Laboratórios de Pesquisa em Refrigeração e Termofísica
Research Laboratories for Emerging Technologies in Cooling and Thermophysics

A NEURAL NETWORK TO PREDICT THE TEMPERATURE DISTRIBUTION IN HERMETIC REFRIGERATION COMPRESSORS

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SUMMARY

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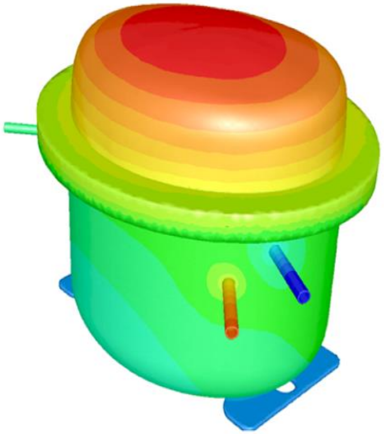
INTRODUCTION

The understanding of heat transfer interactions in refrigeration compressors is of fundamental importance to characterize their overall performance.

Moreover, it is important to monitor temperature of different components, such as motor, oil and shell, due to reliability issues.

Several numerical approaches with different degrees of complexity have been employed to estimate the temperature field in hermetic compressors:

- Semi-empirical model based on experimentally calibrated thermal conductances
- Thermal network model
- Fully CFD model
- Hybrid model



(Sanvezzo *et al*., 2012)

INTRODUCTION

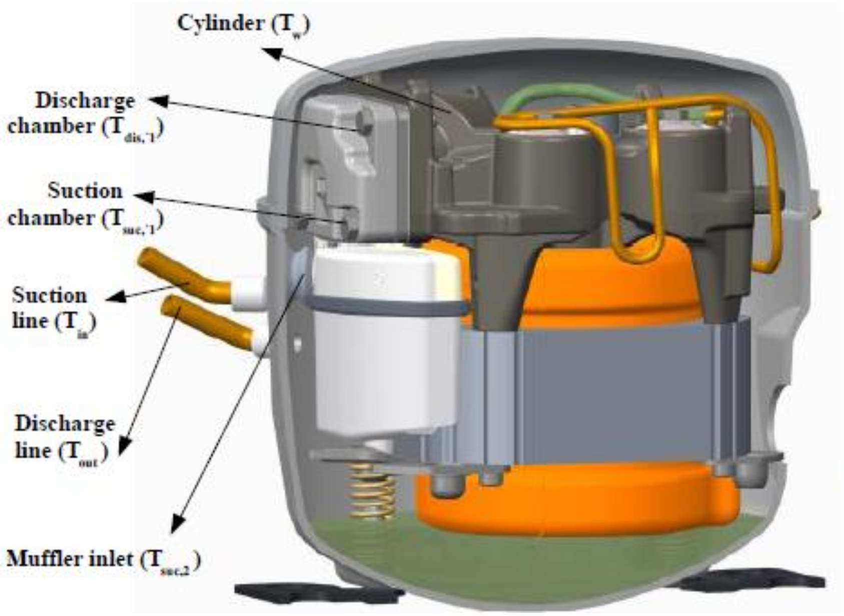
Artificial neural networks are able to reproduce existing relationships between inputs and outputs of highly nonlinear systems and have also been employed in the thermodynamic modeling of compressors:

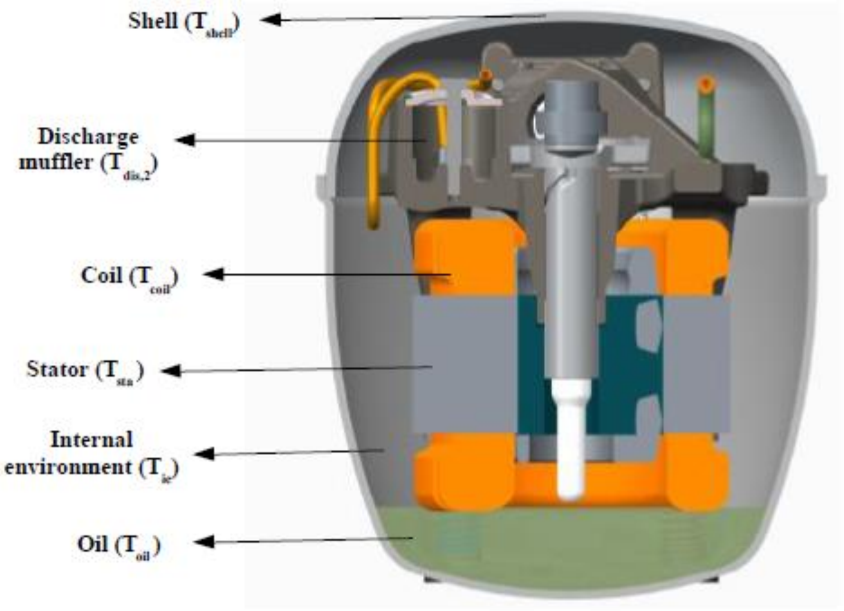
- Loss-efficiency model to predict volumetric and isentropic efficiencies for positive displacement compressors (Yang *et al.*, 2009);
- Prediction of mass flow rate and discharge temperature of a rotary vane compressor (Sanaye *et al*., 2011);
- Prediction of performance maps for axial compressors based on manufacturer data (Yu *et al*., 2007; *Ghorbanian and Gholamrezaei*, 2009).

The present work reports an artificial neural network developed to predict the temperatures at different locations in a reciprocating compressor for different condensing and evaporating temperatures.

EXPERIMENTAL PROCEDURE

The neural network requires experimental data for training. For this reason, a small hermetic reciprocating compressor was instrumented and tested in a hot-cycle test bench.





EXPERIMENTAL PROCEDURE

Tests performed:

- 16 tests to calibrate the artificial neural network. (Te= -25ºC, -20ºC, -15ºC and -10ºC) and (Tc=45ºC, 50ºC, 55ºC and 60ºC). Each test was performed just once.
- 5 tests to evaluate measurement repeatability (Te=-23.3ºC / Tc=54.4ºC).
- 4 randomly selected tests for validation.

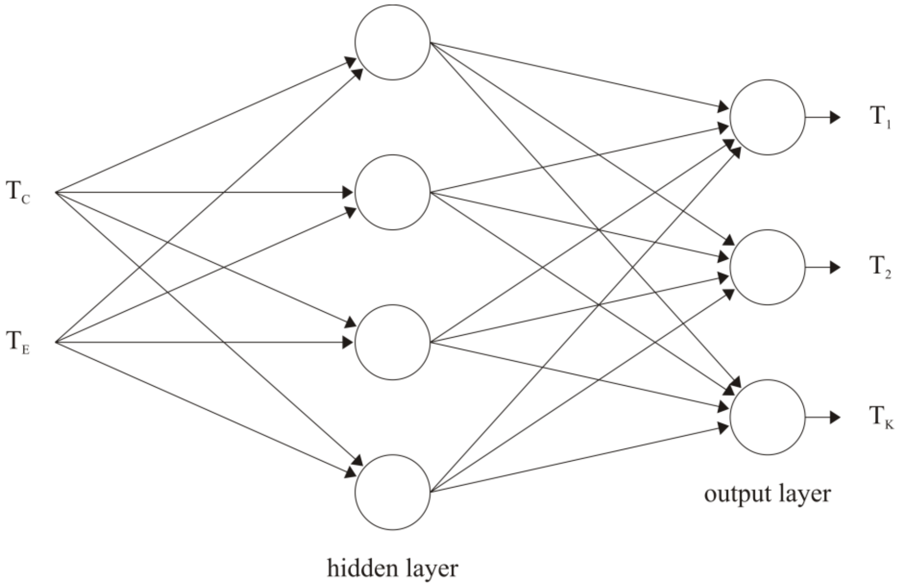
Evaporating temperature [°C]	Condensing temperature [°C]
-17.0	47.9
-21.8	57.5
-19.0	54.0
-14.6	52.0

All tests were carried out randomly and with the compressor thermally stabilized.

NEURAL NETWORK

The neural network was developed in the MATLAB environment, more specifically with Neural Network Toolbox.

It consists of a feed-forward network with two layers: a hidden layer with 8 neurons and a sigmoid transfer function and an output layer with 12 neurons and a linear transfer function.



$$s = \sum_{i=1}^{N} w_i p_i + \theta$$

$$y = f(s)$$

Two training algorithms were evaluated: Levenberg-Marquardt and Bayesian regularization. The last fitted the experimental data with a correlation factor above 0.99.

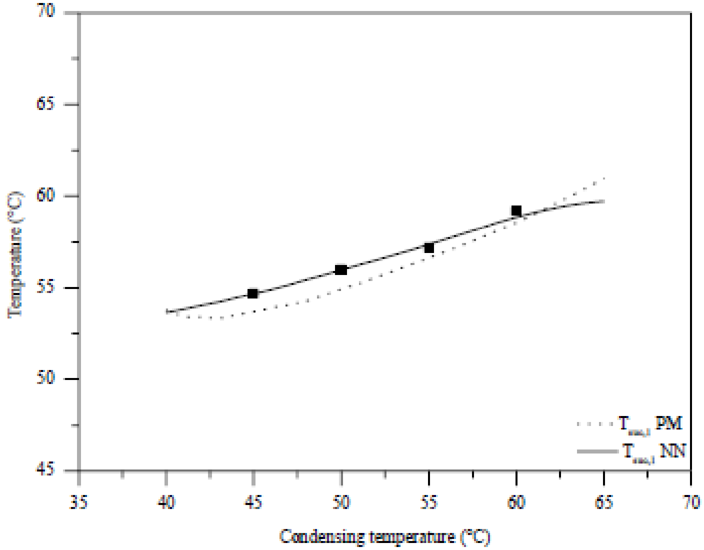
RESULTS

The results obtained (NN) were compared to experimental data (ER) and to predictions of an available numerical model, hereafter denominated physical model (PM).

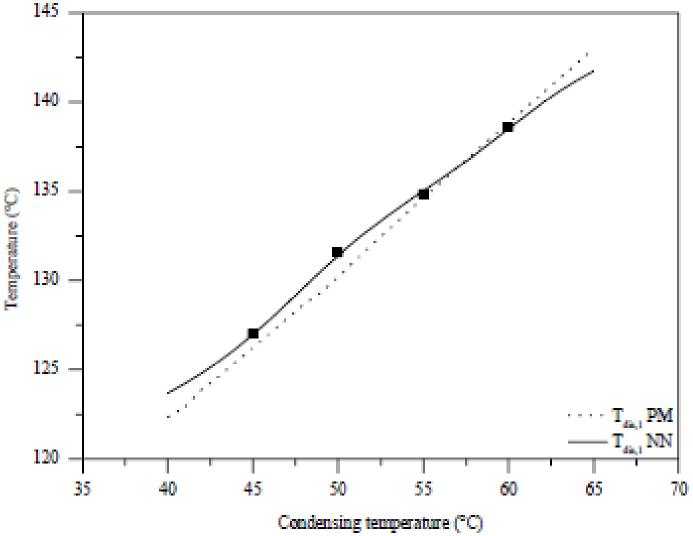
		Temperature (°C)										
Condition / Model		$T_{suc,2}$	$T_{suc,1}$	T_{w}	$T_{dis,1}$	$T_{dis,2}$	T_{out}	T_{oil}	T_{ie}	T_{coil}	T_{sta}	T_{shell}
-17.0°C 47.9°C	**ER**	41.1	51.7	90.0	123.8	106.0	89.2	72.4	82.3	85.6	84.3	74.5
	NN	40.7 *-0.4*	51.6 *-0.1*	89.6 *-0.4*	123.5 *-0.3*	105.6 *-0.4*	89.2 *0.0*	71.6 *-0.8*	82.0 *-0.3*	85.2 *-0.4*	83.8 *-0.5*	74.1 *-0.4*
	PM	-	49.2 *-2.5*	88.3 *-1.7*	120.2 *-3.6*	106.7 *+0.7*	90.6 *+1.4*	-	81.3 *-1.0*	85.8 *+0.2*	-	73.9 *-0.6*
-21.8°C 57.5°C	**ER**	44.1	56.0	97.5	136.0	112.6	92.3	75.8	86.7	90.3	89.3	78.3
	NN	43.8 *-0.3*	56.8 *+0.8*	97.3 *-0.2*	135.3 *-0.7*	112.1 *-0.5*	91.4 *-0.9*	76.2 *+0.4*	86.6 *-0.1*	90.3 *0.0*	89.5 *+0.2*	78.4 *+0.1*
	PM	-	55.7 *-0.3*	96.5 *-1.0*	135.0 *-1.0*	113.2 *+0.6*	92.3 *0.0*	-	86.4 *-0.3*	90.1 *-0.2*	-	78.2 *-0.1*
-19.0°C 54.0°C	**ER**	42.2	53.7	94.2	130.1	109.8	91.5	75.0	85.2	89.0	87.7	77.1
	NN	42.3 *-0.1*	54.4 *+0.7*	94.7 *+0.5*	131.0 *+0.9*	110.7 *+0.9*	92.1 *+0.6*	75.0 *0.0*	85.7 *+0.5*	89.2 *+0.2*	88.1 *+0.4*	77.4 *+0.3*
	PM	-	51.4 *-2.3*	93.2 *-1.0*	129.3 *-0.8*	112.0 *+2.2*	93.0 *+1.5*	-	84.7 *-0.5*	88.9 *-0.1*	-	76.8 *-0.3*
-14.6°C 52.0°C	**ER**	40.7	52.2	91.5	125.4	108.0	92.3	74.0	84.6	88.1	86.5	76.3
	NN	40.5 *-0.2*	51.6 *-0.6*	91.1 *-0.4*	125.2 *-0.2*	107.8 *-0.2*	92.0 *-0.3*	73.2 *-0.8*	84.0 *-0.6*	87.5 *-0.6*	85.8 *-0.7*	75.8 *-0.5*
	PM	-	57.7 *-4.6*	88.9 *-2.6*	121.8 *-3.7*	109.5 *+1.5*	94.0 *+1.7*	-	83.0 *-1.6*	88.1 *0.0*	-	75.3 *-1.0*

RESULTS

Te=-25°C



(a)



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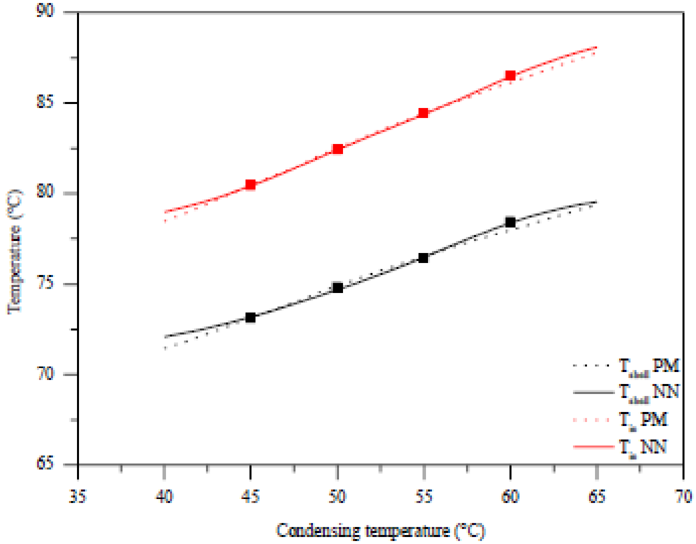

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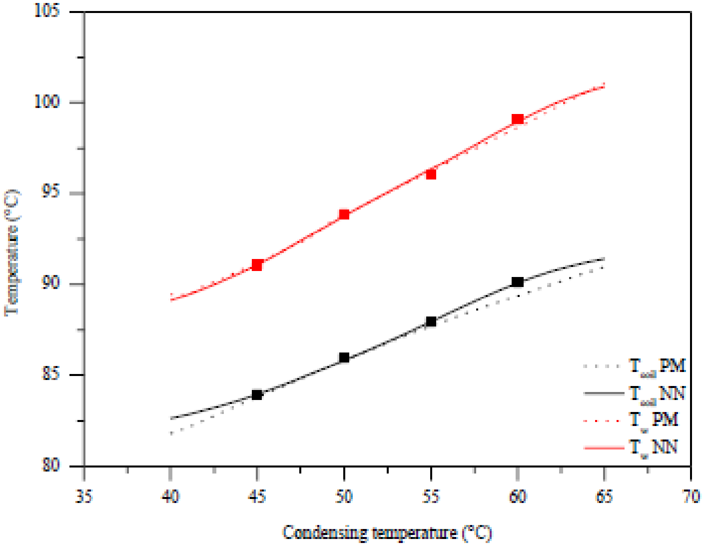
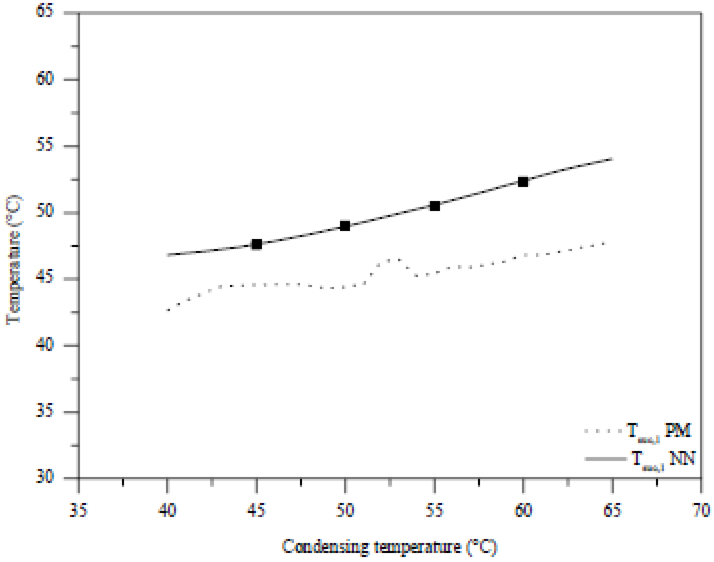


(d)

RESULTS

Te=-10°C



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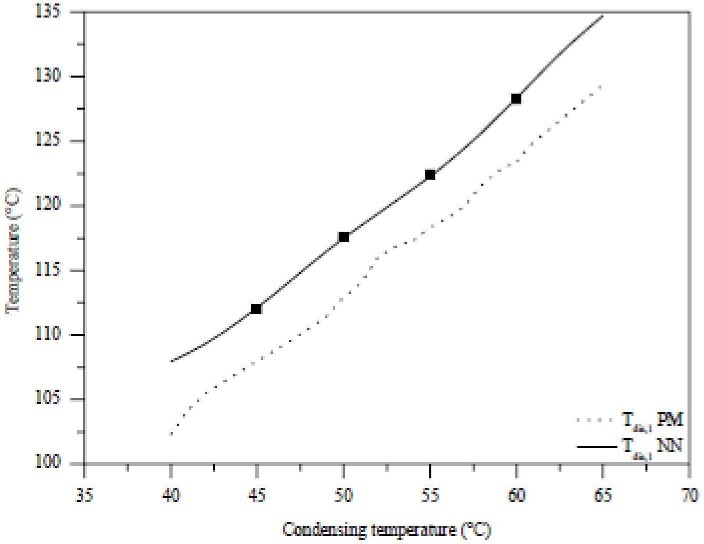

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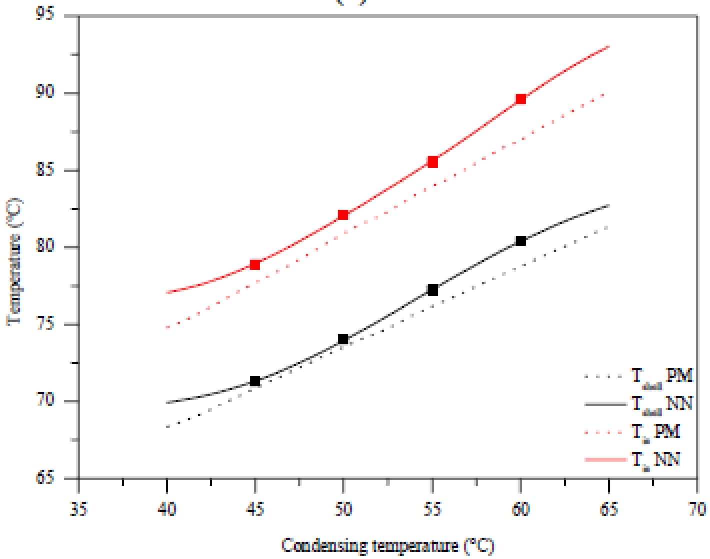

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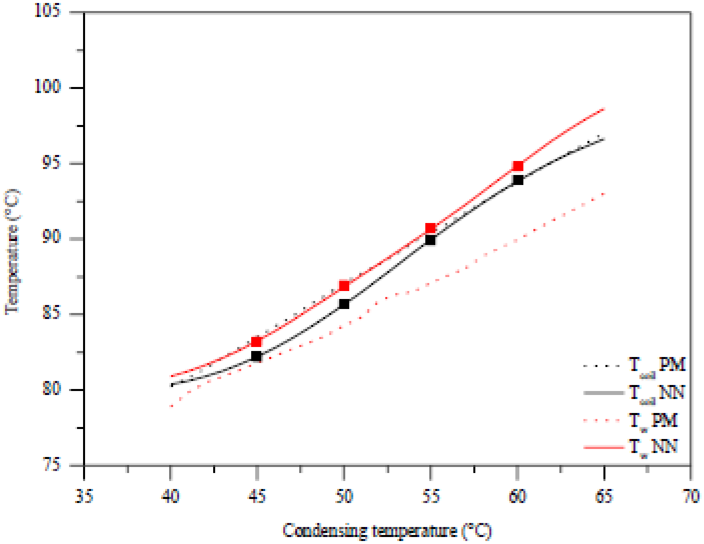

(d)

CONCLUSIONS

→ The present work reported a neural network developed to predict the temperature distribution in a reciprocating compressor adopted for household refrigeration.

→ The neural network was able to predict correctly results for 4 randomly selected operating conditions.

→ The physical model predicts temperatures in excellent agreement with experimental data only when the operating condition is similar to that of its calibration test. On the other hand, the neural network was able to correctly characterize the compressor temperature distribution in all conditions analyzed.

→ The neural network is found to be a valid alternative to predict the temperature distribution of compressor prototypes subjected to different operating conditions. Besides its simplicity, this method provides fast results with excellent accuracy.

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Thank you!

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