Optimization of Reed Valve Based on The Analysis

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Abstract- *In this research paper the reed valve assembly has been simulated considering the complex fluid interaction phenomena occurring during discharge flow of scroll compressor. This project will mainly focus on determining basic valve geometrical parameters with desired mass & stiffness of the reed valve as design constraints. To obtain optimum reed valve finite element model has built that searches for geometrical parameters which meets both target valve parameters and material limitations for reliability and life. The reed valve of a refrigeration compressor is modelled; the natural frequencies, displacement and stresses have been evaluated. Static load, dynamic load and boundary conditions on the valves are discussed. Internal CAD software has been used to generate the 3D model of the reed assembly and general purpose finite element code is used to simulate the reed dynamics. This project focuses on optimizing the reed valve such that it will sustain at dynamic pressure at various working conditions in refrigeration system & confirms the reed valve is effectively working under impact loading and does not cause of crack due to fatigue.*

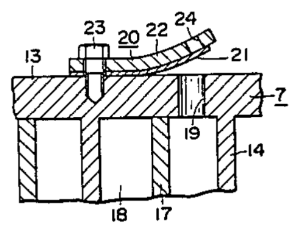
Keywords- Reed, Scroll, reliability, fatigue, Impact

I. INTRODUCTION

Traditionally, pressure actuated reed valves have been used in refrigeration compressors on the discharge ports. A characteristic of these valve operation is the multiple opening and closing motions, during a single suction and discharge pulse, often referred to as the ‘valve flutter’. The compressor efficiency is directly proportional to the amount of pressure losses associated with suction or discharge process. Valve operation is relating with the losses during overpressure and under-pressure processes. Essentially, the design of reed involves material selection, operating values and geometry design. Reed valve design is and intermediate between best performance and better reliability and it is expected to be an optimum [3].

Dynamic mass of the valve and its stiffness regulate the transient response (valve flutter) which affects life and reliability of the valve in operation. The design of the reed valves involves determining the geometrical parameters like length, width, radius and thickness and material properties. This is of particular interest to refrigeration compressors having a high discharge pressure [3].

Reed is a dynamically operated valve & due to impact fatigue it has been observed that primary crack origin sites at the early edges of reed and fatigue crack growth. Some of the valves lost the small fragments from the outer edges where the valve impacted against the seat. In some cases the fracture was propagating straight in the radial direction. However in both cases the radial orientation of primary fatigue cracks was established. A typical fracture due to cyclic impact stress is when small fragments are torn off from the edges, which is usually termed as edge chipping. [12]



Bill Of Material	
Item	Description
7	Fixed Scroll
13	End Plate
18	Gas pocket
21	Leaf Valve
22	Reinforcing Plate
23	Bolt

Figure 1: Typical Reed valve assembly [14]

II. PROBLEM DEFINITION

It has been observed that reed fractures at the tip location of the reed and it is on the edges locations, these fractures show characteristics of impact fatigue, seen in Figure 2[12]. Fractographic examinations detect primary crack region & besides the performance, a valve should also last till designed life which is indicated by root stress, fatigue strengths and impact velocity. Typically, valve materials have high tensile strengths and endurance limits. Also, in a study conducted by Sandvik (Svenzon, 1976)[10] it was shown that over the period of time, valve surface near the ports shows pitting. This type of damage compromises the structural integrity of the reed valve and leads to severe leakages around the valve. The same study correlates the damage on the valve to its impact acceleration and suggests a limiting value for this acceleration [3].

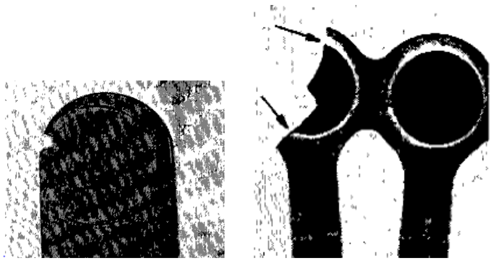


Figure 2: Damaged valve at Tip Fracture [12] [15]

III. OBJECTIVE

The valve design goal is to arrive at a set of optimum valve parameters like thickness that helps in minimizing losses associated with valves, maximize flow rate into and out of the compressor while retaining its performance and life of a compressor. The design encompasses the mechanism and gas dynamics which provide a framework for finding the valve parameters that give the best performance & efficiency. Below are the design parameters listed that will dictate the optimal design of the reed valves.

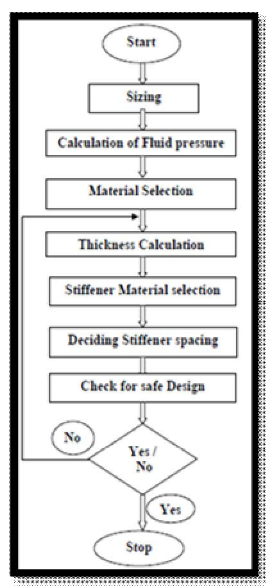
Parameters	Measure
Pressure loading across the valve	ΔP
Impact velocity	±5%

IV. LITERATURE REVIEW

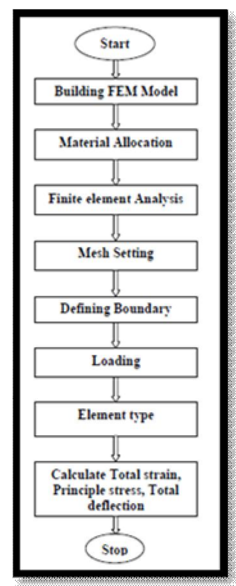
Akenmi Futakawa suggest that the reed impact fatigue is dominated by reed closing velocity [1] Strategic strain measurements were calibrated to a centralized reed displacement point. The first derivative, with respect to time, was taken to quantify velocities at the tip of the valve. From the literature review, impact velocities greater than a significant reduction in fatigue life and was selected as the upper limit for acceptable impact velocities. (Soedel, 1984; Svenzon, 1976; Dhar, 1988). Although much effort has been paid to find early stage of crack initiation, crack propagation and final failure, the mechanism for edge chipping is still not clear (Svenzon, 1976; Dhar, 1988). The earlier work considered that edge chipping occurs when two cracks propagate close to each other (Svenzon, 1976). This was observed that crack initiation occurred between the impact area and the edge of reed, and these cracks radially propagate towards the impact area and the edge. However, it is not considered the action of the shear stress induced by the repeated impact stress. It was also identified that chipping of edge when impact fatigue grows and gets sheared off [1]. Considerable efforts have been taken to come up with higher performance strip valve (Olsson, 1992; Auren and Chai, 2002). R. Dusil, B. Johansson, Influence of Seat Positioning and Seat Design on Valve Fatigue Performance (1980) [12] has derived the relation between the impact intensity against the valve seat area. An increased seat width, i.e. contact area resulted in a higher fatigue performance of the valve reed. [12]

V. METHODOLOGY

This project focuses on reed valve behavior under compression cycle with the simulation and suggest design improvements if any. FEA is validated with forces acting on the reed with respect the crank angle position & numerical calculations have been performed and then validated with the internal general purpose finite element code. In order to evaluate the valve sensitivity, a FEA model that includes reed, valve plate and retainer of compressor and their interactions has been developed. The model encompasses the reed and gas dynamics which provide a framework for finding the impact velocity that give the best efficiency.



Analytical Calculations



FEM Model

VI. ANALYTICAL CALCULATIONS

Width	b
Length	L
Density	ρ
Modulus of Elasticity	E
Mass of Strip	M
Shear Modulus	G
Total Impact area:	$A = W(0.8L + b)$
Lift @ end	w
Tip displacement	X
Natural Frequency	ω
Tip Velocity	$v_0 = X^*\omega(\sin \omega t)$
Longitudinal Wave Velocity	$C_1 = \sqrt{E/\rho}$; $C_2 = \sqrt{G/\rho}$
Shear wave velocity	C_i
Time require to travel wave	$t = \frac{L}{Ci}$
Initial Stress	$\sigma_0 = v_0\sqrt{E\rho}$
Damped Stress	$\sigma = \sigma_0 e^{-tA\sqrt{E\rho}/M}$

Tip velocity has been calculated based on the frequency & deflection at opening and closing cycle of the valve. Analytical data has been compared with the FEA data and only 10% of variation has been found and it is within acceptable range.

VII. METHOD OF ANALYSIS

3D CAD model is created in internal CAD software to define the functional dimension analysis and fit function analysis.

Reed is fully constrained **Boundary conditions:**

1. at the retainer base
2. Insert is fully constrained where it contacts the casing and symmetric boundary conditions are applied to the section face.

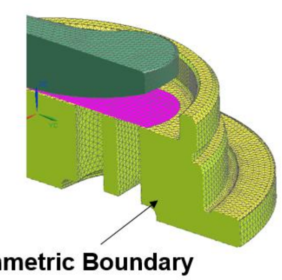


Fig 6. Meshing of Reed

The loads are applied as follow:

- Pressure pulse is applied on reed statically & dynamically to quantify the ratio of static & dynamic deflections and stresses.
- Contact conditions are assigned between the reed and retainer, and between the reed and valve plate.

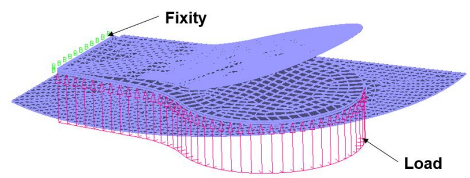


Fig 7: Loading & Boundary Condition

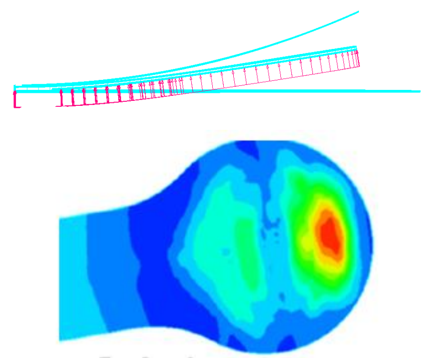


Fig. 8: FEA Simulation stress distribution

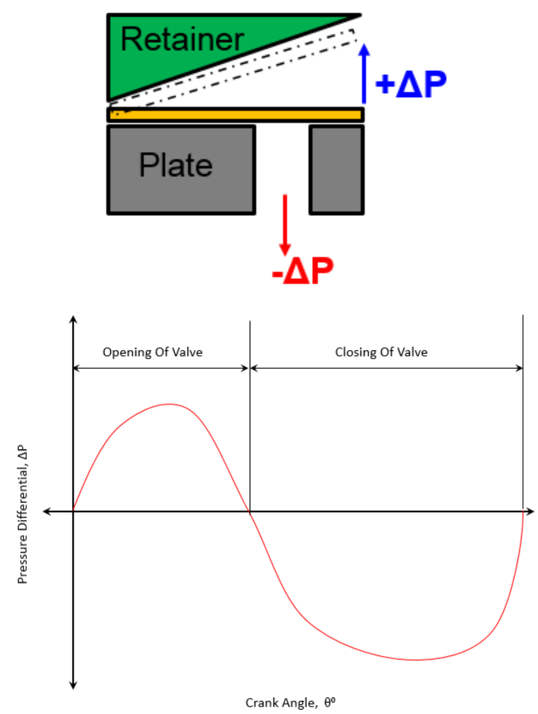


Fig 9: Reed displacement

Finite Element method (FEM) analysis of the reed used for identification of displacement of reed against the pressure differential. It is analyzed for natural frequency, mode shape by FEA tool. The solid model made by internal

CAD software. Internal FEA simulation tool is used for fatigue analysis with the natural frequency of the component. The fatigue analysis is done to find out the maximum displacement of the component about the different crank angle location with respect to the time.

VIII. RESULTS AND DISCUSSION

1. Comparing the analytical calculations and FEA results those are matching very closely and only 10% variation has been found and which is acceptable limit. Peak stresses are developed at the edge of the reed due to high impact velocity.
2. Fracture is occurring at the lower stress areas due to excitation of higher order bending modes and valve does not open completely and moves freely between closed and open position. A systematic approach of shape mode of reed valve assembly components has been studied at higher operating condition.
3. Experimental data and FEA data match for the derived frequencies at different crank angle position of the scrolls. Fatigue analysis results found that the natural frequency at the tip of the reed occur when reed sits on the valve plate.

IX. CONCLUSION

1. Higher tensile strength reed materials have limited ability to deform plastically and relieve the stress concentration.
2. The deflection of reed at various crank angle verses stresses give rise to plastic deformation in the material and can initiate fatigue crack.

X. FUTURE SCOPE

From the impact fatigue analysis scope to optimize the reed found that it is safe at the high velocity and at high frequency. The experimental validation will be done on the new reed concepts and the correlation will be verified with number of iterations based on CAE and experimental results.

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