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Experimental analysis of the scroll compressor performances varying its speed

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Abstract

Referring to a vapour compression plant able to operate both as water chiller and heat pump, the aim of this paper is to evaluate experimentally the energy saving obtainable varying the scroll compressor speed to control the refrigeration capacity instead of the classical thermostatic control. The compressor speed is continuously controlled by means of a fuzzy algorithm regulating an inverter located on the electric line supplying the compressor motor. On the contrary the control by thermostat imposes on/off cycles on the compressor that works at the nominal frequency of 50 Hz. In particular, the performances of a vapour compression experimental plant, generally used in industrial processing or conditioning plants where a supply of refrigerated and reheated water is required, are studied. The experimental plant is made up of an hermetic scroll compressor, a plate-type water heat exchanger inserted in a water tank, a finned tube air heat exchanger, two thermostatic expansion valves that have substituted the classical capillaries not suitable for fast load variations. The use of a scroll compressor allows to have a compressor electric motor supply current frequency even of 15 Hz in comparison with the semi-hermetic reciprocating compressor that for frequency values under 30 Hz presents considerable vibrations and noise increase together with the lubrication troubles due to the splash system. For different working conditions a significant energy saving on average equal to about 20% has been obtained adopting a scroll compressor speed control algorithm, based on the fuzzy logic, in comparison with the classical thermostatic control. Moreover, in this paper the aim has been to determine also experimentally the optimum frequency, corresponding to a definite heating (cooling) load, to be imposed to a compressor electric motor by means of an inverter to obtain the highest energy saving.

Keywords: Experimental plant; Water chiller; Heat pump; Scroll compressor; Variable speed; Fuzzy algorithm; Energy saving

1. Introduction

The inefficient use of electricity to supply the compressors adopted in the air-conditioning and refrigeration is considered an indirect contribution to the greenhouse gases emission in the atmosphere; these emissions can be reduced improving the energy conversion efficiency of the above mentioned systems. For this purpose, it is important to adopt compressors more and more efficient like the scroll compressors. The scroll compressors are successful in a wide variety of applications both residential and commercial. In air-conditioning smaller compressors are found in residential systems such as heat pump systems used to heat and cool homes or business; large compressors are found in commercial applications such as process chillers and in a variety of condensing unit systems. In the refrigeration the scroll compressors are adopted in a wide range of applications including: supermarket racks, bulk milk cooling, truck transport and marine containers. The scroll compressor technology is also applied in cryogenics and with natural gas. It has been already demonstrated that related to air-conditioning applications the scroll compressors offer

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Nomenclature

AC	alternating current	$\dot{Q}$	thermal power exchanged (W)
CEB	finned coil condenser/evaporator	RL	liquid receiver
CP	compressor	*S*	tank drain cock
DC	direct current	SA	storage tank
ECH	plate evaporator/condenser	*T*	temperature (°C)
FA	water filter	VE	tank expansion
FT	filter drier	VEE	summer thermostatic expansion valve
GRA	automatic filling device	VEI	winter thermostatic expansion valve
GWP	global warming potential	VL	fan
INV	inverter	VQ	cycle inversion valve
M	system pressure gauge	VR	nonreturn valve
ODP	ozone depletion potential	VS	safety valve
PA	high pressure switch with manual reset	VSA	automatic air vent
PD	pressure differential switch	VSM	manual air vent
PU	circulation pump		

advantages both in reducing noise and vibration levels and in terms of energetic performances. With further improvements of efficiency it is possible to obtain in the refrigeration results comparable with those of the high efficiency semi-hermetic reciprocating compressor. In fact for high compression ratio values the reciprocating compressor results more efficient than the scroll compressor without injection, but it is possible to increase the scroll compressor efficiency injecting refrigerant in the liquid or vapour phase [1–3]. Another possibility to increase the scroll compressor efficiency is represented by a better tendency of this compressor to modulate the refrigeration capacity varying the compressor speed in comparison with the reciprocating compressor [4–8]. In fact the scroll compressors allow to obtain a compressor electric motor supply current frequency even of 15 Hz [4]; on the contrary it is not possible for a semi-hermetic reciprocating compressor to consider values under 30 Hz because the compressor vibrations and the noise increase considerably together with the lubrication troubles due to the splash system. So the vapour compression refrigeration plants, though designed to satisfy the maximum load, work at part-load for much of their life generally regulated by on/off cycles of the compressor, working at the nominal frequency of 50 Hz, imposed by a thermostatic control which determines a high energy consumption. In this paper, referring to a vapour compression plant able to operate both as water chiller and heat pump, experimental tests have been conducted to compare the plant performances in terms of energy saving obtainable using as scroll compressor refrigeration capacity control systems both an algorithm, based on the fuzzy logic and determined by authors in a former paper, and the classical thermostat that determines on–off cycles of the compressor working at a frequency of 50 Hz. This type of plant is utilized in industrial processing or conditioning systems where a supply of refrigerated and reheated water is necessary. Moreover, in this paper the aim has been to determine also experimentally the optimum frequency, corresponding to a definite heating (cooling) load, to be imposed to a compressor electric motor by means of an inverter to obtain the highest energy saving. This aspect is important because it is not sure that the compressor velocity decrease determines any energy saving in comparison with the thermostatic control.

2. Experimental plant

The experimental plant is principally made up of a monobloc unit that can operate both as refrigeration system and heat pump. It is made up of a hermetic scroll compressor, a plate-type water heat exchanger inserted in a water tank, an finned tube air heat exchanger, two thermostatic expansion valves (Figs. 1 and 2). Moreover, the refrigerant circuit presents check valves, a cycle inversion valve, a nonreturn valve, a liquid receiver. The cycle inversion valve controls the working of the plate-type water heat exchanger that operates as condenser when the plant works as heat pump, and as evaporator when the plant works as water chiller. Referring to the condenser inlet air temperature of 32 °C and the water temperature of 7 °C, the nominal cooling capacity and the nominal electric power are respectively about 9 and 3 kW. The compressor speed is regulated by means of a PWM inverter. It is formed by a rectifier that related to the compressor motor converts the three-phase main voltage (380 V, 50 Hz) to DC voltage and then reverses by an inverter the DC voltage to a three-phase AC supply-voltage; at the output of the inverter the voltage is adjustable in frequency and magnitude.