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ABSTRACT

The paper describes tests carried out on disc valves in which the valve seat was withdrawn from the valve while a pressure difference existed across the valve. Simultaneous measurements were made of the force on the valve, the pressure in the plenum chamber and the displacement of the seat from the valve. Force measurements are compared with values of force measured during continuous flow conditions at selected values of pressure difference and displacement of the valve from its seat. The comparison may, therefore, be considered as relating the force on the valve during dynamic withdrawal of the seat from the valve to the quasi-steady state force on the valve at corresponding pressures and displacements during steady continuous flow through the valve. It is shown that during the early part of the withdrawal, there are significant differences between the force on the valve and the quasi-steady state force. These differences are accentuated by the pressure difference across the valve and the rate at which the valve is opened. The quartz crystal force transducer being mounted directly on the valve had a sufficiently high natural frequency to be excited by small variations in the force on the valve at high frequencies due probably to vortex shedding at the periphery of the valve. The vortex shedding indicated by the force variations is now being investigated using hot wire anemometry techniques. The resonances or peaks exhibited in this fluctuating component could be due to detachment and re-attachment of the air flow from the valve seat but, equally, could be due to coincidence of the frequency of vortex shedding with the natural frequencies of vibration of the measurement system. Concurrent with this work, investigations are proceeding into the relationship between the force on the valve and the quasi steady-state force under conditions of continuous oscillation of the valve and in the presence of a pressure difference across it.

INTRODUCTION

This investigation is a continuation of the work reported by Brown and Lough (1) on the response of disc valves to rapid pressure changes as applied in a shock tube. The present investigation is concerned with conditions relevant to those obtaining in a compressor. To obtain adequate sensitivity in the force measurement, a quartz crystal transducer was adopted. It is well known, however, that a force transducer performs the function of an accelerometer very adequately since both are basically the same instrument. For this reason it was decided to hold the valve stationary by means of the relatively stiff force transducer and withdraw the seat from the valve. As shown in Fig. 1, a plenum chamber was formed behind the valve seat and a pressure transducer was introduced into the plenum chamber in the usual manner. A pressure gauge tapping was also provided in the plenum. It may be noted that the signal due to acceleration, were the valve to be withdrawn from the seat, would be at least an order greater than the signal due to the gas flow through the valve. The equipment was mounted on a cast iron block to minimise interference effects due to acceleration of the transducer mounting. Nevertheless, some vibration was experienced following impact of the plenum cylinder on its stops after the seat was withdrawn from the valve, with a consequent deterioration in the signal/noise ratio of the force measurement. To minimise this effect a force transducer with identical characteristics was mounted on the underside of the cast iron transducer mounting block. The signals from the two transducers were taken to a common input of a charge amplifier. The signal due to acceleration from the two force transducers thus led to cancellation, except at very high frequencies beyond the range of interest. The lack of cancellation at high frequency was due to a phase shift between the transducer outputs, probably due to a slight non-axial vibration of the cast iron block. The dynamic pressure measurement in the plenum chamber is subject to the same acceleration interference but to a greatly reduced extent. Nevertheless, an acceleration compensated pressure transducer was utilised at this location. It was also found necessary to shield the force transducers against variations in ambient temperature due, for example, to the air stream from the valve. The temperature sensitivity of transducers is important when small signals are being measured.

The plenum chamber was withdrawn from the valve by means of an electro-mechanical actuator assisted by springs. The initial force between the valve and the seat and the rate of withdrawal could be adjusted by means of rheostats in the actuator circuit. A Wayne Kerr capacitive type displacement meter was used to determine the displacement of the plenum chamber. Photographic records were taken from the screen of a Tektronix 7000 series storage oscilloscope. In order that the static and dynamic test results might be totally comparable, the continuous flow or "static" tests were carried out in the apparatus in which the dynamic tests were performed.

STATIC FORCE MEASUREMENTS

The time constants of the charge amplifiers used during the dynamic tests were sufficiently long that steady-state measurements could be made using the same equipment. This further ensured the compatibility of the static tests results with the dynamic tests results. During these static tests, measurements were taken by setting the various parameters - pressure, displacement etc., to their required values. When steady conditions had been obtained, the gas flow was interrupted and the drop in force recorded on the oscilloscope. The family of curves obtained from these tests is shown in Fig. 2. The curves shown were derived from tests made on a valve of diameter 8.40 mm and bore 6.35 mm. A typical cross curve derived from this family is shown in Fig. 3. This curve exhibits a minimum value which is typical of all such cross curves over the entire range of measurement. From these graphs it will be observed that a rigid valve has markedly different characteristics from a flexible reed as reported by Wambsganss (2) since the static curves for such flexible reeds exhibited almost linear across curves. The existence of the minimum in the cross curves is clearly reflected in the dynamic force records.

DYNAMIC TESTS

Owing to the essentially non DC nature of piezo-electric transducer systems, extreme care had to be taken to eliminate the possible effect of time constant on the measured parameters. Accuracy of measurement was ensured by superimposing a zero-force line on the stored record before and after each dynamic test. The coincidence of these zero-force lines demonstrated that no time constant or other movement in the zero-force signal had occurred. The zero-force signal was presented on the oscilloscope screen by the use of a voltage backing-off circuit at the output of the charge amplifier. This enabled adequate resolution of the variation in force to be obtained. Superposition of these records was made possible by use of the multi-trace facility of the oscilloscope employed. Fig. 4 shows a typical record obtained during a dynamic test. The fluctuating component of the force on the transducer is clearly evident as also is the minimum value in the force trace. The zero-force trace is also shown. This, as previously mentioned, is two superimposed traces, one drawn before and one drawn after the main record was taken. Each test was complemented by a test under identical conditions except that no air was flowing. This procedure was adopted to ensure that no acceleration components were present in the records. Fig. 4 through 7 show results derived from dynamic tests with quasi-static force curves superimposed. It will be seen that during the early part of the valve opening process there is a significant difference between the dynamic force and the quasi-static force. This is more marked when there is a high pressure difference across the valve. Examination of Fig. 7 shows that when the valve is opened relatively slowly, the dynamic force curve conforms more closely to the quasi-static force curve. Further examination of this figure shows that at least in the higher pressure ranges, there is some divergence between the dynamic and static curves near the minimum in the force curves.

COMMENTS

The difference between the dynamic force and the quasi-static force at the time when the valve is just leaving its seat is sufficiently large to warrant further investigation along the lines being employed. A preliminary theoretical analysis suggests that the conditions obtaining when a valve is removed from its seat are not significantly different from those obtaining when the seat is removed from the valve. This latter was the method employed during the work reported. However, it is hoped to expand the investigation into the more realistic field of investigation in which the valve moves away from the seat. The difficulties of making accurate comparative measurements are, however, considerably increased for reasons already mentioned in this paper.

ACKNOWLEDGEMENTS

This project is being undertaken at the University of Strathclyde in the Department of Dynamics and Control.

REFERENCES

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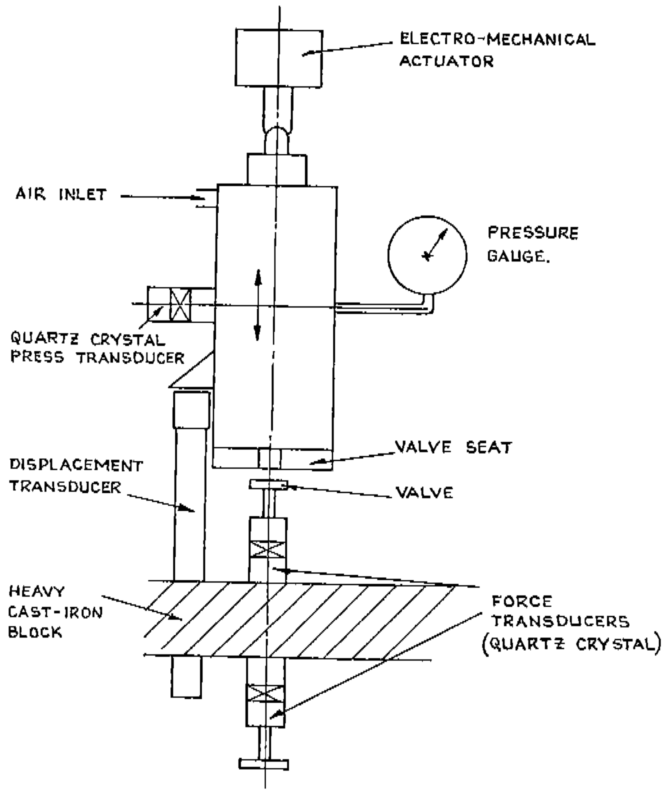

FIGURE 1 Arrangement of Apparatus for Valve Air flow Tests

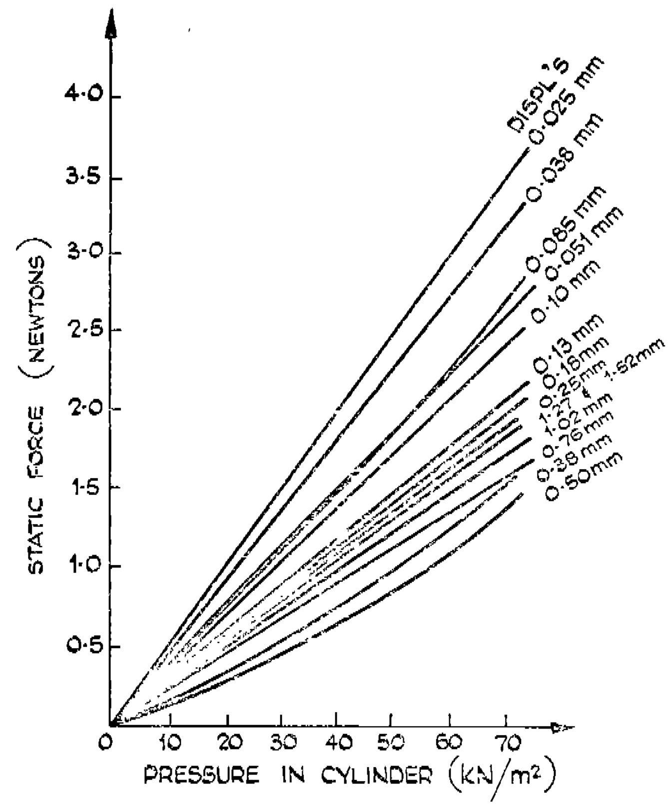

FIGURE 2 Steady Flow Test Results

Valve Disc 9.50 mm OD
Port 6.35 mm bore

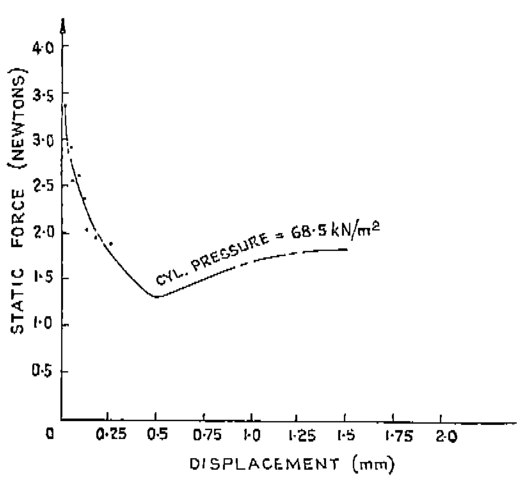

FIGURE 3 Derived Curve from Steady Flow Tests

Valve Disc 9.50 mm OD
Port 6.35 mm bore

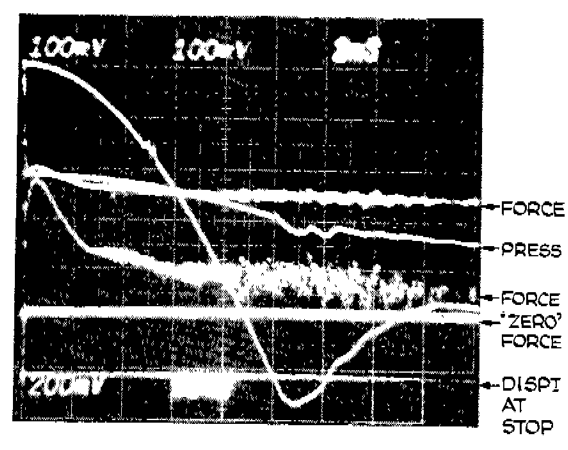

FIGURE 4 Typical Dynamic Flow Test Oscillograms

Valve Disc 8.40 mm OD
Port 6.35 mm bore

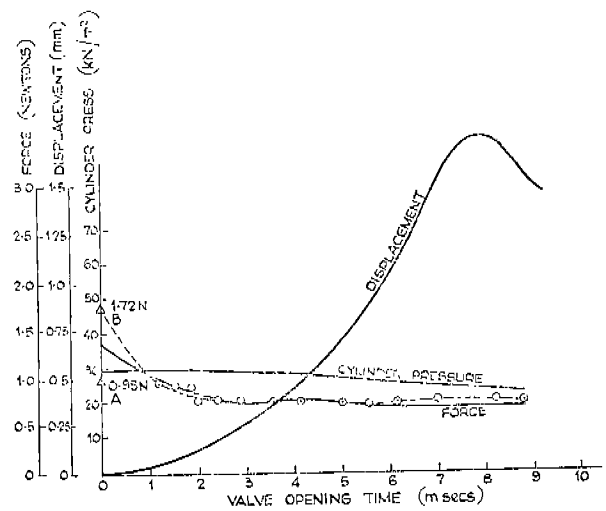

FIGURE 5 Dynamic and Static Force

Valve Disc 8.40 mm OD
Port 6.35 mm bore
Cylinder Pressure 29 kN/m^2

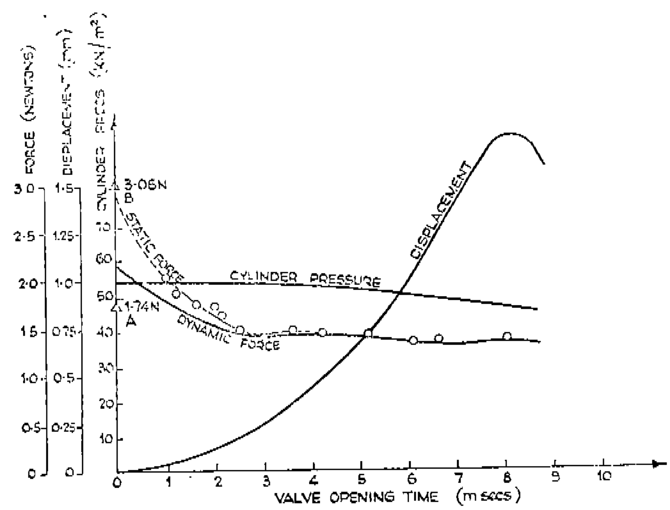

FIGURE 6 Dynamic and Static Force

Valve Disc 8.40 mm OD
Port 6.35 mm bore
Cylinder Pressure 54 kN/m^2

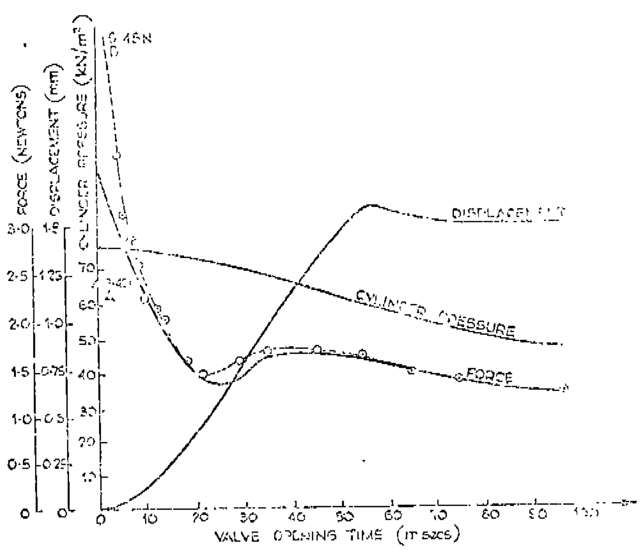

FIGURE 7 Dynamic and Static Force

Valve Disc 9.50 mm OD
Port 6.35 mm bore
Cylinder Pressure 77 kN/m^2