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RESEARCH ARTICLE

PERFORMANCE ENRICHMENT OF REFRIGERATED AIR DRYER CANOPY BASE

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ABSTRACT

Refrigerated air dryers are basically a refrigeration system which is used to remove water vapor from compressed air. Refrigerator, heat exchanging unit are to be placed in a canopy which is affected by static and dynamic stresses acting on it. In this paper the load carrying capacity of canopy base has been analyzed using finite element analysis method with various approaches for the same loading condition. From the analysis results it is concluded that the deformation value of the canopy base varies with respect to overall weight of the refrigerated air dryer and thickness of base plate. By introducing circular disc on the bottom of the canopy, base can obtain high withstanding capacity of canopy base comparing with other two approaches.

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INTRODUCTION

There are many applications where air from the atmosphere is compressed for usage. When air is compressed, it leaves the compressor in saturated condition with moisture. Some of this moisture condenses in the air storage tank and is exhausted through a float. The air is still very close to saturated as it leaves the storage tank. This air may be dehydrated using refrigeration. Refrigerated air dryers are normally self contained refrigeration system that may be air cooled or water cooled, located in the air supply, after the storage tank. The air may be cooled in a heat exchanger, and then moved to the storage tank where much of the water will separate from the air. The air then passes through another heat exchange where the air temperature is reduced to below the dew point temperature. All the needed equipment and its accessories are to be mounted in one enclosure. This enclosure has to be analyzed to minimize the deformation during the static and dynamic conditions.

Literature Survey

A theoretical and experimental investigation on deformation and stress of a flexible discharge ring valve has been carried out, to achieve design concept on this valve type and its accessories (Futakawa *et al*., 1978).

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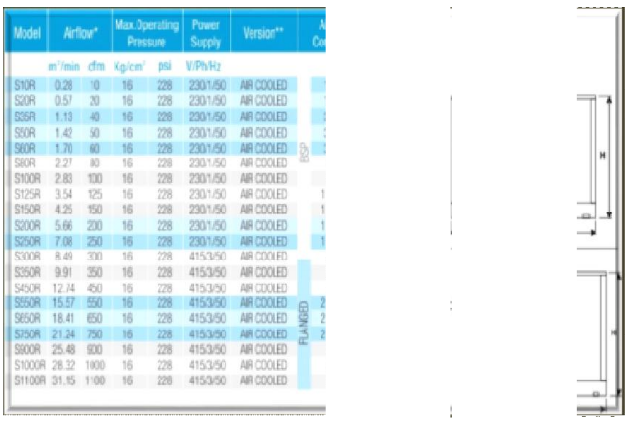
Natural frequency and static state deflection of a compressor mounting plate are computed using Ansys. Further two methods of improving and optimizing the design to increase the natural frequency are illustrated and analyzed (Pushpendra Mahajan, 2005). Design and analysis of an engine mounting bracket was done and compared the weight and performance (Sreedhar *et al*., 2012). Optimized design of Air-Conditioner compressor mounting bracket, highlighted the factors for the failure of the mounting bracket and the effect of the optimization by FEA analysis (Vyankatesh *et al*., 2015). Modeling and analysis of IC engine rubber mount has been done using FEA and deformations of rubber mount obtained from FEA are used in the minitab to develop the mathematical model and deformation (Ramachandran *et al*., 2012).

The finite element model of engine mount is created using CAD & meshing is carried out using Hypermesh and the simulation of the engine mount is carried out using LS-Dyna (Yadavalli Basavaraj *et al*., 2013). The effect of the geometry of rectangular plate with central elliptical hole has been studied and analysed the stress and displacement of the elliptical hole for different aspect ratios by keeping the dimensions of plate fixed and value of maximum equivalent Von-Mises stress and deflection of plate under a constant pressure is determined with the help of ANSYS (Dheeraj Gunwant *et al*., 2013). Conducted a numerical simulation which uses finite element methodology, to estimate the von misses stress subjected to the plate and screw which is used in tibia fracture treatment (Kaman *et al*., 2014). The effect of an initial stretching of a rectangular plate with a cylindrical hole on the stress and displacement distributions around the hole, which are caused by the additional loading, was studied using the finite element method (Mekalke *et al*., 2010). Stress analysis of a series of flat plates with oblique holes subjected to axial tension has been carried out using the finite element method (FEM) (Patle and Bhope, 2012). Rectangular plate with circular hole at center is analyzed by using three dimensional finite element analysis subjected to tensile loading and the effect of ratio of thickness of plate to hole diameter on the stresses and displacements is studied (Saksham Dhanjal and Richa Arora, 2015). Investigated the three-dimensional elastic stress distribution in the vicinity of the sharp corners of an inclined diamond hole in a plate is carried out (Afshar *et al*., 2013).

The stress analysis of plates perforated by holes in square pitch pattern has been analyzed by using the photo elastic method finite element method (Patil *et al*., 2013). An analytical solution is presented for three-dimensional thermo mechanical deformations of a simply supported functionally graded (FG) rectangular plate subjected to time-dependent thermal loads on its top and/or bottom surfaces (Senthil *et al*., 2003). Modeling and nonlinear stress analysis of piezolaminated CNTs/fiber/polymer composite (CNTFPC) plates under a combined mechanical and electrical loading are investigated (Rafiee *et al*., 2014). Static behavior of engine mounting bracket was analyzed using finite element analysis method (Adkine *et al*., 2015). Design optimization of the Mounting Bracket for aerospace vehicle to reduce the weight to a large extent by maintaining High Factor of Safety (Gopala Krishna, 2014). Analyzed the stress and deformation of a frame of a bush pressing machine for pumps was modeled and analyzes using finite element method (Amith Kalekar *et al*., 2015).

Design of Canopy

Design and analysis of the canopy of air dryer for its existing dimensions have been modeled which is shown in the Fig.1. The existing dimension of the canopy is considered from the standard catalogue S200R and S250R model was used to make the design of canopy which is shown in Fig 1. Brain-storming sessions are carried out to generate ideas for alternatives in order to improve the various aspects of the product.



Model	Airflow*		Max.Operating Pressure		Power Supply	Version**
	m³/min	cfm	Kg/cm²	psi	V/Ph/Hz	
S10R	0.28	10	16	228	230/1/50	AIR COOLED
S20R	0.57	20	16	228	230/1/50	AIR COOLED
S35R	1.13	40	16	228	230/1/50	AIR COOLED
S50R	1.42	50	16	228	230/1/50	AIR COOLED
S60R	1.70	60	16	228	230/1/50	AIR COOLED
S80R	2.27	80	16	228	230/1/50	AIR COOLED
S100R	2.83	100	16	228	230/1/50	AIR COOLED
S125R	3.54	125	16	228	230/1/50	AIR COOLED
S150R	4.25	150	16	228	230/1/50	AIR COOLED
S200R	5.66	200	16	228	230/1/50	AIR COOLED
S250R	7.08	250	16	228	230/1/50	AIR COOLED
S300R	8.49	300	16	228	415/3/50	AIR COOLED
S350R	9.91	350	16	228	415/3/50	AIR COOLED
S450R	12.74	450	16	228	415/3/50	AIR COOLED
S550R	15.57	550	16	228	415/3/50	AIR COOLED
S650R	18.41	650	16	228	415/3/50	AIR COOLED
S750R	21.24	750	16	228	415/3/50	AIR COOLED
S900R	25.48	900	16	228	415/3/50	AIR COOLED
S1000R	28.32	1000	16	228	415/3/50	AIR COOLED
S1100R	31.15	1100	16	228	415/3/50	AIR COOLED

Fig. 1. Dimensions of Canopy base

Canopy is the outer cover of the refrigerated air dryer and its assembled view is shown in Fig.2. It consists of base which is used to locate the equipments, pillars to provide support, and a roof. Compared to the base, the effects of roof and pillars of canopy are of negligible effect, hence it is not considered for analysis.

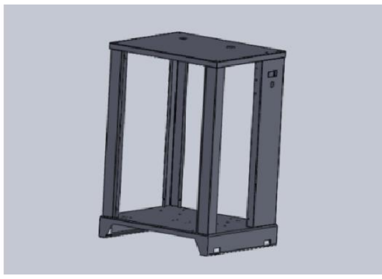


Fig. 2. Assembled View Of Canopy

The static and dynamic loading occurs over the canopy base, hence the static and modal analysis is performed on the canopy base.

MATERIAL AND METHODS

The material used for the canopy is AISI 1020 Steel and the model type is linear elastic isotropic. The Table I depicts the material specifications of canopy.

Table 1. Material properties of canopy

Properties	Value
Poisson's ratio	0.29
Mass density, Kg/m^3	7870
Tensile strength, N/m^2	4.2e+008
Yield strength, N/m^2	3.5e+008

To overcome the Deformation and stress acting on the refrigerated air dryer canopy brainstorming session has been carried out. Among the various suggestions received, it is possible to do any of the following approaches.

Table 2. Types of approaches

S.No	Types of approaches
1	Thickness improvement
2	Providing ribs
3	Providing circular disc

The objective of the above approaches is used to reduce the deformation on the base due to the heavy load acting on it, which reduces the performance efficiency.

RESULTS AND DISCUSSION

Fig. 3 shows the static deformation of the existing canopy base. Static Deformation is used to denote how long the surface would deform under the application of load with maximum deformation of 2.365mm. The maximum von mises stress acting on the existing canopy base is shown in the Figure 4. The maximum von mises stress is 62.6225 Mpa, which is greater than the strength of the material. So the canopy base will definitely deform due to the subjected load. The Fig. 5 shows the deformation shape of the canopy base. It denotes the deformation of the surface under the given load. The overall results obtained from the above analysis are illustrated in Table 2.

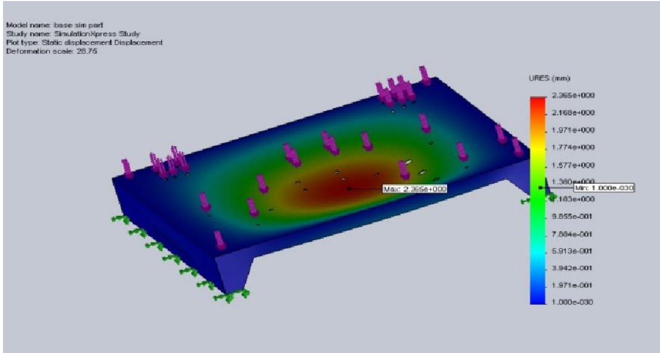


Fig. 3. Static deformation of base

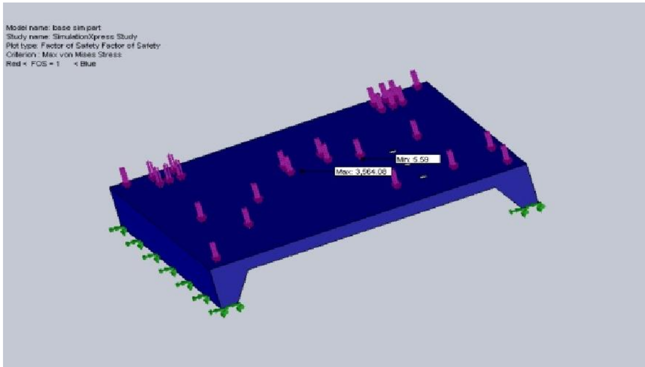


Fig. 4. Max. von mises stress of base

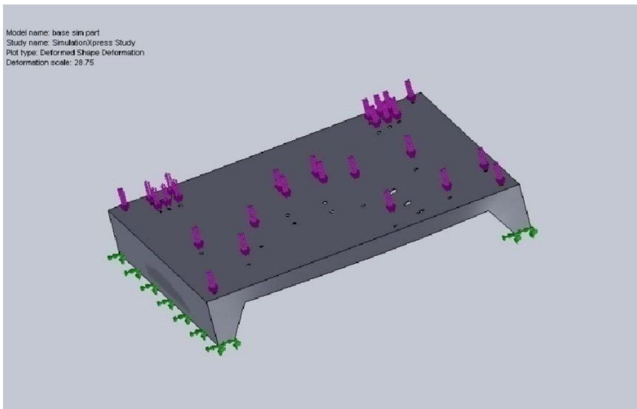


Fig. 5. Deformation shape of base

Table 3. Results of existing canopy base

Parameter	Von Mises Stress, Mpa		Deformation, mm	
	Min	Max	Min	Max
Value	0.098208	62.6225	0	2.36521
Location, mm (x,y,z)	274.486 x 63.0221 x -186.064	389.456 x 62.9792 x -228.331	-14.4578 x 100 x -515.755	321.601 x 68 x -241.909

Modification 1- Increase of Thickness

By increasing thickness of base to 5 mm, the deformation of the base has reduced to 0.18mm with increase in the overall weight of the canopy to 25.9 Kg. fig. 6 depicts the Deformation plot of base for 5 mm thickness.

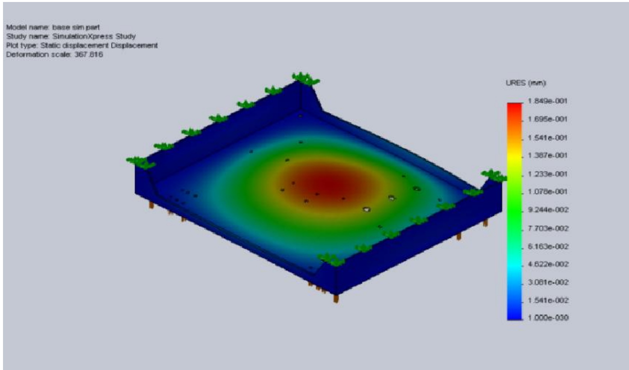


Fig. 6. Deformation of base with 5mm thickness

Modification 2 - Insertion of Ribs

The weight of the canopy base becomes 23.8 kg, for the base with 2 ribs, reduces the deformation to 0.18 mm with 2.2 kg increase in weight of base. The weight of the canopy base is 22.7 kg and it is shown in Fig. 7. The weight of the canopy base accounts to 24.9 kg, for the base with 3 ribs under the base, reduces the deformation to 0.11 mm with 3.3 kg increase in weight of base which is shown in Fig. 8. The number of ribs is increased from 2 to 4 on the bottom side of the canopy base and it is provided perpendicular to the base longitudinal axis. Fig. 9 clearly illustrates the deformation of base after addition of 4 ribs under the base has reduced the deformation to 0.09 mm with 4.4 kg increase in weight of base plate of canopy.

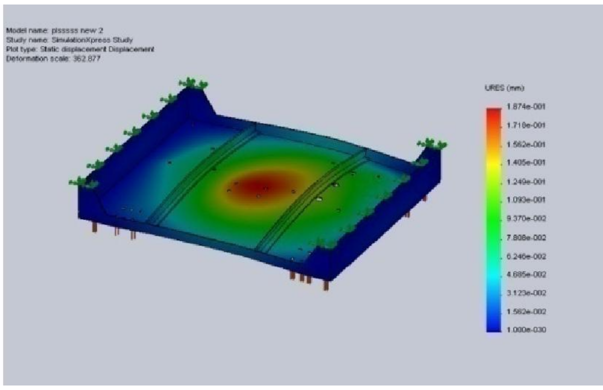


Fig. 7. Deformation of Base with 2 Ribs

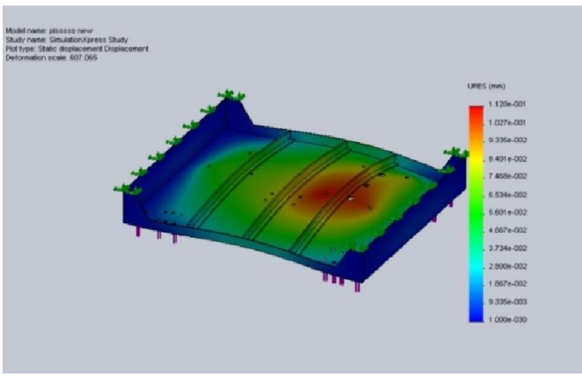


Fig 8. Deformation of base with 3 ribs

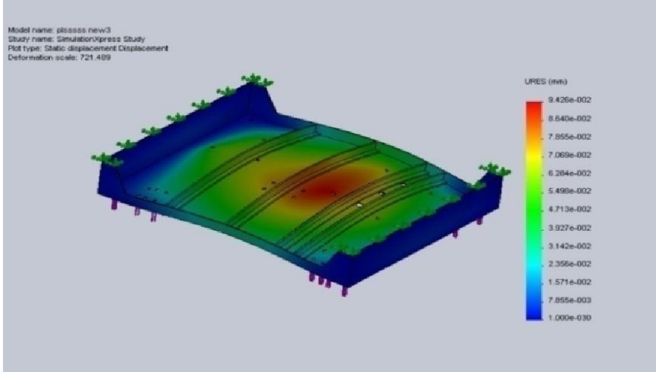


Fig. 9. Deformation of base with 4 ribs

Modification 3 - Insertion of Circular Structure

Fig. 10. depicts the deformation results of canopy base with the combination of a circular structure of 5mm thickness with single rib on the other side at the critical point where the load is maximum, the deformation of the base is reduced to 0.19mm with 1.84 kg increased in weight.

Table 4. Comparison of Deformation Values and Weight

S.No.	Approaches	Deformation in mm	Final weight in Kg
1	Insertion of 2 ribs	0.18	22.7
2	Insertion of 3 ribs	0.11	23.8
3	Insertion of 4 ribs	0.09	24.9
4	Increase of thickness to 5mm	0.18	25.9
5	Combination of Rib with Circular Disc	0.19	22.3

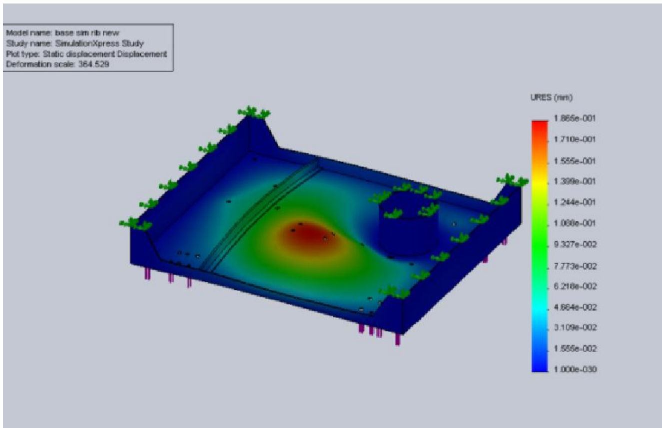


Fig 10. Deformation of base with circular structure

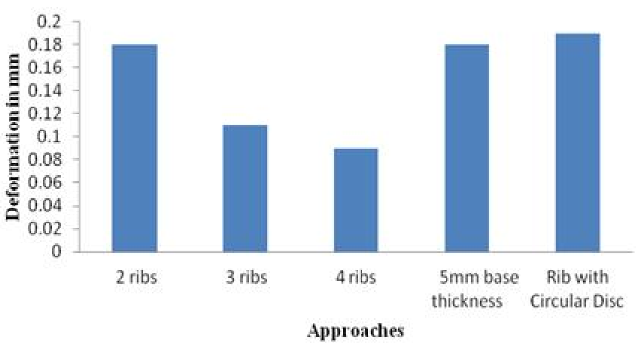


Fig. 11. Alternative Approaches vs deformation of canopy base

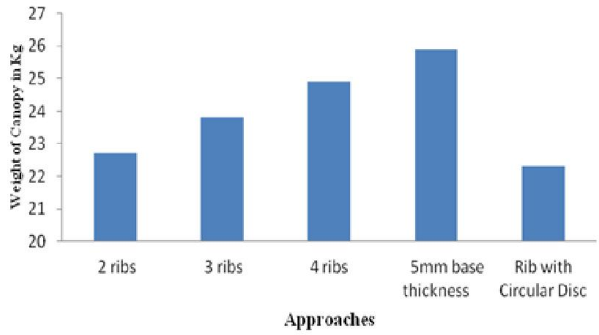


Fig. 12. Alternative Approaches vs Weight of canopy

The overall weight of the canopy accounts to 22.3 kg. Table 3 illustrates the results obtained by using various alternative approaches used to overcome the deformation of refrigerated air dryer canopy. From the results obtained using various approaches, by the addition of four ribs can obtain very minimum value of deformation of 0.09mm when compared with other approaches which is clearly illustrated in Fig. 11. The results obtained by various alternative approaches with respect to weight of canopy base is shown in fig. 12. By introducing a circular disc in the canopy low weight of canopy is achieved with high deformation value when compared to other approaches. Least deformation is obtained by insertion of four ribs on the bottom side of the refrigerated air dryer canopy base with increase in overall weight of the canopy. But combination of circular disc with one rib on the bottom side of the base give least deformation value when compared to other approaches, in this case the overall weight of the canopy is reduced.

Conclusion

The deformation value of the canopy base varies with respect to overall weight of the refrigerated air dryer and thickness of base plate. If the deformation value is maximum, it indicates the withstanding capacity of canopy is minimum, likewise if the deformation value is minimum it indicates the withstanding capacity of canopy as maximum. By introducing circular disc on the bottom of the canopy base can obtain high withstanding capacity of canopy.

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