-variable problems with high efficiency.

Numerous nature-inspired algorithms have been developed, each tailored to specific types of optimization problems. Examples include Genetic Algorithms (GA), Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), and Cohort Intelligence (CI), among others. These techniques simulate natural or social behaviors to iteratively search for optimal solutions.

The figure 25 shows illustrates several widely used nature-inspired algorithms that have proven effective in structural and design optimization tasks.

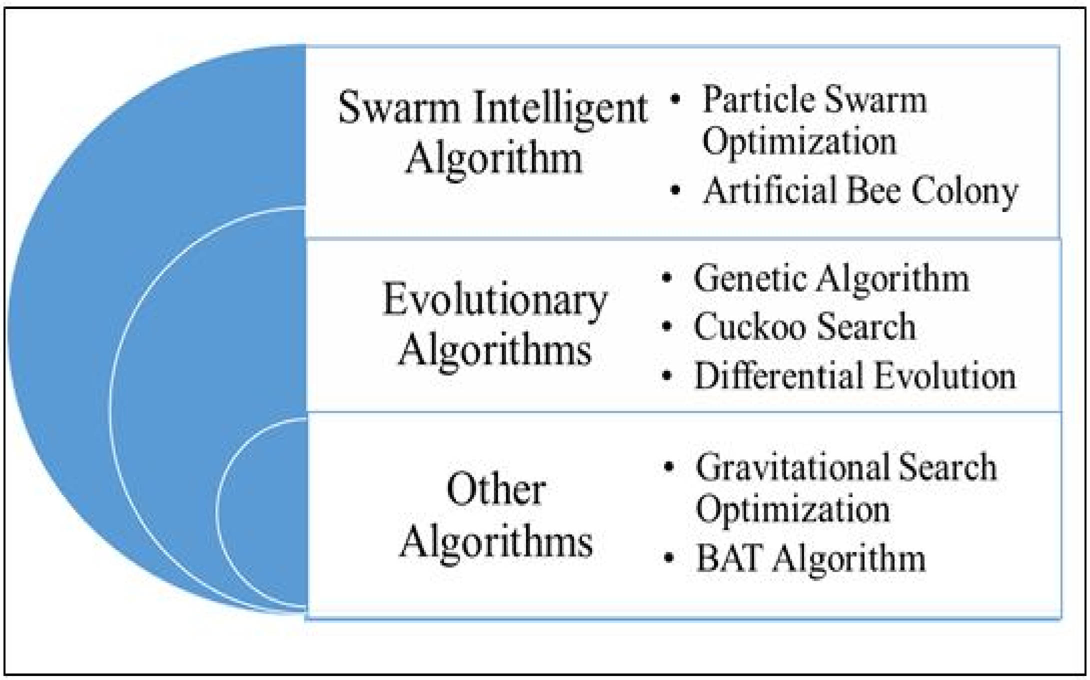

Fig. 25 Classification of Nature Inspired Algorithms

The classification chart presented above categorizes nature-inspired algorithms based on their biological or behavioral origin. Swarm Intelligence Algorithms, which fall under the category of socio-inspired methods, are modeled on the collective behavior of individuals in a group—such as flocks of birds or swarms of insects. Evolutionary Algorithms, on the other hand, draw from Darwin's theory of natural selection, particularly the principle of "Survival of the Fittest." Other algorithms included in the classification are either generic or hybrids that integrate multiple behavioral or biological inspirations.

In this study, Cohort Intelligence (CI)—a Swarm Intelligence-based algorithm—is utilized to optimize the design of the compressor base frame. The CI algorithm mimics the learning behavior within a group of individuals (a cohort), such as selecting the most competent student from a classroom. In the context of base frame optimization, the structural members are treated as students, and the goal is to identify the optimal thickness (the "best student") that satisfies load-bearing requirements with minimal weight.

For the present work, thickness is considered the only variable design parameter, while the overall outer dimensions and cross-sectional profiles of the base frame remain fixed due to functional constraints. The CI algorithm evaluates different thickness values for each structural member and determines the most suitable configuration by minimizing weight while ensuring stress levels remain within acceptable limits.

Unlike traditional design workflows, which rely on detailed manual calculations or CAE simulations, this algorithm-driven approach offers a time-efficient and automated alternative. By providing accurate input parameters, users can quickly obtain near-optimal designs without the need for iterative trial-and-error modeling, thereby improving design speed and decision-making in structural applications.

A. Cohort Intelligence Algorithm

A basic flowchart depicting the working of the algorithm is shown in Fig 26 to get an overview of the overall process of optimization.

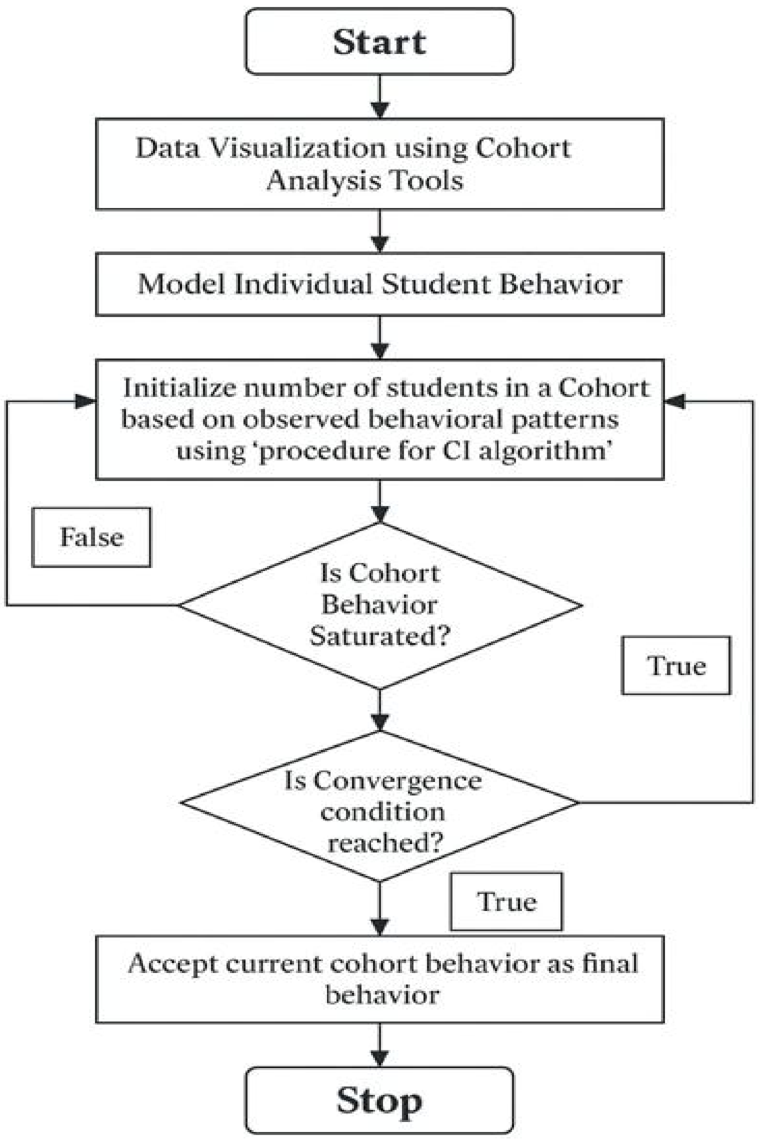

Fig. 26 Cohort Intelligence Algorithm Flowchart

V. RESULTS AND DISCUSSION

The structural analysis of both the existing and modified base frame models was carried out under two distinct loading scenarios: Case 1 – Lifting Condition and Case 2 – Base Mounted Condition. The Finite Element Analysis (FEA) results confirm that in both cases, the induced stresses and deformations remain well within the allowable material limits, indicating the safety and structural adequacy of the modified design for the intended application. These conclusions are supported by the data summarized in the observation table.

Critical stress regions were primarily identified at joints and areas with reduced cross-sectional geometry, as expected under concentrated loading conditions. The applied loads in each scenario were appropriately factored to account for dynamic effects—1.5× for the base mounted condition and 1.2× for the lifting condition. The FEA results conclusively demonstrate that the revised base frame structure performs safely and reliably under both operating and transport conditions.

From the optimization perspective, the base frame was modelled as a three-dimensional indeterminate truss, where the condition m>3j−rm > 3j - rm>3j−r is satisfied (with *m* as number of members, *j* as number of joints, and *r* as reaction forces). Such indeterminate structures cannot be resolved using conventional closed-form methods and require advanced analytical or computational approaches.

VI. CONCLUSION

Finite Element Analysis (FEA) was performed on two distinct base frame models—one fully enclosed with sheet metal and the other featuring a skeletal configuration. The design modification aimed to reduce the overall weight and manufacturing cost of the base frame while maintaining structural performance. The simulation results effectively identified critical stress regions, typically located at joints or areas with reduced cross-sectional geometry.

To address these high-stress zones, especially in skeletal frames, reinforcements such as stiffeners introduced between the legs of C-shaped members to distribute the loads more evenly and minimize local deformations. It is also observed that the majority of stress concentrations behave as localized stresses, affecting only a limited number of nodes and not contributing to major structural failures or fractures. Therefore, these localized stresses are not critical under the current loading conditions.

Both base frame designs are deemed suitable for their intended application, with the skeleton-type frame showing promising results, particularly under lifting and static loading conditions. However, it is recommended that the skeletal frame be structurally enhanced through localized stiffening to improve rigidity across its entire surface. Based on the outcomes, the skeleton-type base frame can be considered viable for prototype development and experimental validation.

Regarding the optimization aspect, the Cohort Intelligence (CI) algorithm demonstrated partial success. Due to the indeterminate nature of the frame structure, the optimization process encountered errors in the later stages of the code. While the algorithm itself is valid for optimization tasks, the structural constraints of the base frame do not fully align with the assumptions of the optimization model. Thus, further customization or algorithmic refinement is needed to effectively apply such techniques to indeterminate structures like base frames.

VII. FUTURE SCOPE

For future studies involving similar base frames or structurally indeterminate assemblies, a customized optimization algorithm can be developed that explicitly accounts for frame indeterminacy. Such an algorithm should incorporate advanced computational techniques capable of resolving statically indeterminate structures and allow seamless integration with design parameters relevant to base frame geometry and loading. Furthermore, the algorithm can be generalized and adapted to accommodate a variety of frame types with similar member orientations and connection patterns. This would significantly reduce design time, streamline the optimization process, and offer substantial benefits in terms of structural efficiency and cost-effectiveness. The development of such tools will be valuable for engineers involved in the rapid and reliable design of industrial support structures, especially in compressor systems and related applications.

VIII. ACKNOWLEDGEMENT

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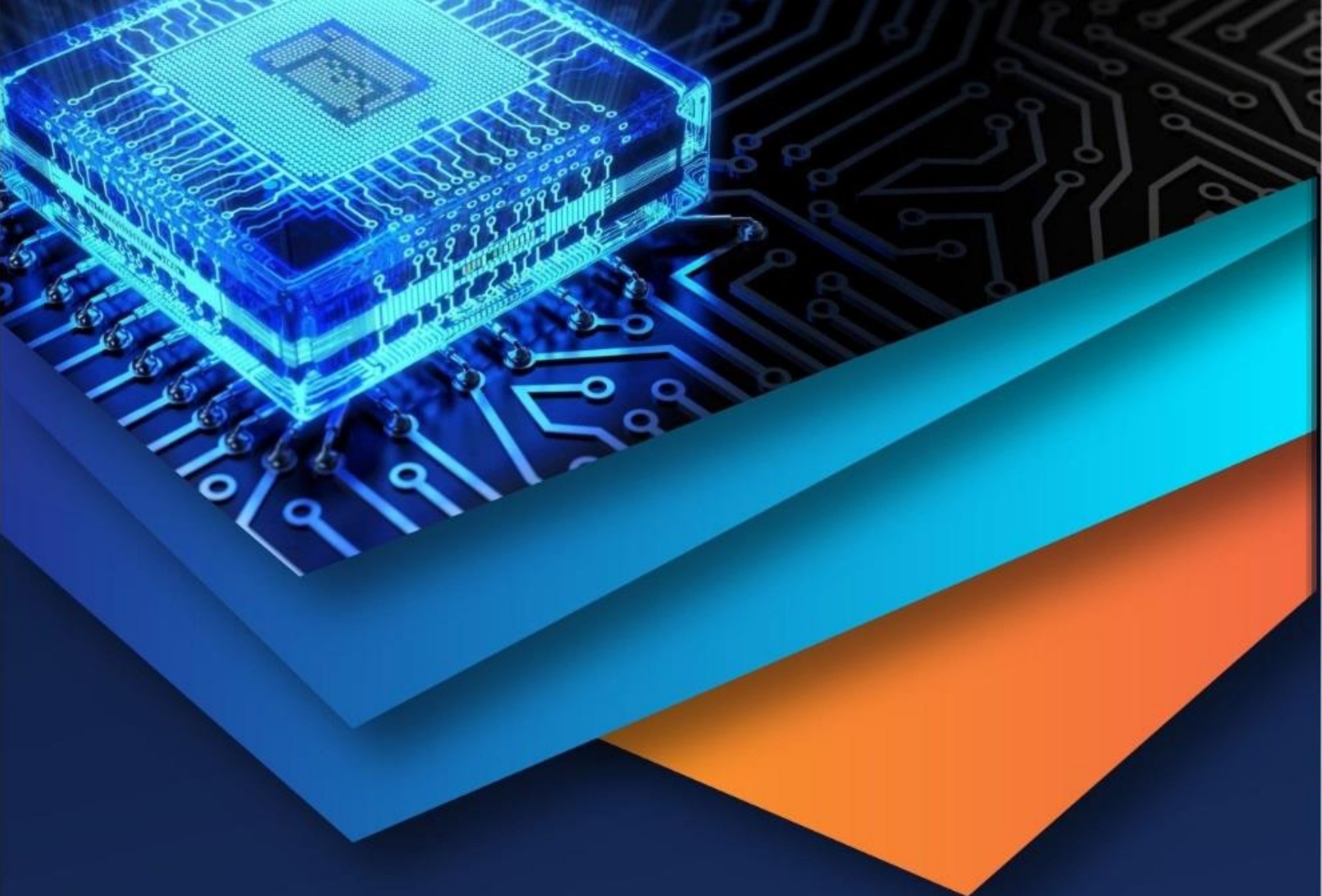

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