INTERNATIONAL JOURNAL OF REFRIGERATION 34 (2011) 764–772

available at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/ijrefrig

Modeling of rotary vane compressor applying artificial neural network

Sepehr Sanaye [a,*], *Masoud Dehghandokht* [a], *Hassan Mohammadbeigi* [b], *Salman Bahrami* [b]

[a] *Energy Systems Improvement Laboratory (ESIL), Department of Mechanical Engineering, Iran University of Science and Technology (IUST), Narmak, Tehran 16844, Iran*

[b] *R&D Division, Sardsaz Khodro Ind. Co., Iran*

ARTICLE INFO

Article history:
Received 21 April 2010
Received in revised form
18 November 2010
Accepted 7 December 2010
Available online 13 December 2010

Keywords:
Neural network
Rotary compressor
Automobile
Air conditioning

ABSTRACT

The thermal modeling of rotary vane compressor (RVC) was performed in this paper by applying Artificial Neural Network (ANN) method. In the first step, appropriate tests were designed and experimental data were collected during steady state operating condition of RVC in the experimental setup. Then parameters including refrigerant suction temperature and pressure, compressor rotating speed as well as refrigerant discharge pressure were adjusted.With these input values, the operating output parameters such as refrigerant mass flow rate and refrigerant discharge temperature were measured. In the second step, the experimental results were used to train ANN model for predicting RVC operating parameters such as refrigerant mass flow rate and compressor power consumption. These predicted operating parameters by ANN model agreed well with the experimental values with correlation coefficient in the range of 0.962–0.998, mean relative errors in the range of 2.79–7.36% as well as root mean square error (RMSE) 10.59 kg h^{-1} and 12 K for refrigerant mass flow rate and refrigerant discharge temperature, respectively. Results showed closer predictions with experimental results for ANN model in comparison with nolinear regression model.

Modélisation d’un compresseur rotatif à l’aide d’un réseau neuronal

Mots clés : Réseau neuronal ; Compresseur rotatif ; Automobile ; Conditionnement d’air

1. Introduction

Rotary vane compressors (RVC) have about 40% lower volume, 30% higher efficiency in comparison with wobble type ones and are widely used in automobile air conditioning applications (Liansheng et al., 1998). The geometry of RVC is shown in Fig. 1. Takeshita (1997) developed a model for predicting the operating condition of the rotary vane compressor. A database of R134a properties and an isentropic process were used to model the compression process in compressor. Tassou and Qureshi

* *Corresponding author*. Energy Systems Improvement Laboratory, Mechanical Engineering Department, Iran University of Science and Technology, Narmak, Tehran 16844, Iran. Tel./fax: +98 21 772 401 92.
E-mail address: sepehr@iust.ac.ir (S. Sanaye).

0140-7007/$ – see front matter
doi:10.1016/j.ijrefrig.2010.12.007

Nomenclature

a	Actual value
ANNs	Artificial neural networks
b	bias
Cov	Covariance
Exp	Expansion
Evap	Evaporator
f	Activation function
h	Refrigerant enthalpy (kj kg^{-1})
$\dot{m}$	Mass flow rate (kg h^{-1})
MRE	Mean relative error
NET	Network
NLREG	non-linear regression
N_{comp}	Compressor speed (rpm)
p	Pressure (kPa), predicted value
Pred	Predicted output
rp	Pressure ratio
R	Correlation coefficient
RMSE	Root mean square error
T	Temperature (K)
U_r/r	Relative uncertainty (%)
Vold	Displacement volume (cm^3 rev^{-1})
$\dot{W}_{comp}$	Power consumption of compressor (Watt)
W	Inter connection weight
X	Input vector of neuron
Greek letters	
ηv	Volumetric efficiency
ρ	Refrigerant density (kg m^{-3})
Subscripts	
r	Refrigerant
in	Input
J	Number of measurement variables
n	Sum of weighted input
dis	discharge
suc	suction

(1998) presented the results of their experiments on the performance of positive-displacement refrigeration compressors for variable-speed capacity control applications. Three types of compressor namely open-type reciprocating, semi-hermetic reciprocating and open-type rotary vane were applied in their experiments. Liansheng et al. (2003) analyzed the design of rotor and stator shapes for RVC of air conditioning systems. Ooi (2005) optimized the performance of a rolling piston compressor under preset operational conditions and design constraints by employing a multi-variable, direct search, constrained optimization technique. The proposed model is also assumed to be a perfectly sealed model and thus effects of leakage are not considered.

The mathematical modeling of RVC is usually complicated, involving the solution of complex differential equations which may yield inaccurate results mainly due to varying compressor speeds. Instead of complex rules and mathematical routines, artificial neural network is able to learn the key information patterns within a multi-dimensional information domain (Liansheng et al., 2003; Yang, 2008; Sen and Yang, 1999). Applying ANN the correlations of physical phenomena in engineering applications is possible without explicit mathematical relations. ANN methods are widely extended and used in engineering science and thermal energy applications (Kalogirou, 2000) such as ground source heat pumps(Esen et al., 2008), ejector-absorption system (Sozen et al., 2003; Sozen and Arcaklioglu, 2007), air cooled heat exchangers (Kumar et al., 2006), solar assisted heat pump (Mohanraj et al., 2009), compressor performance evaluation (Ghorbanian and Gholamrezaei, 2009), mechanical cooling system (Yilmaz and Atik, 2007), generating hot water by solar energy (Cetiner et al., 2005), plate fin heat exchanger (Peng and Ling, 2009), automobile air conditioning system (Hosoz and Ertunc, 2006) and predicting the specifications of refrigerants in various state points (Chouai et al., 2002).

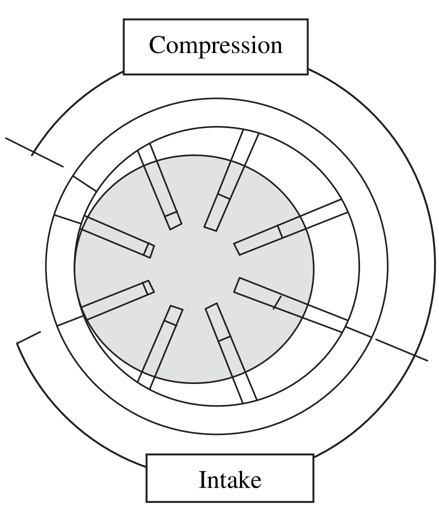

Fig. 1 – Rotary vane compressor.

The contributions of this paper into the subject are:

- Proposing two ANN and non-linear regression (NLREG) models to analyze the experimental data, for predicting the main specifications of RVC, i.e, the refrigerant mass flow rate ($\dot{m}_r$) and the refrigerant discharge temperature (T_{dis}) for R134a refrigerant. It is noticeable that in RVC performance analysis many complex physical phenomena such as leakage and frictional losses are involved. Considering these effects in thermophysical modeling in very complex and tedious (and sometimes not possible and reliable).
- Comparison of ANN and NLREG with three methods of error analysis (MRE, RMSE and correlation).

2. Experimental set up

The empirical test apparatus of automobile air conditioning/refrigeration system includes evaporator, condenser, compressor, and expansion valve. As shown in Fig. 2, the test set up included three flow circuits: refrigerant, the air flow through the condenser, and the air flow through the