# 3 Application of GRNN to a Heat Exchanger

As an example to test the abilities of GRNN, a heat exchanger was chosen. Heat exchange is a long known problem and thoroughly researched. It qualifies therefore to produce data in a synthetic way, a possibility to include errors is given too. Many relationships are known to describe a heat exchanger, and some are very sophisticated and some are very simple and easy to use. In this example a rather sophisticated model is used to generate data. The simple model is then used as a model for an underlying function for the approach to predict data using an underlying function.

The technical system was used to test GRNN on the problems of unequally spaced data, problems at edges, influences of measurement errors and to test the stability of the two approaches, using or not using an underlying function or simple model under these conditions. Another emphasis was put on possible problems with more dimensions and measurement errors.

3.1 The heat exchanger

The heat exchanger is assumed as a long finned pipe. Air is blowing over it in cross flow with a given velocity. The air side has infinite thermal capacity. Water is pumped through the pipe. Pressure losses are neglected.
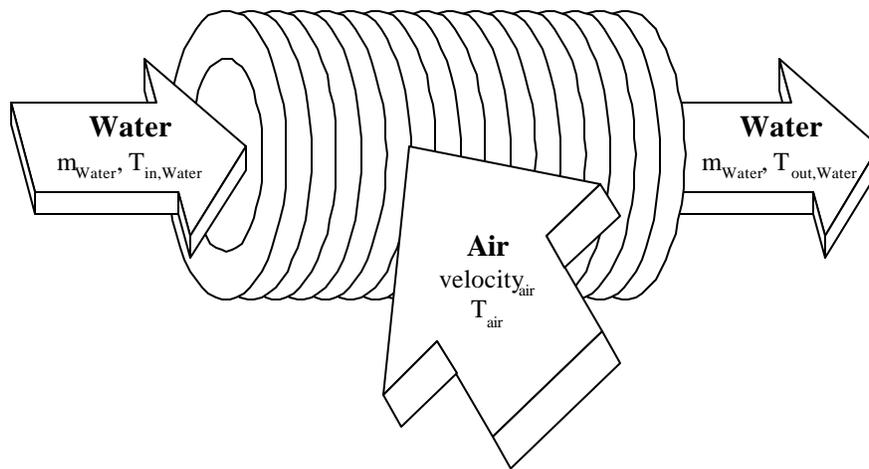
Fig. 3.1-1 The Heat exchanger

The symbols and their meaning, including the units they are used for the equations developing the model are summarized in the nomencalture section on page xvii.

It is common to model a heat exchanger using thermal resistances. The outside resistance for the heat exchanger is [Incropera]

$$R_o = \frac{1}{h_o A_o}$$

Eqn. 3.1-1

where h_o is the heat transfer coefficient that can be calculated from

$$h_o = Nu_o \frac{k_{air}}{D_o}$$

Eqn. 3.1-2

the Nusselt number. Nu_o (Eqn. 3.1-3) can be calculated from the relationship by Churchill and Bernstein [Incropera].

$$Nu_o = 0.3 + \frac{0.62\,Re^{0.5}\,Pr^{1/3}}{\left[1 + \left(\frac{0.4}{Pr}\right)^{2/3}\right]^{0.25}} \times \left[1 + \left(\frac{Re}{282000}\right)^{5/8}\right]^{4/5}.$$

Eqn. 3.1-3

The Resistance (Eqn. 3.1-4) of the wall is

$$R_{wall} = \frac{ln\left(\frac{r_o}{r_i}\right)}{2 \times k_{wall} \times \Pi \times L}.$$

Eqn. 3.1-4

The resistance for the inner side of the tube calculates to

$$R_i = \frac{1}{h_i A_i}$$

Eqn. 3.1-5

where h_i (Eqn. 3.1-6) is again

$$h_i = Nu_i \frac{k_{water}}{D_i}$$

Eqn. 3.1-6

with different relationships for the Nusselt number for turbulent and laminar flow. For laminar

flow the relationship of Kays is used [Incropera] (Eqn. 3.1-7)

$$Nu_i = 3.66 + \frac{0.0688 \times \frac{D_i}{L} Re \times Pr}{1 + 0.04 \times \left(\frac{D_i}{L} \times Re \times Pr\right)^{2/3}}$$

Eqn. 3.1-7

for turbulent flow the relationship from Gnielinski [Incropera] (Eqn. 3.1-8) is used.

$$Nu_i = 3.66 + \cfrac{\frac{f}{8}\left(Re - 1000\right) \times Pr}{1 + 12.7 \times \left(\frac{f}{8}\right)^{1/2} \times \left(Pr^{2/3} - 1\right)} .$$

Eqn. 3.1-8

$$f = \frac{1}{\left(0.79 * ln(Re) - 1.64\right)^2}$$

The **UA** value (Eqn. 3.1-9) calculates with (Eqn. 3.1-1, Eqn. 3.1-4, Eqn. 3.1-5) to

$$UA = \frac{1}{R_i + R_{wall} + R_o} .$$

Eqn. 3.1-9

With the value for **UA** the number of transfer units, **NTU** (Eqn. 3.1-10) can be calculated from

$$NTU = \frac{UA}{mass_{flow} \times c_p}$$

Eqn. 3.1-10

with this relationship it is possible to calculate the effectiveness (Eqn. 3.1-11) with

$$eff = 1 - exp\left(- NTU\right).$$

Eqn. 3.1-11

The outlet temperature can then be calculated from the following equation (Eqn. 3.1-12)

$$eff = \frac{T_{out,water} - T_{in,water}}{T_{air} - T_{in,water}}.$$

Eqn. 3.1-12

The simple model uses a constant **UA** value that was calculated at the design point (Table 3.2-1). In the equations for of the model that was used to generate the training samples, the temperature dependence is not neglected and the values for the properties are calculated at each time. The effectiveness of the heat exchanger will be the variable that will later be predicted with Grnn.

3.2 Training Samples for the Prediction

GRNN should have abilities to predict data for a q-dimensional input vector. The effectiveness was calculated for changes in four parameters of the heat exchanger, namely the inlet temperature of the water, the mass flow rate of water, the velocity of the air flowing across the heat exchanger and the temperature of the air. The ranges of the parameters are given in (Table 3.2-1).

Variable	Design	Range
Length, L	20 m	--
inner Diameter, D_i	5 cm	--
Outer Area of Heat transfer, A_o	$12*L*\boldsymbol{P}*D_o$	
Thickness of wall	5 mm	--
conductivity for Heat exchanger for Aluminum, k_{Al}	238.4 W/mK	--
P_{air}	1 bar	--
P_{water}	1 bar	--
Temperature inlet, $T_{in,water}$	360 K	300K-400K
Temperature air, T_{air}	300 K	300K-400K
Mass flow rate, m_{water}	1.1 kg/s	0.5kg/s-2.9kg/s
Velocity air, vel_{air}	25 m/s	12.5m/s-37.5m/s

Table 3.2-1 Parameters over the range the Heat Exchanger is operated

The simple model that will be used later as an underlying function does not use temperature dependant properties. The simple model uses a constant value for *UA* calculated at the design point. The model with which the training samples were generated uses

temperature dependnent properties. Especially the viscosity changes as temperatures change

other properties are mostly constant.