Optimization of Clearance Volume for Performance Improvement of Reciprocating Compressor

Jayesh Patil, Rajkumar Bhagat

Abstract: The paper addresses to engineers who do design and optimization work in the field of reciprocating compressors. In this paper theoretical and exact contemplations are given which permit to foresee the valve misfortunes. Suction valve misfortunes are additionally bring about a decrease of limit. The most effective part in the development of a reciprocating compressor depends strongly on improvement of its performance. For this purpose, a performance characteristic evaluation of a two stroke reciprocating air compressor is carried out in this paper. By and large stream misfortunes of compressor valves are affected by the valve geometry as well as are intensified by valve pocket misfortunes. The aims were to improve compressor performance by illustrating the effects of various parameters such as clearance between head and piston, stroke length, friction losses, compressor running time, background working condition and air leakage. The effect of each parameter was compared with given performance condition and after it was demonstrated the most important parameter on the performance. The parameter was measured using three techniques. The experiment addressed some factors that led to the inefficient performance of the reciprocating compressor air system and cause energy losses. The results advocate the optimal time for starting time of starting each stage of the two–stage reciprocating compressor. The work in addition may give a insight for the development of the design of multi-stage compression and presents some key design parameter.

Index Terms: Performance, Volumetric efficiency, compressor valve

I. INTRODUCTION

The compressor valves are the most critical and effective component in a reciprocating compressor, because of their effect on the efficiency (horsepower and capacity) and reliability of the compressor. Compressor valves are devices placed in the cylinder to permit or allow one way flow of gas either in or out of the cylinder. There must be one or more valves for inlet and discharge in each compression chamber (cylinder end). Compressor valves are nothing more than check valves, but they are required to operate reliably for about a billion cycles, with opening and closing times measured in milliseconds, with no leakage in the reverse flow direction and with low pressure loss in the forward flow direction. To make matters worse, they are frequently expected to operate in highly corrosive, dirty gas, while covered in sticky deposits.

Compressor valves affect performance due to the pressure drop caused by flow through the valve; the leakage through the valve in the reverse direction and the fact that the valves do not close exactly when an considering ideal valve.

Following factors affect both the capacity & power of the compressor,

a) Due to its inertia, the valve does not open instantaneously.
b) Due to the springing, the valve does not stay at full lift for the full time it is open
c) The valve does not close exactly at the dead centre.
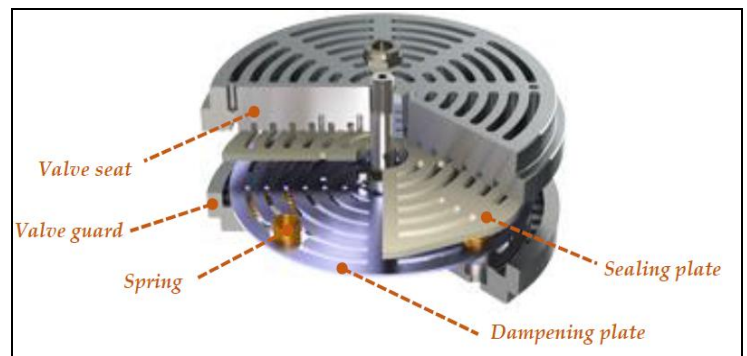

Fig.1 Plate Valve

Basically, an automatic compressor valve requires only three components to do the required work:

1. Valve seat
2. Sealing element
3. A stop to contain the travel of the sealing element

However, a valve comprising only the above components installed in a modern compressor would not fulfil the expected life and efficiency requirements.

Modern compressor valves either incorporate or exhibit the following:

1. Large passage area of valve and good flow dynamics for low throttling effect (pressure drop)
2. Low mass of the moving parts of valve for low impact energy
3. Quick response to low differential pressure
4. Small outside dimension to allow for low clearance volume
5. Low noise level
6. High reliability factor and long life.

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lessening of the mass stream rate. In view of this planner needs to comprehend the dynamic conduct of such a valve. In this paper, numerical and exploratory examinations are done to evaluate the impact of principle parameters of the suction valve on the general execution of the blower. Utilizing the AVL BOOST, a CFD programming program the thermodynamic cycle count is performed. Entire blower space between shell channel and outlet is secured by figuring model. Utilizing an equal spring-damper mass framework, dynamic valve removal is determined. The investigations are affected on a calorimetric test seat.

Aditya Bhakta [6] demonstrates the work straightforwardly relates valve elements to the blower vitality productivity. Past investigations lessening weight misfortunes because of valve geometry, towards improved blower execution is increasingly engaged. All encompassing valve advancement system is finished by breaking down the valve 'shudder' prompts a. Generally, weight incited reed valves is utilized in responding hermetic blowers on the suction and release ports. A normal for these valve task during a solitary suction and release beat they have the numerous opening and shutting movements. This is progressively significant for the suction reed thinking about the more extended (wrench point) term of the suction procedure. In the present work, the reed valve elements has been changed over to rearranged single level of opportunity spring mass framework and is caught by a scientific model inside a 15% precision go for dislodging expectation. Thinking about the present phase of advancement, this is inside adequate breaking points. In-blower valve lift estimations (direct strain check estimations) in a shut circle refrigeration apparatus have been utilized to approve this model, in-blower valve lift estimations (direct strain check estimations) in a shut circle refrigeration apparatus have been utilized. As multifaceted nature and time included is considered with the in-blower estimations, a rearranged system to describe the elements of reed valves outside the blower (roundabout estimations) has additionally been proposed and created. Since the premise of this investigation is examining the trademark valve elements, material science based exchange capacities can make an interpretation of these estimations to the genuine blower reed movement prompting a quicker plan cycle. Likewise To give a nitty gritty knowledge to the stream material science, CFD has been utilized. With the majority of the above data sources, utilizing scientific models distinguishing key plan parameters and assess calculated structures towards a perfect/picked valve reaction.

Gustavo C. Rezende [7clarified spillage through valves can essentially decrease the volumetric and isentropic efficiencies of blowers. In spite of its significance in blower structure, the dimensional portrayal of spillage holes is certainly not a minor errand. In this paper, creator built up a joined trial numerical technique to assess the spillage hole of blower valves. By means of constatnt volume technique estimations of spillage were done, which is generally utilized in the investigation of gas course through small scale channels. Furthermore with a one-dimensional stream model, forecasts were gotten, considering thick contact, slip at the dividers, and gas compressibility. To coordinate the expectation of estimations of spillage for various weight contrasts the spillage hole was balanced in the reenactment

model. For the investigation of three valve structures of refrigeration blowers same technique was connected.

R. E. Drews [8] demonstrates that consistent want to limit machine vacation while getting crest execution of the hardware is the target of each producer and end client. One part of responding blowers Which has a characterize influence on both of these is the blower valve. The creator surveys the advancement program of a responding blower valve that conveys a more drawn out normal life proportion alongside an expansion in the valves stream coefficient.
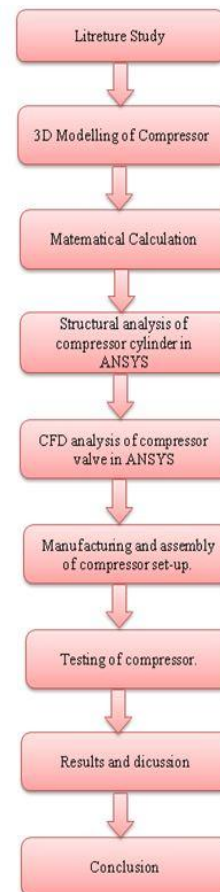
V. METHODOLOGY

Fig.2 Methodology

VI. MATHEMATICAL CALCULATIONS

A. *For piston displacement,*

$Pd=[\pi/4xD^2xSxRPM]+[\pi/4(D^2-d^2)xSxRPM]$
$Pd=16.89$ m^3/min

B. *For volumetric efficiency,*

$\eta_v=[LF-(\% clearance/100)x\{(P2/P1)^{(1/\gamma)}-1\}]x100$
$\eta_v=80.58\%$

C. *For free air delivery,*

$FAD= [Piston displacement x Volumetric efficiency]/100$
$FAD= 13.61$ m^3/min

D. *Cylinder thickness,*

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1. Lame's Equation

$$t = \frac{Di}{2} x \left[\frac{(\sigma t + Pi)^{\frac{1}{2}}}{(\sigma t - Pi)^{\frac{1}{2}}} - 1\right]$$

t = 9.84 mm

2. Chlumsky Equation

$$t = \frac{(Pi \ x \ Di)}{(2 \ x \ \sigma t)} + a$$

t = 10.52 mm

E.   Valve lift calculation,

$$V_B = \frac{\pi \times N}{30} \times h$$

h = 1.4 mm

F.   Pressure drop

$$p_f = 0.4 \times q_{sv} \times p_s$$

P$_f$ = 0.028 bar

G.   Power loss

$$P1 = \frac{(V_H xn)^3 x\rho_s x\lambda_a{}^2}{A_{eff}{}^2} x(1-\varepsilon)x[1 + 0.85(PF-1)]x[1 - (0.7x\lambda_a xM_a)^2]$$

P1= 619.59 W

Total valve loss is 2.2%

Table 1. Material Properties

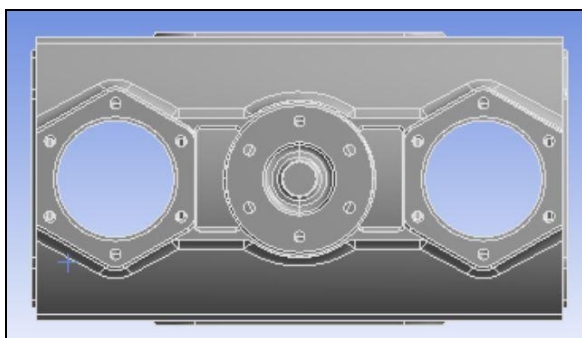| Parameter	Value	Unit	Notation
Tensile Strength	300	Mpa	Sut
Young's Modulus	1.28E5	Mpa	E
Density	7250	Kg/mm 3	ρ

Allowable stress for FG 300 Material= 67.5 Mpa

Fig 2. 3D model of cylinder

VII.   POSTPROSESING RESULTS
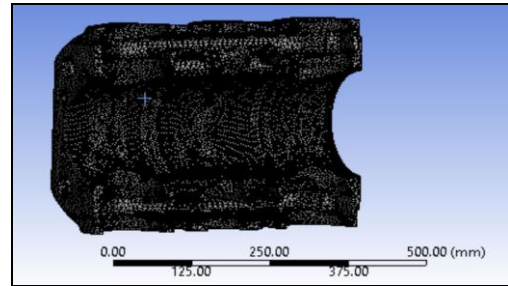
A.   Cylinder

1. Meshing
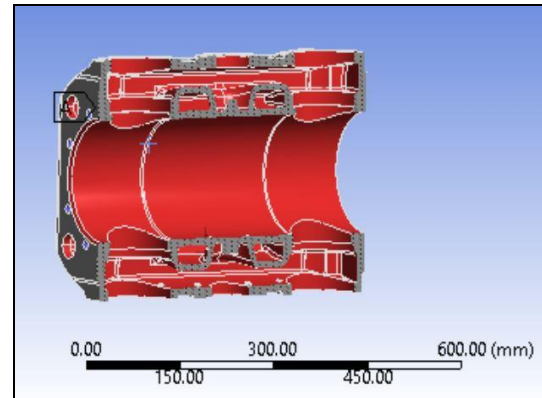

Fig 3. Meshed model

2. Boundry condition

Fig 4. Boundary Condition

For cylinder boundary conditions are at one end it is fixed and at inside the cylinder there is air pressure and at outside in water jacket there is water pressure
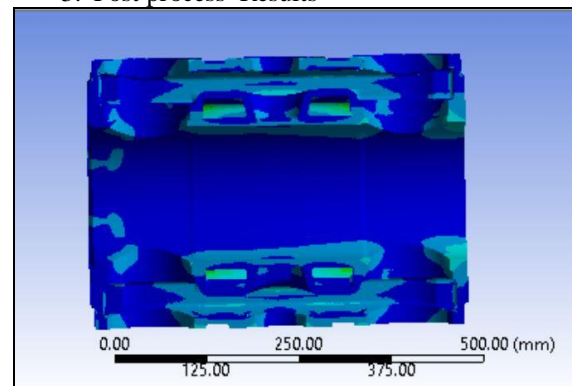
3. Post process Results

Fig 5. Postprocess Results

The maximum deformation comes at the water inspection plate 0.12 mm due to water pressure.
The maximum principle stress comes out 40.21 Mpa which is less than allowable stress 67.5 Mpa.
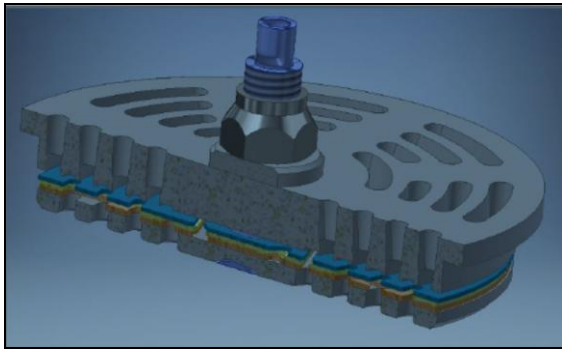Therefore design is safe.

B.   *Valve*

Fig 6. 3D Model Of Valve
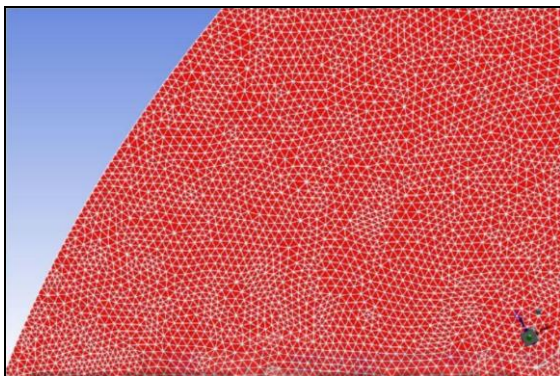
1. Meshing

Fig 7. Meshed Model

For valve the element size is 0.3 mm due to its small clearance or gap for passing of air.
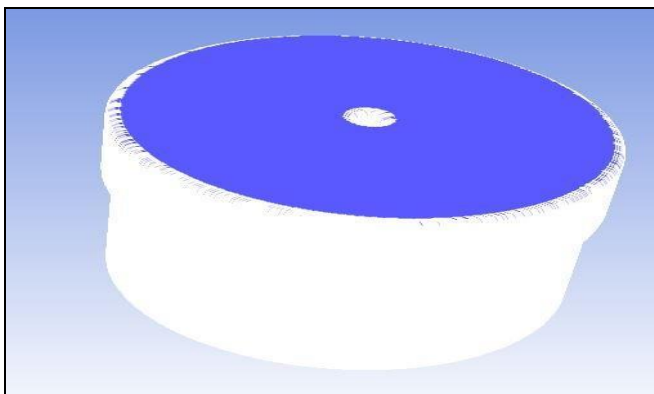
2. Boundary condition

Fig 8. Boundary Condition

For valve inlet we put velocity of air while entering the valve and at valve outlet we put velocity of air while laving the valve.
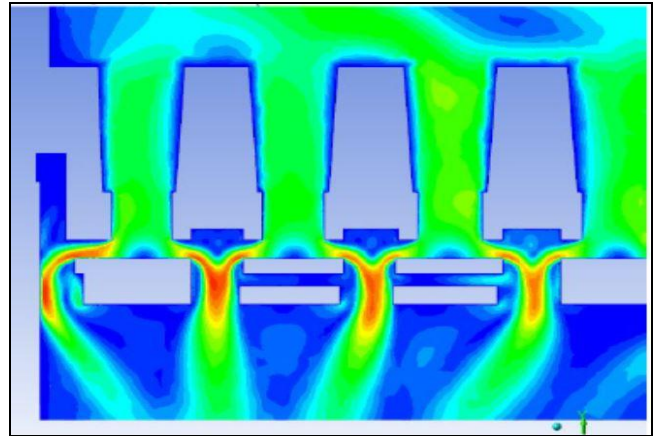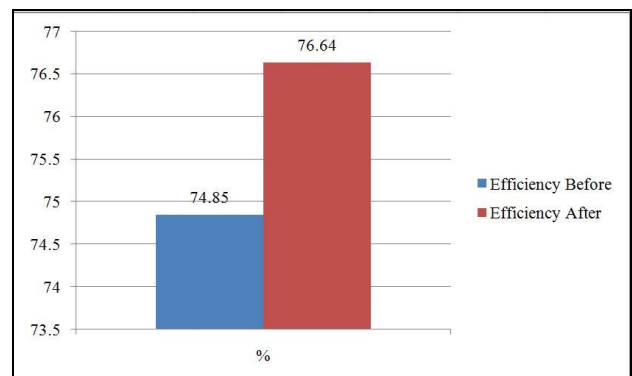
1. Postprocess results

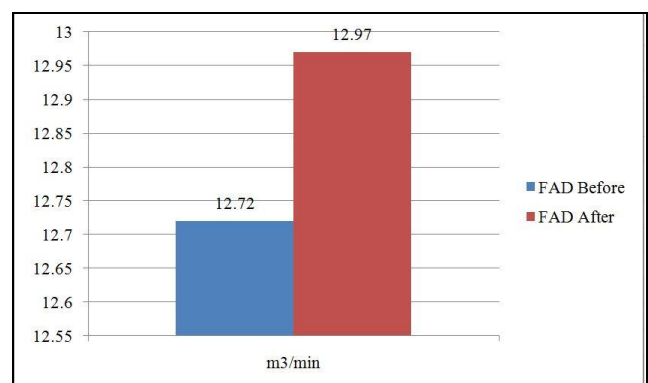

Fig 8. Postprocess results

From the results and above figure bar 1 shows analyticle calculated velocity of air is 19.36 m/s

From the results and above figure bar 2 shows the FEA calculated velocity of air is 19.2 m/s
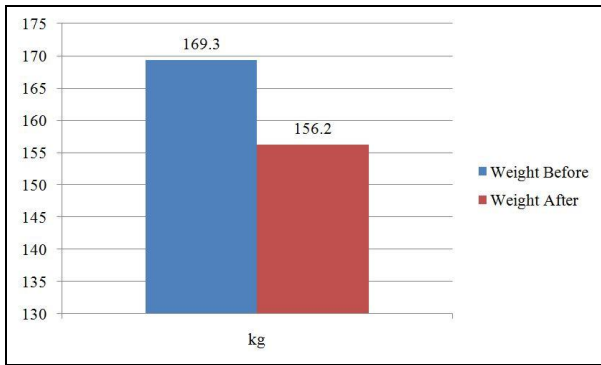
VIII. RESULTS
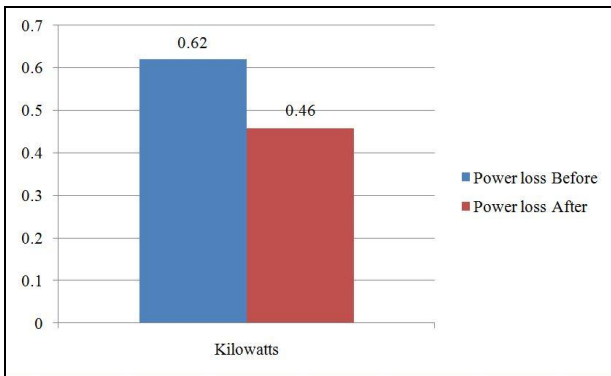
1) Volumetric efficiency:
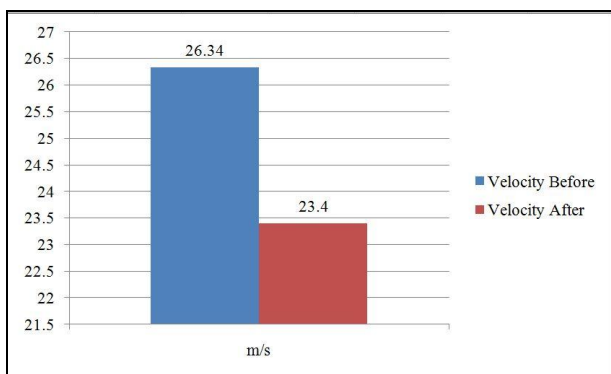

2) Free air delivery (FAD)
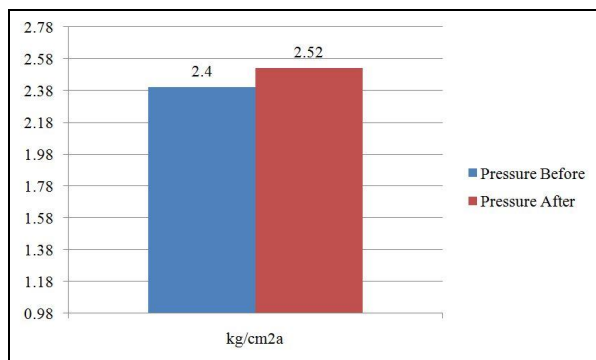

3) Weight optimization

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4) Power loss in valve

5) Velocity difference in valve

6) Pressure difference

IX. CONCLUSION

The results observed during this analysis are within range with similar available existing results and governing standards. The following points can be concluded from the results observed during this study.

1. Due to optimization of clearance volume volumetric efficiency increased by 1.79 %
2. Due to optimization of clearance volume FAD increased by 1.92 %
3. Due to optimizing the thickness of cylinder the weight of cylinder reduced by 7.73 %
4. Due to optimized valve lift velocity reduced by 11.16%
5. Due to optimized valve lift power loss reduced by 0.16 kilowatts
6. Pressure is increased by 4.76%

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