Design of Single Stage Double Cylinder Oil Free Air Compressor

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Abstract— With modernization, pneumatic industry has made exponential growth in its manufacturing capabilities and demand in various fields. Air compressor is a basic requirement for any pneumatic system or a machine which can compress air. Oil free air compressors using in medical, foods, beverages etc. because of oil particles can be harmful in their applications. This design is based on single stage, double cylinder oil free air compressor. The concept of this novel design is based on bull engine mechanism. Due to unique design of pushrod, getting continuous compressed air flow and also high air displacement. With the help of single crank-rod, this is beneficial for dual functions with the help of pushrod. With the help of respective free air delivery in CFM and Power in hp all parts designed. In this dissertation all the components will be well modeled with the help of Solidworks 2016 software and will be analyzed.

Key words: Air Compressor, Piston, Pushrod, Connecting Rod, Crankshaft, Flywheel, Cylinder, Oil-Free, Ansys, Solidworks, Free Air Delivery, Drive, Piston Displacement, Rpm

I. INTRODUCTION

It is a basic requirement for any pneumatic system or a machine which can compress air from lower pressure to higher pressure through mechanical components. In commonly, atmospheric air is used as an inlet and compress it up to certain desired level and discharge it from outlet. In some cases already compressed air comes as an inlet port and compressed up to certain level for more pressure ratio. It is called booster or second stage of air compressor. Compressor is used to operate pneumatic equipment like paint spray, drills, air conditioning, refrigeration systems etc. It is also used field of Pharmaceutical sector, Foods and Beverages sector, Hospitals etc. According to working there are two types Reciprocating air compressors and Rotary air compressor. According to action there are two types Single acting air compressors and Double acting air compressors. According to number of stages there are two types Single and multi-stage. According to motor driven system there are two type direct drive and belt drive system. Lubricated (Oil) compressors containing oil particles in output air. This type of compressors using in local and major industrial purpose use. But in some fields like Medical, Pharmacy, Foods and Beverages never containing oil particles in their usage. Oil particles can be harmful in their applications. In focus of oil free compressor used in these industries, in this dissertation oil free compressor will be designed with new approach.

II. LITERATURE SURVEY

P. Plastinin, V. Khonukhov, A. Khonukhov and S. Gorjunov[1] (ICE conference july 2000) stated out a new law for motion of piston in reciprocating compressors[1].They concluded that it is possible to reduce the energy (power) losses in the suction valves by 40% at nominal r.p.m. of the crankshaft in reciprocating compressors with controlled law of piston motion by selecting a law of piston motion during suction process.It is possible to reduce indicated power by 15% and more at nominal r.p.m. of the crankshaft in reciprocating compressors with mechanism with controlled law of piston motion permits to double the piston average speed and achieve higher efficiency coefficient of the compressor. In reciprocating compressors with controlled law of piston motion power performance improvements due to selection of respective law of piston motion are considerably (several times) higher than friction losses in additional vapour of friction.

Bhaumik Patel and Ashwin Bhabhor[2] (IJAERS,Vol. I, Issue III/, April-June,2012/73-75) states to measure the distribution of the temperature on the top surface of the piston. Which predicts that due to temperature weather the top surface of the piston may be going to damaged or broken during the operating conditions because damaged or broken parts are so expensive to replace and generally are not easily available.[2].They concluded that the stresses which are produced during the operations are less than the design stress. Also the distribution of the temperature is in prescribed limit. The average piston temperature beneath the piston ring is about 650C. so the design is safe to resists specified temperature and pressure.

Mori H, Kasuya K, Takahashi Y, Suzuki A and Aoki M [3] (1986) stated the development of a series of single-stage, oil free screw air compressors with a compression ratio of 8. A new rotor profile, which reduces leakage loss to achieve higher efficiency, and designed for ease of manufacture, is detailed. Additionally, a new design method for the clearance between rotors, to compensate for rotor deformation due to thermal expansion, is also introduced.[3].Finally they completed with a reliable and low cost oil-free screw compressors became available in the capacity range from 120 to 455 m3/h. Formerly, oil-free reciprocating compressors had predominated in this range.

F. Huang[4] (2000) explains the detail difference between the oil free and oil injected compressors in various sectors such as textile, automobile, iron and steel, food and beverages, electronic and the possible effects of each one is been stated up in here.[4]Oil-free screw compressor is the best choice for customers in most of applications, as oil injected compressor has its unique attraction to customers. Where oil free air compressors are a better option in industrial field.

Pascal Stouffs, Mohand Tazerout and Pierre Wauters [5] (2000) stated the thermodynamic analysis of reciprocting air compressor where the theoretical and practical results are very nearer to each other.[5]They concluded out that in cylinder wall, fluid heat transfer is mainly affected to the efficiency of the compressor.

Wai Phyo Aung and Htay Htay[6] (2014) reported that they are design a piston for first and second stage of two

stage compressor and doing analysis of static stress and non-linear nodal stress. [6] They conclude that air discharge is depending on bore diameter and stroke of compressor.

Ajay Raj Singh and Dr. Pushpendrakumar Sharma[7] (2014) noted that the better piston material is selected based on the stress analysis.[7]They selected Al-GHS 1300 alloy due to its lesser stress at factor of safety 6.

Kuldeep B, Arun L.R and Mohammed Faheem[8] (2013) stated that weight can be reduced by changing the material of the current AL360 connecting rod to hybrid AlSic composites . [8] They concluded that the new optimised connecting rod is comparatively much stiffer than the former. They analysed von-mises stress, strain and displacement in ANSYS software.

Ghodake A.P. and Patil K.N[9]. stated that the total deflection, min. principle stress, max. principle stress and von-mises stress for 180 bar pressure of cylinder.[9]They found that stresses generated in piston is in their tolerance limit for specific material and deflection.

Dilip Kumar Sonar and Madhura Chattopadhyay[10] (2015) stated an analysis of thermal stress and damages due to application of pressure is presented and analyzed in this work. It is evident that thermal stress was higher than mechanically induced stress hence it could be concluded that the piston would fail due to the thermal load rather than the mechanical load and hence during optimization design, this could be put into consideration to ensure that thermal load is reduced.[10]

They concluded that although thermal stress is not the responsible for biggest slice of damaged pistons, it remains a problem on engine pistons and its solution remains a goal for piston manufacturers.

Vaishali R. Nimbarte and Prof. S.D. Khamankar[11] (2015) The main objective of this research work is to investigate and analyze the stress distribution of piston at actual engine condition. In this paper pressure analysis, thermal analysis and thermo-mechanical analysis is done. The parameter used for the analysis is operating gas pressure, temperature and material properties of piston.[11]They concluded that analytical and FE analysis results for mechanical, thermal & thermo-mechanical loading are approximately similar. The percentile difference between analytical results & analysis results of piston are very small. Hence the design of piston is safe.

World Health Organization[12] (2009) made an analysis on the various hazardous particles containing in the medicines and thus stated out it effect over the living beings. The survey thus contained various vulnerable factors which were been taken into consideration for proper functioning of the aides.[12]Finally they intended out with various guidelines which were been duly followed and procedure out for harmless pharmaceutical manufacturing firms products.

Amit Solanki and Jaydeepsinh Dodiya[13] explained that theoretical conclusion and FEA modal conclusion for stress is nearly same. [13]And they are also concluded frequency and vibration modal by the harmonic analysis through ANSYS.

P. Grolier[14] (2002) publish a result, which is comparison between experimental and analytical, the values of cooling capacity for same compressor is within accuracy of ±10%.[14] They conclude cooling capacity for better intakes of gas.

Deepak Gupta and Wankhade S.R.[15] (2015) reported that Aluminium alloys 6063 is better as a material. They were doing analysis on circular as well as rectangular fins and conclude that circular fins is better than rectangular fins. They also decreased thickness of fin.[15] They concluded out with decreased thickness of fins and Al 6063 as better material.

L. Borwirth and E. Boff[16] (1976) concluded that for different types of compressors they giving K-values which is in unit of kg.$\frac{m^2}{kW.min}$. [16] They explained all the equation for designing of the flywheel.

III. LITERATURE REVIEW

Conclusion Derived from above literatures

1) Major factors been considered in designing of a compressor lies with the design and analysis of the piston, where air discharge depends upon the bore diameter and stroke.
2) Various methods have been implemented over analysis of reciprocating compressors, thus it results over the compression ratio.
3) The oil free compressors are a boon to the industries and in its final manufacturing products as compared with oil injected compressors.
4) The material consideration has been stated with effect of stress and temperature analysis of compressor parts and thus stating Aluminium silicon carbide(AlSiC) as suitable one for analysis

Sr. no	Research paper	Parameter taken
1	Research of the effectiveness of use of new mechanism in reciprocating compressors	Speed of piston
2	Thermal analysis of a piston of reciprocating air compressor	Safe working temperature of piston
3	Single Stage, Oil-Free Screw Compressor with a Compression Ratio Eight	Compression ratio
4	Oil-Free Screw Compressor or Oil-Injected Screw Compressor?	Oil free is better than oil injected
5	Thermodynamic analysis of reciprocating compressor	Efficiency of reciprocating compressor
6	Design and analysis of piston for two stage reciprocating air compressor	Bore diameter of piston concludes the air discharge rate
7	Design, Analysis and Optimization of three aluminium piston alloys using FEA	Piston material (Al-GHS 1300 alloy)
8	Analysis and optimization of connecting rod using AlSiC composite	Material for connecting rod (AlSiC)

9	Piston design and analysis by CAE tools	Tolerance limit
10	Stress Analysis of Piston Using Pressure Load and Thermal Load	Safe conditions for piston design
11	Design and Analysis of 4-stroke diesel engine	Frequency and vibration analysis
12	A method to estimate the performance of reciprocating compressors	Cooling capacity
13	Design and Analysis of Cooling Fins	Thickness and Al6063 material of fins
14	Calculation and design of flywheel for small and medium compressors	Equations for flywheel

IV. CONCEPT

Here the concept is based on the theory of Bull Engine or pump pendulum mechanism. In this engine there are two cylinder linearly attached with four bar chain mechanism. There are motion converted from rotary to reciprocating. In figure1 shown that there are two cylinder, Crank, Connecting rod and links.

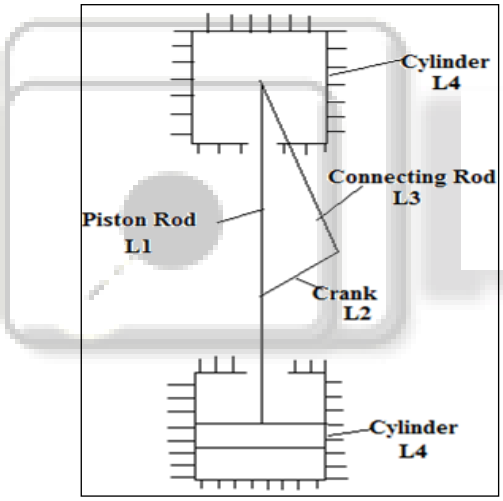

Fig. 1: Pump Pendulum Mechanism

V. PROPOSED FINAL DESIGN

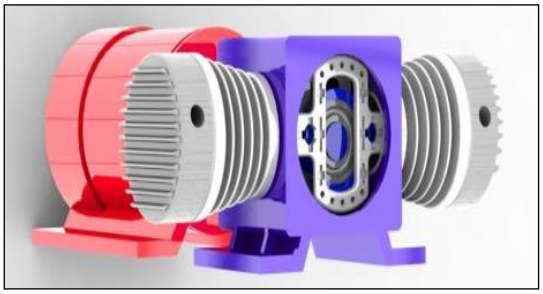

Fig. 2: Final design

VI. CONCLUSION

With compare to existing design of air compressor, this design managed linearly like bull engine type. Advantage of this design is, it is compact design, lower power consumption and higher efficiency. Below table shows that comparison between existing Ingersoll-Rand model and proposed design of new non-lubricant compressor based on FAD and power requirement, finally it saves 9.09% in power consumption and with increment of 8.5% of FAD.

Model	FAD(CFM)	Motor Power(Hp)	Space WxDxH	No. of stages
IR PB4-270-3	21.2	5.5	500x1500x1100	Double
Proposed Design	23 (8.5 % more)	5 (9.09% less)	650x815x270	Single

Fig. 3: Comparison between V-type vs. this design

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