INTERNATIONAL JOURNAL OF REFRIGERATION 35 (2012) 1690–1696

Available online at www.sciencedirect.com

SciVerse ScienceDirect

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

Using artificial neural network for predicting performance of the Ranque–Hilsch vortex tube

*Murat Eray Korkmaz, Levent Gümüşel, Burak Markal**

Karadeniz Technical University, Faculty of Engineering, Mechanical Engineering Department, 61080 Trabzon, Turkey

ARTICLE INFO

Article history:
Received 16 September 2011
Received in revised form
10 April 2012
Accepted 16 April 2012
Available online 23 April 2012

Keywords:
Vortex tube
Neural network
Performance
Modeling

ABSTRACT

In this study, effects of conical valve angle and length to diameter ratio on the performance of a counter flow Ranque–Hilsch vortex tube are predicted with artificial neural networks (ANNs) by using experimental data. In the model, inlet pressure (P_i), conical valve angle (ϕ), length to diameter ratio (L/D) and cold mass fraction (y_c) are used as input parameters while total temperature difference (ΔT) is chosen as the output parameter. The multilayer feed forward model and the Levenberg–Marquardt learning algorithm are used in the network and the hyperbolic tangent function is chosen as a transfer function. The artificial neural network is designed via the NeuroSolutions 6.0 software. Finally, it's disclosed that ANN can be successfully used to predict effects of geometrical parameters on the performance of the Ranque–Hilsch vortex tube with a good accuracy.

Utilisation d'un réseau neuronal artificiel pour prévoir la performance d'un tube vortex Ranque Hilsch

Mots clés : Tube vortex ; Réseau neuronal ; Performance ; Modélisation

1. Introduction

The Ranque–Hilsch vortex tube is a simple device separating an isothermal compressed gas flow into two different flows with different temperatures. It has advantages compared to other refrigerating or heating devices in point of being simple, small and light, having low cost, using no electricity or chemicals and having long operation time.

Vortex tubes have a great variety of applications in industry. They are widely used for cooling in some industrial fields such as especially grilling, turning and welding (Eiamsa-ard and Promvonge, 2008). In addition, they are used for dehumidifying gas samples, cooling electric or electronic control cabinets, cooling food and testing temperature sensors (Aydin and Baki, 2006). Other practical applications include DNA applications, cooling gas, drying gas, cleaning gas, liquefying natural gas (Wu et al., 2007), etc.

In the literature, there are abundant number of studies on vortex tubes. Experimental studies have been generally focused on increasing the performance of vortex tube. Various geometrical parameters such as the tube length, the angle of the conical valve, the diameter of the cold end orifice have

* *Corresponding author*. Tel.: +90 506 371 35 34.
E-mail address: burakmarkal61@gmail.com (B. Markal).

0140-7007/$ – see front matter © 2012 Elsevier Ltd and IIR. All rights reserved.
doi:10.1016/j.ijrefrig.2012.04.013

Nomenclature

a	hyperbolic tangent function
d	inner diameter of helical vortex generator, diameter of cold exit [mm]
D	outer diameter of helical vortex generator, inner diameter of tube [mm]
e	exponential function
h	length of the helical vortex generator [mm]
L	vortex tube length [mm]
$\dot{m}$	mass flow rate [kg s^{-1}]
n	total input
T	temperature [°C]
ΔT	temperature difference [°C]
P	pressure [bar]
R	output
x_j	inputs
w_j	weights
y_c	cold mass fraction

Greek letters

ϕ	angle of the conical (control) valve
δ_{in}	inner diameter of the inlet nozzle
δ_{hot}	inner diameter of the hot end nozzle

Subscripts

c	cold air
h	hot air
i	inlet air
t	total
exp	experimental
pre	predicted

been tested with various thermo physical parameters like inlet gas pressure, cold mass fraction, moisture of inlet gas in order to obtain an optimum vortex tube design.

Excellent reviews of the studies existing in the literature are available in Markal et al. (2010), Aydin et al. (2010), Xue et al. (2010), Yilmaz et al. (2009). Recently, Valipour and Niazi (2011) investigated the influence of uniform curvature of main tube on the performance of the vortex tube. Chang et al. (2011) experimentally investigated effects of divergence angle of hot tube, length of divergent hot tube and number of nozzle intakes on energy separation of a vortex tube. Dincer et al. (2011) experimentally studied the performance of hot cascade type Ranque–Hilsch vortex tube and exergy analysis.

Recently, the Artificial Neural Networks (ANNs) have been used effectively in many thermo-fluids problems. This method can simulate complex systems without requiring any explicit knowledge about input/output relationship. Moreover, they are not free of errors and uncertainties. ANN needs only examples to learn and then it can make prediction for untested parameters easily. Owing to the ANN, a lot of untested parameters used in the experiments can be predicted in an easy way with a reasonable accuracy.

Table 1 – Characteristics and uncertainties of the measurement instruments.

Instrument	Range	Uncertainty
Digital manometer, *HHP-2082*	0–2 bar	±0.15%
Digital thermometer, (*OM-2041*)	−200 to 1370 °C	±0.1% (full scale)
Volumetric flow meter, *CZ-32458-65*	80–560 LPM	±3% (full scale)
Humidity meter, *HT-3006HA*	10–95% R.H.	±3% (<70% R.H.)
Barometer, Testo 435-1 (*Part no: 0632 1535*)	600–1150 mbar	±3%

Diaz et al. (2001) used the artificial neural network technique for the simulation of the time-dependent behavior of a heat exchanger and controlling the temperature of air passing over it. Islamoglu (2003) presented an application of ANN to predict the heat transfer rate of the wire-on-tube type heat exchanger. Xie et al. (2007) applied ANN for heat transfer analysis of shell-and-tube heat exchangers with segmental baffles or continuous helical baffles. Xie et al. (2009) used ANN

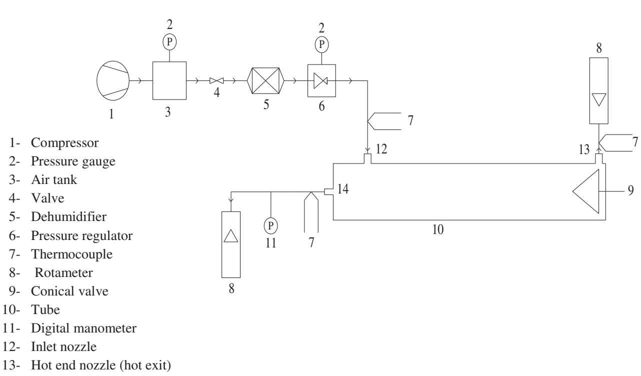

Fig. 1 – The schematic diagram of the experimental setup. 1. Compressor; 2. Pressure gauge; 3. Air tank; 4. Valve; 5. Dehumidifier; 6. Pressure regulator; 7. Thermocouple; 8. Rotameter; 9. Conical valve; 10. Tube; 11. Digital manometer; 12. Inlet nozzle; 13. Hot end nozzle (hot exit); 14. Cold exit.

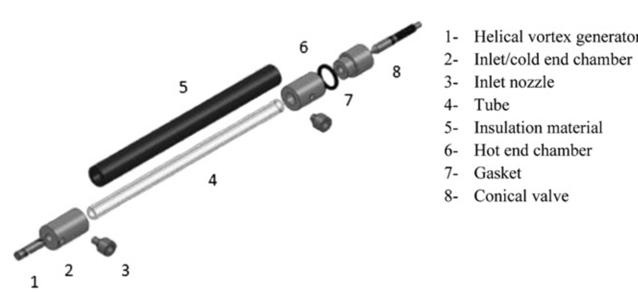

Fig. 2 – An exploded view of vortex tube tested. 1. Helical vortex generator; 2. Inlet/cold end chamber; 3. Inlet nozzle; 4. Tube; 5. Insulation material; 6. Hot end chamber; 7. Gasket; 8. Conical valve.