

Numerical Modelling of Leakage Behaviour of Seal

Raj Gokul P¹, Ebenezer Sathish Paul P², Sreedharan M³

P.G. Student, Department of Mechanical Engineering, PSR Engineering College, Sivakasi, Tamil Nadu, India¹

Assistant Professor, Department of Mechanical Engineering, PSR Engineering College, Sivakasi, Tamil Nadu, India²

P.G. Student, Department of Mechanical Engineering, AarupadaiVeedu Institute of Tech, Chennai, Tamil Nadu, India³

ABSTRACT: Plunger valve is an important tool for manufacturing and engineering, where it can have a major impact on the productivity of a process. The air preparation includes filtration, cooling, water separation, drying, and adding lubricating oil mist. The compressed air in reservoirs is transmitted through transmission lines (pipes and hoses). The pneumatic power is controlled by means of a set of valves such as the pressure, flow, and directional control valves. Then, the pressure energy is converted to the required mechanical energy by means of pneumatic cylinders and motors. This resulted in a conclusion that the samples 2, 3, 4 and 5 had flat washer seal, which has low frictional force, compact, and longer life compared to other seals. Hence, the major dimensional design rules are formulated from these four valves. Among the above four valves the sample 3 had improved flow characteristics. The equivalent flow area is calculated for the prediction of the response and the flow rate of the valve position. The major dimensional design rules are formulated from the study of different spool valves with seal in the spool. Since there is no consistency in the throat gap dimension with respect to the casing throat opening is not formulated by reverse engineering. This dimension defines the response and the flow rate of the valve. Similarly, the frictional force of the flat washer seal obtained by the analytical model is not correlating with the experimental result.

KEYWORDS: Spool Valve, Reverse Engineering, Plunger Valve.

INTRODUCTION

Pneumatic systems are power systems using compressed air as a working medium for the power transmission. Their principle of operation is similar to that of the hydraulic power systems. An air compressor converts the mechanical energy of the prime mover into, mainly, pressure energy of the compressed air. This transformation facilitates the transmission, storage, and control of energy. After compression, the compressed air should be prepared for use. The air preparation includes filtration, cooling, water separation, drying, and adding lubricating oil mist. The compressed air is stored in compressed air reservoirs and transmitted through transmission lines: pipes and hoses.

The Pneumatic power is controlled by means of a set of valves such as the pressure, flow, and directional control valves then, the pressure energy is converted to the required mechanical energy by means of the pneumatic cylinders and motors.

Rubber gasket seals are used in applications which differ completely from metal seals and plastic seals by applying rubber elasticity. For instance, the shape of elastomer seals can be changed according to the desired seal shape, and they can be used for sealing parts with complicated shapes. In addition, they can also be repeatedly used because the recovery of internal strain is excellent even after large deformation. One of the problems with elastomer seals is that they will always exhibit some surface roughness on the sealing surface due to seal material or machining method. Studies have also been done on the fluid leakage mechanism based on these theories. In this study, we therefore reviewed the contact mechanism between elastomer seals and surface roughness of the counter face, and performed experimental analysis of the relation between the contact state and leakage.

Paper is organized as follows. Section II describes literature survey, where the concept of static seal designs, CSR testing, behaviour of elastomeric seal and CFD process has been studied. The Categories of Pneumatic system has been explained in Section III.

Section IV presents theoretical representation where the stress relaxation and prediction on leakage has been derived. Finally, Section V and VI present results and conclusion.

II. LITERATURE SURVEY

Tatsuo Okamura et al, This paper reports on a new concept for static seal designs taking into consideration the surface roughness of sealing surfaces. The concept focuses on fluid penetration from the interstices between the seal and counterface caused by surface roughness. This paper discussed a new concept for static rubber gasket designs taking into consideration the surface roughness of sealing surfaces

Paul Tuckner et al, This Paper discusses, If Compression Stress Relaxation (CSR) testing is to be of value for validation of capability and for specific purposes, different test configurations must provide the same values, and the values determined, should be relevant to the actual applications. The results of these testing shows that the CSR response is dependant not only on the material, but the sample shape and test configuration

Raparelli.T et al, The behaviour of an elastomeric seal for a pneumatic cylinder piston is analysed in this work. The aim of the paper is to validate experimentally a numerical approach to evaluate seal performance, in actual working conditions. The positive results of comparison between experimental and numerical simulation data lead to the conclusion that the methodology followed could be usefully employed in parametric studies of seal behaviour.

Srikanth.C et al, The compressible air flow in a typical puffer chamber with moving contact between fixed electrodes has been studied using computational fluid dynamics techniques. Moving grid methods in CFD process not only plays a pivotal role in understanding the flow behaviour. The CFD study carried out for prediction of several flow characteristics provide valuable insights for quenching the arcs in circuit breakers.

Based on the spool valves and studying the relative movement of the spool with respect to the casing the following design rules are formulated. These rules are formulated for valve with dynamic seal in the spool and seal type. The formulated design rule is capable of giving only the major dimension, which defines the position of the spool with the casing, and all other dimensions of the casing depending on the type of mounting to be adopted, return type and pilot airflow path from supply.

. The seal design and groove design are extracted with the help of profile projector in 10-x magnification and this design can be used for the similar application in other valves The major dimensional design rules are formulated from the study of different spool valves with seal in the spool. Since there is no consistency in the throat gap dimension with respect to the casing throat opening, the design rule for the position of spool with respect to the casing throat opening is not formulated from the reverse engineering. This dimension defines the response and the flow rate of the valve. Similarly, the frictional force of the flat washer seal obtained by the analytical model doesn't correlate with the experimental result because of the assumptions made

III. CATEGORIES OF PNEUMATIC SYSTEM

The air compressor pumps air to the storage tanks. The air compressor is connected to engine through gears or v-belts. The governor controls when the air compressor will pump air into the storage tanks. When air tank pressure rises to the "cut-out" level the governor stops the compressor from pumping air. When tank pressure falls to the "cut-in" pressure the governor allows the compressor to start pumping again.

Generally, the air compressor serves to charge the compressed air reservoir. The compressor operation can be controlled by a governor to keep the air reservoir pressure within certain limits. The pneumatic system is directly fed from the reservoir. However, in some special cases, the pneumatic system does not include an air compressor, such as in some aircraft's and missiles. They use pre-charged high pressure compressed air bottles as a source of pneumatic energy. The pneumatic valves are similar to hydraulic valves in terms of physical concepts. They are categorized into

three classes.

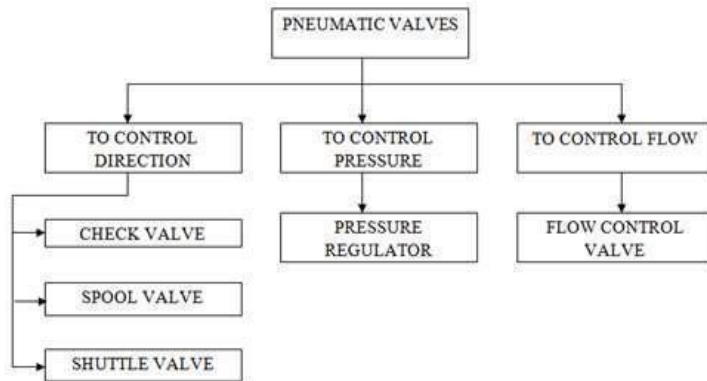


Fig. 1 Categories of Pneumatic Valves

The static seal spool valves are designed for heavy-duty pneumatic system. The ‘O’-ring seals are placed inside the casing and they are arrested by the sheave placed on either side on the seal. The spool is then placed inside the assembly. In this type of valve there are many parts as the number of seals increase, this increases the assembly time and in case of seal failure the repair is difficult. This type of valve is designed for compact assemblies and for low flow rate operations. The dynamic seal spool valves are assembled in the spool grooves and as the spool moves the seal.

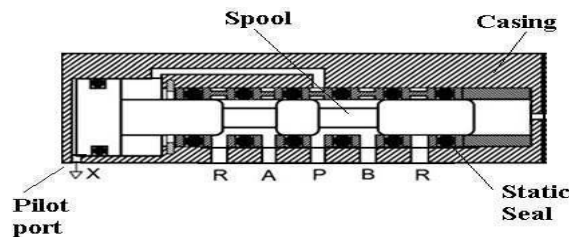
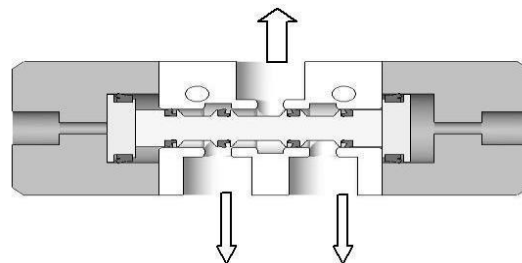


Fig. 2 Static Seal Spool Valve

Delivery



Exhaust

Supply

Fig. 3 Dynamic Seal Spool Valve

IV. THEORETICAL REPRESENTATION

The internal stress relaxation and creep phenomena occur in rubber. As stress relaxation increases when used under fixed load conditions, there is no leakage but when used under constant compression ratio, the interstices inside the seal due to viscous deformation. Measurement of the changes in leakage with time indicates that leakage amount decreases with time. The leakage Q from interstice can be predicted theoretically from equation 1.

$$1 \quad Q = \frac{Lh^3}{m\eta} \frac{P}{w} \longrightarrow \bigcirc$$

The dynamic frictional force of the 'O'-ring seal is given by equation 3. The actual frictional force in static friction is 1.5 to 2 times the dynamic frictional force.

In this paper, the investigation of the relation between surface roughness of the sealing surface and leakage by preparing sealing surfaces with three levels of surface roughness 6.5, 8.2 and 12.5 microns for use in the experiments. The surface roughness is expressed by h_{max} . If the profile of roughness is the same, α is also the same. Taking that the compression ratio required for sealing is the same, the right side of the equation is a fixed value. If a small surface roughness value is set, then interstice 'h' must also be made small proportionately. The critical compression ratio changes proportionately with the surface roughness.

V. RESULT AND DISCUSSION

Based on the spool valves and studying the relative movement of the spool with respect to the casing the following design rules are formulated. These rules are formulated for valve with dynamic seal in the spool and seal type. The formulated design rule is capable of giving only the major dimension, which defines the position of the spool with the casing, and all other dimensions of the casing depending on the type of mounting to be adopted, return type and pilot airflow path from supply.



Fig. 4 Plunger Operated Valve

VI. CONCLUSION

The following conclusions are obtained from the experimental and analytical results. From the reverse engineering of seven spool valves the design of the spool valve for different configurations are studied and the functions of individual part are evaluated. This resulted in a conclusion that the samples 2, 3, 4 and 5 had flat washer seal which has low frictional force, compact and longer life compared to other seals. Hence the major dimensional design rules are

formulated from these four valves. Among the above four valves, sample 3 is found to be improve flow characteristics. The equivalent flow area is calculated for the prediction of the response and the flow rate of the valve position. The frictional force is calculated for different seal from the o-ring frictional force empirical formula. The seal design and groove design are extracted with the help of profile projector in 10-x magnification and this design can be used for the similar application in other valves. The major dimensional design rules are formulated from the study of different spool valves with seal in the spool. Since there is no consistency in the throat gap dimension with respect to the casing throat opening, the design rule for the position of spool with respect to the casing throat opening is not formulated from the reverse engineering. This dimension defines the response and the flow rate of the valve. Similarly, the frictional force of the flat washer seal obtained by the analytical model doesn't correlate with the experimental result because of the assumptions made. From contact analysis, the flat washer seal is modelled as in the samples 3, 4 and 5 and the frictional force evaluated is compared with the experimental results. The frictional force at 0.05mm squeeze and 10bar operating pressure is obtained as 2.40N which is well correlating with the experimental value, 2.45N. Hence, this method of calculating the frictional force is more accurate than the analytical model developed for the 'O'-ring seal.

REFERENCES

1. Green I. and English, C., (1994) "Analysis of Elastomeric O-ring Seals in Compression Using the Finite Element Method",
2. STLE Trib. Trans., Vol. 35, No. 1, pp. 8
3. Itzhak Green and Capel English (1994), "Stresses and Deformation of Compressed Elastomeric O-Ring Seals", 14th
4. International Conference on Fluid Sealing, pp 83-95
5. Jiang et al., "Analysis of Pneumatic directional proportional valve with CFX mesh motion technique", ABCM symposium series in mechatronics - vol. 3- pp 510-518.
6. Tatsuo Okamura, Naohito Suetsugu, Takashi Ohta and Shigeyuki Ono, Masaya Otsuka "A New Concept of Static Rubber Gasket for Sealing Rough Surface" (2003).
7. Paul Tuckner Dyneon LLC, A 3M Company "The Effects of Configuration on Sealing Force Measurement and Compression Stress Relaxation Response", 2003-01-0946.
8. Pedro LuisAndrighetto, Antonio Carlos Valdiero, Leonardo Carlotto, "Study of the friction behavior in industrial pneumatic actuators" ABCM Symposium Series in Mechatronics - Vol. 2 - pp.369-376
9. Qinghui Yuan and Perry Y. Li (2005), "Using Steady Flow Force for Unstable Valve Design: Modeling and Experiments",
10. ASME Journ al of Dynamic Systems, Measurement, and Control, Vol. 127
11. Raparelli.T, Manuello Bertetto and Mazza.L, "Experimental and numerical study of friction in an elastomeric seal for pneumatic cylinders", Tribology International. Vol 30, No 7, pp 547 – 552, 1997, Elsevier science Ltd.
12. Srikanth.C, Bhasker.C, "Flow analysis in valve with moving grids through CFD techniques", Advances in Engineering Software 40 (2009), pp