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S. O. Cho
Goldstar Company

S. K. Park
Goldstar Company

H. S. Kim
Goldstar Company

J. Y. Lim
Goldstar Company

A STUDY OF VALVE DESIGN PROCEDURE IN HERMETIC COMPRESSOR

S.O. Cho, S.K. Park, H.S. Kim, J.Y. Lim
CONSUMER ELECTRONICS RESEARCH LAB.
GOLDSTAR CO., LTD., SEOUL, KOREA

ABSTRACT

Suction and discharge valves of special type refrigerant compressor are designed by finite element method for effective valve design development procedure. It is well known that valve dynamic characteristics, for example, the natural frequencies and vibration modes, are necessary for the computer simulation of compressor valve dynamics, the analysis of flow patterns, noise, impact stresses and their propagation phenomena. This paper has analysed the natural frequencies and vibration modes for the first three orders under the given special boundary conditions and the experiments are conducted by laser holography. And also stress distribution is analysed and experiment by strain gage is followed.

INTRODUCTION

The preliminary design of valves in a hermetic compressor depends on the shapes of valve ports and a cylinder block. And under these confined geometries, the valve is needed for having a good responsibility and reliability to perform continuous operations. So, it is most important to predict the dynamic characteristics and stress distribution of the compressor valve.

During the last two decades, there has been a rapid development of mathematical models,for using a computer, to simulate compressors and provide an aid to the design of these components.

G. C. Griner et. al.[1] showed static and dynamic analysis of valves with finite element methods. S. Papastergiou et. al.[2][3] studied analytical and experimental dynamic analysis of valves. R. Cohen et. al.[4] performed experimental analysis of valves measured by strain gage.

The purpose of this paper is to present a computer based design procedure and describe its use as a valve design tool. This paper presents dynamic and stress analysis predicted by finite element method to compare with experimental results measured by laser holography and strain gage.

FINITE ELEMENT ANALYSIS

The finite element method is widely used to perform the static and dynamic analysis of valves. This method can accommodate modal characteristics.

1. Modal Analysis.

The basic purpose of modal analysis is to determine dynamic characteristics of valves by obtaining natural frequencies and mode shapes. The second purpose is to establish a data base for noise and stress analysis. In order to identify peaks in the sound pressure spectrum of a compressor,knowledge of the natural frequencies of the valve reeds will be neccessary. Through the use of the mode superposition method and a compressor simulation, a detailed valve motion and stress history can be calculated. The third purpose is to provide a data base for a later computer simulation for the purpose of predicting if and how it will interact with gas pulsations when it generates.

In this paper, FEM package is used for modal analysis. Valves are modelled in thin shell elements. Fig.1 and Fig.2 show the finite element models of valves including boundary conditions. And first 3 modes are extracted from these results.

2. Stress Analysis

Stress levels during compressor operation are an important concern for a valve designer. It is assumed that the gas drag force due to the pressure difference across the valve over the port suppresses only at the port area. Valve stopper is considered to limit the displacement of contact nodes. The static displacements and principal stresses for suction and discharge valves were computed.

EXPERIMENTS

1. Holographic Interferometer

The holographic interferometer is used to measure the natural frequencies and mode shapes. Experimental analysis using holographic technology which has high accuracy and non-contact characteristics is useful for experimental approach of thin plates such as compressor valves.

Basic principle of holography is illustrated in Fig.3. The hologram is a photographic recording of the pattern of interference between two beams, one of which is characterized by reflection from, or transmission through, a subject. The other is an analytic beam, collimated, diverging spherical, or converging spherical. These two are usually called the subject and reference beams, respectively.

Test valves are excited by speaker,and exciting signal which is fed to speaker is amplified from signal generator. To compare with the results between analyses and experiments, valve fixture is prepared to fit to the boundary conditions, which is illustrated in Fig.4.

2. Strain Gage

Electrical-Resistance strain gages are normally employed on the free surface of a valve to establish the stress at a particular point on this surface. Strain gage attachment is fitted to principal stress axis from analytic results. Strain gage used in experiment is KFG-5-120-C1-11 type.

For the purpose of comparison with analytic results, compressed air is fed to the test setup which is almost identical with real operating condition of compressor. Fig.5 is schematic diagram of an experimental apparatus.

RESULTS AND DISCUSSION

1. Modal Analysis and Experimental Results using Laser Holography

Fig.6 and Fig.7 show the dynamic characteristics of the suction valve which are obtained by FEM and laser holography. 1st and 2nd mode shapes are the typical bending modes, 3rd mode shape the twisting mode. The fringe in laser hologram represents more displacement than just the fore fringe by the reference scale.

Fig.8 and Fig.9 show FEM and experimental results on the discharge valve. The discharge valve is different from the suction valve, in that 1st, 3rd mode shapes are the bending modes and 2nd mode shape the twisting mode because of the increase in width to length.

Table 1 shows that there is good agreement between the fundamental,2nd and 3rd natural frequencies predicted by FEM and measured by laser holography.

2. Stress Analysis and Experimental Results using Strain Gage

Fig.10 shows calculated results of stress analysis of the suction and discharge valve. From the FEM analysis results, it is convinced that stress concentration point is placed at root of the valve geometry,so a valve must be designed in such a way as to avoid stress concentrations, i.e., small radius, sudden change of area.

For the stress analysis, there is good agreement between FEM analysis and experimental results which measured by strain gage in Table 2.

CONCLUSION

Dynamic and stress analyses of valves are carried out and several experiments are conducted. There is good agreement between computed and experimental results. Therefore, this design procedure by analyses and experiments will be useful for future valve design.

REFERENCE

1. G. C. Griner, G. W. Gatecliff, H. Richardson, "Static and Dynamic Analysis of Reed Valves Using a Minicomputer Based Finite Element System," Proc. of 1980 Purdue Compressor Tech. Conf., pp.172-175.

2. S. Papastergiou, J. Brown, J.F.T. MacLaren, "The Dynamic Behavior of Valve Reed in Reciprocating Gas Compressor-Analytical Study, " Proc. of 1980 Purdue Compressor Tech. Conf., pp.263-272.

3. S. Papastergiou, J. Brown, J.F.T. MacLaren, "The Dynamic Behavior of Valve Reed in Reciprocating Gas Compressor-Experimental Study, " Proc. of 1980 Purdue Compressor Tech. Conf., pp.273-275.

4. R.Cohen,"Valve Stress Analysis-for Fatigue," Proc. of 1972 Purdue Compressor Tech. Conf., pp.129-135.

5. D.N. Lal,"The Use of Finite Element Method for Stress Analysis of Compressor Valves," Proc. of 1978 Purdue Compressor Tech. Conf., pp.203-208.

6. A. Futakawa, K. Namura, G. Hironori, "Deformation and Stress of Refrigeration Compressor Flexible Ring Valve, " Proc. of 1978 Purdue Compressor Tech. Conf., pp.195-202.

7. J.R.Friley, J.E.Hamilton, "Characterization of Reed Type Compressor Valves by the Finite Element Method," Proc. of 1976 Purdue Compressor Tech. Conf., pp.295-301.

8. P. M. Weir, "Analysis of Failure of Compressor Multi-ring Valve Plates," Proc. Institution of Mechanical Engineers, 1979, Vol.2, pp.83-89.

9. W. Soedel,Design and Mechanics of Compressor Valves,Purdue Univ., 1984.

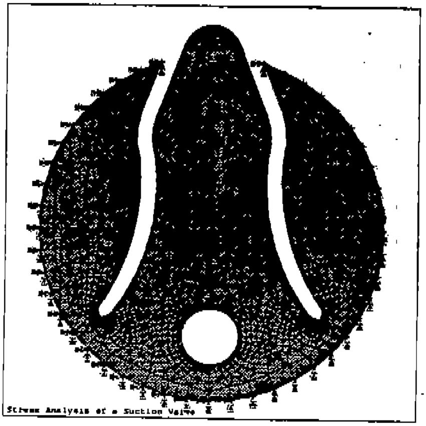


Fig.1 Finite Element Model of Suction Valve

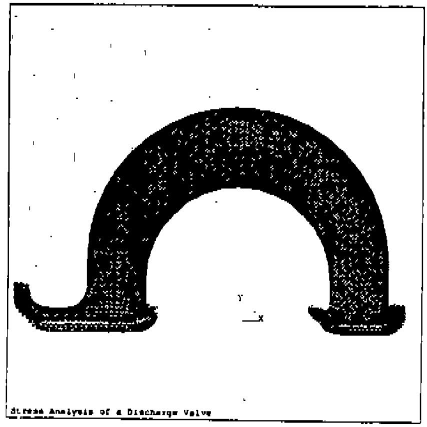


Fig.2 Finite Element Model of Discharge Valve

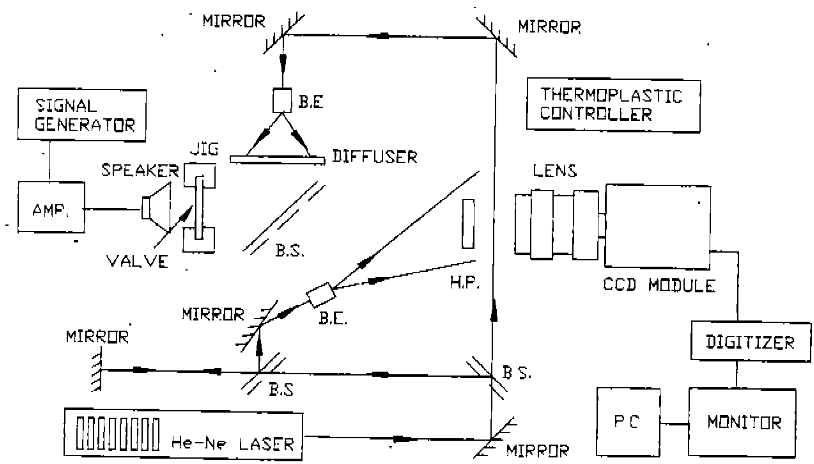


Fig.3 Schematic Diagram of Holographic Interferometer

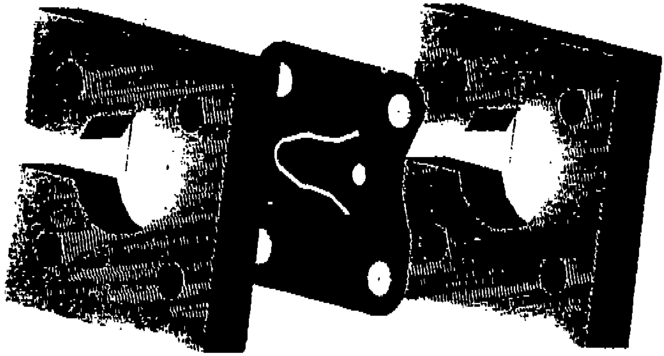


Fig.4 Valve Fixture for Modal Test

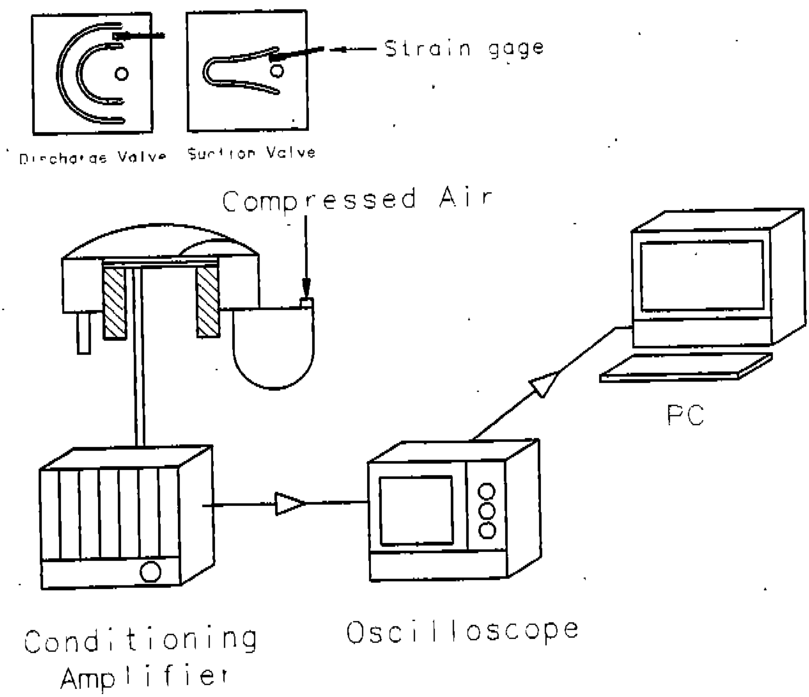
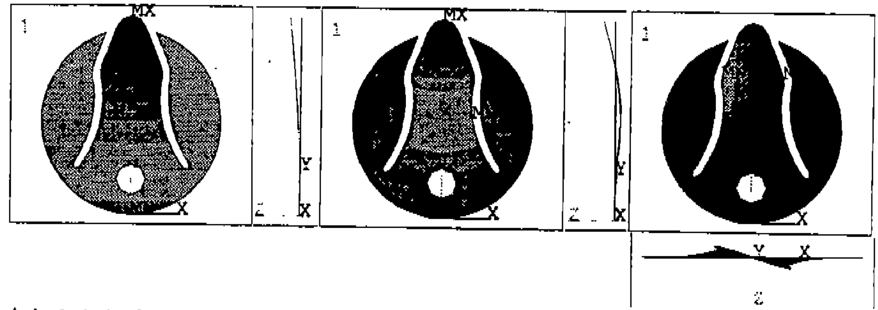


Fig.5 Schematic Diagram of Experimental Apparatus for Stress Measurement

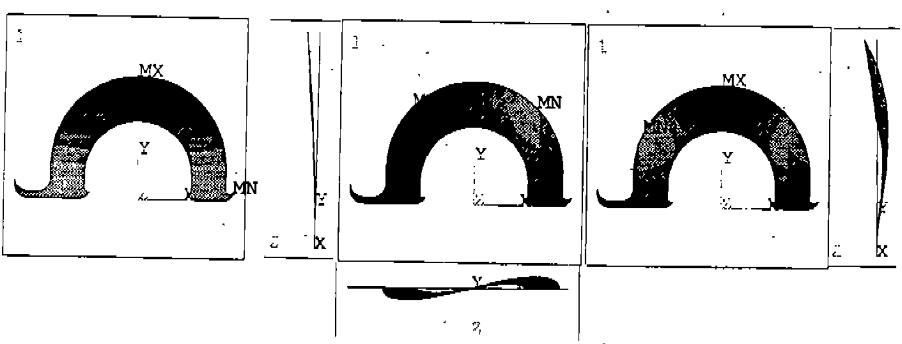


(a) 1st Mode (456Hz) (b) 2nd Mode (2404Hz) (c) 3rd Mode (3020Hz)

Fig.6 Dynamic Characteristics of Suction Valve by FEM

(a) 1st Mode (454Hz) (b) 2nd Mode (2159Hz) (c) 3rd Mode (2865Hz)

Fig.7 Dynamic Characteristics of Suction Valve by Laser Holography

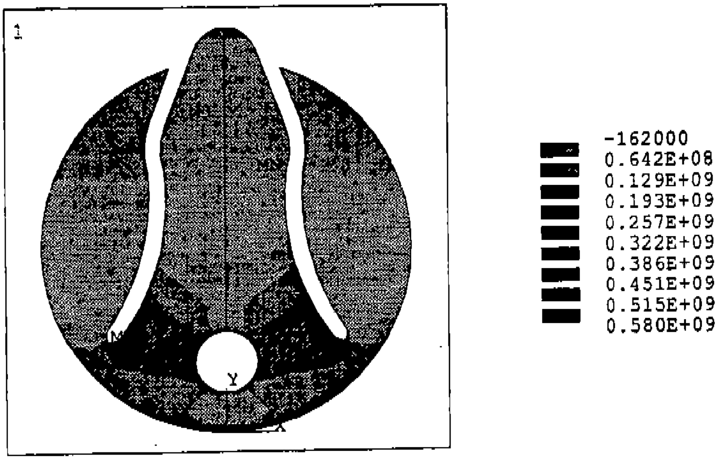


(a) 1st Mode (503Hz) (b) 2nd Mode (1486Hz) (c) 3rd Mode (3224Hz)

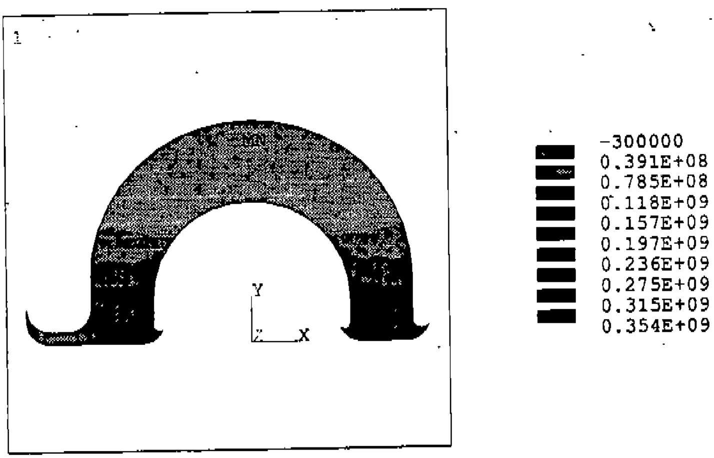
Fig.8 Dynamic Characteristics of Discharge Valve by FEM

(a) 1st Mode (499Hz) (b) 2nd Mode (1375Hz) (c) 3rd Mode (2979Hz)

Fig.9 Dynamic Characteristics of Discharge Valve by Laser Holography



(a) Suction Valve



(b) Discharge Valve

Fig.10 Stress Analysis of Suction and Discharge Valve

MODE	Suction Valve		Discharge Valve	
	FEM	Hologram	FEM	Hologram
1	456	454	503	499
2	2404	2159	1486	1375
3	3020	2865	3224	2979

Table 1 Comparison of Natural Frequencies between FEM and Holography for Valves

		Suction Valve	Dischrge Valve
STRESS	FEM σ_{1max} [N/m²]	0.195×10^9	0.148×10^9
ANALYSIS	Strain Gage σ_{1max} [N/m²]	0.147×10^9	0.110×10^9

Table 2 Comparison of Stress Values between FEM and Strain Gage