APPLICATION OF SUPPORT VECTOR MACHINES PLUS TO REGRESSION ANALYSIS FOR PRESSURE-RELIEF VALVES LEAKING

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Abstract— **Carrying out regression analysis for gas leakage of pressure-relief valve (PRV) to get accurate leakage flow and changing trend of leakage will be helpful in assessing the reliability of PRV. Classic support vector regression (SVR) is an excellent regression model, and has been widely used in various fields. However, standard SVR model does regression only using leakage data without elements closely related to the leakage considered. In this paper a regression model based on support vector regression plus (SVR+) is put forward to perform leakage regression of PRV, in which particle swarm optimization (PSO) is used to select optimum parameters of SVR+, termed PSO_SVR+. The experimental results demonstrate that the proposed model taking the difference of inlet pressure and outlet pressure of PRV as hidden information can access a more favorable regression precision than SVR can provide. Meanwhile this article also investigates effects of PSO and Genetic Algorithm on the performance of regression model (SVR+ or SVR).**

Keywords— **Gas leakage, Regression modeling, Support vector regression, Hidden information, Particle swarm optimization**

I. INTRODUCTION

Pressure-relief valve (PRV) does overpressure protection to the entire pneumatic circuit by adjusting of the inlet pressure and exporting a stable outlet pressure. The uncontrolled delivery of gas flow, due to fit clearances or sealing elements, which occurs between the inside and the outside of PRV or among cavities within PRV is gas leakage. In some cases, even the smaller amount of leakage can also result in severe damage to the outlet pressure and subsequent valve failure (Orchard, 2006). Gas leakage will inevitably result in a potential security risk (Bukowski and Goble, 2008). Basing on the existence and severity of the leakage of PRV, ISO 19973-4:2007 provides both test procedures and failure criteria for assessing the reliability of PRV (ISO, 2007). Hence investigation on the actual value and changing trend of gas leakage of PRV has realistic significance and better practical value in engineering, and attracts the attention of scholars. References (Sharif and Grosvenor, 1999; Instanes and Pedersen, 2008; Kaewwaewnoi *et al.,* 2010) discuss the leakage by using acoustic emission sensor and obtain relatively accurate leakage flow, whereas none of them show changing trend. By analyzing influence of working condition and structure parameters of valves on gas leakage, references (Xu *et al.,* 2009; Tang *et al.,* 2005) build mathematical simulation model of leakage and present changing trend of leakage. But the mathematical simulation model can only acquire an approximate solution, which has a huge difference from actual leakage value. This paper handles with these problems using statistical method to offset these disadvantages.

Artificial neural network (ANN) is capable of fitting any nonlinear function with certain generalization ability and is used widely in engineering, such as (Figueroa and Cousseau, 2008) for time series prediction, (Montandon *et al.,* 2008) for nonlinear model predictive control and (Fonseca *et al.,* 2004) for production of sorbitol and gluconic acid. However, ANN can not guarantee its regression precision for small training samples since over-fitting problem or local minimum problem often happens. Due to perfect theoretical foundation, support vector regression (SVR) is more robust than ANN and other regression models, and has being gained popularity on engineering regression problems (Gunn, 1998; Vapnik, 1999). Taking gas leakage as input vectors, SVR can give a regression model with a higher precision. As (Xu *et al.,* 2009; Tang *et al.,* 2005) indicates, leakage of PRV has close relation with working condition and structure parameters of PRV, but SVR tends to only use leakage data without these elements considered.

In 2009, V. Vapnik proposes an advanced learning model support vector regression plus (SVR+; Vapnik, 2006; Vapnik *et al.*, 2009), which adds hidden information based on SVR. The introduction of the hidden information, which is some correlation inside input vectors, and which is available only for the training examples and not be available (hidden) for the test examples, further boosts the generalization ability of SVR and makes SVR+ have a preferable application prospect.

Sun *et al.* (2011) discusses a new time series regression method based on SVR+, in which Genetic Algorithm (GA) is used to determine parameters of SVR+, and shows that SVR+ is more suitable for regression than ANN.

To attempt to get accurate leakage flow and reflect changing trend of leakage simultaneously, this article puts forward a regression analysis model based on SVR+ and particle swarm optimization (PSO), termed PSO_SVR+, which introduces SVR+ into the gas leakage analysis, and which takes working condition of