Harmonic Analysis of a Pneumatic Fixed Orifice

Dragan Pršić *, Ljubiša Dubonjić, Vladimir Stojanović
[1]Faculty of Mechanical and Civil Engineering in Kraljevo, University of Kragujevac, Kraljevo (Serbia)

Orifices, with constant or variable cross-section areas, are essential components in pneumatic circuits. Dynamic and static characteristics of pneumatic systems depend on their flow characteristics. They have a special role in control components in which are used for mass flow control. In this paper the focus is on pneumatic system consisted of fixed orifices and pneumatic chamber. The characteristics of the fixed orifice are presented in frequency domain. For the purpose of analysis, the sinusoidal input describing function is used, obtained by simulation with nonlinear model.

Key words: fixed orifice, mass flow rate, describing function, Hammerstein model, pneumatic chamber

1. INTRODUCTION

Pneumatic servosystems are widely used in industrial applications because of the favourable performances/price ratio. However, high precision control of such systems is difficult due to their complex physical nature. The main causes of that complexity are: air compressibility, friction between the contact surfaces, nonlinear flow-pressure characteristics of the orifice type restriction and parameter variations [1-3]. In order to solve the problem of design and control of such systems, it is necessary to have better understanding of their nonlinear characteristics. A mathematical model which should clarify the most relevant dynamic and nonlinear behaviour in the pneumatic system is used for that purpose.

Fixed orifices are frequently encountered in pneumatic systems. As the nonlinear characteristics of the orifices reflect in the operation of the whole pneumatic system, they are observed and modelled as a separate subsystems. The paper presents and analyzes the nonlinear mass flow rate characteristics of fixed orifice in frequency domain.

One of the methods of analysis of nonlinear-systems the quasi-linearization method [4, 5]. Linearization in the ordinary sense is not valuable in the case when nonlinearity inputs exceed the limits of acceptable linear approximation or when there is discontinuity at the nominal operating point. The advantages of true linearization are kept in the case of quasi-linearization but there is no limit to the range of input signal magnitudes or to the selection of the operating point. The constraint is that linear description of the system depends on some properties of the input signal. The system description thus depends not only on the system itself, but also on the signals passing through the system (which is a property of nonlinear systems). In other words, quasi-linearization is performed for a certain form of input signal. The problem with nonlinear systems with feedback configurations is in difficult determination of the signal form which occurs on entering the nonlinearity. This is the main constraint of the method. It is not always possible to reduce the nonlinearity input signal to a simple form. The practical solution of the problem is to assume the form of the input signal in advance. In practice, three forms of input signals are used in quasi-linearization [4, 5]: bias, sinusoid and Gaussian process.

The quasi-linear function which approximatively describes nonlinearity is called the describing function (DF). As the design of control systems is frequently realized in the frequency domain, the Sinusoidal Input Describing Function (SIDF) is used in this paper. Assuming that the linear part of the system filters high order harmonics (low-pass filter), every periodic signal is reduced to a basic periodic function on entering the nonlinearity. In the case of memoryless nonlinearity, the SIDF represents the gain which is changed depending on the amplitude of the input signal.

The paper determines the SIDF of the nonlinear mass flow rate characteristic of pneumatic fixed orifice.

2. MASS FLOW-RATE CHARACTERISTIC OF PNEUMATIC FIXED ORIFICE

Fixed orifice characteristics depend on the environment in which a fixed orifice is used. In this paper we consider a pneumatic system consisting of a fixed orifice (Or) and a chamber (Ch) of constant volume (V) as shown in Fig. 1. The system is connected to a variable pressure source (Ps). Downstream pressure P depends on chamber dynamic. The chamber represents a generic load (e.g. actuator chamber) and has a role of low-pass filter. Therefore, it should be noted that the following analysis applies when the fixed orifice is connected to a storage type load.

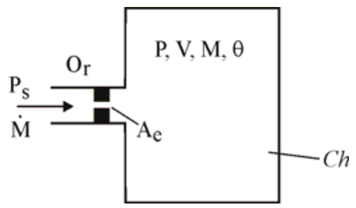

Figure1: Fixed orifice with chamber

The mass flow rate through the restriction can be in sonic or subsonic conditions depending upon the ratio of upstream-downstream pressure. According to the standard theory flow rate through the fixed orifice can be presented

*Corresponding author: Dositejeva 19, Kraljevo 36000, Serbia, prsic.d@mfkv.kg.ac.rs